Lab Notes

Distributed Systems

Securing Java

Introduction

- Brief overview of evolving Java platform security
- Java's digital signing tools to provide authentication in networked Java applications
- The Secure Socket Layer (SSL)

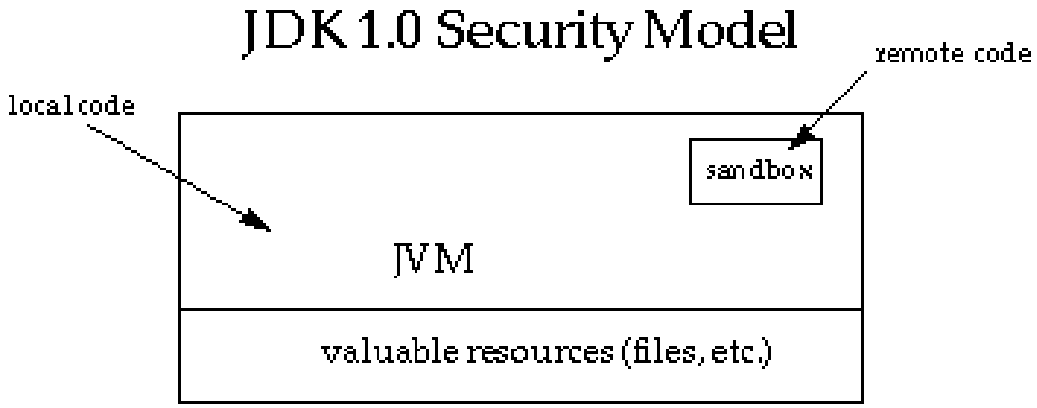
Java 2 Platform Security

- Partly done with language features such as
  - Automatic memory management
  - Garbage collection
  - Range checking on strings and arrays

- Code is executed in the Java Virtual Machine (JVM).
  - Compiler and bytecode verifier ensure that only legitimate Java bytecodes are executed.
  - Bytecode verifier and JVM guarantee language safety at run time.
  - Classloader defines a local name space:
    - An untrusted applet cannot interfere with the running of other programs.
  - JVM mediates access to crucial system resources.
    - SecurityManager class restricts the actions of Java code.

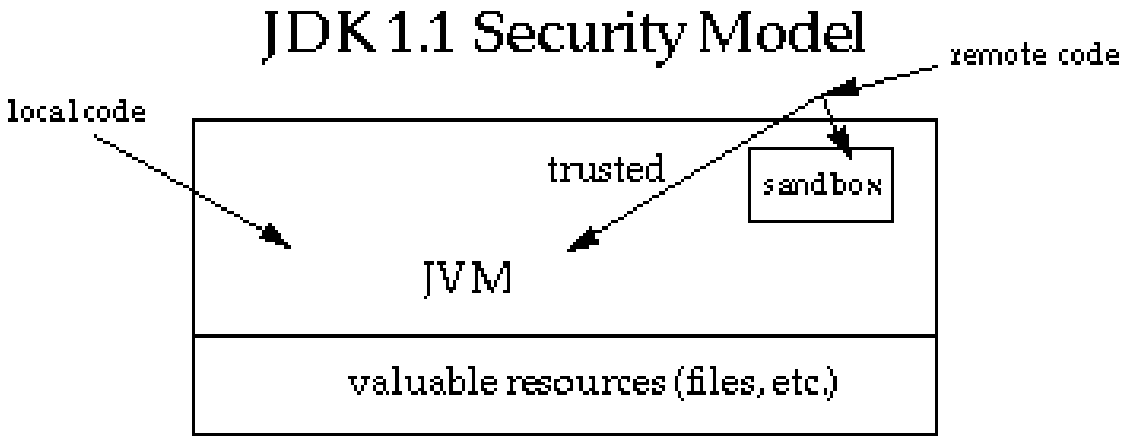
Java 2 Platform Security

- Original Sandbox Model
  - Code is executed in the Java Virtual Machine (JVM).
    - JVM simulates execution of Java Byte Code.
  - Sandbox model allows code to run in a very restricted environment.
  - But, local code has full access to valuable system resources.



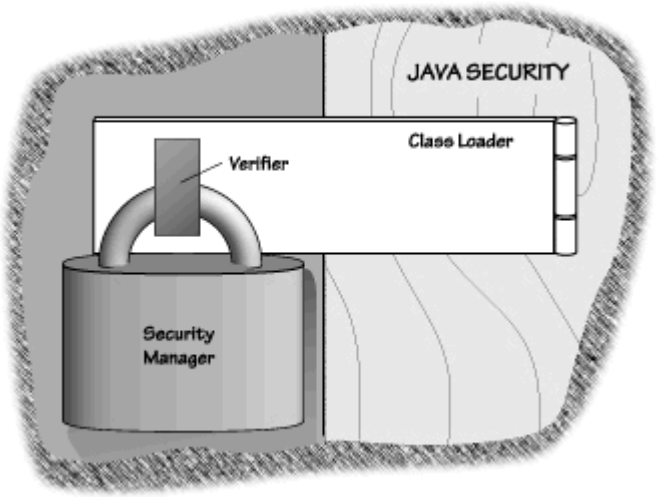
The Sandbox Model

- JDK 1.1: “Signed Applet”
  - Correctly signed applet is treated as trusted applet.
  - Applets and signatures are delivered in the JAR (Java Archive) format.
  - Untrusted applets run in the sandbox.



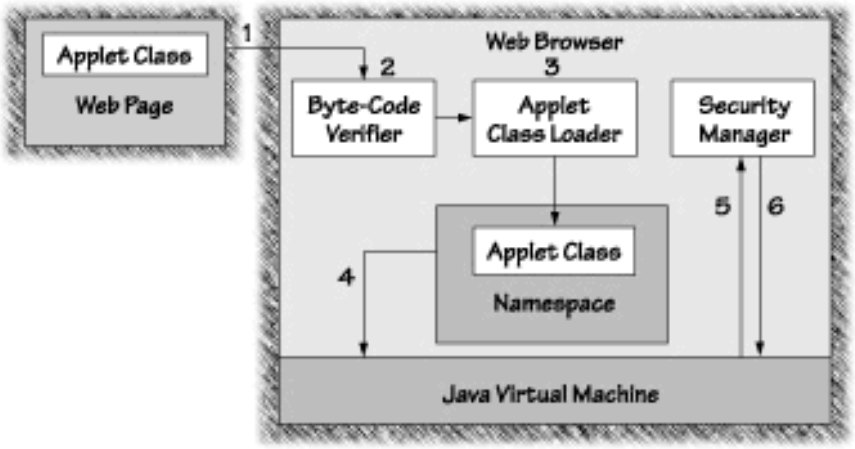
Java Sandbox

- The default sandbox is made of three interrelated parts:
  - The *Verifier* - helps ensure type safety.
  - The *Class Loader* - loads and unloads classes dynamically from the Java runtime environment.
  - The *Security Manager* - acts as a security gatekeeper guarding potentially dangerous functionality.



Java Sandbox

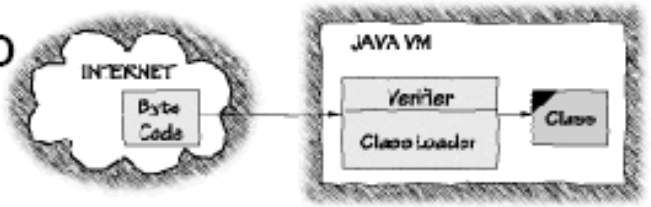
Browser asked to download applet:



1. Fetches the code from the Web
2. Verifies it
3. Instantiates it as a class
4. Applet executes and invokes a dangerous method causing the Security Manager to be consulted before the method runs.
5. The Security Manager performs runtime checks based on the calling class's origin and may veto some activities.

The Verifier

- When Java code arrives at the VM and is formed into a Class by the Class Loader, the Verifier examines it to
  - Make sure that the format of a code fragment is correct.
  - Make sure that byte code does not forge pointers, violate access restrictions, or access objects using incorrect type information.
- If the Verifier discovers a problem with a class file, it throws an exception, loading ceases, and the class file never executes

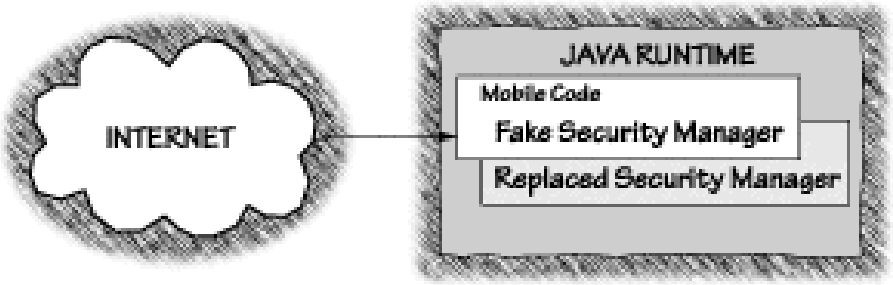


The Verifier

- Once byte code passes through verification, the following things are guaranteed:
  - The class file has the correct format
  - Stacks will not be overflowed or underflowed
  - Byte code instructions all have parameters of the correct type
  - No illegal data conversions (casts) occur
  - Private, public, protected, and default accesses are legal
  - All register accesses and stores are valid

The Class Loader

- Every mobile code system requires the ability to load code from outside a system into the system dynamically
- Class loaders determine when and how classes can be added to a running Java environment
- The fake Security Manager shown must be disallowed from loading into the Java environment and replacing the real Security Manager. This is known as *class spoofing*.

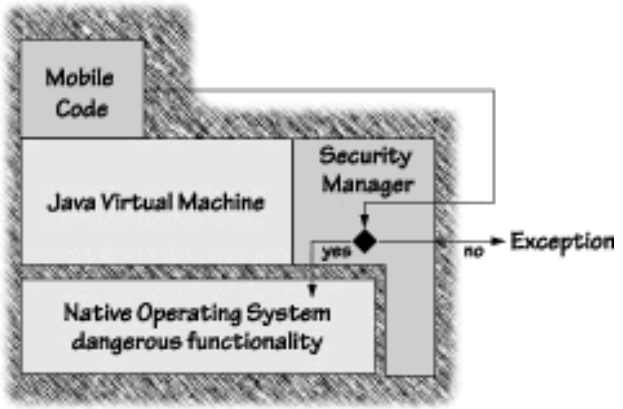


The Class Loader

- Class loading proceeds according to the following general algorithm:
  1. Determine whether the class has been loaded before. If so, return the previously loaded class.
  2. Attempt to load the class from the local CLASSPATH. This prevents external classes from spoofing trusted Java classes.
  3. See whether the Class Loader is allowed to create the class being loaded. The Security Manager makes this decision. If not, throw a security exception.
  4. Read the class file into an array of bytes and construct a Class object and its methods from the class file.
  5. Resolve any static classes referenced by the class before it is used.
  6. Check the class file with the Verifier.

The Security Manager

- The job of the Security Manager is to keep track of who is allowed to do which dangerous operations.
- A standard Security Manager will disallow most operations when they are requested by untrusted code, and will allow trusted code to do whatever it wants.
- Java's Security Manager works as follows:
  1. A Java program makes a call to a potentially dangerous operation in the Java API.
  2. The Java API code asks the Security Manager whether the operation should be allowed
  3. The Security Manager throws a SecurityException if the operation is denied.



Evolving the Sandbox Model: Java 2 Platform Security Model

- Easily configurable security policy.
  - Allows application builders and users to configure security policies without having to program
- Easily extensible access control structure.
  - The new architecture allows typed permissions (each representing an access to a system resource) and automatic handling of all permissions (including yet-to-be-defined permissions) of the correct type.
  - No new method in the SecurityManager class needs to be created in most cases.

Java 2 Platform Security Model

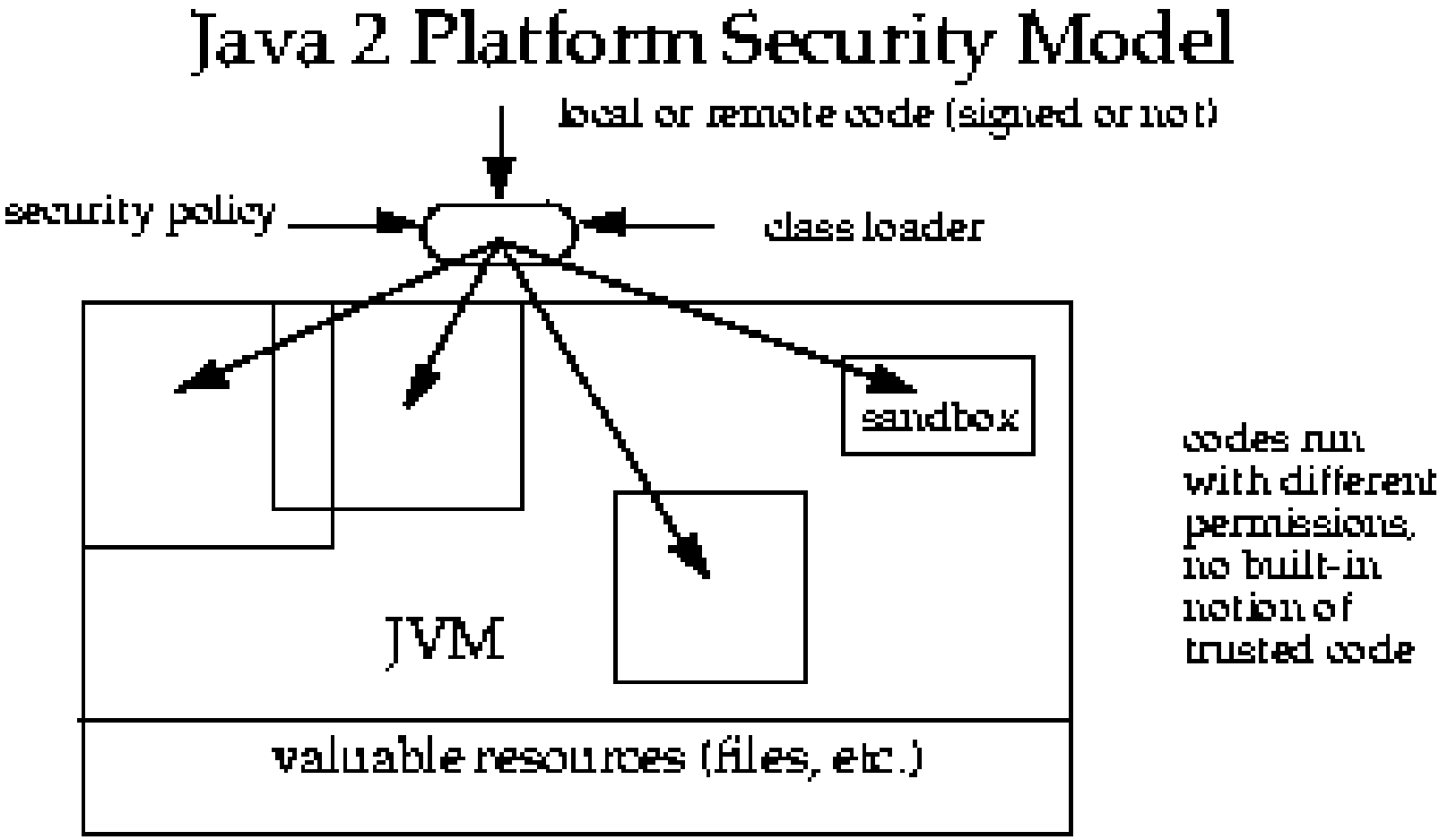
- Extension of security checks to all Java programs, including applications as well as applets.
- There is no longer a built-in concept that all local code is trusted.
- Local code (e.g., non-system code, application packages installed on the local file system)
  - is subjected to the same security control as applets, although it is possible, if desired, to declare that the policy on local code (or remote code) be the most liberal, thus enabling such code to effectively run as totally trusted.

Java 2 Platform Security

- Fine-grained access control.
- Previously, the application writer had to do substantial programming
  - e.g., by subclassing and customizing the SecurityManager and ClassLoader classes.

- Easily extensible access control structure.
- Extension of security checks to all Java programs, including applications as well as applets.
- Trust of local code is no longer a built-in concept.

Java 2 Platform Security

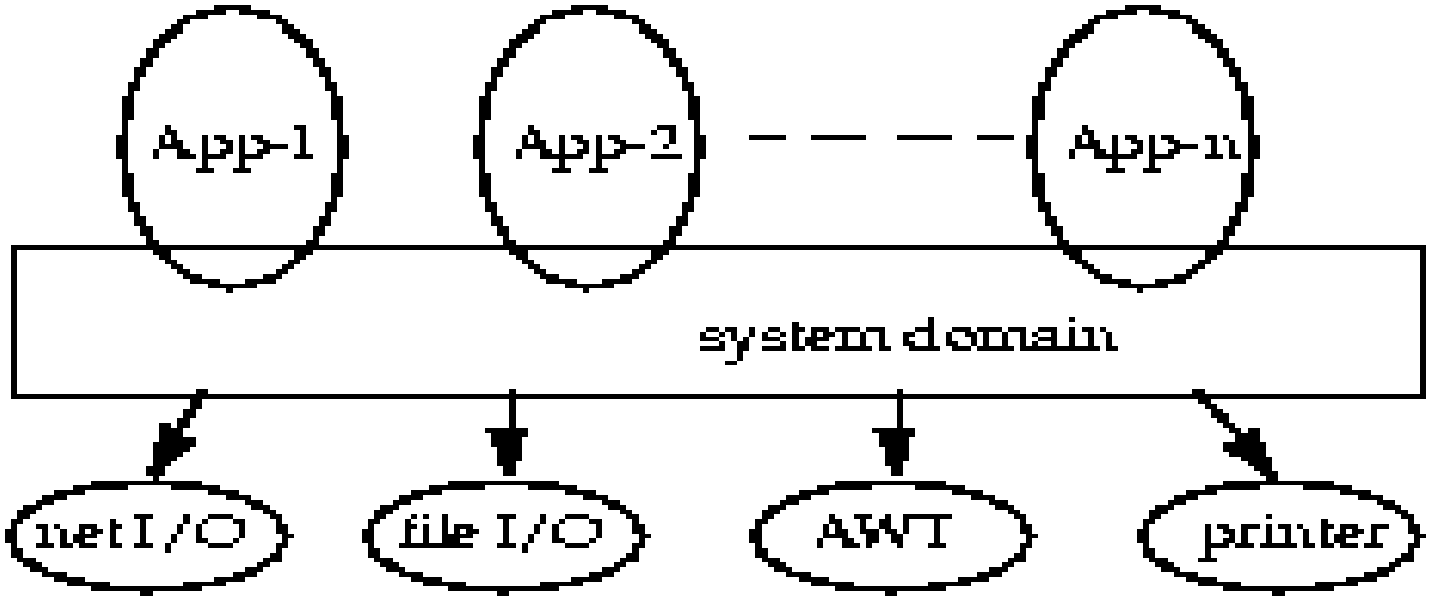


Java 2 Platform Security: Protection Domains

- Protection Domains
  - Set of objects that are currently directly accessible by a principal.
  - Principal is an entity in the computer system to which permissions are granted.
  - Serves to group and to isolate between units of protection.
  - Protection domains are either system domains or application domains.

Java 2 Platform Security: Protection Domains

- Protection domains generally fall into two distinct categories:
  - system domain and application domain.
- It is important that all protected external resources, such as the file system, the networking facility, and the screen and keyboard, be accessible only via system domains.



Java 2 Platform Security: Protection Domains

- A domain conceptually encloses a set of classes whose instances are granted the same set of permissions.
- Protection domains are determined by the policy currently in effect.
- The Java application environment maintains a mapping from code (classes and instances) to their protection domains and then to their permissions.

Java 2 Platform Security: Protection Domains

- Java thread can completely occur within a single protection domain.
- Can also involve application domain and system domain.

- Examples:
  - Application prints out a message.
  - Needs to interact with system domain that is the access point to an output stream.
  - AWT system domain calls an applet’s paint method to display it.

- Important:
  - A less "powerful" domain can NOT gain additional permissions as a result of calling or being called by a more powerful domain.

Java 2 Platform Security: Protection Domains

- Normal rule:
  - The permission set of an execution thread is the intersection of the permissions of all protection domains traversed by the execution thread.
  - Exception: doPrivileged call
    - Enables a piece of trusted code to temporarily enable access to more resources than are available directly to the application that called it.
  - Example:
    - Application may not be allowed direct access to files that contain files, but the system utility displaying those fonts needs to obtain them on behalf of the user.

Java 2 Platform Security: Protection Domains

- When access to a critical system resource (such as file I/O and network I/O) is requested:
  - the resource-handling code invokes a special AccessController class method
    - Evaluates the request
    - Decides if the request should be granted or denied.

Java 2 Platform Security: Protection Domains

- Each domain needs to implement additional protection of internal resources.
- Example:
  - Banking application needs to maintain internal concepts of
    - checking accounts
    - deposits
    - withdrawals

Java 2 Platform Security
Why:

- Original Problem:
  - Users download programs that contain viruses and worms (even in commercial software).
  - Java machines executes downloaded codes, which make the problem worse.
  - Early work focuses on this issue:
    - Java programs are secure because they cannot install, run, or propagate viruses.

SECURE FILE EXCHANGE

Secure Code & File Exchange

- The basic idea in the use of digital signatures is as follows.
  - You "sign" the document or code using one of your *private keys*, which you can generate by using `keytool` or security API methods. That is, you generate a digital signature for the document or code, using the `jarsigner` tool or API methods.
  - You send to the other person, the "receiver," the document or code and the signature.
  - You also supply the receiver with the public key corresponding to the private key used to generate the signature, if the receiver doesn't already have it.
  - The receiver uses the *public key* to verify the authenticity of the signature and the integrity of the document/code.
  - A receiver needs to ensure that the public key itself is authentic before reliably using it to check the signature's authenticity. Therefore it is more typical to supply a *certificate* containing the public key rather than just the public key itself.

Signing Code and Granting Permissions

- In this scenario, Susan wishes to send code to Ray.
- Ray wants to ensure that when the code is received, it has not been tampered with along the way - for instance someone could have intercepted the code exchange e-mail and replaced the code with a virus.

Signing Code and Granting Permissions –Sending side

Susan:

1. Creates an application
2. Create a JAR File containing the class file, using the `jar` tool.
3. Generate keys (if they don't already exist), using the `keytool -genkey` command.
4. Sign the JAR file, using the `jarsigner` tool and the private key.
5. Export the public key certificate, using the `keytool -export` command. Then supply the signed JAR file and the certificate to the receiver Ray.

Signing Code and Granting Permissions - Receiving side

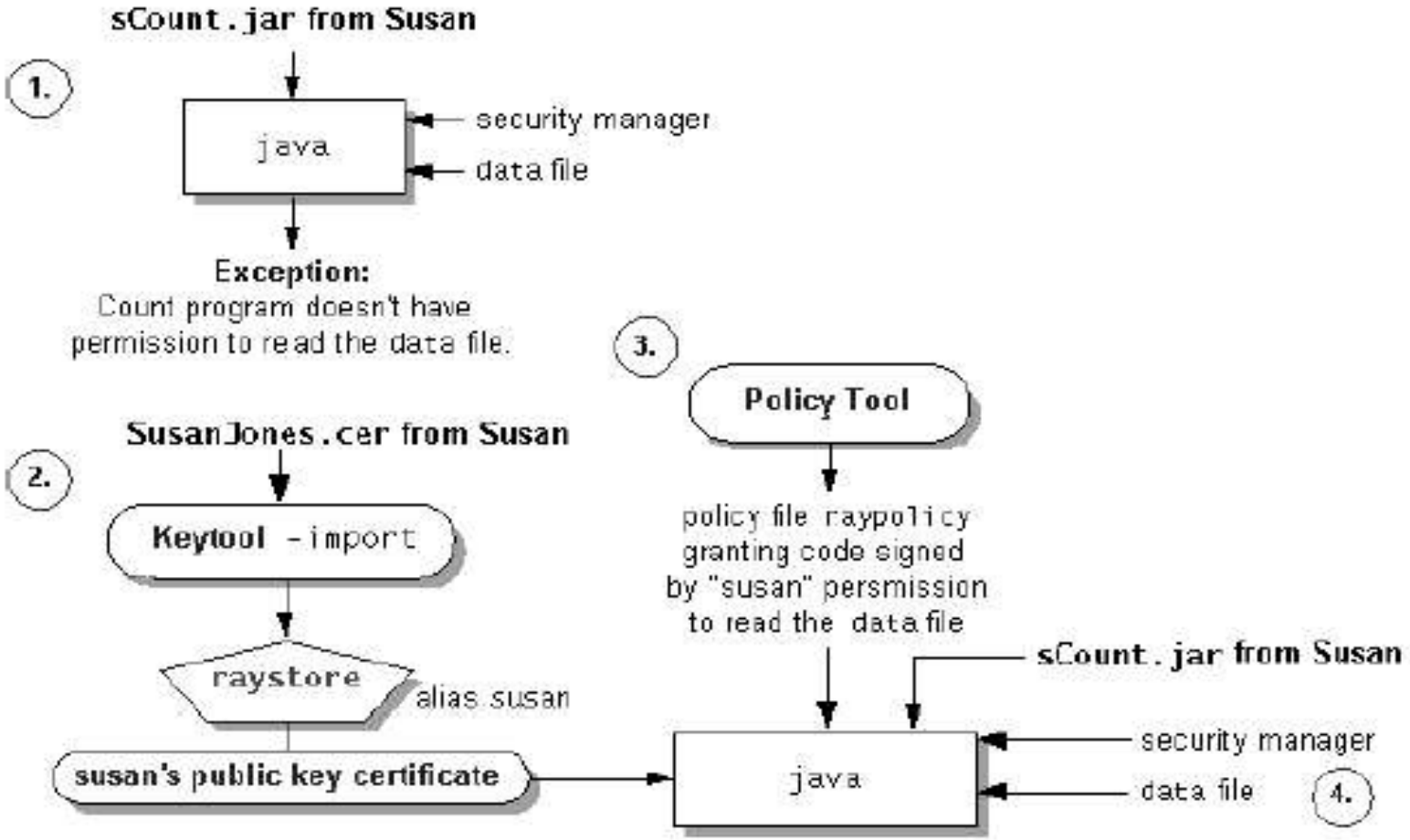
Ray:

1. Tries to run the jar code received from Susan and gets:

```
Exception in thread "main"
java.security.AccessControlException:
```

2. Import the certificate as a trusted certificate, using the `keytool -import` command, and give it the alias susan.
3. Set up a policy file to grant the required permission to permit classes signed by susan to read the specified file.
4. See the policy file effects, that is, see how the application can now read the file.

Signing Code and Granting Permissions - Receiving side



Case study: The Secure Socket Layer (SSL)

The Secure Socket Layer (SSL)

- SSL is a widely-used system component that supports secure and authenticated communication.
- Key distribution and secure channels for internet commerce
  - Hybrid protocol; depends on public-key cryptography
  - Originally developed by Netscape Corporation (1994)
  - Extended and adopted as an Internet standard with the name *Transport Level Security (TLS)*
  - Provides the security in all web servers and browsers and in secure versions of Telnet, FTP and other network applications;
  - Used to secure HTTP interactions for use in Internet e-commerce and other security sensitive applications.

SSL/TLS

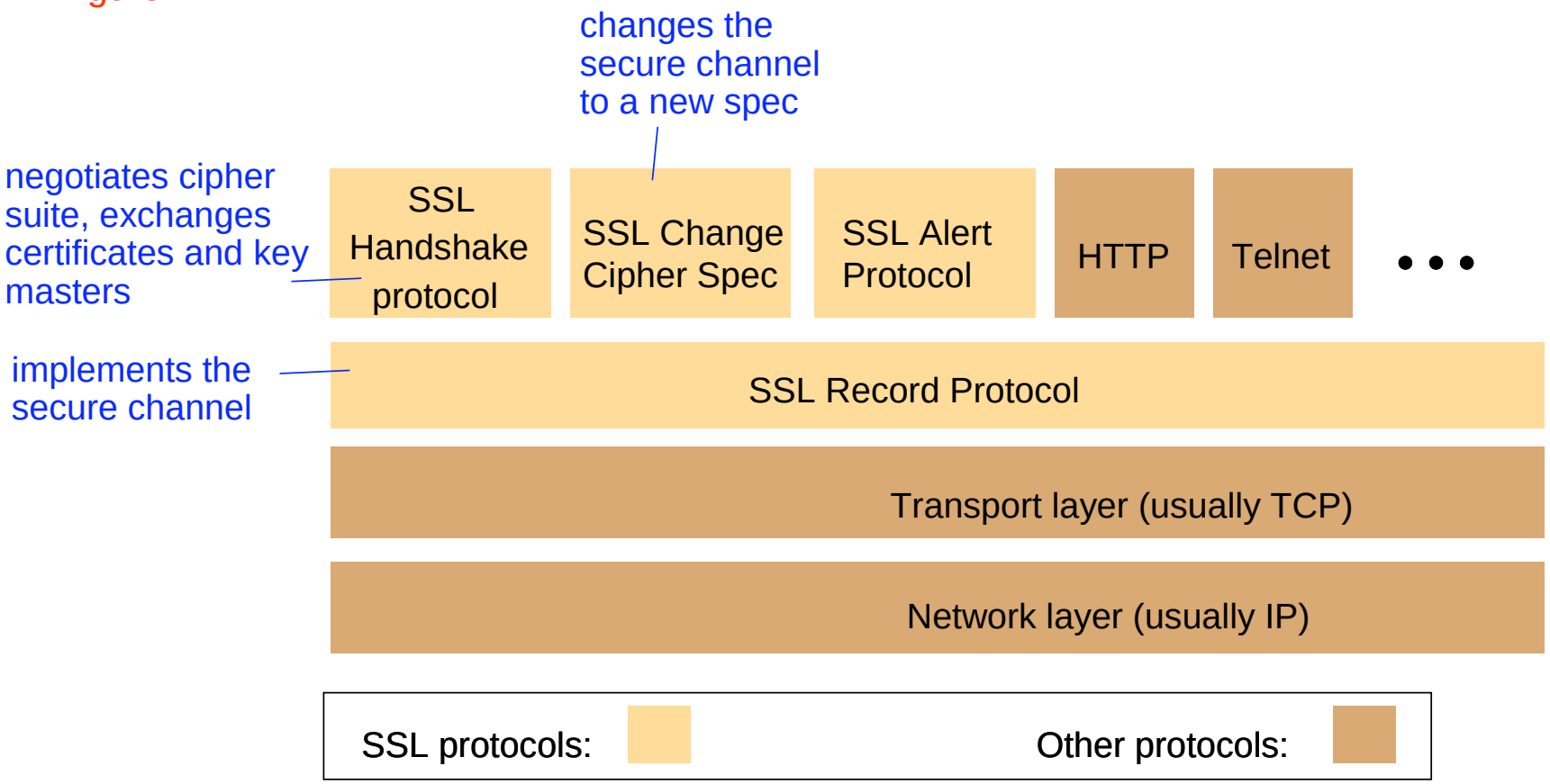
- Design requirements
  - Secure communication without prior negotiation or help from 3rd parties
  - Free choice of crypto algorithms by client and server
  - Communication in each direction can be authenticated, encrypted or both
- Main features:
  - Negotiable encryption and authentication algorithms:
    - algorithms negotiated during the initial handshake.
  - Bootstrapped secure communication:
    - Unencrypted communication is used for the initial exchanges, then public key-key cryptography and finally switching to secret-key cryptography once a shared key has been established.
- Protocol prefix *https*: in URLs initiates the establishment of an TLS secure channel between a browser and a web server.

SSL Layers

- Two layers:
  - *SSL Record Protocol layer* - which implements a secure channel, encrypting and authenticating messages transmitted through any connection-oriented protocol;
  - *handshake layer* – containing the SSL handshake protocol and two other related protocols that establish and maintain an SSL session (that is, a secure channel).

SSL protocol stack

Figure 7.17

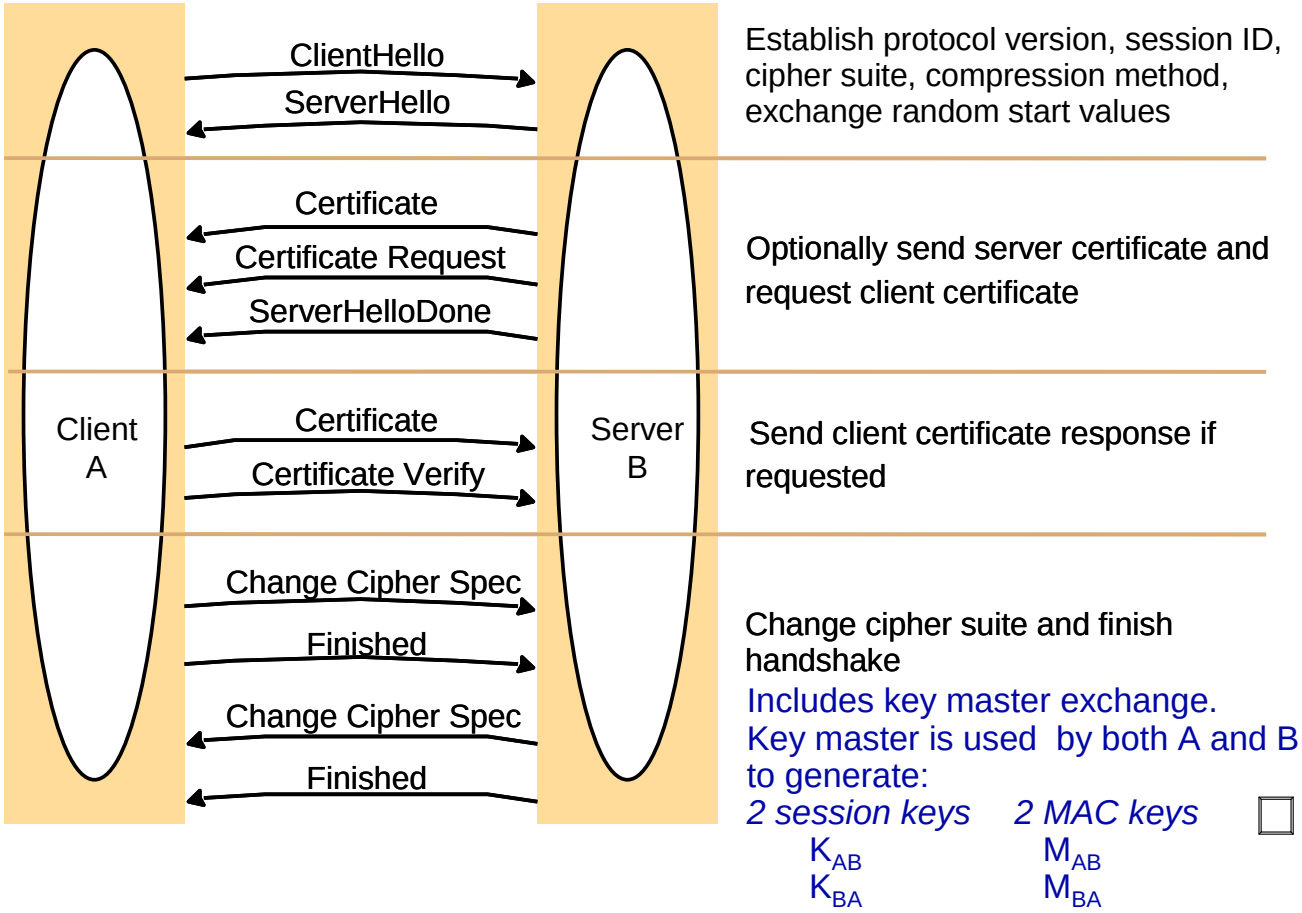


SSL handshake protocol

- Performed over an existing connection.
- Initial handshake
  - The public key used to verify the first certificate received may be delivered by a separate channel
- The partners optionally authenticate each other by exchanging signed public key certificate in X.509 format
- A *pre-master secret* is sent to the other partner encrypted with the public key. A pre-master secret is a large random value that is used by both partners to generate the two session keys (called *write* keys)
- *Session keys* used for encrypting data in each direction and the message authentication secrets to be used for message authentication.
- Secure session can start: triggered by the *ChangeCipherSpec* messages, followed *Finished* messages.
- Once the Finished messages have been exchanged, all further communication is encrypted and signed.

SSL handshake protocol

Figure 7.18



SSL handshake configuration options

- SSL supports a variety of options for the cryptographic functions to be used – *cipher suites*.
- A cipher suite includes a single choice for each of the features shown:

Cipher suite

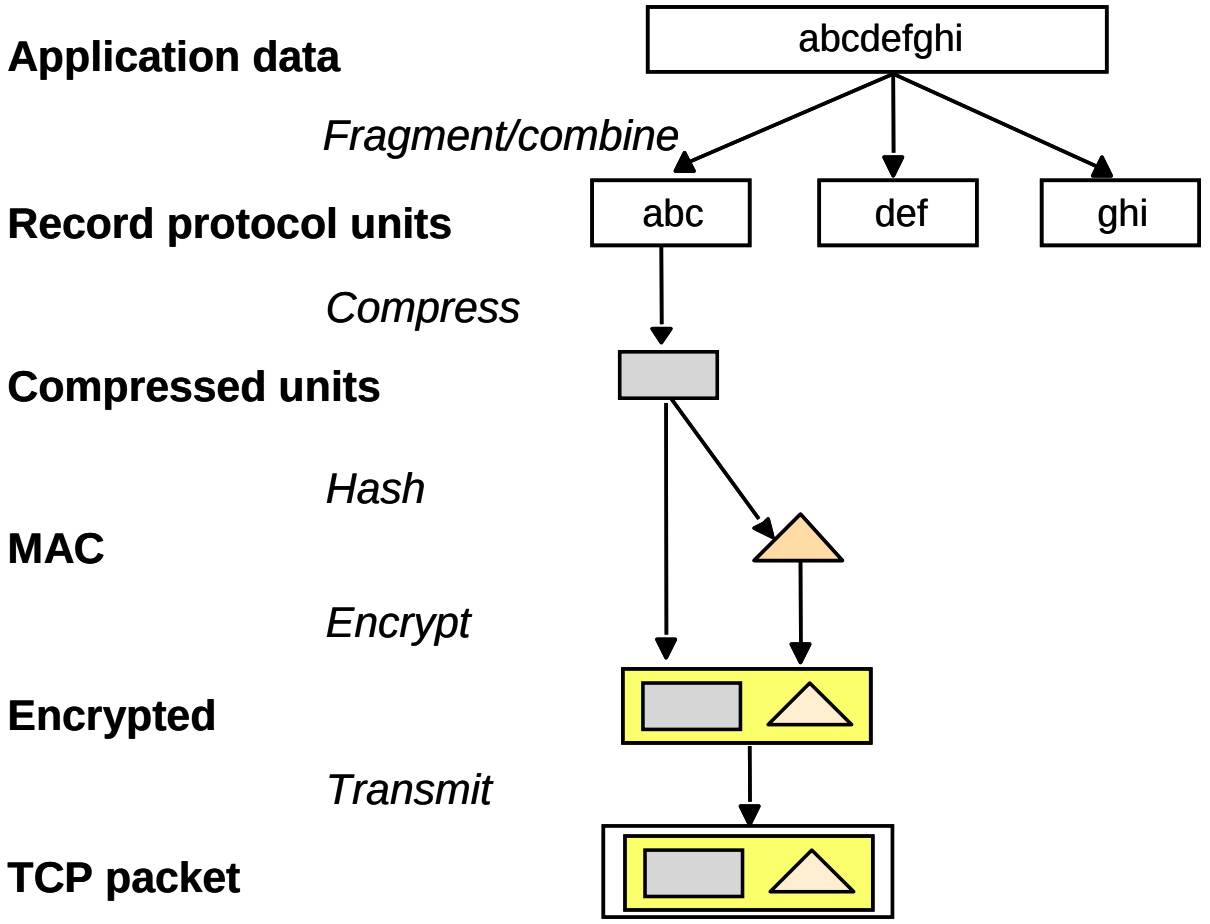
Component	*Description*	*Example*
Key exchange method	the method to be used for exchange of a session key	RSA with public-key certificates
Cipher for data transfer	the block or stream cipher to be used for data	IDEA
Message digest function	for creating message authentication codes (MACs)	SHA

SSL record protocol

- A message for transmission is first fragmented into blocks of manageable size.
- Then the blocks are optionally compressed.
- The encryption and message authentication (MAC) transformations deploy the algorithms specified in the agreed cipher suite.
- The signed and encrypted block is transmitted to the partner through associated TCP connection, where the transformations are reversed to produce the original data block.

SSL record protocol

Figure 7.20



SSL

- A practical implementation of a *hybrid* encryption scheme with authentication and key exchange based on public keys.
- Because the ciphers are negotiated in the handshake, it does not depend upon the availability of any particular algorithms, nor any secure services at the time of session establishment.
- The only requirement is for public-key certificates issued by an authority that is recognized by both parties.
- Published by Netscape in 1996.

References

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    https://docs.oracle.com/javase/7/docs/technotes/guides/security/spec
  - Security Features in Java SE

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- Chapter 11 - Security: Coulouris, Dollimore and Kindberg, Distributed Systems: Concepts and Design