Preface

This is not a book on how to use the Internet. It is a book about how the Internet is made *useful for you*. The Internet is a public global network that runs on TCP/IP, which is frequently called the Internet Protocol Suite. A networking protocol is a set of rules that must be followed to accomplish something, and TCP/IP is actually a synthesis of the first two protocols that launched the Internet in its infancy, the Transmission Control Protocol (TCP) and the Internet Protocol (IP), which of course, allowed the transmission of information across the then youthful Internet. TCP/IP is the heart and soul of modern networks, and this book illustrates how that is accomplished. By using TCP/IP, we can observe how modern networks operate by following the transmission of modern data across all sorts of Internet connections.

Audience

This book is intended as a technical introduction into networking in general and the Internet in particular. I will not pretend that someone who has had no previous experience with either can easily plow through the entire book. But anyone who is experienced enough to check their email online, browse a Web site, download a movie or song, or chat with people around the world should have no trouble tackling the content of this book.

There are questions at the end of each chapter, but this is not a textbook per se. It can be used as a textbook as a first course in computer networking at the high school or undergraduate level. It will fit in with the computer science and electrical engineering departments. It is also explicitly intended for those entering the telecommunications industry or working for a company where the Internet is an essential part of the business plan (of which there are more and more each day).

Only one chapter uses C language code, and that only to provide information for the reader. Mathematical concepts that are not taught in high school are not used. There is no calculus, probability theory, and stochastic process concepts used in any chapter. The "pocket calculator" examples of public key encryption and Diffie-Hellman key distribution were carefully designed to illustrate the concepts, and yet make the mathematics as simple as possible.

What Is Unique about This Book?

What's in this book that you won't find in a half-dozen other books about TCP/IP? The list is not short.

1. This book uses the same network topology and addresses for every example and chapter.

2. This book treats IPv4 and IPv6 as equals.
3. This book covers the routing protocols as well as TCP/IP applications.
4. This book discusses ISPs as well as corporate LANs.
5. This book covers services provided as well as the protocols that provide them.
6. This book covers topics (MPLS, IPSec, etc.) not normally covered in other books on TCP/IP.

Why was the book written this way? Even in the Internet-conscious world we live in today, few study the entire network, the routers, TCP/IP, the Internet, and a host of related topics as part of their general education. What they do learn might seem like a lot, but when considered in relation to the enormous complexity of each of these topics, what is covered in general computer "literacy" or basic programming courses is really only a drop in the bucket.

As I was writing this book, and printing it out at my workplace, a silicon chip engineer-designer found a few chapters on top of the printer bin, and he began reading it. When I came to retrieve the printout, he was fascinated by the sample chapters. He wanted the book then and there. And as we talked, he made me realize that thousands of people are entering the networking industry every day, many from other occupations and disciplines. As the Internet grows, and society's dependence on the digital communication structure continues, more and more people need this overview of how modern networks operate.

The intellectually curious will not be satisfied with this smattering of and condensation of networking knowledge in a single volume. I'm hoping they will seek ways to increase their knowledge in specific areas of interest. This book covers hundreds of networking topics, and volumes have been written devoted to the intricacies of each one. For example, there are 20 to 30 solid books written on MPLS complexities and evolution, while the chapter here runs at about the same number of pages. My hope is that this book and this method of "illustrating" how a modern network works will contribute to more people seeking out those 20 to 30 books now that they know how the overall thing looks and works.

Like everyone else, I learned about networks, including routers and TCP/IP, mostly from books and from listening to others tell me what they knew. The missing piece, however, was being able to play with the network. The books were great, the discussions led to illumination of how this or that operated, but often I never "saw" it working. This book is a bit of a synthesis of the written and the seen. It attempts to give the reader the opportunity to see common tasks in a real, working, hands-on environment of the proper size and scale, and follow what happens behind the scenes. It's one thing to read about what happens when a Web site is accessed, but another to see it in action.

The purpose of this book is to allow you to see what is happening on a modern network when you access a Web site, write an email, download a song, or talk on the phone over the Internet. From that observation you will learn how a modern network works.

What You Won't Find in This Book

It might seem odd to list things that the book does not cover. But rather than have readers slog through and then find they didn't find what they were after, here's what you will not find in this edition of the book.

You will find no mention of the exciting new peer-to-peer protocols that distribute the server function around the network. There is no mention of the protocols used by chat rooms or services. The book does not explore music or movie download services. In other words, you won't find YouTube, IRC, iTunes, or even eBay mentioned in this book.

These topics are, of course, interesting and/or important. But the limitations of time and page count forced me to focus on essential topics. The other topics could easily form the foundation for *The Illustrated Network, Volume II: Beyond the Basics*.

The Illustrated Network

Many people frustrated with simple lab setups and restricted "live" networks have wished for a more complex and realistic yet secure environment where they can feel free to explore the TCP/IP protocols, layers, and applications without worrying that what they are seeing is limited to a quiet lab, or what they do might bring the whole network to its knees.

The days are long gone when an interested party could take over the whole network, from clients to servers to routers, and play with them at night or over the weekend. Networks are run on a normal business-hour schedule, especially now that the Web makes "prime time" on one side of the world when the other half is trying to get some sleep.

Many times I have encountered a new feature or procedure and said to myself, "I wish I could play with this and see what happens." But only after nearly 40 years of networking experience (I hooked up my first modem, about the size of a microwave oven, in 1966), have I finally arrived at the point where I could say, "I want to do this . . .," and someone didn't tell me it could not be done.

Juniper Networks Inc., my employer, was in a unique position to help me with my plans to not merely talk about TCP/IP, or show contrived examples of the protocols in action, but to "illustrate" each piece with a series of clients, servers, routers, and connections (including the public Internet). They had the routers and links, and employed all the Unix and Windows-based hosts that I could possibly need. (In retrospect, there was probably some overkill in the network, as most chapters used only a couple of routers.) We decided not to upgrade the XP hosts to Vista, which was relatively new at the time, and I kept Internet Explorer 6 active, more or less out of convenience.

In any case, with the blessings of Juniper Networks, I set about creating the kind of network I needed for this book. It took a while, but in the end it was well worth it. We assembled a collection of five routers connected with SONET links,
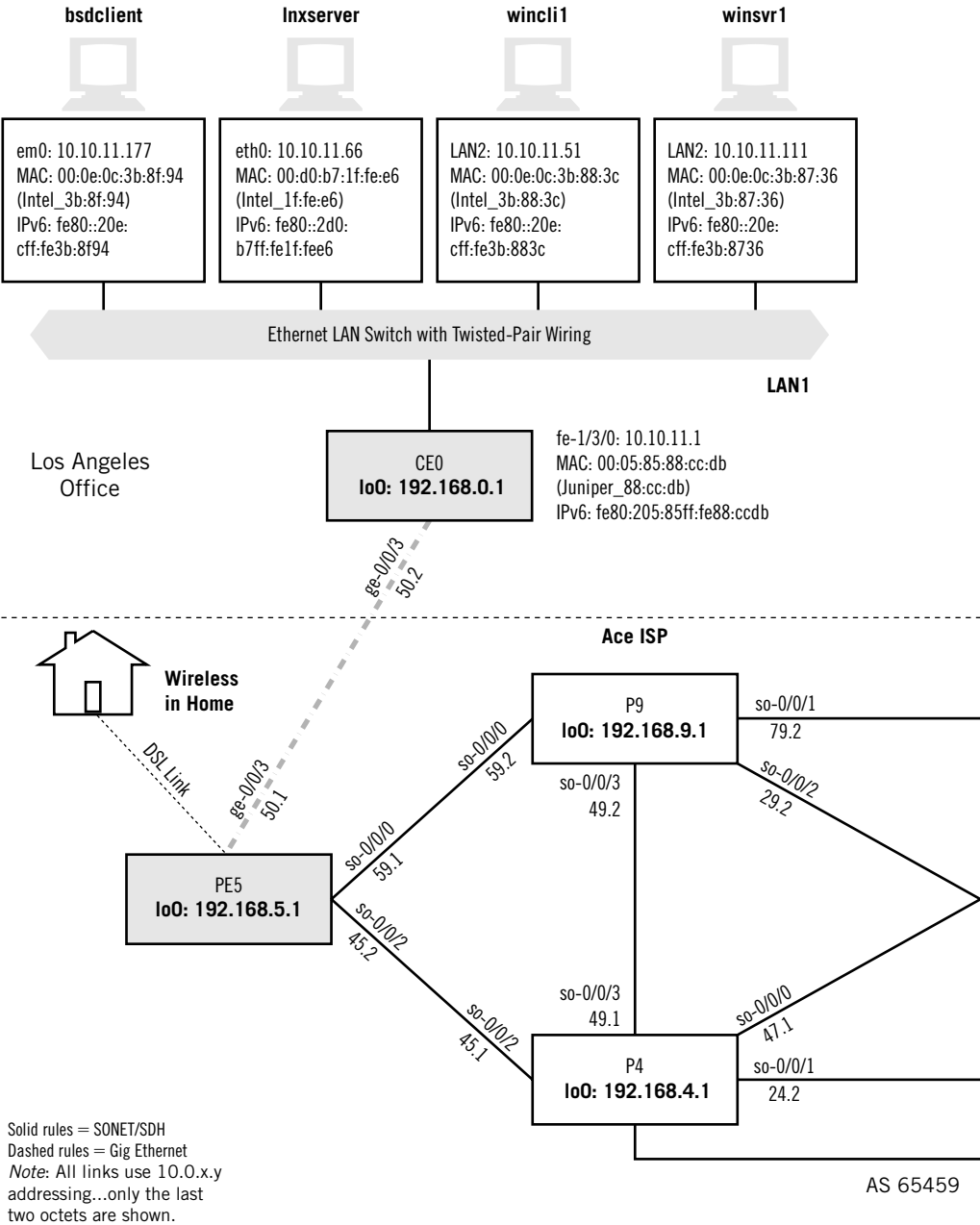
bsdclient

em0: 10.10.11.177
MAC: 00:0e:0c:3b:8f:94
(Intel_3b:8f:94)
IPv6: fe80::20e:
cff:fe3b:8f94

lnxserver

eth0: 10.10.11.66
MAC: 00:d0:b7:1f:fe:e6
(Intel_1f:fe:e6)
IPv6: fe80::2d0:
b7ff:fe1f:fee6

wincli1

LAN2: 10.10.11.51
MAC: 00:0e:0c:3b:88:3c
(Intel_3b:88:3c)
IPv6: fe80::20e:
cff:fe3b:883c

winsvr1

LAN2: 10.10.11.111
MAC: 00:0e:0c:3b:87:36
(Intel_3b:87:36)
IPv6: fe80::20e:
cff:fe3b:8736

Ethernet LAN Switch with Twisted-Pair Wiring

LAN1

Los Angeles
Office

CE0
lo0: 192.168.0.1

fe-1/3/0: 10.10.11.1
MAC: 00:05:85:88:cc:db
(Juniper_88:cc:db)
IPv6: fe80:205:85ff:fe88:ccdb

ge-0/0/3
50.2

**Wireless
in Home**

Ace ISP

DSL Link

ge-0/0/3
50.1

P9
lo0: 192.168.9.1

so-0/0/1
79.2

so-0/0/0
59.2

so-0/0/3
49.2

so-0/0/2
29.2

so-0/0/0
59.1

PE5
lo0: 192.168.5.1

so-0/0/2
45.2

so-0/0/3
49.1

so-0/0/0
47.1

so-0/0/2
45.1

P4
lo0: 192.168.4.1

so-0/0/1
24.2

Solid rules = SONET/SDH
Dashed rules = Gig Ethernet
Note: All links use 10.0.x.y
addressing...only the last
two octets are shown.

AS 65459

FIGURE P.1

The illustrated Network.

bsdserver

lnxclient

winsvr2

wincli2

eth0: 10.10.12.77
MAC: 00:0e:0c:3b:87:32
(Intel_3b:87:32)
IPv6: fe80::20e:
cff:fe3b:8732

eth0: 10.10.12.166
MAC: 00:b0:d0:45:34:64
(Dell_45:34:64)
IPv6: fe80::2b0:
d0ff:fe45:3464

LAN2: 10.10.12.52
MAC: 00:0e:0c:3b:88:56
(Intel_3b:88:56)
IPv6: fe80::20e:
cff:fe3b:8856

LAN2: 10.10.12.222
MAC: 00:02:b3:27:fa:8c

IPv6: fe80::202:
b3ff:fe27:fa8c

Ethernet LAN Switch with Twisted-Pair Wiring

LAN2

New York
Office

CE6
lo0: 192.168.6.1

fe-1/3/0: 10.10.12.1
MAC: 0:05:85:8b:bc:db
(Juniper_8b:bc:db)
IPv6: fe80:205:85ff:fe8b:bcdb

ge-0/0/3
16.2

Best ISP

so-0/0/1
79.1

P7
lo0: 192.168.7.1

so-0/0/2
17.2

ge-0/0/3
16.1

so-0/0/0
47.2

so-0/0/3
27.2

so-0/0/2
17.1

PE1
lo0: 192.168.1.1

so-0/0/2
29.1

so-0/0/3
27.1

so-0/0/0
12.1

so-0/0/1
24.1

P2
lo0: 192.168.2.1

so-0/0/0
12.2

**Global Public
Internet**

AS 65127
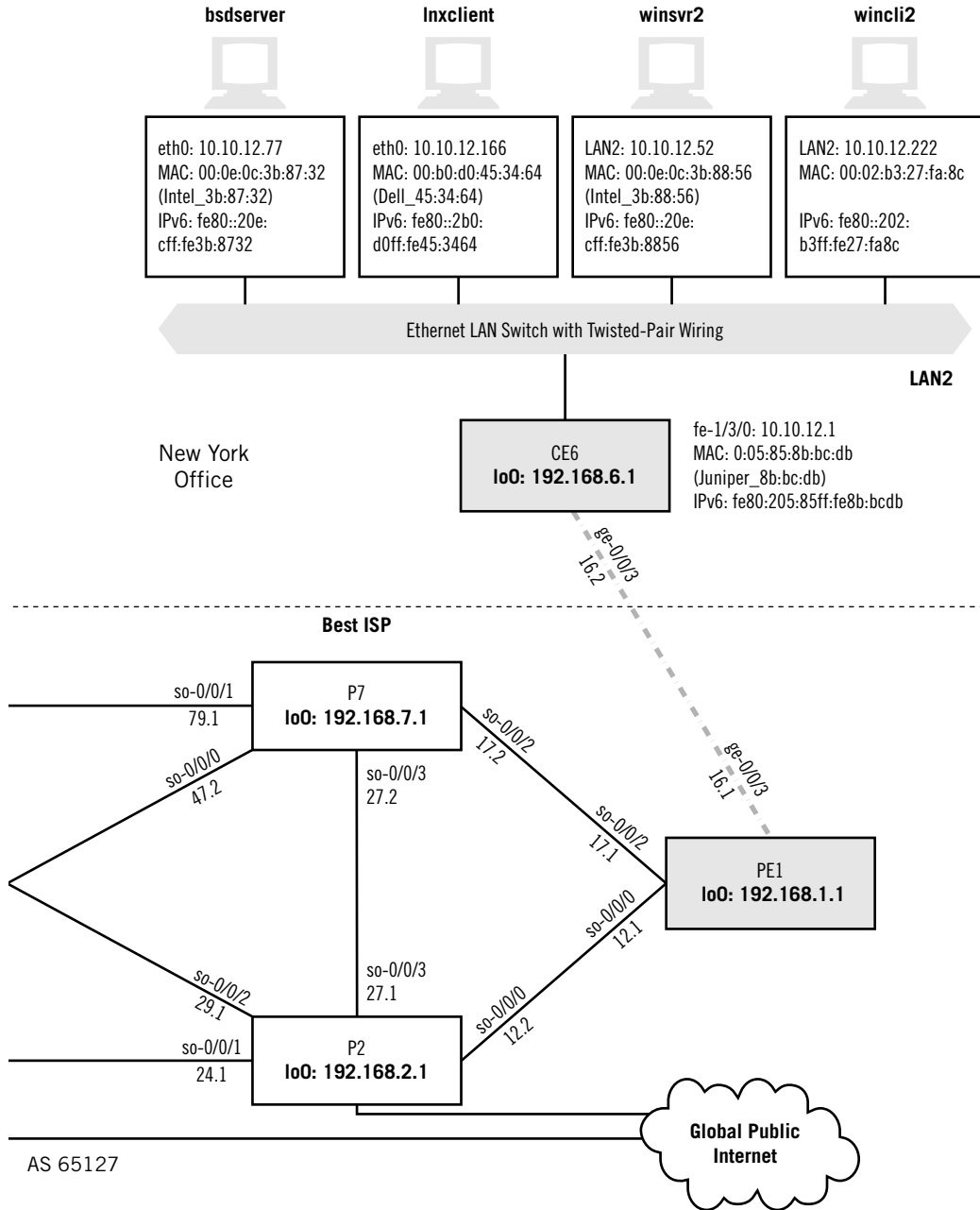
two Ethernet LANs, two pairs of Windows XP clients and servers (Home and Pro editions), one pair of Red Hat Linux hosts (running the RH 9 kernel 2.4.20-8), and a pair of FreeBSD (release 4.10) hosts.

Figure P.1 shows the network that we built and that is used in every chapter of this book to illustrate the networking concepts discussed.

Using This Book

This book is designed to be read from start to finish, chapter by chapter, sequentially. It seems funny to say this, because a lot of technical books these days are not meant to be "read" in the same way as a novel or a biography. Readers tend to look things up in books like this, and then browse from the spot they land on, which you can certainly do with this book, but probably more on a chapter-by-chapter level.

But I hope that the story in this book is as coherent as a mystery, if not as exciting as an adventure tale. From the first chapter, which offers readers a unique look at layered protocols, to the last, this book presents a story that proceeds in a logical fashion from the bottom of the Internet protocol suite to the top (and beyond, in some cases). So if you can, read from start to finish, as the chapters depend on previous ones. If you are new to networking concepts, or just beginning, I recommend this consecutive approach. For those more experienced, bobbing in and out is just fine, but remember that all emphasis is equal in *The Illustrated Network*, and sometimes you may question a topic's coverage, when the item questioned is covered in an earlier chapter.

As you're reading, you'll discover that generally, each chapter has the same structure. The beginning chapters, however, diverge from this format more than the later chapters do, as they require general exploration of the protocol, application, or concept. After the first few chapters, I begin the tasks of illustrating how it all works. In some cases, this involves not only the network built for this book, but the global Internet as well. Note that network configuration specifics, especially those involving the routers, vary somewhat, but these changes are completely detailed as they occur.

The companion Web site for this book is *www.elsevierdirect.com/companions/ 9780123745415*. There you will find many of the capture files to explore some of the protocols on your own.

Source Code

Chapter 3 on network technologies uses examples from wireless network captures supplied by Aeropeek. Chapter 12 on sockets uses listings from utility programs written by Michael J. Donahoo and Kenneth L. Calvert for their excellent book, *TCP/IP Sockets in C* (Morgan Kaufmann, 2001). Thanks to both groups for letting me use their material in this book.

ACKNOWLEDGMENTS

I would like to thank various leaders in their respective fields who have given me their time and read and reviewed selected chapters of this work. Their comments have made this a much better book than it would have been without their involvement. Any errors that remain are mine.

I would like to thank colleagues at Juniper Networks, Inc., who gave their time and effort to create this network. In many cases, they also helped with the book. It starts at the top with Scott Kriens, who has created an environment where creativity and exploration are encouraged. Thanks, Scott!

The list goes on to include June Loy, Aviva Garrett, Michael Tallon, Patrick Ames, Jason Lloyd, Mark Whittiker, Kent Ketell, and Jeremy Pruitt.

Finally I would like to thank my lead technical reviewers, Joel Jaeggli and Robin Pimentel, for the careful scrutiny they gave the book and the many fine corrections and comments they provided.

Lead Technical Reviewers

Joel Jaeggli works in the security and mobile connectivity group within Nokia. His time is divided between the operation of the nokia.net (AS 14277) research network and supporting the strategic planning needs of Nokia's security business. Projects with former employer, the University of Oregon, included the Network Startup Resource Center, Oregon Route views project, the Beyond BGP Project, and the Oregon Videolab. He is an active participant in several industry-related groups including the IETF (working group chair) and NANOG (two terms on the program committee). Joel frequently participates as an instructor or presenter at regional and international network meetings on Internet services and security-related topics.

Robin Pimentel is currently a network engineer at Facebook, where he helps the production network sustain growth alongside Facebook's user and application growth. Previously, Robin worked on the production network teams at Google and Yahoo. Robin also spent 6 years at Teradyne where he performed many networking, security, and Unix infrastructure engineering roles. Prior to his career in computer networks, Robin worked at Cadence Design Systems and Intel Corporation. While working in the chip sector, Robin specialized in silicon place and route, VHDL-based behavioral logic validation, and gate-level logic validation for on-chip memories.