Dataset: Dependency Networks of Open Source Libraries Available Through CocoaPods, Carthage and Swift PM

Kristiina Rahkema
University of Tartu
Tartu, Estonia
kristiina.rahkema@ut.ee

Dietmar Pfahl
University of Tartu
Tartu, Estonia
dietmar.pfahl@ut.ee

ABSTRACT
Third party libraries are used to integrate existing solutions for common problems and help speed up development. The use of third party libraries, however, can carry risks, for example through vulnerabilities in these libraries. Studying the dependency networks of package managers lets us better understand and mitigate these risks. So far, the dependency networks of the three most important package managers of the Apple ecosystem, CocoaPods, Carthage and Swift PM, have not been studied. We analysed the dependencies for all publicly available open source libraries up to December 2021 and compiled a dataset containing the dependency networks of all three package managers. The dependency networks can be used to analyse how vulnerabilities are propagated through transitive dependencies. In order to ease the tracing of vulnerable libraries we also queried the NVD database and included publicly reported vulnerabilities for these libraries in the dataset.

CCS CONCEPTS
- Software and its engineering → Empirical software validation.

KEYWORDS
datasets, iOS, dependency network, package manager, mobile apps

ACM Reference Format:
Kristiina Rahkema and Dietmar Pfahl. 2022. Dataset: Dependency Networks of Open Source Libraries Available Through CocoaPods, Carthage and Swift PM. In 19th International Conference on Mining Software Repositories (MSR ’22), May 23–24, 2022, Pittsburgh, PA, USA. ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3524842.3528016

1 INTRODUCTION
Third party libraries allow developers to use existing solutions for common tasks and speed up development. For almost every popular programming language there is at least one package manager that can be used to manage these dependencies.

A recent vulnerability in the popular log4j java logging library affected around four percent of all projects in the Maven repository [11]. In 2015, a vulnerability in the popular iOS third party library AFNetworking was found. The vulnerability affected around 1000 iOS applications with millions of users [1]. Apps can not only be affected when they directly depend on these libraries, but also when their dependencies or dependencies of dependencies depend on these vulnerable library version.

The dependency network of a package manager contains all libraries distributed through this package manager and their dependency relationships with other libraries. Dependency networks, including their growth and vulnerability, have been studied thoroughly for many package managers such as, among others, npm, RubyGems and Cargo [3, 6].

Both Decan et al. [3] and Kikas et al. [6] highlighted differences between package managers and how policies and quality of the standard library of a language can affect the dependency network structure. So far the dependency networks for the package managers used in iOS development (CocoaPods, Carthage and Swift Package Manager) have not been studied.

We start closing this gap by creating a dataset1 containing the dependency networks for libraries provided through CocoaPods, Carthage and Swift Package Manager. The dataset contains information on open source library versions provided through CocoaPods, Carthage and Swift Package Manager, dependency relationships between these versions and information on publicly disclosed vulnerabilities in the NVD database.

2 RELATED WORK
There are different ways to construct the dependency network of a package manager. Li et al. [7] created a project dependency graph for Java Maven projects where each node represents a project and edges between nodes denote the inter-dependency requirements, for example "> 5.0.0" if all versions starting with the major version 5 are allowed.

Kikas et al. [6] created a dependency graph for JavaScript, Ruby and Rust ecosystems and analysed their evolution. They discussed different approaches for the dependency network construction and highlighted the importance of storing the dependencies between actual versions of libraries as opposed to an aggregated approach where dependencies are connections between library nodes without version information. Dependencies between versions were found by analysing the package manager manifest files. Dependency constraints that allowed the use of multiple library versions were handled by observing which library versions would have been the best match at the time when the current library version was released.

1https://zenodo.org/record/6376009 [9]
The biggest dataset containing information on library dependencies is the newest (2020) version of the open dataset provided by libraries.io [5]. The dataset contains data on 32 package managers and three source code repositories. For many package managers the data includes dependency data between all versions of libraries. Data on the corresponding software repositories also contains information on the dependency constraints used, this data is however based on the last snapshot of the project repository. In 2019 Decan et al. [3] studied the evolution of dependency networks for seven different package managers using the 2017 libraries.io dataset. The package managers CocoaPods, Carthage and Swift Package Manager were not included in the study as the dataset only included data on dependencies between software repositories and there was no data on dependencies between library versions.

The data on dependencies between library versions for CocoaPods, Carthage and SwiftPM is also missing from the newest version of the libraries.io dataset. Data on library versions and dependencies between library versions is however necessary for the analysis of dependency network evolution.

To fill this gap we compiled a database containing library dependency information on version level for CocoaPods, Carthage and SwiftPM package managers. For a more complete picture we also included data on dependency constraints that can be used similarly to [7]. Additionally we queried publicly reported vulnerabilities from the NVD database and matched them to the library versions in our dataset.

3 DATA COLLECTION METHODOLOGY

For data collation it was necessary to identify libraries that are available through each package manager, to collect dependency data for each library and to collect vulnerability data for each library.

3.1 Package Managers

Developers can include third party libraries into projects in multiple ways. Libraries can be either directly downloaded and imported manually or developers can use package managers. Use of a package manager makes it easier to include a new library and foremost it makes it easier to keep the library up to date. The package managers used in Swift development (i.e. for iOS, Mac OS and Watch OS applications) are CocoaPods, Carthage and Swift Package Manager. These package managers are fundamentally different.

CocoaPods is a package manager with a central database of libraries. If a developer wants to distribute their library through CocoaPods they need to create a Podspec file and add it to the CocoaPods Spec repository. This repository is public and can be accessed by anyone.

Swift Package Manager (Swift PM) is the official package manager for Swift. It is however not the most popular package manager and compatibility with iOS projects was not added until 2019[4]. Swift PM does not have a central list of libraries. Any library that includes a Package.swift manifest file can be included through Swift PM by providing its repository address.

Carthage, similarly to Swift PM, is a decentralized package manager. A library can be included by providing its repository address, binary location or path on the local file system.

3.2 Identifying Libraries

Due to the differences in the package managers, we identified libraries for CocoaPods differently than for Carthage and Swift PM. For CocoaPods we cloned the Spec repository² and extracted all repository URLs from the Podspec files. The extracted list included 79557 repository URLs. Among these URL were incorrect values, such as "/", "git", "someone@gmail.com". Some URLs were correct URLs, but they were links to private repositories on company domains.

We discarded all URLs that did not contain github.com or bitbucket.org and 73243 URIs (92%) remained. We looked through these values and noticed that some of the URLs contained references to passwords of the form username:password@github.com. We decided to strip these values before the analysis. This leads to us not being able to access some of the repositories. Nevertheless we assumed that it might have been developers intention to not make the library code accessible to everyone, although the password and username combination would be accessible to anyone through the public Spec repository.

For Carthage and Swift PM we used the libraries.io dataset [5] to get a list of library names. The set of library names is not complete since the dataset was compiled in 2020 and new libraries may have been created after that. We extracted 3880 names for Carthage libraries and 4207 names for Swift PM libraries.

We ran our analysis on these three sets of libraries. The analysis was successful for 56822 CocoaPods libraries, 2118 Swift PM libraries and 3094 Carthage libraries. We then merged the three databases. The merged database contained 60084 successfully analysed libraries.

We then queried libraries that are referenced as dependencies but that are not analysed. There were a total of 4728 library dependencies of which 1047 were not analysed. We gathered the names of these libraries and performed a second round of analysis. We refer to this as library snowballing. There may still exist libraries, that are available through one of the three package managers, that are missed by our approach. These libraries however will not have any dependents and would not be essential to dependency network analysis.

3.3 Collecting Dependency Data

Dependency data was collected by parsing the manifest files Package.swift, Podfile and Cartfile and package manager resolution files Package.resolved, Podfile.lock and Cartfile.resolved. We extracted Library names, versions and version constraints from the mainifest files and stored the data as library definitions. We parsed package manager resolution files and extracted library dependencies with names and versions. Package resolution files contain the exact version of each library that the package manager deemed to be the best match at the time when the developer last updated the dependencies. Package resolution files also contain information on all transitive dependencies. Information on both direct and transitive dependencies were stored in the database.

To match library names extracted from the three package managers it is necessary to "translate" library names. The translation was done by finding information on the library repository URL

²https://github.com/CocoaPods/Specs
We developed GraphifyEvolution for bulk analysis of applications written in Swift. The tool is built in a modular manner and is designed so that it is easy to include analysis results from external analysers. GraphifyEvolution is able to take a list of applications and analyse their evolution based on git commits or tags. For commits the git commit tree is used to determine the evolution between versions. For git tags the evolution between versions is determined by the commit timestamp. Our analysis used the git tag option since tags are normally connected to library versions. All data is entered into a neo4j database.

### 4.2 SwiftDependencyChecker

SwiftDependencyChecker [10] was developed to detect if an app uses dependencies with publicly reported vulnerabilities. Its intended use is as part of the build process inside Xcode to warn developers about vulnerable dependencies, but it can also be used to detect dependencies declared through CocoaPods, Carthage and Swift Package Manager. We integrated SwiftDependencyChecker into GraphifyEvolution as an external analyser. The external analyser implementation finds dependencies declared for each project version and enters libraries and library definitions into the neo4j as nodes. Relationships are created between project version and its direct and indirect dependencies.

### 5 DATASET DESCRIPTION

The dataset is provided as a neo4j database and can be downloaded from the database repository. The database dump can be loaded with the following command, where `--from` points to the database dump file and `--to=<db-name>` specifies the name of an empty database:

```
neo4j-admin load --from=<db-dump> --to=<db-name>
```

The database can be used with either the free community version of the neo4j server or the enterprise version. We also provide the data in json format, which makes it accessible without using neo4j.

- Neo4j is a graph database where data is represented as nodes and relationships. Our database contains the following types of nodes:
  - Project: reference to a repository (75323)
  - App: released version of a project (572131)
  - Library: resolved dependency with exact version (576144)

---

1. [https://nvd.nist.gov](https://nvd.nist.gov)
2. [https://nvd.nist.gov/products/cpe](https://nvd.nist.gov/products/cpe)
3. [https://github.com/kristinara/LibraryDependencyAnalysis](https://github.com/kristinara/LibraryDependencyAnalysis)
4. [https://github.com/kristinara/SwiftDependencyChecker](https://github.com/kristinara/SwiftDependencyChecker)
5. [https://github.com/kristinara/GraphifyEvolution](https://github.com/kristinara/GraphifyEvolution)
6. [https://libraries.io/api](https://libraries.io/api)
7. [https://github.com/CocoaPods/Specs](https://github.com/CocoaPods/Specs)
8. [https://nvd.nist.gov/products/cpe](https://nvd.nist.gov/products/cpe)
9. [https://zenodo.org/record/6376009](https://zenodo.org/record/6376009)
10. [https://neo4j.com/product/neo4j-graph-database/](https://neo4j.com/product/neo4j-graph-database/)
11. [https://zenodo.org/record/6376009](https://zenodo.org/record/6376009)
The work evolution has been studied for many different languages [3, 4]. There were certain limitations on which libraries we were able to develop. Developers are more wary of including third party libraries in their projects and might be more inclined to update library versions due to the amount of libraries, finishing the analysis was challenging. In total it took 11 days to run the dependency analysis on all libraries. Fortunately updating this database will take less time, as there are distinctive differences between Swift and other languages (for example JavaScript) that could have an effect on its third party library dependency network.

It is necessary to better understand these differences to help developers in protecting their apps against possible vulnerabilities in third party dependencies as effectively as possible. The inclusion of vulnerability data allows us to analyse the real world risks that stem from using outdated dependencies on this platform.

One of our goals was to make this database as easily accessible as possible. Therefore after the data and neo4j has been downloaded the dataset can be imported with a single command. Additionally all tools used to compile this dataset are open source and as it is possible to query last commits that were analysed and start the new analysis from that point.

8 CONCLUSIONS

We compiled a database containing the library dependency network for CocoaPods, Carthage and Swift PM. So far, the dependency networks of these package managers have not been studied yet. There are distinctive differences between Swift and other languages (for example JavaScript) that could have an effect on its third party library dependency network.

It is necessary to better understand these differences to help developers in protecting their apps against possible vulnerabilities in third party dependencies as effectively as possible. The inclusion of vulnerability data allows us to analyse the real world risks that stem from using outdated dependencies on this platform.

One of our goals was to make this database as easily accessible as possible. Therefore after the data and neo4j has been downloaded the dataset can be imported with a single command. Additionally all tools used to compile this dataset are open source and available on GitHub.

The database contains dependency information on 60533 libraries. There are 312454 dependencies between library versions and a total of 159 vulnerabilities. It took our script 11 days to analyse all libraries.
ACKNOWLEDGMENTS

Funding of this research came from the Estonian Center of Excellence in ICT research (EXCITE), the European Social Fund via IT Academy program, the Estonia Research Council grant (PRG 1226), the Austrian ministries BMVIT and BMDW, and the Province of Upper Austria under the COMET (Competence Centers for Excellent Technologies) Programme managed by FFG.

REFERENCES

[1] Lucian Constantin. 2015. HTTPS snooping flaw in third-party library affected 1,000 iOS apps with millions of users. Retrieved January 11, 2022 from https://www.computerworld.com/article/2912402/https-snooping-flaw-in-third-party-library-affected-1000-ios-apps-with-millions-of-users.html

[2] Alexandre Decan, Tom Mens, and Eleni Constantinou. 2018. On the impact of security vulnerabilities in the npm package dependency network. In Proceedings of the 15th International Conference on Mining Software Repositories. 181–191. https://doi.org/10.1145/3196398.3196491

[3] Alexandre Decan, Tom Mens, and Philippe Grosjean. 2019. An empirical comparison of dependency network evolution in seven software packaging ecosystems. Empirical Software Engineering 24, 1 (2019), 381–416. https://doi.org/10.1007/s10664-017-9589-y

[4] Tom Elliott. 2020. Swift Package Manager for iOS. Retrieved January 21, 2022 from https://www.raywenderlich.com/7242045-swift-package-manager-for-ios

[5] Jeremy Katz. 2020. Libraries io Open Source Repository and Dependency Metadata. https://doi.org/10.5281/zenodo.3626071

[6] Riivo Kikas, Georgios Gousios, Marlon Dumas, and Dietmar Pfahl. 2017. Structure and evolution of package dependency networks. In 2017 IEEE/ACM 14th International Conference on Mining Software Repositories (MSR). IEEE, 102–112. https://doi.org/10.1109/MSR.2017.55

[7] Qiang Li, Jinke Song, Dawei Tan, Haining Wang, and Jiqiang Liu. 2021. PDGraph: A Large-Scale Empirical Study on Project Dependency of Security Vulnerabilities. In 2021 51st Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN). 161–173. https://doi.org/10.1109/DSN48987.2021.00031

[8] Kristiina Rahkema and Dietmar Pfahl. 2021. GraphifyEvolution-A Modular Approach to Analysing Source Code Histories. In Proceedings of the IEEE/ACM 8th International Conference on Mobile Software Engineering and Systems. 24–27. https://doi.org/10.1109/MobileSoft52590.2021.00009

[9] Kristiina Rahkema and Dietmar Pfahl. 2022. Dependency Networks of Open Source Libraries Available Through CocoaPods, Carthage and Swift PM. https://doi.org/10.5281/zenodo.6376009

[10] Kristiina Rahkema and Dietmar Pfahl. 2022. SwiftDependencyChecker: Detecting Vulnerable Dependencies Declared Through CocoaPods, Carthage and Swift PM. In Proceedings of the IEEE/ACM 9th International Conference on Mobile Software Engineering and Systems. https://doi.org/10.1109/MobileSoft52590.2022.00006

[11] James Wetter and Nicky Ringland. 2021. Understanding the Impact of Apache Log4j Vulnerability. Retrieved January 11, 2022 from https://security.googleblog.com/2021/12/understanding-impact-of-apache-log4j.html

[12] Markus Zimmermann, Cristian-Alexandru Staicu, Cam Tenny, and Michael Pradel. 2019. Small World with High Risks: A Study of Security Threats in the npm Ecosystem. In 28th USENIX Security Symposium (USENIX Security 19). USENIX Association, Santa Clara, CA, 995–1010. https://www.usenix.org/conference/usenixsecurity19/presentation/zimmerman
This figure "libraries2.png" is available in "png" format from:

http://arxiv.org/ps/2206.06083v1
This figure "sample-franklin.png" is available in "png" format from:

http://arxiv.org/ps/2206.06083v1