



## A Case Study: An Android Security

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### ABSTRACT

Software security has made great progress; code analysis tools perform extensive checks for code defects, it is useful to have a basic understanding of the different warnings and emphasize the bug. However, this is beyond the state of the art for many types of application security flaws. Thus, such tools frequently serve for an analyst to help them zero in on security relevant portions of code so they can find flaws more efficiently, rather than a tool that simply finds flaws automatically. In cooperation with a security expert, we carried out a case study with the mobile phone platform Android, and employed the reverse engineering tool-suite Bauhaus for this security assessment. During the investigation we found some inconsistencies in the implementation of the Android security concepts. Based on the lessons learned from the case study, we propose several research topics in the area of reverse engineering that would support a security analyst during security assessments.

## 1. Introduction

Over the last years, static code analysis for security has made great progress. Commercial available tools are employed by software vendors to detect implementation-level security bugs, such as buffer overflows and injections vulnerabilities. Certainly, employing these tools is only the first step towards secure software as it is restricted to common bug classes. More seriously are design-level flaws, since literature states that the later a change must be applied to the design of an application, the more costs will arise. Methods such as Microsoft's threat modelling or the architectural risk analysis proposed by McGraw should help to discover security problems already during the software-design phase. In academia, more formal approaches to dealing with software security have been established, notably, language-based security, model-driven security, and stepwise refinement. Although these approaches are promising, they can just be applied when software is developed from scratch, which is rarely the case. Owing to the fact that our work is focused more on the aspect of program understanding we expect that program comprehension tools can help a security analyst detecting security flaws in code, such as divergences between documentation and code. We imply that none of such flaws can be detected in a fully automated way, and a security analyst must assess the situation by her own. What we yet can expect is that the tool helps us to assess the risks of the software and, for example, pinpoints security-critical areas of the code. Therefore, we chose a reverse-engineering tool-suite, called Bauhaus, to analyse a well-known security aspect, in the open-source software system Android. We compared the implementation of permission enforcement to the official Android documentation and discovered a divergence.

## 2. Related Works

Software security is an emerging research area with a strong practical impact. For example, we have static analysis tools, that focus on common implementation-level bugs which are mostly related to improper input validation. Nevertheless, these tools do not help one to understand the security aspects. To our knowledge, only a few works deal with reverse engineering the security architecture out of code. use the Software Architecture Visualization and Evaluation tool to detect a security back door — they completely removed the security check —that they added for the case study. To detect the back door they used static as well as dynamic information and compared the resulting information with the results of the correct implementation. Mancoridis reports about common bug classes and names techniques a software maintenance-engineer can use to improve the security of a software. Moreover, he emphasizes several techniques that must be developed to tackle these problems properly. He stresses that it is necessary to develop formal notations and tools to allow the specification of software-security architectures. Mancoridis assumes that the developer has the security architecture of her software in her mind, what is not necessarily the case. Sometimes literature on static code analysis treats program comprehension as a side topic, for example, Chess and West briefly mention program comprehension tools such as CAST and Fujaba in their book on static analysis for software security, but do not give further details of how they might help one to address the problem of software security.

## 3. A Case Study

It is expected that Android will become one of the major mobile phone platforms in the future and is used for other devices as well. As it gains a lot of market share and is open source, it is an interesting target for security analyses. For this reason, we started a security assessment project. During the analysis, we faced several challenges, mostly related to the lacking documentation of Android's security concepts and the complexity of the code. We started our review of the Android platform with the assumption that not only the Linux kernel is security-critical, but also the Android middleware (the Android framework classes). For example, the permission enforcement and the reference monitor,

which mediates the access to Android components, is implemented within the Java-based middleware, although the kernel is accessed to retrieve data for security decisions. We aimed to explore and understand the implementation of Android's security mechanisms. Due to the fact that the structure of the code and specifically the software architecture are unknown to us at the beginning, we used a reverse engineering tool-suite called Bauhaus, to gain a better insight into the code. Other tools such as Fujaba or CAST could have been used, too. The reason for employing Bauhaus was that the tool is available at our institute and hence had experience with it. Generally, tools for program comprehension contain functionality to represent information about the program, which can be gathered statically as well as dynamically. With the help of these tools, one can obtain information on the components, modules, classes, methods, and member variables, as well as relationships between these elements, such as call relations or member accesses. We focus our analyzes on permission checking and enforcement because access control is a basic security concept for IT systems and applications, going back to Lampson's access control matrix. Further literature on authorization can be found in standard works on computer security.

#### 4. Android Concepts

We first describe Android's main concepts, before presenting the challenges related to analyzing the platform with respect to security. Note that there does not exist a comprehensive document on Android's security concepts. The information is scattered throughout the Android developer's website.

- (a) **Android Components:** An Android application consists of different parts, called components, having, according to its task, one of four basic component types. Activities are the presentation layer of an application, allowing a user to interact with the application. Services represent background processes without a user interface. Content providers are data stores that allow developers to share databases across application boundaries. Finally, broadcast receivers are components that receive and react to broadcast messages, for example, the Android OS itself sends such a broadcast message if the battery is low. Each component of an application runs as a separate task, making an Android device to a large distributed system, even if all processes are running on the same device.
- (b) **Inter-Process Communication:** The Android platform supports inter-process communication (IPC) for communication between components. One foundation for this IPC is the Binder, an Android specific kernel device that allows efficient but safe communication. A way to communicate with components not known at the development time, are messages, which may include arbitrary data, called intents. Intent is an abstract description of an operation to be performed on the platform. For example, an intent can start a new activity or service, or communicate with background services. An advantage of this technique is that a client application is no longer linked to a specific program, but can access any possible service for the specified need.
- (c) **Android Security Mechanisms:** Android has two basic methods of security enforcement. Firstly, applications run as Linux processes with their own user IDs and thus are separated from each other. This way, vulnerability in one application does not affect other applications. In contrast to Java, the virtual machine is not a security barrier because the Linux kernel takes over the task of separating processes. Since Android provides IPC mechanisms, which need to be secured, a second enforcement mechanism comes into play. Android implements a reference monitor to mediate access to application components based on permission labels. If an application intends to access another component, the end user must grant the appropriate permissions at installation time. Furthermore, the security model has several refinements that increase the model's complexity.

## 4.1. Software Security Comprehension

In the preceding section, we showed that program- comprehension and reverse-engineering techniques can be used in the area of software security. Now, we discuss research topics that need to be investigated more deeply, to develop useful techniques and tools for a security evaluator. For our more general discussion, we also consider experience gained in a research project called ASKS, which is currently being carried out with enterprises that made available their business applications, which are implemented using the Java platform, Enterprise Edition technology, for a security analysis. One conclusion that we drew from our security review is that it is necessary to create more formal architectural security views (see also Mancoridis' statement. These views need to be language- and platform-independent in order to be a common language to communicate with security experts who are not necessarily experts for the programming language. With the help of these views, it is easier to understand the security architecture of an application or even of a distributed system. In the following, we discuss some further ideas of how these views can be created and what security aspects may be of interest for such views.

### 5.1. Possible Architectural Views

There are many software aspects related to security. In companion with our security expert, we identified some aspects that are suitable to be extracted from source and be useful for a security specialist.

- (a) Visualization of Trust Zones: It is helpful to group the identified software parts into trust zones based on the criticality of the data/components accessed. With the help of such a view, one can conduct a security-related impact analysis of changes and identified bugs, to balance out the improvements against the threats.
- (b) Visualization of Attack Surfaces: Beyond the decomposition of the code base into different zones, it is helpful to add information about the boundaries of components (architectural components or whole processes). Therefore, it is necessary to identify framework means that allow communications between processes. By means of this knowledge, it is possible to identify data sources and sinks. In combination with a dependence graph, it would be feasible to estimate the attack impact.

(c) Access Control Policy: In this section, we described how to extract parts of the access control policy of Android's Bluetooth service. Since access control is crucial to many platforms and applications, we can apply the task of extracting the access control policy on other platforms. For example, we extracted the access control policy of a Java enterprise application and compared that policy with the documentation employing the reflexion analysis.

### 5.2. Towards Automatic Extraction of Architectural Views

The aforementioned views must be created with the help of techniques already known in the reverse-engineering community, but that need to be tailored towards the specific security needs to give reasonable results.

- (a) Abstraction: From our point of view, it is inevitable to introduce graphical abstractions beyond the known visualizations, such as UML-diagrams and implementation-level dependence graphs, to make security comprehension easier. The abstraction of constructs in the software which are imposed by the framework, such as IPC mechanisms and Java Beans, would help one to concentrate on the essential parts of the application. Furthermore, it is common in current frameworks that parts of the implementation are generated automatically. During an assessment a reviewer must analyse the generated parts to "understand" the whole application and he cannot differentiate between

handwritten and generated source code. These technical entities hide the real intent behind the code. Therefore, it is necessary to remove these details and replace them with a presentation which is more meaningful to a security analyst.

- (b) **Component Detection:** A slightly different kind of abstraction is the process of component detection and aggregation, to allow a developer to build up a mental map of the system more easily. This is useful if the architectural components are spread over several classes and packages. The ideal case would be a supportive mechanism to restructure the application's representation semi-automatically such that it resembles the existing architecture, specified by domain experts. Within the reverse-engineering and program-comprehension community, there already exists experience with various clustering techniques to extract components automatically from code. The components that are of interest for detection are mostly domain- and implementation-specific, as well as the aforementioned abstractions we must introduce. Therefore, it is a necessity to involve framework experts to achieve reasonable results.
- (c) **Security Pattern Detection:** Often, security features are integrated into the software architecture by common and well-known aspects like enforcement points. Some of these aspects can be merged to security patterns which have the goal to harden software against attacks and misuse.

Existing design-pattern detection approaches, however, can only detect a few of the common design patterns. Presently, none of them supports the detection of security patterns, although ensuring security is a significant task.

Due to the fact that not everybody reengineering a system has appropriate security knowledge automated approaches of detection are desirable. When a security pattern has been detected, it can be highlighted in a software-architecture representation. Such visualized security aspects can support hardening software before it will be released or used by different user groups to post-check a software system.

## 7. Conclusion

We conducted a case study focusing on permission checking in the Android framework and showed that the Bauhaus tool-suite can support a security expert during a security assessment. We were able to enhance our understanding of the Android framework, in particular, a divergence between the documentation of the Bluetooth API and the framework implementation has been found. Moreover, the comprehension of the IPC mechanism for intents and the unexpected missing of permission checks were other results of the case study. Based on our experience, we discussed new challenges and research problems for program comprehension in security assessments. Further research must be carried out to apply the techniques of program comprehension to the field of software security. Our impression is that neither the security-research community discusses this topic adequately nor is industry making use of such techniques to better understand the security status of their software. Using state-of-the-art tools for finding security bugs cannot reveal logical security problems such as undesirable interactions between components. With the increasing complexity of software, software companies need to understand the security risks of their code, and tools employing program comprehension functionality will support them with this challenging task. We truly believe that "software-security comprehension" will be a fruitful research topic for the future with also a broad practical impact.

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