Preface

I thank the many readers who have taken the time to write to me with comments on previous editions of *Computer Networks And Internets*. The reviews have been incredibly positive, and the audience is surprisingly wide. In addition to students who use the text in courses, networking professionals have written to praise its clarity and to describe how it helped them pass professional certification exams. Many enthusiastic comments have also arrived from countries around the world; some about the English language version and some 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.

What's New In This Edition

In response to suggestions from readers and recent changes in networking, the new edition has been completely revised and updated. As always, material on older technologies has been significantly reduced and replaced by material on new technologies. The significant changes include:

- Updates throughout each chapter
- Additional figures to enchance explanations
- Integration of IPv4 and IPv6 in all chapters
- Improved coverage of MPLS and tunneling
- New chapter on Software Defined Networking and OpenFlow
- New chapter on the Internet of Things and Zigbee

Approach Taken

Should courses take a top-down or bottom-up approach to the subject? In a bottom-up approach, one starts with transmission of bits over a single wire, and then learns how successive layers of protocols expand the functionality. In a top-down approach, one starts with high-level applications, initially learning only enough to understand how such applications operate. Later, one learns about the underlying details.

This text combines the best of top-down and bottom-up approaches. 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.

Intended Audience

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

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

Organization Of The Material

The text is divided into five parts. The first part (Chapters 1–4) 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 presents background on the underlying hardware, the basic vocabulary, and fundamental concepts used throughout networking, such as bandwidth, modulation, and multiplexing. The final chapter in the second part presents access and interconnection technologies used in the Internet, and uses concepts from previous chapters to explain each technology.

The third part (Chapters 13–19) focuses on packet switching and packet switching network technologies. Chapters give the motivation for using packets, introduce the IEEE model for layer 2 protocols, and consider wired and wireless networking technologies, such as Ethernet and Wi-Fi. The third part also introduces the four basic categories of network technologies: 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 20–26) 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 IPv4, IPv6, TCP, UDP, ICMP, ICMPv6, and ARP are reviewed in detail, allowing students to understand how the concepts relate to practice. Because IPv6 has (finally) begun to be deployed, material on IPv6 has been integrated into the chapters. Each chapter presents general concepts, and then explains how the concepts are implemented in IPv4 and IPv6. Chapter 25 on TCP covers the important topic of reliability in transport protocols.

The final part of the text (Chapters 27–33) considers topics that cross multiple layers of a protocol stack, including network performance, network security, network management, bootstrapping, multimedia support, and the Internet of Things. Chapter 31 presents Software Defined Networking, one of the most exciting new developments in networking. Each 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.

Use In Courses

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. Although many instructors choose to skip over the material on data communications, I encourage them to extract key concepts and terminology that will be important for later chapters. No matter how courses are organized, 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 forwarding table to choose a next hop for an IP datagram; 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 propagates across a wire at the speed of light; explain why TCP is classified as end-to-end; know why machine-to-machine communication is important for the Internet of Things; and understand the motivation for SDN.

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 II 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, either in labs or as homework problems.

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. The excitement continues because networking keeps changing, as the new era of Software Defined Networking illustrates.

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 encourage students to keep a list of terms (and have found that a weekly vocabulary quiz helps persuade students to learn terminology as the semester proceeds, rather than waiting until an exam).

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 visit a web site and 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 packet analyzer software, such as *Wireshark*.

In addition to code for the simplified API, the web site for the text contains extra materials for students and instructors:

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

I thank all the people who have contributed to editions of the book. Many grad students at Purdue have contributed suggestions and criticism. Baijian (Justin) Yang and Bo Sang each recommended the addition of text and figures to help their students understand the material better. Fred Baker, Ralph Droms, and Dave Oran from Cisco contributed to earlier editions. Lami Kaya suggested how the chapters on data communications could be organized, and made many other valuable suggestions. Special thanks go to my wife and partner, Christine, whose careful editing and helpful suggestions made many improvements throughout.

Douglas E. Comer

†A separate 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.