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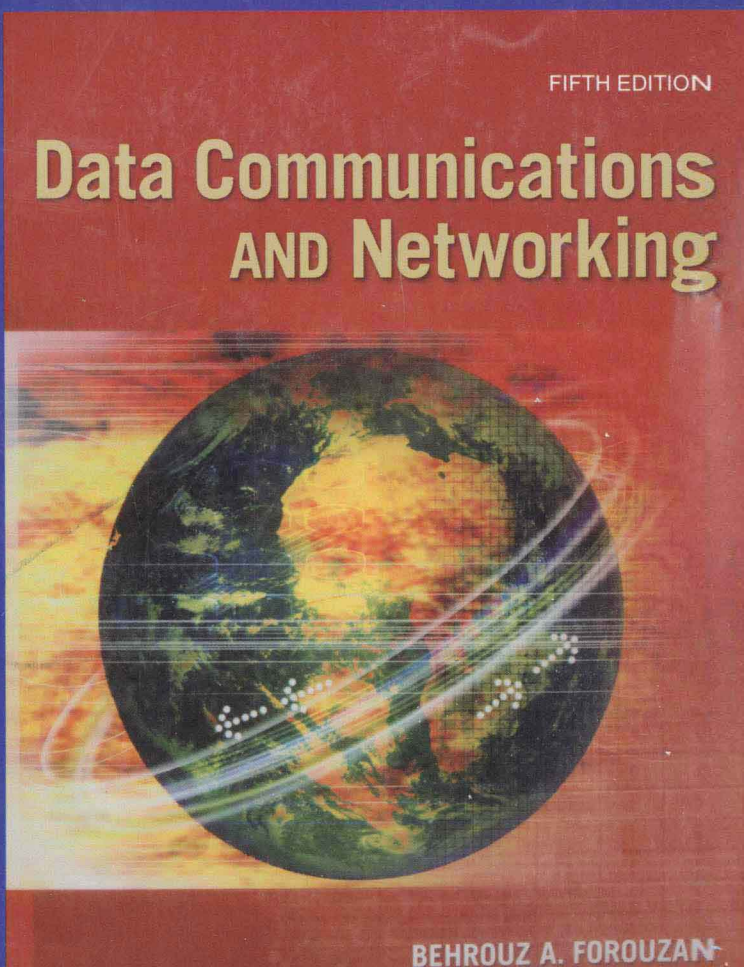
数据通信与网络

（美）Behrouz A. Forouzan 著

（英文版·第5版）

Data Communications and Networking (Fifth Edition)



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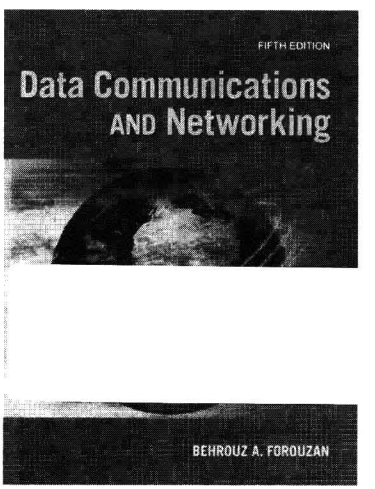

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出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭示了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短的现状下，美国等发达国家在其计算机科学发展的几十年间积淀和发展的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起到积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章公司较早意识到“出版要为教育服务”。自 1998 年开始，我们就将工作重点放在了遴选、移译国外优秀教材上。经过多年的不懈努力，我们与 Pearson，McGraw-Hill，Elsevier，MIT，John Wiley & Sons，Cengage 等世界著名出版公司建立了良好的合作关系，从他们现有的数百种教材中甄选出 Andrew S. Tanenbaum，Bjarne Stroustrup，Brain W. Kernighan，Dennis Ritchie，Jim Gray，Afred V. Aho，John E. Hopcroft，Jeffrey D. Ullman，Abraham Silberschatz，William Stallings，Donald E. Knuth，John L. Hennessy，Larry L. Peterson 等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及珍藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而原书的作者也相当关注其作品在中国的传播，有的还专程为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近两百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍。其影印版“经典原版书库”作为姊妹篇也被越来越多实施双语教学的学校所采用。

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PREFACE

Technologies related to data communication and networking may be the fastest growing in our culture today. The appearance of some new social networking applications every year is a testimony to this claim. People use the Internet more and more every day. They use the Internet for research, shopping, airline reservations, checking the latest news and weather, and so on.

In this Internet-oriented society, specialists need be trained to run and manage the Internet, part of the Internet, or an organization's network that is connected to the Internet. This book is designed to help students understand the basics of data communications and networking in general and the protocols used in the Internet in particular.

Features

Although the main goal of the book is to teach the principles of networking, it is designed to teach these principles using the following goals:

Protocol Layering

The book is designed to teach the principles of networking by using the protocol layering of the Internet and the TCP/IP protocol suite. Some of the networking principles may have been duplicated in some of these layers, but with their own special details. Teaching these principles using protocol layering is beneficial because these principles are repeated and better understood in relation to each layer. For example, although *addressing* is an issue that is applied to four layers of the TCP/IP suite, each layer uses a different addressing format for different purposes. In addition, addressing has a different domain in each layer. Another example is *framing and packetizing*, which is repeated in several layers, but each layer treats the principle differently.

Bottom-Up Approach

This book uses a bottom-up approach. Each layer in the TCP/IP protocol suite is built on the services provided by the layer below. We learn how bits are moving at the physical layer before learning how some programs exchange messages at the application layer.

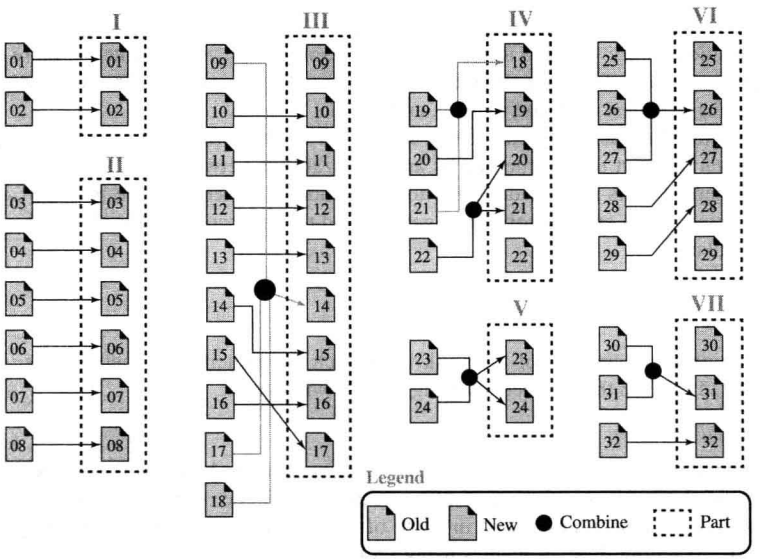
Changes in the Fifth Edition

I have made several categories of changes in this edition.

Changes in the Organization

Although the book is still made of seven parts, the contents and order of chapters have been changed. Some chapters have been combined, some have been moved, some are

new. Sometimes part of a chapter is eliminated because the topic is deprecated. The following shows the relationship between chapters in the fourth and fifth editions.



- Some chapters have been combined into one chapter. Chapters 9, 17, and 18 are combined into one chapter because some topics in each chapter have been deprecated. Chapters 19 and 21 are combined into Chapter 18. Chapters 25, 26, and 27 are also combined into one chapter because the topics are related to each other. Chapters 30 and 31 are also combined because they cover the same issue.
- Some chapters have been split into two chapters because of content augmentation. For example, Chapter 22 is split into Chapters 20 and 21.
- Some chapters have been first combined, but then split for better organization. For example, Chapters 23 and 24 are first combined and then split into two chapters again.
- Some chapters have been moved to better fit in the organization of the book. Chapter 15 now becomes Chapter 17. Chapters 28 and 29 now become Chapters 27 and 28.
- Some chapters have been moved to fit better in the sequence. For example, Chapter 15 has become Chapter 17 to cover more topics.
- Some chapters are new. Chapter 9 is an introduction to the data-link layer. Chapter 25 is an introduction to the application layer and includes socket-interface programming in C and Java. Chapter 30 is almost new. It covers QoS, which was part of other chapters in the previous edition.

New and Augmented Materials

Although the contents of each chapter have been updated, some new materials have also been added to this edition:

- *Peer-to-Peer paradigm* has been added as a new chapter (Chapter 29).
- *Quality of service* (QoS) has been augmented and added as a new chapter (Chapter 30).
- Chapter 10 is augmented to include the *forward error correction.*
- WiMAX, as the wireless access network, has been added to Chapter 16.
- The coverage of the transport-layer protocol has been augmented (Chapter 23).
- Socket-interface programming in Java has been added to Chapter 25.
- Chapter 28, on multimedia, has been totally revised and augmented.
- Contents of unicast and multicast routing (Chapters 20 and 21) have gone through a major change and have been augmented.
- The next generation IP is augmented and now belongs to Chapter 22.

Changes in the End-Chapter Materials

The end-chapter materials have gone through a major change:

- The practice set is augmented; it has many new problems in some appropriate chapters.
- Lab assignments have been added to some chapters to allow students to see some data in motion.
- Some applets have been posted on the book website to allow students to see some problems and protocols in action.
- Some programming assignments allow the students to write some programs to solve problems.

Extra Materials

Some extra materials, which could not be fit in the contents and volume of the book, have been posted on the book website for further study.

New Organization

This edition is divided into seven parts, which reflects the structure of the Internet model.

Part One: Overview

The first part gives a general overview of data communications and networking. Chapter 1 covers introductory concepts needed for the rest of the book. Chapter 2 introduces the Internet model.

Part Two: Physical Layer

The second part is a discussion of the physical layer of the Internet model. It is made of six chapters. Chapters 3 to 6 discuss telecommunication aspects of the physical layer.

Chapter 7 introduces the transmission media, which, although not part of the physical layer, is controlled by it. Chapter 8 is devoted to switching, which can be used in several layers.

Part Three: Data-Link Layer

The third part is devoted to the discussion of the data-link layer of the Internet model. It is made of nine chapters. Chapter 9 introduces the data-link layer. Chapter 10 covers error detection and correction, which can also be used in some other layers. Chapters 11 and 12 discuss issues related to two sublayers in the data-link layer. Chapters 13 and 14 discuss wired networks. Chapters 15 and 16 discuss wireless networks. Chapter 17 shows how networks can be combined to create larger or virtual networks.

Part Four: Network Layer

The fourth part is devoted to the discussion of the network layer of the Internet model. Chapter 18 introduces this layer and discusses the network-layer addressing. Chapter 19 discusses the protocols in the current version. Chapters 20 and 21 are devoted to routing (unicast and multicast). Chapter 22 introduces the next generation protocol.

Part Five: Transport Layer

The fifth part is devoted to the discussion of the transport layer of the Internet model. Chapter 23 gives an overview of the transport layer and discusses the services and duties of this layer. Chapter 24 discusses the transport-layer protocols in the Internet: UDP, TCP, and SCTP.

Part Six: Application Layer

Chapter 25 introduces the application layer and discusses some network programming in both C and Java. Chapter 26 discusses most of the standard client-server programming in the Internet. Chapter 27 discusses network management. Chapter 28 is devoted to the multimedia, an issue which is very hot today. Finally, Chapter 29 is an introduction to the peer-to-peer paradigm, a trend which is on the rise in the today's Internet.

Part Seven: Topics Related to All Layers

The last part of the book discusses the issues that belong to some or all layers. Chapter 30 discusses the quality of service. Chapters 31 and 32 discuss security.

Appendices

The appendices (available online at http://www.mhhe.com/forouzan) are intended to provide a quick reference or review of materials needed to understand the concepts discussed in the book. There are eight appendices that can be used by the students for reference and study:

- Appendix A: Unicode
- Appendix B: Positional Numbering System
- Appendix C: HTML,CSS, XML, and XSL
- Appendix D: A Touch of Probability
- Appendix E: Mathematical Review

- Appendix F: 8B/6T Code
- Appendix G: Miscellaneous Information
- Appendix H: Telephone History

References

The book contains a list of references for further reading.

Glossary and Acronyms

The book contains an extensive glossary and a list of acronyms for finding the corresponding term quickly.

Pedagogy

Several pedagogical features of this text are designed to make it particularly easy for students to understand data communication and networking.

Visual Approach

The book presents highly technical subject matter without complex formulas by using a balance of text and figures. More than 830 figures accompanying the text provide a visual and intuitive opportunity for understanding the material. Figures are particularly important in explaining networking concepts. For many students, these concepts are more easily grasped visually than verbally.

Highlighted Points

I have repeated important concepts in boxes for quick reference and immediate attention.

Examples and Applications

Whenever appropriate, I have included examples that illustrate the concepts introduced in the text. Also, I have added some real-life applications throughout each chapter to motivate students.

End-of-Chapter Materials

Each chapter ends with a set of materials that includes the following:

Key Terms

The new terms used in each chapter are listed at the end of the chapter and their definitions are included in the glossary.

Recommended Reading

This section gives a brief list of references relative to the chapter. The references can be used to quickly find the corresponding literature in the reference section at the end of the book.

Summary

Each chapter ends with a summary of the material covered by that chapter. The summary glues the important materials together to be seen in one shot.

Practice Set

Each chapter includes a practice set designed to reinforce salient concepts and encourage students to apply them. It consists of three parts: quizzes, questions, and problems.

Quizzes

Quizzes, which are posted on the book website, provide quick concept checking. Students can take these quizzes to check their understanding of the materials. The feedback to the students' responses is given immediately.

Questions

This section contains simple questions about the concepts discussed in the book. Answers to the odd-numbered questions are posted on the book website to be checked by the student. There are more than 630 questions at the ends of chapters.

Problems

This section contains more difficult problems that need a deeper understanding of the materials discussed in the chapter. I strongly recommend that the student try to solve all of these problems. Answers to the odd-numbered problems are also posted on the book website to be checked by the student. There are more than 600 problems at the ends of chapters.

Simulation Experiments

Network concepts and the flow and contents of the packets can be better understood if they can be analyzed in action. Some chapters include a section to help students experiment with these. This section is divided into two parts: applets and lab assignments.

Applets

Java applets are interactive experiments that are created by the authors and posted on the website. Some of these applets are used to better understand the solutions to some problems; others are used to better understand the network concepts in action.

Lab Assignments

Some chapters include lab assignments that use Wireshark simulation software. The instructions for downloading and using Wireshark are given in Chapter 1. In some other chapters, there are a few lab assignments that can be used to practice sending and receiving packets and analyzing their contents.

Programming Assignments

Some chapters also include programming assignments. Writing a program about a process or procedure clarifies many subtleties and helps the student better understand the concept behind the process. Although the student can write and test programs in any computer language she or he is comfortable with, the solutions are given in Java language at the book website for the use of professors.

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Audience

This book is written for both academic and professional audiences. The book can be used as a self-study guide for interested professionals. As a textbook, it can be used for a one-semester or one-quarter course. It is designed for the last year of undergraduate study or the first year of graduate study. Although some problems at the end of the chapters require some knowledge of probability, the study of the text needs only general mathematical knowledge taught in the first year of college.

Instruction Resources

The book contains complete instruction resources that can be downloaded from the book site http://www.mhhe.com/forouzan. They include:

Presentations

The site includes a set of colorful and animated PowerPoint presentations for teaching the course.

Solutions to Practice Set

Solutions to all questions and problems are provided on the book website for the use of professors who teach the course.

Solution to Programming Assignments

Solutions to programming assignments are also provided on the book website. The programs are mostly in Java language.

Student Resources

The book contains complete student resources that can be downloaded from the book website http://www.mhhe.com/forouzan. They include:

Quizzes

There are quizzes at the end of each chapter that can be taken by the students. Students are encouraged to take these quizzes to test their general understanding of the materials presented in the corresponding chapter.

Solution to Odd-Numbered Practice Set

Solutions to all odd-numbered questions and problems are provided on the book website for the use of students.

Lab Assignments

The descriptions of lab assignments are also included in the student resources.

Applets

There are some applets for each chapter. Applets can either show the solution to some examples and problems or show some protocols in action. It is strongly recommended that students activate these applets.

Extra Materials

Students can also access the extra materials at the book website for further study.

How to Use the Book

The chapters in the book are organized to provide a great deal of flexibility. I suggest the following:

- Materials provided in Part I are essential for understanding the rest of the book.
- Part II (physical layer) is essential to understand the rest of the book, but the professor can skip this part if the students already have the background in engineering and the physical layer.
- Parts III to VI are based on the Internet model. They are required for understanding the use of the networking principle in the Internet.
- Part VII (QoS and Security) is related to all layers of the Internet mode. It can be partially or totally skipped if the students will be taking a course that covers these materials.

Website

The McGraw-Hill website contains much additional material, available at www.mhhe.com/forouzan. As students read through *Data Communications and Networking,* they can go online to take self-grading quizzes. They can also access lecture materials such as PowerPoint slides, and get additional review from animated figures from the book. Selected solutions are also available over the Web. The solutions to odd-numbered problems are provided to students, and instructors can use a password to access the complete set of solutions.

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Behrouz A. Forouzan
Los Angeles, CA.
January 2012

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ACRONYMS

2B1Q	two-binary, one-quaternary
4B/5B	four binary, five binary
4D-PAM5	4-dimensional, 5-level pulse amplitude modulation
8B/10B	eight binary, ten binary
8B6T	eight binary, six ternary
AAL	(ATM) application adaptation layer
AAS	adaptive antenna system
ABM	asynchronous balanced mode
ABR	available bit rate
ACK	acknowledgment
ACL	asynchronous connectionless link
ADM	adaptive DM
ADPCM	adaptive DPCM
ADSL	asymmetric digital subscriber line
AES	Advanced Encryption Standard
AH	authentication header
AIMD	additive increase, multiplicative decrease
AM	amplitude modulation
AMI	alternate mark inversion
AMPS	Advanced Mobile Phone System
ANSI	American National Standards Institute
ANSNET	Advanced Networks and Services Network
AP	access point
API	application programming interface
APS	automatic protection switching
ARP	Address Resolution Protocol
ARPA	Advanced Research Projects Agency
ARPANET	Advanced Research Projects Agency Network
ARQ	automatic repeat request
AS	authentication server
AS	autonomous system
ASCII	American Standard Code for Information Interchange
ASK	amplitude shift keying
ASN.1	Abstract Syntax Notation One
ATM	Asynchronous Transfer Mode
AUI	attachment unit interface
B-frame	bidirectional frame
B8ZS	bipolar with 8-zero substitution
BASK	binary amplitude shift keying
Bc	committed burst size
BECN	backward explicit congestion notification
BER	Basic Encoding Rules
BGP	Border Gateway Protocol
BNC	Bayone-Neill-Concelman
BOOTP	Bootstrap Protocol
BRI	basic rate interface
BSS	basic service set
CA	Certification Authority
CATV	community antenna TV
CBC	cipher-block chaining
CBR	constant bit rate
CBT	Core-Based Tree
CCITT	Consultative Committee for International Telegraphy and Telephony
CCK	complementary code keying
CDMA	code division multiple access
CDPD	cellular digital packet data
CDV	cell delay variation
CEPT	Comité Européen de Post et Telegraphie
CGI	common gateway interface
CHAP	Challenge Handshake Authentication Protocol
CIDR	Classless Interdomain Routing
CIR	committed information rate
CLP	cell loss priority
CLR	cell loss ratio
CMS	Cryptographic Message Syntax
CMTS	cable modem transmission system
CPE	customer premises equipment
CRC	cyclic redundancy check
CS	convergence sublayer
CSM	cipher stream mode
CSMA	carrier sense multiple access
CSMA/CA	carrier sense multiple access with collision avoidance
CSMA/CD	carrier sense multiple access with collision detection
CSNET	Computer Science Network
CSRC	contributing source
CSS	Cascading Style Sheets
CTS	clear to send
D-AMPS	digital AMPS
DARPA	Defense Advanced Research Projects Agency
dB	decibel
DC	direct current
DCF	distributed coordination function
DCT	discrete cosine transform
DDNS	Dynamic Domain Name System

DDS	digital data service
DE	discard eligibility
DEMUX	demultiplexer
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DHT	distributed hash table
DiffServ	Differentiated Services
DIFS	distributed interframe space
DISC	disconnect
DMT	discrete multitone technique
DNS	Domain Name System
DOCSIS	Data Over Cable System Interface Specification
DPCM	differential PCM
DS-*n*	digital signal-*n*
DSL	digital subscriber line
DSLAM	digital subscriber line access multiplexer
DSS	Digital Signature Standard
DSSS	direct sequence spread spectrum
DTE	data terminal equipment
DVMRP	Distance Vector Multicast Routing Protocol
DWDM	dense wave-division multiplexing
EBCDIC	extended binary coded decimal interchange code
eBGP	external BGP
ECB	electronic codebook
EGP	Exterior Gateway Protocol
EIA	Electronic Industries Alliance
ENQ	enquiry frame
ESP	Encapsulating Security Payload
ESS	extended service set
FA	foreign agent
FCC	Federal Communications Commission
FCS	frame check sequence
FDD	frequency division duplex
FDDI	Fiber Distributed Data Interface
FDM	frequency division multiplexing
FDMA	frequency division multiple access
FEC	forward error correction
FHSS	frequency-hopping spread spectrum
FIFO	first-in, first-out
FM	frequency modulation
FRMR	frame reject
FQDN	fully qualified domain name
FSK	frequency shift keying
FTP	File Transfer Protocol
GEO	geostationary Earth orbit
GIF	graphical interchange format
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HA	home agent
HDLC	High-level Data Link Control
HDSL	high bit rate digital subscriber line
HEC	header error check
HFC	hybrid-fiber-coaxial
HMAC	hashed MAC (hashed message authentication code)
HR-DSSS	high-rate direct-sequence spread spectrum
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
Hz	hertz
I-frame	inter-coded frame
IAB	Internet Architecture Board
IANA	Internet Assigned Numbers Authority
iBGP	internal BGP
ICANN	Internet Corporation for Assigned Names and Numbers
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
IFDMA	interleaved FDMA
IFS	interframe space
IGMP	Internet Group Management Protocol
IGP	Interior Gateway Protocol
IKE	Internet Key Exchange
ILEC	incumbent local exchange carrier
IMAP	Internet Mail Access Protocol
INTERNIC	Internet Network Information Center
IntServ	Integrated Services
IP	Internet Protocol
IPCP	Internetwork Protocol Control Protocol
IPng	Internet Protocol, next generation
IPSec	IP Security
IPv4	Internet Protocol, version 4
IPv6	Internet Protocol, version 6
IRTF	Internet Research Task Force
IS-95	Interim Standard 95
ISAKMP	Internet Security Association and Key Management Protocol
ISDN	Integrated Services Digital Network
ISN	initial sequence number
ISO	International Organization for Standardization
ISOC	Internet Society
ISP	Internet service provider
ITM-2000	Internet Mobile Communication 2000
ITU	International Telecommunications Union
ITU-T	ITU, Telecommunication Standardization Sector
IV	initial vector

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