TONGDAO
同 道
KCon
2024
JAVA反序列化新思路
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PART ONE
01
Java反序列化简介
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Java反序列化简介

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01
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序列化

将Java对象转化为字节存储于内存或磁盘中，保存对象的过程

02
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反序列化

将存储于内存或磁盘中的Java字节码还原为对象的过程

03
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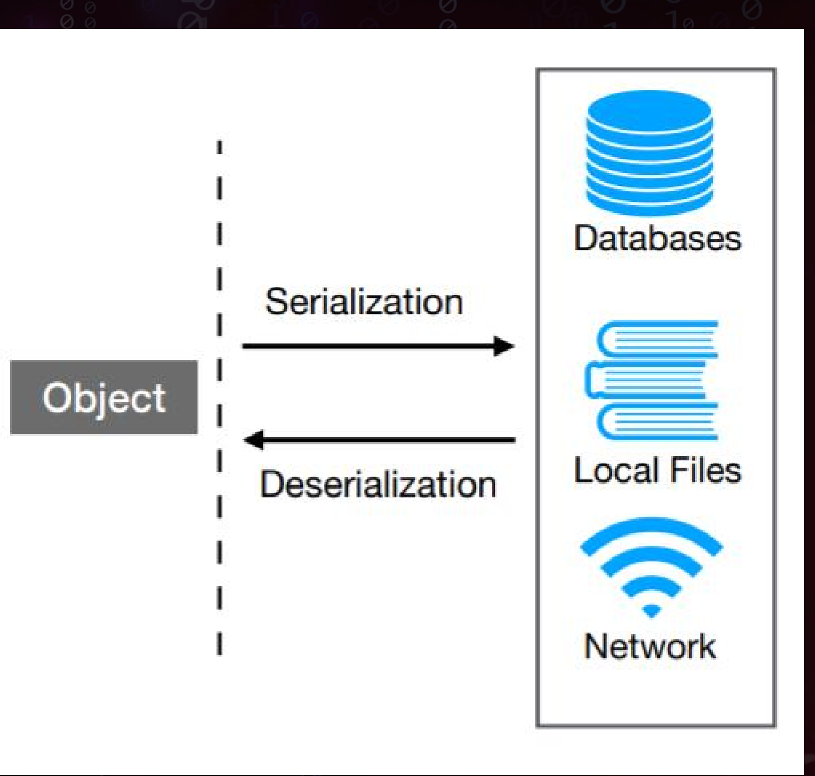
用途

远程网络对象传输
远程方法调用
不同环境间对象存储



Java反序列化简介

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ObjectInputStream.readObject
readObject0
TC_OBJECT
是
readOrdinaryObject
ObjectStreamClass desc = readClassDesc(false)
resolveProxyClass（限制接口方法）
readNonProxyDesc->resolveClass
desc.isExternalizable()
否
readSerialData
是
readExternalData
obj.readExternal(ObjectInput in)
hasData（类描述符）
否
readObjectNoDataMethod
是
desc.hasReadObjectMethod
否
defaultReadFields
是
readObjectMethod
读取类中的信息并保存初始化

writeObjectMethod = getPrivateMethod(cl, "writeObject", new Class<?>[] { ObjectOutputStream.class }, Void.TYPE);

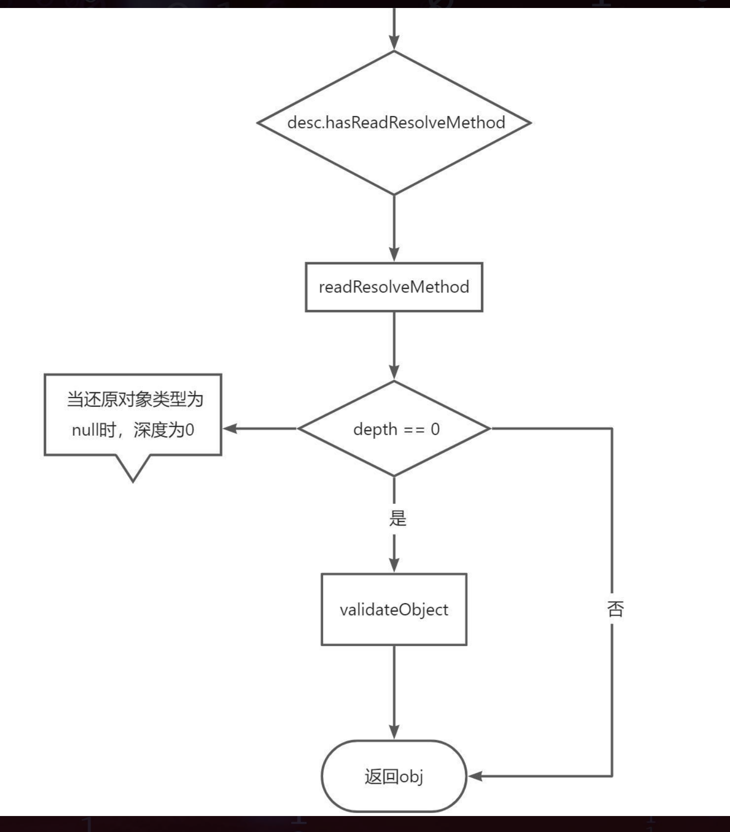
readObjectMethod = getPrivateMethod(cl, "readObject", new Class<?>[] { ObjectInputStream.class }, Void.TYPE);

readObjectNoDataMethod = getPrivateMethod(cl, "readObjectNoData", null, Void.TYPE);

writeReplaceMethod = getInheritableMethod(cl, "writeReplace", null, Object.class);

readResolveMethod = getInheritableMethod(cl, "readResolve", null, Object.class);

Serializable.class.isAssignableFrom(cl)
!Externalizable.class.isAssignableFrom(cl)
!Proxy.isProxyClass(cl)
!cl.isInterface()
!Modifier.STATIC | Modifier.TRANSIENT
cl.getDeclaredField("serialPersistentFields")



反序列化流程图
基于ObjectInputStream流，进行对象恢复

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远程传输任意字节码 还原任意对象

反序列化过程中 存在恶意方法

环境中存在薄弱可利用库

json转换Obj

xml转换Obj

自实现对象转换

攻击点

薄弱攻击点

魔术方法

void readObject (ObjectInputStream.class)

void readObjectNoData()

Object writeReplace()

void validateObject()

Object readResolve()

void writeObject (ObjectOutputStream.class)

void readExternal (ObjectInput.class)

Java反序列化简介

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```java
private void readObject(ObjectInputStream in) throws IOException, ClassNotFoundException {
    in.defaultReadObject();
    OutputStream output = this.getOutputStream();
    if (this.cachedContent ≠ null) {
        output.write(this.cachedContent);
```

```java
public OutputStream getOutputStream() throws IOException {
    if (this.dfos == null) {
        File outputFile = this.getTempFile();
        this.dfos = new DeferredFileOutputStream(this.sizeThreshold, outputFile);
    }

    return this.dfos;
}

}
```

```java
private transient DeferredFileOutputStream dfos;
private transient File tempFile;
```

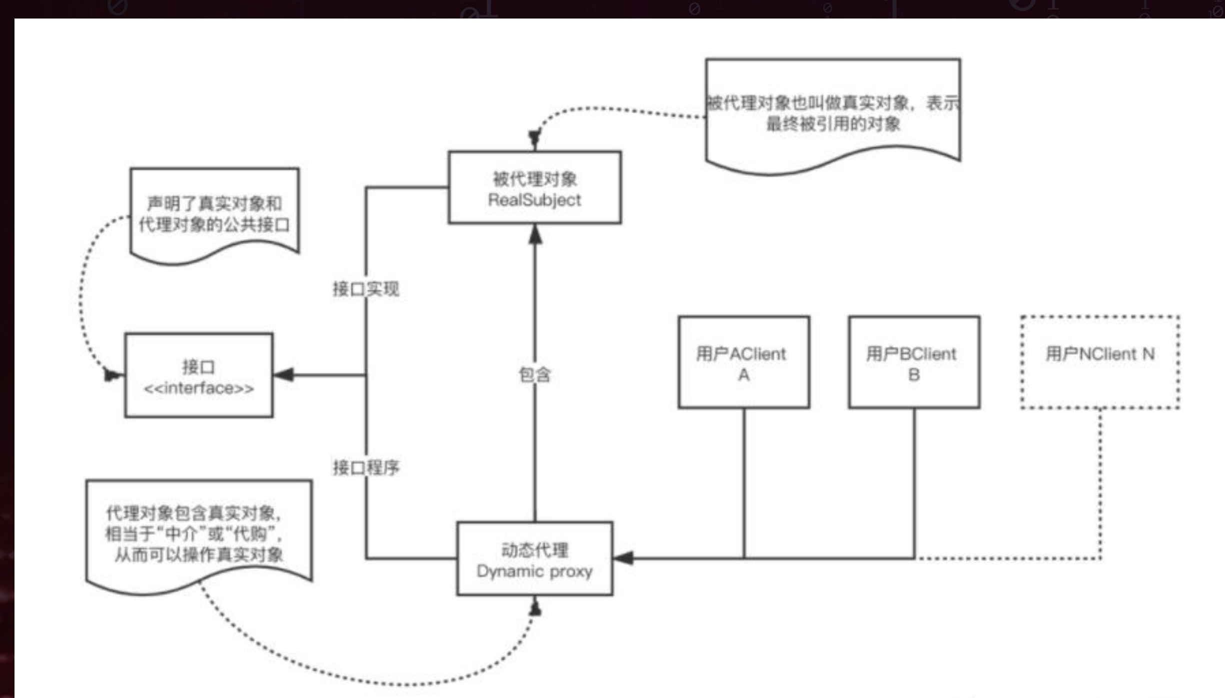
getOutputStream获取输出流并通过write或copy写入

其中有个知识点：
transient修饰的变量无法序列化和反序列化

Java代理模式应用

动态代理方式：
将接口方法 “ 代理 ” 给 InvocationHandler 接口
通过 Proxy 类创建代理对象

在反序列化漏洞中代表的jdk7u21就是采用了动态代理的方式，利用hash碰撞调用equals方法，进一步通过AnnotationInvocationHandler进行反射调用




```
public static boolean isProxyClass(Class<?> cl)
```

```
InvocationHandler getInvocationHandler(Object proxy)
```

```
Class<?> getProxyClass(ClassLoader loader,
                       Class<?>... interfaces)
```

```
Object newProxyInstance(ClassLoader loader,
                        Class<?>[] interfaces,
                        InvocationHandler h)
```

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02
常见防御思路与思考
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常见防御思路与思考

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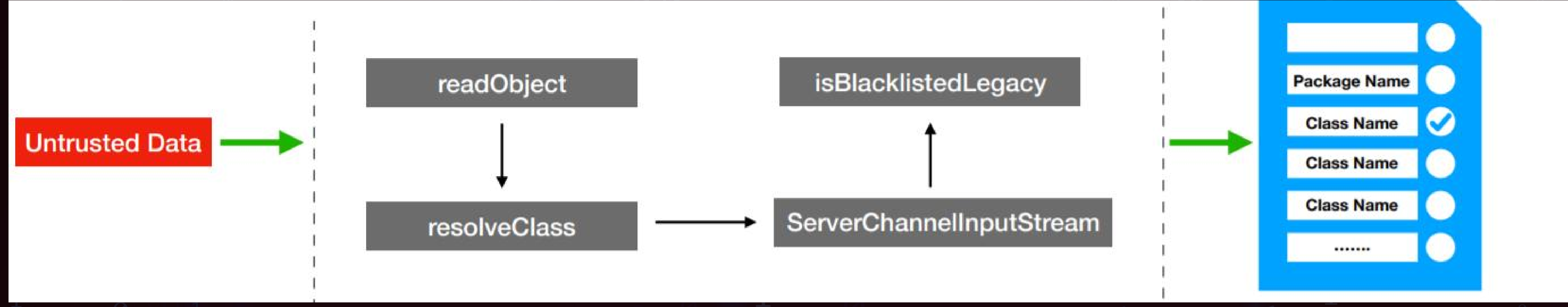
继承ObjectInputStream并重写resolveClass方法，添加过滤方法
在可序列化存在可利用的类中，添加readResolve方法，过滤变量某些属性
高版本中利用JEP290机制继承ObjectInputFilter类，添加过滤方法




```
766 #
767 # Serialization process-wide filter
768 #
769 # A filter, if configured, is used by java.io.ObjectInputStream during
770 # deserialization to check the contents of the stream.
771 # A filter is configured as a sequence of patterns, each pattern is either
772 # matched against the name of a class in the stream or defines a limit.
773 # Patterns are separated by ";" (semicolon).
774 # Whitespace is significant and is considered part of the pattern.
775 #
776 # If the pattern ends with ".**" it matches any class in the package and all subpackages.
777 # If the pattern ends with ".*" it matches any class in the package.
778 # If the pattern ends with "*", it matches any class with the pattern as a prefix.
779 # If the pattern is equal to the class name, it matches.
780 # Otherwise, the status is UNDECIDED.
781 #
782 jdk.serialFilter=pattern;pattern
783 jdk.serialFilter=!sun.rmi.server.**;!org.codehaus.groovy.runtime.**
```

jre/lib/security/java.security

```
jdk.serialFilter=pattern;pattern
jdk.serialFilter=!sun.rmi.server.**;
jdk.serialFilter=!org.codehaus.groovy.runtime.**;
jdk.serialFilter=org.apache.commons.beanutils.BeanComparator
jdk.serialFilter=!org.codehaus.groovy.runtime.MethodClosure
```

常见绕过方式

基于继承ObjectInputStream类设置过滤方法
- 寻找新的调用链，绕过现有黑名单机制
- 寻找二次反序列化点，在低版本或未设置jep290的情况下，绕过过滤方法
- 寻找其他可替代流去反序列化对象，绕过过滤方法

序列化类中存在readResolve方法，过滤变量某些属性
- 寻找其他可操作的参数，在反序列化时，触发某些敏感操作

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继承ObjectInputFilter类设置过滤方法
- 低版本下，过滤方法失效
- 高版本下，寻找可利用替换流反序列化对象，绕过过滤方法

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03
以点带面深入分析
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安全与性能-Coherence

Oracle coherence是行业先进的内存中数据网格解决方案，通过快速访问常用数据，让企业能够以可预测的方式扩展任务关键型应用。通过实现自定义序列化机制，对序列化与反序列化数据进行了更细致的定制化处理，继承Serializable类，实现新的ExternalizableLite接口类并增加对原始DataInput和DataOutput流的操作方法，实现了高效的处理应用程序数据。

同时为了方便处理实现不同接口的类，官方还提供了对应接口助手类ExternalizableHelper，根据实现的不同接口调用不同方法进行反序列化处理

```
public static int getStreamFormat(Object o) {
    return o == null ? 0 : (o instanceof String ? 6 : (o instanceof Number ? (o instanceof Integer ? 1 : (o instanceof Long ? 2 : (o instanceof Double ? 3 : (o instanceof BigInteger ? 4 : (o instanceof BigDecimal ? 5 : (o instanceof Float ? 14 : (o instanceof Short ? 15 : (o instanceof Byte ? 16 : 11)))))))) : (o instanceof byte[] ? 8 : (o instanceof ReadBuffer ? 7 : (o instanceof XmlBean ? 12 : (o instanceof ExternalizableHelper.IntDecoratedObject ? 13 : (o instanceof ExternalizableLite ? 10 : (o instanceof Boolean ? 17 : (o instanceof Serializable ? 11 : (o instanceof Optional ? 22 : (o instanceof OptionalInt ? 23 : (o instanceof OptionalLong ? 24 : (o instanceof OptionalDouble ? 25 : (o instanceof XmlSerializable ? 9 : 255))))))))))))));
}
```

获取类属性并对其赋值

以点带面深入分析

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深入思考实现

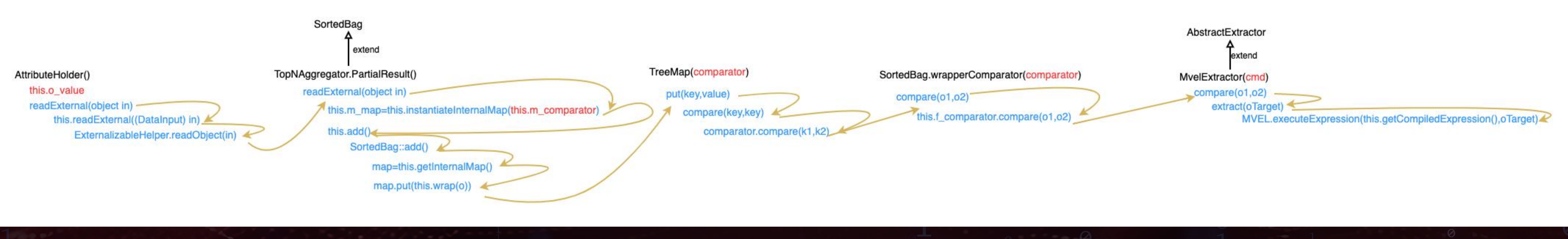
coherence在反序列化中实现新的处理方式：
通过直接调用DataInput反序列化readUTF读取类名，loadClass直接加载类的方式，代替了传统ObjectStreamClass.getName()读取类名的方式，进而绕过了在ObjectInputStream侧设置的ObjectInputFilter以及resolveClass的防御措施
再循环调用readExternal方法，进一步反序列化对应参数

```java
public static ExternalizableLite readExternalizableLite(DataInput in, ClassLoader loader) throws IOException {
  ExternalizableLite value;
  if (in instanceof PofInputStream) {
    value = (ExternalizableLite)((PofInputStream)in).readObject();
  } else {
    String sClass = readUTF(in);
    try {
      value = loadClass(sClass, loader, (ClassLoader)null).newInstance();
    } catch (InstantiationException e) {
      throw new IOException("Unable to instantiate an instance of class '" + sClass + "'; this is most likely due to a missing public " + "
    } catch (Exception e) {
      throw new IOException("Class initialization failed: " + e + "\n" + getStackTrace(e) + "\nClass: " + sClass + "\nClassLoader: " + loade
    }
    value.readExternal(in);
  }
  return value;
}
```

调用方式：寻找可以将ObjectInputStream流替换为DataInput流的魔术方法

CVE-2020-14756

- 利用条件需要继承ExternalizableLite类并使用了接口助手类ExternalizableHelper进行反序列化操作
- 利用AttributeHolader作为调用方式，将流进行转换
- 寻找TopNAggregator.PartialResult进行转接，调用Map的put处理，触发compare键值操作
- 最后直接利用之前compare->extract的调用链，完成对黑名单机制的绕过



以点带面深入分析

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```java
public static ExternalizableLite readExternalizableLite(DataInput in, ClassLoader loader) throws IOException {
  ExternalizableLite value;
  if (in instanceof PofInputStream) {
    value = (ExternalizableLite)((PofInputStream)in).readObject();
  } else {
    WrapperDataInputStream wrapperDataInputStream1;
    String sClass = readUTF(in);
    WrapperDataInputStream inWrapper = (in instanceof WrapperDataInputStream) ? (WrapperDataInputStream)in : null;
    try {
      Class<?> clz = loadClass(sClass, loader, (inWrapper == null) ? null : inWrapper
          .getClassLoader());
      if (in instanceof ObjectInputStream) {
        ObjectInputStream ois = (ObjectInputStream)in;
        if (!checkObjectInputFilter(clz, ois))
          throw new InvalidClassException("Deserialization of class " + sClass + " was rejected");
      }
      value = (ExternalizableLite)clz.newInstance();
    } catch (InstantiationException e) {
      throw new IOException("Unable to instantiate an instance of class '" + sClass + "'; this is most likely due to a mi

          getStackTrace(e) + "\nClass: " + sClass + "\nClassLoader: " + loader + "\nContextClassLoader: " +

          getContextClassLoader());
```

```java
protected static boolean checkObjectInputFilter(Class<?> clz, ObjectInputStream ois) {
  try {
    Object filter = (HANDLE_GET_FILTER == null) ? null : HANDLE_GET_FILTER.invoke(ois);
    if (filter == null)
      return true;
    DynamicFilterInfo dynamic = s_tloHandler.get();
    dynamic.setClass(clz);
    Object oFilterInfo = dynamic.getFilterInfo();
    Enum status = HANDLE_CHECKINPUT.invoke(filter, oFilterInfo);
    dynamic.setClass(null);
    return (status != null && !status.name().equals("REJECTED"));
  } catch (ClassNotFoundException|IllegalAccessException|java.lang.reflect.InvocationTargetException e) {
    err("Unable to invoke checkInput on objectInputFilter ");
    err(e);
  } catch (Throwable throwable) {}
  return false;
}
```

```java
try {
  Class<?> clzFilter = null;
  Class<? extends Enum> clzFilterStatus = null;
  String sFilterMethod = null;
  Method methodGet = null;
  if ((clzFilter = getClass("java.io.ObjectInputFilter")) != null) {
    clzFilterInfo = Class.forName("java.io.ObjectInputFilter$FilterInfo");
    clzFilterStatus = (Class)Class.forName("java.io.ObjectInputFilter$Status");
    sFilterMethod = "getObjectInputFilter";
  } else if ((clzFilter = getClass("sun.misc.ObjectInputFilter")) != null) {
    clzFilterInfo = Class.forName("sun.misc.ObjectInputFilter$FilterInfo");
    clzFilterStatus = (Class)Class.forName("sun.misc.ObjectInputFilter$Status");
    sFilterMethod = "getInternalObjectInputFilter";
  }
  if (sFilterMethod != null) {
    Class<ObjectInputStream> clzObjectInputStream = ObjectInputStream.class;
    methodGet = clzObjectInputStream.getDeclaredMethod(sFilterMethod, new Class[0]);
    methodGet.setAccessible(true);
    MethodType mtCheckInput = MethodType.methodType(clzFilterStatus, clzFilterInfo);
    MethodHandles.Lookup lookup = MethodHandles.lookup();
    handleGetFilter = lookup.unreflect(methodGet);
    handleCheckInput = lookup.findVirtual(clzFilter, "checkInput", mtCheckInput);
  }
} catch (ClassNotFoundException|NoSuchMethodException|SecurityException|IllegalAccessException e) {
  CacheFactory.log("ObjectInputFilter will not be honored due to: " + e
      .getMessage() + '\n' + Base.printStackTrace(e), 3);
}
s_clzFilterInfo = clzFilterInfo;
HANDLE_GET_FILTER = handleGetFilter;
HANDLE_CHECKINPUT = handleCheckInput;
s_astats = new Stats[6451];
s_mapSerializerByClassLoader = Collections.synchronizedMap(new WeakHashMap<>());
}
```

- ObjectInputStream流进行了二次处理，进一步通过黑名单过滤的恶意类。
- checkObjectInputFilter方法使用了JEP290特性
- 低版本下，此修复无效

以点带面深入分析

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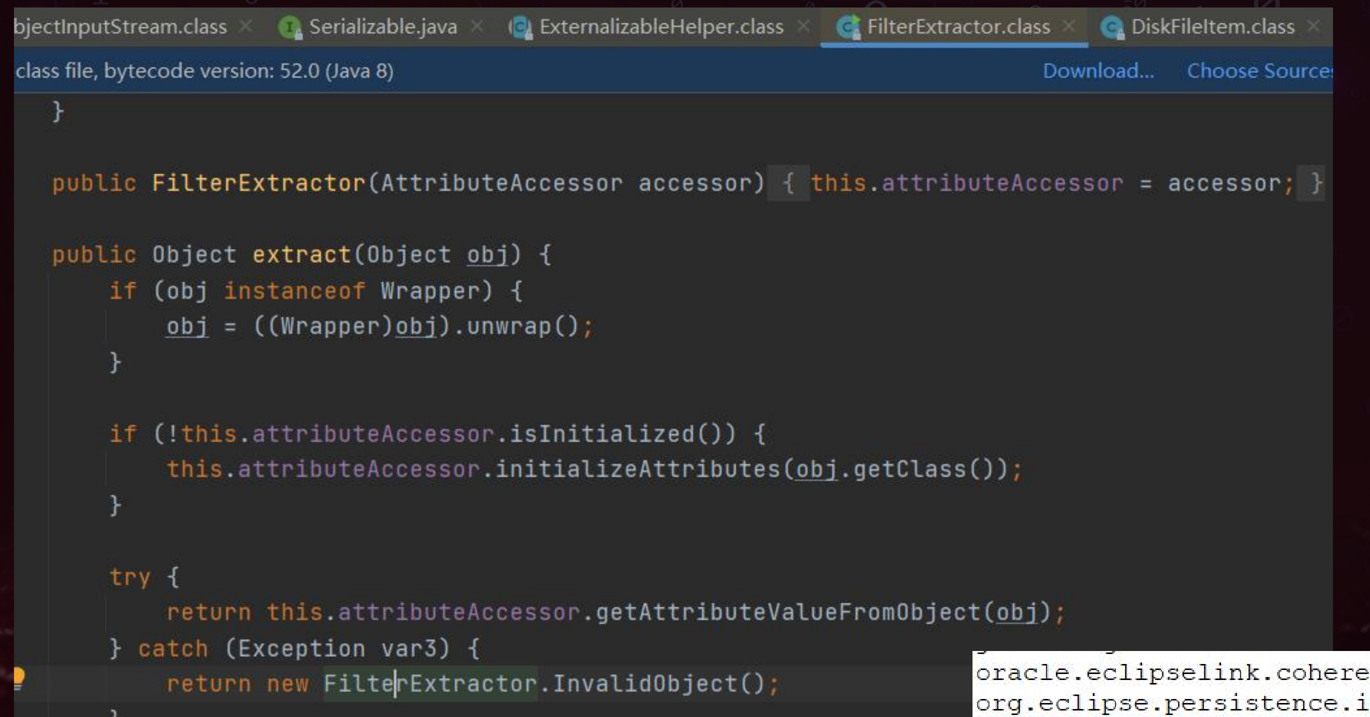
站在巨人的肩膀上思考问题，扩散思维

- 寻找其他存在的loadClass
- 寻找可控点存在的恶意行为
- 寻找extract方法中存在的可控点
- 寻找除loadClass加载类的其他方式



Object (java.lang)
AttributeAccessor (org.eclipse.persistence.mappings)
MultitenantPrimaryKeyAccessor (org.eclipse.persisten
OrmAttributeAccessor (org.eclipse.persistence.interna
JAXBArrayAttributeAccessor (org.eclipse.persistence.i
InstanceVariableAttributeAccessor (org.eclipse.persist
ValuesAccessor (org.eclipse.persistence.internal.dynan
IsSetNullPolicyIsSetParametersAttributeAccessor in Ob
IsSetNullPolicyIsSetParameterTypesAttributeAccessor
CustomAccessorAttributeAccessor (org.eclipse.persist
NullPolicyAttributeAccessor in ObjectPersistenceRunti
MapValueAttributeAccessor (org.eclipse.persistence.i
StoredFunctionResultAccessor in ObjectPersistenceRu
StoredProcedureArgumentsAccessor in ObjectPersiste
MethodAttributeAccessor (org.eclipse.persistence.int
SDOFragmentMappingAttributeAccessor (org.eclipse.

- 正常通过反序列化操作恢复变量，只能操
- 作图中的类，再通过筛选可序列化和
- 除黑名单外的类，发现并无可利用的点。

```
oracle.eclipselink.coherence.integrated.internal.cache.LockVersionExtractor
org.eclipse.persistence.internal.descriptors.MethodAttributeAccessor
org.eclipse.persistence.internal.descriptors.InstanceVariableAttributeAccessor
```

黑名单

以点带面深入分析

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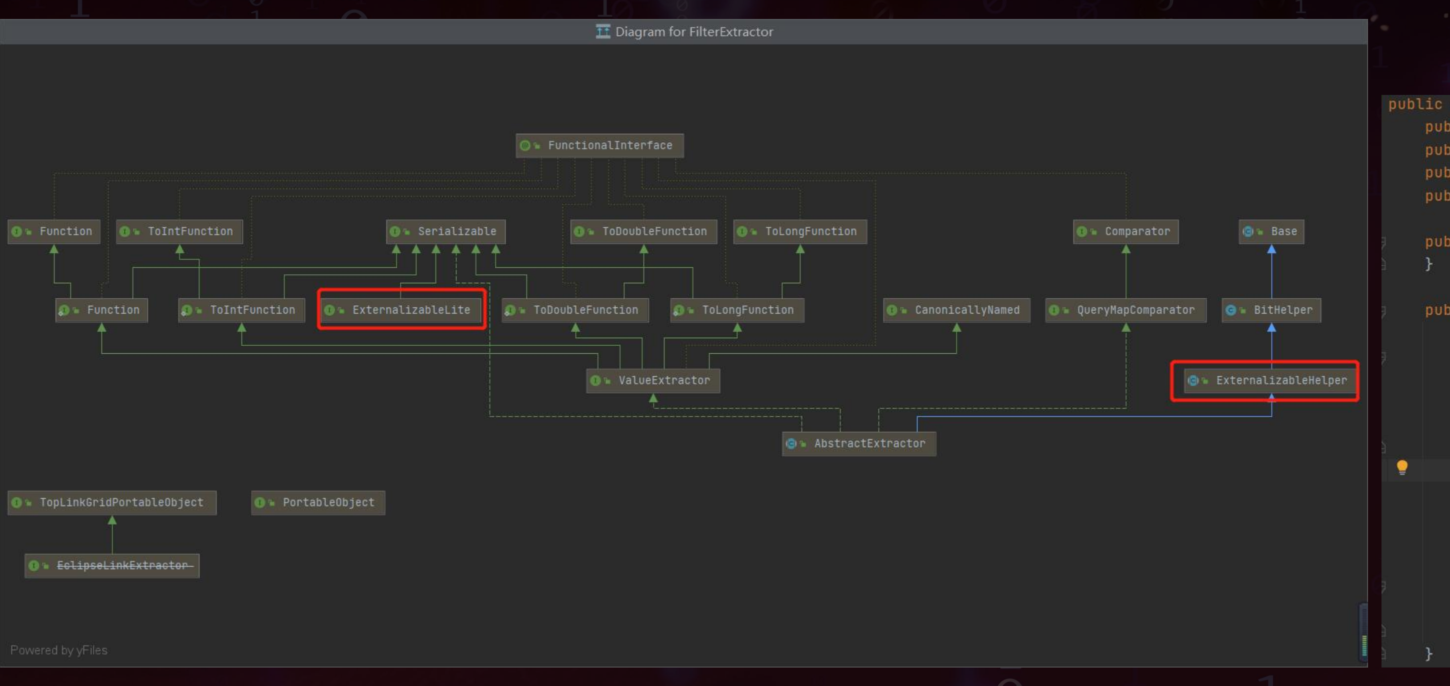
整体继承图，发现存在接口助手类并继承了ExternalizableLite类，观察对于DataInput流的自定义处理

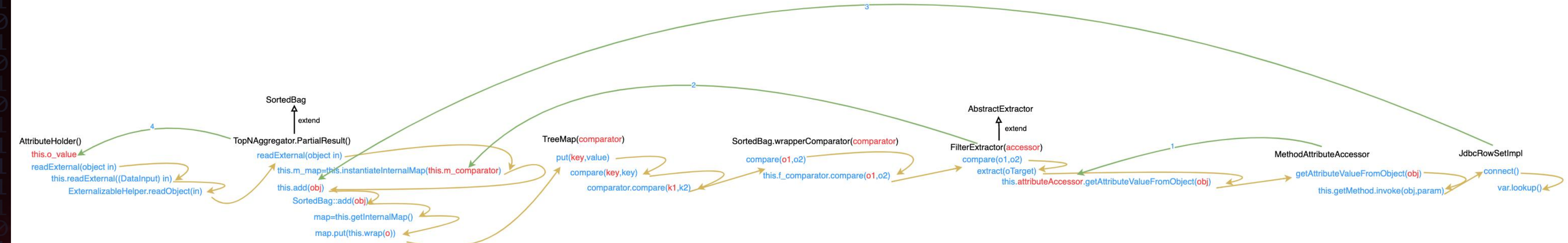



```java
public class SerializationHelper {
    public static final int OTHER = -1;
    public static final int INSTANCE_ACCESSOR = 0;
    public static final int METHOD_ACCESSOR = 1;
    public static final int ACCESSOR_ARRAY = 2;

    public SerializationHelper() {
    }

    public static AttributeAccessor readAttributeAccessor(DataInput in) throws IOException {
        int id = ExternalizableHelper.readInt(in);
        if (id == 0) {
            InstanceVariableAttributeAccessorExtended accessor = new InstanceVariableAttributeA
            accessor.setAttributeName((String)ExternalizableHelper.readObject(in));
            return accessor;
        } else if (id == 1) {
            MethodAttributeAccessor accessor = new MethodAttributeAccessor();
            accessor.setAttributeName((String)ExternalizableHelper.readObject(in));
            accessor.setGetMethodName((String)ExternalizableHelper.readObject(in));
            accessor.setSetMethodName((String)ExternalizableHelper.readObject(in));
            return accessor;
        } else {
            return null;
        }
    }
```

```java
public void readExternal(DataInput in) throws IOException {
    this.attributeAccessor = SerializationHelper.readAttributeAccessor(in);
}
```

CVE-2021-2394

- 利用AttributeHoladerr作为调用方式，将流进行转换
- 转换后的流执行自定义readExternal方法，通过SerializationHelper恢复变量，绕过黑名单
- 寻找TopNAggregator.PartialResult进行转接，调用Map的put处理，触发compare键值操作
- 利用之前compare->extract的调用链，调用任意代码执行



以点带面深入分析

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高版本与ObjectInputFilter类设置黑名单双重防护

- 寻找新的利用链，难度较大
- 寻找新的转换流方法，转换其他新的流
- 寻找可替代ObjectInputStream的流，完成反序列化操作

```java
public static <T> T fromBinary(Binary bin) { return fromBinary(bin, ensureSerializer((ClassLoader)null)); }
```

ExternalizableHelper.fromBinary

```java
private static <T> T deserializeInternal(Serializer serializer, ReadBuffer buf, Remote.Function<ReadBuffer.BufferInput, ReadBuffer.BufferIn
  long nMask;
  int cb;
  ReadBuffer.BufferInput in = buf.getBufferInput();
  int nType = in.readUnsignedByte();
  switch (nType) {
    case 13:
      readInt(in);
      nType = in.readUnsignedByte();
      break;
    case 18:
    case 19:
      nMask = (nType == 18) ? in.readByte() : in.readPackedLong();
      if ((nMask & 0x1L) == 0L)
        throw new EOFException("Decorated value is missing a value");
      cb = in.readPackedInt();
      in = buf.getReadBuffer(in.getOffset(), cb).getBufferInput();
      nType = in.readUnsignedByte();
      break;
  }
  if (supplierBufferIn != null)
    in = (ReadBuffer.BufferInput)supplierBufferIn.apply(in);
  Object o = (nType == 21) ? serializer.deserialize(in, clazz) : readObjectInternal((DataInput)in, nType, ((ClassLoaderAware)serializer)
      .getContextClassLoader());
  return realize(o, serializer);
}
```

- 将Binary类转换为ReadBuffer，进一步从buffer中读取BufferInput缓冲区输入流进行反序列化操作。绕过了之前对ObjectInputStream流的黑名单过滤操作，可以接着调用loadClass方法还原变量

以点带面深入分析

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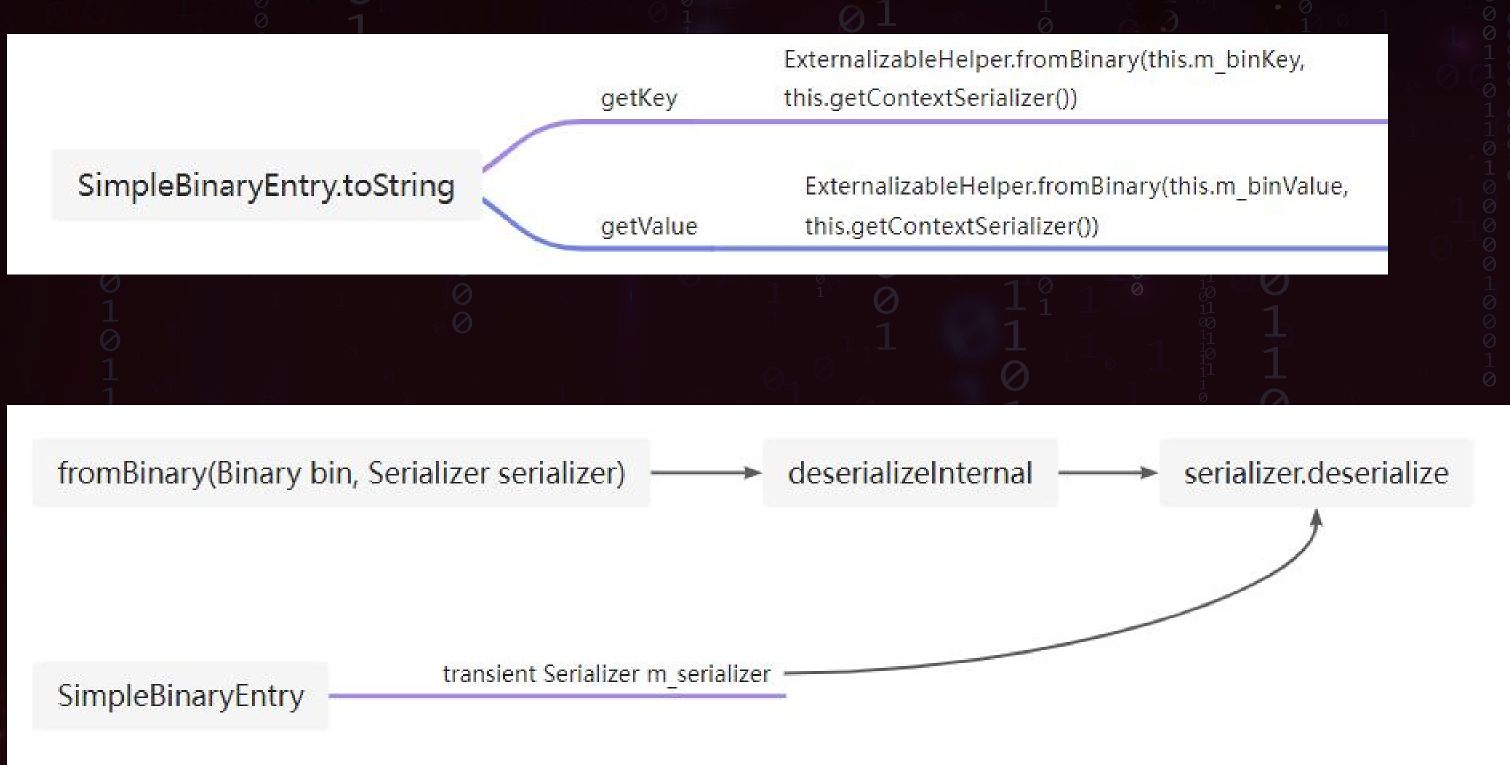
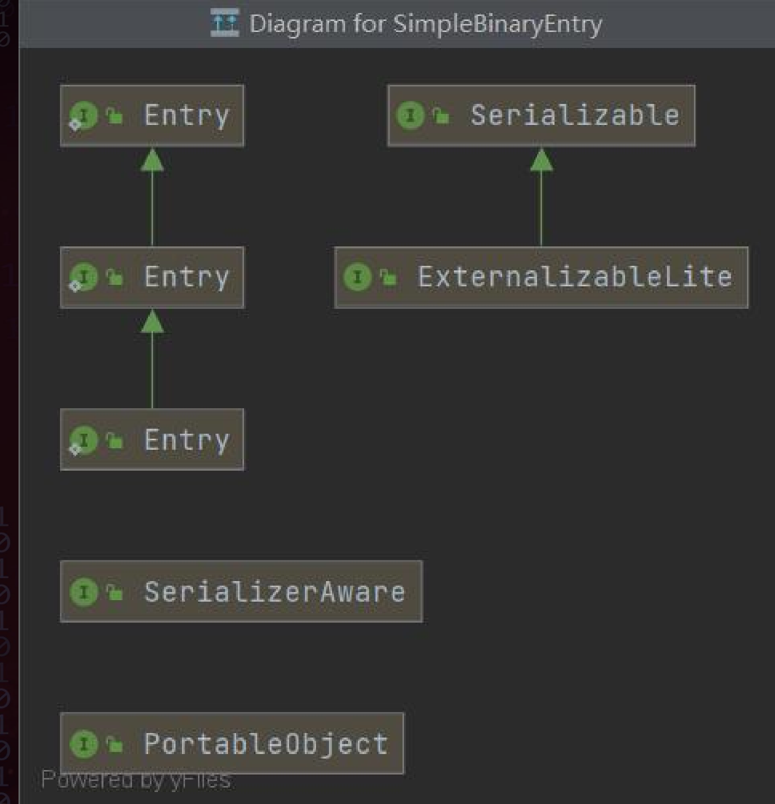
全局搜索调用fromBinary方法的类，首先分析简单调用





以点带面深入分析

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绕过transient修饰变量无法序列化

value instanceof SerializerAware

readExternalizableLite → setContextSerializer → ensureSerializer(ClassLoader) → ensureClassLoader(ClassLoader) → getContextClassLoader → Thread.currentThread().getContextClassLoade

loader==null

Base.class.getClassLoader() → ClassLoader.getSystemClassLoader()

s_mapSerializerByClassLoader.get(loader)

DefaultSerializer.setContextClassLoader(loader)

s_mapSerializerByClassLoader.put(loader,serializer)

关键节点：

- 需要调用obj.toString方法
- 需要继承ExternalizableLite类
- 同时满足上述两点
- 需要依据readExternal方法进行拓展

突破点：

- 根据readExternal方法拓展，联想到Map等类型操作
- 根据equals，hashcode等方法进一步拓展，找到任意类调用toString
- source AttributeHolader转换流存在上述操作

以点带面深入分析

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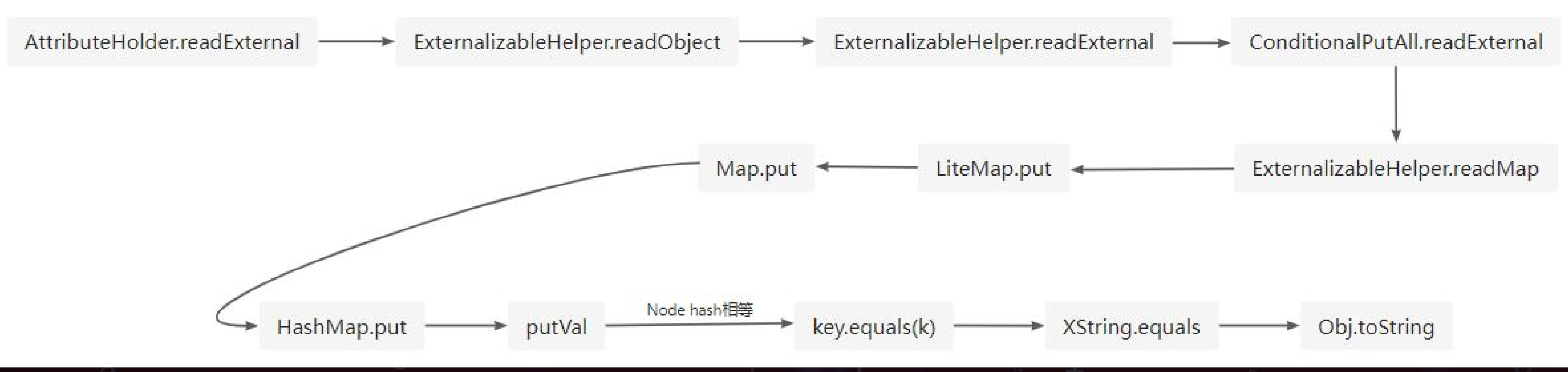



```java
public static int readMap(DataInput in, Map<Object, Object> map, ClassLoader loader) throws IOException {
  int cEntries;
  if (in instanceof PofInputStream) {
    PofInputStream inPof = (PofInputStream)in;
    inPof.getPofReader().readMap(inPof.nextIndex(), map);
    cEntries = map.size();
  } else {
    cEntries = in.readInt();
    for (int i = 0; i < cEntries; i++) {
      Object oKey = readObject(in, loader);
      Object oVal = readObject(in, loader);
      map.put(oKey, oVal);
    }
  }
  return cEntries;
}
```

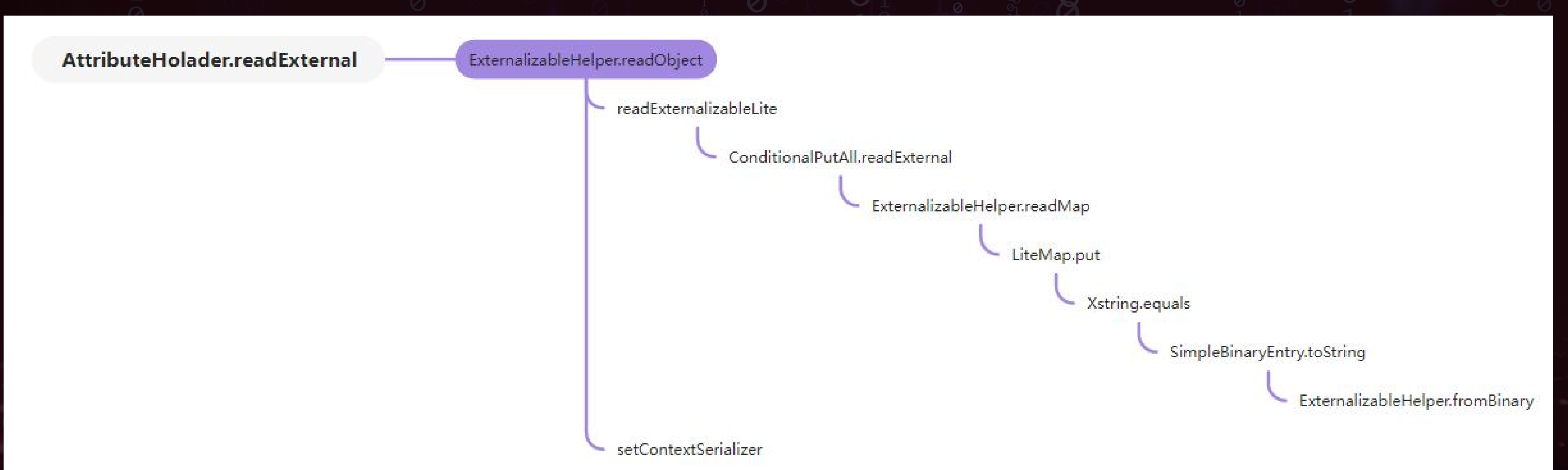
```java
public static HashMap makeMap ( Object v1, Object v2 ) throws Exception, ClassNotFoundException, NoSuch
        IllegalAccessException, InvocationTargetException {
    HashMap s = new HashMap();
    Reflections.setFieldValue(s, "size", 2);
    Class nodeC;
    try {
        nodeC = Class.forName("java.util.HashMap$Node");
    }
    catch ( ClassNotFoundException e ) {
        nodeC = Class.forName("java.util.HashMap$Entry");
    }
    Constructor nodeCons = nodeC.getDeclaredConstructor(int.class, Object.class, Object.class, nodeC);
    Reflections.setAccessible(nodeCons);

    Object tbl = Array.newInstance(nodeC, 2);
    Array.set(tbl, 0, nodeCons.newInstance(0, v1, v1, null));
    Array.set(tbl, 1, nodeCons.newInstance(0, v2, v2, null));
    Reflections.setFieldValue(s, "table", tbl);
    return s;
}
```

以点带面深入分析

MANT EUM E

CVE-2021-2394

- 利用AttributeHolader作为调用方式，将流进行转换
- 转换后的流执行满足条件的readExternal方法，调用Map相关操作
- 寻找ConditionalPutAll类作为调用满足条件的readExternal方法
- 利用HashMap对键的比较，调用Xstring.equals->SimpleBinaryEntry.toString
- 最后通过ExternalizableHelper.fromBinary处理新流，绕过基于ObjectInputStream流黑名单



以点带面深入分析

MANT EUM E

将之前的利用的类加入黑名单后如何绕过：

- 寻找可利用的魔术方法，重新实例化类
- 寻找Coherence在提高性能时，在序列化与反序列化操作存在的不同点
- 寻找其他类的可利用方法，调用到黑名单类，无需在反序列化时进行实例化操作

```java
public static XmlSerializable readXmlSerializable(DataInput in, ClassLoader loader) throws IOException {
  XmlSerializable value;
  if (in instanceof PofInputStream) {
    value = (XmlSerializable)((PofInputStream)in).readObject();
  } else {
    String sClass = readUTF(in);
    try {
      value = loadClass(sClass, loader, (ClassLoader)null).newInstance();
    } catch (Exception e) {
      throw new IOException("Class initialization failed: " + e + "\n" +

          getStackTrace(e) + "\nClass: " + sClass + "\nClassLoader: " + loader +

          getContextClassLoader());
    }
    String sXml = readUTF(in);
    XmlDocument xmlDocument = (new SimpleParser(false)).parseXml(sXml);
    value.fromXml((XmlElement)xmlDocument);
  }
  return value;
}
```

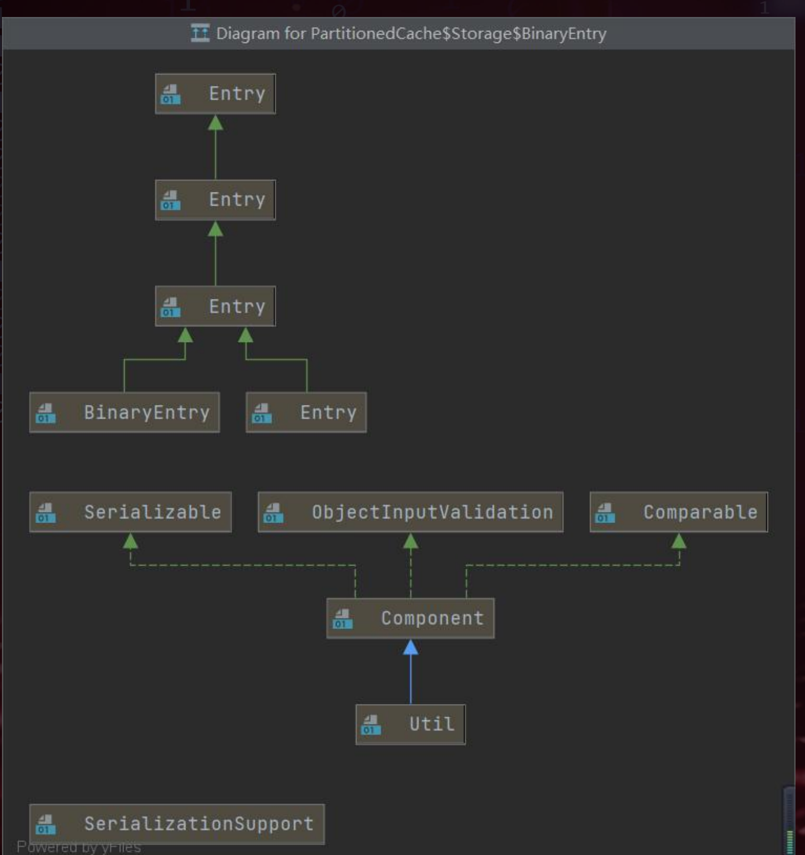
```java
public static Object replace(Object o) throws ObjectStreamException {
  if (Lambdas.isLambda(o))
    o = Lambdas.ensureRemotable((Serializable)o);
  if (o instanceof SerializationSupport)
    o = ((SerializationSupport)o).writeReplace();
  return o;
}

public static <T> T realize(Object o, Serializer serializer) throws ObjectStreamException {
  if (o instanceof SerializerAware)
    ((SerializerAware)o).setContextSerializer(serializer);
  if (o instanceof SerializationSupport) {
    o = ((SerializationSupport)o).readResolve();
    if (o instanceof SerializerAware)
      ((SerializerAware)o).setContextSerializer(serializer);
  }
  return (T)o;
}
```

以点带面深入分析

MANT EUM E

寻找满足以上条件的类：PartitionedCache$Storage$BinaryEntry

```java
public Object writeReplace() throws ObjectStreamException {
    return new SimpleBinaryEntry(this.getBinaryKey(), this.getBinaryValue());
}
```



- 继承序列化与SerializationSupport接口
- 满足在序列化时调用writeReplace方法的条件
- 寻找在反序列化时会触发序列化的操作

```java
public static void writeObject(DataOutput out, Object o) throws IOException {
    if (out instanceof PofOutputStream) {
        ((PofOutputStream)out).writeObject(o);
    } else {
        o = replace(o);
```

```java
private static WriteBuffer serializeInternal(Serializer serializer, Object o, boolean fBinary)
    boolean fDeco = false;
    int nDeco = 0;
    int cb = 1;
    boolean fUser = false;
    ExternalizableHelper.Stats stats = null;
    if (o instanceof ExternalizableHelper.IntDecoratedObject) {
        ExternalizableHelper.IntDecoratedObject ido = (ExternalizableHelper.IntDecoratedObject
        fDeco = true;
        nDeco = ido.getDecoration();
        cb += 5;
        o = ido.getValue();
    }

    o = replace(o);
```

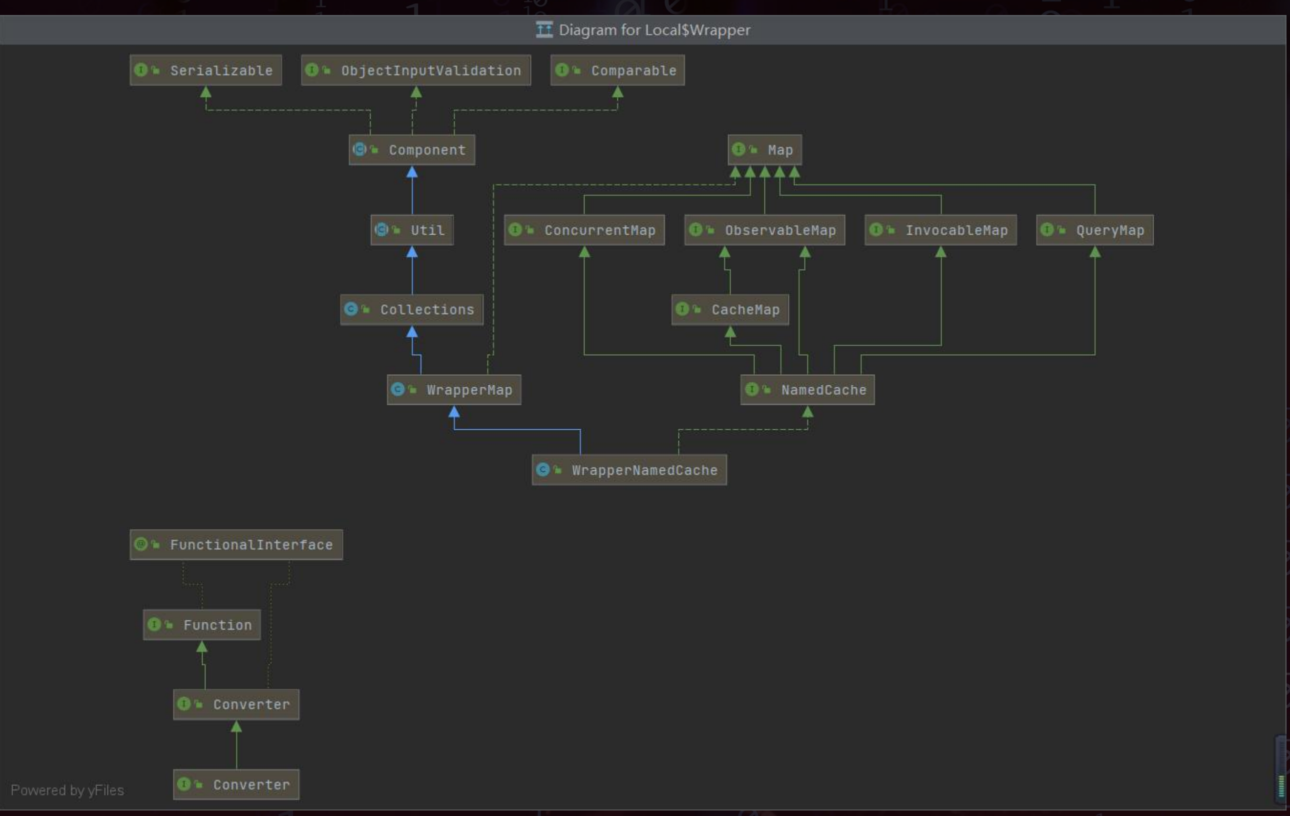
以点带面深入分析

MANT EUM E

向上链接Local$Wrapper满足条件

```java
public static Binary toBinary(Object o, Serializer serializer) {
    try {
        return serializeInternal(serializer, o,  fBinary: true).toBinary();
    } catch (IOException var3) {
        throw new WrapperException(var3);
    }
}
```

```java
public Object convert(Object o) { return this.ensureClone(o); }

public Object ensureClone(Object o) {
    boolean fImmutable = false;
    if (o instanceof Number) {
        fImmutable = ((((((o instanceof Byte ? true : o instanceof Short) ? true : o instance
    } else {
        fImmutable = ((o instanceof String ? true : o instanceof Binary) ? true : o instanceo
    }

    if (fImmutable ? true : o == null) {
        return o;
    } else {
        if (o instanceof Cloneable) {
            try {
                return ClassHelper.invoke(o,  sName: "clone", ClassHelper.VOID);
            } catch (Throwable var6) {
            }
        }

        Serializer serializer;
        try {
            serializer = ((Local)this.get_Module()).getNamedCache().getCacheService().getSeri
        } catch (RuntimeException var5) {
            serializer = ExternalizableHelper.ensureSerializer(o.getClass().getClassLoader())
        }

        return ExternalizableHelper.fromBinary(ExternalizableHelper.toBinary(o, serializer),
}
```



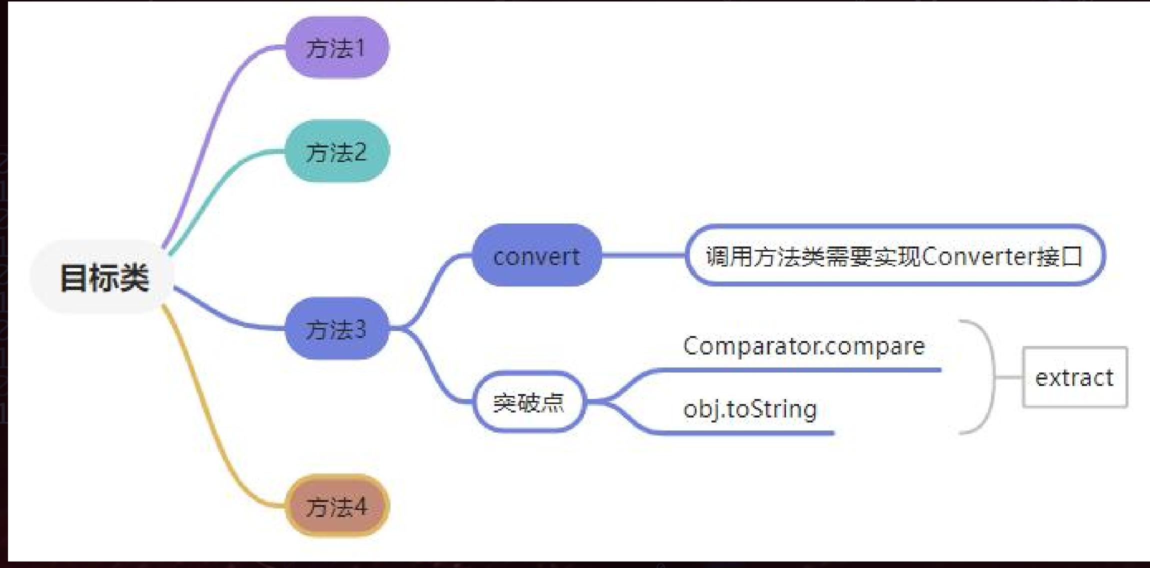
根据接口类进一步挖掘相关调用实现类

以点带面深入分析

MANT EUM E

整理目前得到的信息以及接下来需要寻找的方向：

- 目标类方法内部需要调用到convert方法
- 调用到convert方法的类需要实现Converter接口
- 目标类需要符合可序列化要求
- 简化调用链，最好可以利用到之前的突破点



- 根据整理信息找到ConverterCollections.ConverterComparator满足以上条件

```java
public static class ConverterComparator<F, T> implements Comparator<T>, Serializable {
  private final Converter<T, F> m_conv;

  private final Comparator<? super F> m_comparator;

  public ConverterComparator(Comparator<? super F> comparator, Converter<T, F> conv) {
    this.m_comparator = comparator;
    this.m_conv = conv;
  }

  public int compare(T o1, T o2) {
    Converter<T, F> conv = this.m_conv;
    return this.m_comparator.compare((F)conv.convert(o1), (F)conv.convert(o2));
  }
}
```

这里调用PriorityQueue类作为起始类，调用compare方法

至此调用链串通，由于在序列化时会调用writeReplace方法，需要利用javassist重写方法或直接覆盖类

以点带面深入分析

MANT EUM E

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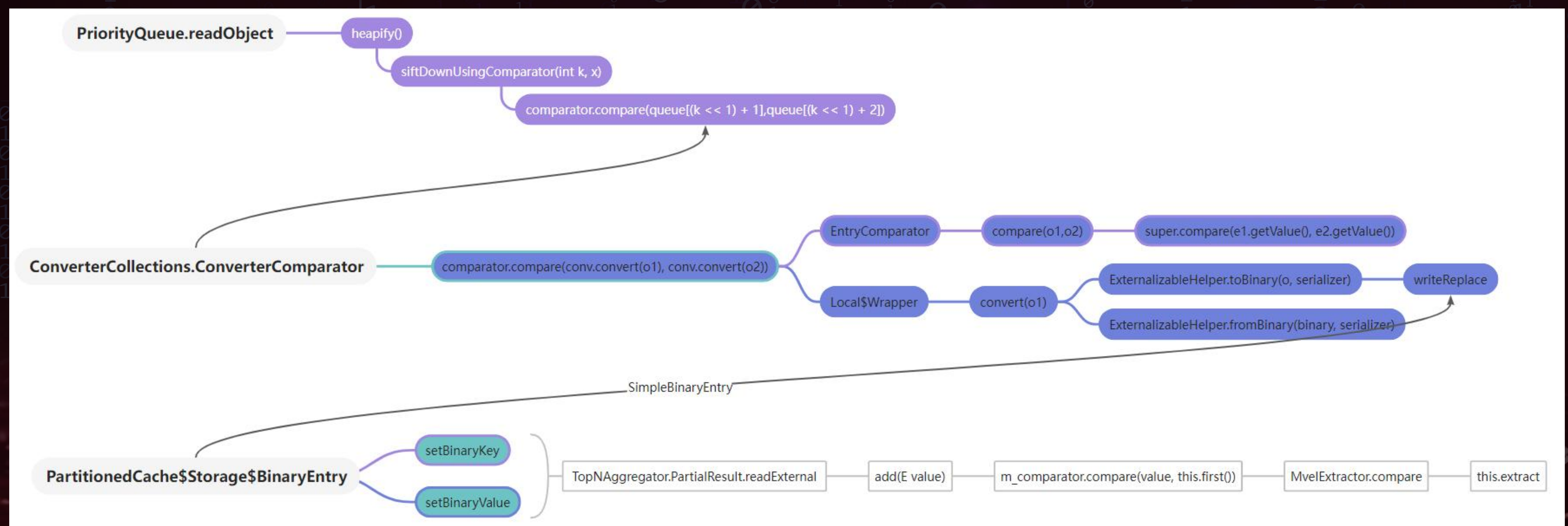
CVE-2021-35617

- 利用PartitionedCache$Storage$BinaryEntry替换黑名单类SimpleBinaryEntry
- Local$Wrapper类承载序列化后的Binary数据
- 调用ConverterCollections.ConverterComparator串联Converter.convert与compare方法
- 利用之前compare->extract的调用链，调用任意代码执行



以点带面深入分析

MANT EUM E

同样在换汤不换药的修复方式下，思考如何在之前的利用的类加入黑名单后如何绕过：

- 通过魔术方法重新生成黑名单中的可利用类
- 已知Coherence在反序列化中有新的处理方式，是否在对原生数据处理上有所不同可利用
- 寻找除黑名单之外的其他利用类

```java
public static Object readSerializable(DataInput in, ClassLoader loader) throws IOException {
  Object o;
  if (in instanceof PofInputStream) {
    o = ((PofInputStream)in).readObject();
  } else {
    ObjectInput streamObj = getObjectInput(in, loader);
    try {
      o = streamObj.readObject();
      if (o instanceof SerializerAware)
        ((SerializerAware)o).setContextSerializer(ensureSerializer(loader));
    } catch (IOException e) {
      throw e;
    } catch (Exception e) {
      throw new IOException("readObject failed: " + e + "\n" +

          getStackTrace(e) + "\nClassLoader: " + loader);
    }
  }
  return o;
}
```

```java
public static class DefaultObjectStreamFactory implements ObjectStreamFactory {
  public ObjectInput getObjectInput(DataInput in, ClassLoader loader, boolean fForceNew) thr
    if (!fForceNew && in instanceof ObjectInput && (!ExternalizableHelper.FORCE_RESOLVING_ST
      return (ObjectInput)in;
    InputStream stream = ExternalizableHelper.getInputStream(in);
    loader = Base.ensureClassLoader((loader == null && in instanceof WrapperDataInputStream)
        .getClassLoader() : loader);
    return (ObjectInput)new ResolvingObjectInputStream(stream, loader);
  }
```

```java
factory = AccessController.<ObjectStreamFactory>doPrivileged(new PrivilegedAction<ObjectStreamFactory>() {
      public ObjectStreamFactory run() {
        try {
          if (!XmlHelper.isInstanceConfigEmpty(xmlFactory))
            return (ObjectStreamFactory)XmlHelper.createInstance(xmlFactory, ExternalizableHelper.class
                .getClassLoader(), null);
        } catch (Exception e) {
          Base.err("Unable to instantiate an ObjectStreamFactory \"" + xmlFactory + "\":");
          Base.err(e);
        }
        return new ExternalizableHelper.DefaultObjectStreamFactory();
      }
    });
```

通过分析，如果类继承了原生的Serializable接口，那么依旧会经过ObjectFilter的过滤，无法绕过黑名单

```java
public class ResolvingObjectInputStream extends ObjectInputStream implements Resolving {
  private ClassLoader m_loader;

  public ResolvingObjectInputStream(InputStream stream, ClassLoader loader) throws IOException {
    super(stream);
    this.m_loader = loader;
  }

  protected Class resolveClass(ObjectStreamClass descriptor) throws IOException, ClassNotFoundException {
    ClassLoader loader = this.m_loader;
    if (loader != null)
      try {
        return Class.forName(descriptor.getName(), false, loader);
      } catch (ClassNotFoundException classNotFoundException) {}
    return super.resolveClass(descriptor);
  }
}
```

以点带面深入分析

MANT EUM E

如果在原生数据的处理上无差别的情况下，经过CVE-2020-1475补丁的修复，是否还有利用可能

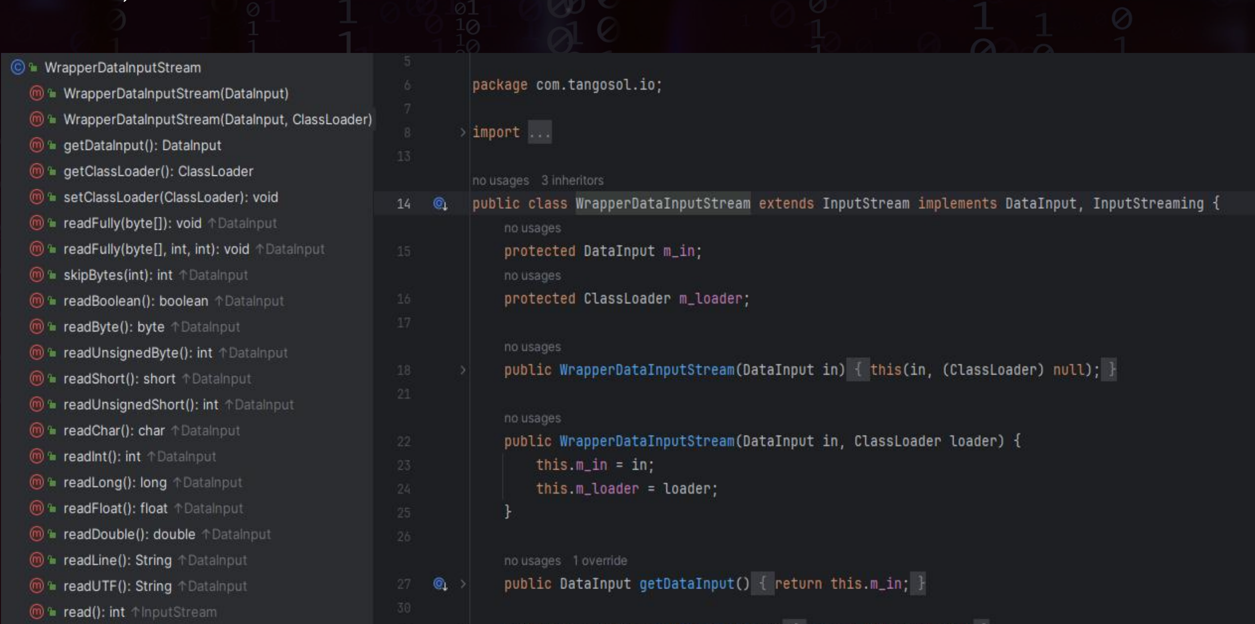
```java
public static ExternalizableLite readExternalizableLite(DataInput in, ClassLoader loader) throws IOException {
  ExternalizableLite value;
  if (in instanceof PofInputStream) {
    value = (ExternalizableLite)((PofInputStream)in).readObject();
  } else {
    WrapperDataInputStream wrapperDataInputStream1;
    String sClass = readUTF(in);
    WrapperDataInputStream inWrapper = (in instanceof WrapperDataInputStream) ? (WrapperDataInputStream)in : null;
    try {
      Class<?> clz = loadClass(sClass, loader, (inWrapper == null) ? null : inWrapper
          .getClassLoader());
      if (in instanceof ObjectInputStream) {
        ObjectInputStream ois = (ObjectInputStream)in;
        if (!checkObjectInputFilter(clz, ois))
          throw new InvalidClassException("Deserialization of class " + sClass + " was rejected");
      }
      value = (ExternalizableLite)clz.newInstance();
    } catch (InstantiationException e) {
      throw new IOException("Unable to instantiate an instance of class '" + sClass + "'; this is most likely due to a missing public no-ar

          getStackTrace(e) + "\nClass: " + sClass + "\nClassLoader: " + loader + "\nContextClassLoader: " +

          getContextClassLoader());
    } catch (Exception e) {
      throw new IOException("Class initialization failed: " + e + "\n" +

          getStackTrace(e) + "\nClass: " + sClass + "\nClassLoader: " + loader + "\nContextClassLoader: " +

          getContextClassLoader(), e);
    }
    if (loader != null)
      if (inWrapper == null) {
        wrapperDataInputStream1 = new WrapperDataInputStream(in, loader);
      } else if (loader != inWrapper.getClassLoader()) {
        inWrapper.setClassLoader(loader);
      }
    value.readExternal((DataInput)wrapperDataInputStream1);
    if (value instanceof SerializerAware)
      ((SerializerAware)value).setContextSerializer(ensureSerializer(loader));
  }
  return value;
}
```



思考

- 已知修复方式也是基于ObjectFilter进行过滤，是否存在差异化
- 对于不同的数据流，如何处理
- WrapperDataInputStream是否也存在黑名单的过滤

分析

- 在传入数据流不是基于ObjectInputStream时，不会进入黑名单过滤
- WrapperDataInputStream是Coherence新的处理数据流类，不存在黑名单过滤
- 寻找是否存在数据流转换，不基于ObjectInputStream实现了对象的还原

以点带面深入分析

MANT EUM E

经过前面的分析，对于转换流马上可以联想到CVE-2021-35617的处理方式，但是入口类被加入黑名单的情况下，如何再次利用转换

```java
public class PartitionedCache$Storage$EntryToBinaryEntryConverter extends Util implements Converter {
  public PartitionedCache$Storage$EntryToBinaryEntryConverter() {
    super(null, null, true);
  }

  public PartitionedCache$Storage$EntryToBinaryEntryConverter(Object sName, Object compParent, boolean fInit) {
    super((String)sName, (Component)compParent, false);
    if (fInit)
      super.__init();
  }
```

PartitionedCache$Storage.class

```java
public PartitionedCache$Storage$BinaryEntry instantiateBinaryEntry(Binary binKey, Binary binValue, boolean fReadOnly) {
  entry = new PartitionedCache$Storage$BinaryEntry();
  entry.setBinaryKey(binKey);
  entry.setBinaryValue(binValue);
  if (fReadOnly)
    entry.ensureReadOnly();
  _linkChild((Component)entry);
  return entry;
}
```

```java
  protected void __initPrivate() {
    super.__initPrivate();
  }

  public Object convert(Object o) {
    entry = (Map.Entry)o;
    return ((PartitionedCache$Storage)get_Parent()).instantiateBinaryEntry((Binary)entry.getKey(), (Binary)entry.getValue(), true);
  }
```

寻找满足以上条件的类：PartitionedCache$Storage$EntryToBinaryEntryConverter

- 继承了Converter类
- convert方法中实现了黑名单中的类

以点带面深入分析

MANT EUM E

已知在PartitionedCache$Storage$BinaryEntry的writeReplace方法中会还原SimpleBinaryEntry，目前调用链可以回溯到反序列化中调用用convert方法使PartitionedCache$Storage$EntryToBinaryEntryConverter生成PartitionedCache$Storage$BinaryEntry，接下来如何再次通过序列化重新生成SimpleBinaryEntry，需要进一步挖掘sink

```java
@Deprecated
public static class ConverterEntry extends ConverterCollections.ConverterEntry {
  public ConverterEntry(Map.Entry entry, Converter conKeyUp, Converter conValUp, Conv
    super(entry, conKeyUp, conValUp, conValDown);
  }
}
```

```java
public static class ConverterEntry<FK, TK, FV, TV> extends AbstractConverterEntry<FK, TK, FV, T
  protected final Converter<FK, TK> m_convKeyUp;

  protected final Converter<FV, TV> m_convValUp;

  protected final Converter<TV, FV> m_convValDown;

  public ConverterEntry(Map.Entry<FK, FV> entry, Converter<FK, TK> convKeyUp, Converter<FV, TV
    super(entry);
    this.m_convKeyUp = convKeyUp;
    this.m_convValUp = convValUp;
    this.m_convValDown = convValDown;
  }

  protected Converter<FK, TK> getConverterKeyUp() {
    return this.m_convKeyUp;
  }

  protected Converter<FV, TV> getConverterValueUp() {
    return this.m_convValUp;
  }

  protected Converter<TV, FV> getConverterValueDown() {
    return this.m_convValDown;
  }
}
```

```java
protected static abstract class AbstractConverterEntry<FK, TK, FV, TV> implements Map.Entry<TK, TV>, Serializable {
  protected final Map.Entry<FK, FV> m_entry;

  protected transient TK m_oKeyUp;

  protected transient TV m_oValueUp;

  protected AbstractConverterEntry(Map.Entry<FK, FV> entry) {
    this.m_entry = entry;
  }

  protected abstract Converter<FK, TK> getConverterKeyUp();

  protected abstract Converter<FV, TV> getConverterValueUp();

  protected abstract Converter<TV, FV> getConverterValueDown();

  public TK getKey() {
    TK oKeyUp = this.m_oKeyUp;
    if (oKeyUp == null)
      this
        .m_oKeyUp = oKeyUp = (TK)getConverterKeyUp().convert(getEntry().getKey());
    return oKeyUp;
  }

  public TV getValue() {
    TV oValueUp = this.m_oValueUp;
    if (oValueUp == null)
      this
        .m_oValueUp = oValueUp = (TV)getConverterValueUp().convert(getEntry().getValue());
    return oValueUp;
  }

  public TV setValue(TV value) {
    this.m_oValueUp = null;
    return (TV)getConverterValueUp().convert(
        getEntry().setValue((FV)getConverterValueDown().convert(value)));
  }
```

以点带面深入分析

MANT EUM E

CVE-2022-21420

- 利用PartitionedCache$Storage$EntryToBinaryEntryConverter的convert方法实现黑名单中的PartitionedCache$Storage$BinaryEntry类
- 调用ConverterCollections.ConverterEntry，通过嵌套的方式，将上述生成的类再利用Local$Wrapper类承载序列化后的Binary数据
- 利用Binary数据绕过ObjectFilter机制，再使用toString->getKey->extract的调用链，调用任意代码执行

KCon
PART ONE
04
代理模式下的利用
MANDAMUS MEDIOCREM REREHENDUNT

代理模式下的利用

MANT EUM E

Java代理模式，引入代理类控制其他对象的访问，主要用于控制对复杂对象的访问和操作，或在访问对象时添加额外的功能。代表有jdk的AnnotationInvocationHandler，著名的jdk7u21与jdk8u20的反序列化就诞生于此。以防促攻，挖掘补丁以及修复手段，从而发现新的利用方式

```java
private synchronized void readObject(ObjectInputStream ois) throws IOException,
ClassNotFoundException {

    synchronized(BeanContext.globalHierarchyLock) {
        ois.defaultReadObject();

        initialize();

        bcsPreDeserializationHook(ois);

        if (serializable > 0 && this.equals(getBeanContextPeer()))
            readChildren(ois);

        deserialize(ois, bcmListeners = new ArrayList( initialCapacity: 1));
    }
}
```

```java
            var8 = var9.memberValues.get(var6);
        } else {
            try {
                var8 = var5.invoke(var1);
```

在jdk7u21时未对反序化的字段进行数据校验，所以在代理到equals方法时，可以反射执行恶意方法

在jdk8u20时通过抛出异常结束反序列化，绕过是因为找到一个类在反序化时捕捉了异常未抛出，导致反序列化继续进行，绕过了异常抛出的修复方式

```java
public final void readChildren(ObjectInputStream ois) throws IOException, ClassNotFoundException
{
    int count = serializable;

    while (count-- > 0) {
        Object                      child = null;
        BeanContextSupport.BCSChild bscc  = null;

        try {
            child = ois.readObject();
            bscc  = (BeanContextSupport.BCSChild)ois.readObject();
        } catch (IOException ioe) {
            continue;
        } catch (ClassNotFoundException cnfe) {
            continue;
        }
```

代理模式下的利用

MANT EUM E

Jdk8u20的修复方式，在获取对应class的方法时增加了限制。站在巨人的肩膀上，分析可以挖掘的点：

- 继承并实现Serializable与InvocationHandler接口
- 代理类实现功能时，存在对传入方法进行自定义的处理
- 没有对代理类的type或method进行限制

```java
class AnnotationProxy implements Annotation, InvocationHandler, Serializable {

    private static final long serialVersionUID = 6907601010599429454L;
    private static final Log log = LoggerFactory.make();

    private final Class<? extends Annotation> annotationType;
    private final Map<String, Object> values;
    private final int hashCode;

    AnnotationProxy(AnnotationDescriptor<?> descriptor) {
        this.annotationType = descriptor.type();
        values = Collections.unmodifiableMap( getAnnotationValues( descriptor ) );
        this.hashCode = calculateHashCode();
    }

    @Override
    public Object invoke(Object proxy, Method method, Object[] args) throws Throwable {
        if ( values.containsKey( method.getName() ) ) {
            return values.get( method.getName() );
        }
        return method.invoke( this, args );
    }
```

```java
public boolean equals(Object obj) {
    if ( this == obj ) {
        return true;
    }
    if ( obj == null ) {
        return false;
    }
    if ( !annotationType.isInstance( obj ) ) {
        return false;
    }

    Annotation other = annotationType.cast( obj );

    //compare annotation member values
    for ( Entry<String, Object> member : values.entrySet() ) {

        Object value = member.getValue();
        Object otherValue = getAnnotationMemberValue( other, member.getKey() );

        if ( !areEqual( value, otherValue ) ) {
            return false;
        }
    }
```

```java
private Object getAnnotationMemberValue(Annotation annotation, String name) {
    try {
        return run( GetDeclaredMethod.action( annotation.annotationType(), name ) ).invoke( annotation );
    }
```

代理模式下的利用

MANT EUM E

CVE-2022-21306

- 利用AnnotationProxy生成代理类，携带调用方法名，通过equals方法进入invoke调用getAnnotationMemberValue
- 通过getAnnotationMemberValue转换对应method属性，通过二次代理AnnotationProxy，对应调用方法返回调用目标方法正常返回方法属性
- 将上述返回的方法通过ProxyIndirectionHandler进行链接，将返回的方法属性赋予需要需要后续调用的类，完成任意无参方法调用
- 寻找满足将AnnotationProxy与ProxyIndirectionHandler串联的类

BadAttributeValueExpException.toString
ExtractorEventTransformer.equals
extractorOld
Proxy.newProxyInstance("".class.getClassLoader(),new Class[]{ ValueExtractor.class},AnnotationProxy)
annotationType
Annotation
values
hashMap
key:getConnection
value:aaa
invoke
method.invoke(this, args)
equals
getAnnotationMemberValue
annotation name=getConnection
extractorNew
Proxy.newProxyInstance(Xxx_I2_2_1_4_0.class.getClassLoader(), new Class[]{Annotation.class,RowSetInternal.class,ValueExtractor.class},CompositeInvocationHandlerImpl)
classToInvocationHandler
Annotation
AnnotationProxy
annotationType
Annotation
values
key:annotationType
value:RowSetInternal.class
method:annotationType()
RowSetInternal
ProxyIndirectionHandler
ValueHolder
JdbcRowSetImpl
invoke
getValue
get(method.getDeclaringClass)
invoke
return:RowSetInternal.class
name:getConnection

TONGDAO

KCon
2024

KCon 2024

THANKS

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