

APPENDIX A

PROJECTS FOR TEACHING CRYPTOGRAPHY AND NETWORK SECURITY

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Analysis and observation, theory and experience must never disdain or exclude each other; on the contrary, they support each other.

— *On War*, Carl Von Clausewitz

Many instructors believe that research or implementation projects are crucial to the clear understanding of cryptography and network security. Without projects, it may be difficult for students to grasp some of the basic concepts and interactions among components. Projects reinforce the concepts introduced in the book, give the student a greater appreciation of how a cryptographic algorithm or protocol works, and can motivate students and give them confidence that they are capable of not only understanding but implementing the details of a security capability.

In this text, I have tried to present the concepts of cryptography and network security as clearly as possible and have provided numerous homework problems to reinforce those concepts. However, many instructors will wish to supplement this material with projects. This appendix provides some guidance in that regard and describes support material available in the **Instructor's Resource Center (IRC)** for this book, accessible to instructors from Prentice Hall. The support material covers 12 types of projects and other student exercises:

- Sage computer algebra projects
- Hacking project
- Block cipher projects
- Laboratory exercises
- Research projects
- Programming projects
- Practical security assessments
- Firewall projects
- Case studies
- Writing assignments
- Reading/report assignments
- Discussion topics

A.1 SAGE COMPUTER ALGEBRA PROJECTS

One of the most important new features for this edition is the use of Sage for cryptographic examples and homework assignments. Sage is an open-source, multiplatform, freeware package that implements a very powerful, flexible, and easily learned mathematics and computer algebra system. A computer algebra system (CAS) is software that can perform symbolic as well as numerical calculations. CASs have been used for teaching since their inception some decades ago, and there is now a considerable literature on their use. A CAS is a natural tool for extending the learning experience in a cryptography course.

Unlike competing systems such as Mathematica, Maple, and MATLAB, there are no licensing agreements or fees involved with Sage. Thus, Sage can be made available on computers and networks at school, and students can individually download the software to their own personal computers for use at home. Another advantage of using Sage is that students learn a powerful, flexible tool that can be used for virtually any mathematical application, not just cryptography. The Sage Web site (<http://www.sagemath.org>) provides considerable documentation on how to install, set up, and use Sage on a variety of computers and how to use it online via the Web.

The use of Sage can make a significant difference to the teaching of the mathematics of cryptographic algorithms. Appendix B provides a large number of examples of the use of Sage covering many cryptographic concepts. Appendix C lists exercises in each of these topic areas to enable the student to gain hands-on experience with cryptographic algorithms. Copies of both appendices are available online so that students do not have to key in lines of code that are printed in the appendices.

The IRC contains solutions to all of the exercises in Appendix C.

Dan Shumow of Microsoft and the University of Washington developed all of the examples and assignments in Appendices B and C.

A.2 HACKING PROJECT

The aim of this project is to hack into a corporation's network through a series of steps. The corporation is named Extreme In Security Corporation. As the name indicates, the corporation has some security holes in it, and a clever hacker is able to access critical information by hacking into its network. The IRC includes what is needed to set up the Web site. The student's goal is to capture the secret information about the price on the quote the corporation is placing next week to obtain a contract for a governmental project.

The student should start at the Web site and find his or her way into the network. At each step, if the student succeeds, there are indications as to how to proceed on to the next step as well as the grade until that point.

The project can be attempted in three ways:

1. Without seeking any sort of help
2. Using some provided hints
3. Using exact directions

The IRC includes the files needed for this project:

1. Web Security project
2. Web Hacking exercises (XSS and Script-attacks) covering client-side and server-side vulnerability exploitations, respectively
3. Documentation for installation and use for the above
4. A PowerPoint file describing Web hacking. This file is crucial to understanding how to use the exercises since it clearly explains the operation using screen shots.

This project was designed and implemented by Professor Sreekanth Malladi of Dakota State University.

A.3 BLOCK CIPHER PROJECTS

This is a lab that explores the operation of the AES encryption algorithm by tracing its execution, computing one round by hand, and then exploring the various block cipher modes of use. The lab also covers DES. In both cases, an online Java applet is used (or can be downloaded) to execute AES or DES.

For both AES and DES, the lab is divided into three separate parts:

- **Block cipher internals:** This part involves encrypting plaintext and analyzing the intermediate results after each round. There is an online calculator for both AES and DES that provides the intermediate results and the final ciphertext.
- **Block cipher round:** This part involves calculating one round by hand and comparing the results to those produced by the calculator.
- **Block cipher modes of use:** Enables the student to compare the operation of CBC and CFB modes.

The IRC contains the .html and .jar files needed to set up these labs on your own Web site. Alternatively, the material is available from the Student Resources section of this book's Web site. Click on the rotating globe.

Lawrie Brown of the Australian Defence Force Academy developed these projects.

A.4 LABORATORY EXERCISES

Professor Sanjay Rao and Ruben Torres of Purdue University have prepared a set of laboratory exercises that are included in the IRC. These are implementation projects designed to be programmed on Linux but could be adapted for any Unix environment. These laboratory exercises provide realistic experience in implementing security functions and applications.

A.5 RESEARCH PROJECTS

An effective way of reinforcing basic concepts from the course and for teaching students research skills is to assign a research project. Such a project could involve a literature search as well as an Internet search of vendor products, research lab activities, and standardization efforts. Projects could be assigned to teams or, for smaller projects, to individuals. In any case, it is best to require some sort of project proposal early in the term, giving the instructor time to evaluate the proposal for appropriate topic and appropriate level of effort. Student handouts for research projects should include

- A format for the proposal
- A format for the final report
- A schedule with intermediate and final deadlines
- A list of possible project topics

The students can select one of the topics listed in the IRC or devise their own comparable project. The IRC includes a suggested format for the proposal and final report as well as a list of 15 possible research topics.

A.6 PROGRAMMING PROJECTS

The programming project is a useful pedagogical tool. There are several attractive features of stand-alone programming projects that are not part of an existing security facility:

1. The instructor can choose from a wide variety of cryptography and network security concepts to assign projects.
2. The projects are platform and language independent. Students can program the projects on any available computer and in any appropriate language.
3. The instructor need not download, install, and configure any particular infrastructure for stand-alone projects.

There is also flexibility in the size of projects. Larger projects give students more a sense of achievement, but students with less ability or fewer organizational skills can be left behind. Larger projects usually elicit more overall effort from the best students. Smaller projects can have a higher concepts-to-code ratio and, because more of them can be assigned, the opportunity exists to address a variety of different areas.

Again, as with research projects, the students should first submit a proposal. The student handout should include the same elements listed in the preceding section. The IRC includes a set of 12 possible programming projects.

The following individuals have supplied the research and programming projects suggested in the IRC: Henning Schulzrinne of Columbia University; Cetin Kaya Koc of Oregon State University; and David M. Balenson of Trusted Information Systems and George Washington University.

A.7 PRACTICAL SECURITY ASSESSMENTS

Examining the current infrastructure and practices of an existing organization is one of the best ways of developing skills in assessing its security posture. The IRC contains a list of such activities. Students, working either individually or in small groups, select a suitable small- to medium-sized organization. They then interview some key personnel in that organization in order to conduct a suitable selection of security risk assessment and review tasks as it relates to the organization's IT

infrastructure and practices. As a result, they can then recommend suitable changes, which can improve the organization's IT security. These activities help students develop an appreciation of current security practices and the skills needed to review these and recommend changes.

Lawrie Brown of the Australian Defence Force Academy developed these projects.

A.8 FIREWALL PROJECTS

The implementation of network firewalls can be a difficult concept for students to grasp initially. The IRC includes a Network Firewall Visualization tool to convey and teach network security and firewall configuration. This tool is intended to teach and reinforce key concepts including the use and purpose of a perimeter firewall, the use of separated subnets, the purposes behind packet filtering, and the shortcomings of a simple packet filter firewall.

The IRC includes a `.jar` file that is fully portable, and a series of exercises. The tool and exercises were developed at U.S. Air Force Academy.

A.9 CASE STUDIES

Teaching with case studies engages students in active learning. The IRC includes case studies in the following areas:

- Disaster recovery
- Firewalls
- Incidence response
- Physical security
- Risk
- Security policy
- Virtualization

Each case study includes learning objectives, case description, and a series of case discussion questions. Each case study is based on real-world situations and includes papers or reports describing the case.

The case studies were developed at North Carolina A&T State University.

A.10 WRITING ASSIGNMENTS

Writing assignments can have a powerful multiplier effect in the learning process in a technical discipline such as cryptography and network security. Adherents of the Writing Across the Curriculum (WAC) movement (<http://wac.colostate.edu/>) report substantial benefits of writing assignments in facilitating learning. Writing assignments lead to more detailed and complete thinking about a particular topic. In

addition, writing assignments help to overcome the tendency of students to pursue a subject with a minimum of personal engagement, just learning facts and problem-solving techniques without obtaining a deep understanding of the subject matter.

The IRC contains a number of suggested writing assignments, organized by chapter. Instructors may ultimately find that this is an important part of their approach to teaching the material. I would greatly appreciate any feedback on this area and any suggestions for additional writing assignments.

A.11 READING/REPORT ASSIGNMENTS

Another excellent way to reinforce concepts from the course and to give students research experience is to assign papers from the literature to be read and analyzed. The student is then asked to write a brief report on the assigned paper. The IRC includes a suggested list of papers, one or two per chapter, to be assigned. The IRC provides a PDF copy of each of the papers. The IRC also includes a suggested assignment wording.

A.12 DISCUSSION TOPICS

One way to provide a collaborative experience is discussion topics, a number of which are included in the IRC. Each topic relates to material in the book. The instructor can set it up so that students can discuss a topic either in a class setting, an online chat room, or a message board. Again, I would greatly appreciate any feedback on this area and any suggestions for additional discussion topics.