Preface

Welcome to the sixth edition of *Computer Networking: A Top-Down Approach.* Since the publication of the first edition 12 years ago, our book has been adopted for use at many hundreds of colleges and universities, translated into 14 languages, and used by over one hundred thousand students and practitioners worldwide. We've heard from many of these readers and have been overwhelmed by the positive response.

What's New in the Sixth Edition?

We think one important reason for this success has been that our book continues to offer a fresh and timely approach to computer networking instruction. We've made changes in this sixth edition, but we've also kept unchanged what we believe (and the instructors and students who have used our book have confirmed) to be the most important aspects of this book: its top-down approach, its focus on the Internet and a modern treatment of computer networking, its attention to both principles and practice, and its accessible style and approach toward learning about computer networking. Nevertheless, the sixth edition has been revised and updated substantially:

- The Companion Web site has been significantly expanded and enriched to include VideoNotes and interactive exercises, as discussed later in this Preface.
- In Chapter 1, the treatment of access networks has been modernized, and the description of the Internet ISP ecosystem has been substantially revised, accounting for the recent emergence of content provider networks, such as Google's. The presentation of packet switching and circuit switching has also been reorganized, providing a more topical rather than historical orientation.
- In Chapter 2, Python has replaced Java for the presentation of socket programming. While still explicitly exposing the key ideas behind the socket API, Python code is easier to understand for the novice programmer. Moreover, unlike Java, Python provides access to raw sockets, enabling students to build a larger variety of network applications. Java-based socket programming labs have been replaced with corresponding Python labs, and a new Python-based ICMP Ping lab has been added. As always, when material is retired from the book, such as Java-based socket programming material, it remains available on the book's Companion Web site (see following text).
- In Chapter 3, the presentation of one of the reliable data transfer protocols has been simplified and a new sidebar on TCP splitting, commonly used to optimize the performance of cloud services, has been added.
- In Chapter 4, the section on router architectures has been significantly updated, reflecting recent developments and practices in the field. Several new integrative sidebars involving DNS, BGP, and OSPF are included.

- Chapter 5 has been reorganized and streamlined, accounting for the ubiquity of switched Ethernet in local area networks and the consequent increased use of Ethernet in point-to-point scenarios. Also, a new section on data center networking has been added.
- Chapter 6 has been updated to reflect recent advances in wireless networks, particularly cellular data networks and 4G services and architecture.
- Chapter 7, which focuses on multimedia networking, has gone through a major revision. The chapter now includes an in-depth discussion of streaming video, including adaptive streaming, and an entirely new and modernized discussion of CDNs. A newly added section describes the Netflix, YouTube, and Kankan video streaming systems. The material that has been removed to make way for these new topics is still available on the Companion Web site.
- Chapter 8 now contains an expanded discussion on endpoint authentication.
- Significant new material involving end-of-chapter problems has been added. As with all previous editions, homework problems have been revised, added, and removed.

Audience

This textbook is for a first course on computer networking. It can be used in both computer science and electrical engineering departments. In terms of programming languages, the book assumes only that the student has experience with C, C++, Java, or Python (and even then only in a few places). Although this book is more precise and analytical than many other introductory computer networking texts, it rarely uses any mathematical concepts that are not taught in high school. We have made a deliberate effort to avoid using any advanced calculus, probability, or stochastic process concepts (although we've included some homework problems for students with this advanced background). The book is therefore appropriate for undergraduate courses and for first-year graduate courses. It should also be useful to practitioners in the telecommunications industry.

What Is Unique about This Textbook?

The subject of computer networking is enormously complex, involving many concepts, protocols, and technologies that are woven together in an intricate manner. To cope with this scope and complexity, many computer networking texts are often organized around the "layers" of a network architecture. With a layered organization, students can see through the complexity of computer networking—they learn about the distinct concepts and protocols in one part of the architecture while seeing the big picture of how all parts fit together. From a pedagogical perspective, our personal experience has been that such a layered approach

indeed works well. Nevertheless, we have found that the traditional approach of teaching—bottom up; that is, from the physical layer towards the application layer—is not the best approach for a modern course on computer networking.

A Top-Down Approach

Our book broke new ground 12 years ago by treating networking in a top-down manner—that is, by beginning at the application layer and working its way down toward the physical layer. The feedback we received from teachers and students alike have confirmed that this top-down approach has many advantages and does indeed work well pedagogically. First, it places emphasis on the application layer (a "high growth area" in networking). Indeed, many of the recent revolutions in computer networking—including the Web, peer-to-peer file sharing, and media streaming—have taken place at the application layer. An early emphasis on application-layer issues differs from the approaches taken in most other texts, which have only a small amount of material on network applications, their requirements, application-layer paradigms (e.g., client-server and peer-to-peer), and application programming interfaces. Second, our experience as instructors (and that of many instructors who have used this text) has been that teaching networking applications near the beginning of the course is a powerful motivational tool. Students are thrilled to learn about how networking applications work—applications such as e-mail and the Web, which most students use on a daily basis. Once a student understands the applications, the student can then understand the network services needed to support these applications. The student can then, in turn, examine the various ways in which such services might be provided and implemented in the lower layers. Covering applications early thus provides motivation for the remainder of the text.

Third, a top-down approach enables instructors to introduce network application development at an early stage. Students not only see how popular applications and protocols work, but also learn how easy it is to create their own network applications and application-level protocols. With the top-down approach, students get early exposure to the notions of socket programming, service models, and protocols—important concepts that resurface in all subsequent layers. By providing socket programming examples in Python, we highlight the central ideas without confusing students with complex code. Undergraduates in electrical engineering and computer science should not have difficulty following the Python code.

An Internet Focus

Although we dropped the phrase "Featuring the Internet" from the title of this book with the fourth edition, this doesn't mean that we dropped our focus on the Internet! Indeed, nothing could be further from the case! Instead, since the Internet has become so pervasive, we felt that any networking textbook must have a significant

focus on the Internet, and thus this phrase was somewhat unnecessary. We continue to use the Internet's architecture and protocols as primary vehicles for studying fundamental computer networking concepts. Of course, we also include concepts and protocols from other network architectures. But the spotlight is clearly on the Internet, a fact reflected in our organizing the book around the Internet's five-layer architecture: the application, transport, network, link, and physical layers.

Another benefit of spotlighting the Internet is that most computer science and electrical engineering students are eager to learn about the Internet and its protocols. They know that the Internet has been a revolutionary and disruptive technology and can see that it is profoundly changing our world. Given the enormous relevance of the Internet, students are naturally curious about what is "under the hood." Thus, it is easy for an instructor to get students excited about basic principles when using the Internet as the guiding focus.

Teaching Networking Principles

Two of the unique features of the book—its top-down approach and its focus on the Internet—have appeared in the titles of our book. If we could have squeezed a *third* phrase into the subtitle, it would have contained the word *principles*. The field of networking is now mature enough that a number of fundamentally important issues can be identified. For example, in the transport layer, the fundamental issues include reliable communication over an unreliable network layer, connection establishment/teardown and handshaking, congestion and flow control, and multiplexing. Two fundamentally important network-layer issues are determining "good" paths between two routers and interconnecting a large number of heterogeneous networks. In the link layer, a fundamental problem is sharing a multiple access channel. In network security, techniques for providing confidentiality, authentication, and message integrity are all based on cryptographic fundamentals. This text identifies fundamental networking issues and studies approaches towards addressing these issues. The student learning these principles will gain knowledge with a long "shelf life"—long after today's network standards and protocols have become obsolete, the principles they embody will remain important and relevant. We believe that the combination of using the Internet to get the student's foot in the door and then emphasizing fundamental issues and solution approaches will allow the student to quickly understand just about any networking technology.

The Web Site

Each new copy of this textbook includes six months of access to a Companion Web site for all book readers at http://www.pearsonhighered.com/kurose-ross, which includes:

- *Interactive learning material.* An important new component of the sixth edition is the significantly expanded online and interactive learning material. The book's Companion Web site now contains VideoNotes—video presentations of

important topics thoughout the book done by the authors, as well as walkthroughs of solutions to problems similar to those at the end of the chapter. We've also added Interactive Exercises that can create (and present solutions for) problems similar to selected end-of-chapter problems. Since students can generate (and view solutions for) an unlimited number of similar problem instances, they can work until the material is truly mastered. We've seeded the Web site with VideoNotes and online problems for chapters 1 through 5 and will continue to actively add and update this material over time. As in earlier editions, the Web site contains the interactive Java applets that animate many key networking concepts. The site also has interactive quizzes that permit students to check their basic understanding of the subject matter. Professors can integrate these interactive features into their lectures or use them as mini labs.

- *Additional technical material.* As we have added new material in each edition of our book, we've had to remove coverage of some existing topics to keep the book at manageable length. For example, to make room for the new material in this edition, we've removed material on ATM networks and the RTSP protocol for multimedia. Material that appeared in earlier editions of the text is still of interest, and can be found on the book's Web site.
- *Programming assignments.* The Web site also provides a number of detailed programming assignments, which include building a multithreaded Web server, building an e-mail client with a GUI interface, programming the sender and receiver sides of a reliable data transport protocol, programming a distributed routing algorithm, and more.
- *Wireshark labs.* One's understanding of network protocols can be greatly deepened by seeing them in action. The Web site provides numerous Wireshark assignments that enable students to actually observe the sequence of messages exchanged between two protocol entities. The Web site includes separate Wireshark labs on HTTP, DNS, TCP, UDP, IP, ICMP, Ethernet, ARP, WiFi, SSL, and on tracing all protocols involved in satisfying a request to fetch a web page. We'll continue to add new labs over time.

Pedagogical Features

We have each been teaching computer networking for more than 20 years. Together, we bring more than 50 years of teaching experience to this text, during which time we have taught many thousands of students. We have also been active researchers in computer networking during this time. (In fact, Jim and Keith first met each other as master's students in a computer networking course taught by Mischa Schwartz in 1979 at Columbia University.) We think all this gives us a good perspective on where networking has been and where it is likely to go in the future. Nevertheless, we have resisted temptations to bias the material in this book

towards our own pet research projects. We figure you can visit our personal Web sites if you are interested in our research. Thus, this book is about modern computer networking—it is about contemporary protocols and technologies as well as the underlying principles behind these protocols and technologies. We also believe that learning (and teaching!) about networking can be fun. A sense of humor, use of analogies, and real-world examples in this book will hopefully make this material more fun.

Supplements for Instructors

We provide a complete supplements package to aid instructors in teaching this course. This material can be accessed from Pearson's Instructor Resource Center (http://www.pearsonhighered.com/irc). Visit the Instructor Resource Center or send e-mail to computing@aw.com for information about accessing these instructor's supplements.

- *PowerPoint® slides.* We provide PowerPoint slides for all nine chapters. The slides have been completely updated with this sixth edition. The slides cover each chapter in detail. They use graphics and animations (rather than relying only on monotonous text bullets) to make the slides interesting and visually appealing. We provide the original PowerPoint slides so you can customize them to best suit your own teaching needs. Some of these slides have been contributed by other instructors who have taught from our book.
- *Homework solutions.* We provide a solutions manual for the homework problems in the text, programming assignments, and Wireshark labs. As noted earlier, we've introduced many new homework problems in the first five chapters of the book.

Chapter Dependencies

The first chapter of this text presents a self-contained overview of computer networking. Introducing many key concepts and terminology, this chapter sets the stage for the rest of the book. All of the other chapters directly depend on this first chapter. After completing Chapter 1, we recommend instructors cover Chapters 2 through 5 in sequence, following our top-down philosophy. Each of these five chapters leverages material from the preceding chapters. After completing the first five chapters, the instructor has quite a bit of flexibility. There are no interdependencies among the last four chapters, so they can be taught in any order. However, each of the last four chapters depends on the material in the first five chapters. Many instructors first teach the first five chapters and then teach one of the last four chapters for "dessert."

One Final Note: We'd Love to Hear from You

We encourage students and instructors to e-mail us with any comments they might have about our book. It's been wonderful for us to hear from so many instructors and students from around the world about our first four editions. We've incorporated many of these suggestions into later editions of the book. We also encourage instructors to send us new homework problems (and solutions) that would complement the current homework problems. We'll post these on the instructor-only portion of the Web site. We also encourage instructors and students to create new Java applets that illustrate the concepts and protocols in this book. If you have an applet that you think would be appropriate for this text, please submit it to us. If the applet (including notation and terminology) is appropriate, we'll be happy to include it on the text's Web site, with an appropriate reference to the applet's authors.

So, as the saying goes, "Keep those cards and letters coming!" Seriously, please *do* continue to send us interesting URLs, point out typos, disagree with any of our claims, and tell us what works and what doesn't work. Tell us what you think should or shouldn't be included in the next edition. Send your e-mail to kurose@cs.umass.edu and ross@poly.edu.

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