Did You Forkget It?

Detecting One-Day Vulnerabilities in Open-source Forks With Global History Analysis

19/02/2026

Work under peer review

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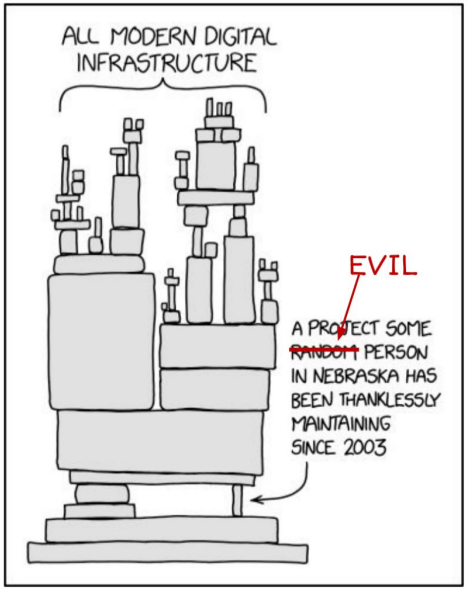
OSS supply chain security

- OSS are at the **heart** of modern and modular software[1]
- **96%** of studied private software contained **OSS dependency** [1] [2]
- A software **attack surface** includes all its OSS dependencies

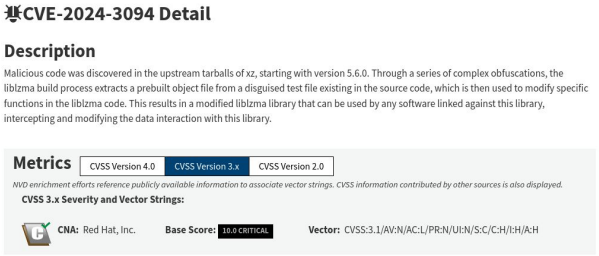


OSS security is critical

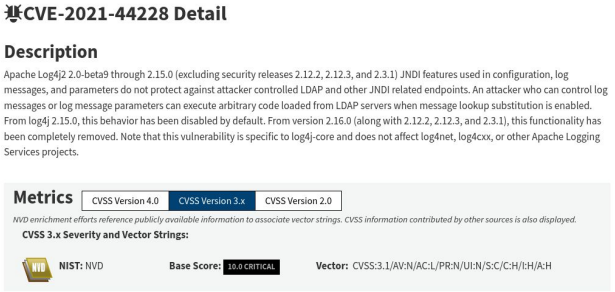
[1] https://www.linuxfoundation.org/hubfs/Research%20Reports/lfr_harvard_censusII_mar2022_042824b.pdf?hsLang=en
[2] https://www.blackduck.com/resources/analyst-reports/open-source-security-risk-analysis.html#introMenu

One-day vulnerability

- Definition : Vulnerabilities that are **publicly known, but not fixed yet** in a software you use
- Challenge : identify them quickly and exhaustively, then apply countermeasure



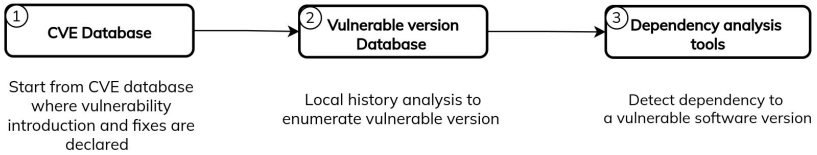
xz utils backdoor



Log4J vulnerability

One-day vulnerability in open source **via declared dependencies**

- Well-known and documented challenges
- Many tools available (OSV scanner, OWASP Dependency check, Snyk, Gitlab Dependency scanning, Dependabot ...)
- Based on CVE Databases (OSV, NVD, CVE List, etc.)



https://owasp.org/www-project-dependency-check/
https://docs.dependencytrack.org/datasources/snyk/
https://docs.gitlab.com/ee/user/application_security/dependency_scanning/
https://docs.github.com/en/code-security/dependabot

One-day vulnerability in open source **via forking**

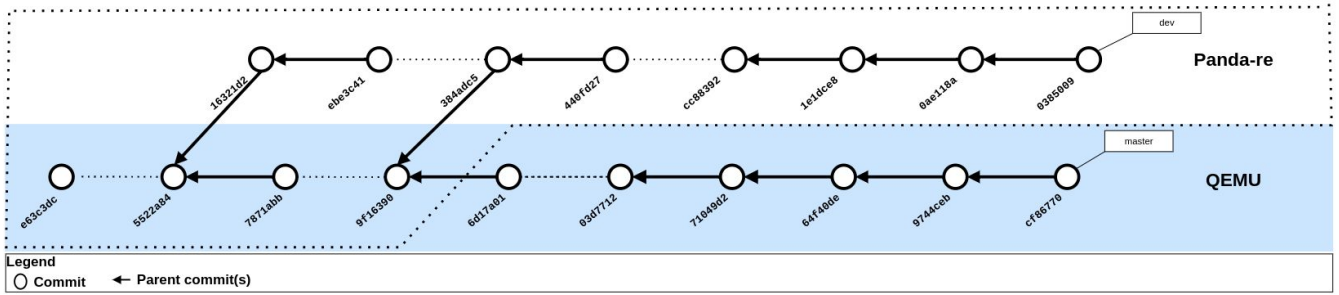
Definition :

- Creating a new repository by copying the source code and the history of an existing project [1]
- Shared commit fork [2] : Two repositories are considered as forks if they **shared a commit**

Typical scenario :

1) Start from existing OSS (e.g. QEMU)
2) Create your own (e.g. Panda-re)
3) Periodically integrate changes

More than 40% of repository hosted on GitHub are forks [3]

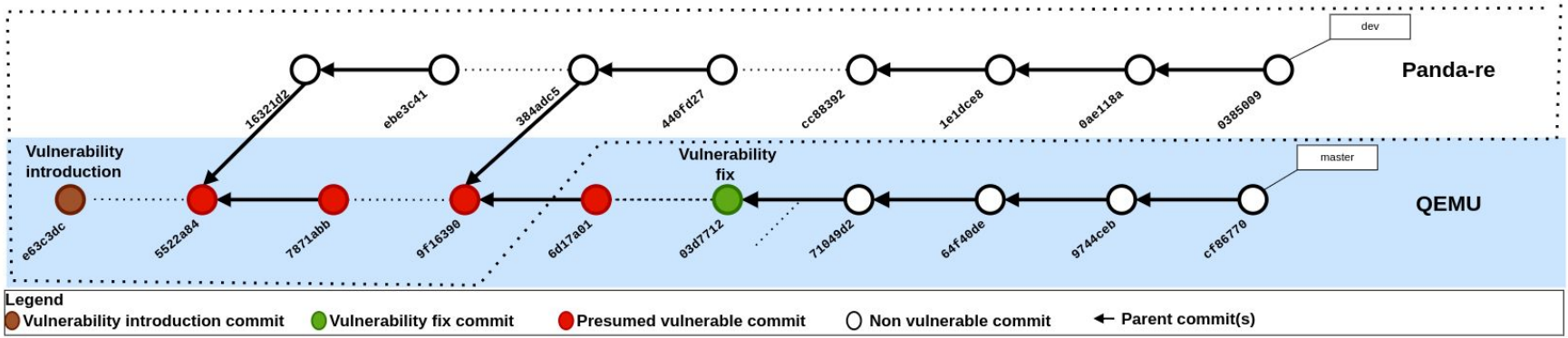


Deduplicated git history in a fork ecosystem

[1] Shurui Zhou, Bogdan Vasilescu, and Christian Kästner. 2020. How has forking changed in the last 20 years? a study of hard forks on GitHub. ICSE '20
[2] Antoine Pietri, Guillaume Rousseau, and Stefano Zacchiroli. 2020. Forking Without Clicking: on How to Identify Software Repository Forks. MSR' 20
[3] Analysis based on an export of Software Heritage as of April 3, 2024

One-day vulnerability in open source **via forking**

- Any commit **can introduce a new vulnerability**.
- Or it can **fix an existing vulnerability**.
- What happens if a project is forked **between introduction and fix** of a vulnerability?
- It inherits the vulnerability, . . . until the change with the fix is integrated.



One-day vulnerability in open source **via forking**

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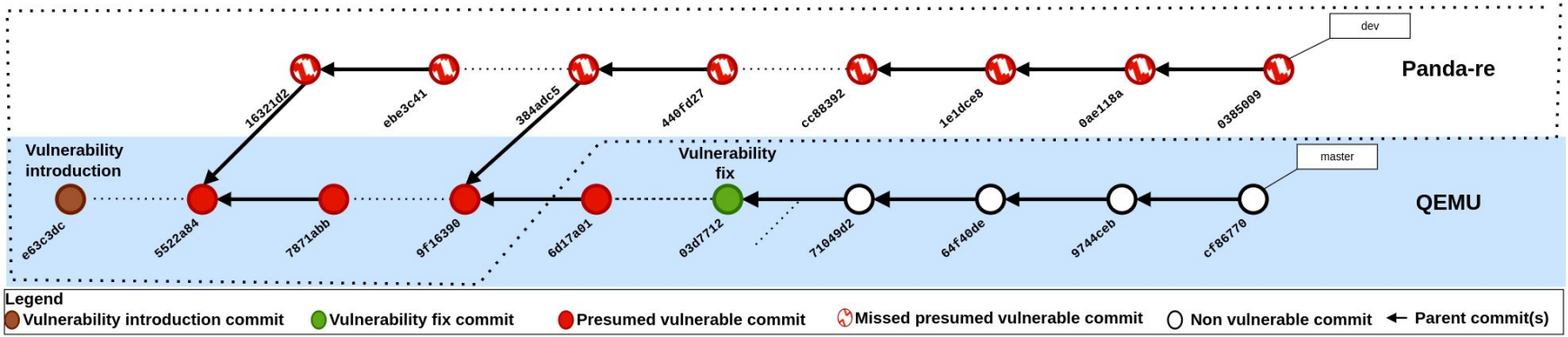


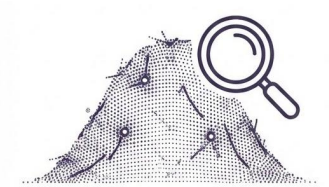
Current approach failed to handle vulnerable commit in forks

One-day vulnerability related to forking is not studied

Detecting One-Day Vulnerabilities in Open-Source Forks
Challenges

1. Forks identification

Forks can be hosted on heterogeneous forge.



2. Large Scale analysis

Research question

RQ1 - Is it feasible to propagate the information about which commits introduce and fix known vulnerabilities to the global commit graph of public code?

RQ2 - Can we use the global vulnerability propagation to identify unpatched forks?

The **O**pen **S**ource **V**ulnerability (OSV) database as input

OSV | Open Source Vulnerabilities

- Standardization initiative [1]
- Map vulnerability with affected software version and/or vulnerability event on git history
- Aggregate multiple database

```
"ranges": [ {
    "type": "GIT",
    "repo": "https://github.com/owner/repo",
    "events": [
      { "introduced": "X" },
      { "fixed": "Y" },
    ]
} ]
```

```
{ "last_affected": "Y" },
```

```
{ "limit": "Y" },
```

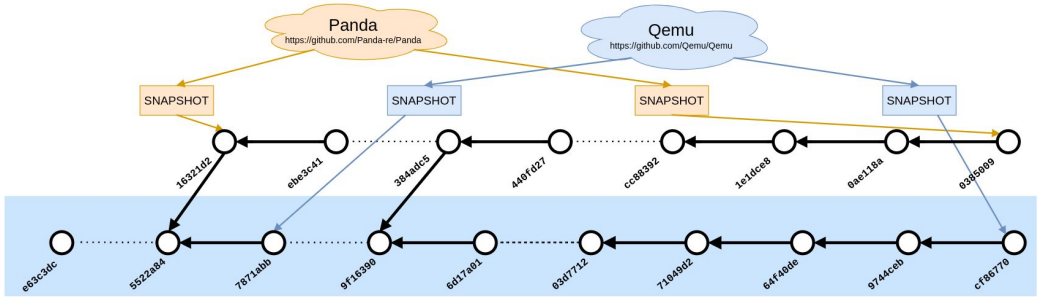
[1] https://ossf.github.io/osv-schema/

Software Heritage, a perfect candidate

Cross forges

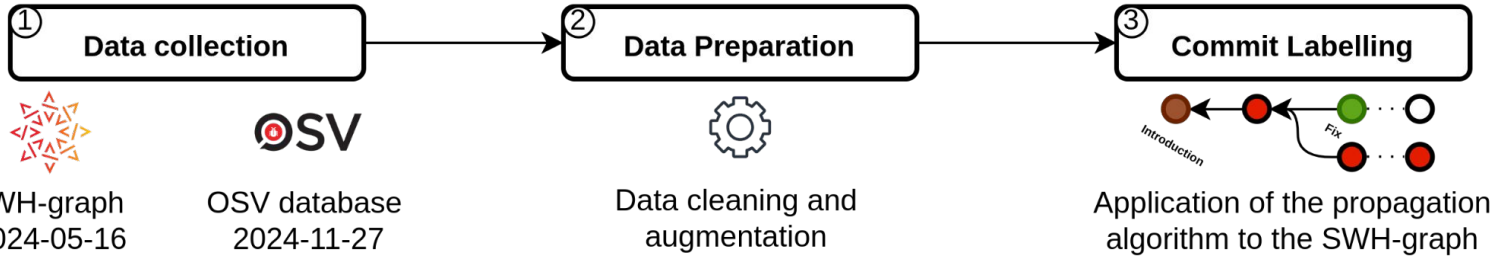
Bitbucket 2,578,359 origins	56,983 origins	git 31,718 origins
27,377 origins	debian 139,881 origins	78,672 origins
GitHub 232,393,948 origins	gitiles 23,763 origins	GitLab 5,649,327 origins
git 3,476 origins	Gogs 260 origins	1,751,100 origins
Guix 63,697 origins	GNU 354 origins	heptapod 1,322 origins
launchpad 631,066 origins	Maven 312,181 origins	NixOS 48,864 origins
npm 4,003,267 origins	5,337 origins	Packagist 376,324 origins
fedora PAGURE 72,458 origins	Phabricator 223 origins	pub.dev 57,087 origins
python 570,379 origins	SOURCEFORGE 382,294 origins	stagit 327 origins

Deduplicated model

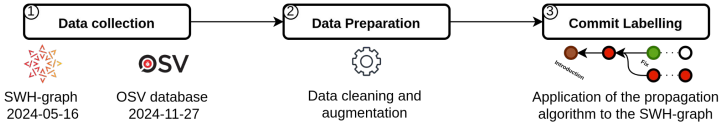


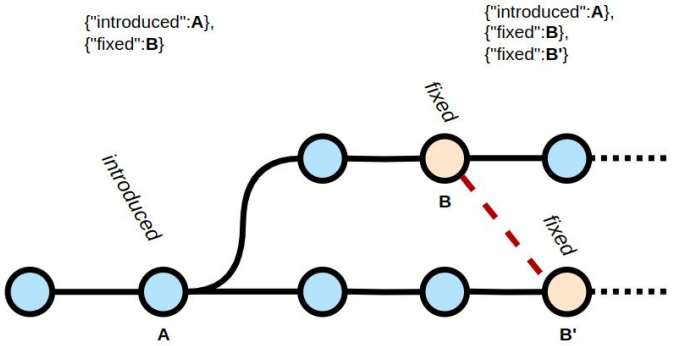
Di Cosmo, Roberto & Zacchiroli, Stefano. (2023). The Software Heritage Open Science Ecosystem. 10.1007/978-3-031-36060-2_2.

Experimental Protocol



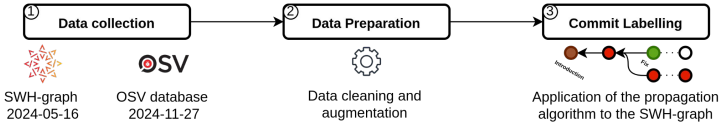
Data preparation

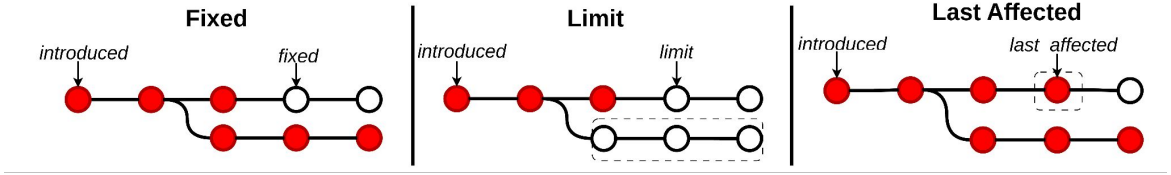


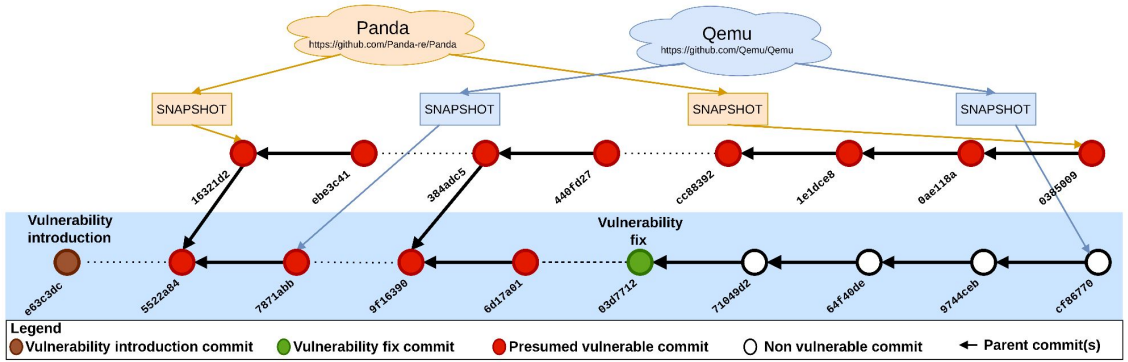


https://ossf.github.io/osv-schema/

Labelling

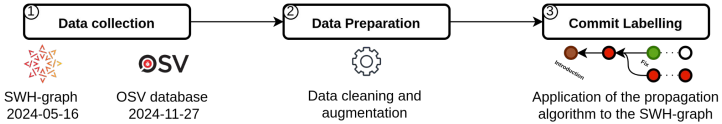






Algorithm that label the SWH graph based on OSV event semantic

Results



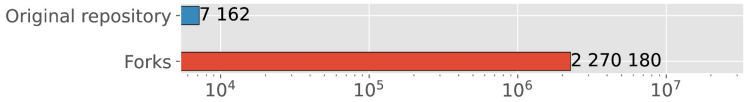


Fig 1. Number of forks having at least one vulnerable commit.

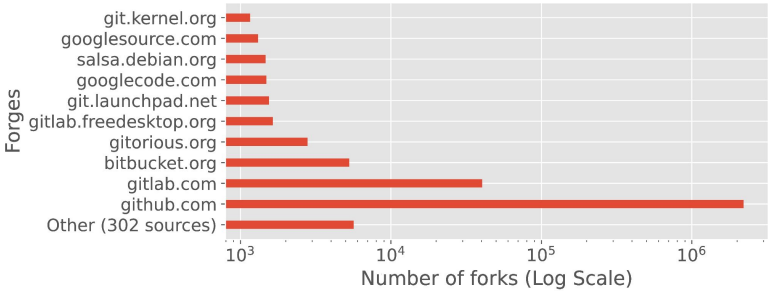
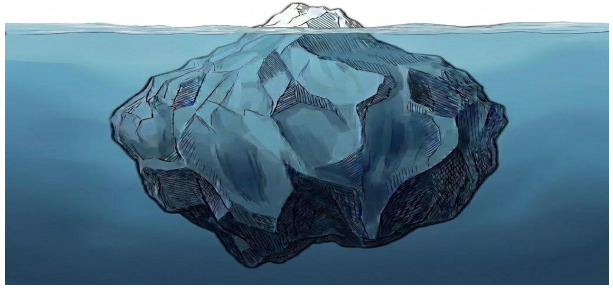


Fig 2. Number of forks having at least one vulnerable commit by forge.

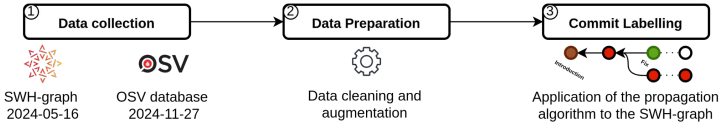
7 162 OSV referenced repos



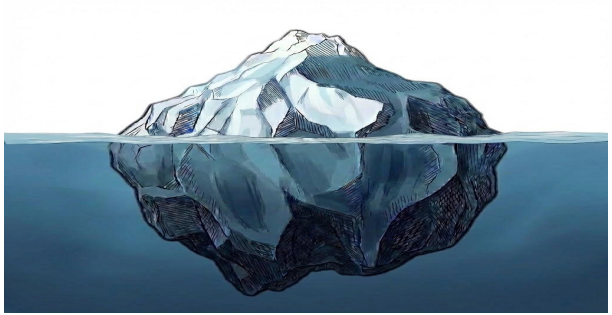
2.2 M associated forks with at least a vulnerable commit

From more than **302 forges**

Results



72 M commits presumed vulnerable on **referenced repos**



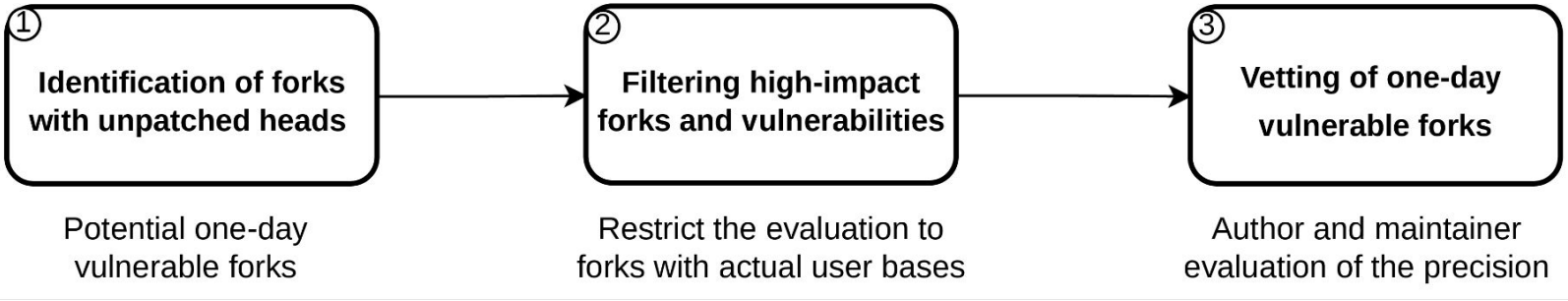
86 M commits presumed vulnerable on **forks**

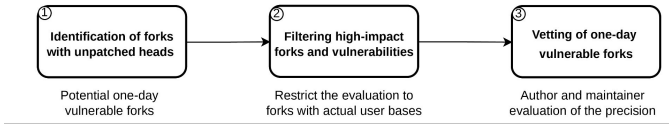
Research question

RQ1 - Is it feasible to propagate the information about which commits introduce and fix known vulnerabilities to the global commit graph of public code?

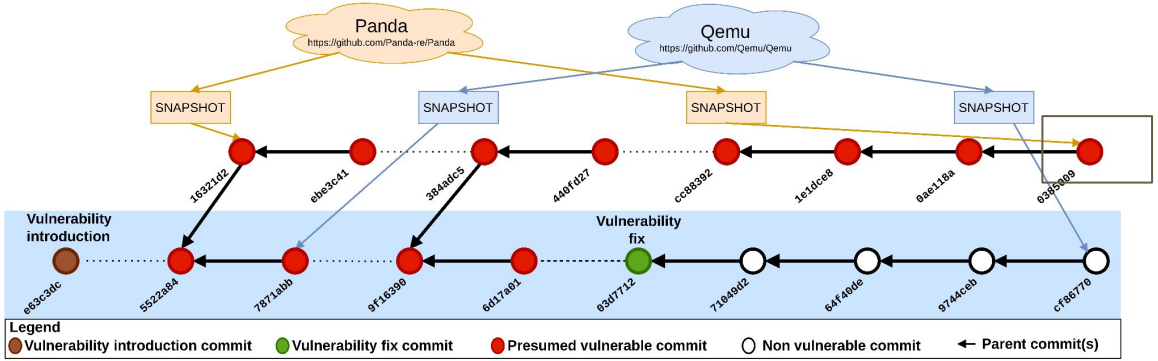
RQ2: Can we leverage the proposed global history analysis approach to detect at scale one-day vulnerabilities in real-world forked OSS?

Experimental protocol

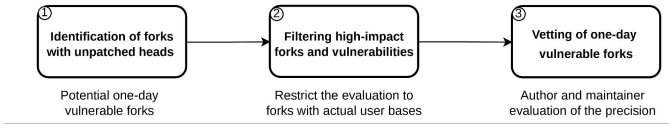




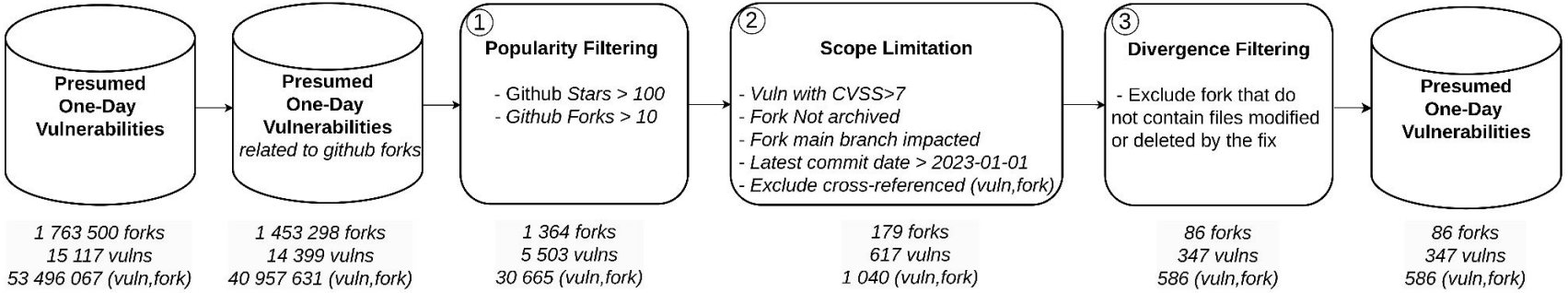
1- Identifying unpatched forks



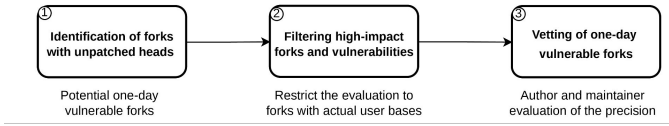
1.7 M forks with an unpatched head among the 2.2 M



2- Filtering high-impact forks and vulnerabilities

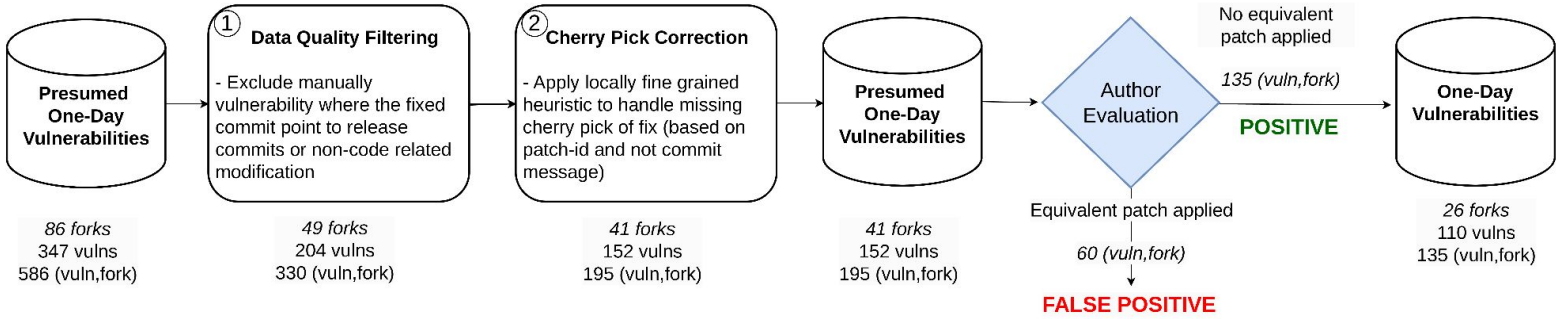


86 forks with **586** (vuln,fork) presumed one-day vulnerabilities



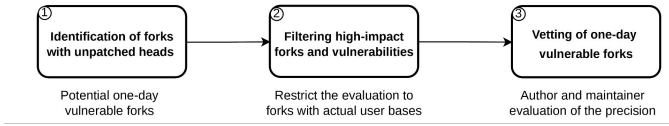
3- Vetting of one-day vulnerable forks

Author evaluation



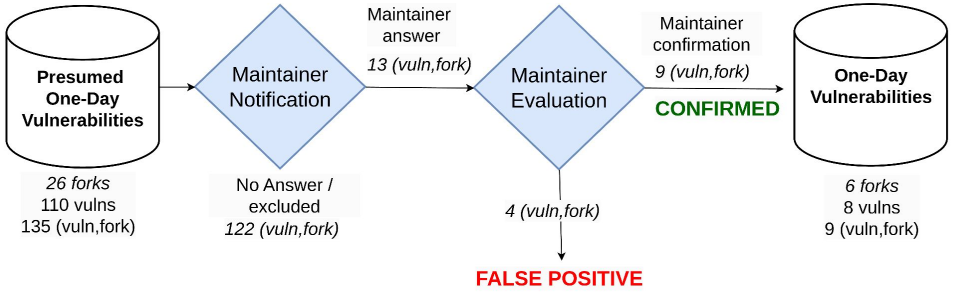
Detecting equivalent patch that could have been applied by fork maintainer

135 positive and **60** false-positive one-day vulnerability (fork,vulnerability)
69 % of precision



3- Vetting of one-day vulnerable forks

Maintainer evaluation



Maintainer response = the only ground truth

9 positive and **13** false-positive one-day vulnerability (fork,vulnerability)
69 % of precision

Confirmed cases

Panda.re

Fork of QEMU System emulator and virtualizer
CVE-2019-13164

XPERIA
Sony Smartphone

sonyxperiadev/kernel

Fork of linux kernel for xperia dev community
CVE-2021-45485
CVE-2021-4154

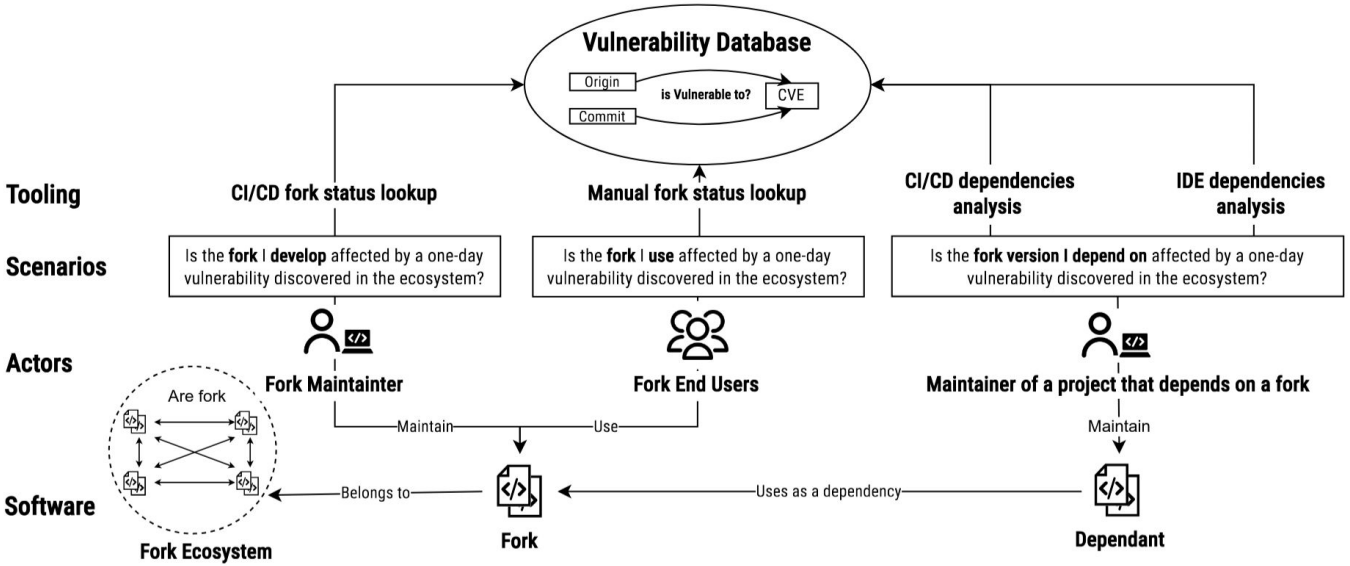
go-nv/goenv

Fork of pyenv for go
CVE-2022-35861

bitcoin-sv/bitcoin-sv

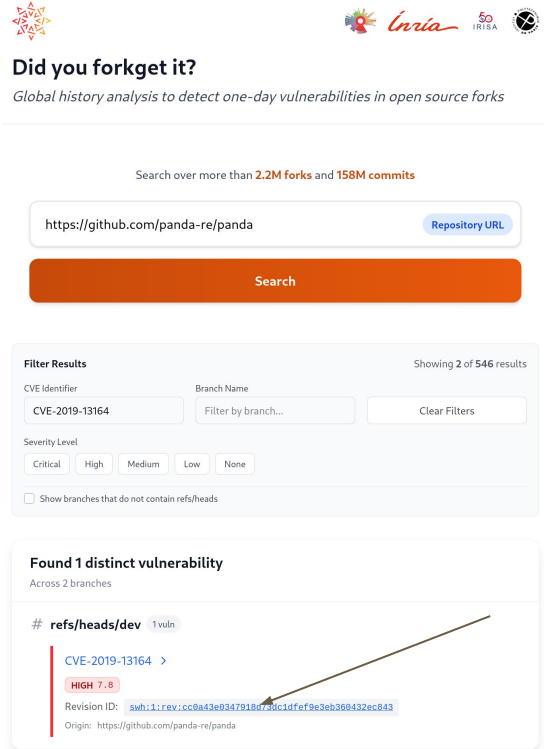
Fork of bitcoin
CVE-2021-37492

Integration in software development processes

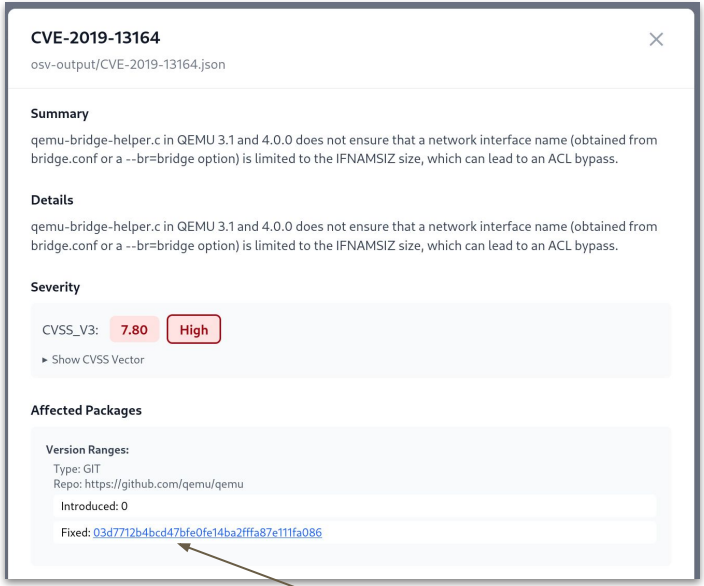


Prototype : Enabling fork status lookup

Database lookup
didyouforkgetit.dev



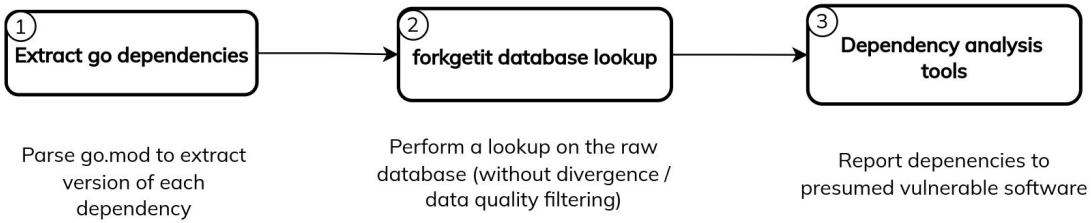
Vulnerable head commit identifier (SWHID)



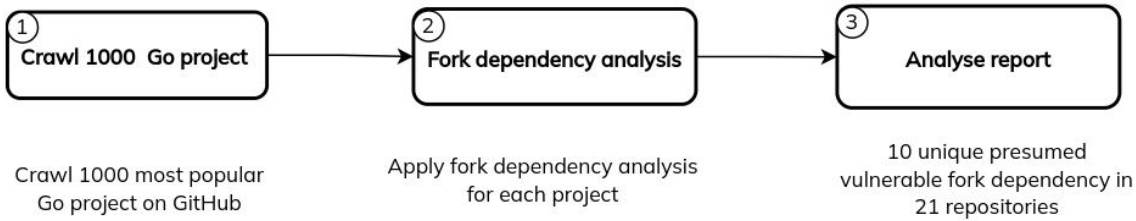
Associated fixed commit

Prototype : Go dependency analysis

Approach

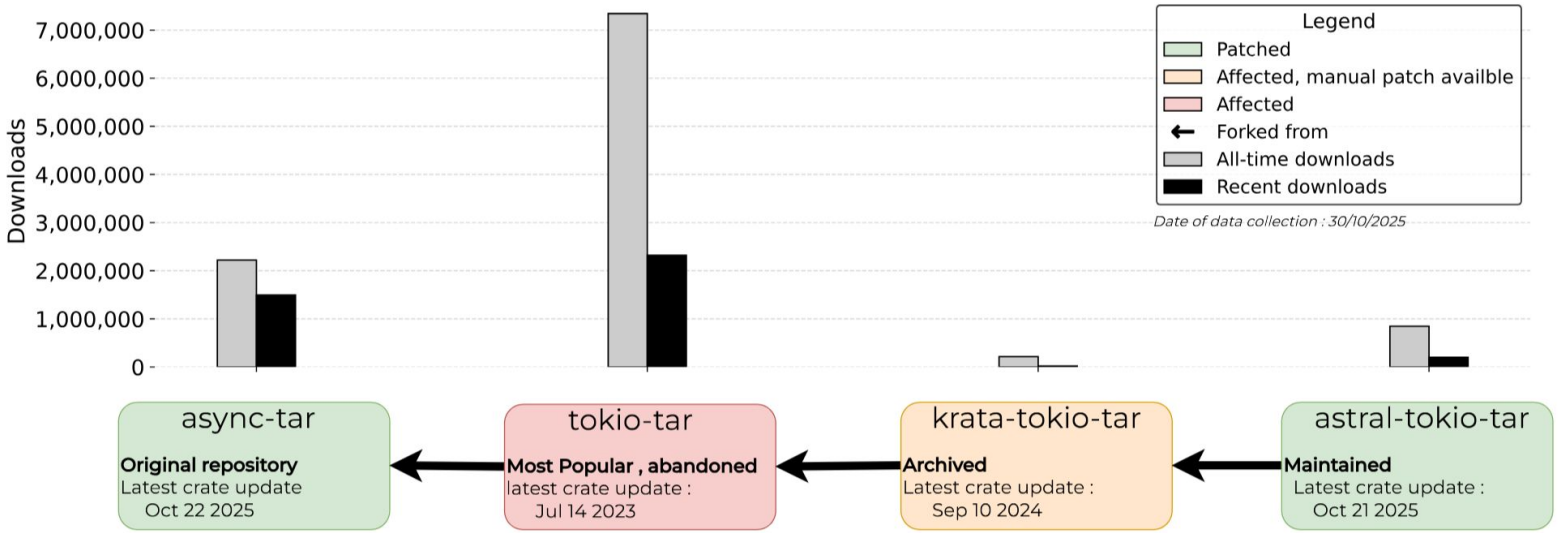


Case study



21 repositories reported as dependent to presumed vulnerable forks

Responsible disclosure
The case of CVE-2025-62518 called “Tarmagedon”



Conclusion

RQ1 - Labelling global commit graph with vulnerability information

- Global history analysis based on SWH
- **2.2 M forks** with presumed vulnerable commit

RQ2 - Detecting one-day vulnerabilities in real-world forked OSS

- Author evaluation : **135** positive one-day with 69 % of precision
- Maintainer evaluation : **9 confirmed positive** over 13 response

Perspective : Integration in software development processes

Thanks !

Database lookup
didyouforkgetit.dev

Preprint