# Unboxing Android

## Everything you wanted to know about Android packers

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# Who Are We?

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Experienced in OS Internal research, mobile security, linux kernel.

@Slava

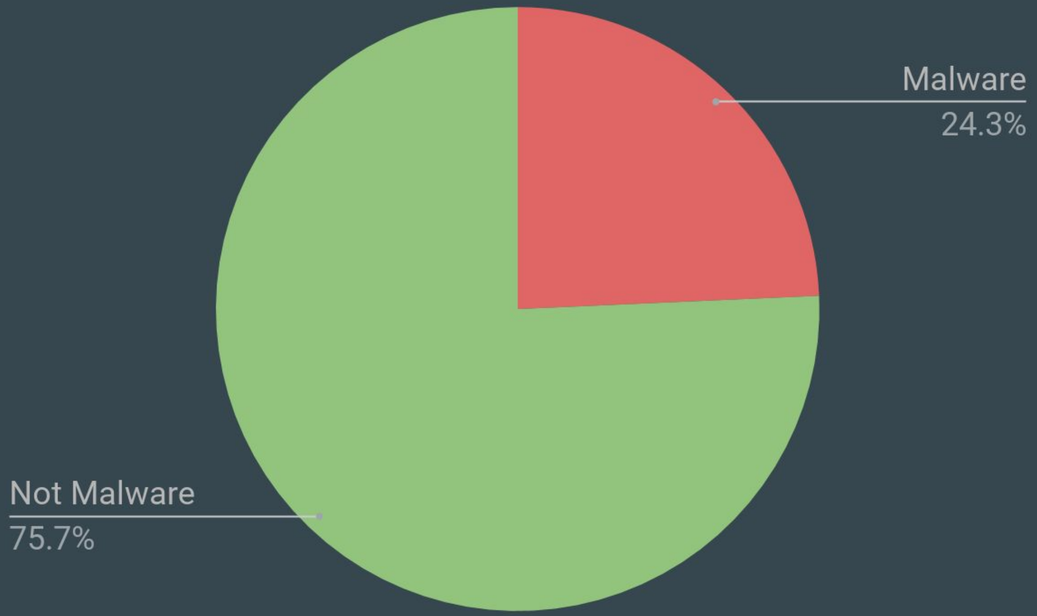
Senior Security Researcher at Check Point, former Security Researcher at Verint.

Vast experience in mobile OS research and linux internals.

# “Boxing” Apps

- Malware authors use various “boxing” techniques to prevent
  - Static Code Analysis
  - Reverse Engineering
- This can be done by proprietary techniques or 3rd party software
- This Includes
  - Code Obfuscation
  - Anti Debugging
  - Anti Tampering
  - Anti Dumper
  - Anti Decompiler
  - Anti Runtime Injection

# Maliciousness of Packed Apps



Analyzed 13,000 Apps (July 2017)

# Techniques to protect an app’s code

# Apk Protection Techniques

- **Obfuscators**
- Packers
- Protectors

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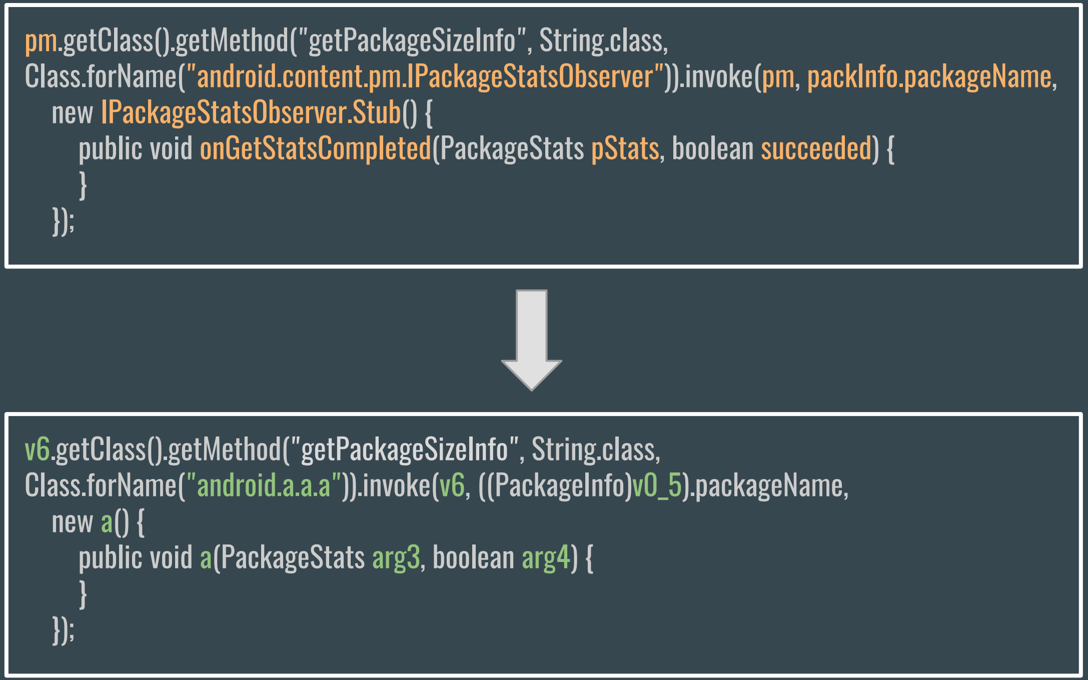

```
pm.getClass().getMethod("getPackageSizeInfo", String.class,
Class.forName("android.content.pm.IPackageStatsObserver")).invoke(pm, packInfo.packageName,
    new IPackageStatsObserver.Stub() {
        public void onGetStatsCompleted(PackageStats pStats, boolean succeeded) {
        }
    });
```

```
v6.getClass().getMethod("getPackageSizeInfo", String.class,
Class.forName("android.a.a.a")).invoke(v6, ((PackageInfo)v0_5).packageName,
    new a() {
        public void a(PackageStats arg3, boolean arg4) {
        }
    });
```

# Apk Protection Techniques

- Obfuscators
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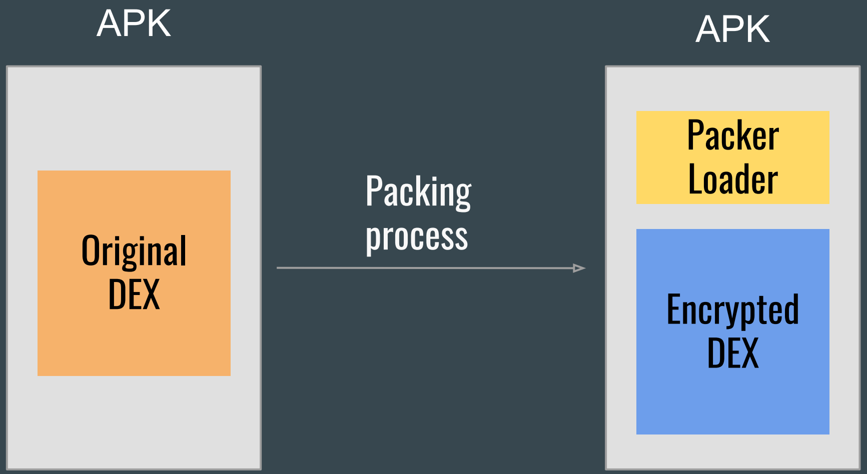
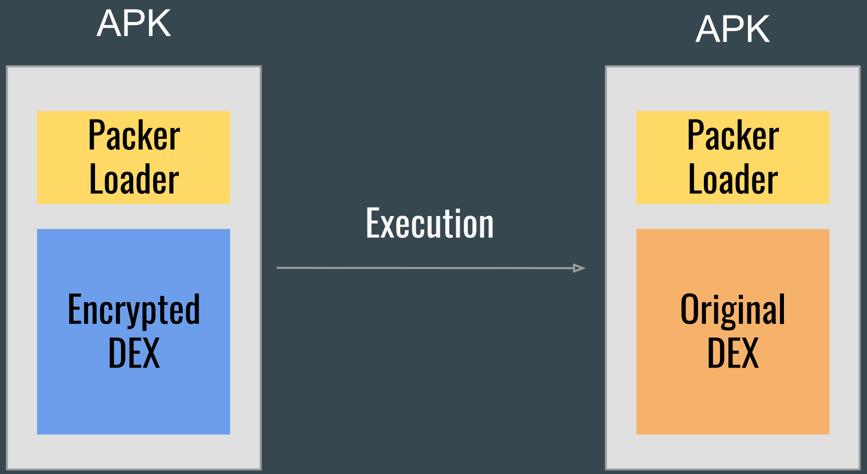


# Apk Protection Techniques

- Obfuscators
- **Packers**
- Protectors



# Apk Protection Techniques

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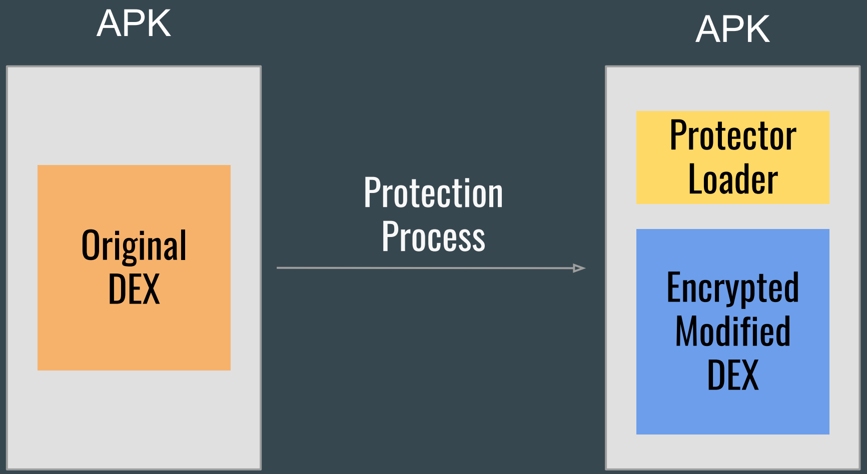
- **Protectors**



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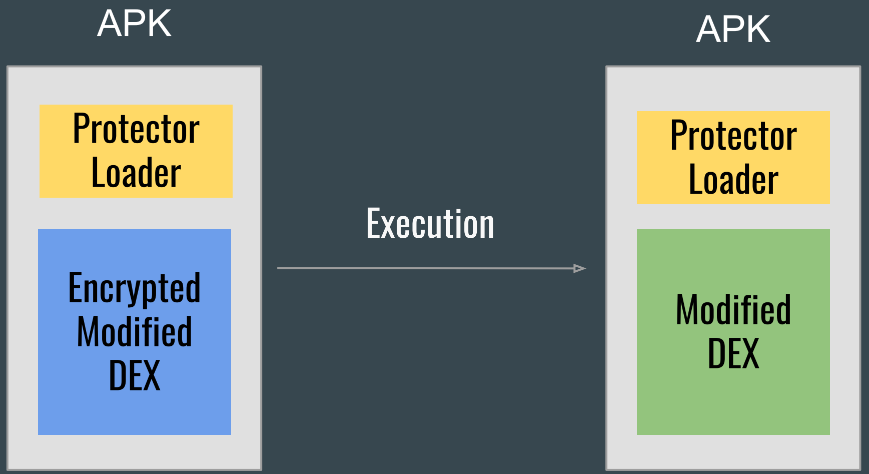
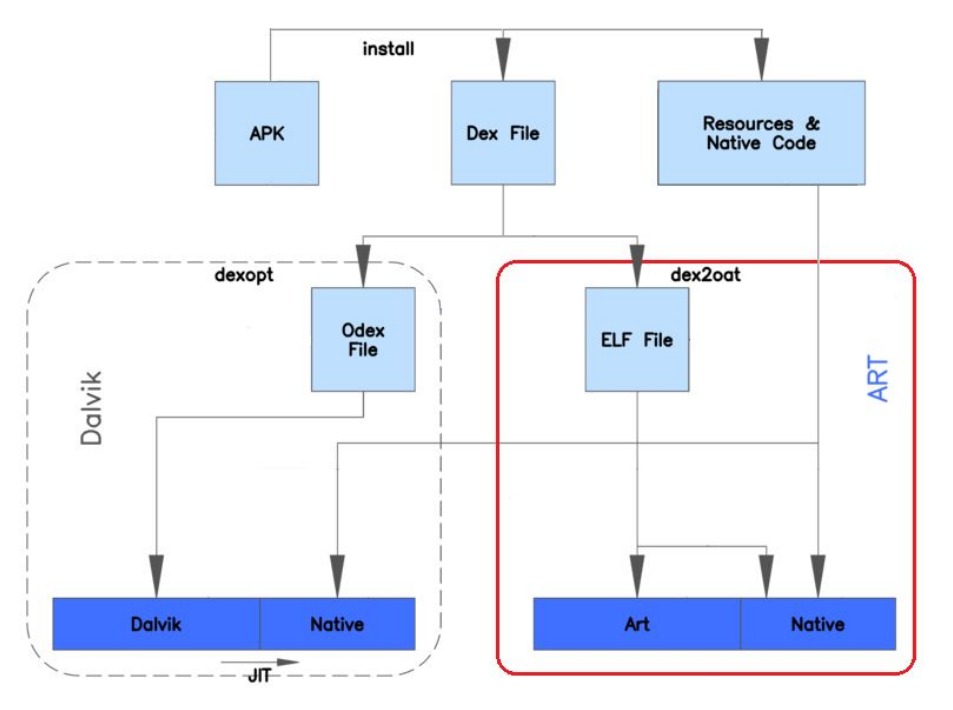
- Obfuscators
- Packers
- **Protectors**



# Back to Basics!

# ART - Android RunTime VM

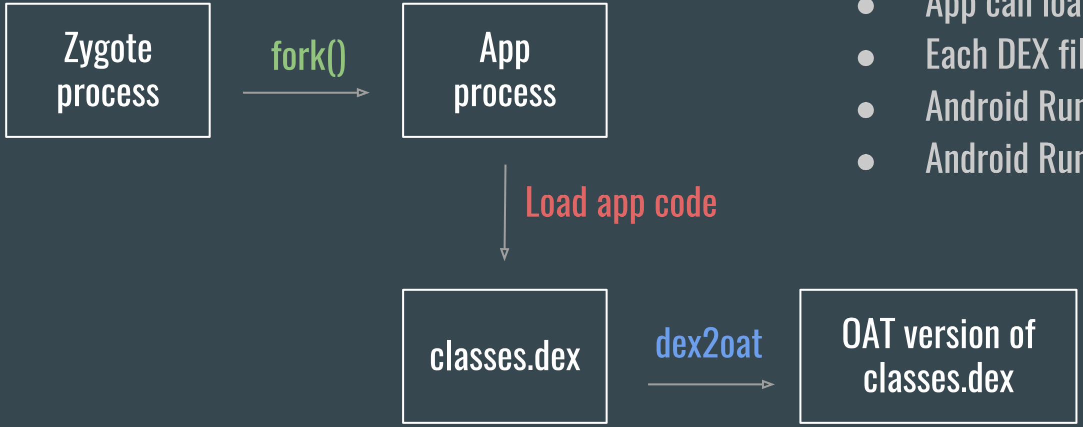


Provided an Ahead of Time (AOT) compilation approach

DEX to OAT

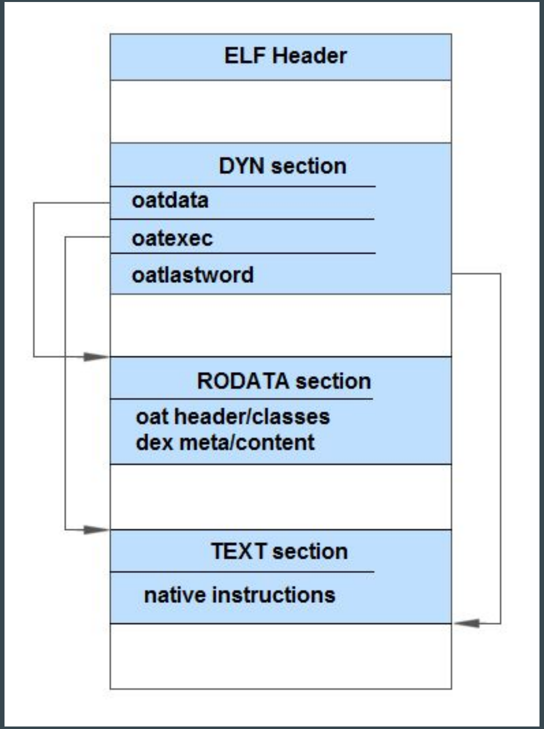
- Pre-compilation at install time
  - installation takes more time
  - more internal storage is required
- OAT vs JIT
  - Reduces startup time of applications
  - Improves battery performance
  - Uses less RAM

# DEX Loading Process



- App contains minimum one DEX file
- App can load other DEX files during execution
- Each DEX file will be compiled in OAT file
- Android Runtime executes OAT files
- Android Runtime checks DEX files checksum

# OAT - Ahead of Time File



OAT is ELF

- Three special symbols in dynamic section
  - oatdata
  - oatexec
  - aotlastword
- Original DEX file is contained in the oatdata section
- Compiled native instructions are contained in the oatexec section

# Android Java Native Interface (JNI)

- Allows calling native code directly from JVM.
- Execution path starts from System.loadLibrary
- Used by some of the popular packers for the packing logic.
- Packer library is called after activity is started

# How to unpack?

# Possible Approaches to Unpack an Android App

- Find the algorithm
- Extract DEX from compiled OAT
- Dump DEX from memory
- Runtime environment modification

# Notable Previous Work

- Android Hacker Protection Level 0
    - Tim Strazzere and Jon Sawyer
    - DEFCON 22, 2015
    - Released a set of unpacking scripts
- The Terminator to Android Hardening Services
    - Yueqian Zhang, Xiapu Luo , Haoyang Yin
    - HITCON,  2015
    - Released DexHunter - modified version of Android Dalvik/ART VM

# Our Approach

# Goals

- What did want
  - Find a solution that
    - Require minimal changes to Android
    - Will work on most of the packers
- How did we do it?
  - Reversed most popular packers
  - Patched few code rows of Android Runtime

## Goals

- What did want
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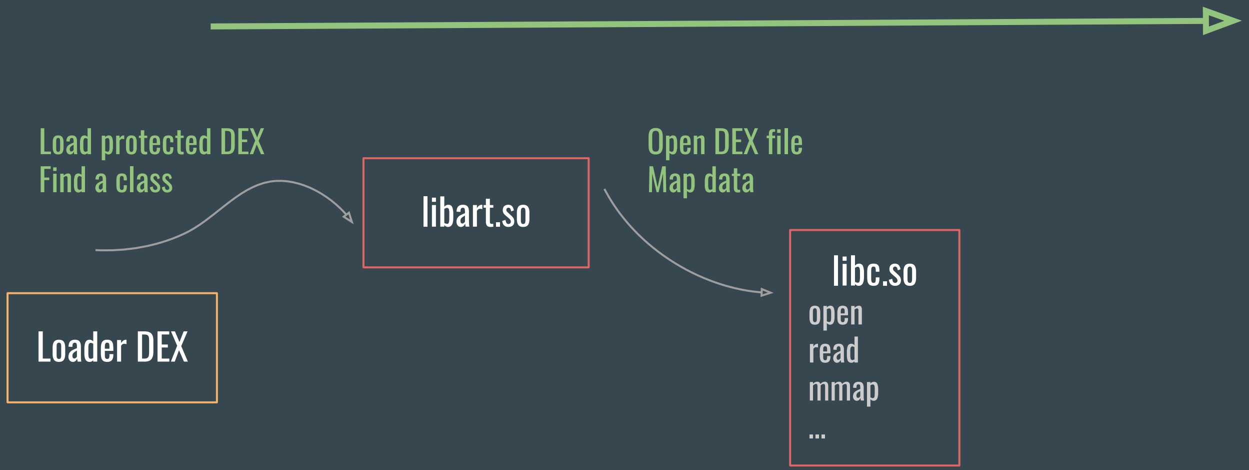
PROFIT

# Analyzed Packers

## Most popular packers encountered

- Baidu
- Bangcle
- Tencent
- Ali
- 360 Jiagu
- ... (and a few more)

# Abstract Packer Model



Load protected DEX
Find a class

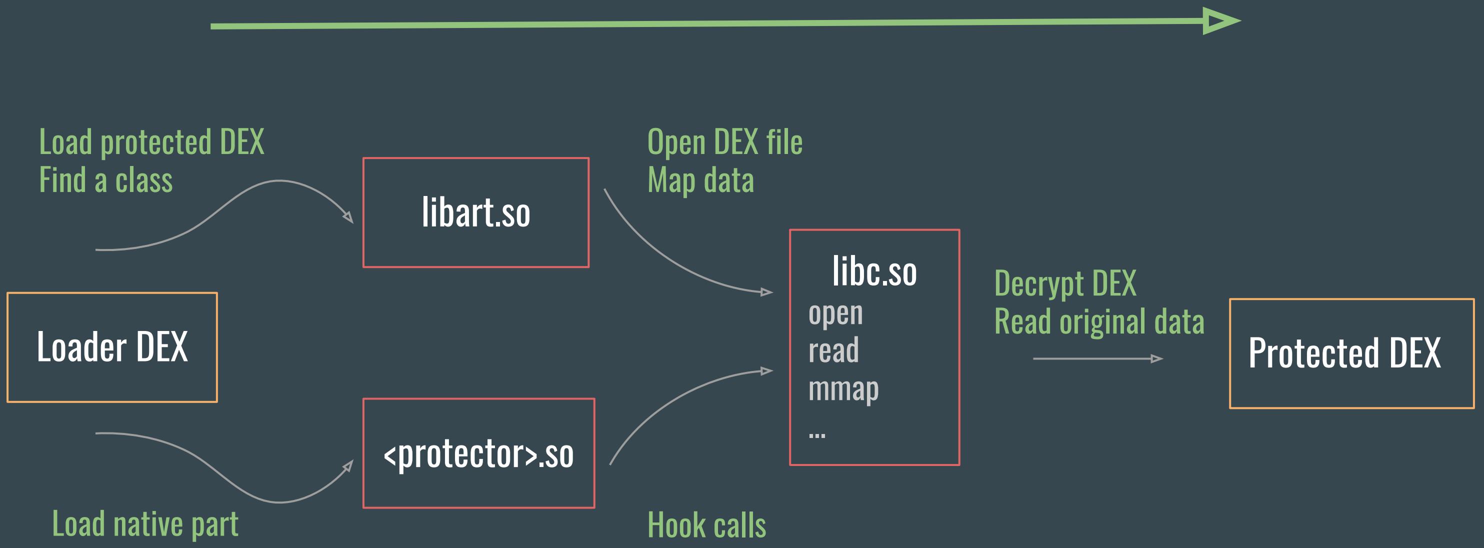
Loader DEX

libart.so

Open DEX file
Map data

libc.so
open
read
mmap
...

# Abstract Packer Model



Load protected DEX
Find a class

libart.so

Open DEX file
Map data

Loader DEX

libc.so
open
read
mmap
...

Decrypt DEX
Read original data

Protected DEX

<protector>.so

Load native part

Hook calls

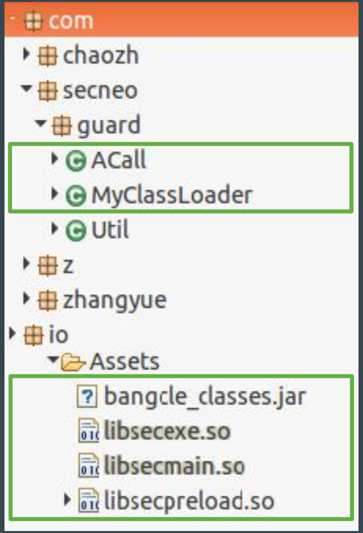
# Bangcle - Classification

Classes

- ApplicationWrapper
- FirstApplication
- MyClassLoader
- ACall

Files

- libsecse
- libsecmain
- libsecexe
- libsecpreload
- bangcle_classes (original dex)



```
com
  chaozh
  secneo
    guard
      ACall
      MyClassLoader
      Util
  z
  zhangyue
io
  Assets
    bangcle_classes.jar
    libsecexe.so
    libsecmain.so
    libsecpreload.so
```

# Bangcle - Java Loader Implementation

| | | |
|---|---|---|
| assets/libsecexe.so | → | /data/data/<pkg>/.cache/libsecexe.so |
| assets/libsecmain.so | → | /data/data/<pkg>/.cache/libsecmain.so |
| assets/libsecpreload.so | → | /data/data/<pkg>/.cache/libsecpreload.so |
| assets/bangcle_classes.jar | → | /data/data/<pkg>/.cache/classes.jar |

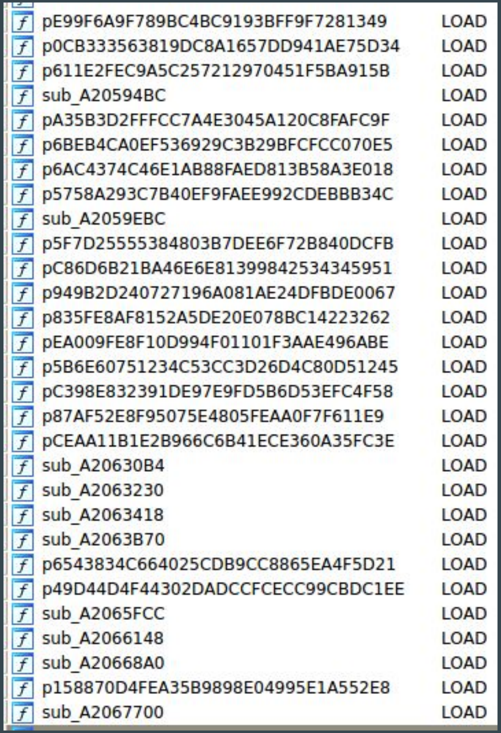
```
System.load("/data/data/" + getPackageName() + "/.cache/libsecexe.so");
Acall.getACall().a1(...);
Acall.getACall().r1(...);
Acall.getACall().r2(...);
...

public class MyClassLoader extends DexClassLoader {
    ...
}

cl = new MyClassLoader("/data/data/" + getPackageName() + "/.cache/classes.jar", ...);
realApplication = cl.loadClass(v0).newInstance();
```

# Bangcle - Native Loader Implementation

## Java Interface

```
public class ACall {
    public native void a1(byte[] arg1, byte[] arg2);
    public native void at1(Application arg1, Context arg2);
    public native void at2(Application arg1, Context arg2);
    public native void c1(Object arg1, Object arg2);
    public native void c2(Object arg1, Object arg2);
    public native Object c3(Object arg1, Object arg2);
    public native void jniCheckRawDexAvailable();
    public native boolean jniGetRawDexAvailable();
    public native void r1(byte[] arg1, byte[] arg2);
    public native void r2(byte[] arg1, byte[] arg2, byte[] arg3);
    public native ClassLoader rc1(Context arg1);
    public native void s1(Object arg1, Object arg2, Object arg3);
    public native Object set1(Activity arg1, ClassLoader arg2);
    public native Object set2(Application arg1, ...);
    public native void set3(Application arg1);
    public native void set3(Object arg1, Object arg2);
    public native void set4();
    public native void set5(ContentProvider arg1);
    public native void set8();
}
```

## Native Functions



```
pE99F6A9F789BC4BC9193BFF9F7281349     LOAD
p0CB333563819DC8A1657DD941AE75D34     LOAD
p611E2FEC9A5C257212970451F5BA915B     LOAD
sub_A20594BC                          LOAD
pA35B3D2FFFCC7A4E3045A120C8FAFC9F     LOAD
p6BEB4CA0EF536929C3B29BFCFCC070E5     LOAD
p6AC4374C46E1AB88FAED813B58A3E018     LOAD
p5758A293C7B40EF9FAEE992CDEBBB34C     LOAD
sub_A2059EBC                          LOAD
p5F7D25555384803B7DEE6F72B840DCFB     LOAD
pC86D6B21BA46E6E81399842534345951     LOAD
p949B2D240727196A081AE24DFBDE0067     LOAD
p835FE8AF8152A5DE20E078BC14223262     LOAD
pEA009FE8F10D994F01101F3AAE496ABE     LOAD
p5B6E60751234C53CC3D26D4C80D51245     LOAD
pC398E832391DE97E9FD5B6D53EFC4F58     LOAD
p87AF52E8F95075E4805FEAA0F7F611E9     LOAD
pCEAA11B1E2B966C6B41ECE360A35FC3E     LOAD
sub_A20630B4                          LOAD
sub_A2063230                          LOAD
sub_A2063418                          LOAD
sub_A2063B70                          LOAD
p6543834C664025CDB9CC8865EA4F5D21     LOAD
p49D44D4F44302DADCCFCECC99CBDC1EE     LOAD
sub_A2065FCC                          LOAD
sub_A2066148                          LOAD
sub_A20668A0                          LOAD
p158870D4FEA35B9898E04995E1A552E8     LOAD
sub_A2067700                          LOAD
```

## Mapping

| Func | Offset | Func | Offset |
|---|---|---|---|
| a1 | 0x4638 | set1 | 0xCFFC |
| at1 | 0x8A44 | set2 | 0x9BC8 |
| at2 | 0x9184 | set3 | 0x566C |
| c1 | 0xF984 | set3 | 0x8CE8 |
| c2 | 0x103E8 | set4 | 0x63B4 |
| c3 | 0x12E48 | set5 | 0x4AA0 |
| r1 | 0x4938 | set8 | 0x16828 |
| r2 | 0xDE38 | s1 | 0x126B4 |
| jniCheckRawDexAvailable | 0x4408 | rc1 | 0xBFE4 |
| jniGetRawDexAvailable | 0x44A0 | | |

# Bangcle - libsecexe.so

| | |
|---|---|
| Class: | ELF32 |
| Type: | DYN (Shared object file) |
| Machine: | ARM |
| Entry point address: | 0x433c |
| Start of program headers: | 52 (bytes into file) |
| Start of section headers: | 92204 (bytes into file) |
| Size of program headers: | 32 (bytes) |
| Number of program headers: | 6 |
| Size of section headers: | 0 (bytes) |
| Number of section headers: | 0 |

Entry address points to compressed code (anti-debugging)
Start of section table is out of file bounders
No section table (anti-debugging)
Exception Index Table is out of file bounders (IDA crash)

## Program headers:

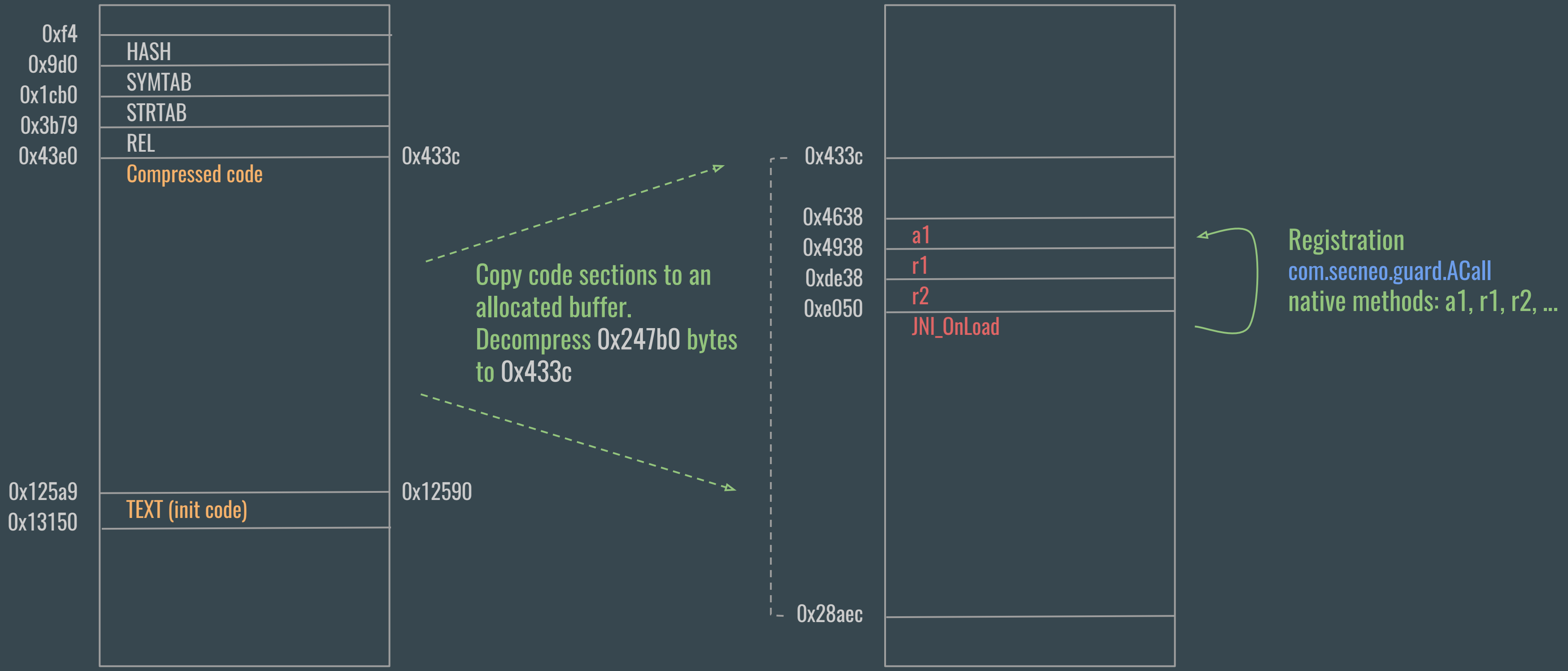
| Type | Offset | VirtAddr | PhysAddr | FileSiz | MemSiz | Flg | Align |
|---|---|---|---|---|---|---|---|
| EXIDX | 0x028584 | 0x00028584 | 0x00028584 | 0x00568 | 0x00568 | R | 0x4 |
| LOAD | 0x000000 | 0x00000000 | 0x00000000 | 0x131ec | 0x131ec | RE | 0x8000 |
| LOAD | 0x018c1c | 0x00030c1c | 0x00030c1c | 0x00520 | 0x01538 | RW | 0x8000 |
| DYNAMIC | 0x018c80 | 0x00030c80 | 0x00030c80 | 0x00108 | 0x00108 | RW | 0x4 |
| GNU_STACK | 0x000000 | 0x00000000 | 0x00000000 | 0x00000 | 0x00000 | RW | 0x4 |
| GNU_RELRO | 0x018c1c | 0x00030c1c | 0x00030c1c | 0x003e4 | 0x003e4 | R | 0x1 |

## Dynamic section:

| | |
|---|---|
| 0x0000000c (INIT) | 0x125A9 |
| 0x00000019 (INIT_ARRAY) | 0x30C1C |
| ... | |

Real entry point

# Bangcle - libsecexe.so



Copy code sections to an allocated buffer.
Decompress 0x247b0 bytes to 0x433c

Registration
com.secneo.guard.ACall
native methods: a1, r1, r2, ...

# Bangcle - Processes

Function a1

Extract ELF /data/data/<pkg>/.cache/<pkg> from apk (Assets)

Function r2

fork app process

execl /data/data/<pkg>/.cache/<pkg> <pkg> -1114751212 1 /data/app/<pkg>/base.apk 34 <pkg> 43 44 0

fork pkg process (from libsecmain.so::so_main)

anti-debugging thread

fork pkg process if .cache/classes.dex (OAT) does not exist

LD_PRELOAD=/data/data/<pkg>/.cache/libsecpreload.so

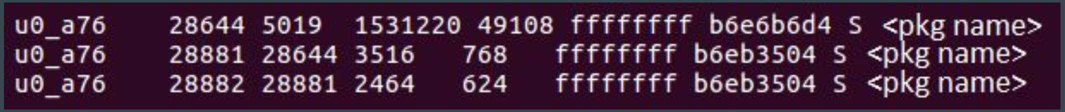
LD_PRELOAD_ARGS=<pkg> 9 13

LD_PRELOAD_SECSO=/data/data/<pkg>/.cache/libsecmain.so

execl /system/bin/dex2oat

–zip-fd=9 –zip-location=/data/data/<pkg>/.cache/classes.jar –oat-fd=13

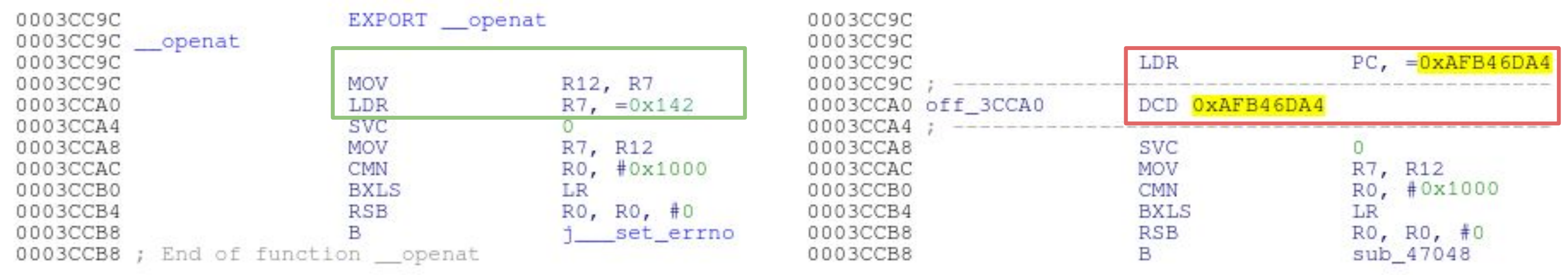
–oat-location=/data/data/<pkg>/.cache/classes.dex –instruction-set=arm



```
u0_a76    28644 5019   1531220 49108 ffffffff b6e6b6d4 S <pkg name>
u0_a76    28881 28644  3516    768   ffffffff b6eb3504 S <pkg name>
u0_a76    28882 28881  2464    624   ffffffff b6eb3504 S <pkg name>
```

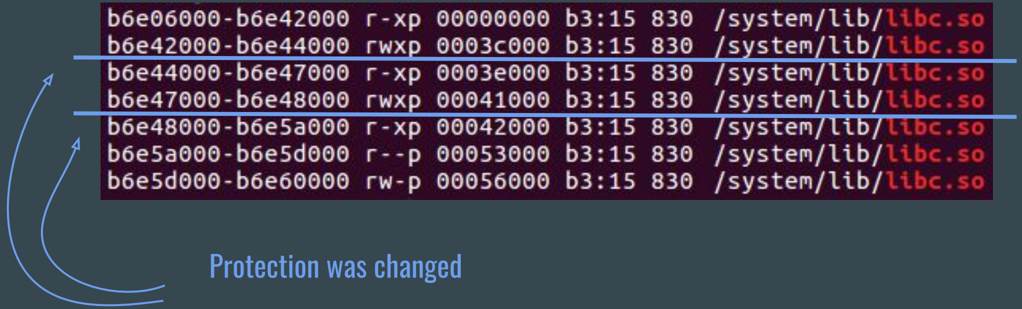
# Bangcle - libc.so hook

## Function r1



```
0003CC9C                 EXPORT __openat
0003CC9C __openat
0003CC9C
0003CC9C                 MOV             R12, R7
0003CCA0                 LDR             R7, =0x142
0003CCA4                 SVC             0
0003CCA8                 MOV             R7, R12
0003CCAC                 CMN             R0, #0x1000
0003CCB0                 BXLS            LR
0003CCB4                 RSB             R0, R0, #0
0003CCB8                 B               j___set_errno
0003CCB8 ; End of function __openat
```

```
0003CC9C
0003CC9C
0003CC9C                 LDR             PC, =0xAFB46DA4
0003CC9C ; ---------------------------------------------------------------
0003CCA0 off_3CCA0       DCD 0xAFB46DA4
0003CCA4 ; ---------------------------------------------------------------
0003CCA8                 SVC             0
0003CCAC                 MOV             R7, R12
0003CCB0                 CMN             R0, #0x1000
0003CCB4                 BXLS            LR
0003CCB8                 RSB             R0, R0, #0
0003CCB8                 B               sub_47048
```



```
b6e06000-b6e42000 r-xp 00000000 b3:15 830  /system/lib/libc.so
b6e42000-b6e44000 rwxp 0003c000 b3:15 830  /system/lib/libc.so
b6e44000-b6e47000 r-xp 0003e000 b3:15 830  /system/lib/libc.so
b6e47000-b6e48000 rwxp 00041000 b3:15 830  /system/lib/libc.so
b6e48000-b6e5a000 r-xp 00042000 b3:15 830  /system/lib/libc.so
b6e5a000-b6e5d000 r--p 00053000 b3:15 830  /system/lib/libc.so
b6e5d000-b6e60000 rw-p 00056000 b3:15 830  /system/lib/libc.so
```

Protection was changed

| libc func | Offset | libc func | Offset |
|---|---|---|---|
| munmap | 0x15BD8 | close | 0x14FAC |
| msync | 0x15F88 | __openat | 0x14DA4 |
| read | 0x15118 | pread64 | 0x162F8 |
| __mmap2 | 0x15420 | pwrite64 | 0x166DC |
| __open | 0x14B9C | write | 0x152FC |

# Bangcle - Summary

- Creates a stub in Java activity to load native library.
- Native library is protected with different anti research techniques.
- Native library hooks libc for handling the opening of the OAT file.

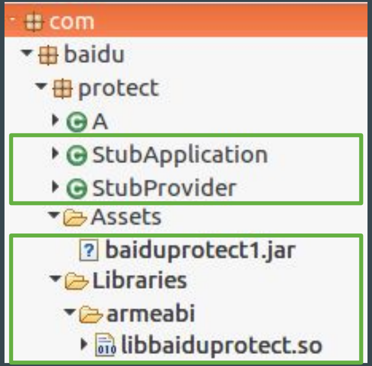
# Baidu - Classification

Classes

- StubApplication
- StubProvider

Files

- libbaiduprotect
- baiduprotect1 (original dex)



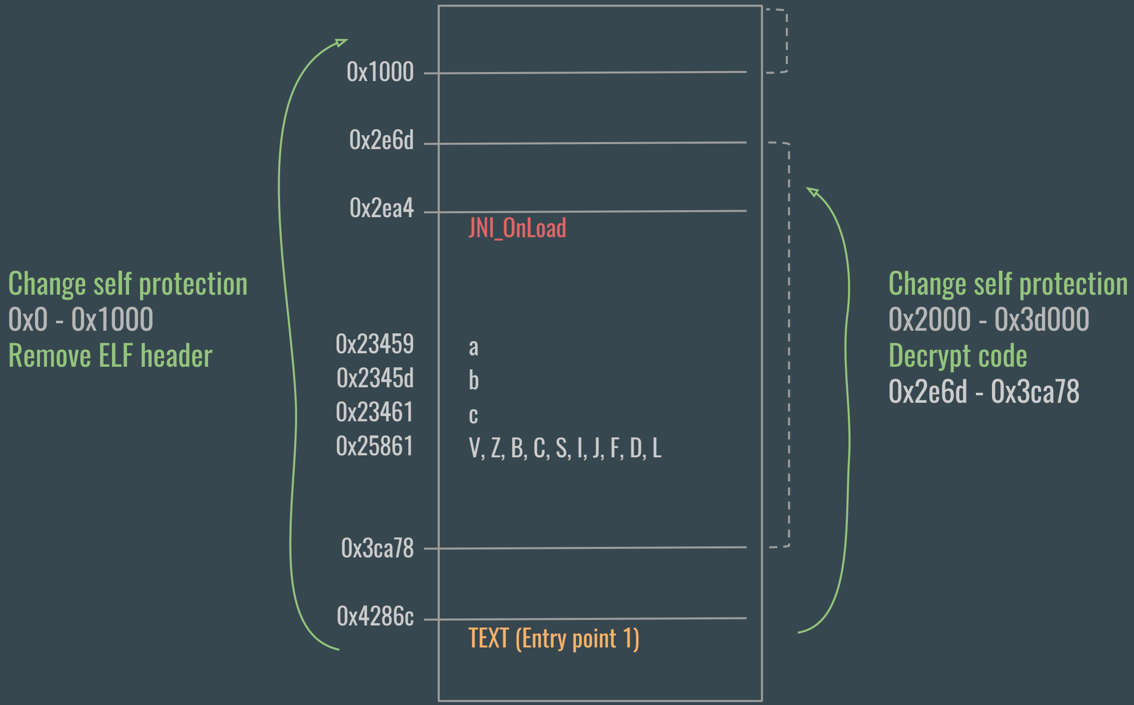
```
com
  baidu
    protect
      A
      StubApplication
      StubProvider
    Assets
      baiduprotect1.jar
    Libraries
      armeabi
        libbaiduprotect.so
```

# Baidu - Native Loader Implementation

```
public class A implements Enumeration {
    public static native byte B(int arg0, Object arg1, ...);
    public static native char C(int arg0, Object arg1, ...);
    public static native double D(int arg0, Object arg1, ...);
    public static native float F(int arg0, Object arg1, ...);
    public static native int I(int arg0, Object arg1, ...);
    public static native long J(int arg0, Object arg1, ...);
    public static native Object L(int arg0, Object arg1, ...);
    public static native short S(int arg0, Object arg1, ...);
    public static native void V(int arg0, Object arg1, ...);
    public static native boolean Z(int arg0, Object arg1, ...);
    public static native void a();
    public static native void b();
    public static native String[] c();
}
```

| Func | Offset |
|---|---|
| a | 0x23459 |
| b | 0x2345d |
| c | 0x23461 |
| V, Z, B, C, S, I, J, F, D, L | 0x25861 |

# Baidu - libbaiduprotect.so



Change self protection
0x0 - 0x1000
Remove ELF header

0x1000

0x2e6d

0x2ea4 JNI_OnLoad

0x23459 a
0x2345d b
0x23461 c
0x25861 V, Z, B, C, S, I, J, F, D, L

0x3ca78

0x4286c TEXT (Entry point 1)

Change self protection
0x2000 - 0x3d000
Decrypt code
0x2e6d - 0x3ca78

# Baidu - JNI_OnLoad

Anti-debugging

Registration of native methods: a, b, c, ...

Extract packed DEX /Assets/baiduprotect1.jar to /data/data/<pkg>/.1/1.jar
Create empty DEX file /data/data/<pkg>/.1/classes.jar

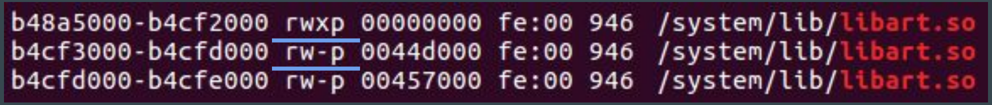
Hook libart.so

Create DexClassLoader(/data/data/<pkg>/.1/classes.jar) + Merge with main class loader by extending BaseDexClassLoader::pathList::dexElements

# Baidu - Anti-debugging

- Obfuscation
- Logs disabling
- For each /proc/ check that /proc/<pid>/cmdline does not contain gdb, gdbserver, android_server
- For each /proc/self/task check that /proc/self/task/<pid>/status does not contain TracerPid
- For each /proc/self/task check that /proc/self/task/<pid>/comm does not contain JDWP
- Check android.os.Debug.isDebuggerConnected
- select call (timer) based technique
- inotify watch (IN_ACCESS + IN_OPEN) of
  - /proc/self/mem
  - /proc/self/pagemap
  - For each /proc/self/task
    - /proc/self/task/<pid>/mem
    - /proc/self/task/<pid>/pagemap

# Baidu - libart.so hook



```
b48a5000-b4cf2000 rwxp 00000000 fe:00 946  /system/lib/libart.so
b4cf3000-b4cfd000 rw-p 0044d000 fe:00 946  /system/lib/libart.so
b4cfd000-b4cfe000 rw-p 00457000 fe:00 946  /system/lib/libart.so
```

### Function __android_log_print

No logs

### Function execv

dex2oat hook:

Add environment variable ANDROID_LOG_TAGS=*:f

Prevent code compilation: add --compiler-filter=verify-none command line parameter

### Function open

Decrypt /data/data/<pkg>/.1/1.jar in case of /data/data/<pkg>/.1/classes.jar file loading

| libc func | Libart hook | Offset |
|---|---|---|
| read | 0x309BC8 | 0xA75C |
| open | 0x309BDC | 0x8FAC |
| close | 0x309BE4 | 0x9168 |
| mmap | 0x309BE8 | 0x9474 |
| strstr | 0x309C58 | 0x8BD8 |
| fork | 0x309F3C | 0x92DC |
| waitpid | 0x309F40 | 0xA5E4 |
| execv | 0x309F4C | 0xA324 |
| __android_log_print | 0x309FAC | 0xA750 |

# Baidu - Summary

- Creates a stub in Java activity to load native library.
- Native library is protected with different anti research techniques .
- Native library hooks libc for handling the opening of the DEX file.

NOT SURE IF REPOST
OR JUST DEJA VU
quickmeme.com

# libc::open == decryption

Bangle

Baidu

Filter by file path:

/data/data/<pkg>/.cache/classes.dex

/data/data/<pkg>/.1 /classes.jar

Expect to see:

OAT

DEX

# Using the DEX Loading Process to Unpack Apps

Where is first call of DEX/OAT file opening?

DEX

OAT

dalvik.system.DexClassLoader::DexClassLoader
dalvik.system.DexFile::DexFile
DexFile::openDexFileNative

DexFile_openDexFileNative
ClassLinker::OpenDexFilesFromOat
OatFileAssistant::MakeUpToDate
OatFileAssistant::OatFileIsUpToDate

OatFileAssistant::GivenOatFileIsUpToDate
OatFileAssistant::GetRequiredDexChecksum
DexFile::GetChecksum
OpenAndReadMagic

OatFileAssistant::GetOatFile
OatFile::Open
OatFile::OpenElfFile → DexFile::DexFile

# platform/art/runtime/dex_file.cc patch

## DEX

```
static int OpenAndReadMagic(const char* filename, uint32_t* magic, std::string* error_msg)
{
    CHECK(magic != nullptr);
    ScopedFd fd(open(filename, O_RDONLY, 0));
    ...

    char* fn_out = new char[PATH_MAX];
    strcpy(fn_out, filename);
    strcat(fn_out, "__unpacked");

    int fd_out = open(fn_out, O_WRONLY|O_CREAT|O_EXCL, S_IRUSR|S_IWUSR|S_IRGRP|S_IROTH);

    struct stat st;
    if (!fstat(fd.get(), &st)) {
      char* addr = (char*)mmap(NULL, st.st_size, PROT_READ, MAP_PRIVATE, fd.get(), 0);
      write(fd_out, addr, st.st_size);
      munmap(addr, st.st_size);
    }

    close(fd_out);
    delete fn_out;

    ...
}
```

## OAT

```
DexFile::DexFile(const uint8_t* base, size_t size,
                 const std::string& location,
                 uint32_t location_checksum,
                 MemMap* mem_map,
                 const OatDexFile* oat_dex_file)
    : begin_(base),
      size_(size),
      ...
{
    ...

    std::ofstream dst(location + "__unpacked", std::ios::binary);
    dst.write(reinterpret_cast<const char*>(base), size);
    dst.close();

    ...
}
```

# Demo Time!

Unpacking modification instructions to AOSP can be found @checkpoint github repo

# Questions?