The Terminator to Android Hardening Services

360加固保 未雨绸缪保安全
—防止APP被恶意篡改
—防止APP被植入恶意代码、广告
—防止APP被反编译、二次打包
—时刻保护开发者和用户的利益
马上加固
防篡改
防二次打包
防破解
防伪造
反调试
防反编译

一站式解决您应用的安全问题
特有的应用安全全面防护方案，可以从内到外完美解决应用安全加密，安全存储，安全加签，反调试，反篡改等难题

应用加固
反静态分析，反动态调试，
反内存窃取，反恶意篡改...

梆梆 for Android 保护你的App
• 防止App被篡改
• 防止App反编译
• 防止App被动态注入
• 防止App数据被窃取

APKTOOL
IDA Pro
gdb
① 有人要破解我 好害怕
② 爱加密移动应用安全保护平台
③ 再也不担心安全问题啦

抗盗版神器
腾讯云应用加固
渠道监控 • 加固保护 • 漏洞检测
立即体验
盗版详情分析
防二次打包
盗版监测
防反编译
防资源盗用
APP

Outline

- Background
- DexHunter
- Analysis of major products
- Related resources

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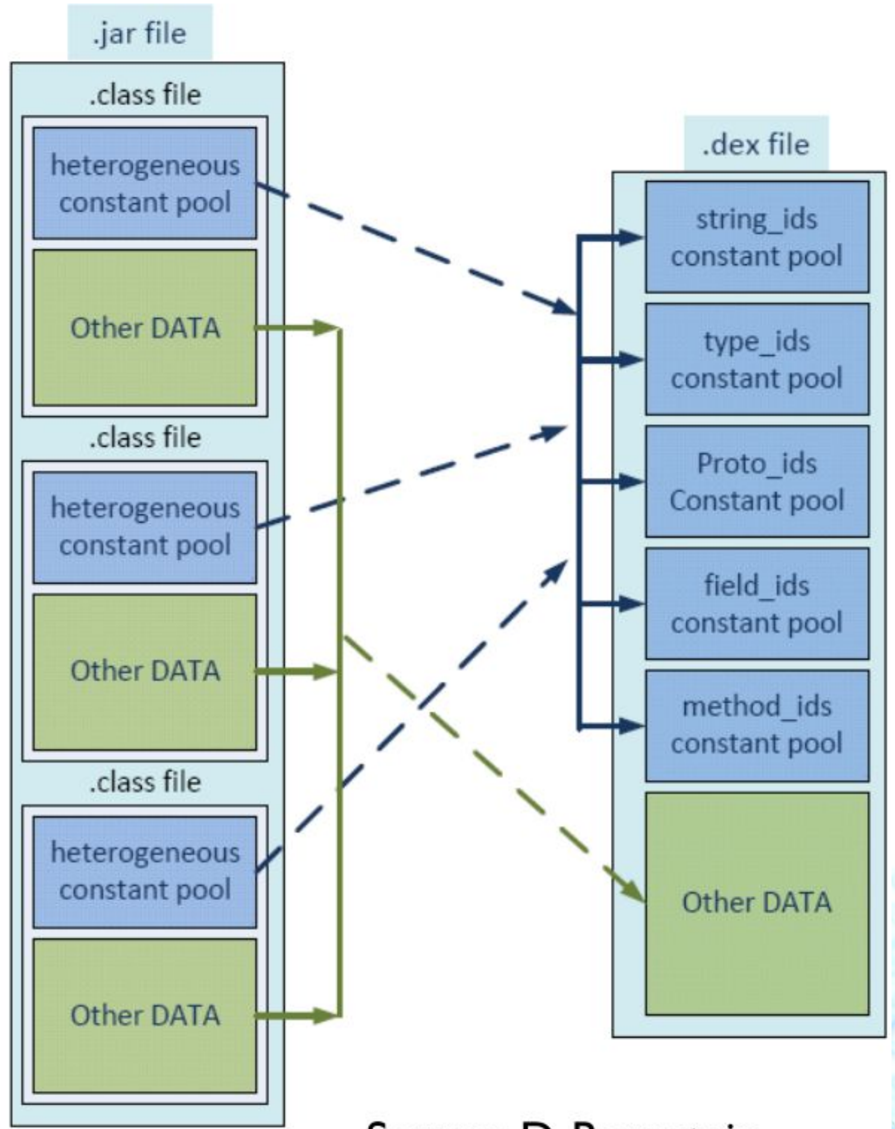
Dex File

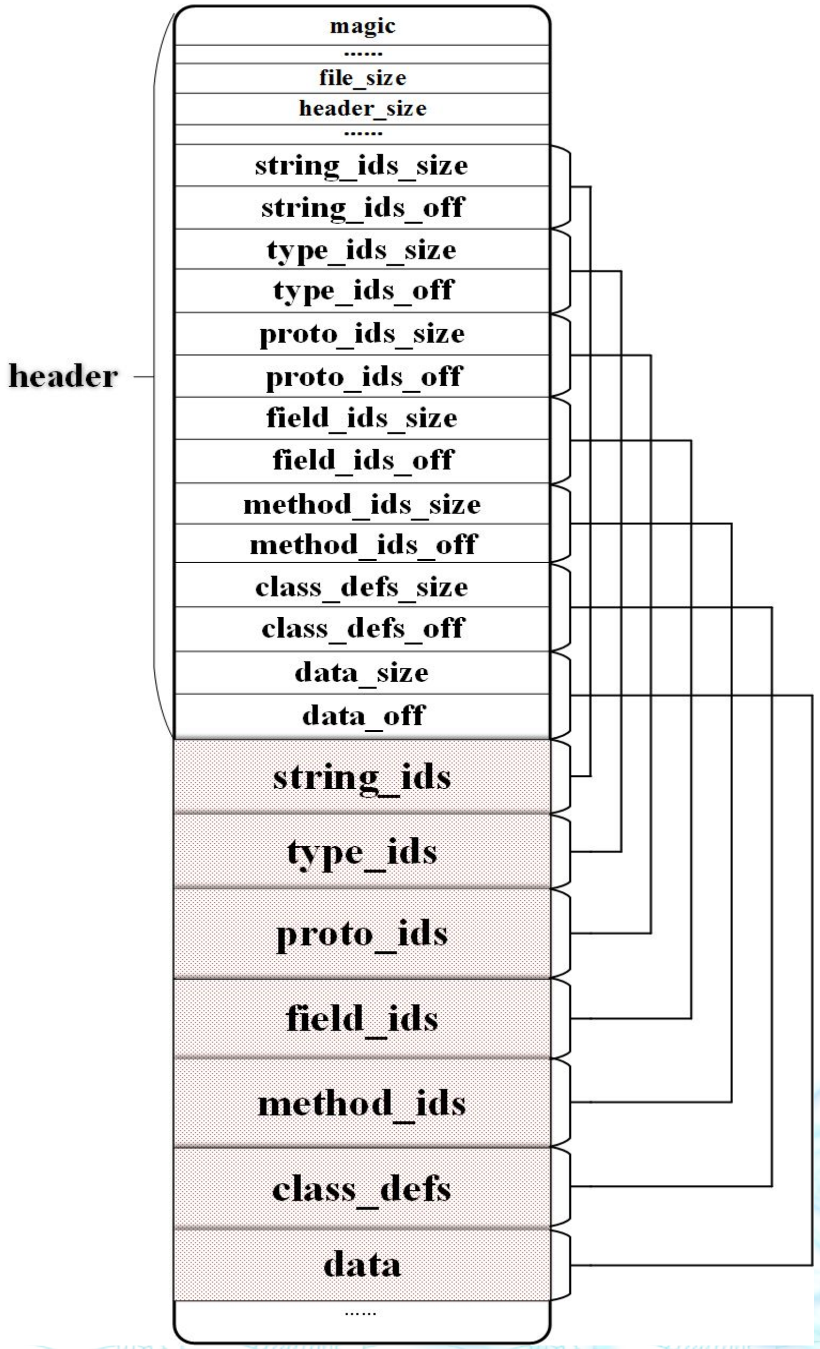
- Java source code -> Java class -> dex
  - Java class: each file contains one class
  - dex: one file contains all classes
- Reorganize constant pools in each class file into shared and type-specific constant pools



Source: D. Bornstein

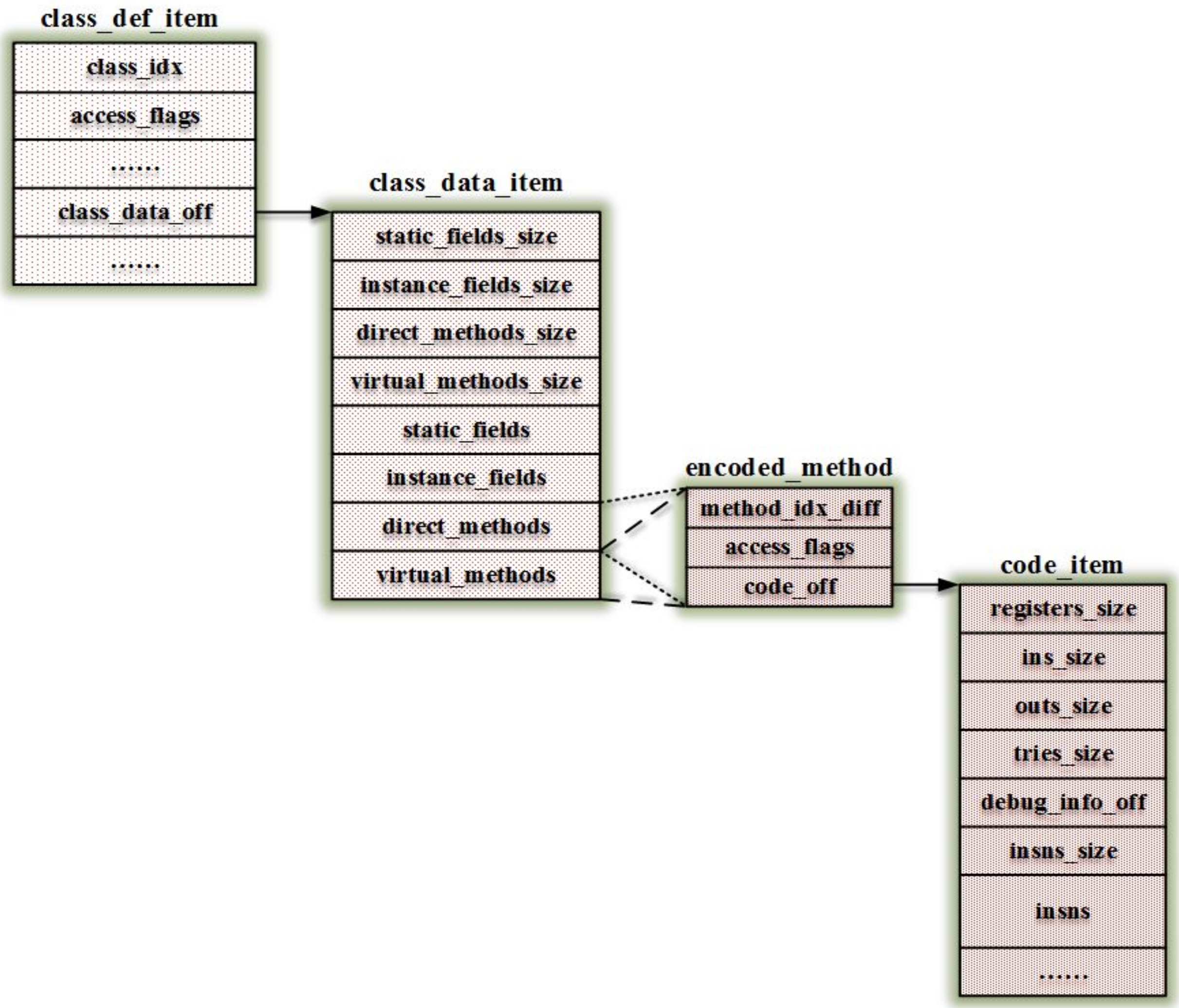
Dex File

- The executable of an App.
- The header contains the length and the offset for each section.
- ***class_defs*** section contains ***class_def_item***s, each of which describes a class.



class_def_item

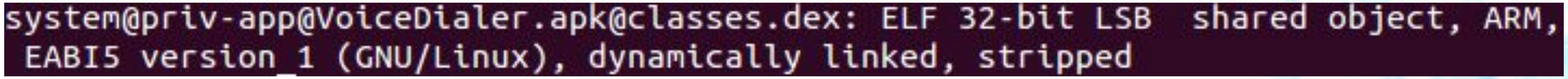
- A ***class_def_item*** points to a ***class_data_item***.
- A ***class_data_item*** contains the data of a class.
- Each method is described by an ***encoded_method***.
- An ***encoded_method*** points to a ***code_item***.
- A ***code_item*** contains the instructions of a method.



OAT File

- It is generated while an app is installed or a jar file is loaded.
    - /frameworks/base/services/java/com/android/server/pm/PackageManagerService.java
    - Constructor method □ ***scanDirLI ()*** □ ***scanPackageLI()*** □ ***performDexOptLI()*** □ ***mInstaller.dexopt()***

- It is an ELF file.



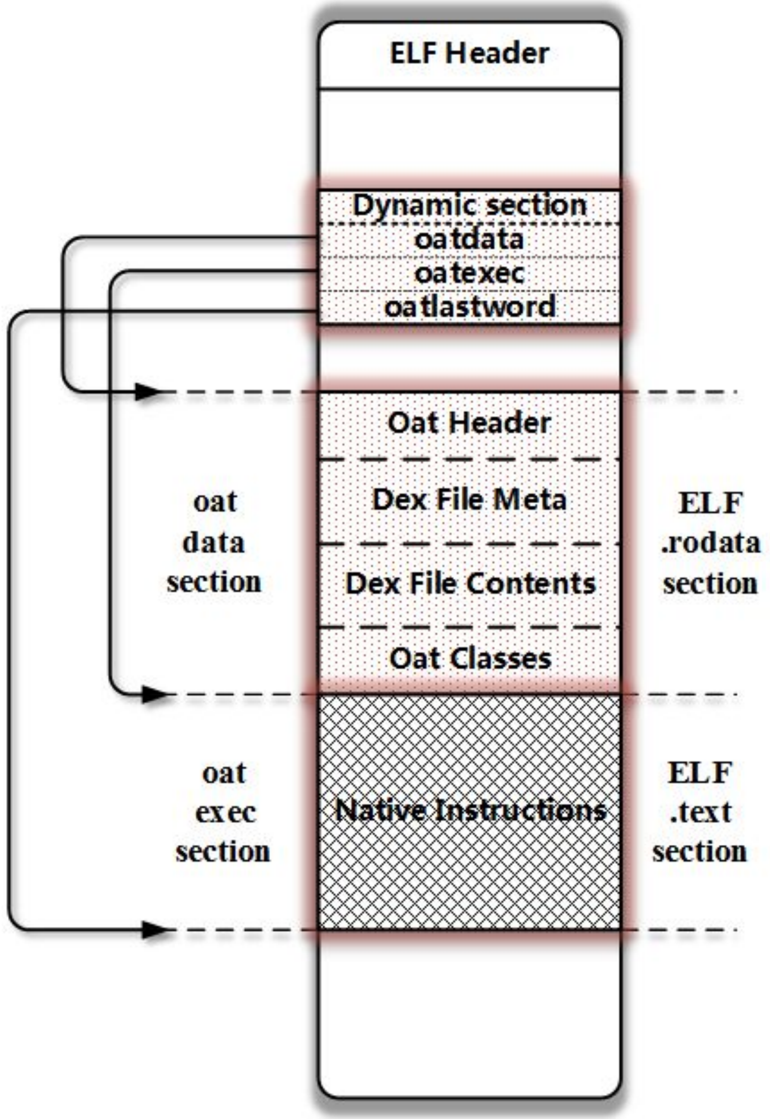
```
system@priv-app@VoiceDialer.apk@classes.dex: ELF 32-bit LSB  shared object, ARM,
 EABI5 version 1 (GNU/Linux), dynamically linked, stripped
```

OAT File

- Three symbols in dynamic section.
  - oatdata
  - oatexec
  - oatlastword

- The original dex file is contained in the ***oatdata*** section.

- The compiled native instructions are contained the ***oatexec*** section.

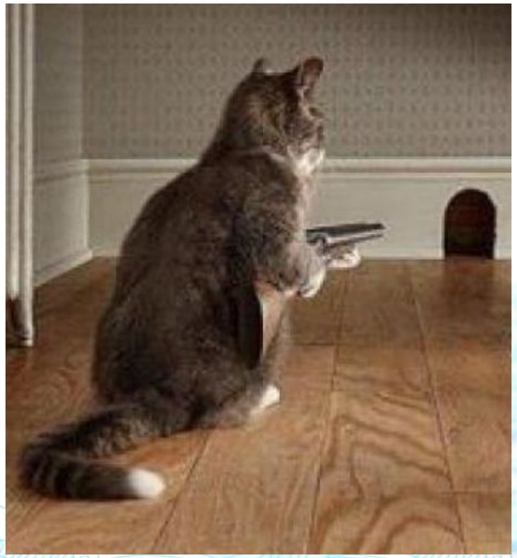


Outline

- Background
- DexHunter
  - Where to unpack the app?
  - When to unpack the app?
  - How to unpack the app?
- Analysis of major products
- Related resources

Where to dump dex file?

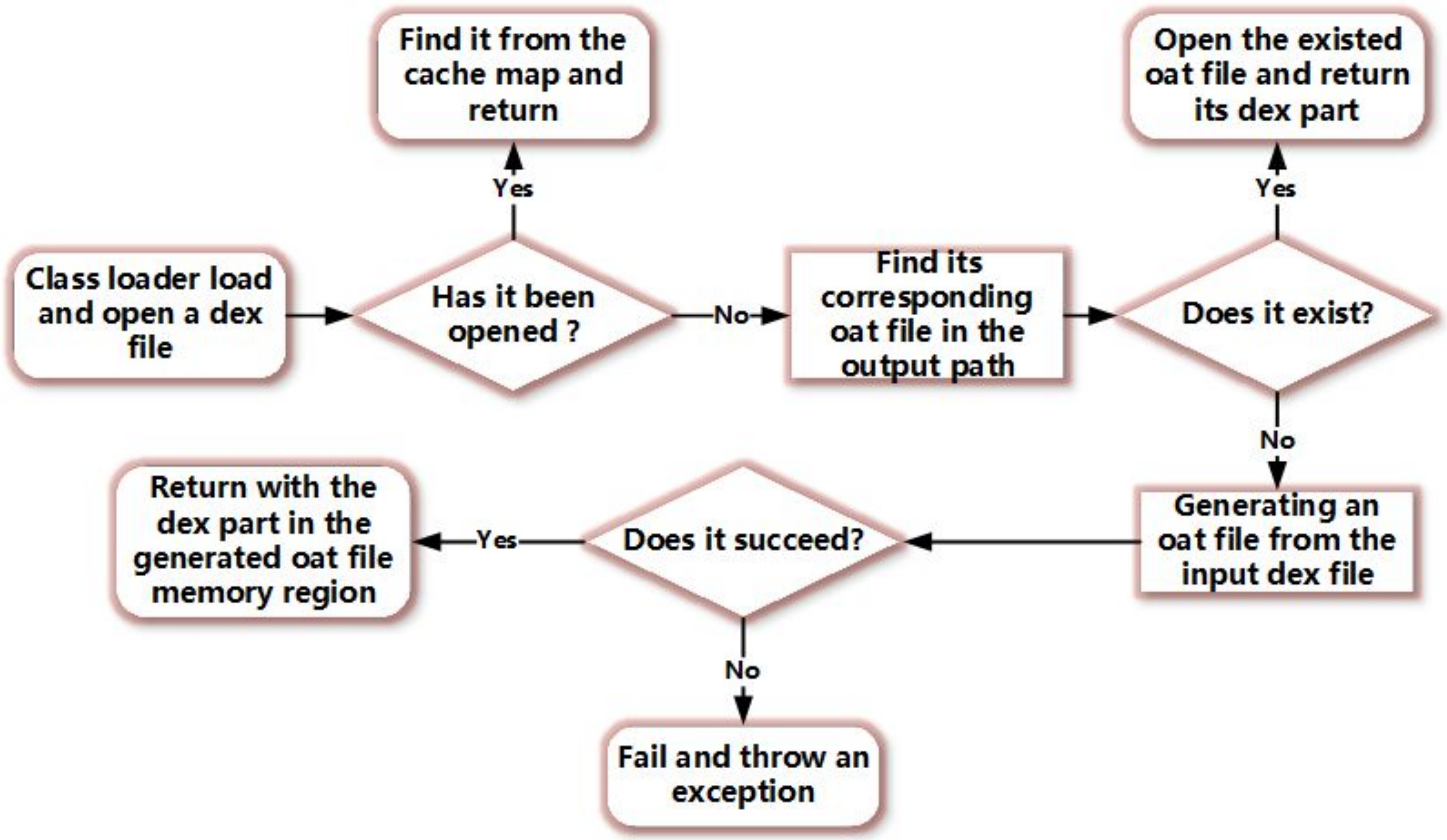
- Four occasions
  - Opening a Dex file;
  - Loading a class;
  - Initializing a class;
  - Invoking a method;



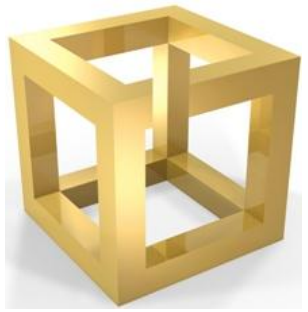
Opening a Dex File

- Operations
  - Open an APK file;
  - Check whether it has been cached;
  - If not, extract the dex file from the APK and generate the cached dex file;
  - Open the cached dex file.

Procedure of Opening a Dex File in ART


Class loader load and open a dex file
Has it been opened ?
Yes
Find it from the cache map and return
No
Find its corresponding oat file in the output path
Does it exist?
Yes
Open the existed oat file and return its dex part
No
Generating an oat file from the input dex file
Does it succeed?
Yes
Return with the dex part in the generated oat file memory region
No
Fail and throw an exception

Loading a Class



- Operations
  - Form a class object from the data;
  - Verify the legitimacy of access flags and the data;
  - Populate all fields in the class object;
  - Deal with its super classes and/or interfaces;
  - Conduct some other checking.

Two Ways of Loading a Classes

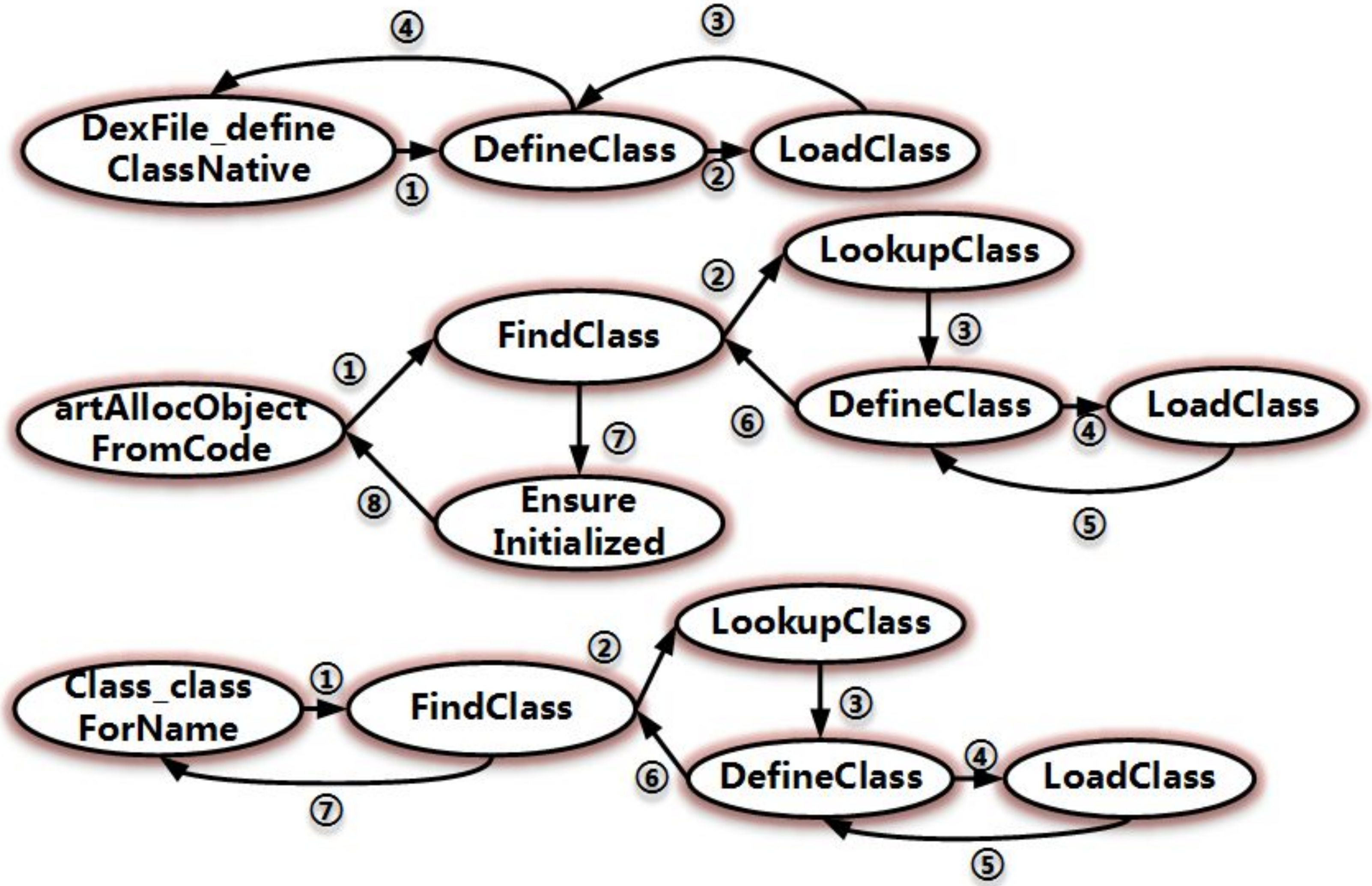
- Explicit approach
  - ***Class.forName()***, ***ClassLoader.loadClass()***.

- Implicit approach
  - E.g., ***new*** operation, accessing static members, etc.

Implementation in ART

- Explicit
  - ***ClassLoader.loadClass*** □***DexFile_defineClassNative***
  - ***Class.forName*** □***Class_classForName***
- Implicit
  - ***new*** operations and so on□ ***artAllocObjectFromCode***

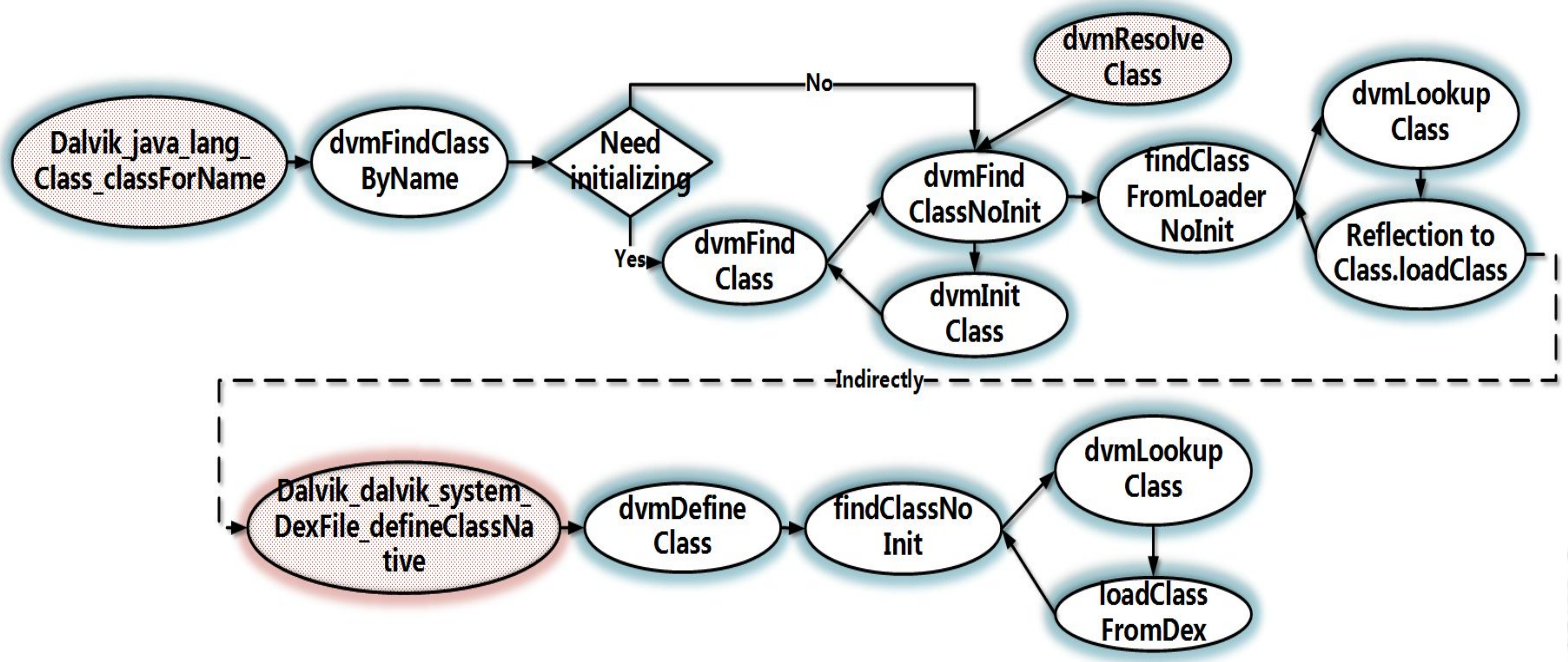
Implementation in ART



Implementation in DVM

- Explicit
  - ***ClassLoader.loadClassDalvik_dalvik_system_DexFile defineClassNative***
  - ***Class.forName Dalvik_java_lang_Class_classForName***
- Implicit
  - ***new*** operations and so on ***dvmResolveClass***

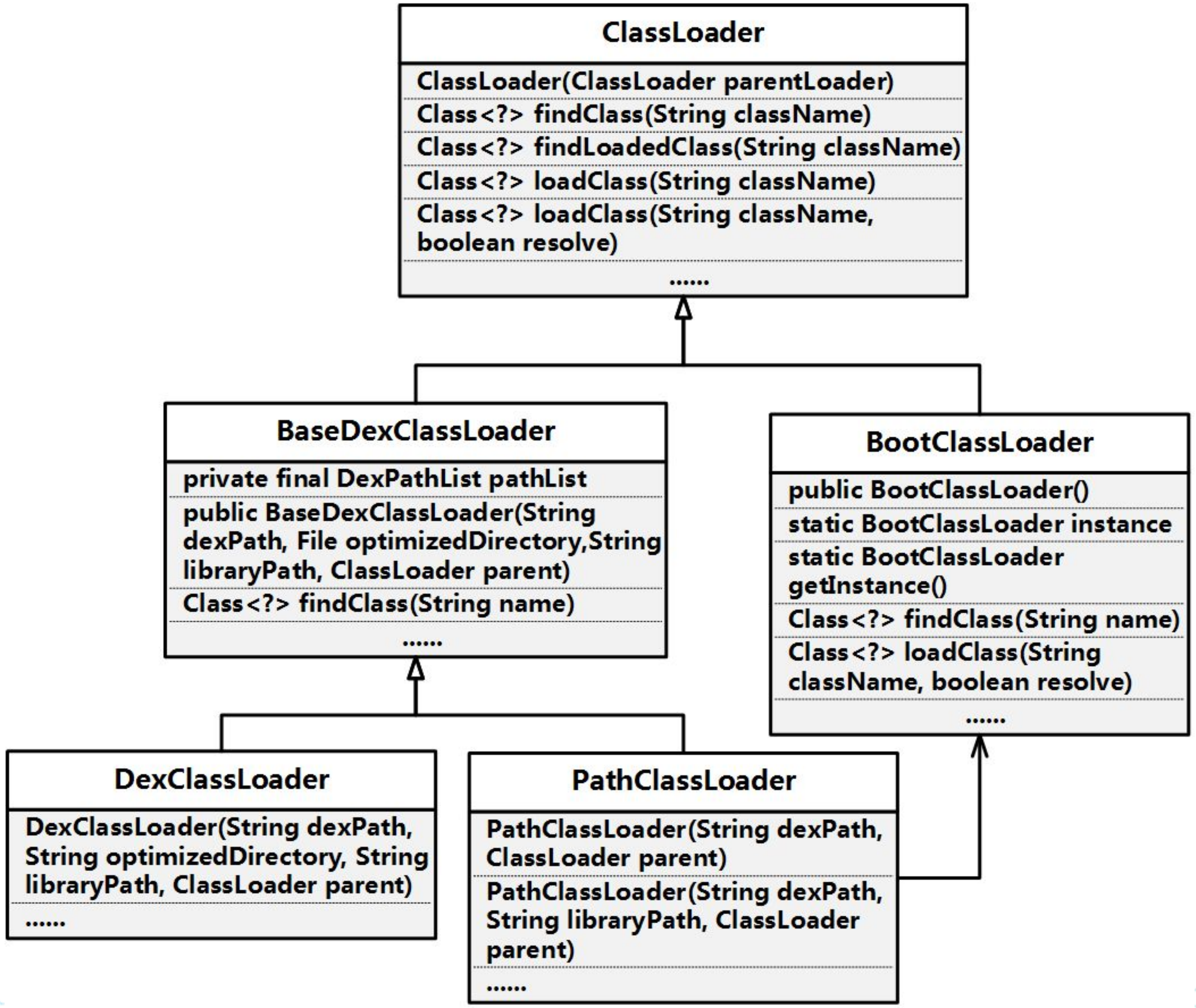
Implementation in DVM



Class Loaders at Java Level

- Three class loaders
  - ***BootClassLoader***
    - It is used for loading system classes.
  - ***DexClassLoader***
    - It is used for loading external files.
  - ***PathClassLoader***
    - It is used by the framework.

Inheritance Relationship


ClassLoader
ClassLoader(ClassLoader parentLoader)
Class<?> findClass(String className)
Class<?> findLoadedClass(String className)
Class<?> loadClass(String className)
Class<?> loadClass(String className, boolean resolve)
......
BaseDexClassLoader
private final DexPathList pathList
public BaseDexClassLoader(String dexPath, File optimizedDirectory,String libraryPath, ClassLoader parent)
Class<?> findClass(String name)
......
BootClassLoader
public BootClassLoader()
static BootClassLoader instance
static BootClassLoader getInstance()
Class<?> findClass(String name)
Class<?> loadClass(String className, boolean resolve)
......
DexClassLoader
DexClassLoader(String dexPath, String optimizedDirectory, String libraryPath, ClassLoader parent)
......
PathClassLoader
PathClassLoader(String dexPath, ClassLoader parent)
PathClassLoader(String dexPath, String libraryPath, ClassLoader parent)
......

Parent Delegation Model

```
Class<?> loadClass(String className, boolean resolve {
    Class<?> clazz = findLoadedClass(className);
    if (clazz == null) {
        clazz = parent.loadClass(className, false);
      }
      if (clazz == null) {
        clazz = findClass(className);
      }
    }
    return clazz;
 }
```

Parent Delegation Model

- Each subclass of ClassLoader implements its own ***findClass***().

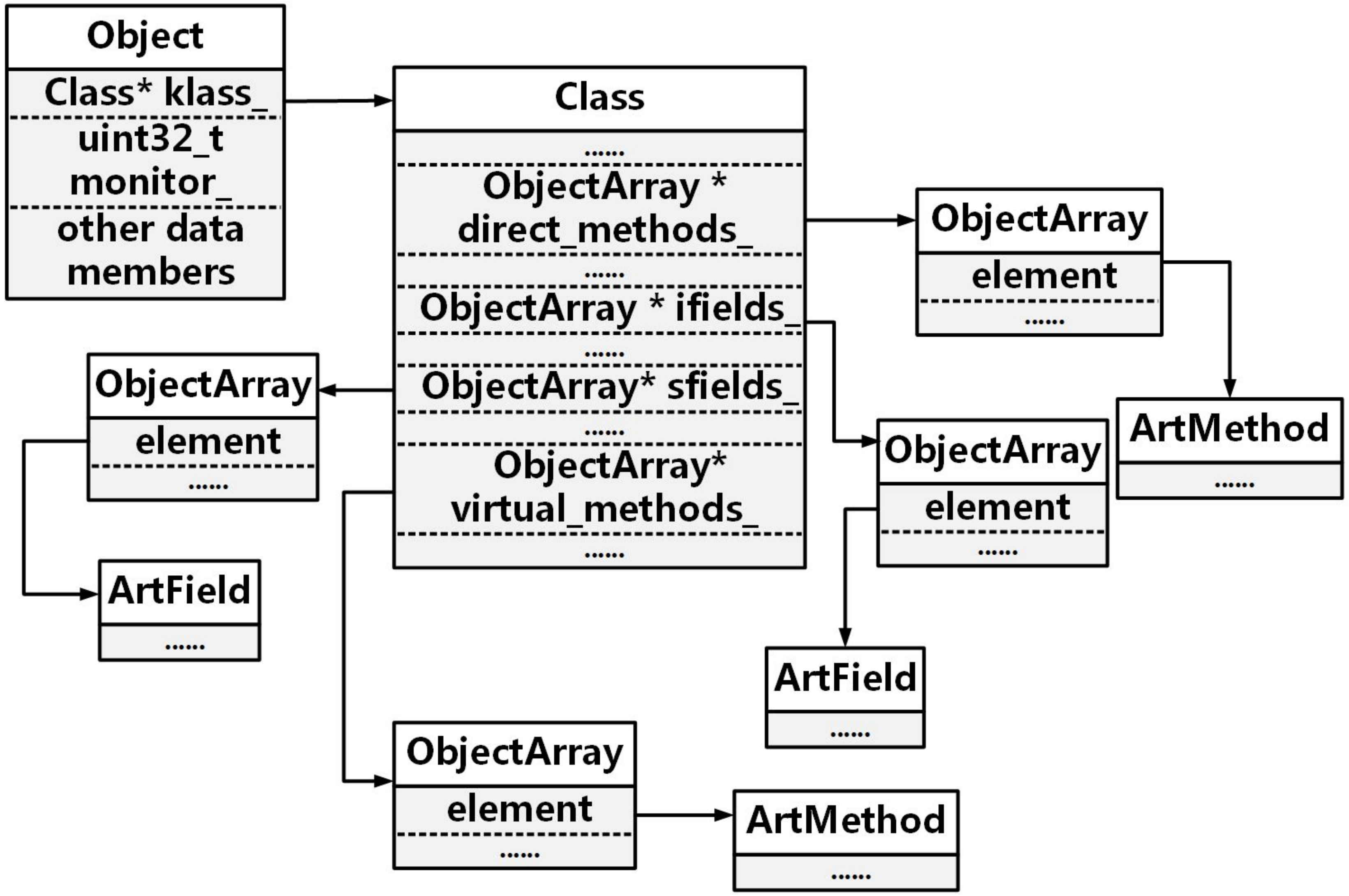
- Each subclass of ClassLoader inherits ***loadClass***() except ***BootClassLoader***.

Differences between Java and Android

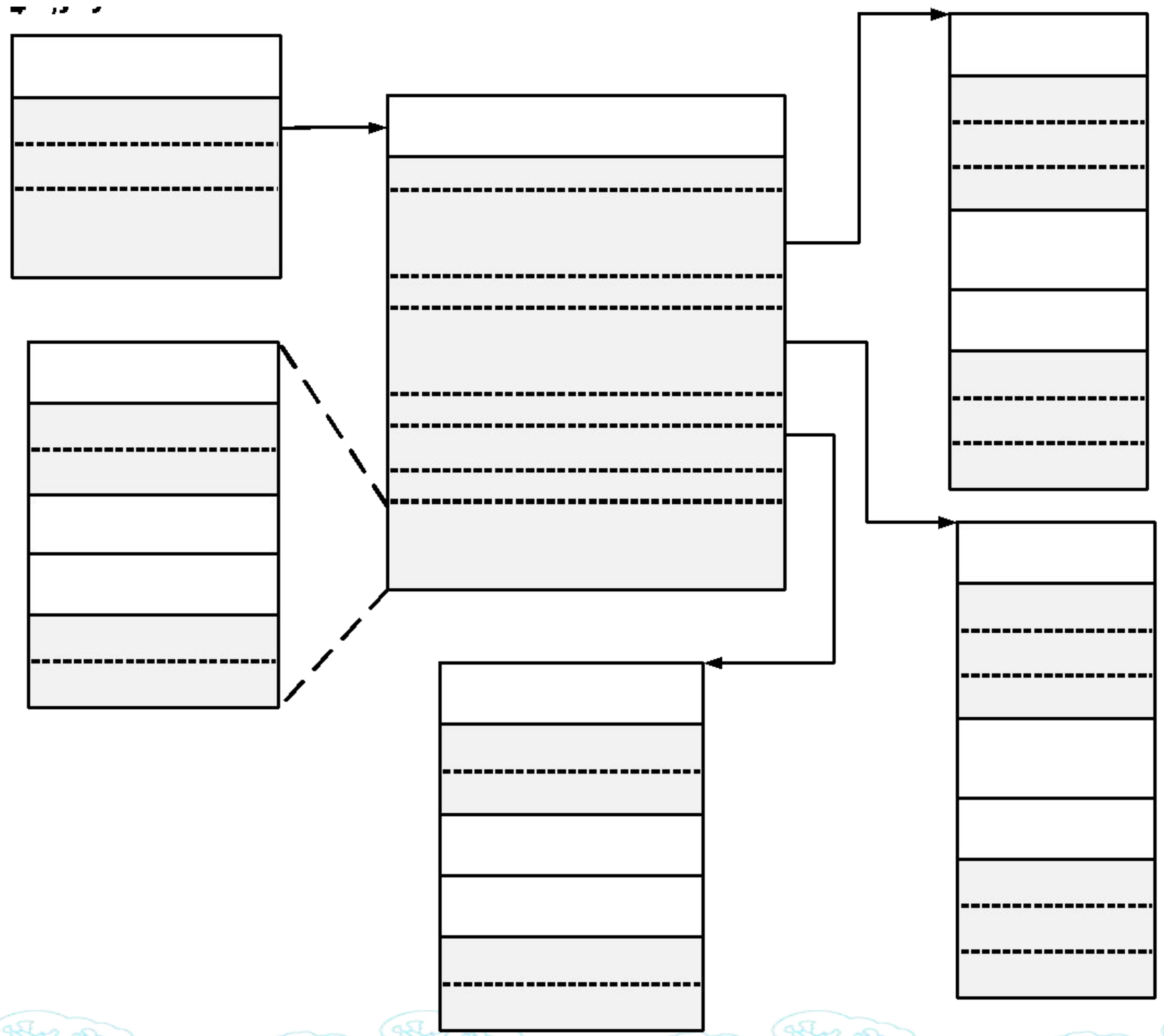
- ***defineClass()*** in ***ClassLoader*** (Android) is not implemented.
    - Throw **UnsupportedOperationException**

- ***URLClassLoader*** in Android also cannot load a class, because
    - ***URLClassLoader.findClass()***
      URLHandler/URLJarHandler.findClass()
      createClass ()
      ClassLoader.defineclass()

A Loaded Class Object in ART



A Loaded Class Object in DVM



When does Initializing Classes happen?

- Before the class object is used;
- Before the first static data member is accessed;
- Before the first static method is invoked;
- Before the first instance is generated;
- …

Invoking a Method

- DVM or ART interpreting mode
  - Execute the instructions in the ***code_item***.

- ART native mode
  - Execute the native instructions in ***oatexec*** section.

When to unpack the app?

- When the first class of the app is being loaded.

- Why?
  - Before a class is loaded, the content of the class should be available in the memory;

  - When the class is initialized, some content in memory may be modified dynamically;

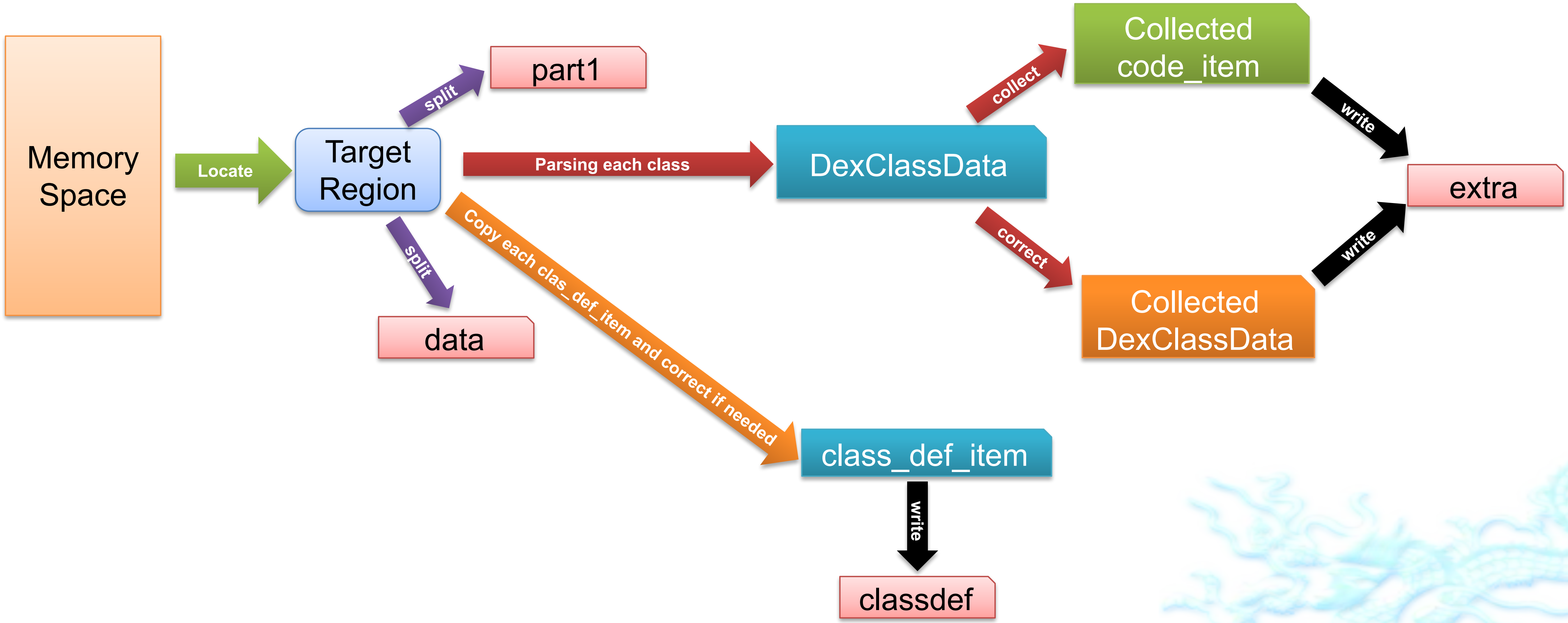
  - Just before a method is invoked, its ***code_item*** or instructions should be available.

- How?
  - Load and initialize all classes proactively.

How to unpack the apk?

- Integrate our tool into Android runtime including DVM and ART.
- Wait for the proper occasion.
- Locate the target memory region.
- Dump the selected memory.
- Correct and reconstruct the dex file.

DexHunter


Memory Space
Locate
Target Region
split
part1
split
data
Parsing each class
DexClassData
collect
Collected code_item
correct
Collected DexClassData
write
write
extra
Copy each clas_def_item and correct if needed
class_def_item
write
classdef

Loading & Initializing Classes

- Traverse all ***class_def_items*** in the dex file.
- For each one, we load it with ***FindClass*** function (ART) or ***dvmDefineClass*** function (DVM).
- Then we initialize it with ***EnsureInitialized*** function (ART) or ***dvmIsClassInitialized*** & ***dvmInitClass*** functions (DVM).

Locating the Target Memory Region

- The target memory region contains the dex file.
- We use a special string to determine whether the current dex file is what we want.

The Special String in ART

- ART: the string “**location_**” in ***DexFile*** objects.

- The opened apk file’s path □
  dex_file_location in generated oat file’s header
  □ ***dex_file_location_*** in ***OatDexFile*** objects
  □ ***location_*** in DexFile objects by function ***DexFile::Open***

The Special String in DVM

DVM: the string “**fileName**” in ***DexOrJar*** objects.

The opened apk file path
fileName in ***DexOrJar*** objects by function ***Dalvik_dalvik_system_DexFile_openDexFileNative***.

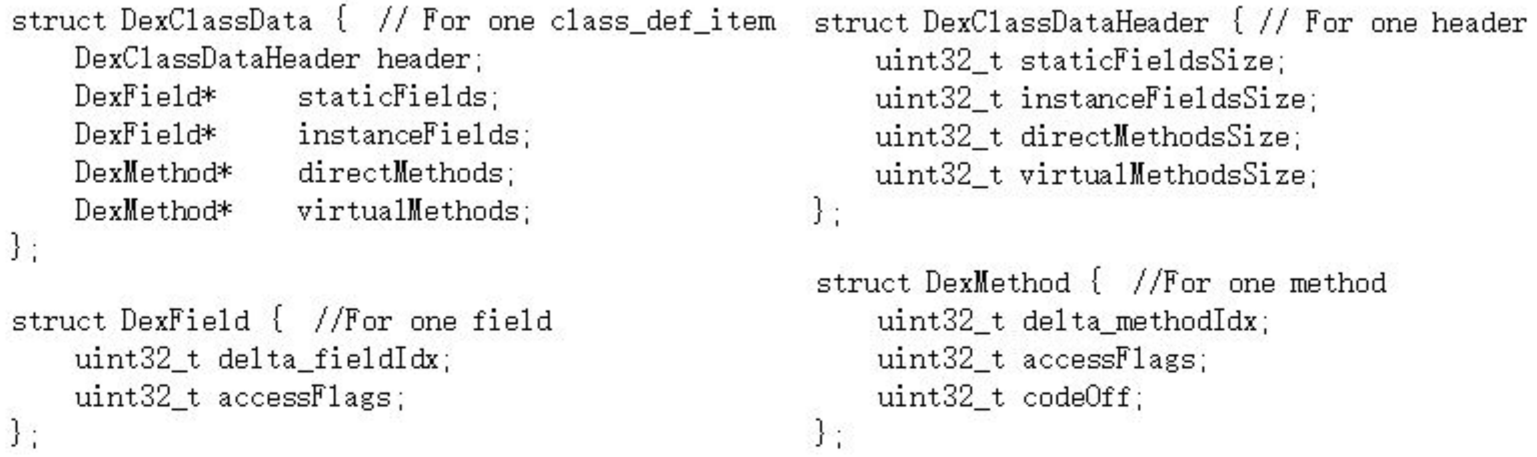
For ***Dalvik_dalvik_system_DexFile_openDexFile_bytearray***, fileName is always equal to “***<memory>***”.

Extracting the Dex File in Memory

- Divide the target memory region
  - Part 1: the content before the ***class_defs*** section
  - Part 2: the ***class_defs*** section
  - Part 3: the content after the ***class_defs*** section
- Dump part 1 into a file named **part1** and part 3 into a file named **data**.

Parsing the Content

- Parse ***class_defs*** section.
- Getting each ***class_data_item*** from ***class_def_item***.
- Read the corresponding content into a ***DexClassData*** object.
- Notice: some fields in a ***class_data_item*** are encoded by LEB128 algorithm.



```
struct DexClassData {  // For one class_def_item
    DexClassDataHeader header;
    DexField*      staticFields;
    DexField*      instanceFields;
    DexMethod*     directMethods;
    DexMethod*     virtualMethods;
};

struct DexField {  //For one field
    uint32_t delta_fieldIdx;
    uint32_t accessFlags;
};
```

```
struct DexClassDataHeader { // For one header
    uint32_t staticFieldsSize;
    uint32_t instanceFieldsSize;
    uint32_t directMethodsSize;
    uint32_t virtualMethodsSize;
};

struct DexMethod {  //For one method
    uint32_t delta_methodIdx;
    uint32_t accessFlags;
    uint32_t codeOff;
};
```

Correcting and Collecting

- Why?
  - Packing services may modify the memory dynamically.
  - The memory consists of the region containing the dex file and the method objects (i.e., ***ArtMethod*** in ART, ***Method*** in DVM) managed by runtime.
  - The runtime executes instructions according to the managed method objects.

Correcting and Collecting

- We check each:
  - ***class_data_off*** in ***class_def_item***.

  - ***accessflag*** and ***codeoff*** in ***DexMethod*** of parsed ***class_data_item*** (i.e., ***DexClassData*** object).

How?

- Determine whether the ***class_data_off*** in ***class_def_item*** exists in the scope of the dex file.
  - Copy all ***class_def_items*** and write them into a file named **classdef**.
  - Collect the outside ***class_data_items*** into a file named **extra**.

- Correct the fields in selected ***DexClassData*** object according to the managed method object.

Scenario I

- Compare the ***accessFlags*** in ***DexMethod*** with the access flag in the managed method object.
- Compare the ***codeoff*** in ***DexMethod*** with the ***code_item_off*** in the managed method object.
- If at least one is not equal, we modify the value in the ***DexMethod*** object according to the managed method object and write the relevant ***DexClassData*** into **extra** file.

Scenario II

- Check whether ***code_item_off*** exists in the scope of the dex file.

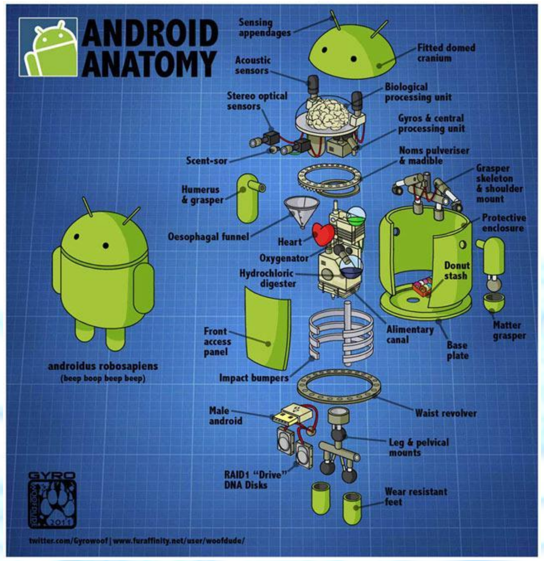
- If not, we collect the correct ***code_item*** and write it into **extra** file.

Reconstructing the Dex File

- We now have four files: **part1**, **classdef**, **data**, **extra**.

- We combine them as the sequence
  1. **part1**
  2. **classdef**
  3. **data**
  4. **extra**

- Finally, we obtain a complete dex file.



Outline

- Background
- DexHunter
- Analysis of major products
- Related resources

Products under Investigation

- 360 http://jiagu.360.cn/

  360加固保 jiagu.360.cn

- Ali http://jaq.alibaba.com/

  阿里聚安全 应用更安全，用户更安心！

- Baidu http://apkprotect.baidu.com/

  应用加固 反静态分析，反动态调试，反内存窃取，反恶意篡改...

- Bangcle http://www.bangcle.com/

  梆梆安全 BANGCLE

- Tencent http://jiagu.qcloud.com/

  腾讯云 应用加固

- ijiami http://www.ijiami.cn/

  爱加密 IJIAMI.CN

Experiment Setup

nexus 4

String List

360	/data/data/XXX/.jiagu/classes.dex
Ali	/data/data/XXX/files/libmobisecy1.zip
Baidu	/data/data/XXX/.1/classes.jar
Bangcle	/data/data/XXX/.cache/classes.jar
Tencent	/data/app/XXX-1.apk (/data/app/XXX-2.apk)
ijiami	/data/data/XXX/cache/.

XXX stands for its package name.

Anti-debugging

- All products detect debugger
- Anti-ptrace
- Anti-JWDP
- ….
- They cannot detect DexHunter.

360

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jiagu.360.cn

- Version: 06-21-2015
- It encrypts the dex file and saves it in libjiagu.so/libjiagu_art.so.
- It releases the data into memory and decrypts it while running.

Ali

- Version: 21-06-2015

- It splits the original dex file into two parts
  - One is the main body saved in libmobisecy.so
  - The other one contains the ***class_data_item***s and the ***code_item***s of some ***class_def_item***s.

- It releases both two parts into memory as plain text and corrects some offset values in the main body while running.

- Some ***annotation_off***s are set to incorrect values.

Baidu

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- Version: 21-06-2015
- It moves some class_data_items to other places outside the dex file.
- It wipes the magic numbers, checksum and signature in the header after the dex file has been opened.

Baidu

百度手机卫士

- It fills in an empty method just before it is invoked and erases the content after the method is finished.

- We instrument method invocation to dump these methods which is available only just before invoking.
  - ***DoInvoke*** (ART)
  - ***dvmMterp_invokeMethod*** (DVM)

Bangcle

- Version: 21-06-2015
- It prepares the odex file or oat file in advance.
- It encrypts the file and stores it in an external jar file.
- It decrypts the data while running
- It hooks several functions in libc.so, such as
  - read,write, mmap, …

ijiami

- Version: 21-06-2015
- Similar to Bangcle
- The string changes every time the app runs.
- It releases the decrypted file, which is also encrypted as a jar file, with different file names each time while they are in the same directory.

Tencent

- Version: 25-05-2015
- It can protect the methods selected by users.
- If a method is selected, it cannot be found in the relevant ***class_data_item***.
- It releases the real ***class_data_item*** and adjusts the offset.
  - The ***code_item*** of the selected method is still in the **data** section.
- Some ***annotation_offs***s and ***debug_info_offs***s are set to 0xFFFFFFFF.
- It can only runs in DVM.

Outline

Related resources

- https://source.android.com/devices/tech/dalvik/dex-format.html
- /libcore/libart/src/main/java/java/lang/ClassLoader.java
- /libcore/libdvm/src/main/java/java/lang/ClassLoader.java
- /libcore/dalvik/src/main/java/dalvik/system/DexClassLoader.java
- /libcore/dalvik/src/main/java/dalvik/system/PathClassLoader.java
- https://github.com/anestisb/oatdump_plus#dalvik-opcode-changes-in-art

DEMO

thank you!