Programming Securely II

Computer Security Lecture 14

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Outline

Programming and Security

Programming Securely: To develop code in a secure manner so that the code itself is not a vulnerability that can be exploited by an attacker.

Programming Security: To develop code for security-specific functions such as encryption, digital signatures, firewalls, etc.

In this lecture, we look at both sides:

- continuing programming securely: some **web application** security issues and some **Java** guidelines.
- programming security: overview of **Java security APIs** and **current and future trust models**.

Web security: client-side threats

- Risky treatment of **MIME-types**: e.g., shell-escapes in `troff`. By design, downloaded **active content** (e.g., Java, ActiveX controls) should run in a restricted environment. Problems come when restrictions fail, or aren't tight enough.
- SSL issues: revoked certificates, spoofed site names, mixed encrypted/unencrypted pages.
- Browsers store **cookies** which have confidentiality implications. Even without cookies, web browsing is less anonymous than it feels: information is stored in browser's history and document cache, firewall and proxy logs, and the remote sites visited, even before any spyware is present. (All great for market researchers).
- Untrained users unwittingly make bad security decisions.
- Buggy browsers: buffer overflows, crypto bugs, etc.

Web security: server-side threats

- Access control: should prevent certain files being served.
- Complex or malicious URLs
- Denial of service attacks
- Remote authoring and administration tools
- Buggy servers, with attendant security risks
- Server-side **scripting languages**: C or shell CGI, PHP, ASP, JSP, Python, Ruby, all have serious security implications in configuration and execution. File systems and permissions have to be carefully designed. That's before any implemented *web application* is even considered...

Web programming: application security

Many issues (some of which are introduced in the practical).

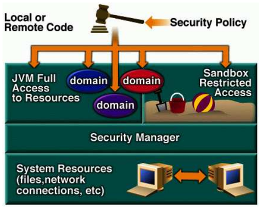
- **Input validation**: to prevent SQL injection, command injection, other confidentiality attacks. Ajax: *beware client-side validation!* Understand metacharacters at every point. Use labels/indexes for hidden values, not values themselves.
- **Output filtering**: cross-site scripting (XSS), when attacker-generated HTML appears on site: used for session hijacking, phishing attacks. Beware passing informative error messages.
- **Careful cryptography**: encryption/hashing to *protect server state in client*, use of *appropriate authentication* mechanisms for web accounts (never Referer header).

Java Secure Coding Guidelines

- **Using modifiers.** Reduce scope of methods and fields; beware non-final public static (*global*) variables; avoid public fields, and add security checks to public accessors.
- **Protecting packages.** Stop insertion of untrusted classes in a package using java.security properties or "sealed" JAR file; avoid package-level access.
- **Beware mutable objects.** Returning or storing mutables may be risky, if caller then updates them; use immutable or *cloned* objects instead.
- **Serialization.** Once serialized, objects are outside JVM security. Designate **transient** fields and encrypt/sign persistent data. Beware overriding of serialization methods (among others).
- **Clear sensitive information.** Store sensitive data in mutable objects, then clear explicitly ASAP, to prevent heap-inspection attacks. Can't rely on Java's garbage collection to do this.

Access Control in Java

Java 1.0 had a **sandbox** security model, where downloaded Java applets ran in a restricted environment with no access to local files, etc: often too restrictive. Java 2 has a more flexible, fine-grained level of control:

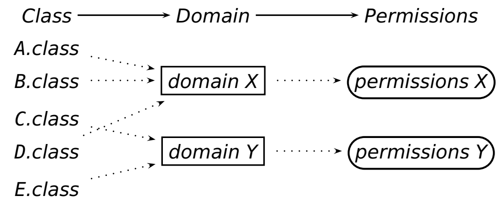


Applications and applets are subject to a **security policy** which specifies **protection domains** based on **location** of code, whether it is **signed** by a trusted entity, and the user **identity**. Each domain specifies a set of **permissions** for accessing resources.

This picture is reproduced from the Java Security Tutorial (c) Sun

Java security architecture

- A `SecurityManager` is installed by web browsers for Java applets; an application must either itself install the security manager, or be invoked with the option `-Djava.security.manager`. If the security manager's checks fail, a `java.lang.SecurityException` is raised.
- Access control in Java is based on **protection domains** which group together the set of objects which are currently accessible by a principal.



Java access control permissions

- Domains are associated with sets of **permissions**

`java.security.AllPermission`	every resource
`java.io.FilePermission`	file system access
`java.net.SocketPermission`	accept/connect based on host/IP
`java.awt.AWTPermission`	window-system permissions
`java.lang.RuntimePermission`	JVM config; threads; printing
`java.security.SecurityPermission`	accessing security policy, key store

- Some are associated with **target** and **actions**:

```
import java.io.FilePermission;
FilePermission p1 = new
FilePermission("/tmp/myfile", "read");
FilePermission p2 = new
FilePermission("/tmp/*", "read");
```

Permissions implement an **implies** method for access control decisions. Here `p2.implies(p1)`.

Java security policies

- The system security policy for a Java application environment specifies permissions available for code from various sources, represented by a `Policy` object. Only one in effect at a time.
- A `Policy` object evaluates the global policy using the `ProtectionDomain` for a class, and returns an appropriate `Permissions` object.
- Java supplies a GUI **policytool** utility for editing ASCII format policy files, with entries like this, specifying a key store and zero or more "grant" entries:

```
keystore ".keystore", "JKS";
grant principal com.sun.security.auth.UnixPrincipal "da" {
  permission java.util.PropertyPermission "java.home", "read";
  permission java.io.FilePermission "/tmp/foo", "read,write";
};
```

Default, system policy is in *javahome*/lib/security/java.policy. User policy is in *userhome*.java.policy.

Java security extensions

- The Java security extensions add additional APIs for programming security features.
- **Java Cryptography Extension** (JCE) A Java framework for cryptographic functionality, including message digests, encryption, signing, and X.509 certificates.
- **Java Secure Socket Extension** (JSSE).
- **Java Authentication and Authorization Service** (JAAS). Used for "reliable and secure" authentication of users, to determine who is currently executing Java code; and for authorization of users to ensure they have the permissions necessary for desired actions.
- **Java GSS-API**. Bindings for Generic Security Service API (RFC2853). Used for securely exchanging messages between communicating applications, using various underlying mechanisms (e.g., Kerberos).

Java Cryptography Extension (JCE)

- Crypto framework. A *provider* plug-in architecture allows multiple simultaneous implementations. Inclusion restricted because of import/export restrictions.
- Has *algorithm independence*, clients don't need to understand algorithms; abstract "engine" classes provide different services.
- *Service provider interfaces* (SPIs) added statically or dynamically; clients query installed providers to find out supported services. JVM and clients specify preference orders.
- Key management is through a "keystore" database. Different providers may have different formats.
- SUN provider implements common formats and proprietary keystore type JKS.
- See: `javax.crypto`, `javax.crypto.interfaces`, `javax.crypto.spec`.

JCE cryptography services

- A cryptography service is associated with a particular algorithm or type, and manipulates or generates data, keys, algorithm parameters, keystores, or certificates.
- Engine classes include:

`MessageDigest`	generate message digests (MDCs)
`Signature`	sign data and verify digital signatures.
`KeyPairGenerator`	generate public-private key-pair.
`CertificateFactory`	create certificates and CRLs.
`KeyStore`	create and manage key databases.
`AlgorithmParameters`	manage parameters for an algorithm.
`SecureRandom`	random or pseudo-random numbers.

- Factory methods in engine classes are used to return instances of the class, e.g. `Signature.getInstance("SHA1withDSA")`.

Java Secure Socket Extension (JSSE)

- The JSSE is also based on a provider plug-in architecture.
- Has a simple structure. Main use is with SSL client sockets, SSL server sockets, and SSL session handles. Sample classes:

`SSLSocket`	socket for SSL/TLS/WTLS protocols
`SSLSocketFactory`	factory for SSLSocket objects
`SSLServerSocket`	sever socket for SSL/TLS/WTLS
`··· Factory`	factory for SSLServerSockets
`SSLSession`	encapsulation of SSL session

- Creating SSL client or server sockets is as easy as creating ordinary Java TCP/IP sockets: each SSL class extends the corresponding ordinary TCP socket class, and provides a few extra hooks for setting security parameters.
- See `javax.net.ssl`, also `javax.net` and `javax.security.cert`.

Authentication and Authorization (JAAS)

- JAAS has a pluggable architecture; applications independent of underlying authentication methods. Implementation is decided at runtime, in a **login configuration file**.
- A `Subject` may have multiple identities; each is a `Principal` (name). Subjects own public and private **credentials** (e.g., key material).
- To authenticate, a `LoginContext` object is created, which then consults a configuration to load the required `LoginModules`. To authenticate a subject the `login` method is invoked for each module.
- **Authorization** happens when a subject is associated with a thread's `AccessControlContext` using the **doAs** methods for performing actions (`java.security.PrivilegedAction.run`). Then principal-based entries in the current security policy are used.

Flaws in the Java infrastructure

- Java was touted from the start as a secure mechanism for mobile code. But it has suffered from flaws in both design and implementation, surveyed in 1999 by McGraw and Felten in *Securing Java*, see `http://www.securingjava.com`.
- Most fundamental are any problems in the **Byte Code Verifier**, which checks proper use of JVML (protecting against "malicious" or merely buggy compilers):
  - no operand stack overflow/underflow
  - correct types and conversions
  - field accesses obey visibility modifiers

  Type safety relies on byte code verification being correct. Unfortunately getting this right is complicated. . .

Flaws in Java itself – continued

- The Java Language Specification is written in English. It suffers from usual problems of large language specifications: missing details, ambiguity, and other inaccuracies.
  - Sun BUG ID 6360463 (Dec 05): "offset item of the stack map frame" not defined in specification . . . "renders most of discussion on type checking moot"
- Sun's implementations are usually taken as the reference behaviour. But these have had a series of type safety and access control failings (from 1.x SDKs to J2ME in mobile phone KVMs).
  - 8th Feb 2006, CVE-2006-0614,0615,0617: Sun fixes seven vulnerabilities in current JREs which allowed remote code to bypass sandbox using reflection.
- Shows *defence in depth* is important; even with a careful Java security policy restricting what downloaded code can do, you should still beware *untrusted* code.

The Trusted Computing Base

Trusted Computing Base (TCB)

The set of all components (harware, software, human, . . .) whose correct functioning is sufficient to ensure that the security policy is enforced.

- Equivalently: failure of the TCB causes failure of security.
  Misplaced trust can hurt you!
- This motivates design principles for the TCB:
  - make it as small as possible
  - do not change it often
  - verify it carefully: so it is as secure as possible
- In access control systems, the TCB is the **Reference Monitor** implementation.

Palladium/TCPA/NGSCB/Trustworthy Computing

- PCs now contain a **Trusted Platform Module** (TPM) security chip with embedded master keys.
- Security model idea: PC boots, hashing BIOS, OS and application code. Builds a chain of trust.
- Protection domains in OS extended into hardware (secure keyboard reading, sound channels). Desire: close down an open system (cf XBox).
- Allows certificates, e.g. "this document created with v 1751 of MS Word, on Windows Vista Trusted, 27th August 2008, on Dell Megaplex ZZ5 S/N 5091237896". Files stored encrypted, cannot be decrypted on other machines.
- Many uses. Strong anti-privacy measures. Business clients: financial services, government, and healthcare. Home PC users: reduction in spyware, digital rights management (DRM). New uses: renting, lending, time-limited, etc. Considerable controversy (Stallman: "Treacherous Computing").

Language-based security

An active research area: applying programming language theory, designing new constructs and mechanisms.
Most work applies verification technology including static analysis, extended type systems and theorem proving.

- Proof-carrying code (PCC), which equips code with independently checkable safety certificates.
- Cyclone, Vault and others.
  Add richer, safer and more expressive typing and annotations to existing languages.
- Other security specialised typing includes:
  - detecting and preventing illegal **information flows**
  - **ensuring authentication** before authorisation
  - fixing patterns of **access control**, e.g. close file after opening.

References

- Mark G. Graff and Kenneth R. van Wyk.
  Secure Coding: Principles & Practices.
  O'Reilly, 2003.
- Sverre H. Huseby.
  Innocent Code: a security wake-up call for web programmers.
  Wiley.
- Gary McGraw.
  Securing Java.
  John Wiley & Sons, 1999.

Recommended Reading

For web programming: Huseby's book, or the more recent information at OWASP, `https://www.owasp.org`.
For Java security: the Oracle/CERT guidelines at `https://www.securecoding.cert.org`