Secure Coding Guidelines, Continued: Preventing Attacks and Avoiding Antipatterns

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Goal

Learn more about how to reduce vulnerabilities by avoiding insecure coding patterns

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

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 Programming Language

- C-based antipatterns often exploit buffer overflows
- Java runtime environment safely manages memory
  - Performs automatic bounds checks on arrays
  - No pointer arithmetic
- The Java runtime environment 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 programming 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
- Make a copy of mutable input parameters

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

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 platform 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

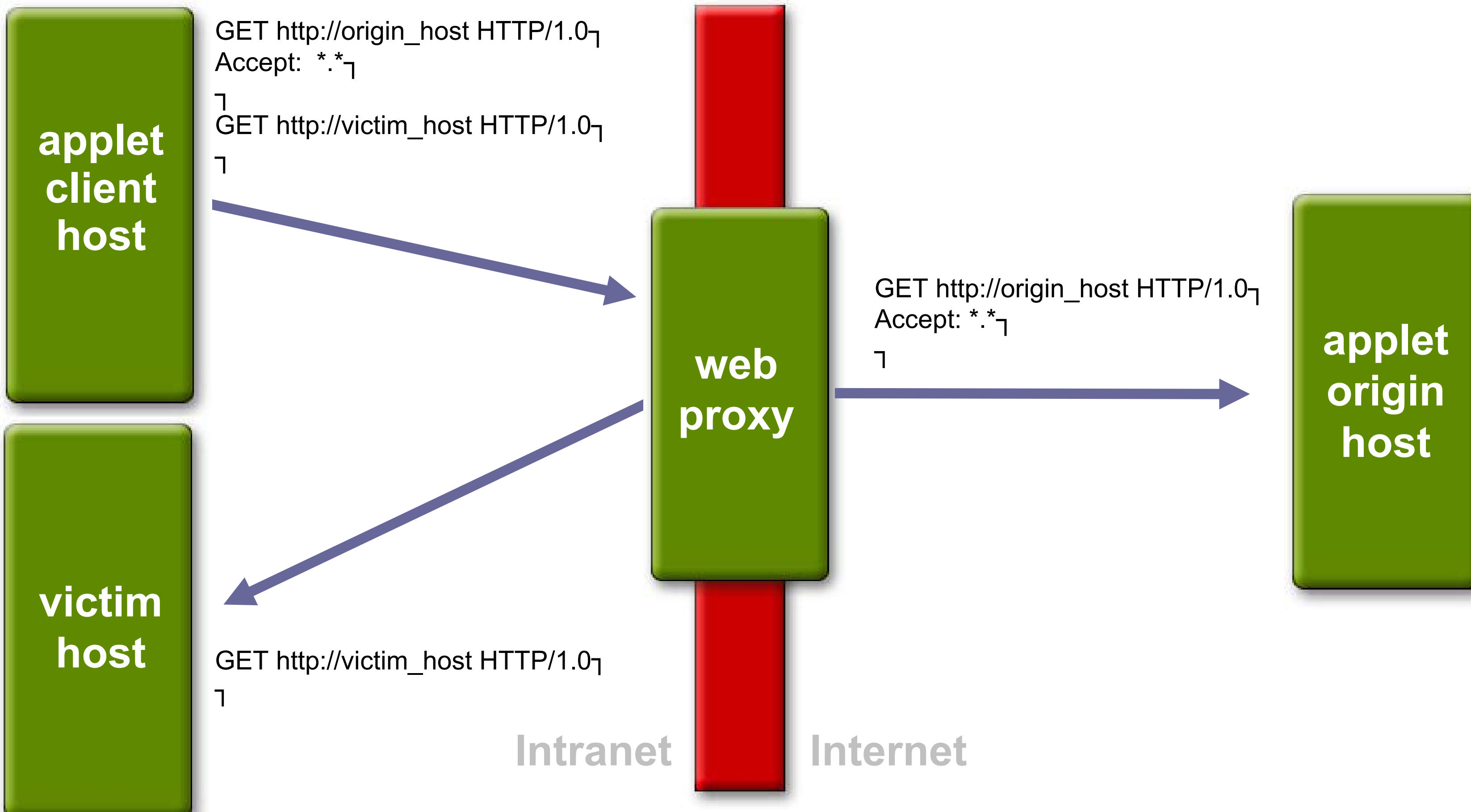
```
package sun.net.www.protocol.http;

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 sub-components
  - Wrap native methods in Java programming language wrapper to validate inputs
  - Make native methods private

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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 assessor 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
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 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 (SecurityException 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
    }
}
```

Common Java Platform Antipatterns

7. Assuming exceptions are harmless
8. Believing deserialization is unrelated to construction
9. Believing deserialization field values are unshared

Antipattern 7: Assuming Exceptions Are Harmless

Problem

- Exceptions may contain sensitive data such as directory paths that imply user identity

Antipattern 7: Assuming Exceptions Are Harmless

Attacker can learn sensitive data

```
public class PersonalData {
    public load() throws IOException {
        String homedir = System.getProperty("user.dir");
        File f = new File(homedir, "personal.dat");
        FileInputStream s = new FileInputStream(f);
    }
}

try { personal.load(); } catch (IOException e) {
    String homedir = parsePath(e.message());
    String username = parseUser(homedir);
}
```

Antipattern 7: Assuming Exceptions Are Harmless

Secure coding guidelines

- Sanitize or mask exceptions

```
public class PersonalData {
    public load() throws IOException {
        try {
            ...
        } catch (Exception e) {
            throw new IOException("Could not load data");
        }
    }
}
```

Common Java Platform Antipatterns

7. **Assuming exceptions are harmless**
8. **Believing deserialization is unrelated to construction**
9. **Believing deserialization field values are unshared**

Antipattern 8: Believing Deserialization Is Unrelated to Constructors

Example from JDK 1.1 software

```
package java.math;

public class BigInteger extends Number {
    private int signum;
    public BigInteger(int signum, byte[] magnitude){
        if (signum < -1 || signum > 1) {
            throw new NumberFormatException()
          ...
    }
}
```

Antipattern 8: Believing Deserialization Is Unrelated to Constructors

Attacker can deserialize a stream with invalid field data

```
package java.math;

public class BigInteger extends Number {
    private int signum;
    public BigInteger(int signum, byte[] magnitude){
       if (signum < -1 || signum > 1) {
          throw new NumberFormatException()
         ...
    }
}
ObjectInputStream is = new FileInputStream("bad.ser");
BigInteger bigInt = is.readObject();
```

Antipattern 8: Believing Deserialization Is Unrelated to Constructors

Problem

- The default deserialization mechanism cannot automatically apply the same invariant and parameter checking present in the constructor
  - Attacker can create a malicious serialization stream with invalid field values

Antipattern 8: Believing Deserialization Is Unrelated to Constructors

Secure coding guidelines

- Create a custom readObject() method that shares the same validation checking as the class constructors

```
private void readObject(ObjectInputStream s) {
    s.defaultReadObject();
    // Validate signum
    if (signum < -1 || signum > 1)
       throw new StreamCorruptedException();
}
```

Common Java Platform Antipatterns

7. Assuming exceptions are harmless
8. Believing deserialization is unrelated to construction
9. Believing deserialization field values are unshared

Antipattern 9: Believing Deserialized Field Values Are Unshared

Example from JDK 1.1 software

```
package java.math;

public class BigInteger extends Number {
    private byte[] magnitude;
    public BigInteger(int signum, byte[] magnitude){
        this.magnitude = stripLeadingZeroBytes(magnitude);
          ...
    }
}
```

Antipattern 9: Believing Deserialized Field Values Are Unshared

Attacker can deserialize a stream with malicious 'extra' references to mutable fields

```
package java.math;

public class BigInteger extends Number {
    private byte[] magnitude;
    public BigInteger(int signum, byte[] magnitude){
        this.magnitude = stripLeadingZeroBytes(magnitude);
         ...
    }
}
ObjectInputStream is = new FileInputStream("bad.ser");
BigInteger bigInt = is.readObject();
byte[] magnitudeCopy = is.readObject();
```

Antipattern 9: Believing Deserialized Field Values Are Unshared

Problem

- The default deserialization mechanism assumes object references in a stream might have multiple legitimate references
  - Attacker can create a malicious serialization stream with unintended extra references to a mutable field object instance

Antipattern 9: Believing Deserialized Field Values Are Unshared

Secure coding guidelines

- Create a custom readObject() method that creates an unshared private copy of mutable field instances

```
private void readObject(ObjectInputStream s) {
    s.defaultReadObject();
    magnitude = (byte [])magnitude.clone();
}
```

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

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  - Andreas Sterbenz, Charlie Lai

For More Information

- Contact the Java Platform, Standard Edition (Java SE Platform) Security Team with comments
  - java-security@sun.com
- Meet the Java SE Platform Security Team
  - BOF-2516 8:55pm–9:45pm, Thurs. May 10
- Secure coding guidelines for Java technology
  - http://java.sun.com/security/seccodeguide.html

Q&A

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