Programming Securely II

Computer Security Lectures 16 & 17

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Outline

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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.

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- Buggy browsers: buffer overflows, crypto bugs, etc.

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- 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...

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Huseby's book *Innocent code — a security wake-up call for web programmers* is recommended.

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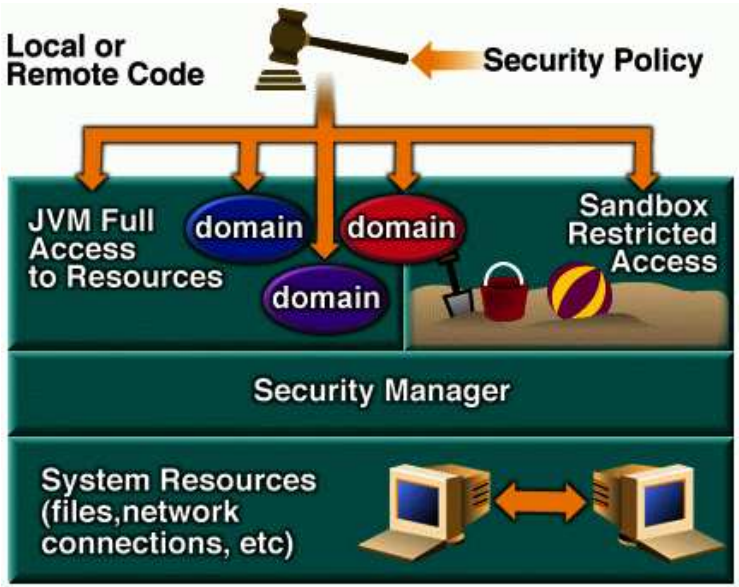
Security in Java

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:

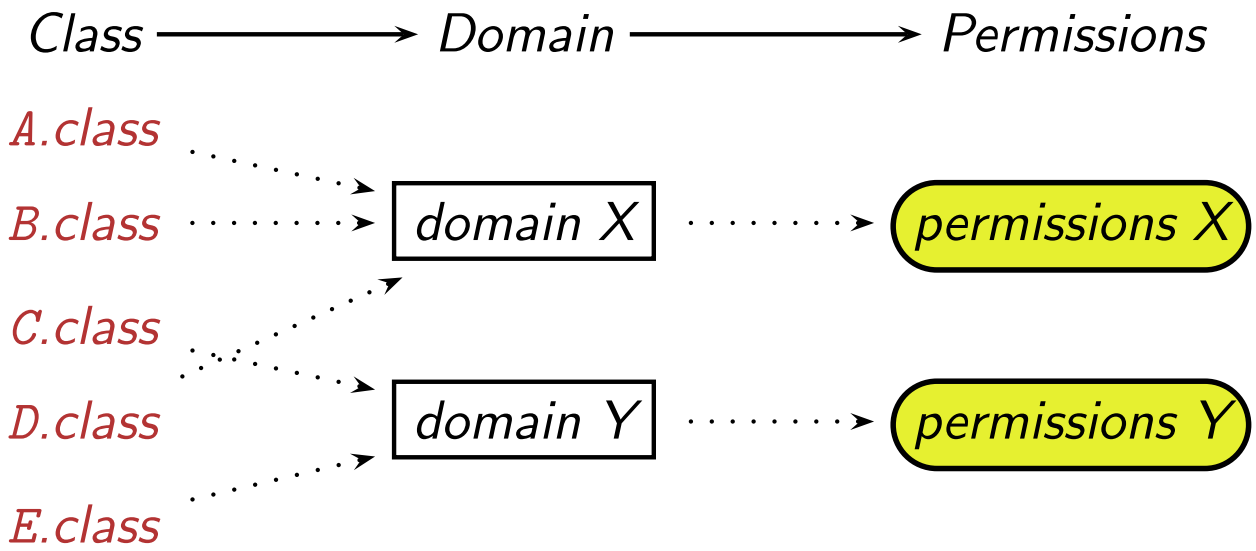


Applications and applets are subject to a **security policy** which specifies **protection domains** based on **location** of code, whether it is **signed** by a trusted entity, and the user **identity**. Each domain specifies a set of **permissions** for accessing resources.

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.



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Permissions implement an **implies** method used to make 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.

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- **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).

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- See: `javax.crypto`, `javax.crypto.interfaces`, `javax.crypto.spec`.

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KeyPairGenerator	generate public-private key-pair.
CertificateFactory	create certificates and CRLs.
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- 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
$\cdots$ Factory	factory for SSLServerSockets
SSLSession	encapsulation of SSL session (an interface)

- 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`.

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- **Authorization** happens when a subject is associated with a thread's `AccessControlContext` using the **doAs** methods for performing actions (`run` methods of a `java.security.PrivilegedAction` object). Then principal-based entries in the current security policy are used.

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

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  - 8th Feb 2006, CVE-2006-0614,0615,0617: Sun fixes seven vulnerabilities in current JREs which allowed remote code to bypass sandbox using reflection.
- This serves to point out the importance of *defence in depth*; even if you have a carefully configured Java security policy restricting what arbitrary downloaded code can do, you should still beware *untrusted* code.

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- 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").

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  2. More seriously, the code might not be secure anyway, if Microsoft fails to program securely, or virus/corruption occurs before signing (also happened: MS accidently distributed Nimda virus with VS .NET!)

Code signing: worth the bits?

- So far, we're trusting code based on authentication of its source (or maybe some security-verification agent). I'll trust updates to IE only if they're signed by Microsoft.
- Code signing is better than trusting unauthenticated code: a digital version of "shrink-wrapping" software with holographic certificates. However, this trust is fallible:
  1. Microsoft's signing scheme may be compromised (this has actually happened, by a infamous social engineering attack on Verisign),
  2. More seriously, the code might not be secure anyway, if Microsoft fails to program securely, or virus/corruption occurs before signing (also happened: MS accidently distributed Nimda virus with VS .NET!)
- The problem is that we delegate trust to somebody else rather than examining the code for ourselves. Examining the code ourselves to **prove** that it is secure for us is a possible solution, but hardly feasible. Or is it?

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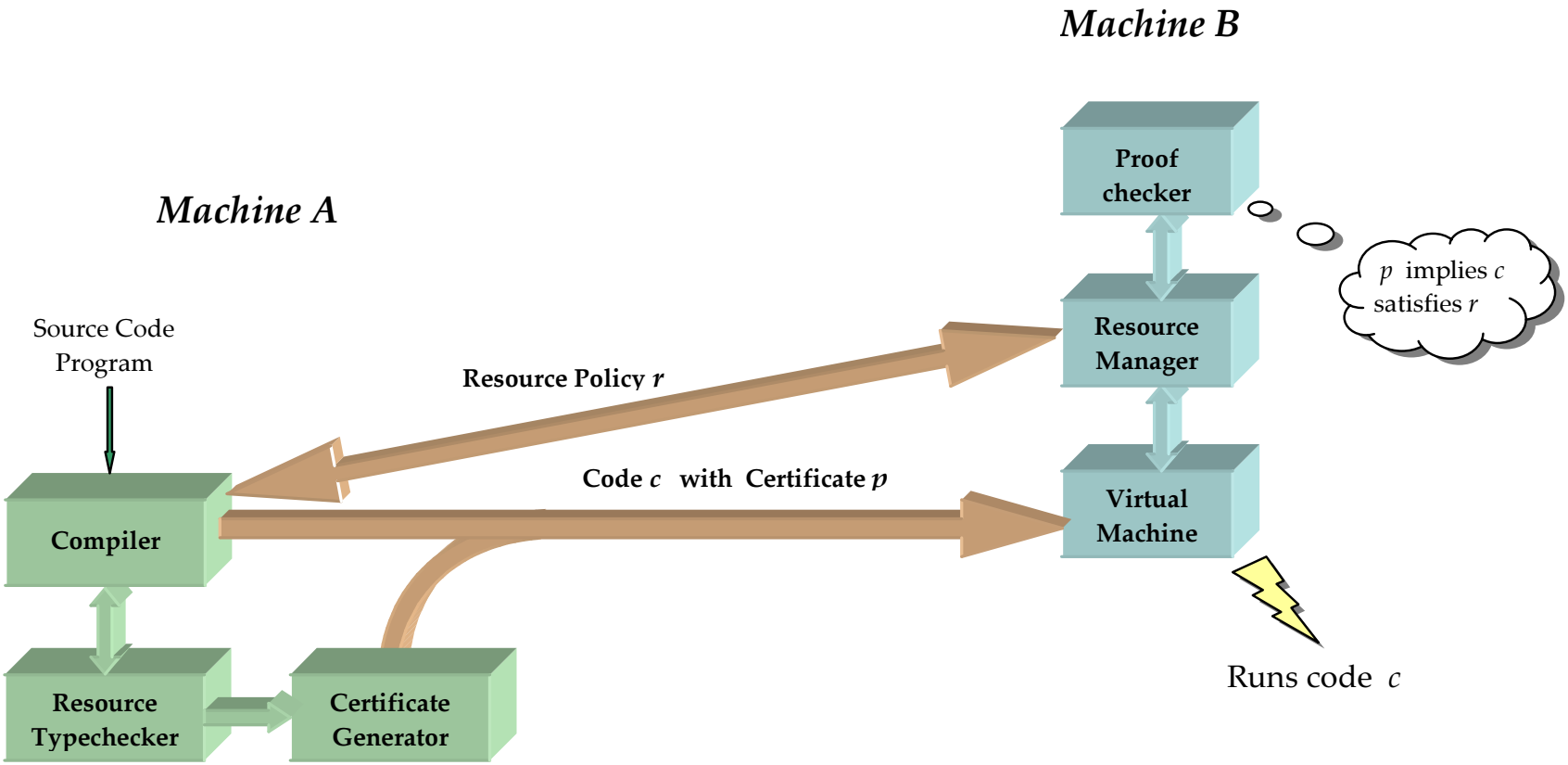
- In practice, the PCC protocol allows for some negotiation to set security policy. It might also allow for the combination of cryptographic and proof certificates. Theoretical work of LFCS, Edinburgh from 80s–90s is being applied today in PCC.

Resource bounded code

The general framework of PCC is wide in scope: recent LFCS research investigated **mobile resource guarantees**, which are PCC certificates attesting that a program will work within particular constraints on resources (time, space, number of network connections, etc). Here is a picture of our scheme:



Outline

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  - 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.

John Viega and Matt Messier.

Secure Programming Cookbook for C and C++.

O'Reilly, 2003.