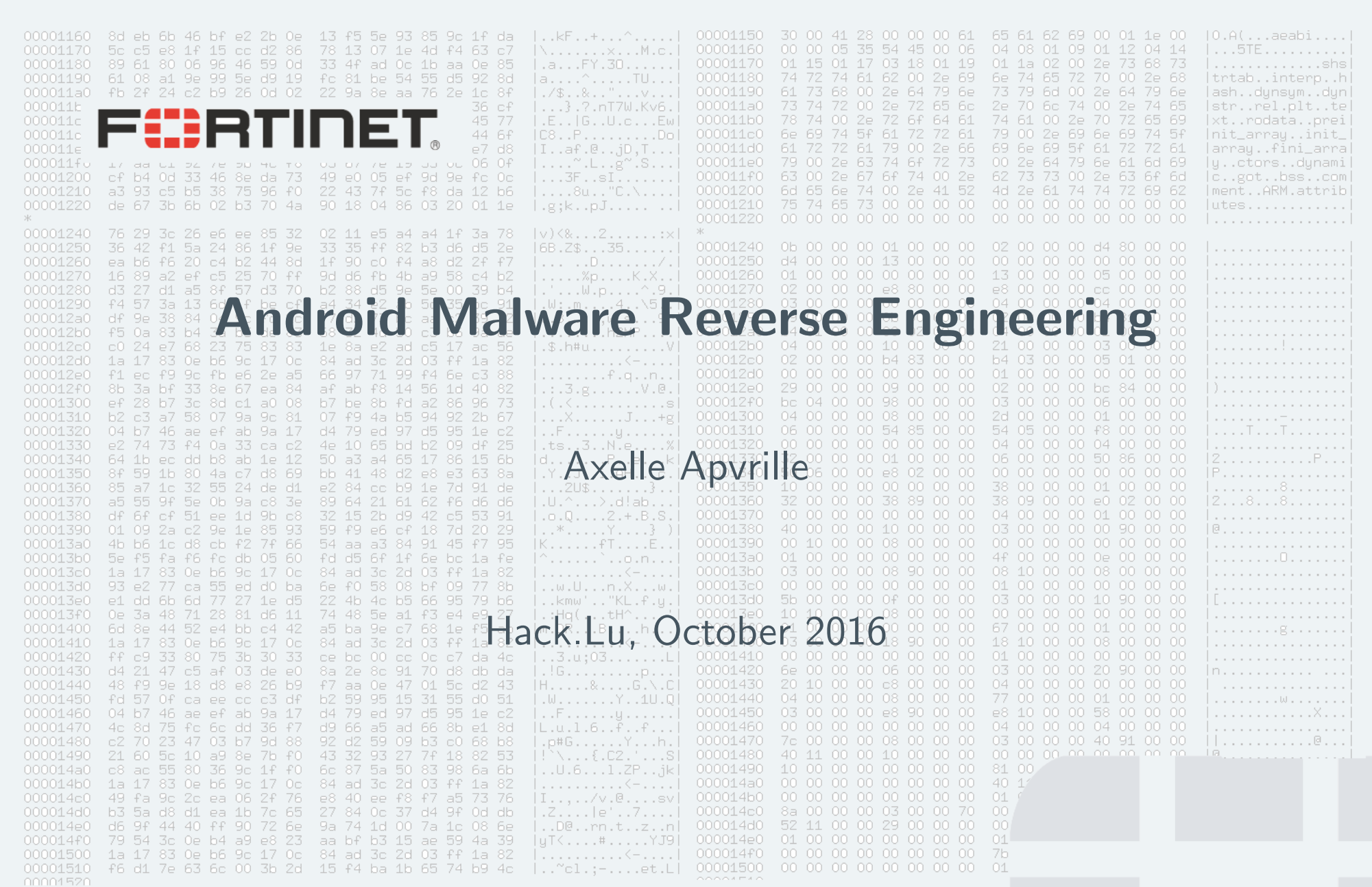


Android Malware Reverse Engineering

Axelle Apvrille

Hack.Lu, October 2016

Welcome!

Who am I? Axelle Apvrille

- Security researcher at Fortinet, Fortiguard Labs
- Topic: malware for smart devices (phones, IoT...)
- Email: aapvrille at fortinet dot com
- Twitter: @cryptax
- GPG: 5CE9 C366 AFB5 4556 E981 020F 9EAA 42A0 37EC 490C

Agenda

- Contents of an APK
- Static analysis
- Dynamic analysis
- De-obfuscation

$2 + 1$ hour workhop

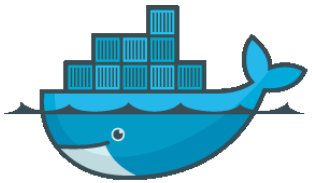
This is a training. You're going to work :=)

For the labs

Copy the contents of the USB key, and pass to your neighbour!

Thanks!

Requirements: install either Docker or VirtualBox



https://www.docker.com/products/overview

https://www.virtualbox.org/wiki/Downloads

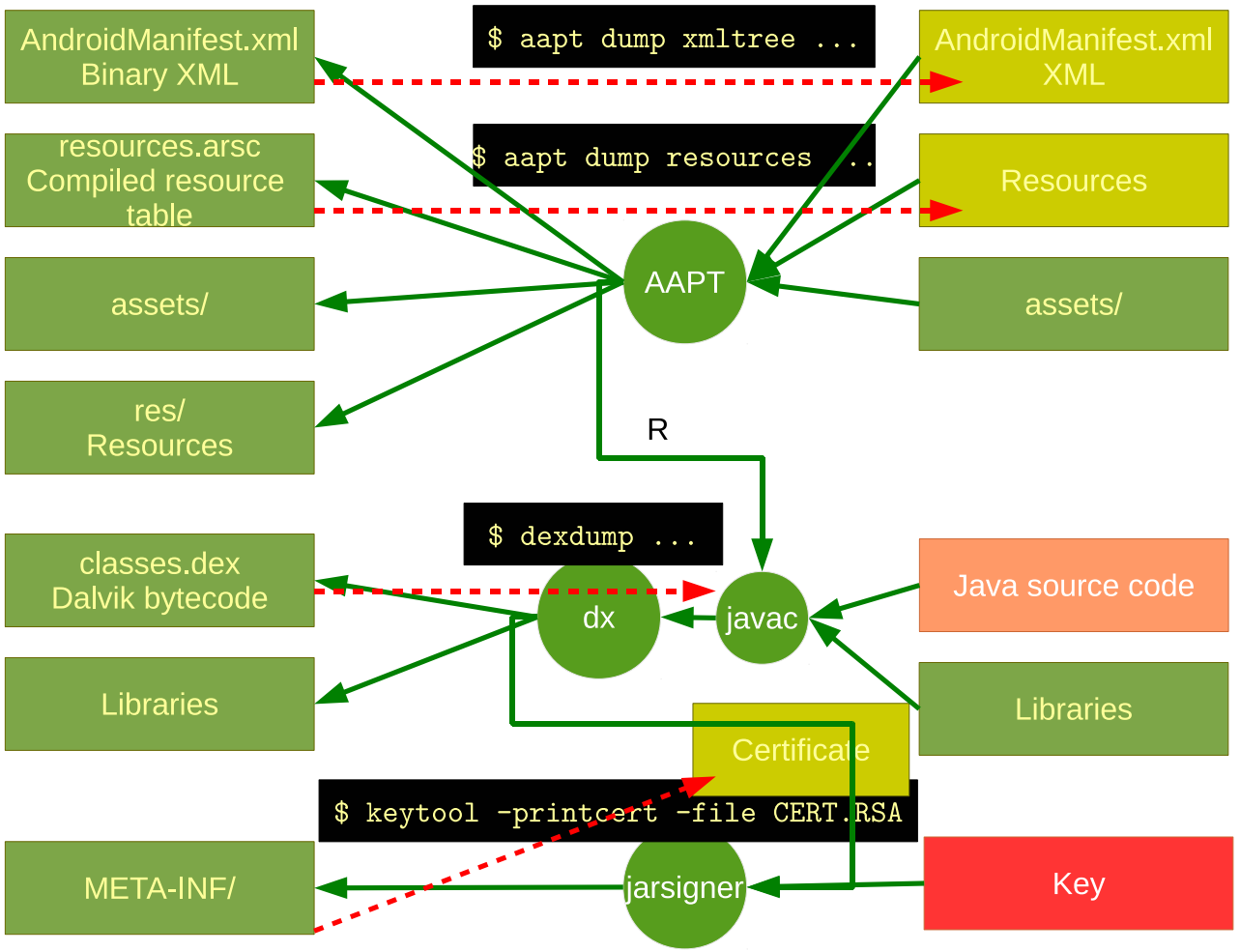
What's an APK?

It is a Zip !

Taken from Android/Spitmo.C!tr.spy

```
$ unzip criptomovil.apk
Archive:  criptomovil.apk
  inflating: res/layout/main.xml
  inflating: AndroidManifest.xml
 extracting: resources.arsc
 extracting: res/drawable-hdpi/icon.png
 extracting: res/drawable-ldpi/icon.png
 extracting: res/drawable-mdpi/icon.png
  inflating: classes.dex
  inflating: META-INF/MANIFEST.MF
  inflating: META-INF/CERT.SF
  inflating: META-INF/CERT.RSA
```

APK - Android Packages



Apktool - all in 1 tool

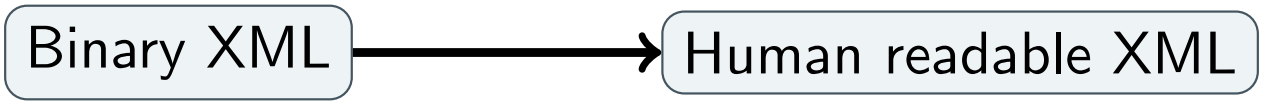
https://ibotpeaches.github.io/Apktool/

Apktool and (most) other tools are already installed on the images for the lab

```
$ java -jar apktool.jar d YOURPACKAGE.apk -o OUTPUTDIR
```

- **d** is for decoding
- Will retrieve Android manifest, resources and smali code

Converting binary XML



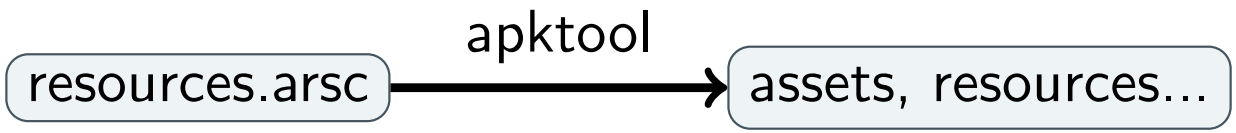
AXMLPrinter or newer from rednaga:

```
java -jar AXMLPrinter2.jar AndroidManifest.binary.xml
```

Alternatives:

- **aapt**: `aapt dump xmltree yourpack.apk AndroidManifest.xml`
- **Androaxml.py** from Androguard
- Apktool: all in one tool

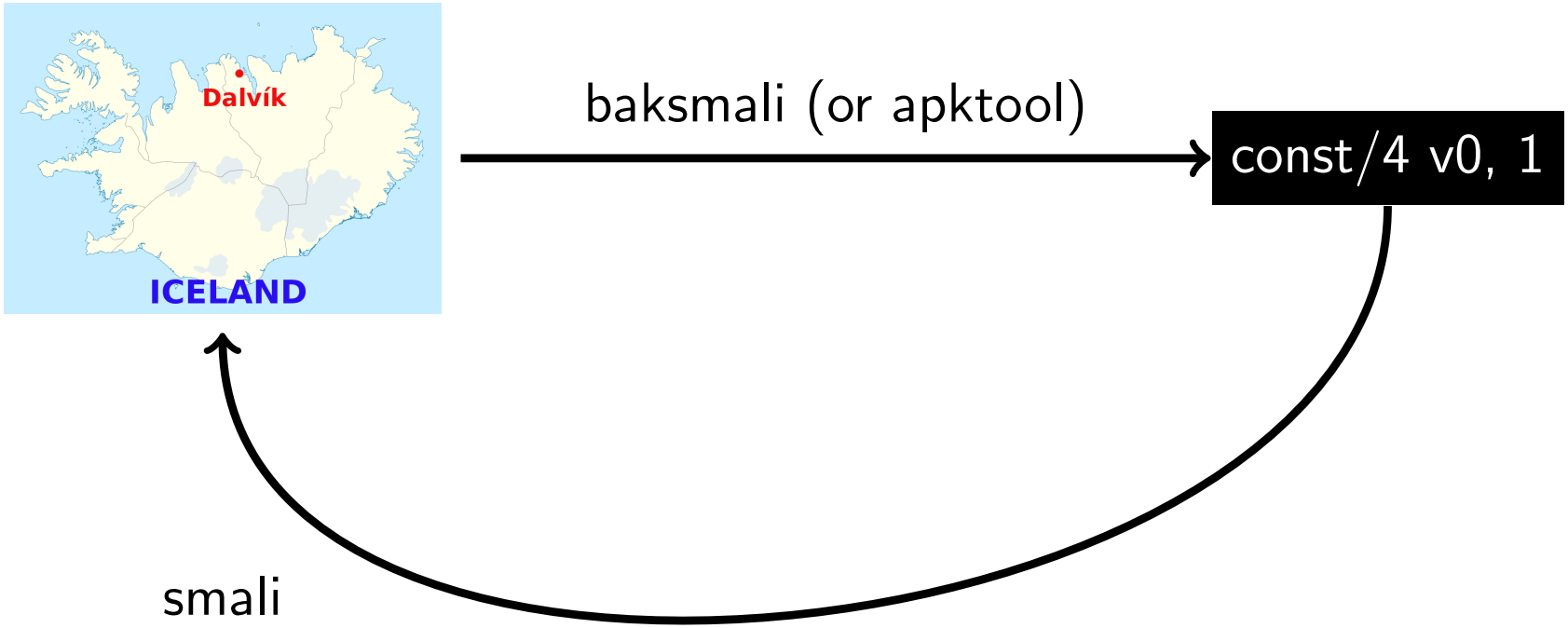
How to read resources?



What if apktool does not work?

- `aapt dump resources` works, but output not excellent
- Layouts only: use AXMLPrinter, androaxl to convert binary XML to XML

Dalvik Executables (.dex)



- **D**alvik **Ex**exutable (DEX): similar to .class for Java
- **smali** means assembler in icelandic

What if apktool fails to produce smali?

- Baksmali `java -jar baksmali.jar -o output-dir classes.dex`
- Androguard: `androdd -i classes.dex -o output` or

```
$ androlyze -s
d, dx = AnalyzeDex("classes.dex")
d.create_python_export()
```

- Use your favorite disassembler (if it supports it): IDA Pro, Radare2

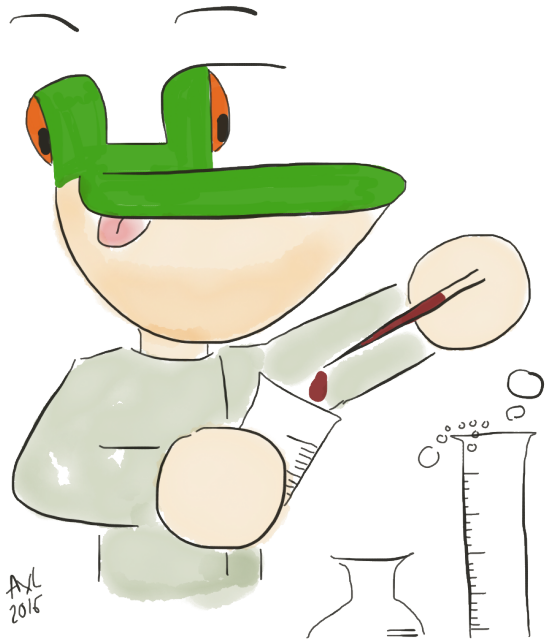
You don't like smali? Use a decompiler!

- Androguard embeds a good decompiler.

```
a, d, dx = AnalyzeAPK('sample.apk.vpk',decompiler='dad')
d.CLASS_xxxx.METHOD_yyy.source()
```

- JADX `jadx -d output-dir classes.dex`
- Convert to **jar** using dex2jar and then use a Java decompiler (Krakatau, Procyon, CFR, JD, ClassyShark...)
- Dedexer produces .ddx files $\approx$ Jasmin w/ Dalvik opcodes
- DED Decompiler or Dare
- JEB Decompiler: not free - but excellent. Trial version exists.

Lab 1 and Lab 2



Samples are located in /data
Tools are located in /opt
You have a work dir in /workshop

Understanding Smali

`AdminService` class, inheriting from `Service`. Source file name is missing:

```
.class public AdminService
.super Service
.source ""
```

```
.method static <clinit>()V
          .registers 1
 const/4           v0, 0
 sput-object       v0, AdminService->cOIcOOo:Thread
return-void
.end method
```

- Dalvik is registered based, not stack based
- Java signatures for methods: V for void, B for byte, Z for boolean...
- Dalvik instructions: `const/4`, `sput-object`...

Understanding smali 2/2

```
.method public constructor <init>(I)V
          .registers 4
          .param p1, "initialCapacity"
```

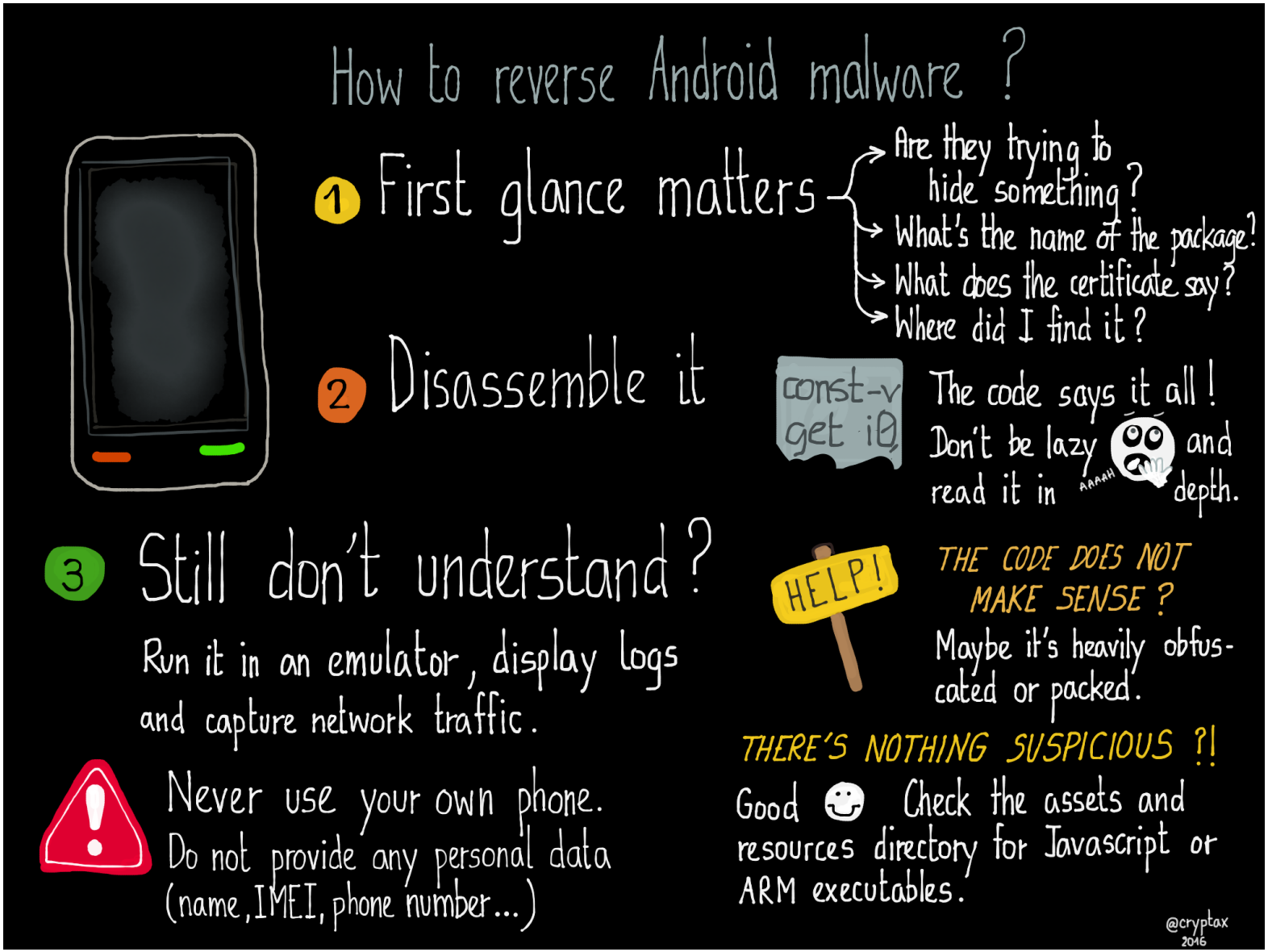
- p0 is for this, p1 is first argument of method
- naming is not always provided!

Calls

```
invoke-virtual {v0, v1, p1}, L.../TinyDB;
   ->putInt(Ljava/lang/String;I)V
```

Means to `this.putInt(v1, p1);`

Guidelines


How to reverse Android malware ?
1 First glance matters
Are they trying to hide something ?
What's the name of the package?
What does the certificate say?
Where did I find it ?
2 Disassemble it
const-v get i0
The code says it all !
Don't be lazy and read it in depth.
AAAAH
3 Still don't understand ?
Run it in an emulator, display logs and capture network traffic.
HELP!
THE CODE DOES NOT MAKE SENSE ?
Maybe it's heavily obfuscated or packed.
THERE'S NOTHING SUSPICIOUS ?!
Good Check the assets and resources directory for Javascript or ARM executables.
Never use your own phone.
Do not provide any personal data (name, IMEI, phone number...)
@cryptax 2016

Read the manifest

Taken from Android/Spitmo.C!tr.spy

- Identify the main entry point

```
<activity android:label="@7F040001" android:name=".MainActivity">

        <intent-filter>

                <action android:name="android.intent.action.MAIN">

                </action>

                <category android:name="android.intent.category.LAUNCHER">

                </category>
```

Read the manifest

Taken from Android/Spitmo.C!tr.spy

- Identify the main entry point
- Background services

```
<service android:enabled="true" android:name=".KavService">


</service>
```

Read the manifest

Taken from Android/Spitmo.C!tr.spy

- Identify the main entry point
- Background services
- Receivers: called when events occur

```
<receiver android:name=".SmsReceiver">

        <intent-filter android:priority="999999">

                <action android:name="android.provider.Telephony.SMS_RECEIVED">

                </action>

                <action android:name="android.intent.action.NEW_OUTGOING_CALL">

                </action>

                <action android:name="android.intent.action.BOOT_COMPLETED">

                </action>
```

Read the manifest

Taken from Android/Spitmo.C!tr.spy

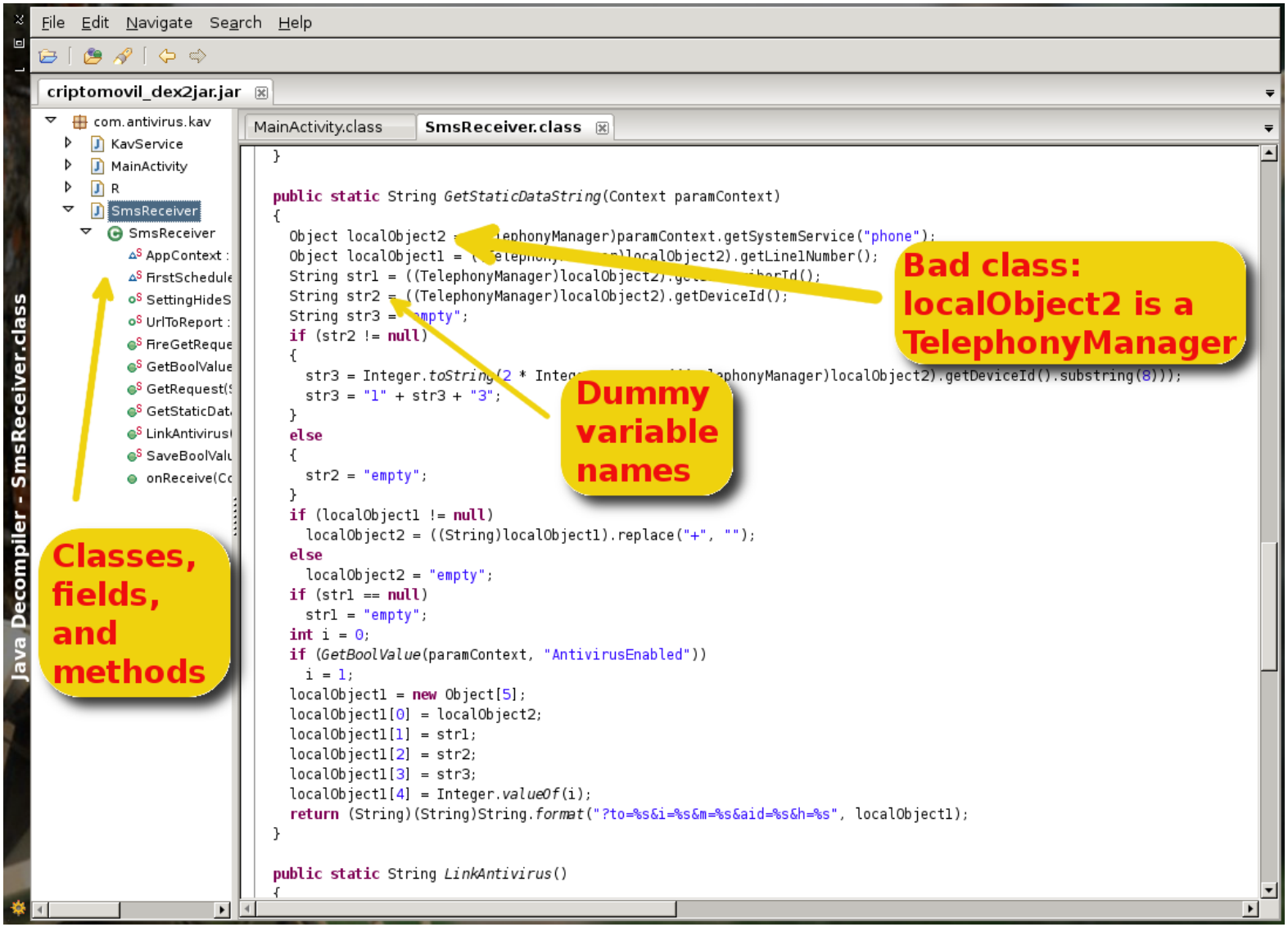
- Identify the main entry point
- Background services
- Receivers: called when events occur
- Permissions

```
<uses-permission android:name="android.permission.READ_SMS">

</uses-permission>

<uses-permission android:name="android.permission.RECEIVE_SMS">
```

Decompiled Java source code - at a glance



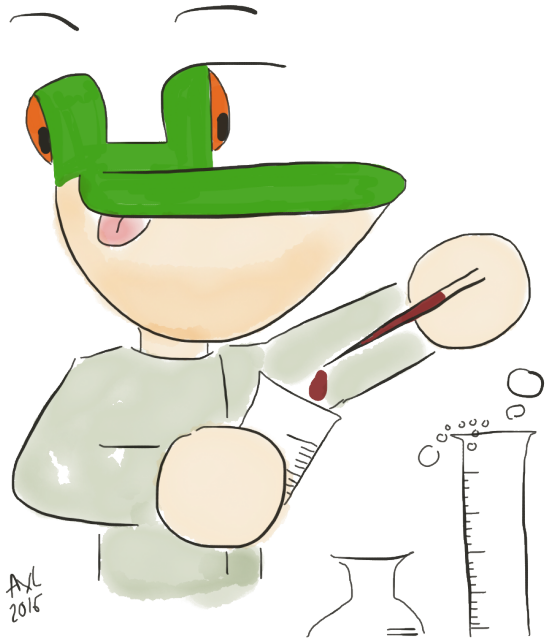
Who's using this method/field?

- Good news: smali are text files. You can grep etc.
- **Androguard**: show_xref(), show_dref()
- **JEB**: Ctrl-X
- **Radare**: axt, axf

Beware

Inheritance, interfaces, events "break" the call tree :(

Lab 3: Static analysis



Patching an APK

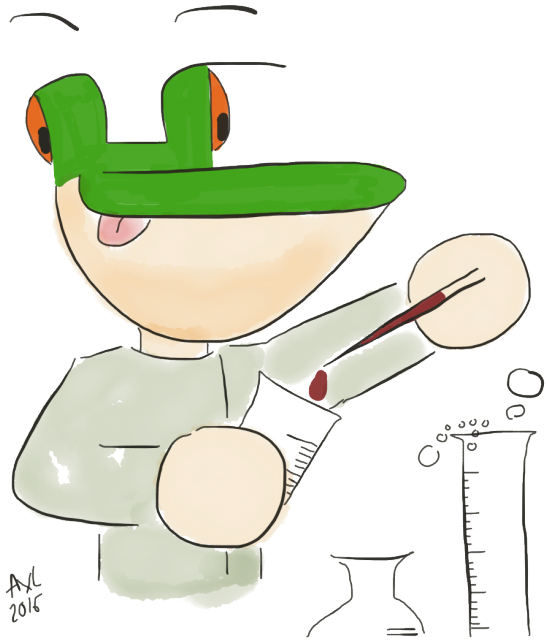
Modify the smali code

1. Baksmali to get the smali
2. Modify the smali source
3. Smali to re-create the DEX
4. Zip the DEX with resources
5. Sign it (if necessary create keys before)

Patch to insert logs

```
const-string v0, "Hello there"
const-string v6, "MY TAG: "
invoke-static {v6, v0},
  Landroid/util/Log;->v(Ljava/lang/String;
  Ljava/lang/String;)I
```

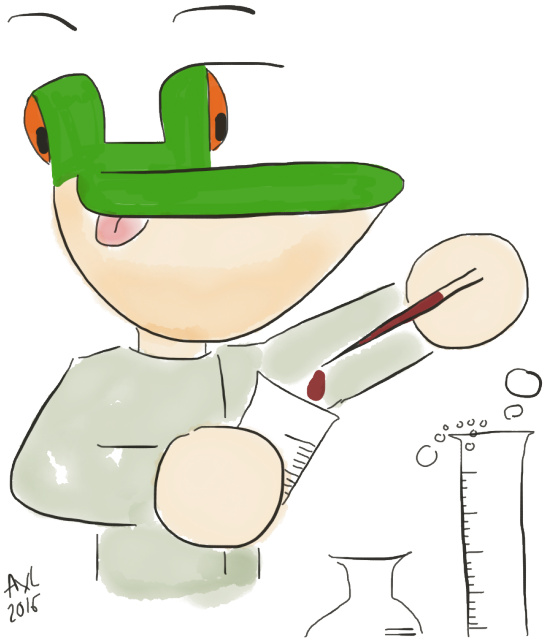
Lab 4: Patching a package



Dynamic analysis

- Make sure you won't be sending data to the malware authors
- Some malware perform anti-emulator tricks

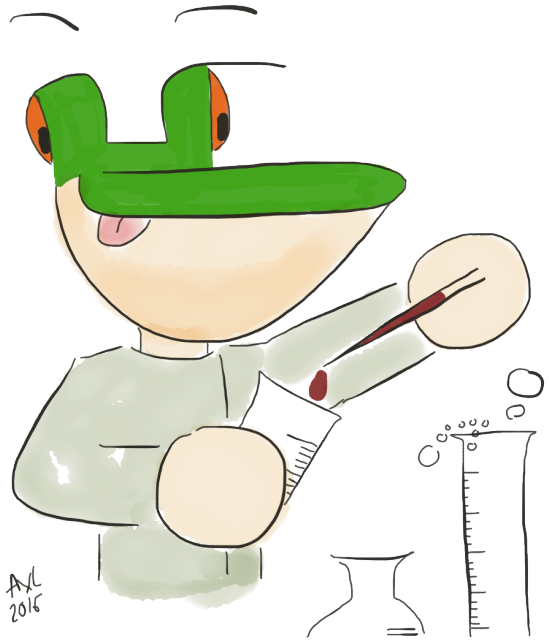
Dynamic analysis: SpyBanker in (safe) action!



Androguard: quick start

- Launch androlyze with interactive shell: `androlyze -s`. Python shell.
- Analyze the APK: `a, d, dx = AnalyzeAPK('your.apk', decompiler='dad')`
- Perform actions on the package through object **a**. Use **completion** (Tab). Example: `a.get_main_activity()`, `a.get_receivers()`, `a.get_services()`
- Actions on the code: use `d.CLASS`, then use **completion** (Tab). To specify a method add **_METHOD** and use completion. Call `source()` to see decompiled code, or use completion.
- Method cross references: use `CLASS_xxx.METHOD_yyy.show_xref()`.
- Field cross references: `CLASS_xxx.FIELD_yyy.show_dref()`
- List used permissions: `show_Permissions(dx)`

Lab 6: Using Androguard



Counter anti-emulator tricks

IMEI

On emulator, IMEI default value is 000000000000000.
Very common check in malware.
Get the value:

- Program: getDeviceId()
- Emulator <Android 5: `adb shell dumpsys iphonesubinfo`
- Emulator $\geq$ Android 5: `adb shell service call iphonesubinfo code`
  5.1.1: $code = 1$

Set the value: search for **+CGSN**

```
00370320  53 3d 00 2b 43 49 4d 49  00 33 31 30 32 36 30 30  |S=.+CIMI.3102600|
00370330  30 30 30 30 30 30 30 30  00 2b 43 47 53 4e 00 30  |00000000.+CGSN.0|
00370340  30 30 30 30 30 30 30 30  30 30 30 30 30 30 00 2b  |000000000000.+|
```

More anti-emulator tricks (and solutions)

IMSI

Get the value:

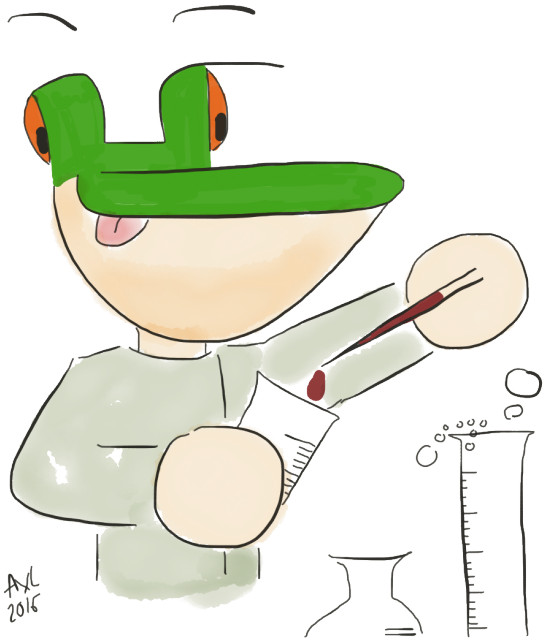
- Program: getSubscriberId()
- Emulator: same as IMEI, except service code is 7 (Android 5.1.1).

Set the value: search for **+CIMI**

Geographic location

Common especially in Adware.
Set the value: `adb emu geo fix longitude latitude altitude`
Get the value: `adb shell dumpsys location` ? (does not work on emulator)

Lab 7: Patching the emulator

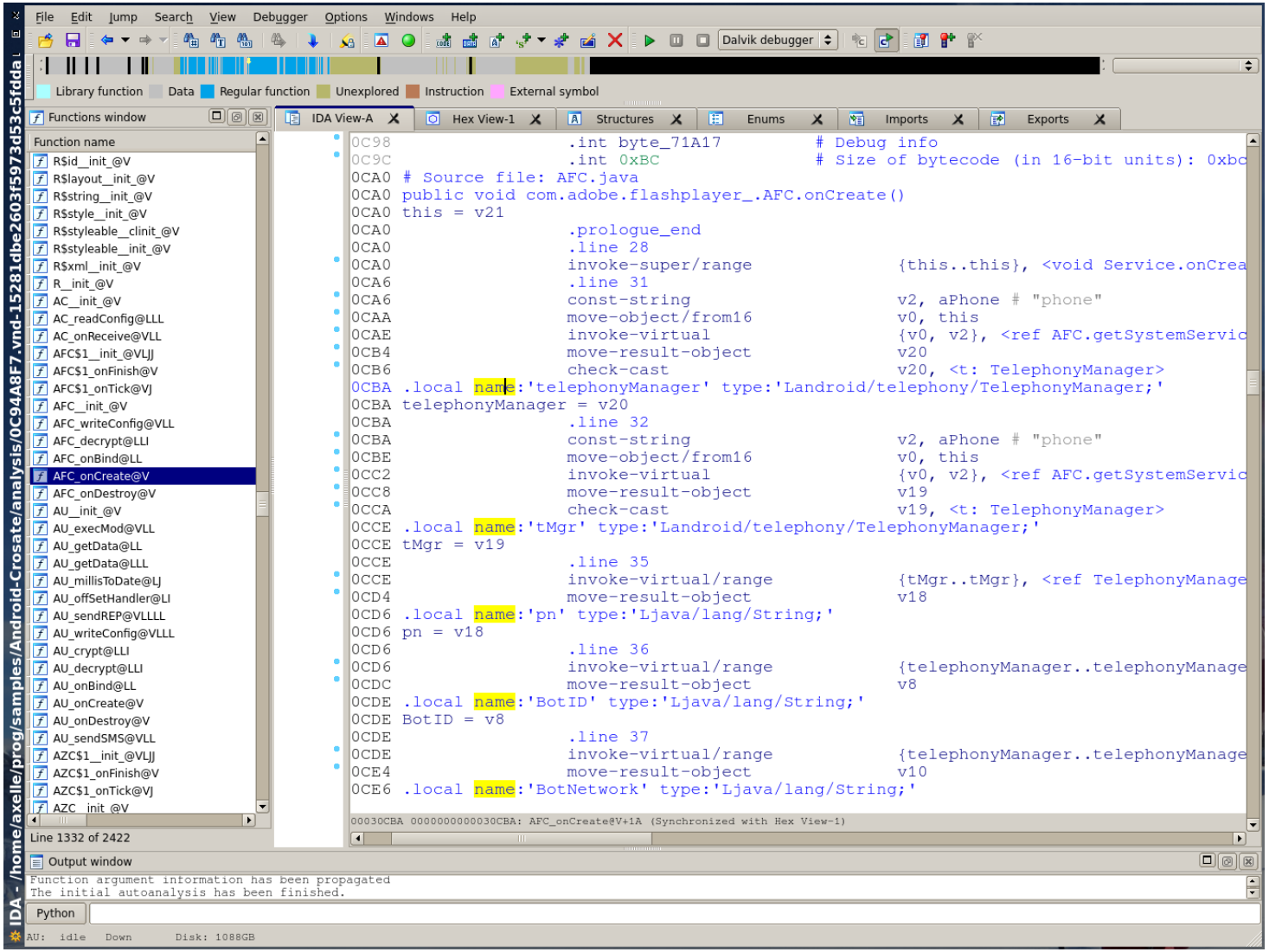


Dalvik disassembly with Radare

http://www.radare.org

- It works on the classes.dex. Automatic detection of Dalvik. (If not, use `r2 -a dalvik file`).
- List classes, methods and fields: `ic`, or list functions: `afl`
- List imports: `ii`
- List strings: `iz` (method names in there too)
- Cross references: `axt` (references TO this address) or `axf` (from)
- Search for string http: `f http` or `/ http`
- Disassemble: `pd LINES @ ADDR`

Dalvik in IDA Pro



Obfuscation...

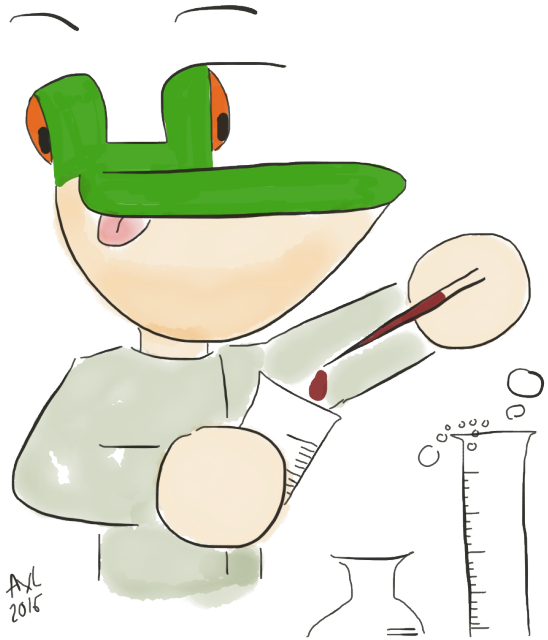
- **Obfuscators**. Generic term. Proguard, Dexguard, Allatori,
- **Protectors**. e.g. anti-debugging, anti-emulator techniques ApkProtect
- **Packers**. Executable 'compressor'. Decompression stub decompresses sample *in place* (dump memory) or *on disk* (inspect /data/data for example). Pangxie, LIAPP, Bangcle

Solutions to obfuscated malware 1/5

1. **Understand** how it is obfuscated and write code/scripts to de-obfuscate Identification of packers with APKiD

```
[!] APKiD 0.9.3 :: from RedNaga :: rednaga.io
[*] 2164084.apk
 |-> packer : Ijiami
[*] 2164084.apk!classes.dex
 |-> compiler : dexlib 2.x
[*] 2164084.apk!assets/ijm_lib/armeabi/libexec.so
 |-> packer : Ijiami (UPX)
[*] 2164237.apk
 |-> packer : Jiangu
[*] 2164237.apk!classes.dex
 |-> compiler : dexlib 2.x
[*] 2164332.apk!classes.dex
```

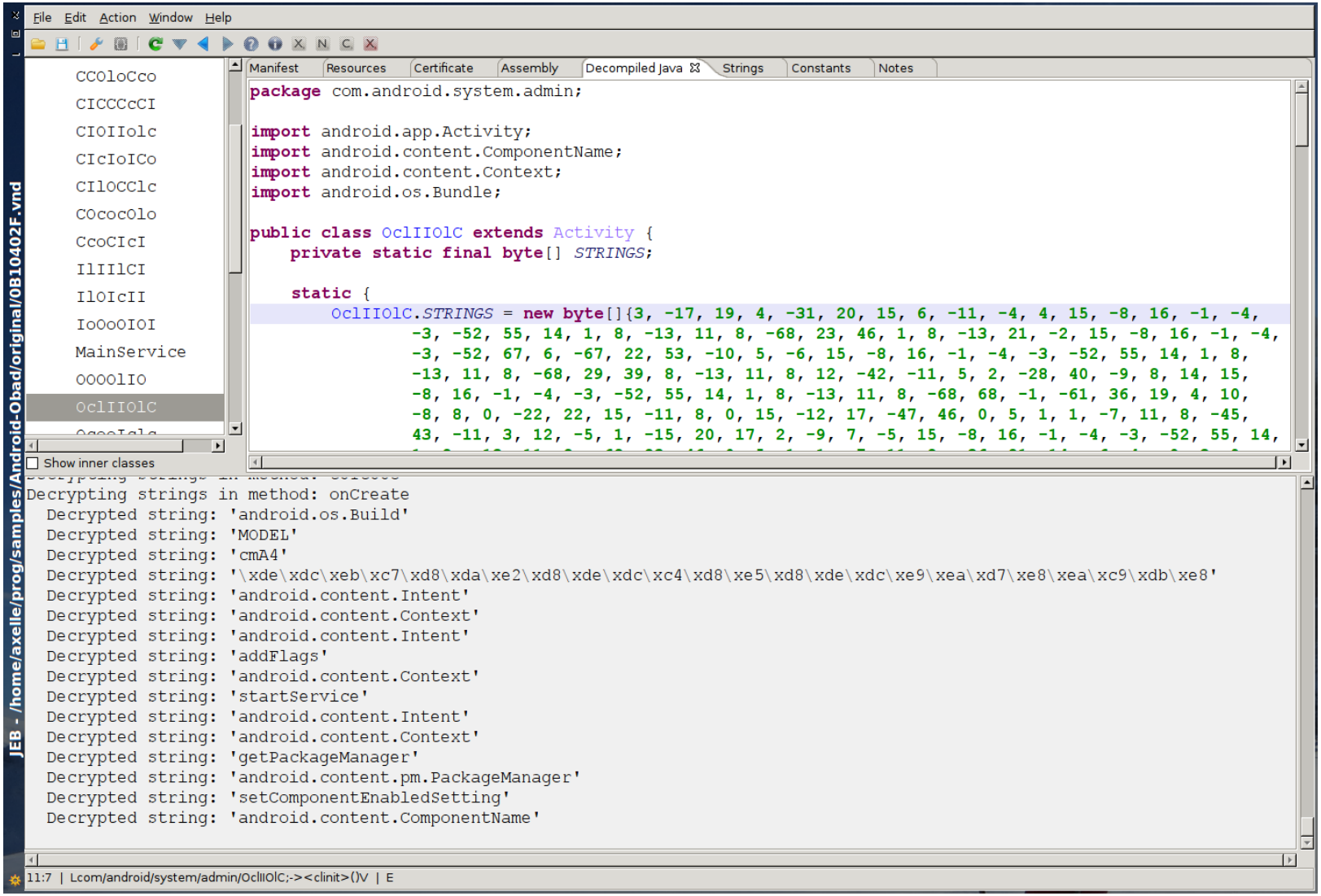
Lab 8: De-obfuscating Obad strings



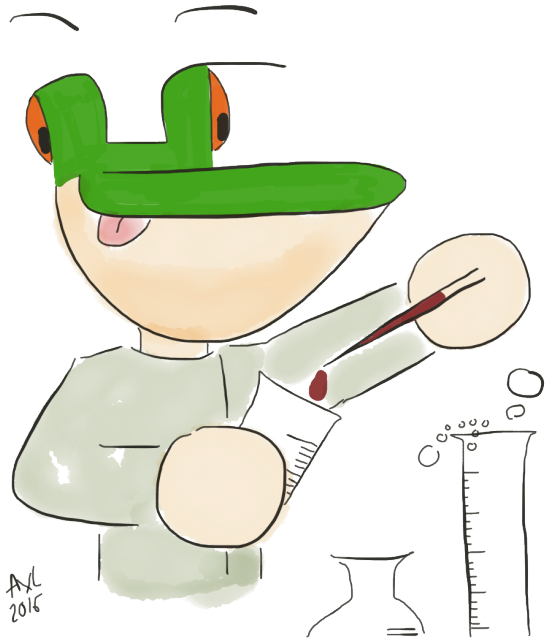
Solutions to obfuscated malware 2/5

1. Understand how it is obfuscated and write code/scripts to de-obfuscate
2. **Use off-the-shelf tools that already do the work ;P**
   - d2j-decrypt-string.sh
   - DexHunter: Android 4.4.3
   - Simplify
   - JEB plugins

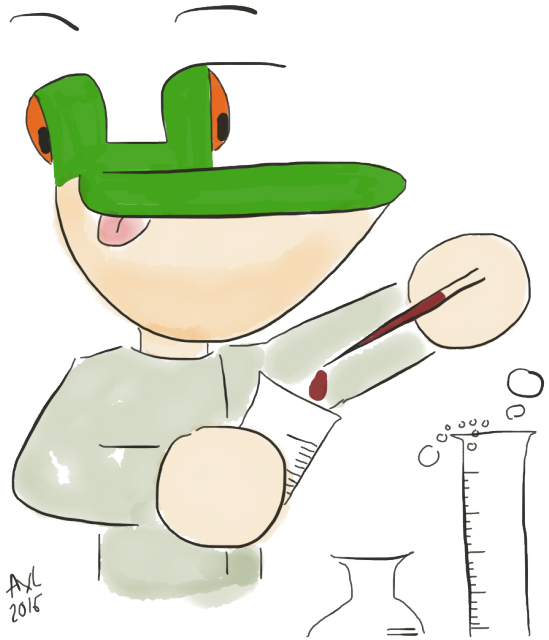
JEB scripts to decrypt strings



Lab 9: Using JEB Plugins



Lab 10: Unpacking Pangxie



Solutions to obfuscated malware 3/5

1. Understand how it is obfuscated and write code/scripts to de-obfuscate
2. Use off-the-shelf tools that already do the work ;P
3. **Modify the sample and print the de-obfuscated string/class etc.**

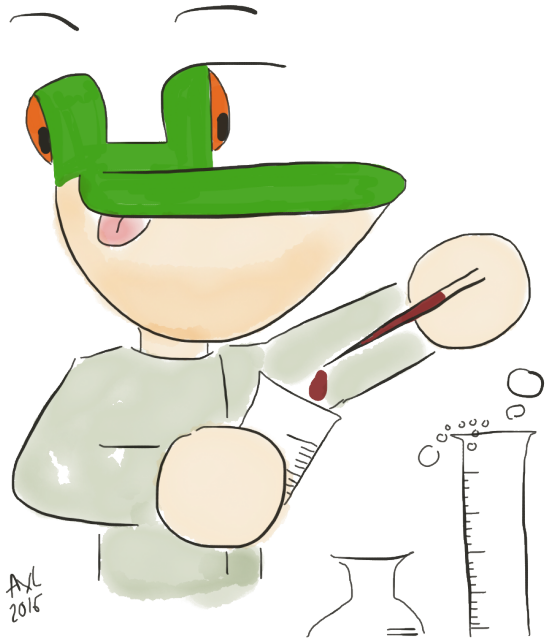
Solutions to obfuscated malware 4/5

1. Understand how it is obfuscated and write code/scripts to de-obfuscate
2. Use off-the-shelf tools that already do the work ;P
3. Modify the sample and print the de-obfuscated string/class etc.
4. Debug the sample and set a breakpoint where you want to see the obfuscated data.
   - JEB2
   - CodeInspect

Solutions to obfuscated malware 5/5

1. Understand how it is obfuscated and write code/scripts to de-obfuscate
2. Use off-the-shelf tools that already do the work ;P
3. Modify the sample and print the de-obfuscated string/class etc.
4. Debug the sample and set a breakpoint where you want to see the obfuscated data.
5. **Dump memory of the phone and search for de-obfuscated data**
   - GDB
   - kisskiss

Lab 11: Unpacking LIAPP



References

- Dalvik Opcodes
- Collection of Android tools
- Using Androguard for RE
- Emacs smali mode: Tim Strazzere
- Obfuscation in Android malware and to fight back
- Android App "Protection"
- My own publications

The end

Thank You!

Thank you for attending!
Special thanks to Ruchna Nigam, Tim Strazzere
CodeInspect and JEB for providing free licenses

Please bring the USB keys back :)

Like the slides? Thanks. This is LaTeX