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Deserialization exploits in Java: why should I care?!

Brian Vermeer I @BrianVerm

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Space the final frontier

STAR TREK
#hulu

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Brian Vermeer

Staff Developer Advocate

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Java Champion

Virtual JUG leader

NLJUG leader

DevSecCon co-leader

Top 21 Developers Shaping Tech

Foojay Community Manager Security

The gift that keeps on giving

Serialization

Deserialization

```
public class ValueObject implements Serializable

    private String value;
    private String sideEffect;

    private ValueObject() {
        this("empty");
    }

    public ValueObject(String value) {
        this.value = value;
        this.sideEffect = java.time.LocalTime.now().toString();
    }
}
```

Serialization

```java
public class ValueObject implements Serializable {

    private String value;
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    private ValueObject() {
        this("empty");
    }

    public ValueObject(String value) {
        this.value = value;
        this.sideEffect = java.time.LocalTime.now().toString();
    }

}
```

```java
FileOutputStream fileOut = new FileOutputStream(filename);
ObjectOutputStream out = new ObjectOutputStream(fileOut);
out.writeObject(object);
out.close();
fileOut.close();
```

```
00000000: aced 0005 7372 0031 6e6c 2e62 7269 616e  ....sr.1nl.brian
00000010: 7665 726d 6565 722e 6578 616d 706c 652e  vermeer.example.
00000020: 7365 7269 616c 697a 6174 696f 6e2e 5661  serialization.Va
00000030: 6c75 654f 626a 6563 744c ab0f 247c 22e5  lueObjectL..$|".
00000040: ba02 0002 4c00 0a73 6964 6545 6666 6563  ....L..sideEffec
00000050: 7474 0012 4c6a 6176 612f 6c61 6e67 2f53  tt..Ljava/lang/S
00000060: 7472 696e 673b 4c00 0576 616c 7565 7100  tring;L..valueq.
00000070: 7e00 0178 7074 000f 3133 3a30 303a 3039  ~..xpt..13:00:09
00000080: 2e39 3531 3631 3474 0002 4869            .951614t..Hi
```

```
00000000: aced 0005 7372 0031 6e6c 2e62 7269 616e  ....sr.1nl.brian
00000010: 7665 726d 6565 722e 6578 616d 706c 652e  vermeer.example.
00000020: 7365 7269 616c 697a 6174 696f 6e2e 5661  serialization.Va
00000030: 6c75 654f 626a 6563 744c ab0f 247c 22e5  lueObjectL..$|".
00000040: ba02 0002 4c00 0a73 6964 6545 6666 6563  ....L..sideEffec
00000050: 7474 0012 4c6a 6176 612f 6c61 6e67 2f53  tt..Ljava/lang/S
00000060: 7472 696e 673b 4c00 0576 616c 7565 7100  tring;L..valueq.
00000070: 7e00 0178 7074 000f 3133 3a30 303a 3039  ~..xpt..13:00:09
00000080: 2e39 3531 3631 3474 0005 4861 6c6c 6f    .951614t..Hallo
```


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Deserialization

```
public class ValueObject implements Serializable {

    private String value;
    private String sideEffect;

    private ValueObject() {
        this("empty");
    }

    public ValueObject(String value) {
        this.value = value;
        this.sideEffect = java.time.LocalTime.now().toString();
    }

}
```

```
FileInputStream fileIn = new FileInputStream(filename);
ObjectInputStream in = new ObjectInputStream(fileIn);
ValueObject vo = (ValueObject) in.readObject();
```

Gadgets

```java
public class Gadget implements Serializable {

    private Runnable command;

    public Gadget(Command command) {
        this.command = command;
    }

    private final void readObject(ObjectInputStream in) throws IOException, ClassNotFoundException {
        in.defaultReadObject();
        command.run();
    }
}
```

```java
FileInputStream fileIn = new FileInputStream(filename);
ObjectInputStream in = new ObjectInputStream(fileIn);
ValueObject vo = (ValueObject) in.readObject();
```

https://brandur.org/fragments/gadgets-and-chains

Check the implementation on HashMap!

ysoserial

frohoff/ysoserial: A proof-of-c

github.com/frohoff/ysoserial

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frohoff test fixes (#166) 8eb5cbf on 18 Aug 164 com

src	test fixes (#166)	last m
.editorconfig		
.gitignore		
.travis.yml		
DISCLAIMER.txt	init-commit	7 years
Dockerfile	fix for dockerfile	2 years
LICENSE.txt	init-commit	7 years
README.md	test fixes (#166)	last m
appveyor.yml	attempt to fix jdk6/7 appveyor config	3 years
assembly.xml	assembly to include tests in jar	2 years
pom.xml	New gadget chain based on Apache Click (#154)	8 months
ysoserial.png	init-commit	7 years

README.md

ysoserial

chat on gitter | download master | build passing | build passing

A proof-of-concept tool for generating payloads that exploit unsafe Java object deserialization.

```
$  java -jar ysoserial.jar
Y SO SERIAL?
Usage: java -jar ysoserial.jar [payload] '[command]'
  Available payload types:
    Payload             Authors                    Dependencies
    -------             -------                    ------------
    AspectJWeaver       @Jang                      aspectjweaver:1.9.2, commons-collections:3.2.2
    BeanShell1          @pwntester, @cschneider4711 bsh:2.0b5
    C3P0                @mbechler                  c3p0:0.9.5.2, mchange-commons-java:0.2.11
    Click1              @artsploit                 click-nodeps:2.3.0, javax.servlet-api:3.1.0
    Clojure             @JackOfMostTrades          clojure:1.8.0
    CommonsBeanutils1   @frohoff                   commons-beanutils:1.9.2, commons-collections:3.1
    CommonsCollections1 @frohoff                   commons-collections:3.1
    CommonsCollections2 @frohoff                   commons-collections4:4.0
    CommonsCollections3 @frohoff                   commons-collections:3.1
    CommonsCollections5 @matthias_kaiser, @jasinner commons-collections:3.1
    CommonsCollections7 @scristalli, @hanyrax, @EdoardoVignati commons-collections:3.1
    FileUpload1         @mbechler                  commons-fileupload:1.3.1, commons-io:2.4
    Groovy1             @frohoff                   groovy:2.3.9
    Hibernate1          @mbechler
    Hibernate2          @mbechler
    JBossInterceptors1  @matthias_kaiser           javassist:3.12.1.GA, jboss-interceptor-core:2.0
    JRMPClient          @mbechler
    JRMPListener        @mbechler
    JSON1               @mbechler                  json-lib:jar:jdk15:2.4, spring-aop:4.1.4.RELEAS
    JavassistWeld1      @matthias_kaiser           javassist:3.12.1.GA, weld-core:1.1.33.Final, co
    Jdk7u21             @frohoff
    Jython1             @pwntester, @cschneider4711 jython-standalone:2.5.2
    MozillaRhino1       @matthias_kaiser           js:1.7R2
    MozillaRhino2       @_tint0                    js:1.7R2
    Myfaces1            @mbechler
    Myfaces2            @mbechler
    ROME                @mbechler                  rome:1.0
    Spring1             @frohoff                   spring-core:4.1.4.RELEASE, spring-beans:4.1.4.RE
    Spring2             @mbechler                  spring-core:4.1.4.RELEASE, spring-aop:4.1.4.REL
    URLDNS              @gebl
    Vaadin1             @kai_ullrich               vaadin-server:7.7.14, vaadin-shared:7.7.14
    Wicket1             @jacob-baines              wicket-util:6.23.0, slf4j-api:1.6.4
```

https://i.blackhat.com/us-18/Thu-August-9/us-18-Haken-Automated-Discovery-of-Deserialization-Gadget-Chains.pdf

Results: Netflix Internal Webapp 2

1. com.thoughtworks.xstream.mapper.AbstractAttributeAliasingMapper.readResolve() (0)
2. org.apache.commons.configuration.ConfigurationMap$ConfigurationSet.iterator() (0)
3. ...configuration.ConfigurationMap$ConfigurationSet$ConfigurationSetIterator.<init>() (0)
4. org.apache.commons.configuration.CompositeConfiguration.getKeys() (0)
5. clojure.lang.APersistentMap$KeySeq.iterator() (0)
6. com.netflix.internal.utils.collections.IteratorWrapper$CallableWrapper.iterator() (0)
7. java.util.concurrent.Executors$RunnableAdapter.call() (0)
8. org.apache.commons.exec.StreamPumper.run() (0)
9. org.eclipse.core.internal.localstore.SafeFileOutputStream.close() (0)
10. org.eclipse.core.internal.localstore.SafeFileOutputStream.commit() (0)
11. org.eclipse.core.internal.localstore.SafeFileOutputStream.copy(File, File) (2)
12. java.io.FileOutputStream.<init>(File) (1)

com.thoughtworks.xstream:xstream
commons-configuration:commons-configuration
org.clojure:clojure
netflix:netflix-utils
JRE
org.apache.commons:commons-exec
org.aspectj:aspectjtools

XDA Developers

Dangerous "Log4j" security vulnerability affects everything from Apple to Minecraft

A dangerous security vulnerability identified in the Log4j Java logging library has exposed huge swathes of the internet to malicious...

9to5Mac

Apple patches Log4Shell iCloud vulnerability, described as most critical in a decade

Apple patches Log4Shell iCloud vulnerability, described as most critical in a

New York Post

Why is the Log4j cybersecurity flaw the 'most serious' in decades?

Most hacking attempts using Log4j so far have involved attackers ... The Cybersecurity and Infrastructure Security Agency published an...

FTC warns of legal action against organizations that fail to patch Log4j flaw

U.S. organizations that fail to secure customer data against Log4Shell, a zero-day vulnerability in the widely used Log4j Java logging...

17K

Java packages impacted

800K

attempted attacks in 72h

57%

of projects have Log4j as transitive dependency

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Log4J
JNDI & LDAP

```java
public  class Evil implements  ObjectFactory  {
    @Override
    public Object getObjectInstance (Object obj, Name name, Context nameCtx,
Hashtable<?, ?> environment) throws Exception {
        String[] cmd = {
            "/bin/sh",
            "-c",
            "open -a Calculator"
        };
        Runtime.getRuntime().exec(cmd);
        return  null;
    }
}
```

According to **this article by Luncasec** about this issue, this impacts all Java versions. JDK version greater than 6u211, 7u201, 8u191, and 11.0.1 did not seem to be affected by this LDAP attack, because these versions set `com.sun.jndi.ldap.object.trustURLCodebase` to `false` by default. However, if the class, returned by the LDAP server, is already available on the classpath, it will be executed even in newer versions of the JDK and even if `com.sun.jndi.ldap.object.trustURLCodebase` is set to `false`.

https://snyk.io/blog/log4j-rce-log4shell-vulnerability-cve-2021-44228/

But what about record in JDK ~~16~~ 17

```java
public record TwoValue(String a, String b) implements Serializable {

    public TwoValue(String a, String b) {
        System.out.println("creating a twovalue via constructor");
        this.a = a;
        this.b = b;
    }
}
```

```java
var value =  new TwoValue("One", "Two");
var filename = "twovalue.ser";

//serialize
System.out.println("---serialize");
FileOutputStream fileOut = new FileOutputStream(filename);
ObjectOutputStream out = new ObjectOutputStream(fileOut);
out.writeObject(value);
out.close();
fileOut.close();


System.out.println("---deserialize");
FileInputStream fileIn = new FileInputStream(filename);
ObjectInputStream in = new ObjectInputStream(fileIn);
TwoValue tv = (TwoValue) in.readObject();
System.out.println(tv);
```

```
creating a twovalue via constructor
---serialize
---deserialize
creating a twovalue via constructor
TwoValue[a=One, b=Two]
```

@BrianVerm

What can we do?

```
private final void readObject(ObjectInputStream in) throws java.io.IOException {
    throw new java.io.IOException("Deserialized not allowed");
}
```

```
// apache commons io

FileInputStream fileIn = new FileInputStream("Gadget.ser");
ValidatingObjectInputStream in = new ValidatingObjectInputStream(fileIn);
in.accept(ValueObject.class);
var obj = (ValueObject)in.readObject();
```

```
// JEP 290 (& JEP 415)

FileInputStream fileIn = new FileInputStream(filename);
ObjectInputStream in = new ObjectInputStream(fileIn);
ObjectInputFilter filesOnlyFilter =
ObjectInputFilter.Config.createFilter("nl.brianvermeer.example.serialization.example2.ValueObject;!*");
in.setObjectInputFilter(filesOnlyFilter);
ValueObject vo = (ValueObject) in.readObject();
```

```
// JEP 415

ObjectInputFilter.Config.setSerialFilterFactory((f1, f2) -> ObjectInputFilter.merge(f2,f1));
```

APPLICATION SECURITY | ECOSYSTEMS | ENGINEERING

New Java 17 features for improved security and serialization

Brian Vermeer
October 21, 2021

In December 2020, I wrote the article Serialization and deserialization in Java: explaining the Java deserialize vulnerability about the problems Java has with its custom serialization implementation. The serialization framework is so deeply embedded inside Java that knowing how dangerous some implementation can be is important. Insecure deserialization can lead to arbitrary code executions if a gadget chain is created from your classpath classes.

https://snyk.io/blog/new-java-17-features-for-improved-security-and-serialization/

JSON deserialization with Jackson

```
ObjectMapper om = new ObjectMapper();
om.enableDefaultTyping();

Animal myPet = om.readValue(Files.readAllBytes(Paths.get("mypet.json")), Animal.class);
```

```
ObjectMapper om = new ObjectMapper();
om.enableDefaultTyping();

Person myvalue = om.readValue(Files.readAllBytes(Paths.get("file.json")), Person.class);
System.out.println("name:"+myvalue.name+" \n"+"Age:"+myvalue.age);
```

```
public class Person {

    @JsonTypeInfo(use = Id.CLASS)
    public Object name;
    public int age;
}
```

```
{"age":37, "name": "Brian Vermeer"}
```

```
ObjectMapper om = new ObjectMapper();
om.enableDefaultTyping();

Person myvalue = om.readValue(Files.readAllBytes(Paths.get("file.json")), Person.class);
System.out.println("name:"+myvalue.name+" \n"+"Age:"+myvalue.age);
```

```
public class Person {

    @JsonTypeInfo(use = Id.CLASS)
    public Object name;
    public int age;
}
```

```
{"age":37, "name": ["nl.brianvermeer.example.serialization.example4.Gadget", "ls -l"]}
```

snyk Vulnerability DB

Developer Tools ⌄ About Snyk

Find out if you have vulnerabilities that put you at risk

Test your applications

com.fasterxml.jackson.core:jackson-databind

VULNERABILITY	AFFECTS	TYPE	PUBLISHED
M Denial of Service (DoS)	com.fasterxml.jackson.core:jackson-databind [,2.12.7.1) [2.13.0,2.13.4)	Maven	2 Oct 2022
M Denial of Service (DoS)	com.fasterxml.jackson.core:jackson-databind [,2.12.7.1) [2.13.0,2.13.4.1)	Maven	2 Oct 2022
H Denial of Service (DoS)	com.fasterxml.jackson.core:jackson-databind [,2.12.6.1) [2.13.0, 2.13.2.1)	Maven	11 Mar 2022
M Denial of Service (DoS)	com.fasterxml.jackson.core:jackson-databind [2.13.0,2.13.1) [2.10.0.pr1,2.12.6)	Maven	26 Dec 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.7)	Maven	18 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021
H Deserialization of Untrusted Data	com.fasterxml.jackson.core:jackson-databind [,2.9.10.8)	Maven	7 Jan 2021

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do not enable default typing and update your libraries

YAML

XML

- do not deserialize input from unknown sources
- prevent Java custom serialization
- use filters if you still need to it
- be aware how your JSON / XML / Yaml marshaler works
- check for insecure (default) values
- update insecure libraries

Develop fast.

Stay secure.