Secure Coding Antipatterns: Avoiding Vulnerabilities

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Goal

Learn how to reduce vulnerabilities by avoiding insecure coding patterns (antipatterns)

What Is a Vulnerability?

A weakness in a system allowing an attacker to violate the integrity, confidentiality, access control, availability, consistency or audit mechanism of the system or the data and applications it hosts

Source: http://en.wikipedia.org/wiki/Vulnerability_%28computer_science%29

What Causes Vulnerabilities?

- Faulty assumptions in the application architecture
- Errors in configuration
- Incorrect logic
- Insecure programming practices (antipatterns)
- …

This session focuses on antipatterns

Secure Coding Antipatterns

- Programming practices you should avoid
  - Negative counterpart to a design pattern
  - e.g. Implementing methods that don't validate input params
- Antipatterns not set in stone
  - Generally should avoid them, but there are exceptions
  - Make sure you understand the consequences
- Vulnerabilities may exist in various locations
  - Application code, shared libraries, Java™ platform core libraries

Antipatterns in C Versus the Java Language

- C-based antipatterns often exploit buffer overflows
- Java runtime safely manages memory
  - Performs automatic bounds checks on arrays
  - No pointer arithmetic
- The Java runtime often executes untrusted code
  - Must protect against access to unauthorized resources
- Results in a different set of coding antipatterns than C

How This Presentation Is Organized

- List common coding antipatterns
- For each antipattern:
  - Show real example from an older JDK™ software release
  - Explain the problem and attack scenario
  - Describe the proper secure coding guidelines
- Summary
  - URL pointing to more comprehensive list of Java language secure coding guidelines

Common Java Platform Antipatterns

1. **Assuming objects are immutable**
2. Basing security checks on untrusted sources
3. Ignoring changes to superclasses
4. Neglecting to validate inputs
5. Misusing public static variables
6. Believing a constructor exception destroys the object

Antipattern 1: Assuming Objects Are Immutable

Example From JDK 1.1 Software

```
package java.lang;

public class Class {

    private Object[] signers;

    public Object[] getSigners() {
       return signers;
    }
}
```

*Class.getSigners() is actually implemented as a native method, but the behavior is equivalent to the above. See http://java.sun.com/security/getSigners.html

Antipattern 1: Assuming Objects Are Immutable

Attacker Can Change Signers of a Class

```
package java.lang;

public class Class {

    private Object[] signers;

    public Object[] getSigners() {
       return signers;
    }
}

Object[] signers = this.getClass().getSigners();
signers[0] = <new signer>;
```

Antipattern 1: Assuming Objects Are Immutable

Problem

- Mutable input and output Objects can be modified by the caller
- Modifications can cause applications to behave incorrectly
- Modifications to sensitive security state may result in elevated privileges for attacker
  - E.g. altering the signers of a class can give the class access to unauthorized resources

Antipattern 1: Assuming Objects Are Immutable

Secure Coding Guidelines

- Make a copy of mutable output parameters

```
public Object[] getSigners() {
    // signers contains immutable type X509Certificate.
    // shallow copy of array is OK.
    return signers.clone();
}
```

- Make a copy of mutable input parameters

```
public MyClass(Date start, boolean[] flags) {
    this.start = new Date(start.getTime());
    this.flags = flags.clone();
}
```

- Perform deep cloning on arrays if necessary

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Antipattern 2: Basing Security Checks on Untrusted Sources

Example From JDK 5.0 Software

```
public RandomAccessFile openFile(final java.io.File f) {
    askUserPermission(f.getPath());
    ...
    return (RandomAccessFile)AccessController.doPrivileged() {
        public Object run() {
            return new RandomAccessFile(f.getPath());
        }
    }
}
```

Antipattern 2: Basing Security Checks on Untrusted Sources

Attacker Can Pass in Subclass of java.io.File That Overrides getPath()

```
public RandomAccessFile openFile(final java.io.File f) {
    askUserPermission(f.getPath());
    ...
       return new RandomAccessFile(f.getPath());
    ...
}

public class BadFile extends java.io.File {
    private int count;
    public String getPath() {
       return (++count == 1) ? "/tmp/foo" : "/etc/passwd";
    }
}
```

Antipattern 2: Basing Security Checks on Untrusted Sources

Problem

- Security checks can be fooled if they are based on information that attackers can control
- It is easy to assume input types defined in the Java core libraries (like java.io.File) are secure and can be trusted
  - Non-final classes/methods can be subclassed
  - Mutable types can be modified

Antipattern 2: Basing Security Checks on Untrusted Sources

Secure Coding Guidelines

- Don’t assume inputs are immutable
- Make defensive copies of non-final or mutable inputs and perform checks using copies

```
public RandomAccessFile openFile(File f) {
    final File copy = f.clone();
    askUserPermission(copy.getPath());
    ...
       return new RandomAccessFile(copy.getPath());
}
```

Antipattern 2: Basing Security Checks on Untrusted Sources

Secure Coding Guidelines

- WRONG: clone() copies attacker's subclass

```
public RandomAccessFile openFile(java.io.File f) {
    final java.io.File copy = f.clone();
    askUserPermission(copy.getPath());
    ...
}
```

- RIGHT

```
java.io.File copy = new java.io.File(f.getPath());
```

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Antipattern 3: Ignoring Changes to Superclasses

Example From JDK 1.2 Software

```
java.util.Hashtable                 put(key, val)
                                    remove(key)
        ▲
        │ extends
        │
java.util.Properties

        ▲
        │ extends
        │
java.security.Provider              put(key, val) // security check
                                    remove(key)   // security check
```

Antipattern 3: Ignoring Changes to Superclasses

Example From JDK 1.2 Software (Cont.)

```
java.util.Hashtable              put(key, val)
        ▲                        remove(key)
        | extends                Set entrySet()
        |
java.util.Properties
        ▲
        | extends
        |
java.security.Provider           put(key, val) // security check
                                 remove(key)   // security check
```

Antipattern 3: Ignoring Changes to Superclasses

Attacker Bypasses remove Method and Uses Inherited entrySet Method to Delete Properties

```
java.util.Hashtable           put(key, val)
        ▲                     remove(key)
        |  extends            Set entrySet() //supports removal
        |
java.util.Properties
        ▲
        |  extends
        |
java.security.Provider        put(key, val)  // security check
                              remove(key)    // security check
```

Antipattern 3: Ignoring Changes to Superclasses

Problem

- Subclasses cannot guarantee encapsulation
  - Superclass may modify behavior of methods that have not been overridden
  - Superclass may add new methods
- Security checks enforced in subclasses can be bypassed
  - Provider.remove security check bypassed if attacker calls newly inherited entrySet method to perform removal

Antipattern 3: Ignoring Changes to Superclasses

Secure Coding Guidelines

- Avoid inappropriate subclassing
  - Subclass when the inheritance model is well-specified and well-understood
- Monitor changes to superclasses
  - Identify behavioral changes to existing inherited methods and override if necessary
  - Identify new methods and override if necessary

```
java.security.Provider  put(key, value)// security check
                        remove(key)    // security check
                        Set entrySet() // immutable set
```

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Antipattern 4: Neglecting to Validate Inputs

Example From JDK 1.4 Software

```
package sun.net.www.protocol.http;

public class HttpURLConnection extends
                                java.net.HttpURLConnection {
    /**
     * Set header on HTTP request
     */
    public void setRequestProperty(String key, String value) {
       // no input validation on key and value
    }
}
```

Antipattern 4: Neglecting to Validate Inputs

Attacker Crafts HTTP Headers With Embedded Requests That Bypass Security

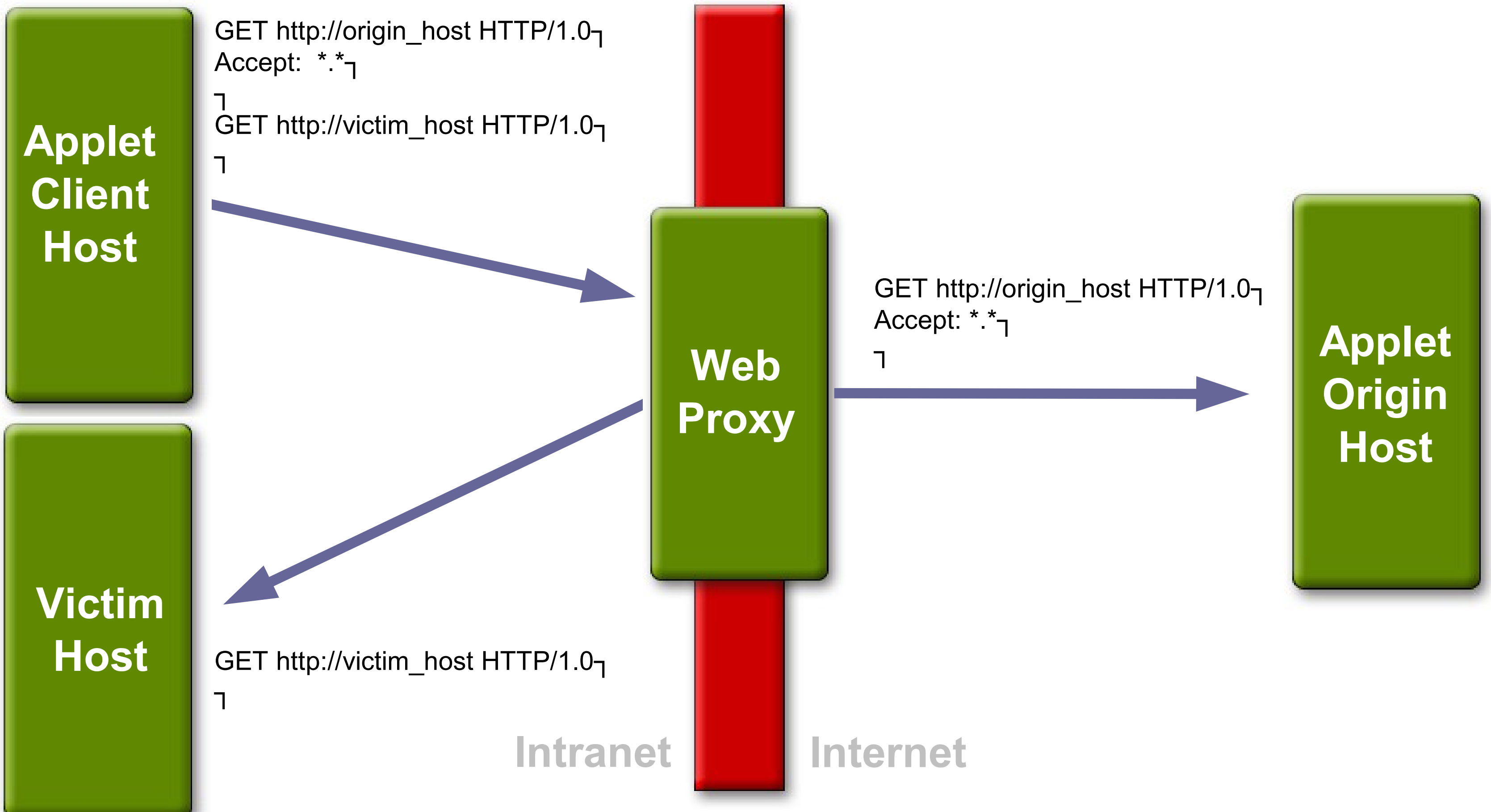
```
package sun.net.www.protocol.http;

public class HttpURLConnection extends java.net.URLConnection {
    public void setRequestProperty(String key, String value) {
       // no input validation on key and value
    }
}

urlConn.setRequestProperty
       ("Accept",
       "*.*\r\n\r\nGET http://victim_host HTTP/1.0\r\n\r\n");
```

Antipattern 4: Neglecting to Validate Inputs

Embedded Request Bypasses Security Check



Antipattern 4: Neglecting to Validate Inputs

Problem

- Creative inputs with out-of-bounds values or escape characters can be crafted
- Affects code that processes requests or delegates to subcomponents
  - Implements network protocols
  - Constructs SQL requests
  - Calls shell scripts
- Additional issues when calling native methods
  - No automatic array bounds checks

Antipattern 4: Neglecting to Validate Inputs

Secure Coding Guidelines

- Validate inputs
  - Check for escape characters
  - Check for out-of-bounds values
  - Check for malformed requests
  - Regular expression API can help validate String inputs
- Pass validated inputs to subcomponents
  - Wrap native methods in Java language wrapper to validate inputs
  - Make native methods private

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5. **Misusing public static variables**
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Antipattern 5: Misusing Public Static Variables

Example From JDK 1.4.2 Software

```
package org.apache.xpath.compiler;

public class FunctionTable {
    public static FuncLoader m_functions;
}
```

Antipattern 5: Misusing Public Static Variables

Attacker Can Replace Function Table

```
package org.apache.xpath.compiler;

public class FunctionTable {
    public static FuncLoader m_functions;
}
```

```
FunctionTable.m_functions = <new_table>;
```

Antipattern 5: Misusing Public Static Variables

Problem

- Sensitive static state can be modified by untrusted code
  - Replacing the function table gives attackers access to the XPathContext used to evaluate XPath expressions
- Static variables are global across a Java runtime environment
  - Can be used as a communication channel between different application domains (e.g. by code loaded into different class loaders)

Antipattern 5: Misusing Public Static Variables

Secure Coding Guidelines

- Reduce the scope of static fields

```
private static FuncLoader m_functions;
```

- Treat public statics primarily as constants
  - Consider using enum types
  - Make public static fields final

```
public class MyClass {
    public static final int LEFT = 1;
    public static final int RIGHT = 2;
}
```

Antipattern 5: Misusing Public Static Variables

Secure Coding Guidelines

- Define accessor methods for mutable static state
  - Add appropriate security checks

```
public class MyClass {
    private static byte[] data;

    public static byte[] getData() {
       return data.clone();
    }
    public static void setData(byte[] b) {
       securityCheck();
       data = b.clone();
    }
}
```

Common Java Platform Antipatterns

1. Assuming objects are immutable
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5. Misusing public static variables
6. **Believing a constructor exception destroys the object**

Antipattern 6: Believing a Constructor Exception Destroys the Object

Example From JDK 1.0.2 Software

```
package java.lang;

public class ClassLoader {
    public ClassLoader() {
        // permission needed to create class loader
        securityCheck();
        init();
    }
}
```

Antipattern 6: Believing a Constructor Exception Destroys the Object

Attacker Overrides Finalize to Get Partially Initialized ClassLoader Instance

```
package java.lang;

public class ClassLoader {
    public ClassLoader() {
        securityCheck();
        init();
    }
}
```

```
public class MyCL extends ClassLoader {
    static ClassLoader cl;

    protected void finalize() {
        cl = this;
    }

    public static void main(String[] s) {
        try {
            new MyCL()
        } catch (Exception e) { }

        System.gc();
        System.runFinalization();
        System.out.println(cl);
    }
}
```

Antipattern 6: Believing a Constructor Exception Destroys the Object

Problem

- Throwing an exception from a constructor does not prevent a partially initialized instance from being acquired
  - Attacker can override finalize method to obtain the object
- Constructors that call into outside code often naively propagate exceptions
  - Enables the same attack as if the constructor directly threw the exception

Antipattern 6: Believing a Constructor Exception Destroys the Object

Secure Coding Guidelines

- Make class final if possible
- If finalize method can be overridden, ensure partially initialized instances are unusable
  - Do not set fields until all checks have completed
  - Use an initialized flag

```
public class ClassLoader {
    private boolean initialized = false;

    ClassLoader() {
        securityCheck();
        init();
        initialized = true; // check flag in all relevant methods
    }
}
```

Summary

- Vulnerabilities are a concern for all developers
  - Can have severe impacts on security and privacy
- Follow secure coding guidelines to reduce vulnerabilities
  - Encourages secure programming from the outset
  - Helps limit bad assumptions that might be made
  - Avoids common antipatterns

For More Information

- Contact the Java SE Security Team with comments
  - java-security@sun.com
- Meet the Java SE Security Team
  - 10:30pm, May 18, Gateway 102/103
- Secure coding guidelines for Java technology
  - http://java.sun.com/security/seccodeguide.html
    - Currently being updated, new version to be posted soon

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Q&A

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