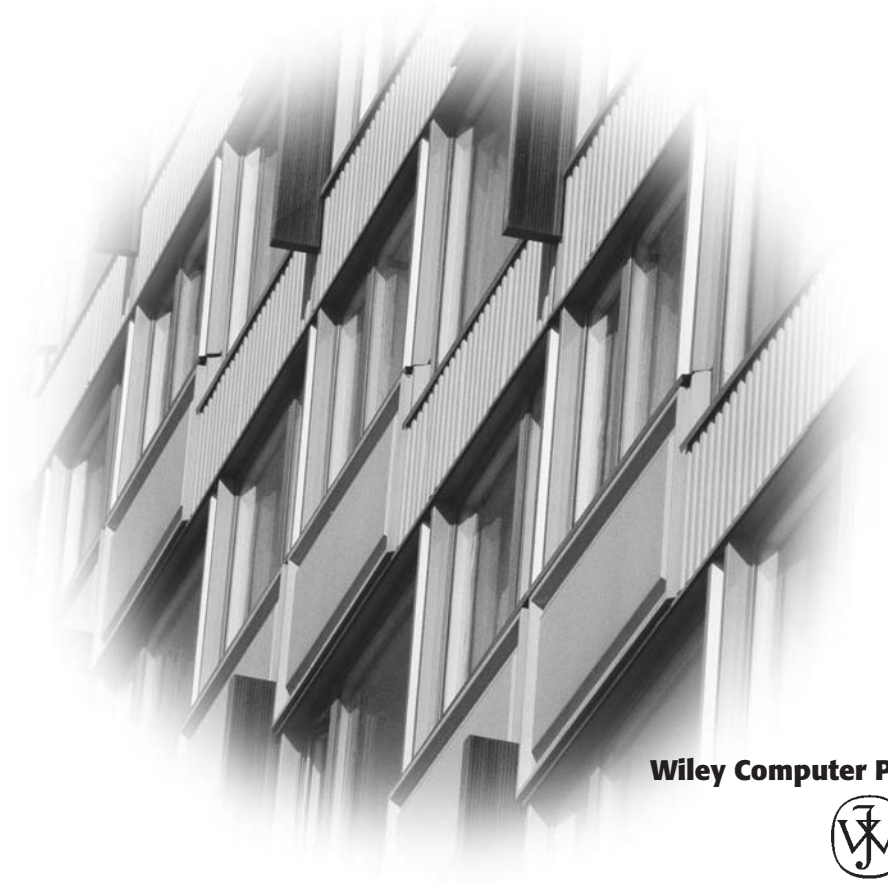
Designing Security Architecture Solutions

Jay Ramachandran



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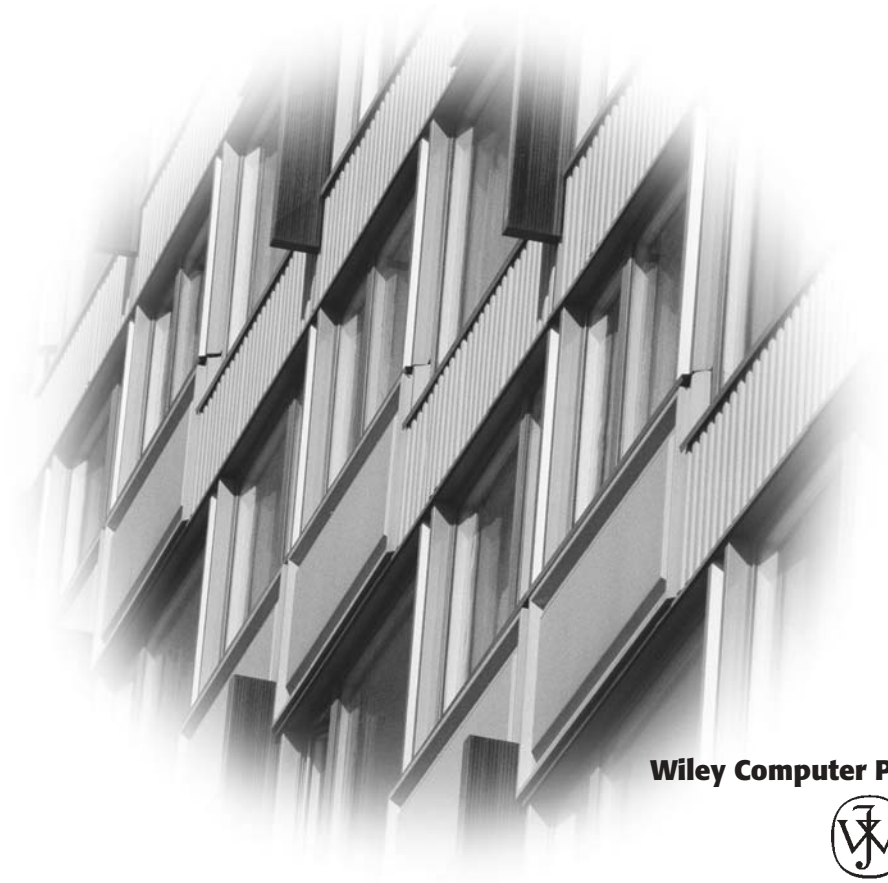

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DEDICATION

For Ronak, Mallika, and Beena

There is an invisible elephant in this book: your application. And, it sits at the center of every topic we touch in each chapter we present. This book is for systems architects who are interested in building security into their applications. The book is designed to be useful to architects in three ways: as an introduction to security architecture, as a handbook on security issues for architecture review, and as a catalog of designs to look for within a security product.

Audience

This book is meant to be a practical handbook on security architecture. It aims to provide software systems architects with a contextual framework for thinking about security. This book is not for code writers directly, although we do talk about code when appropriate. It is targeted toward the growing technical community of people who call themselves systems architects. A systems architect is the technical leader on any large project with overall responsibility for architecture, design, interface definition, and implementation for the system. Architects play nontechnical roles, as well. They are often involved in the planning and feasibility stages of the project, helping its owners make a business case for the system. They must ensure that the project team follows corporate security guidelines and the software development process all the way to delivery. Architects have deep domain knowledge of the application, its function, and its evolution but often are not as experienced in security architecture.

The primary audience for this book consists of project managers, systems architects, and software engineers who need to secure their applications. It provides a conceptual architectural framework that answers the questions, "What is systems security architecture? How should I choose from a bewildering array of security product offerings? How should I then integrate my choices into my software? What common problems occur during this process? How does security affect the other goals of my system architecture? How can I justify the expense of building security into my application?"

If you are currently working on a large project or you have access to the architecture documentation of a software system you are familiar with, keep it handy and use its architecture to give yourself a frame of reference for the discussion. A good application can give additional depth to a particular recommendation or provide context for any architectural issues on security or software design.

We assume that you have some experience with implementing security solutions and getting your hands dirty. Although we introduce and present many security concepts, we would not recommend learning about computer security from this book, because in the interests of covering as many aspects of architecture and security as we can, we will often cheerfully commit the sin of simplification. We will always add references to more detail when we do simplify matters and hope this situation will not confuse the novice reader. We hope that by the end of the book, the systems architects among you will have gained some insights into security while the security experts wryly note our mastery of the obvious. That would mean that we have succeeded in striking the right balance!

Software Architecture

Software architecture in the past 10 years has seen growing respectability. More and more software professionals are calling themselves software *architects* in recognition that enterprise systems are increasingly complex, expensive, and distributed. Applications have raised the bar for feature requirements such as availability, scalability, robustness, and interoperability. At the same time, as a business driver, enterprise security is front and center in the minds of many managers. There is a tremendously diverse community of security professionals providing valuable but complicated services to these enterprise architects. Architects have clear mandates to implement corporate security policy, and many certainly feel a need for guidelines on how to do so. We wrote this book to provide architects with a better understanding of security.

Software development converts requirements into systems, products, and services. Software architecture has emerged as an important organizing principle, providing a framework upon which we hang the mass of the application. Companies are recognizing the value of enterprise architecture guidelines, along with support for process definition, certification of architects, and training. Software architecture promises cost savings by improving release cycle time, reducing software defects, enabling reuse of architecture and design ideas, and improving technical communication.

There are many excellent books on security and on software architecture. There is also a vast and mature collection of academic literature in both areas, many listed in our bibliography. This book targets readers in the intersection of the two fields.

When we use the term *system* or *application* in this book, we mean a collection of hardware and software components on a platform to support a business function with boundaries that demark the inside and outside of the system, along with definitions of interfaces to other systems. Systems have business roles in the company. They belong to business processes and have labels: customer Web application, benefits directory, employee payroll database, customer order provisioning, billing, network management, fulfillment, library document server, and so on.

Security can be approached from perspectives other than the viewpoint of securing a system. A project might be developing a shrink-wrapped product, such as a computer

game or a PC application; or might be providing a distributed service, such as an e-mail or naming server; or be working on an infrastructure component, such as a corporate directory. Security goals change with each change in perspective. Our presentation of security principles in this book is general enough to apply to these other viewpoints, which also can benefit from secure design.

Project Objectives versus Security Experience

Companies wish to include security policy into architecture guidelines but run into difficulties trying to chart a path on implementation decisions. Unless we realize that the problem does not lie with our talented and competent development teams but instead lies in their lack of background information about security, we will run into significant resistance project after project—repeatedly going over the same security issues at the architecture review. We must be able to present security issues in an architectural context to guide the project.

As system architects, we would like to believe that all our decisions are driven by technical considerations and business goals. We would like to believe that every time our project team meets to make a decision, we would be consistent—arriving at the same decision no matter who took the day off. Human nature and personal experience inform our decisions as well, however. On a system that is under construction within the confines of budget and time, the strengths of the lead architects and developers can strongly warp the direction and priority of functional and non-functional goals.

An object-oriented methodology guru might spend a fair amount of resources developing the data model and class diagrams. A programmer with a lot of experience building concurrent code might introduce multi-threading everywhere, creating producers and consumers that juggle mutexes, locks, and condition variables in the design. A database designer with experience in one product might bring preconceived notions of how things should be to the project that uses another database. A CORBA expert might engineer interface definitions or services with all kinds of detail to anticipate evolution, just because he knows how. A Web designer on the front-end team might go crazy with the eye candy of the day on the user interface. None of these actions are inherently bad, and much of it is very valuable and clearly useful. At the end, however, if the project does not deliver what the customer wants with adequate performance and reliability, we have failed.

What if no one on your team has much experience with security? In a conflict between an area where we are somewhat lost and another where we can accomplish a significant amount of productive work, we pick the task where we will make the most progress. The problem arises with other facets of systems architecture as well, which might fall by the wayside because of a lack of experience or a lack of priority. Project teams declare that they cannot be highly available, cannot do thorough testing, or cannot do performance modeling because they do not have the time or the money to do so. This situation might often be the case, but if no one on the team has expertise building

reliable systems or regression testing suites or queuing theoretic models of service, then human nature might drive behavior away from these tasks.

Security architecture often suffers from this syndrome. Fortunately, we have a solution to our knowledge gap: Buy security and hire experts to secure our system. This point is where vendors come in to help us integrate their solutions into our applications.

Vendor Security Products

The Internet boom has also driven the growth of security standards and technologies. Software vendors provide feature-rich security solutions and components at a level of complexity and maturity beyond almost all projects. Building our own components is rarely an option, and security architecture work is primarily integration work. In today's environment, the emerging dominance of vendor products aiding software development for enterprise security cannot be ignored.

We interact with vendors on many levels, and our understanding of their product offerings depends on a combination of information from many sources: marketing, sales, customer service support, vendor architects, and other applications with experience with the product. We have to be careful when viewing the entire application from the perspective of the security vendor. Looking at the application through a fisheye lens to get a wide-angle view could give us a warped perspective, with all of the elements of the system distorted around one central component: their security product. Here are three architectural flaws in vendor products:

The product enjoys a central place in the architecture. The product places itself at the center of the universe, which might not be where you, as the architect, would place it.

The product hides assumptions. The product hides assumptions that are critical to a successful deployment or does not articulate these assumptions as clear architectural prerequisites and requirements to the project.

The context behind the product is unclear. Context describes the design philosophy behind the purpose and placement of the product in some market niche. What is the history of the company with respect to building this particular security product? The vendor might be the originator of the technology, might have diversified into the product space, acquired a smaller company with expertise in the security area, or might have a strong background in a particular competing design philosophy.

Vendors have advantages over architects.

- They tend to have comparatively greater security expertise.
- They often do not tell architects about gaps in their own product's design voluntarily. You have to ask specific questions about product features.
- They rarely present their products in terms clearly comparable with those of their competitors. Project teams have to expend effort in understanding the feature sets well enough to do so themselves.

- They deflect valid criticism of holes in their design by assigning resolution responsibility to the user, administrator, application process, or other side of an interface, and so on.
- They rarely support the evolution path of an application over a two- to three-year timeframe.

This book is meant to swing the advantage back in the architect's court. We will describe how projects can evaluate vendor products, discover limitations and boundaries within solutions, and overcome them. Vendors are not antagonistic to the project's objectives, but miscommunication during vendor management might cause considerable friction as the application evolves and we learn more about real-world deployment issues surrounding the product. Building a good relationship between application architect and lead vendor engineers is critical and holds long-run benefits for the project and vendor alike. We hope that better information will lead to better decisions on security architecture.

Our Goals in Writing This Book

On a first level, we will present an overview of the software process behind systems architecture. We focus on the architecture review, a checkpoint within the software development cycle that gives the project an opportunity to validate the solution architecture and verify that it meets requirements. We will describe how to assess a system for security issues, how to organize the architecture to add security as a system feature, and how to provide architectural context information that will help minimize the impact of implementing one security choice over another. We emphasize including security early in the design cycle instead of waiting until the application is in production and adding security as an afterthought.

On a second level, this book will provide hands-on help in understanding common, repeating patterns of design in the vast array of security products available. This book will help describe the vocabulary used surrounding security products as applied to systems architecture. We borrow the term *patterns* from the Object Patterns design community but do not intend to use the term beyond its common-sense meaning. Specifically, something is a security pattern if we can give it a name, observe its design appearing repeatedly in many security products, and see some benefit in defining and describing the pattern.

On a third level, we describe common security architecture issues and talk about security issues for specific technologies. We use three layers of application granularity to examine security.

- Low-level issues regarding code review, cryptographic primitives, and trusting code.
- Mid-level issues regarding middleware or Web services, operating systems, hosts, and databases.
- High-level issues regarding security components, conflicts between security and other system goals, and enterprise security.

On the fourth and final level, we discuss security from a financial standpoint. How can we justify the expense of securing our application?

Reading This Book

We have organized the book into five parts, and aside from the chapters in Part I, any chapter can be read on its own. We would recommend that readers with specific interests and skills try the following tracks, however:

Project and software process managers. Begin by reading Chapters 1, 2, 3, 4, and 15. These chapters present vocabulary and basic concerns surrounding security architecture.

Security assessors. Begin by reading Chapters 1, 2, 3, 4, 13, and 14. Much of the information needed to sit in a review and understand the presentation is described there.

Developers. Read Chapters 1 through 4 in order and then Chapters 5 through 12 in any order—looking for the particular platform or software component that you are responsible for developing.

Systems architects. Read the book from start to finish, one complete part at a time. The presentation order, from Process to Technology to Enterprise concerns, parallels the requirements of systems architecture for a large application. All of these topics are now considered part of the domain of software architects.

Business executives. Read Chapters 1, 2, 16, and 17 for a start and then continue as your interests guide you with anything in between.

Outline of the Book

Each chapter is a mix of the abstract and the concrete. For more detail on any technical matter, please see the list of bibliographic references at the end of the book. Each chapter will also contain questions to ask at an architecture review on a specific subject.

Part I, Architecture and Security, introduces the business processes of architecture review and security assessments. We describe the basics of security architecture and a catalog of security patterns.

Chapter 1, "Architecture Reviews," describes a key checkpoint in the software development cycle where architects can ask and answer the question, "Does the solution fit the problem?" We present a description of the review process along with its benefits.

Chapter 2, "Security Assessments," defines the process of security assessment by using the Federal Information Technology Security Assessment Framework along with other industry standards. We describe how assessments realize many of the benefits of architecture reviews within the specific context of security.

Chapter 3, *"Security Architecture Basics,"* defines the concept of assurance. We describe the concepts of authentication, authorization, access control, auditing, confidentiality, integrity, and nonrepudiation from an architectural viewpoint. We discuss other security properties and models of access control.

Chapter 4, *"Architecture Patterns in Security,"* defines the terms architectural style and pattern and describes how each of the basic security architecture requirements in the previous chapter lead to common implementation patterns. We also present a catalog of security patterns.

Part II, Low-Level Architecture, describes common issues surrounding developing secure software at the code level. We introduce the basics of cryptography and discuss its application in trusting code and in communications security protocols.

Chapter 5, *"Code Review,"* discusses the importance of code review from a security viewpoint. We describe buffer overflow exploits, one of the most common sources of security vulnerabilities. We discuss strategies for preventing exploits based on this attack. We also discuss security in Perl and the Java byte code verifier.

Chapter 6, *"Cryptography,"* introduces cryptographic primitives and protocols and the difficulty an architect faces in constructing and validating the same. We present guidelines for using cryptography.

Chapter 7, *"Trusted Code,"* discusses one consequence of the growth of the Web: the emergence of digitally delivered software. We describe the risks of downloading active content over the Internet, some responses to mitigating this risk, and why code is hard to trust.

Chapter 8, *"Secure Communications,"* introduces two methods for securing sessions—the SSL protocol and IPSec—and discusses the infrastructure support needed to implement such protocols. We discuss security layering and describe why is there plenty of security work left to be done at the application level.

Part III, Mid-Level Architecture, introduces common issues faced by application architects building security into their systems from a component and connector viewpoint.

Chapter 9, *"Middleware Security,"* discusses the impact of platform independence, a central goal of middleware products, on security. We describe the CORBA security specification, its service modules, and the various levels of CORBA-compliant security and administrative support. We also discuss other middleware security products at a high level.

Chapter 10, *"Web Security,"* is a short introduction to Web security from an architecture viewpoint, including information on security for standards such as J2EE.

Chapter 11, *"Application and OS Security,"* reviews the components that go into the design of an application, including OS security, network services, process descriptions, interface definitions, process flow diagrams, workflow maps, and administration tools. We discuss operating systems hardening and other deployment and development issues with building secure production applications. We also discuss UNIX ACLs.

Chapter 12, "Database Security," introduces the state-of-the-art in database security architecture. We discuss the evolution of databases from a security standpoint and describe several models of securing persistent data. We also discuss the security features within Oracle, a leading commercial database product.

Part IV, High-Level Architecture, introduces common issues faced by enterprise architects charged with guiding software architecture discipline across many individual applications, all sharing some "enterprise" characteristic, such as being components of a high-level business process or domain.

Chapter 13, "Security Components," discusses the building blocks available to systems architects and some guidelines for their usage. The list includes single sign-on servers, PKI, firewalls, network intrusion detection, directories, along with audit and security management products. We discuss issues that architects should or should not worry about and components they should or should not try to use. We also discuss the impact of new technologies like mobile devices that cause unique security integration issues for architects.

Chapter 14, "Security and Other Architectural Goals," discusses the myths and realities about conflicts between security and other architectural goals. We discuss the impact of security on other goals such as performance, high availability, robustness, scalability, interoperability, maintainability, portability, ease of use, adaptability, and evolution. We conclude with guidelines for recognizing conflicts in the architecture, setting priorities, and deciding which goal wins.

Chapter 15, "Enterprise Security Architecture," discusses the question, "How do we architect security and security management across applications?" We discuss the assets stored in the enterprise and the notion of database-of-record status. We also discuss common issues with enterprise infrastructure needs for security, such as user management, corporate directories, and legacy systems. We present and defend the thesis that enterprise security architecture is above all a data-management problem and propose a resolution using XML-based standards.

Part V, Business Cases for Security, introduces common issues faced by architects making a business case for security for their applications.

Chapter 16, "Building Business Cases for Security," asks why it is hard to build business cases for security. We present the *Saved Losses Model* for justifying security business cases. We assign value to down time, loss of revenue, and reputation and assess the costs of guarding against loss. We discuss the role of an architect in incident prevention, industry information about costs, and the reconstruction of events across complex, distributed environments in a manner that holds water in a court of law. We ask whether security is insurable in the sense that we can buy hacker insurance that works like life insurance or fire insurance and discuss the properties that make something insurable.

Chapter 17, "Conclusion," reviews security architecture lessons that we learned. We present some advice and further resources for architects.

We conclude with a bibliography of resources for architects and a glossary of acronyms.

Online Information

Although we have reviewed the book and attempted to remove any technical errors, some surely remain. Readers with comments, questions, or bug fixes can email me at book@jay-ramachandran.com or visit my Web site at www.jay-ramachandran.com for Web links referred to in the text, updated vendor product information, or other information.

Conclusion

A note before we start: although it might seem that way sometimes, our intent is not to present vendors and their security offerings as in constant conflict with your application and its objectives and needs. Security vendors provide essential services, and no discussion of security will be complete without recognition of their value and the role that their products play.

Security is commonly presented as a conflict between the good and the bad, with our application on one hand and the evil hacker on the other. This dichotomy is analogous to describing the application as a medieval castle and describing its defense: "Put the moat here," "Make it yea deep," "Use more than one portcullis," "Here's where you boil the oil," "Here's how you recognize a ladder propped against the wall," and so on. This view presents security as an active conflict, and we often use the terms of war to describe details. In this case, we view ourselves as generals in the battle and our opponents as Huns (my apologies if you are a Hun, I'm just trying to make a point here).

Our basic goal is to frame the debate about systems security around a different dichotomy, one that recognizes that the castle also has a role in peacetime, as a market place for the surrounding villages, as the seat of authority in the realm, as a cantonment for troops, and as a place of residence for its inhabitants. Think of the system's architect as the mayor of the town who has hired a knight to assemble a standing army for its defense. The knight knows warfare, but the mayor has the money. Note that we said that the architect is the mayor and not the king—that would be the customer.

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