

教育部高等教育司推荐
国外优秀信息科学与技术系列教学用书

数据与计算机通信

(第七版 影印版)

DATA AND COMPUTER COMMUNICATIONS

(Seventh Edition)

■ William Stallings

PEARSON
Prentice
Hall



高等教育出版社
Higher Education Press

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序

20 世纪末，以计算机和通信技术为代表的信息科学和技术对世界经济、科技、军事、教育和文化等产生了深刻影响。信息科学技术的迅速普及和应用，带动了世界范围信息产业的蓬勃发展，为许多国家带来了丰厚的回报。

进入 21 世纪，尤其随着我国加入 WTO，信息产业的国际竞争将更加激烈。我国信息产业虽然在 20 世纪末取得了迅猛发展，但与发达国家相比，甚至与印度、爱尔兰等国家相比，还有很大差距。国家信息化的发展速度和信息产业的国际竞争能力，最终都将取决于信息科学技术人才的质量和数量。引进国外信息科学和技术优秀教材，在有条件的学校推动开展英语授课或双语教学，是教育部为加快培养大批高质量的信息技术人才采取的一项重要举措。

为此，教育部要求由高等教育出版社首先开展信息科学和技术教材的引进试点工作。同时提出了两点要求，一是要高水平，二是要低价格。在高等教育出版社和信息科学技术引进教材专家组的努力下，经过比较短的时间，第一批引进的 20 多种教材已经陆续出版。这套教材出版后受到了广泛的好评，其中有不少是世界信息科学技术领域著名专家、教授的经典之作和反映信息科学技术最新进展的优秀作品，代表了目前世界信息科学技术教育的一流水平，而且价格也是最优惠的，与国内同类自编教材相当。

这项教材引进工作是在教育部高等教育司和高教社的共同组织下，由国内信息科学技术领域的专家、教授广泛参与，在对大量国外教材进行多次遴选的基础上，参考了国内和国外著名大学相关专业的课程设置进行系统引进的。其中，John Wiley 公司出版的贝尔实验室信息科学研究中心副总裁 Silberschatz 教授的经典著作《操作系统概念》，是我们经过反复谈判，做了很多努力才得以引进的。William Stallings 先生曾编写了在美国深受欢迎的信息科学技术系列教材，其中有多种教材获得过美国教材和学术著作者协会颁发的计算机科学与工程教材奖，这批引进教材中就有他的两本著作。留美中国学者 Jiawei Han 先生的《数据挖掘》是该领域中具有里程碑意义的著作。由达特茅斯学院 Thomas Cormen 和麻省理工学院、哥伦比亚大学的几

位学者共同编著的经典著作《算法导论》，在经历了 11 年的锤炼之后于 2001 年出版了第二版。目前任教于美国 Massachusetts 大学的 James Kurose 教授，曾在美国三所高校先后 10 次获得杰出教师或杰出教学奖，由他主编的《计算机网络》出版后，以其体系新颖、内容先进而倍受欢迎。在努力降低引进教材售价方面，高等教育出版社做了大量和细致的工作。这套引进的教材体现了权威性、系统性、先进性和经济性等特点。

教育部也希望国内和国外的出版商积极参与此项工作，共同促进中国信息技术教育和信息产业的发展。我们在与外商的谈判工作中，不仅要坚定不移地引进国外最优秀的教材，而且还要千方百计地将版权转让费降下来，要让引进教材的价格与国内自编教材相当，让广大教师和学生负担得起。中国的教育市场巨大，外国出版公司和国内出版社要通过扩大发行数量取得效益。

在引进教材的同时，我们还应做好消化吸收，注意学习国外先进的教学思想和教学方法，提高自编教材的水平，使我们的教学和教材在内容体系上，在理论与实践的结合上，在培养学生的动手能力上能有较大的突破和创新。

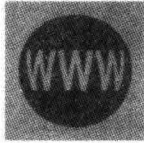
目前，教育部正在全国 35 所高校推动示范性软件学院的建设和实施，这也是加快培养信息科学技术人才的重要举措之一。示范性软件学院要立足于培养具有国际竞争力的实用性软件人才，与国外知名高校或著名企业合作办学，以国内外著名 IT 企业为实践教学基地，聘请国内外知名教授和软件专家授课，还要率先使用引进教材开展教学。

我们希望通过这些举措，能在较短的时间，为我国培养一大批高质量的信息技术人才，提高我国软件人才的国际竞争力，促进我国信息产业的快速发展，加快推动国家信息化进程，进而带动整个国民经济的跨越式发展。

教育部高等教育司

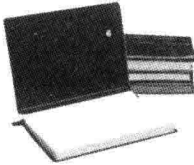
二〇〇二年三月

For my scintillating wife
ATS



Useful Web Sites

The DCC7e Web site includes links to relevant Web sites, organized by chapter. The links cover a broad spectrum of topics and will enable students to explore timely issues in greater depth.



Supplemental Documents

The DCC7e Web site includes a number of documents that expand on the treatment in the book. Topics include standards organizations, Sockets, TCP/IP checksum, ASCII, and the sampling theorem.



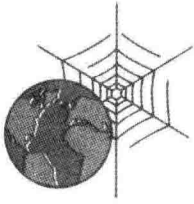
Internet Mailing List

An Internet mailing list is maintained so that instructors using this book can exchange information, suggestions, and questions with each other and the author. Subscription information is provided at the book's Web site.



Simulation and Modeling Tools

The Web site includes links to the *cnet* Web site and the *modeling tools* Web site. These packages can be used to analyze and experiment with protocol and network design issues. Each site includes downloadable software and background information. The instructor's manual includes more information on loading and using the software and suggested student projects. See Appendix D for more information.



WEB SITE FOR DATA AND COMPUTER COMMUNICATIONS

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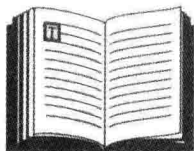
The Web site at WilliamStallings.com/DCC/DCC7e.html provides support for instructors and students using the book. It includes the following elements.



Course Support Materials

The course support materials include

- Copies of figures from the book in PDF format
- A detailed set of course notes in PDF format suitable for student handout or for use as viewgraphs
- A set of PowerPoint slides for use as lecture aids
- Computer Science Student Support Site: contains a number of links and documents that the student may find useful in his/her ongoing computer science education. The site includes a review of basic, relevant mathematics; advice on research, writing, and doing homework problems; links to computer science research resources, such as report repositories and bibliographies; and other useful links.
- An errata sheet for the book, updated at most monthly



DCC Courses

The DCC7e Web site includes links to Web sites for courses taught using the book. These sites can provide useful ideas about scheduling and topic ordering, as well as a number of useful handouts and other materials.

前言

宗旨

本书的宗旨是向读者完整地介绍数据与计算机通信这一广阔领域。作者通过书中的章节，将庞大的论题划分为易于理解的各个部分，逐步向读者揭示这一领域的新进展。本书的重点放在基本原理以及与该领域的技术和体系结构有关的重要问题上，同时详细讨论了一些前沿技术。

本书所讨论的内容围绕以下几条主线展开。

- **基本原理：**尽管本书涵盖面甚广，但有一些基本原理作为主线反复出现，并以其统贯全领域内容，例如复用、流量控制和差错控制。书中反复强调这些基本原理，并将它们在各个专项技术领域内的应用进行了对比。
- **设计方法：**本书详细介绍了满足特定通信要求的多项可选设计方法。
- **标准：**在数据与计算机通信领域中，标准起着越来越重要的作用，甚至是决定性的作用。要了解某一技术的现状和发展趋势，就必须全面讨论其相关标准。

内容安排

本书的内容共分五大部分。此外，书后还附有详尽的词汇表、常用缩略语对照表及参考文献。每一章都附有习题和进一步阅读的建议。

本书的阅读对象包括学术研究人员和专业技术人员。对数据与计算机通信领域有兴趣的专业技术人员可将本书视为基础入门教材，并十分适合于自学。作为教材，本书可用于一个学期或两个学期的课程。书中内容全面涵盖了 ACM/IEEE Computing Curricula 2001 计算机核心课程建议中通信与网络构成的范围。本书模块化的章节结构为课程安排提供了极大的灵活性。以下是对课程安排的几点建议。

- **数据通信基础：**第 1 部分（概论）、第 2 部分（数据通信）以及第 10 章和第 11

章（电路交换、分组交换和异步传输模式）。

- **通信网络:** 针对已经掌握了数据通信基础知识的学生, 课程可包括第 1 部分（概论）、第 3 部分（广域网）和第 4 部分（局域网）。
- **计算机网络:** 对于已经掌握了数据通信基础知识的学生, 课程可包括第 1 部分（概论）、第 6 章、第 7 章（数据通信技术和数据链路控制）以及第 5 部分（协议）。

此外, 作为涉及全面内容的精简课程, 可以略去某些对第一次阅读来说并不重要的章节。可选的章节包括: 第 3 章（数据传输）、第 4 章（传输介质）、若学生对这些章节已有基本了解。其他可选章节还包括: 第 8 章（复用）、第 9 章（扩频）、第 12 章~第 14 章（路由选择、拥塞控制、蜂窝无线网络）、第 18 章（网际互连）和第 21 章（网络安全）。

向师生提供的因特网服务

本书配有 Web 网站, 专门为师生提供教学支持。该网站提供到其他相关站点的链接、书中的清晰图片以及本书的电子邮件列表的注册信息。该网站地址是 WilliamStallings.com/DCC/DCC7e.html。详情请参见本书目录之前的“WEB SITE FOR DATA AND COMPUTER COMMUNICATIONS”一节。为了方便采用本书的教师相互之间以及教师与作者之间交流教学信息、建议和问题, 还设立了一个 Internet 电子邮件列表。一旦发现任何排版错误或其他错误, 可以利用 WilliamStallings.com 下的关于本书的勘误表。

用于数据与计算机通信教学的课程设计项目

许多教师认为, 数据通信或者网络课程教学中的一个重要环节是完成一个或一套课程设计项目。通过课程设计项目, 学生可以亲自动手实践以加深对课程中概念的理解。本书为课程设计环节提供了不同程度的支持。教师手册不仅对如何安排和组织这些课程设计提供了指导, 而且还推荐了一组课程设计, 这些课程设计覆盖了书中所讨论的广泛内容, 其中包括研究项目、仿真项目、模型分析项目以及课外阅读/报告作业。详情请参见附录 D。

Socket 编程

本书简单介绍了 Socket 程序设计（附录 C），更详细的介绍可以在本书的 Web 网站上找到。教师手册中包括一套编程项目。Socket 编程是一件“简单”的事，非常适合作为学

生动手练习的项目。

第七版的新内容

本书的第七版在第六版发行后不到 4 年的时间内问世了。在此期间,数据与计算机通信领域的发展速度丝毫没有减慢。在第七版中,作者在对整个领域进行全面介绍的同时,试图跟上这些变化。在进行改版之前,由多位讲授该课程的教授对本书的第六版做了大量审阅工作。因此,本版在很多地方的叙述比以往更清晰、更严谨,并且改进了许多示例。另外,还增加了许多新的现场实验题目。

除了使本书更适用于教学和阅读之外,全书还有一些实质性的主要变化。书中的每一章都做了修订,并增加了一些新的章节,全书的整体结构也发生了变化。值得关注的地方有以下几个方面。

- **无线通信与网络构成:** 近来有关无线通信、无线网络以及无线标准的素材大量增加,本书的新版专门为扩频技术、蜂窝无线网络和无线局域网分别设置一章。
- **千兆以太网:** 对千兆以太网的内容进行了更新,并且增加了对 10-Gbps 以太网的介绍。
- **区分服务:** 自从本书第六版问世以来,因特网在支持各种多媒体和高时效流量方面取得了显著进展。其中最重要的进展就是区分服务(DS),它也可能是在基于 IP 的网络中提供服务质量(QoS)的最重要的实现手段。本版全方位地介绍了 DS。
- **保证帧速率(GFR):** 自第六版问世以来,一种新的 ATM 服务 GFR 已被标准化。GFR 是为了支持 IP 主干网而专门设计的。第七版对 GFR 做了解释并探讨了支持 GFR 服务的机制。
- **多协议标签交换(MPLS):** MPLS 已作为因特网的一个基础性的重要技术出现,因此在新版中也包括了这一内容。
- **TCP/IP 详解:** 此次改版为介绍 TCP 和 IP 的背景知识专门增加了一章,从而将分散在第六版各章节中的相关内容整合为一体。这些内容对于理解 QoS 和 IP 网络中的性能问题至关重要。

除此之外,书中讨论的所有内容均做了更新,反映了自本书第五版发行以来这些标准

和技术的发展。

致谢

此次新版得益于诸多人士的鼎力支持，他们慷慨地付出了自己的时间和专长。参与审阅本书原稿全部或大部分内容的人员有：Michael J. Donahoo (Baylor 大学)、Gary Harkin (Montana 州立大学)、Larry Owens (California 州立大学 Fresno 分校)、S. Hossein Hosseini (Wisconsin 大学 Milwaukee 分校)、Charles Baker 博士 (Southern Methodist 大学)。

同时也感谢仔细对具体章节进行技术审阅的同仁：Dave Tweed、Bruce Lane、Denis McMahon、Charles Freund、Paul Hoadley、Stephen Ma、Sandeep Subramaniam、Dragan Cvetkovic、Fernando Gont、Neil Giles、Rajesh Thundil 及 Rick Jones。

最后还要感谢为本书的出版而付出努力的人们，他们的工作一如既往地出色。其中包括 Prentice Hall 出版公司的工作人员，特别是本书编辑 Alan Apt 和他的助手 Patrick Lindner 以及制作人 Rose Kernan。另外，Warde 出版公司的 Jake Warde 负责补编与审核，Patricia M. Daly 负责文字编辑工作。

PREFACE

OBJECTIVES

This book attempts to provide a unified overview of the broad field of data and computer communications. The organization of the book reflects an attempt to break this massive subject into comprehensible parts and to build, piece by piece, a survey of the state of the art. The book emphasizes basic principles and topics of fundamental importance concerning the technology and architecture of this field and provides a detailed discussion of leading-edge topics.

The following basic themes serve to unify the discussion:

- **Principles:** Although the scope of this book is broad, there are a number of basic principles that appear repeatedly as themes and that unify this field. Examples are multiplexing, flow control, and error control. The book highlights these principles and contrasts their application in specific areas of technology.
- **Design approaches:** The book examines alternative approaches to meeting specific communication requirements.
- **Standards:** Standards have come to assume an increasingly important, indeed dominant, role in this field. An understanding of the current status and future direction of technology requires a comprehensive discussion of the related standards.

PLAN OF THE TEXT

The book is divided into five parts:

In addition, the book includes an extensive glossary, a list of frequently used acronyms, and a bibliography. Each chapter includes problems and suggestions for further reading.

The book is intended for both an academic and a professional audience. For the professional interested in this field, the book serves as a basic reference volume and is suitable for self-study. As a textbook, it can be used for a one-semester or two-semester course. It covers the material in the Communication and Networking core course of the joint ACM/IEEE Computing

Curricula 2001. The chapters and parts of the book are sufficiently modular to provide a great deal of flexibility in the design of courses. The following are suggestions for course design:

- **Fundamentals of Data Communications:** Parts One (overview) and Two (data communications) and Chapters 10 and 11 (circuit switching, packet switching, and ATM).
- **Communications Networks:** If the student has a basic background in data communications, then this course could cover Parts One (overview), Three (WAN), and Four (LAN).
- **Computer Networks:** If the student has a basic background in data communications, then this course could cover Part One (overview), Chapters 6 and 7 (data communication techniques and data link control), and Part Five (protocols).

In addition, a more streamlined course that covers the entire book is possible by eliminating certain chapters that are not essential on a first reading. Chapters that could be optional are Chapters 3 (data transmission) and 4 (transmission media), if the student has a basic understanding of these topics; Chapter 8 (multiplexing); Chapter 9 (spread spectrum); Chapters 12 through 14 (routing, congestion control, cellular networks); Chapter 18 (internetworking); and Chapter 21 (network security).

INTERNET SERVICES FOR INSTRUCTORS AND STUDENTS

There is a Web site for this book that provides support for students and instructors. The site includes links to other relevant sites, transparency masters of figures in the book, and sign-up information for the book's Internet mailing list. The Web page is at WilliamStallings.com/DCC/DCC7e.html; see the section, "Web Site for Data and Computer Communications," preceding the Table of Contents, for more information. An Internet mailing list has been set up so that instructors using this book can exchange information, suggestions, and questions with each other and with the author. As soon as typos or other errors are discovered, an errata list for this book will be available at WilliamStallings.com.

PROJECTS FOR TEACHING DATA AND COMPUTER COMMUNICATIONS

For many instructors, an important component of a data communications or networking course is a project or set of projects by which the student gets hands-on experience to reinforce concepts from the text. This book provides an unparalleled degree of support for including a projects component in the course. The instructor's manual not only includes guidance on how to assign and structure the projects, but also includes a set of suggested projects that covers a broad range of topics from the text, including research projects, simulation projects, analytic modeling projects, and reading/report assignments. See Appendix D for details.

SOCKETS PROGRAMMING

The book includes a brief description of Sockets (Appendix C), with a more detailed description available at the book's Web site. The Instructors manual includes a set of programming projects. Sockets programming is an "easy" topic and one that can result in very satisfying hands-on projects for students.

WHAT'S NEW IN THE SEVENTH EDITION

This seventh edition is seeing the light of day less than 4 years after the publication of the sixth edition. During that time, the pace of change in this field continues unabated. In this new edition, I try to capture these changes while maintaining a broad and comprehensive coverage of the entire field. To begin the process of revision, the sixth edition of this book was extensively reviewed by a number of professors who teach the subject. The result is that, in many places, the narrative has been clarified and tightened, and illustrations have been improved. Also, a number of new "field-tested" problems have been added.

Beyond these refinements to improve pedagogy and user-friendliness, there have been major substantive changes throughout the book. Every chapter has been revised, new chapters have been added, and the overall organization of the book has changed. Highlights include:

- **Wireless communications and networking:** There is a significant increase in the amount of material on wireless communications, wireless networks, and wireless standards. The book now devotes one chapter each to spread spectrum technology, cellular wireless networks, and wireless LANs.
- **Gigabit Ethernet:** The discussion on Gigabit Ethernet has been updated and an introduction to 10-Gbps Ethernet has been added.
- **Differentiated services:** There have been substantial developments since the publication of the sixth edition in enhancements to the Internet to support a variety of multimedia and time-sensitive traffic. The most important development, and perhaps the most important vehicle for providing QoS in IP-based networks, is Differentiated Services (DS). This edition provides thorough coverage of DS.
- **Guaranteed frame rate (GFR):** Since the sixth edition, a new ATM service has been standardized: GFR. GFR is designed specifically to support IP backbone subnetworks. This edition provides an explanation of GFR and examines the mechanisms underlying the GFR service.
- **Multiprotocol label switching (MPLS):** MPLS has emerged as a fundamentally important technology in the Internet and is covered in this edition.
- **TCP/IP details:** A new background chapter on TCP and IP has been added, pulling together material scattered throughout the sixth edition. This material is vital to an understanding of QoS and performance issues in IP-based networks.

In addition, throughout the book, virtually every topic has been updated to reflect the developments in standards and technology that have occurred since the publication of the fifth edition.

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