



DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Master's Thesis in Informatics

**Analysis of Android Cracking Tools and
Investigations in Counter Measurements
for Developers**

Johannes Neutze, B. Sc.





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**Analyse von Android Crackingtools und Untersuchung
geeigneter Gegenmaßnahmen für Entwickler**

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Submission Date:	March 15, 2015



I confirm that this master's thesis in informatics is my own work and I have documented all sources and material used.

Munich, March 15, 2015

Johannes Neutze, B. Sc.

Acknowledgments

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Assumptions

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Abstract

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Glossary

- .class** Java Byte Code produced by the Java compiler from a .java file.
- .dex** Dalvik Byte Code file, translated from the Java bytecode. Dalvik Executables are designed to run on system with memory or processor constraints. For example, the .dex file of the Phone application is inside the system/app/Phone.apk.
- .jar** The Java Archive is a package file containing Java class files and the associated metadata and resources of applications of the Java platform..
- .odex** Optimized Dalvik Byte Code file are Dalvik Executables optimized for the current device the application is running on. For example, the .odex file of the Phone application is system/app/Phone.odex.
- ADB** The Android Debug Bridge is a command-line application providing different debugging tools.
- API** The Android Debug Bridge is a command-line application providing different debugging tools.
- APK** An Android Application Package is the file format used for distributing and installing applications on the Android operating system. It contains the applications assets, code (.dex file), manifest and resources.
- assembler** Ein Assembler (auch Assemblierer[1]) ist ein Computerprogramm, das Assemblersprache in Maschinsprache übersetzt, beispielsweise den Assemblersprachentext „CLI“ in den Maschinsprachentext „11111010“..
- disassembler** Ein Disassembler ist ein Computerprogramm, das die binär kodierte Maschinsprache eines ausführbaren Programmes in eine für Menschen lesbarere Assemblersprache umwandelt. Seine Funktionalität ist der eines Assemblers entgegengesetzt..

Acronyms

.dex Dalvik EXecutable file.

.jar Java Archive.

.odex Optimized Dalvik EXecutable file.

ADB Android Debug Bridge.

ADT Android Developer Tools.

AOT Ahead-Of-Time.

APK Application Programming Interface.

APK Android Application Package.

ART Android RunTime.

DRM Digital Rights Management.

DVM Dalvik Virtual Machine.

ELF Extensible Linking Format.

GC Garbage Collection.

IP Intellectual Property.

JIT Just-In-Time.

JNI Java Native Interface.

JVM Java Virtual Machine.

NDK Native Development Kit.

OS operating system.

SDK Software Development Kit.

VM virtual machine.

1 Introduction

1.1 Licensing

Software Licensing is the legally binding agreement between two parties regarding the purchase, installation and use of software according to its terms of use. It defines the rights of the licensor and the licensee. On the one hand, the goal is to protect the software creator's intellectual property (IP) or other features and enable him to commercialize it as a product. On the other hand it defines the boundaries for the user and prevents him from illicit usage [40].

Since licensing software often includes fees, these products often have mechanisms implemented to enforce the legal agreement and to prevent unauthorized use. The solutions range from providing limited features or usage for a limited time to disabling the software in case no legit account or serial key is provided.

But as long as there have been these protection mechanisms there have been software pirates who tried to circumvent it. It is an everlasting arms race[41].

1.2 Motivation

According to Google's in September 2015 there were over 1.4 billion active devices in the last 30 days and a market share of almost 82.8% in Q2 of 2015 [14][23]. This giant number of Android devices is powered by Google Play [22], Google's marketplace. It offers different kinds of digital goods, as movies, music or ebooks, but also hardware. In the application section of Google Play user can chose from over 1.6 million applications for Android [44]. In 2014 Google's marketplace overtook Apple's Appstore, which had a revenue of over 10 billion in 2013, and became the biggest application store on a mobile platform [27].

The growth has many advantages. Some time ago developers only considered iOS user as profitable and thus most applications were developed for Apple's operating system (OS). Now with this reach and potential users they also focus on Android[33]. But there are downsides as well. The expanding market for Android, offering many high

quality applications, also draws the attention of software pirates. But Crackers do not only to bypass license mechanisms and offer applications for free. Redirect cash flow or distributing malware using plagiates is an lucrative business model as well. Android developers are aware of this situation [46] and express their need to protect their IP on platforms like xda-developers [37] or stackoverflow [38]. Many of the developers having problems with the license verification mechanism name Lucky Patcher as one of their biggest problems [39].

The scope of this thesis is to analyse Android cracking applications and to investigate in counter measurements for developers.

2 Foundation

Before understanding the attack mechanisms and discussing counter measurements, necessary background knowledge has to be provided. Motivation and risks of software piracy and the basics of Android will be explained as well as existing licensing solutions and reengineering tools and methodologies.

2.1 Software Piracy

According to Apple, 11 billion Dollars are lost each year due to piracy. Software piracy is defined as unauthorized reproduction, distribution and selling of software [10]. It includes the not terms of use conform installation software by an individual as well as commercial resale of illegal software. Piracy is subject on all platforms and considered stealing.

2.1.1 Developers

Especially for software developers piracy is a problem. The most apparent issue is regarding lost revenue and clear at first glance.

When people are downloading an application for free and do not pay for it, there is no revenue generated and the developer does not earn any money.

At second glance, the facts are more complex. Income is not only lost when the user is not paying on purchase, the pirate can also modify the application to influence the follow up revenue. An example for the loss of future earnings is the unlocking of inapp purchases. Inapp purchases are a popular source of income for so called freemium games or lite versions of apps. The application itself is for free but has, for example, an ingame currency (freemium) respectively limited features (lite version). The revenue is generated by offering additional ingame currency (freemium) or the unlocking of all features (lite version) in exchange for money. When the inapp purchases are unlocked, the process executed with success but no payment is transfered. Thus no earnings are generated for the developer.

An different example for the redirection of revenue is the modification of the Ad Unit ID [21]. The Ad Unit ID is responsible to assign earnings generated by an mobile advertisement to the developer. When an application is pirated, this code can be replaced

by the pirate's one. Future revenues generated by advertisements in the application will not be assigned to the developer but the pirate.

Additional problems arise when the app is taken from the environment of an official app store and moved to a blackmarket store or website. The first is the loss of control over the application. The developer can no longer provide support or updates for the application in case of malfunction. The second one is that users connect malicious behaviour to the developer and not to the pirated version. Both these issues cause mistrust in the developer and might influence future revenues which are not even connected to this application. The third problem is unpredictable traffic. When distributing an application over Google Play the developer can monitor growth and adjust eventual servers accordingly. But when the application is distributed over unknown sources the developer cannot evaluate, the traffic can increase dramatically and cause a bad user experience for legitimate users as well [30].

Developers have to live of their applications. When they do not earn money, either because the revenue stream is redirected or because their IP is stolen and commercialized by someone else, they cannot continue with developing and their skills are lost.

2.1.2 Users

Pirated software is not only bad for developers but for users as well. Users use pirated applications because they seem to be free. The application might be altered in different ways, e.g. malware can be included, it steals personal data or has changed permissions. The user will not notice it right away since these "features" often happen in the background without the knowledge of the user, e.g. send SMS using an expensive service. Even if there is no malicious content implemented, the applications can suffer from bad stability due to removed license verification. In general the risk is very high that pirated software has a worse user experience than the original.[13][30]

In general pirated software should not be installed since it cannot be ensured without deep inspection that the application is doing what it is supposed to do.

2.1.3 Android

Piracy is widespread on the Android platform. Especially in countries like China piracy is as high as 90% due to restricted access to Google Play [19]. Sources for pirated applications can be easily found on the internet. Simple searches containing "free apk" and the applications name return plenty of results on Google Search. The links direct to blackmarket applications, as Blackmart [11], and websites for cracked Android

Application Package (APK)s, as crackApk[18]. These providers claim to be user friendly because they offer older versions of applications or do not charge money for complete version of applications. In general they practice professional stealing and are dangerous for users. When downloading an APK it is not possible to guarantee the integrity of the program.

An example for the dimensions piracy can reach for a single application is "Today Calendar Pro". The developer stated in a Google+ post that the piracy rate of the application is as high as 85%. This results in only 15% being legitimately purchased and installed. [37][46]

For this reason some developers do not implement any copy protection at all since it is cracked within days [24]. Especially Android applications are at high risk for piracy due bytecode in general is an easy target to reverse engineer.

2.2 Android

Android is an open source mobile OS launched in 2007 and currently developed by Google. It is based on the Linux kernel and targets touch screen devices as mobile devices or wearables. The system is designed to run efficiently on battery powered devices with limited hardware and computational capacity. Android's main hardware platform is the ARM architecture since these processors with their low power consumption are often used in this scenario. The following will give an quick overview over the architecture of Android and a deeper insight in the runtime powering Android.

The architecture of the software stack of Android can be seen in figure 2.1.

The basis of the system is its kernel. The kernel is responsible for power and memory management and is capable to execute standard Unix commands. It provides an hardware abstraction layer for software and controls the device drivers.

The layer on top of the kernel contains Android RunTime (ART), which will be explained in detail, as well as the the native libraries of the system. Android libraries are usually written in Java except these native and speed critical ones. They are written in C or C++ and allow low level interaction between applications and the kernel by using the Java Native Interface (JNI). This includes libraries like OpenGL, multimedia playback or the SQLite database.

Above this layer is the application framework. The application framework provides generic functionality as notification support to applications over Androids Application Programming Interface (API).

Applications are installed and executed on the top layer.

This structure enables Android to be run on a wide range of devices.

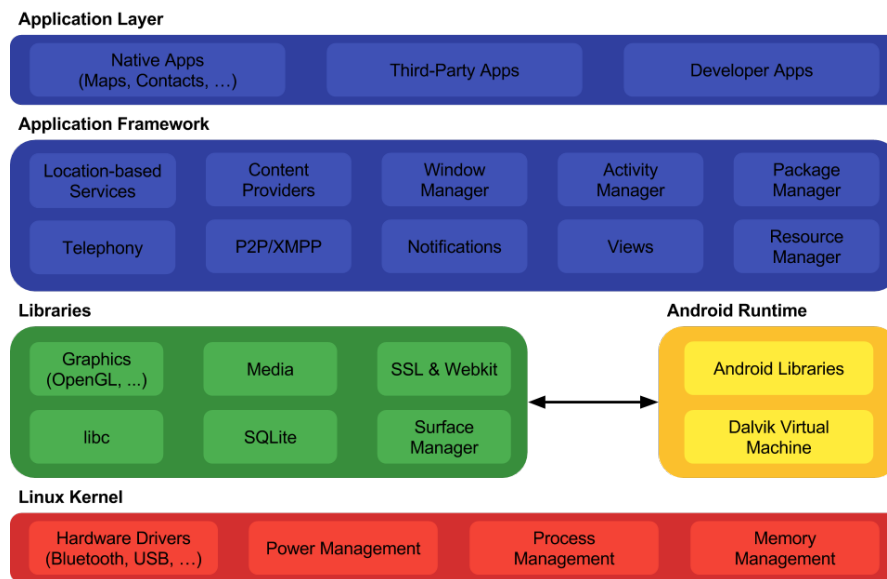


Figure 2.1: Android's architecture [32]

2.2.1 Android Application Package (APK)

Android applications are installed and distributed in the APK file format. They can either be installed from an appstore like Google Play or downloaded and installed manually or by using Android Debug Bridge (ADB) from any other source. The APK format is based on the ZIP file archive format and contains the resources of the application. The resources are added in the build process which is visualized in figure 2.2.

Android applications are usually written in Java.

step 1 Java files which will be compiled into .class files by a Java Compiler, similar to a Java program build process, class files contain Java bytecode representing the compiled application, optional step apply a Java Obfuscator

Standard Java environment compiles each separate class in the .java source code file into a corresponding Java bytecode .class file. Each class will be compiled into a single .class file. These are later packed together in a single .jar archive file. The JVM unpacks the .class files, parses and executes their code at runtime.

step 2: transformation from Java bytecode into Dalvik bytecode, see oben, dx programm from android sdk (due to it is necessity for building an application for the Android platform), output saved in singel .dex file, included in an APK in next step, possible to apply a further obfuscator operating on Dalvik bytecode(ERKLÄRUNG)

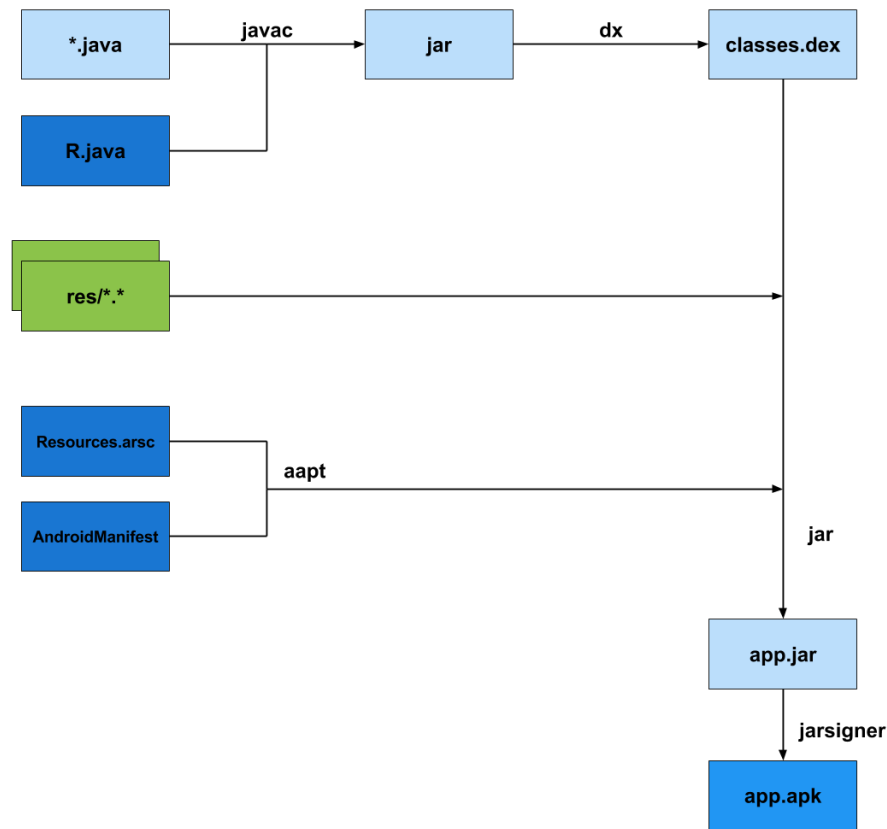


Figure 2.2: APK build process [29]

On the Android platform, the build process differs after the point when the .class files have been generated. Once having the latter, they are forwarded to the “dx” tool which is part of the standard Android SDK. This tool compresses all .class files into a single `classes.dex` file i.e. the .dex file is the sole bytecode container for all the application’s classes. After it has been created, the `classes.dex` is forwarded to the `ApkBuilder` tool altogether with the application resources and shared object (.so) files which, if present, contain native code. As a result, the APK archive is created and the final compulsory step is its signing. Figure 1.2 shows the APK build process and the possible obfuscation manipulations which are optional during the build stages

In the third step the `ApkBuilder` creates an APK which includes the `classes.dex` file and other resources. `classes.dex`: The classes compiled in the dex file format understandable by the Dalvik virtual machine

In the fourth and final step the jarsigner adds the developers signature to the package. lib: the directory containing the compiled code that is specific to a software layer of a processor, the directory is split into the different processor types res: the directory containing resources not compiled into resources.arsc (see below). assets: a directory containing applications assets, which can be retrieved by AssetManager. resources.arsc: a file containing precompiled resources, such as binary XML for example. AndroidManifest.xml: An additional Android manifest file, describing the name, version, access rights, referenced library files for the application. This file may be in Android binary XML that can be converted into human-readable plaintext XML with tools such as AXMLPrinter2, android-apktool, or Androguard. classes.dex: The classes compiled in the dex file format understandable by the Dalvik virtual machine

The signing does not improve security of the application itself but makes it possible to identify the developer and makes it possible to install updates for the application. META-INF directory: MANIFEST.MF: the Manifest file CERT.RSA: The certificate of the application. CERT.SF: The list of resources and SHA-1 digest of the corresponding lines in the MANIFEST.MF file

2.2.2 Dalvik Executable File Format

Android applications deliver their code in Dalvik EXecutable (.dex) bytecode. Applications on Android are executed by the Dalvik Virtual Machine (DVM) in .dex bytecode. It can be compared to Java bytecode except some differences. While the Java virtual machine (VM) is stack-based the DVM is register-based, this circumstances have influence on the code. The Java bytecode is actually more compact than dex since it uses 8bit constants .dex which has instructions of 16bit multiples.

The bytecode is more suited to run on the ARM architecture since it supports direct mapping from dex registers to the registers of the ARM processor. Registers in .dex bytecode are 32bits wide and store values such as integers or float values. In case there are 64bit values, adjacent registers are used to store it. The .dex bytecode supports 218 valid opcodes which have a dest-sort ordering for its arguments. The instructions refer to indexes in pools.

The applications for Android are written using the Java programming language. The process can be seen in figure 2.2. The first steps are similar to the build process of Java applications. In the first step the Java files are compiled The Java files are compiled into .class files by the Java compiler step 1: Java files which will be compiled into .class files by a Java Compiler, similar to a Java program build process, class files contain Java bytecode representing the compiled application, optional step apply a Java Obfuscator

When compiling, the application is first compiled to .jar file using the Java compiler

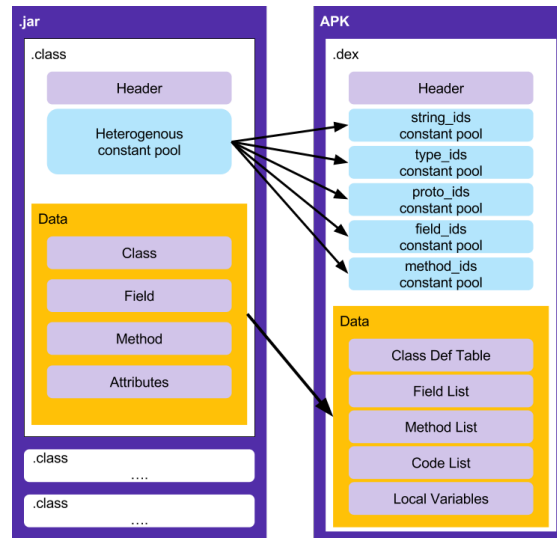


Figure 2.3: Java Archive (.jar) to APK transformation [12]

javac. The jar contains the .class, which are the Java classes in bytecode, as well as the heterogenous constant pool. In order to create the dex file, which is called classes.dex, dx is used on the .jar file. Dx compiles the Java bytecode to .dex byte code and sorts string, type and method from the heterogenous pool in seperated pools and removes dublicates. This results in figure 2.3 This is most effective for string and this action results in a memory footprint which is up to 44% lower than the one of the .jar. The result is that the .dex file has significant more references than the .jar file. The .dex file is stored as classes.[20]

Like Java bytecode .dex bytecode allows easy decompilation to Java. Also since the bytecode is in contrast to other architectures pretty simple and only in rare cases protection is applied, it is an easy target for reverse engineering.

Since .dex bytecode supports optimization, improvements for the underlying architecture can be applied to the bytecode upon installation. The resulting .dex file is called Optimized Dalvik EXecutable (.odex). The optimizations are executed by a programm called dexopt which is part of the Android plattform. For the DVM it makes no difference whether .dex or .odex files are executed, except speed improvements.

2.2.3 Installing an APK

Installation two steps: primary is the APK verification and secondary is the bytecode optimization/art

legitimate signature as well as correct classes.dex structure cannot be verified are

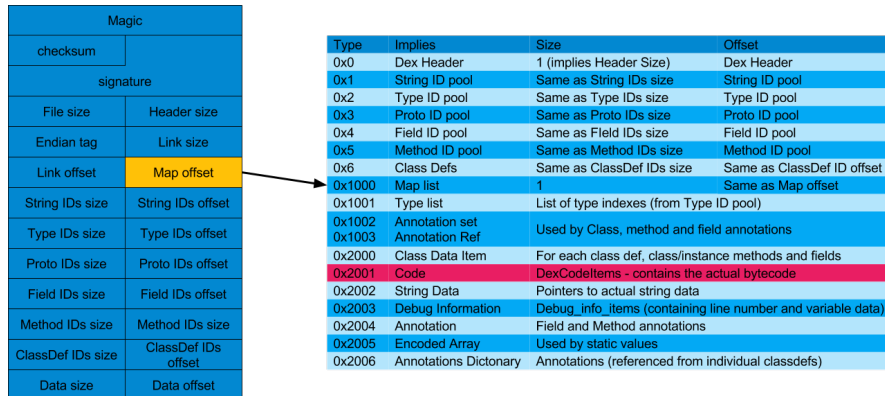


Figure 2.4: .dex file format [29]

rejected for installation by the OS

Once verified, the .dex file is forwarded for optimization: a necessary step due to the high diversity of Android running hardware (dex)-see- Dalvik executable is a generic file format which needs additional processing to achieve best performance for the concrete device architecture (odex)

optimization

step removes the classes.dex from the original APK archive and loads in memory the .odex file upon execution, occurs only once, during the initial run of the application which explains the usually slower first application launch comparing to the subsequent ones[26]

In order to create a sandboxed environment, Android assigns each application a separate user ID on install to ensure that nobody except users with the same ID can access the applications resources. The Android operating system is a multi-user Linux system in which each app is a different user. By default, the system assigns each app a unique Linux user ID (the ID is used only by the system and is unknown to the app). The system sets permissions for all the files in an app so that only the user ID assigned to that app can access them Each process has its own virtual machine (VM), so an app's code runs in isolation from other apps. By default, every app runs in its own Linux process. Android starts the process when any of the app's components need to be executed, then shuts down the process when it's no longer needed or when the system must recover memory for other apps[5]

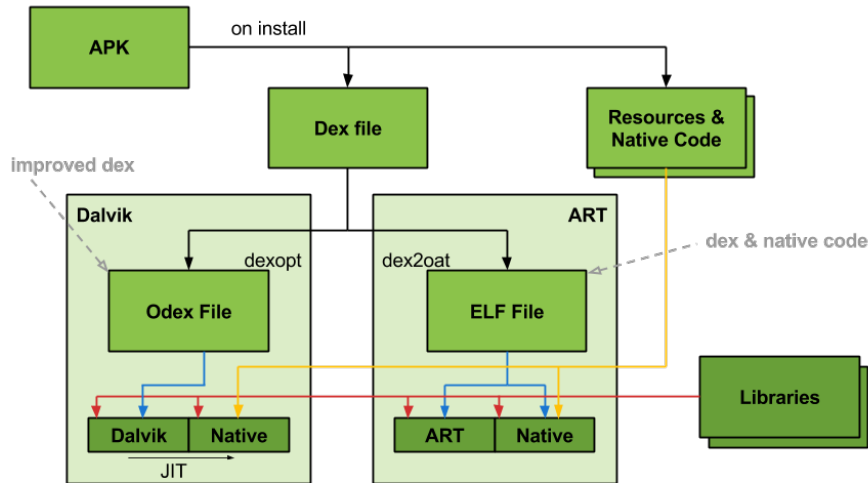


Figure 2.5: Installing an APK on a device [9]

2.2.4 Dalvik Virtual Machine

The DVM, created by Dan Bornstein and named after an Icelandic town, was introduced along with Android.

In contrast to a stationary computer a mobile device have a lot of constraints. Since they are powered by battery the processing power and RAM are limited to fit power consumption. In addition to these hardware limitations Andriod has some additional requirements, like no swap for the RAM, the need to run on a diverse set of devices and a sandboxed application runtime . In order to run efficient it has to be designed according to these requirements. The DVM a customized and optimized Java Virtual Machine (JVM) based on Apache Harmony and thus is related to Java. It is not fully J2SE or J2ME compatible since it uses 16bit opcodes and register-based architecture in contrast to the standard JVM being stack-based and using 8bit opcodes. The advantage of register-based architecture is that they need less instructions for execution than stack-based architecture which results in less CPU cycles. The downside is an approximately 25% larger codebase and negligible larger fetching times [20]. In addition to the lower level changes the DVM is optimized for memory sharing, it stores references bitmaps seperately from objects and optimizes application startup by using zygotes [29].

The last change made to DVM was the introduction of Just-In-Time (JIT) in Android version 2.2 "Froyo".

2.2.5 Android Runtime

<https://source.android.com/devices/tech/dalvik/index.html>

In Android version 4.4 "Kitkat" Google introduced ART which was optional and only available through the developer options. With the release of version 5.0 "Lollipop" ART it became the runtime of choice since DVM had some major flaws.

JIT is slow, consuming both cycles and battery power garbage collection causes hangs/jitters dalvik is 32bit, cannot benefit from 64bit architecture

art introduced in kitkat 4.4, available only through developer options, declared to be preview release, own risk, very little documentation, if any in lollipop art becomes runtime of choice, supersedes dalvik, breaks compatibility with older dex, as well as itself, very little docu constantly evolving through marshmallow, major caveat : oftenc changes in between android minor versions, android optimizes apps everytime you update

art was designed to address shortcomings of dalvik: virtual machine maintenance is expensive, interpreter/jit simply aren't efficient as native code, doing jit all over again on every execution is wasteful, maintenance threads require significantly more cpu cycles, cpu cycles translate to slower performance and shorter battery life dalvik garbage collection frequently causes hangs/jitter virtual machine architecture is 32bit only, android is following ios into 64bit space

advantages of art art moves compilation from JIT to Ahead-Of-Time (AOT) VM maintenance not as expensive as dalvik, art compiles to native AOT not JIT, less maintenance threads and overhead cycles than dalvik garbage collection parallelizable (foreground/background), non blocking -see- QUELLE 64bit bus some issues still exist -see- quelle

main idea of art/aot: actually compilation can be to one of two types, quick (native code), portable(llvm code) in practice preference is to compile to native code, portable implies another layer of IR (LLVM's bit code)

Art itself: art uses not one but two file formats art - only one file, boot.art, in /system/framework/architecture (arm,...) oat - master file, boot.oat, in /system/framework/architecture (arm,...) - odex files no longer optimized dex but oat, alongside apk for system apps/frameworks, /data/dalvik-cache for 3rd party apps, still uses odex extension, now file format is elf/oat

art files is a proprietary format, poorly documented, changed format internally repeatedly art file maps in memory right before oat, which links with it contains pre-initialized classes, objects and support structures

ART/OAT files are created (on device or on host) by dex2oat art still optimizes dex but uses dex2oat instead, odex files are actually oat files (elf shared objects WAS IST DAS), actual dex payload buried deep inside command line saved inside oat file's key value

store

```

shell@flounder ~ dextra -h /system/framework/arm64/boot.oat
..
Key value store Len: 2318
Key: debuggable Value: false
Key: dex2oat-cmdline Value: --runtime-arg -Xms64m --runtime-arg -Xmx64m --image-
classes=frameworks/base/preloaded-classes
--dex-file=out/target/common/obj/JAVA_LIBRARIES/core-libart_intermediates/javali
b.jar
--dex-file=out/target/common/obj/JAVA_LIBRARIES/conscrypt_intermediates/javali
b.jar
--dex-file=out/target/common/obj/JAVA_LIBRARIES/okhttp_intermediates/javali
b.jar
..
--dex-file=out/target/common/obj/JAVA_LIBRARIES/org.apache.http.legacy.boot_intermediates/javali
b.jar
--dex-location=/system/framework/core-libart.jar
...
--dex-location=/system/framework/org.apache.http.legacy.boot.jar
--oat-symbols=out/target/product/flounder/symbols/system/framework/arm64/boot.oat
--oat-file=out/target/product/flounder/dex_bootjars/system/framework/arm64/boot.oat
--oat-location=/system/framework/arm64/boot.oat
--image=out/target/product/flounder/dex_bootjars/system/framework/arm64/boot.art --base=0x70000000
--instruction-set=arm64 --instruction-set-variant=denver64 --instruction-set-features=default
--android-root=out/target/product/flounder/system --include-patch-information --runtime-arg
-Xnorelocate --no-generate-debug-info
Key: dex2oat-host Value: x86_64
Key: pic Value: false

```

Figure 2.6: oat

art file format

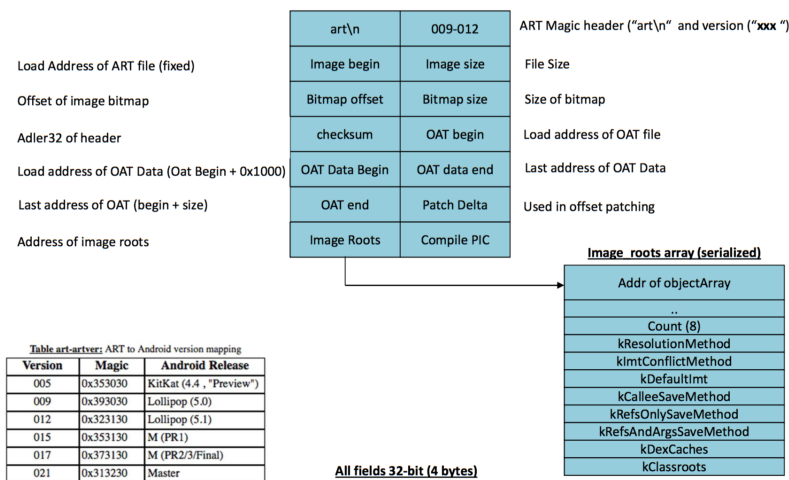


Figure 2.7: art

the oat dexfile header oat headers are 1...n dex files, actual value given by dexfilecount field in header

finding dex in oat odex files will usually have only one (=original) dex embedded booat.oat is something else entirely, some 14 dex files the best of the android framework jars, each dex contains potentially hundreds of classes

2 Foundation

Lollipop (5.x)	
art\n	009-012
Image begin	Image size
Bitmap offset	Bitmap size
checksum	OAT begin
OAT Data begin	OAT data end
OAT end	Patch Delta
Image Roots	Compile PIC

Marshmallow (PR1)	
art\n	015
Image begin	Image size
ART Fields Offset	ART Fields Size
Bitmap offset	Bitmap size
checksum	OAT begin
OAT Data begin	OAT data end
OAT end	Patch Delta
Image Roots	Compile PIC

Marshmallow (PR2-Release)	
art\n	017-???
Image begin	Image size
OAT checksum	OAT begin
OAT Data begin	OAT Data end
OAT end	Patch Delta
Image Roots	Size of Pointer
Compile_pic	Objects Offset
Objects Size	Fields Offset
Fields Size	Methods offset
Methods size	Strings Offset
Strings size	Bitmap offset
Bitmap size	

... Followed by Image Roots

All fields 32-bit (4 bytes)

Figure 2.8: art2

art code generation oat method headers point to offset of native code each method has a quick or portable method header, contains mapping from virtual register to underlying machine registers each method has a quick or portable frame info, provides frame size in bytes, core register spill mask, fp register spill mask generated code uses unusual registers, especially fond of using lr as call register, still saves/restores registers so as not to violate arm conventions

art supports mutiple architectures(x86,arm/64,mips) compiler is layered architecture, using portable (llvm) adds another lvl with llvm bitcode (not in this scope)
vergleich java/dex/odex(art) code

lessons base code is dex so vm is still 32bit, no 64bit registers or operands so mapping to underlying arch inst always 64bit, there are actually a frw 64bit instructions but most dex code doesnt use them generated code isnt always that efficient, not on same par as an optimizing antive code compiler, likely to improve with llvm optimizations overall code (determined by Mir optimizations) flow is same garbage collection, register maps, likewise same cavears: not all methods guaranteed to be compiled, reversing can be quite a pain

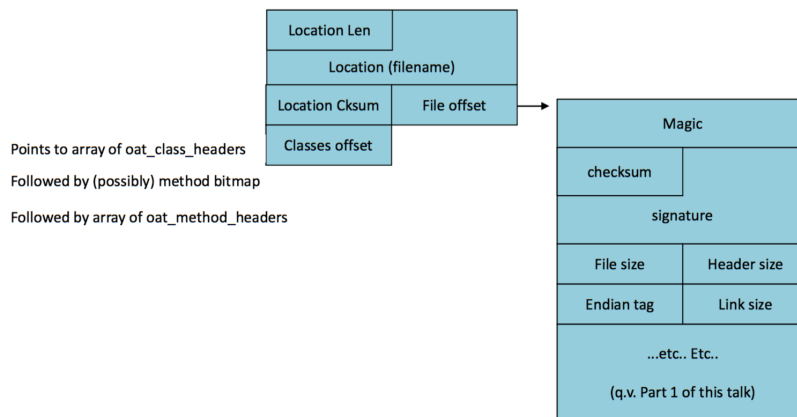


Figure 2.9: oatdex

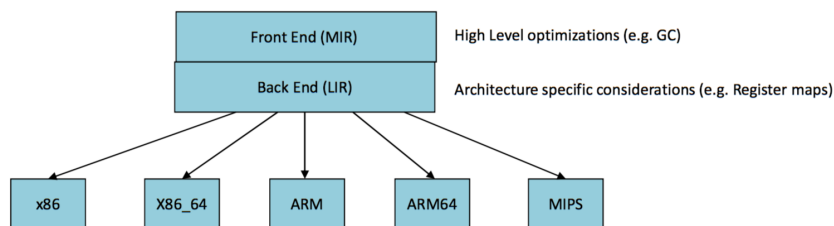


Figure 2.10: artarch

ART runtime threads the daemon threads are started in java by libcore, daemon class wraps thread class and provides singleton INSTANCE, do same basic operations as they did in "classic" dalvikVM, libart subtree in libcore implementation slightly different

isn't android all dalvik now? art is runtime but application compile into dex, art is compiled on device during install, art binaries has dalvik embedded, some methods may be left as dex to be interpreted, dalvik is much easier to debug than art –see-evaluation
[29]

2.2.6 Copy Protection and Root

unauthorized usage of an app through copy protection apk was installed in a location on the phone /data/app user could not access useless if single user can get apk and redistribute, gained by root successful as long as root was not easy for everyone -see-samsung rooting odin QUELLE, did not have too big impact as today, oneclick root kits QUELLE, standard for nexus

on install app's classes.dex is copied an optimized version (odex) to dalvik cache /data/dalvik-cache/, for faster startup (contains system apps and frameworks as well) odex erklären, byteswapping, structure realigning and memory-mapping when app is started optimized code from dalvik cache will be executed instead of apk old system was to put APK in folder user cannot access, unless you root weak, almost non-existent, anyone who can copy it can distribute it

It replaces the old system copy protection system, wherein your APKs would be put in a folder that you can't access. Unless you root. Oh, and anyone who can copy that APK off can then give it to someone else to put on their device, too. It was so weak, it was almost non-existent. kann mit root umgangen werden

Im original vom Markt direkt heruntergeladen und dann wird sie an den ort geschoben und kann nicht mehr zugegriffen werden -see- rechte etc, QUELLE

getting root/rooting process of modifying the operation system that shipped with your device to grant you complete control over it overcome limitations by carriers/-manufacturers, extend system functionality, upgrade to custom flavor root comes from Linux OS world, most privileges user on the system is called root rooting fairly simple, many videos and tutorials, sometimes oneclick tools not approved by manufacturers or carriers, can not prevent usually exploits vulnerability in operating system code or device drivers, a list of root vulnerabilities can be found on <http://androidvulnerabilities.org/all>, allows the "hacker" to upload a special program called su to the phone, su provides root access to programs that request it usually superuser permissions bundled with root approve/deny requests from applications who want root replaces conventional password with approve/deny, not secure but much more convenient rooting the phone modifies the software thus can brick the phone, meaning the phone is nonfunctional since the software is broken

rooting has benefits access all files on the phone, even those which the normal user has no permissions for, modify add delete

examples modify system variables, e.g. to utilize the notification led on motorola devices which is usually disabled install custom roms

but there are downsides as well android's content protection are invalid when rooted DRm can be bypassed coupled with dex decompilation big problem, app can be decompiled, modded and repackaged[28]

2.3 License Verification Libraries

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Since the original approach of subsection 2.2.6 was voided, another method had to be introduced due to ineffectiveness and rising pressure from developer community, google as owner of android and its biggest sore released lvi - <https://developer.android.com/google/play/licensing/overview.html> auch für andere stores interessant da selbe probleme und wollen developer binden amazon (eigenes ökosystem, pushen mit underground und billigen tablets die als einstieg dienen und app store soll generieren), samsung (wollen was besonderes sein, wie apple, spezielle apps für galaxy/note devices, haben auch eigene services), gibt auch chinesische aber die nicht genau betrachtet da nur in china relevanz und westliche eher auf westlichen market (vllt besonderheiten), ausserdem proivder noch [31]

put copy protection methods into app itself, kind of DRM

First looks great, puts the copy protection inside the app, a from of DRM communicate with server, authorize use of application does not prevent user from copying/transferring app, but copy useless since the app does run without the correct account

google die ersten, andere folgen, anfangs problem, dass dadurch nur durch google store geschützt war, grund dafür dass evtl ein programmierer in meinen store kommt

2.3.1 Google's License Verification Library

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network service, queries Licensing Server from Google check whether current user has license library provided by google transparent since google delivers code

[31]

manages a connection between your app and Google Play, performs a license check with server to see if valid license (.e.g purchased from google play) Digital Rights Management (DRM) [25]

introduced to fight piracy in Google Play, introduced 07/27/2010 simple and free service [16]

Functional Principle

This is my real text! Rest might be copied or not be checked!

integrate into application by developer, allows simple checking and callback process with google asks google play app whether the app was bought on the appstore by the

user, takes care of the complicated process (webservice, network etc) on respond google app passes response to the callback

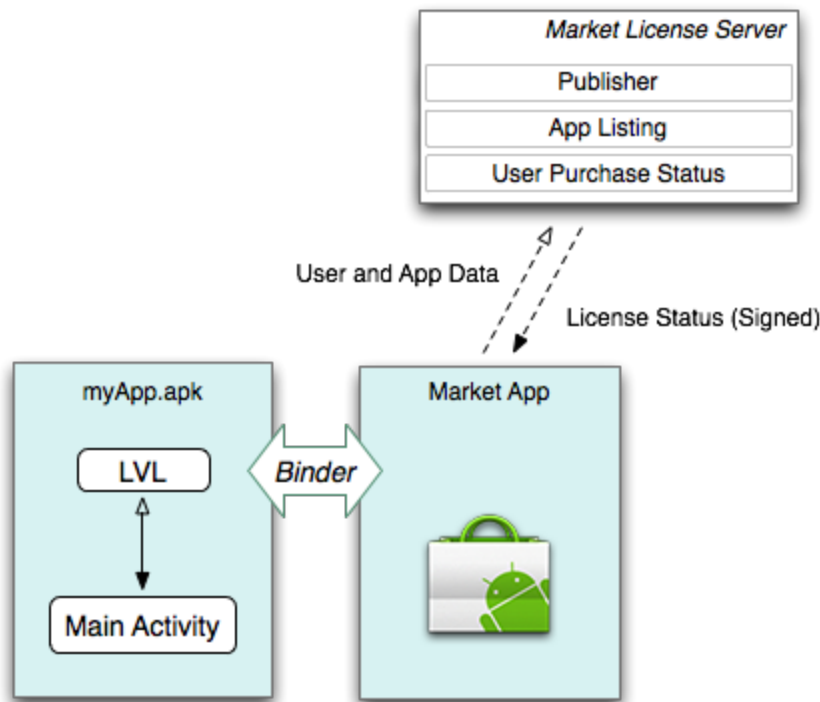


Figure 2.11: Google's implementation of license checking [7]

determine license status of an app, licensing service needs two information: - package name of app, a nonce that has to be present in every server response to ensure attacker security, callback for async handling of server response, implemented in initial license check - user - specific info user and device such as primary google acc and imsi, collected and provided by google play - google play

security of response important every published app in playstore, play generates public/private key pair, developer gets public key public key is embedded into app google play licensing server signs response with app private key public key used to check signature of response, effective mechanism is established to ensure origin and detect tampering [31]

The information about the application, the device and the user goes off to Google's servers. Google then checks your name against the list of people it knows have paid for the application on Google Play. (It could also check the name of the application against a list of applications it knows that you've downloaded from Google Play) If it can see

that you have downloaded (and paid for) the application from Google Play it sends back that you have a license, if not then it tells the app you don't.

request starts when app initiates to service on Google Play client application Google Play sends request to licensign server and receives result google play passes it to app and app decides what happens [7]

network based service lets query trusted Google Play licensign server, determine whether application is licensed for current user based on buyers database when, and how often, you want your application to check its license control over how it handles the response, verifies the signed response data, and enforces access controls

need internet, Google account (else you werent able to buy the applciations), google play installed adding licensing to app does not affect way the app functions when run on a device that does not offer Google Play

saves license on device with timed life

replace as copy protection flexible, secure mechanism for controlling access to ap-
plication replaces copy protection mechanism which is no longer supported that was
previously offered on Google play license based model that is enforceable on all devices
that have acces to google play access is not bound to characteristics of host device, but
google play and licensing policy definded can be installed, manages on any device and
any storage, even SD card [7]

no google services licensechecker, checkAccess: Could not bind to service. activity,
callback: license not verified

airplane first time licensechecker, responsecode: ERROR_CONTACTING_SERVER =
0x101 = 257 activity, callback: license not verified second time stored license[4]

a la: für die erste registrierung ist internet nötig...

Implementation of the License Verification Library

This is my real text! Rest might be copied or not be checked!

run time, set of libraries provided by google app can query Google Play licensing
Server to determine the license status of user returns information on whether your user
is authorized to use the app based on stored sales revords real time over network [16]

what you need

google publisher account on google play google play developer console at Services &
API, app specific public key for licensing, implement it into the application copy it later
into the app

[4]

- Adding the licensing permission your application's manifest
- Implementing a Policy, provided by LVL or own - Implementing an Obfuscator, if
Policy caches any license response data. 2.2 line 59, cannot be reused or manipulated

```
7 ...  
8 <uses-permission android:name="com.android.vending.CHECK_LICENSE" />  
9 ...
```

Code Snippet 2.1: Include permission to check the license in AndroidManifest.xml

by a root user - adding code to check license in application main activity_main [4]

<https://developer.android.com/google/play/licensing/setting-up.html>

<https://developer.android.com/google/play/licensing/adding-licensing.html>

```
57 final String mAndroidId = Settings.Secure.getString(this.getContentResolver(),  
58     Settings.Secure.ANDROID_ID);  
59 final AESObfuscator mObfuscator = new AESObfuscator(SALT, getPackageName(),  
    mAndroidId);  
60 final ServerManagedPolicy serverPolicy = new ServerManagedPolicy(this, mObfuscator);  
61 mLicenseCheckerCallback = new MyLicenseCheckerCallback();  
62 mChecker = new LicenseChecker(this, serverPolicy, BASE64_PUBLIC_KEY);  
63  
64 mChecker.checkAccess(mLicenseCheckerCallback);
```

Code Snippet 2.2: Setting up the LVL license check call

2.3.2 Amazon DRM (Kiwi)

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Amazon wants piece of Android pie, also earn money from selling apps, alternative to Google play Amazon introduced its appstore on the 03/22/2011 for Android and Fire tablets comes with own DRM which is free to enable/disable by developer[2] since the Google LVL only works with Google Play named Kiwi (taken from decompilation) store is completely independent [3]

Functional Principle

This is my real text! Rest might be copied or not be checked!

sis is text was sind voraussetzungen? amazon app, account active der die app hat

high level prerequisites amazon developer account

when uploading the app, user is asked whether

different approach to perform license verification and enforce result google lvl include and integrate modified version of lvl library, not required to implement any mechanism

```

57 private class MyLicenseCheckerCallback implements LicenseCheckerCallback {
58
59     @Override
60     public void allow(final int reason) {
61         ...
62     }
63
64     @Override
65     public void dontAllow(final int reason) {
66         ...
67     }
68
69     @Override
70     public void applicationError(final int errorCode) {
71         ...
72     }
73 }

```

Code Snippet 2.3: LVL license check callback

Apply Amazon DRM? Protect your application from unauthorized use. Without DRM, your app can be used without restrictions by any user.

☒ Yes (Recommended) ☐ No

Appstore Certificate Hashes
As part of the ingestion process Amazon removes your developer signature and applies an Amazon signature. This signature is unique to you, does not change, and is the same for all apps in your account.

SHA-1 ⓘ	Hexadecimal	53:A8:F2:16:61:15:B0:D8:3B:2E:D2:BC:9B:80:7B:F7:64:F6:E3:2C
	Base64	U6jyFmEVsNg7LtK8m4B792T24yw=
MD5 ⓘ	Hexadecimal	F8:C6:B6:83:39:5F:85:AA:D3:D2:BF:84:74:C7:D9:9C
	Base64	+Ma2gzlfharT0r+EdMfZnA==

Figure 2.12: Developer preferences in the Amazon developer console [1]

on their own, done by amazon packaging tool when submitting can check amazon DRM (see picture), apply amazon DRM to "Protect your application from unauthorized use. Without DRM, your app can be used without restrictions by any user." as the description says "As part of the ingestion process Amazon removes your developer signature and applies an Amazon signature. This signature is unique to you, does not change, and is the same for all apps in your account." as the description says, so developer signing the application by the developer before submitting is not necessary, amazon decompiles apk, injects drm code, compiles it and signs it with the "amazon developer" certificate [31]

amazon appstore has to be installed the whole time and user has to be logged in order that the DRM works

airplane first time activity, callback: license not verified second time stored license

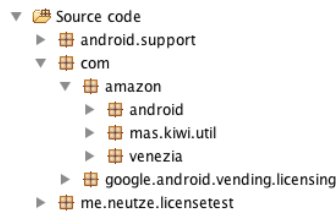


Figure 2.13: Amazon library structure in decompiled application

Implementation of Kiwi

This is my real text! Rest might be copied or not be checked!

kind of wrapper no sample implementation to add by developer but inject own logic in each app (same for every app)

example shows implementation recovered by reengineering explained in 2.4 amazon drm contains numerous namespaces and calsses, most have been mangled by obfuscation tools, see proguard startup in main activity myActivity drm logic not interweaved with app logic, could only be done by a human developer anyways

[31]

```
77 public void onCreate(Bundle bundle) {  
78     onCreateMainActivity(bundle);  
79     Kiwi.onCreate((Activity) this, true);  
80 }
```

Code Snippet 2.4: Amazon's onCreate() injection to call Kiwi license verification as well

rename onCreate to onCreateMainActivity start in new onCreate, also start Kiwi.onCreate((Activity) this, true); which handles the

2.3.3 Samsung DRM (Zirconia)

This is my real text! Rest might be copied or not be checked!

Samsung as a major player in the smartphone business has also his own app store [17] Galaxy Apps by Samsung, formerly known as Samsung Apps, for devices by Samsung renamed in July 2015 called zirconia for android [35]

Functional Principle

This is my real text! Rest might be copied or not be checked!

library prohibiting reventive measure against illegal reproduction works only on samsung devices since samsung store has to be installed and logged in inspects the license of application executed to prevent illegal use checks for license from license server upon init and stores it on device for future offline check, timed life also checks if license from server if stored license has been removed or damkages, license from server unique for each device/application if app is copied to another device, application will not execute

interior process: makes query for stored licensetest if found, app can execute if not exist or invalid, infromation of device and applciation will be send to server (once stored internet connection not required anymore) if purchased for device, server returns license back to zirconia zirconia stores license on device return step 1

callback method, asynch, zirconia does not return license validity result as boolean 2.6 does not work if network is offline or in airplane

[35]

no store services needed, direct communication with server

airplane first time activity, callback: license not verified second time verified if license was stored

Implementation of Zirconia

This is my real text! Rest might be copied or not be checked!

java package .jar and JNI native library have to be added to project for check and query of license server zirconia needs device info and internet connection (READ_PHONE_STATE and INTERNET permission)

4 basics steps (see 2.5) create

can be implemented in any stage of the application, e.g. start or when saving

[35]

```
57 final Zirconia zirconia = new Zirconia(this);
58 final MyLicenseCheckListener listener = new MyLicenseCheckListener();
59 listener.mHandler = mHandler;
60 listener.mTextView = mStatusText;
61 zirconia.setLicenseCheckListener(listener);
62 zirconia.checkLicense(false, false);
```

Code Snippet 2.5: Setting up the Zirconia license check call

```
57      @Override
58      public void licenseCheckedAsValid() {
59          mHandler.post(new Runnable() {
60              public void run() {
61                  ...
62              }
63          });
64      }
65
66      @Override
67      public void licenseCheckedAsInvalid() {
68          mHandler.post(new Runnable() {
69              public void run() {
70                  ...
71              }
72          });
73      }
```

Code Snippet 2.6: Zirconia license check callback

2.4 Code Analysis

The Cracking Tool has to alter an application's behaviour by applying patches only to the APK file, since it is the only source of code on the phone. This is the reason for the investigations to start with analysing the APK. This is done using static analysis tools. The aim is to get an accurate overview of how the circumventing of the license verification mechanism is achieved. This knowledge is later used to find counter measurements to prevent the specific Cracking Tool from succeeding.

The reengineering has to be done by using different layers of abstraction. The first reason is because it is very difficult to conclude from the altered bytecode, which is not human-readable, to the new behaviour of the application. The second reason is because the changes in the Java code are interpreted by the decompiler, which might not reflect the exact behaviour of the code or even worse, cannot be translated at all.

These problems are encountered by analysing the different abstraction levels of code as well as different decompilers.

recover the original code of an application bytecode analysis is most often used. By applying both dynamic and static techniques to detect how behavior is altered dynamic analysis during runtime, static raw code, done by automatic tools using reverse engineering algorithms, best case whole code recovered, worst case none

When speaking of reverse engineering an Android application we mostly mean to reverse engineer the bytecode located in the dex file of this application.

The classes.dex file is a crucial component regarding the application's code security because a reverse engineering attempt is considered successful when the targeted source code has been recovered from the bytecode analysis. Hence studying the DEX file format together with the Dalvik opcode structure is tightly related to both designing a powerful obfuscation technique or an efficient bytecode analysis tool. [26]

dex to java .dex and .class are isomorphic dex debug items map dex offsets to java line numbers tools like dex2jar can easily decompile from dex to a jar extremely useful for reverse engineering, even more so useful for malice

flow from dex to java is bidirectional, decompile code back to java, remove annoyances

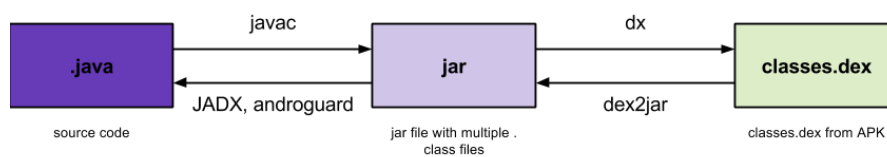


Figure 2.14: Java .class and .dex can be transformed bidirectional [29]

like ads, registration, uncover sensitive data (app logic, secrets), replace certain classes with others (malicious ones), recompile back to jar, then dex, put cloned/trojaned version of your app on play or other market [29]

android vulnerability of app is reverse engineering the source code, patching security mechanism and recompiling the app best case scenario is obtaining one to one copy of original source code since reading and understanding high level code is easiest so will the patching be reality often not possible due various protecting of source code, also unnecessary since lower level representation of source code might be enough to reveal mechanism patch and compile low level code tools and documentation have matured many tools and techniques

gaining information about a program and its implementation details, process aims at enabling an analyst to understand the concrete relation between implementation and functionality, optimal output of such a process would be the original source code of the application, not possible in general

Therefore, it is necessary for such a process to provide on the one hand abstract information about structure and inter-dependencies and on the other hand result in very detailed information like bytecode and mnemonics that allow interpretation of implementation

hoffentlich starting points für investigations

java, e.g. read the program code faster

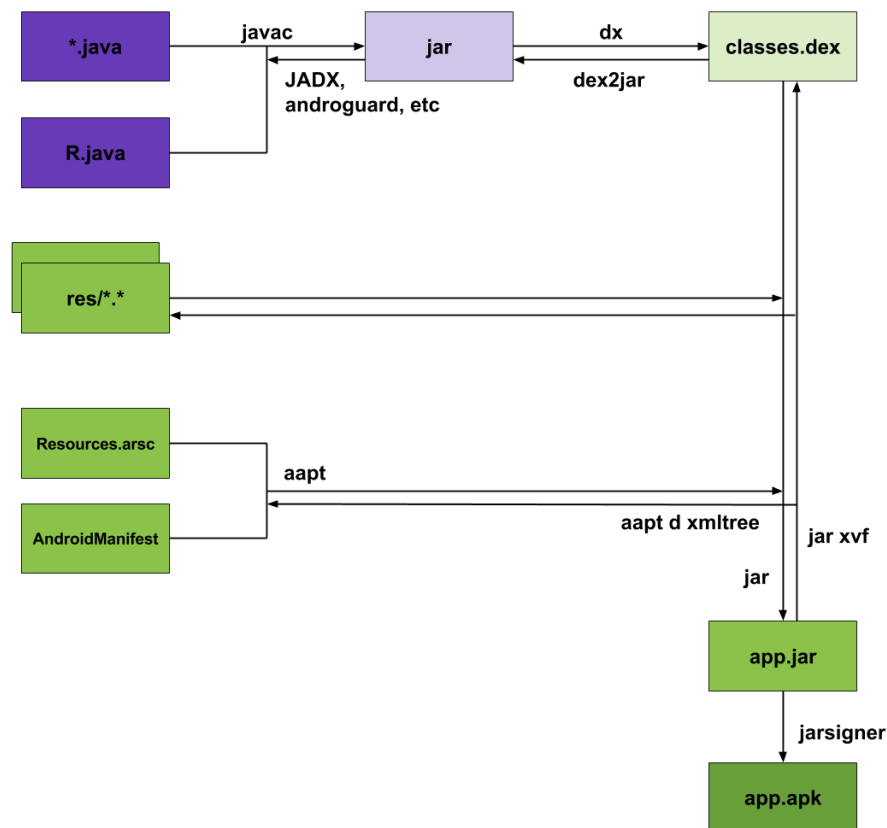


Figure 2.15: Overview of build and reverse engineering of an APK [29]

was ist reengineering? wie funktioniert es? was ist das ziel?
reverse engineering process makes use of a whole range of different analysis method-
ologies and tools.
only consider static analysis tools

IN ORDER TO GET FULL OVERVIEW DEX/SMALI/JAVA -see- WARUM?

WAS MACHEN DIE TOOLS IM ALLGEMEINEN? WOZU BENUTZEN WIR SIE?

- It comes as no surprise that .dex and .class are isomorphic
- DEX debug items map DEX offsets to Java line numbers
- Dex2jar tool can easily “decompile” from .dex back to a .jar
- Extremely useful for reverse engineering – Evenmoresousefulformaliceand-

mischief

- Flow from DEX to JAVA is bidirectional, meaning that an attacker can:
- Decompile your code back to Java
- Remove annoyances like ads, registration
- Uncover sensitive data (app logic, or poorly guarded secrets)
- Replace certain classes with others, potentially malicious ones
- Recompile back to JAR, then DEX
- Put cloned/trojaned version of your app on Play or another market
- ASEC/OBB “solutions” for this fail miserably when target device is rooted.

<https://mobilesecuritywiki.com/>

https://net.cs.uni-bonn.de/fileadmin/user_upload/plohmann/2012-Schulz-Code_Protection_in_Android.pdf

main tools

2.4.1 Retrieving an APK

5 most apps are installed /data/app, android restricts access, with root possible

to get installed applications on phone use android package manager after connecting phone to computer and having ADB tools installed adb shell pm list packages -f(1) outputs a list of installed apps in formatf <namespace>.<appName> and an appended number "-1", each is a folder of installed app containing a base.apk (the application apk) example 2 enthält return von (1)

then find app which should be transferred to computer and use adb pull /data/app/me.neutze.licensetest1/base.apk to download app into current folder

in case you have root you can use file manager as solid explorer to access the folder directly and copy apk to user-defined location/send per mail

[31]

In the following there will be an example application to generalise the procedure. The application is called LicenseTest and has for our purpose a license verification library included (Amazon, Google or Samsung).

In order to analyse an APK, it has to be pulled from the Android device onto the computer. First the package name of the app has to be found out. This can be done by using the ADB. Entering example 1 returned example 2

dann auf verschiedenen leveln anschauen mit den folgenden tools

2.4.2 dex Analysis

This is my real text! Rest might be copied or not be checked!

nur dex weil die apps im moment so vorliegen

asop-supplied dexdumo to disassemble dex

[29] always attack dex since the protection mechanism is in there (except JNI?) since apk is zip like decompression tool like 7zip can extract classes.dex from apk file
hexdump to get bytecode
code wie er vorliegt, wenn was geändert wird wird es hier geändert
SCRIPT (LISTING BENUTZEN UND RICHTIGE APP) RESULT OUTPUT dex hex-

```
1 #!/bin/bash
2 #hexdump dex
3 unzip lvltest-version.apk -d /tmp/
4 hexdump -C /tmp/classes.dex >> /dex/version/classes.txt
```

Code Snippet 2.7: Script to extract the .dex byte code from the APK

dump, start of the dex file, e.g first 8 byte represent the dex header magic dex.035, version 35[6] LINE | bytecode | ASCII representation

```
00000000 64 65 78 0a 30 33 35 00 ae a5 51 7e 06 f7 00 84 |dex.035...Q~...|
00000010 ee 23 5d 3b 4a 61 bb 08 51 a7 c9 02 c1 4e d2 91 |.#];Ja..Q....N..|
00000020 0c fb 21 00 70 00 00 00 78 56 34 12 00 00 00 00 |...!.p...xV4....|
00000030 00 00 00 00 ac 88 06 00 f4 4e 00 00 70 00 00 00 |.....N..p...|
00000040 ad 09 00 00 40 3c 01 00 0a 0e 00 00 f4 62 01 00 |....@<.....b..|
00000050 3d 27 00 00 6c 0b 02 00 ff 4b 00 00 54 45 03 00 |='.1....K..TE..|
```

Code Snippet 2.8: dex hexdump example

jedes tool:
woher kommt es?
wozu wurde es erfunden?
wer hat es erfunden? quelle
blabla von der seite
wozu benutze ich es?
welches abstrahierungslevel
beispiel
additional features?
WARUM SCHAUEN WIR ES UNS AN?
wo findet man es?
welches level?
vorteil
blabla aus dem internet

2.4.3 Smali Analysis

This is my real text! Rest might be copied or not be checked!

basically jasmin syntax smali, most popular Dalvik bytecode decompilers (used by multiple reverse engineering tools as a base disassembler, amongst which is the also well-known apktool) [26]

stichwort mnemonics, eine seite dex und auf der anderen seite smali, dex bytecode vs smali, Only a few pieces of information are usually not included like the addresses of instructions

unintuitive representation, deswegen smali mit corresponding mnemonics

mnemonics and vice versa is available due to the bijective mapping

correct startaddress and offset can be challenging. There are two major approaches: linear sweep disassembling and recursive traversal disassembling, The linear sweep algorithm is prone to producing wrong mnemonics e.g. when a assembler inlines data so that instructions and data are interleaved. The recursive traversal algorithm is not prone to this but can be attacked by obfuscation techniques like junkbyte insertion as discussed in section 4.4. So for obfuscation, a valuable attack vector on disassembling is to attack the address finding step of these algorithms

<https://github.com/JesusFreke/smali>

Smali code is the generated by disassembling Dalvik bytecode using baksmali. The result is a human-readable, assambler-like code

The smali [7] program is an assemblerhas own disassembler called "baksmali"

can be used to unpack, modify, and repack Android applications

interesting part for obfuscation and reverse engineering is baksmali. baksmali is similar to dexdump but uses a recursive traversal approach to find instructions

vorteil? -see- So in this approach the next instruction will be expected at the address where the current instruction can jump to, e.g. for the "goto" instruction. This minimizes some problems connected to the linear sweep approach. baksmali is also used by other reverse engineering tools as a basic disassembler

RESULT OUTPUT: selbe wie dex, jedoch human readable, no big difference, nebeneinanderstellung dex/smali

SCRIPT (LISTING BENUTZEN UND RICHTIGE APP)

EXAMPLE BESCHREIBEN code snippet 2.10

jedes tool:

woher kommt es?

wozu wurde es erfunden?

wer hat es erfunden? quelle


```
1 #!/bin/bash
2 #baksmali
3 java -jar baksmali.jar -x lvltest-version.apk -o /baksmali/version/
```

Code Snippet 2.9: Script to generate the corresponding smali code for a given APK

```
.method protected onDestroy()V
    .registers 2

    .prologue
    .line 77
    invoke-super {p0}, Landroid/support/v7/app/CompatActivity;->onDestroy()V

    .line 78
    iget-object v0, p0, Lme/neutze/licensetest/MainActivity;->mChecker:Lcom/google/android/
        vending/licensing/LicenseChecker;

    invoke-virtual {v0}, Lcom/google/android/vending/licensing/LicenseChecker;->onDestroy()V

    .line 79
    return-void
.end method
```

Code Snippet 2.10: smali example

blabla von der seite
wozu benutze ich es?
welches abstrahierungslevel
beispiel
additional features?
WARUM SCHAUEN WIR ES UNS AN?
wo findet man es?
welches level?
vorteil
blabla aus dem internet

2.4.4 Java Analysis

This is my real text! Rest might be copied or not be checked!
dex different patterns for mobile Usage, java does not really now, thats why different

java decompiler

probleme des disassemblers erklären

interpretations sache

deswegen zwei compiler

unterschiedliche interpretation resultiert in flow und auch ob sies können ist unterschiedlich

ectl unterschiede/vor-nachteile

ggf bezug zu DALVIK/buildprocess (Java wird disassembled und dann assembler)

androguard

This is my real text! Rest might be copied or not be checked!

An analysis and disassembling tool processing both Dalvik bytecode and optimized bytecode

DAD which is also the fastest due to the fact it is a native decompiler, WAS ist dad? ERKLÄREN? .dex files was performed with DAD, the default disassembler in the androguard analysis tool, largest successful disassembly ratio

underlying algorithm is recursive traversal

androguard has a large online open-source database with known malware patterns [26]

<https://github.com/androguard/androguard>

powerful analysis tool is Androguard

includes a disassembler and other analysis methods to gather information about a program

Androguard helps an analyst to get a good overview by providing call graphs and an interactive interface -see- habe nur CLI benutzt

The integrated disassembler also uses the recursive traversal approach for finding instructions like baksmali, see section 2.2

one most popular analysis toolkits for Android applications due to its big code base and offered analysis methods -see- quelle, warum

RESULT OUTPUT code Listing

SCRIPT (LISTING BENUTZEN UND RICHTIGE APP)

SCRIPT (LISTING BENUTZEN UND RICHTIGE APP)

EXAMPLE BESCHREIBEN code snippet 2.12

jedes tool:

woher kommt es?

```
1 #!/bin/bash
2 #androguard
3 python androdd.py -i lvltest-version.apk -o /androguard/version/
```

Code Snippet 2.11: Script to decompile to Java using androguard

```
private void doCheck()
{
    this.mCheckLicenseButton.setEnabled(0);
    this.setProgressIndicatorIndeterminateVisibility(1);
    this.mStatusText.setText(2131099673);
    this.mChecker.checkAccess(this.mLicenseCheckerCallback);
    return;
}
```

Code Snippet 2.12: Java code example using androguard

wozu wurde es erfunden?
wer hat es erfunden? quelle
blabla von der seite
wozu benutze ich es?
welches abstrahierungslevel
beispiel
additional features?
WARUM SCHAUEN WIR ES UNS AN?
wo findet man es?
welches level?
vorteil
blabla aus dem internet

JADX

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RESULT OUTPUT code Listing

SCRIPT (LISTING BENUTZEN UND RICHTIGE APP)

EXAMPLE BESCHREIBEN code snippet 2.14

<https://github.com/skylot/jadx>

jedes tool:

woher kommt es?

```
1 #!/bin/bash
2 #jadx
3 jadx -d /jadx/version/ --deobf --show-bad-code lvltest-version.apk
```

Code Snippet 2.13: Script to decompile to Java using JADX

```
private void doCheck() {
    this.mCheckLicenseButton.setEnabled(false);
    setProgressBarIndeterminateVisibility(true);
    this.mStatusText.setText(C0213R.string.checking_license);
    this.mChecker.checkAccess(this.mLicenseCheckerCallback);
}
```

Code Snippet 2.14: Java code example using JADX

wozu wurde es erfunden?
wer hat es erfunden? quelle
blabla von der seite
wozu benutze ich es?
welches abstrahierungslevel
beispiel
additional features?
WARUM SCHAUEN WIR ES UNS AN?
wo findet man es?
welches level?
vorteil
blabla aus dem internet

Es gibt noch mehr tools, wurden angewendet und verglichen, aber diese waren die haupttools und haben ihren dienst erfüllt

2.4.5 Detect Code Manipulations

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vergleich gibts guten einblick was geändert wurde und wie es auf dem gegebenenem lvl funtkioniert

vergleich von original und modifizierten code einer apk auf einer code ebene
needed to see differences before and after cracking tool

diff is used

```
1 #!/bin/bash
2 #dex
3 diff -Naur /dex/original/ /dex/manipulated/ > dex.diff
4 #smali
5 diff -Naur /baksmali/original/ /baksmali/manipulated/ > baksmali.diff
6 #jadx
7 diff -Naur /jadx/original/ /androguard/jadx/ > jadx.diff
8 #androguard
9 diff -Naur /androguard/original/ /androguard/manipulated/ > andro.diff
```

Code Snippet 2.15: Script to compare the original and manipulated APK to see the modifications in the different presentations

erklärung command [45] -N: Treat absent files as empty; Allows the patch create and remove files.

-a: Treat all files as text; Allows the patch update non-text (aka: binary) files.

-u: Set the default 3 lines of unified context; This generates useful time stamps and context.

-r: Recursively compare any subdirectories found; Allows the patch to update subdirectories.

script erklären

RESULT code snippet 3.1

wo findet man es?

welches level?

vorteil

blabla aus dem internet

3 Cracking Android Applications with LuckyPatcher

Cracking apps are a widespread phenomenon on Android these days. There are a number of applications which try to attack and alter Android apps. This piracy thread is discussed a lot in the Android developer community. This thesis focuses on the popular cracking app called LuckyPatcher, especially on its license verification bypassing mechanism.

3.1 LuckyPatcher

reason lucky patcher is taken extremely popular and easy (no technical knowledge except root but apps can be traded)

main goal is to circumvent license verification, app should behave as it is legally acquired in app store, by user hence work normally, full features

most common way client-server license verification, app gathers info and sends to server, server checks info and depending on this sends response, finally app acts according to response code

since server is not accessible and man-in-the-middle has to break encryption, like spoofing, which is difficult (encryption in general), has to work in application

effective, popular, vielseitig (viel internet -see- quelle) high damage potential since popular, automated and general use by non professional

[31]

written by ChelpuS

for this master's thesis the version 5.9.5 written by chelphus requires root and busybox, an application which provides standard UNIX tools for Android[42] apply patches: - Remove license check in premium apps (used to crack DRM) - remove ads -Customize and restrict permissions and activities -Create a modified app (means an APK file to install the app with a patch already applied)

not 100percent warranty that patching works due to modified libraries

erklären wie man ihn getestet hat, woher die apps, nachgefragt ob ok etc

LuckyPatcher is described as following on the official webpage: "Lucky Patcher is a great Android tool to remove ads, modify apps permissions, backup and restore apps,

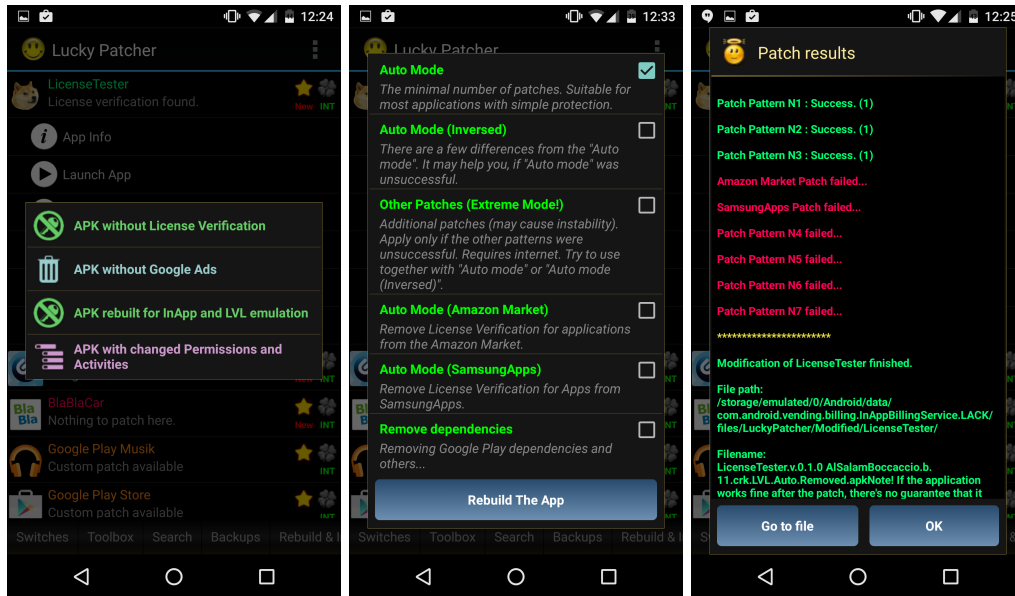


Figure 3.1: c

Left: Features offered LuckyPatcher Middle: Variants to crack license verification Right: Result after patching

bypass premium applications license verification, and more. To use all features, you need a rooted device." [15]

install apk from playstore -see- have root -see- open lucky -see- chose mode

this thesis focuses on the removing of licensing check, angewendet auf verschiedene apps aus den jeweiligen stores

3.2 Code Manipulation

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analysis done by looking at patched applications since luckypatcher has done a lot of obfuscation etc which makes it almost impossible to undertand (tools crash, junkbyte injection, only a few giant classes in java which do not make sense, some classes not decompiled since crash, dex/smali not very useful since no names etc), poor decompilation result hard to analyze since of obfuscation and anti-decompilation measure

so look at cracked application in order to udnerstand how lucky aoptcher works diff between code of unpatched and patched version of application which have lvl included first it was tested with a simple app which was created and implemented lvl also for

apps from app store to see behaviour diff tool to compare code base and see positions lucky patcher attacks

multiple tools used to reverse engineer the license verification circumvention by lucky patcher (see tools from reengineering) first look at java code (higher representation, human readable), to understand what/where class/function have been modified smali for having names for the bytecode executions dex to see exactly how it was modified document intended change by luckypatcher

luckypatcher works by patching dex (patching based not call intercept)

most patching options target googles lvl, but also available for amazon and samsung information if lvl is contained can be pulled from manifest because of `com.android.vending.CHECK_LICENSE` permission, only to show user and can circumvent anyway since solely for user to flag in market (ist das noch so?), trying to trick and not declare would break violate permissions and be stopped by android

luckypatcher extracts original `classes.dex` from apk and patches it patching is done on binary level and done by using different patterns which are dependent on the modus (see patterns/modi) the result is either used to substitute the optimized `classes.dex` of attacked app with the patched `.odex` in dalvik cache (`/data/dalvik-cache/`), or can be output as an apk

works on most applications but has few problems on custom modified lvl libraries (liste der apps wo es funzt aus gdrive tabelle)

after applying patterns LP needs to update file header to reflect new checksum and hash values

[31]

wo arbeitet er?

warum dex und nicht odex anschauen?

Since the code is modified directly a static analysis is sufficient.

UM ES EINFACHER ZU MACHEN, KEINE ODEX (WARUM), APK CREATEN UND AUF EINEM NORMALEN HANDY INSTALLIEREN(dann sieht man dass man die app wem anders gecracked geben kann - ringschluss blackmarket)

after modification the dex is signed again in order to work on the phone (see installation und signature)

WIE IST MEIN VORGEHEN? aufgrund dass odex dateien device spezifisch sind und allgemeiner ansatz gesucht wird, wird die app playstore -> modified APK erstellen -> analysieren

3.3 Cracking License Verification

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patterns und patching modes grob erklären (modi von luckypatcher die verschiedene operationen (pattern) auf app anwenden) => vorgehensweise zur

see figure 3.1 middle liuckypatcher offeres different sets of methods to remove the license verification Auto Mode - "The monomal number of patches. Suitable for most applications with simple protection" - uses patterns

Auto Mode (Inversed) - "There are a few differences from the "Auto mode". It may help you, if "Auto mode" was unsuccessful." - uses patterns

Other Patches (Extreme Mode!) - "Additional patches (mnay cause instability). Apply only if the other patterns were unsuccessful. Requires internet. Try to use together with "Auto mode" or "Auto mode (Inversed)"." - uses patterns

Auto Mode (Amazon Market) - "Removes License Verification for applciations from Amazon Market" - uses patterns

Auto Mode (SamsungApps) - "Removes License Verification for Apps from SamsungApps" - uses patterns (is now GalaxyApps)

in order to find out what patterns are doing, different apps had to be analysed after patching the apps chosen were already owned, in addition an app for each license verification model was created, uploaded and installed from the store so the license verification was working

to verify that license check is enabled, each app was extracted from the device using method described in 2.4.1 and installed on a device with a different google account then for each app a modified apk see figure 3.1 left, using one modus is created and copied to a computer for further inspection. so for each app there are 5 modified apks now

as example apps to show results Runtastic Pro[34], Version 6.3, the created LicenseTest and Teamspeak 3[43], Version 3.0.20.2, are chosen

the result after patching the different apps with each modus returned the patterns used by each modus

3.4 Patching Patterns

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In order to identify the single patterns, the information from the output of cracking 3.1 right, of the apps was matched with the changes in the code. the changes in the code were inspected on dex, smali and java level with the tools explained in Section 2.4.

Modus	Application		
	LicenseTester	Runtastic Pro	Teamspeak 3
Purchased	yes	yes	yes
Pirated	no	no	no
Auto	yes	yes	no
Auto (Inversed)	no	yes	no
Extreme	no	yes	no
Auto+Extreme	yes	yes	no
Auto (Inversed)+Extreme	no	yes	no

Table 3.1: Functionality for the test apps before and after patching

in case of LVL, from the information where in the package the change was done, conclusion to the original class from in the lvl could be done

diff for original app and modified app

example code taken from an app which was inspected, modification happens for all at the same spot/manner

dex == smali, smali better readable but dex to see how easy change since the translation from java to dex does some optimizations/logik, dex and java do not express the same, but it is how it is in the decompiled code, java is also an abstraction of the actual code, sometimes java also a little confusing since changes happened in dex code and cannot be decompiled to java in a good manner, very messy, it is included for better understanding anyways since humanreadable

The names of the patterns/patches are taken from the patching result output figure 3.1 on the right

Patch Pattern N1

classes it attacks com/google/android/vending/licensing/LicenseValidator LicenseValidator, responsible for decrypting and verifying the response from the licensing server[8]

```
@@ Pattern N1 @@
- 03 01 00 00 0f 00 00 00 1a 00 00 00 0f 00 00 00 |.....|
+ 03 01 00 00 0f 00 00 00 0f 00 00 00 1a 00 00 00 |.....|
```

Code Snippet 3.1: Diff on Dex level for N1 pattern

values are swapped

```
@@ Pattern N1 @@
```

```
- 0x1 -> :sswitch_e0
- 0x2 -> :sswitch_d5
+ 0x1 -> :sswitch_d5
+ 0x2 -> :sswitch_e0
```

Code Snippet 3.2: Diff on Smali level for N1 pattern

switch case for input 0x01 (not licensed) and 0x02 (old license key) are swapped

```
@@ Pattern N1 @@
- case LICENSED_OLD_KEY: handleResponse();
- case NOT_LICENSED: handleError();
+ case NOT_LICENSED: handleResponse();
+ case LICENSED_OLD_KEY: handleError();
```

Code Snippet 3.3: Diff on Java level for N1 pattern (abstracted)

old code when license code not licensed return in case not licensed with error after patching when not licensed return as old license key

Patch Pattern N2

classes it attacks com/google/android/vending/licensing/LicenseValidator.java LicenseValidator, responsible for decrypting and verifying the response from the licensing server[8] greift auch zB. google maps api (com/google/android/gms/) oder in app billing (com/android/iab/v3/) an, collateral schaden one Pattern

```
@@ Pattern N2 @@
- 0c 05 6e 20 9d 4a 53 00 0a 05 39 05 2d 00 1a 05 |..n .JS...9.-...|
+ 0c 05 6e 20 9d 4a 53 00 12 15 39 05 2d 00 1a 05 |..n .JS...9.-...|
```

Code Snippet 3.4: Diff on Dex level for N2 pattern

move-result is replaced by move const

```
@@ Pattern N2 @@
- move-result v5
+ const/4 v5, 0x1
```

Code Snippet 3.5: Diff on Smali level for n2 pattern

instead of moving the result from a function to v3, it is initiated with true/1

```
@@ Pattern N2 @@
- if (sig.verify(Base64.decode(signature))) {...;}
```

```
+ sig.verify(Base64.decode(signature); ...;
```

Code Snippet 3.6: Diff on Java level for N2 pattern (abstracted)

old code: signature was verified, if true it is continued after patching the verification is treated as always true and so it is continued

Patch Pattern N3

classes it attacks com/google/android/vending/licensing/APKExpansionPolicy.java com/google/android/vending/licensing/ServerManagedPolicy.java Policy integration of License Verification Library, those are the two examples offered by Google[8]

```
@@ Pattern N3 @@
- 12 10 12 01 71 00 a6 89 00 00 0b 02 52 84 c1 1c |....q.....R...|
+ 12 10 12 11 71 00 a6 89 00 00 0b 02 52 84 c1 1c |....q.....R...|

@@ Pattern N3i @@
- 34 00 00 00 12 11 12 00 71 00 70 9d 00 00 0b 02 |4.....q.p.....|
+ 34 00 00 00 12 01 12 00 71 00 70 9d 00 00 0b 02 |4.....q.p.....|
```

Code Snippet 3.7: Diff on Dex level for N3 pattern

for forward value 0x0 is switched with 0x1 and for inverse...inversed

```
@@ Pattern N3 @@
- const/4 v1, 0x0
+ const/4 v1, 0x1

@@ Pattern N3i @@
- const/4 v1, 0x1
+ const/4 v1, 0x0
```

Code Snippet 3.8: Diff on Smali level for N3 pattern

variable is initiated with opposite of what they were initiated before

```
@@ Pattern N3 @@
- return false;
+ return true;

@@ Pattern N3i @@
- return true;
+ return false;
```

Code Snippet 3.9: Diff on Java level for N3 pattern (abstracted)

old code variable is initiated false and true for inversed as basic return value after patching the return is the opposite, meaning all true results are now false and all false are now true, meaning wrong input is declared as OK

Patch Pattern N4

classes it attacks com/google/android/vending/licensing/LicenseChecker.java LicenseChecker, class that instatiates a license check[8]

```
@@ Pattern N4 @@
- d5 70 00 00 0a 00 38 00 0e 00 1a 00 5a 20 1a 01 |.p....8.....Z ..|
+ d5 70 00 00 0a 00 33 00 0e 00 1a 00 5a 20 1a 01 |.p....3.....Z ..|
```

Code Snippet 3.10: Diff on Dex level for N4 patch

if-eqz is repalces by if-ne

```
@@ Pattern N4 @@
- if-eqz v0, :cond_15
+ if-ne v0, v0, :cond_15
```

Code Snippet 3.11: Diff on Smali level for N4 patch

in the original code variable v0 is compared for not equality with zero after it is patched it is always compared with itself which returns always true and the condition is always called

```
@@ Pattern N4 @@
- if(licenseCached()) {...}
+ b = licenseCached();
+ if(b == b) {...}
```

Code Snippet 3.12: Diff on Java level for N4 patch (abstracted)

in the original code it is checked whether the license is already cached, fi yes, condition is called after patching the result of the check is always compared to itself, and thus the condition is always called

Patch Pattern N5

classes it attacks com/google/android/vending/licensing/LicenseValidator.java

works the same way as pattern N2

im gegensatz zu N2 wird jetzt die condition nie aufgerufen anstatt sie immer aufzurufen wie in N5 result is that the check for the result code given to the function and extracted from the server response is disabled since the result of the check is set to always false

Patch Pattern N6

classes it attacks com/google/android/vending/licensing/LicenseValidator.java

```
@@ Pattern N6 @@
- 38 0a 06 00 32 4a 04 00 33 5a 21 01 1a 00 ab 15 |8...2J..3Z!.....|
+ 12 0a 00 00 32 00 04 00 33 5a 21 01 1a 00 ab 15 |...2...3Z!.....|
```

Code Snippet 3.13: Diff on Dex level for N6 patch

if-eqz is replaced by move constant, variables for if-eq are changed

```
@@ Pattern N6 @@
- if-eqz p2, :cond_e
+ const/4 p2, 0x0

- if-eq p2, v4, :cond_e
+ nop
+
+ if-eq v0, v0, :cond_e
```

Code Snippet 3.14: Diff on Smali level for N6 patch

instead of testing for zero and then calling a condition, the to test variable is changed and the condition removed the second equal check is done by comparing a variable with itself thus always true and the condition is called

```
@@ Pattern N6 @@
- if (p2 == 0 || p2 == v8) {...}
+ p2 = 0;
+ if (v0 == v0) {...}
```

Code Snippet 3.15: Diff on Java level for N6 patch (abstracted)

instead checking two variables for a case, the condition is just always called

Patch Pattern N7

classes it attacks com/google/android/vending/licensing/ILicenseResultListener.
java ILicenseResultListener, IPC callback implementation, receives async response
from server[8] einfach auf alles was in com/android/ ist, some kind of bruteforce
similar to N2, but Java result is more generic

```
@@ Pattern N7 @@  
- x = foo();  
+ x = false;
```

Code Snippet 3.16: Diff on Java level for N7 patch (abstracted)

instead of initializing variable with result from function, it is always initialized with
false / 0

Amazon Market Patch

also applies pattern N2

classes it attacks com/amazon/android/licensing/b.java com/amazon/android/o/d.
java
see, obfuscated
similar like pattern N4

```
@@ Pattern A @@  
- 0a 00 38 00 0a 00 62 00 56 20 1a 01 4e 49 6e 20 |..8...b.V ..NIn |  
+ 0a 00 33 00 0a 00 62 00 56 20 1a 01 4e 49 6e 20 |..3...b.V ..NIn |
```

Code Snippet 3.17: Diff on Dex level for Amazon patch

if-eqz is replaced by if-ne

```
@@ Pattern A @@  
- if-eqz v0, :cond_1f  
+ if-ne v0, v0, :cond_1f
```

Code Snippet 3.18: Diff on Smali level for Amazon patch

in the original code variable v0 is compared for not equality with zero after it is patched
it is always compared with itself which returns always true and the condition is always
called

```
@@ Pattern A @@  
- if(v0.equals("LICENSED")) {...}  
+ b = v0.equals("LICENSED")
```

```
+ if(b == b) {...}
```

Code Snippet 3.19: Diff on Java level for Amazon patch (abstracted)

in the original code the result from the server is tested whether it is "LICENSED" after patching the response is always evalauted and the result is compared with itself which is always true

result never the less what the check for "LICENSED" returns, the condition for "LICENSED" is always called

Samsung Market Patch

also applies pattern N2

classes it attacks com/samsung/zirconia/LicenseRetriever.java com/samsung/zirconia/Zirconia.java

not obfuscated

two patterns, lets call it S1 and S2, S1 used on both, S2 used twice on zirconia

```
@@ Pattern S1 @@
- 08 00 0c 08 6e 10 66 4a 08 00 0a 06 32 d6 0a 00 |....n.fJ....2...|
+ 08 00 0c 08 6e 10 66 4a 08 00 0a 06 32 00 0a 00 |....n.fJ....2...|

@@ Pattern S2 @@
- 10 02 0a 00 0f 00 00 00 03 00 01 00 02 00 00 00 |.....|
+ 10 02 12 10 0f 00 00 00 03 00 01 00 02 00 00 00 |.....|
```

Code Snippet 3.20: Diff on Dex level for Samsung patch

S1 input for if-eq is modified S2 move-result is replaced by move const

```
@@ Pattern S1 @@
- if-eq v6, v13, :cond_52
+ if-eq v0, v0, :cond_52

@@ Pattern S2 @@
- move-result v0
+ const/4 v0, 0x1
```

Code Snippet 3.21: Diff on Smali level for Samsung patch

S1 in the original code checks whether to different variables are equal after patching the check is done with the same variables and thus always returns true

S3 in the original code the result of a function is moved to v0 and returned after patching true/1 is always moved to v0 and returned


```

@@ Pattern S1 @@
- if (v6 == 12) {...}
+ if (v0 == v0) {...}

@@ Pattern S2 @@
- return foo();
+ return 1;

```

Code Snippet 3.22: Diff on Java level for Samsung patch (abstracted)

com/samsung/zirconia/LicenseRetriever.java always starts condition, even though input is not "12" as supposed to start com/samsung/zirconia/Zirconia.java S1 always returns true for checkLicenseFile and checkLicenseFilePhase2, does not check anything which is done normally S2 always starts condition, even though input is not as supposed to start com/samsung/zirconia/Zirconia.java

Modus	Patterns							
	N1	n3	N3	N3i	N4	N5	N6	N7
Auto	X	X	X		X			
Auto (Inversed)	X	X		X	X			
Extreme						X	X	X
Auto+Extreme	X	X	X		X	X	X	X
Auto (Inversed)+Extreme	X	X		X	X	X	X	

Table 3.2: Overview of License Verification Library patching patterns applied by each modus

summarizing what patterns each modus applies Table 3.2

auto: just applies minimum patches, N1 swaps switch cases so not licensed is treated here as old license key in the LicenseValidator, N2 skips the signature verification in the LicenseValidator, N3 inverts the return boolean for the policy checks in the implemented Policy class by initializing with 0/false, and N4 skips, in the only case occurred in the test set, the check whether download is allowed and allows it always auto inverse: does the same as auto but initializes the policy check with 1/true instead of false extreme: auto+extreme: applies auto and extreme patches auto inverse+extreme: applies auto and extreme patches

!!! kann man das excel sheet in die dateien machen und nicht als appendix, da manche apps ihre ergebnisse nicht öffentlich sehen wollen !!!

3.5 Learnings and Conclusion

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first patching point could be the initial call, in case modified lvl patching initial call would be not enough since the on success block could contain important code (like ui creation) then it would be useless, target on specific points where decisions are made to alter as few code as possible

since automated customizations have to be implemented to trick it make false checks to detect tampering -see- user patch

amazon/samsung not much to do since from company, beyond control of developer since injection after developer and a library provided by samsung which is only called, that is why the following not simple methods target lvl

known bytecode patterns, replace with custom, makes mechanism useless

following present ways of protecting against patching attempts, especially predefined recipes circumventing the LVL high motivation, the patterns/patching modes cover many apps, more than custom

should not use one but many methods solution for current version of lucky patcher, future might be different, arms race scenario [31]

nur ja/nein test bzw ergebnis zuweisung und drauf folgender test kann IMMER geskippt werden

4 Counter Measurements for Developers

blabla

5 Conclusion

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research and also a valuable market for companies

Because source code can be easier recovered from an application in comparison to x86, there is a strong need for code protection and adoption of existing reverse engineering methods. Main parts of Android application functionalities are realized in Dalvik bytecode. So Dalvik bytecode is of main interest for this topic

Also, the Android system does not prevent modification of this bytecode during runtime, This ability of modifying the code can be used to construct powerful code protection schemata and so make it hard to analyze a given application.

[36]

current state of license verification on Android reverse engineering far too easy due to OS, extract/install allowed gaining root easy, allows everyone especially pirates avoiding protection mechanisms java was chosen to support a lot of hardware, java has bad protection

lvl popular but broken, has not done much since beginning of known issues [31]

auch wichtig weil wenn crackable dann upload zu stores und dann malware

<http://www.hotforsecurity.com/blog/mobile-app-development-company-fights-off-android-malware-with-obfuscation-tool-3717.html>

5.1 Summary

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jedes chapter beschreiben

5.2 Discussion

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clear in beginnign that lvl not sufficiently safe with current technology unclear degree and fixavle

shortly after start insufficient resilience against reverse engineering, not exclusively to lvl thus shift from lvl protection to general protection against reverse engineering, decompilation and patching

eternal arms race no winning solution against all cases, just small pieces quantitative improvement no qualitatively improve resilience limited to quantitative resilience, matter of time until small steps generate more work for reengineering, ggf lower motivation for cracker only matter of time until patching tools catch up, completely new protection schemes need to be devised to counter those [31]

not a question of if but of when bytecode tool to generate the license library on the fly, using random permutations and injecting it everywhere into the bytecode with an open platform we have to accept a crack will happen [25]

um das ganze zu umgehen content driven, ala spotify, jedoch ist dies nicht mit jeder geschäftsidee machbar

alles hilft gegen lucky patcher auf den ersten blick, jedoch custom patches, welche LuckyPatcher anbietet[31], können es einfach umgehen, deswegen hilft nur reengineering schwerer zu machen viele piraten sind nicht mehr motiviert wenn es zu schwer ist every new layer of obfuscation/modification adds another level complexity

solange keine bessere lösung vorhanden unique machen um custom analysis und reengineering zu enforzen und dann viele kleine teile um die schwierigkeit des reengineerens und angriffs zu erschweren und viel zeit in anspruch zu nehmen um die motivation der angreifer zu verringern und somit die app zu schützen

5.3 Future Work

This is my real text! Rest might be copied or not be checked!

lvl has room for improvement art promising but not root issue, dex is distributed and art compilation to native on device needs to become relevant so developers can release art only apps, native code and no issue with reverse engineering stop/less important until lvl see major update custom improvements have to be done [31]

nicht mehr zu rettendes model, dex hat zu viele probleme, google bzw die anderen anbieter müssen eine über lösung liefern denn für den einzelnen entwickler so etwas zu erstellen ist nicht feasible, da einen mechanismus zu erstellen komplexer ist als die app itself

se/tee muss es eine lösung geben sonst braucht man für verschiedene apps verschiedene se, gemeinsame kraft um die eine lösung zu verbessern und nicht lauter schweizer käse zu ahben

google hat schon sowas wie google vault

all papers with malware and copyright protection is interesting since they also want to hide their code

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