INFORMATION SECURITY SERIES

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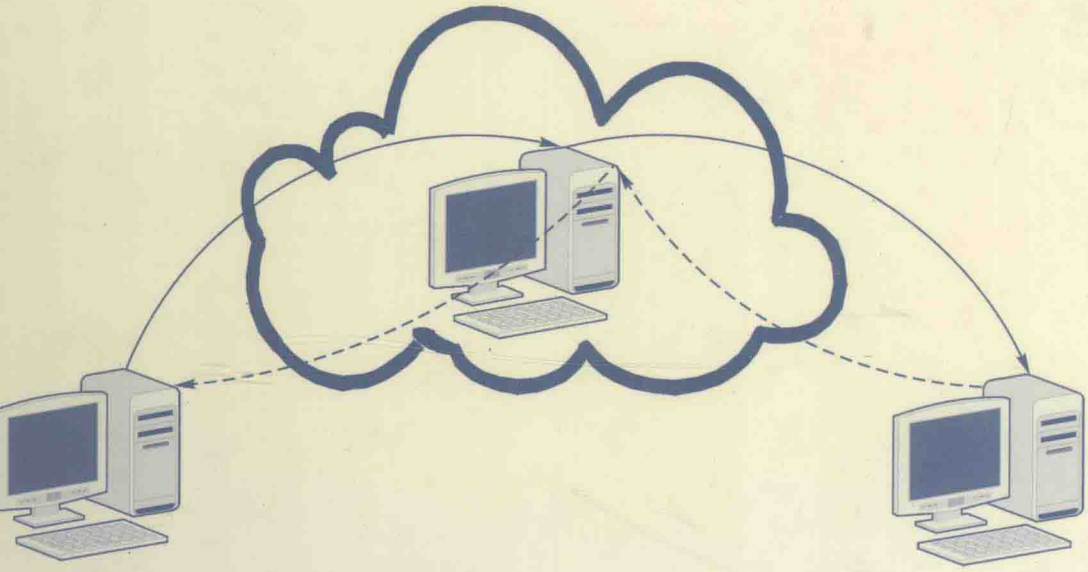

Jie Wang
Zachary A. Kissel

Introduction to Network Security

Theory and Practice

网络安全导论

理论与实践（英文版）

高等教育出版社

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INFORMATION SECURITY SERIES

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Information Security Series systematically introduces the fundamentals of information security design and application. The goals of the Series are:

- to provide fundamental and emerging theories and techniques to stimulate more research in cryptology, algorithms, protocols, and architectures
- to inspire professionals to understand the issues behind important security problems and the ideas behind the solutions
- to give references and suggestions for additional reading and further study

Publications consist of advanced textbooks for graduate students as well as researcher and practitioner references covering the key areas, including but not limited to:

— Modern Cryptography
— Cryptographic Protocols and Network Security Protocols
— Computer Architecture and Security
— Database Security
— Multimedia Security
— Computer Forensics
— Intrusion Detection

Preface

People today are increasingly relying on public computer networks to conduct business and take care of household needs. However, public networks may be insecure because data stored in networked computers or transmitted through networks can be stolen, modified, or fabricated by malicious users. Thus, it is important to know what security measures are available and how to use them. Network security practices are designed to prevent these potential problems. Originating from meeting the needs of providing data confidentiality over public networks, network security has grown into a major academic discipline in both computer science and computer engineering, and also an important sector in the information industry.

The goal of network security is to give people the liberty of enjoying computer networks without the fear of compromising their rights and interests. Network security accomplishes this goal by providing confidentiality, integrity, nonrepudiation, and availability of useful data that are transmitted in open networks or stored in networked computers.

Network security will remain an active research area for several reasons. Firstly, security measures that are effective today may no longer be effective tomorrow because of advancements and breakthroughs in computing theory, algorithms, and computer technologies. Secondly, after the known security problems are solved, other security loopholes that were previously unknown may at some point be discovered and exploited by attackers. Thirdly, when new applications are developed or new technologies are invented, new security problems may also be created with them. Thus, network security is meant to be a long-lasting scuffle between the offenders and the defenders.

Research and development in network security has mainly followed two lines. One line studies computer cryptography and uses it to devise security protocols. The other line examines loopholes and side effects of the existing network protocols, software, and system configurations. It develops firewalls, intrusion detection systems, anti-malicious-software software, and other countermeasures. Interweaving these two lines together provides the basic building blocks for constructing deep layered defense systems against network security attacks.

This book is intended to provide a balanced treatment of network security along these two lines, with adequate materials and sufficient depth for teaching a one-semester introductory course on network security for graduate and upper-level undergraduate students. It is intended to inspire students to think about network security and prepare them for taking advanced network security courses. This book may also be used as a reference for IT professionals.

This book is a revision and extension of an early textbook written by the first author under the title of "Computer Network Security: Theory and Practice," which was co-published in 2008 by the Higher Education Press and Springer. The book is structured into 10 chapters.

Chapter 1 presents an overview of network security. It discusses network security goals, describes common network attacks, characterizes attackers, and defines a basic network security model.

Chapter 2 presents standard symmetric-key encryption algorithms, including DES, AES, and RC4. It discusses their strength and weaknesses. It also describes common block-cipher modes of operations and a recent block-cipher offset-codebook mode of operations. Finally, it presents key generation algorithms.

Chapter 3 presents standard public-key encryption algorithms and key-exchange algorithms, including Diffie–Hellman key exchange, RSA public-key cryptosystem, and elliptic-curve cryptography. It also discusses how to transmit and manage keys.

Chapter 4 presents secure hash functions and message authentication code algorithms for the purpose of authenticating data, including SHA-512, Whirlpool, SHA-3, cryptographic checksums, and the standard hash message authentication codes. It then discusses birthday attacks on secure hash functions and describes the digital signature standard. It presents a dual signature scheme used for electronic transactions and a blind signature scheme used for producing electronic cash. It concludes with a description of the Bitcoin protocol.

Chapter 5 presents several network security protocols commonly used in practice. It first describes a standard public-key infrastructure for managing public-key certificates. It then presents IPsec, a network-layer security protocol; SSL/TLS, a transport-layer security protocol; and several application-layer security protocols, including PGP and S/MIME for sending secure email messages, Kerberos for authenticating users in local area networks, and SSH for protecting remote logins.

Chapter 6 presents common security protocols for wireless local area networks at the data-link layer, including WEP for providing wired-equivalent privacy, WPA and IEEE 802.11i/WPA2 for providing wireless protected access, and IEEE 802.1X for authenticating wireless users. It then presents the Bluetooth security protocol and the ZigBee security protocol for wireless personal-area networks. Finally, it discusses security issues in wireless mesh networks.

Chapter 7 presents the key security issues involved in the burgeoning area of cloud computing, including a discussion of the multitenancy problem and issues of access control. It then presents advanced topics of searchable encryption for cryptographic cloud storage.

Chapter 8 presents firewall technologies and basic structures, including network-layer packet filtering, transport-layer stateful inspections, transport-layer gateways, application-layer proxies, trusted systems and bastion hosts, screened subnets, and network address translations.

Chapter 9 presents intrusion detection technologies, including intrusion detection system architecture and common intrusion detection methods. It also discusses event signatures, statistical analysis, and data mining methods. Finally, it introduces honeypot technologies.

Chapter 10 describes malicious software, such as viruses, worms, and Trojan horses, and introduces countermeasures. It also covers Web security and discusses mechanisms against denial of service attacks.

Since the publication of the first edition, a number of readers have kindly shared with us their personal experiences in dealing with network security attacks. Some of their stories, after minor editing, are included in the text and the exercise problems.

To get the most out of this book, readers are assumed to have taken undergraduate courses on discrete mathematics, algorithms, data communications, and network programming, or

have equivalent preparations. For convenience, Chapter 3 includes a section reviewing basic concepts and results of number theory used in public-key cryptography. While it does not introduce socket programming, the book contains socket API client–server programming exercises. These exercises are designed for computer science and computer engineering students. Readers who do not wish to do them or simply do not have time to write code may skip them. Doing so would not affect much the learning of materials presented in the book.

Exercise problems for each chapter are divided into discussion problems and homework problems. There are six discussion problems in each chapter, designed to help stimulate readers to think about the materials presented in that chapter at the conceptual level. These problems are intended to be discussed in class, with the instructor being the moderator. The homework problems are designed to have three levels of difficulty: regular, difficult (designated with *), and challenging (designated with **). This book contains a number of hands-on drills, presented as exercise problems. Readers are encouraged to try them all.

This book is intended to provide a concise and balanced treatment of network security with sufficient depth suitable for teaching a one-semester introductory course on network security. It was written on the basis of what the first author learned and experienced during the last 18 years from teaching these courses and on student feedback accumulated over the years. Powerpoint slides of these lectures can be found at `http://www.cs.uml.edu/~wang/NetSec`. Due to space limitations, some interesting topics and materials are not presented in this book. After all, one book can only accomplish one book's mission. We only hope that this book can achieve its objective. Of course, only you, the reader, can be the judge of it. We will be grateful if you will please offer your comments, suggestions, and corrections to us at wang@cs.uml.edu or kisselz@merrimack.edu.

We have benefited a great deal from numerous discussions over the last 20 years with our academic advisors, colleagues, teaching assistants, as well as current and former students. We are grateful to Sarah Agha, Stephen Bachelder, Yiqi Bai, William Baker, Samip Banker, David Bestor, Robert Betts, Ann Brady, Stephen Brinton, Jeff Brown, William Brown, Matthew Byrne, Robert Carbone, Jason Chan, Guanling Chen, Mark Conway, Michael Court, Andrew Cross, Daniel DaSilva, Paul Downing, Matthew Drozdz, Chunyan Du, Paul Duvall, Adam Elbirt, Zheng Fang, Daniel Finch, Jami Foran, Xinwen Fu, Anthony Gendreau, Weibo Gong, Edgar Goroza, Swati Gupta, Peter Hakewessell, Liwu Hao, Steve Homer, Qiang Hou, Marlon House, Bei Huang, Jared Karro, Christopher Kraft, Fanyu Kong, Lingfa Kong, Zaki Jaber, Ming Jia, Kimberly Johnson, Ken Kleiner, Minghui (Mark) Li, You (Stephanie) Li, Joseph Litman, Benyuan Liu, Yan (Jenny) Liu, Wenjing Lou, Jie Lu, Shan (Ivory) Lu, David Martin, Randy Matos, Laura Mattson, Thomas McCollem, Caterina Mullen, Paul Nelson, Dane Netherton, Michael Niedbala, Gerald Normandin, Kelly O'Donnell, Sunday Ogundijo, Xian Pan, Alexander Pennace, Sandeep Sahu, Subramanian Sathappan, John Savage, Kris Schlatter, Patrick Schrader, Susan Schueller, Liqun (Catherine) Shao, Blake Skinner, Chunyao Song, Adnan Suljevic, Hengky Susanto, Anthony Tiebout, David Thompson, Nathaniel Tuck, John Uhaneh, John Waller, Tao Wang, Brian Werner, Brian Willner, Christopher Woodard, Fang Wu, Jianhui Xie, Jie (Jane) Yang, Zhijun Yu, and Ning Zhong for their comments and feedbacks.

During the writing of the first edition, Jared Karro read the entire draft, Stephen Brinton read Chapters 1–5 and 7–8 (cloud security not included), Guanling Chen read Chapter 6, and Wenjing Lou read Chapters 2 and 6. Their comments have helped improve the quality of the

first edition in many ways, and to them we owe our gratitude. We are grateful to Anthony Gendreau and Adnan Suljevic for pointing out typos in the first edition.

We thank the reviewers for interesting suggestions and Ying Liu at the Higher Education Press for initiating this book project and editing the first edition of the book.

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Dr. Jie Wang is Professor and Chair of Computer Science at the University of Massachusetts Lowell. He is also Director of the University Center for Internet Security and Forensics Education and Research. He received a Ph.D. degree in Computer Science from Boston University in 1990, an M.S. degree in Computer Science from Zhongshan University in 1985, and a B.S. degree in Computational Mathematics from Zhongshan University in 1982. He has over 23 years of teaching and research experience at the university level and has worked as a network security consultant in the financial industry. He represented the University of Massachusetts system in the education task force of the Advanced Cyber Security Center in New England from 2011 to 2013. His research interests include network security, big data modeling and applications, algorithms and computational optimization, computational complexity theory, and wireless sensor networks. His research has been funded continuously by the National Science Foundation since 1991. His research has also been funded by IBM, Intel, and the Natural Science Foundation of China. He has published over 160 journal and conference papers, six books and four edited books. He is active in professional service, including chairing conference program committees and organizing workshops, editing journals and serving as the editor-in-chief of a book series on mathematical modeling.

Dr. Zachary A. Kissel is Assistant Professor of Computer Science at Merrimack College in North Andover, MA. He received a Ph.D. degree in Computer Science from the University of Massachusetts Lowell in 2013, an M.S. degree in Computer Science from Northeastern University in 2007, and a B.S. degree in Computer Science from Merrimack College in 2005. He has network security industry experience working in a security group at Sun Mircrosystems (later Oracle) where he was responsible for maintaining firewalls and cryptographic libraries. His research interests include cryptography and network security. His work has focused mainly on searchable symmetric encryption and access control for data stored on an untrusted cloud.

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