ANDROID COMPILER FINGERPRINTING

CALEB FENTON - TIM “DIFF” STRAZZERE

03.10.2017

Android Security Symposium 2017

REDNAGA

WHO ARE WE

RED NAGA

- Banded together by the love of 0days, fuzzing, making oem/bad guys lives harder, hot sauces
- Random out of work collaboration and pursuit of up-leveling the community
  - Disclosures / Code / Lessons available on GitHub
- rednaga.io
- github.com/RedNaga

WHO ARE WE

CALEB

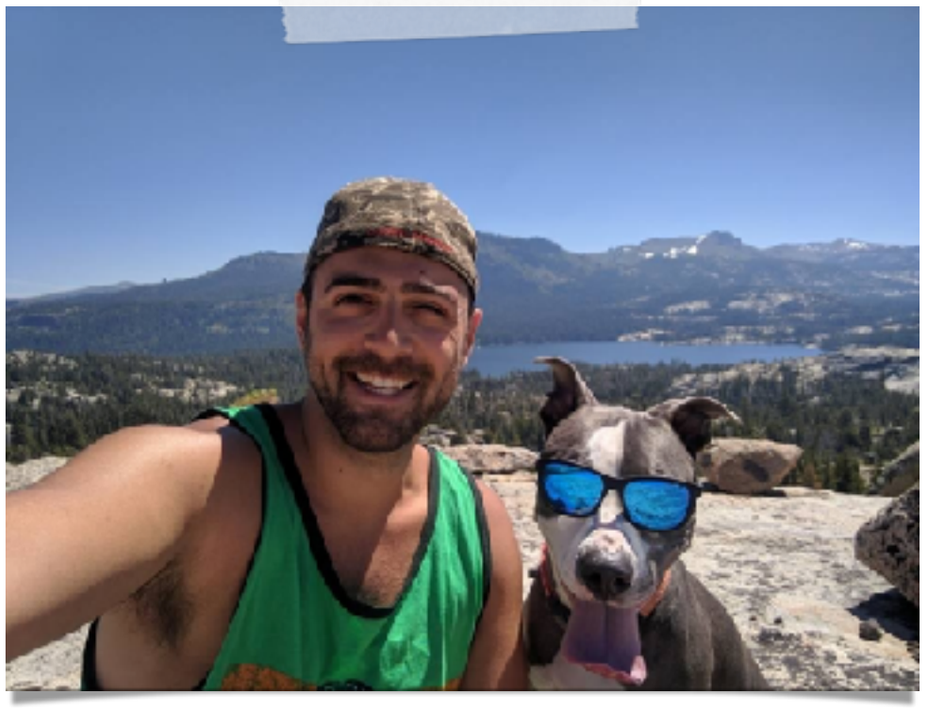
- Security Researcher
- Loves generalizing problems and automating solutions
- Creator of “Simplify”
- @caleb_fenton
- github.com/CalebFenton
- Airline moved flight back twice, second time without notice (Turkish Airlines)

WHO ARE WE

DIFF

- Threat Intel / Sec. Eng. @ CloudFlare
- Former Researcher @ Lookout, SentinelOne
- Fuzzing, Obfuscation, Packer Junkie
- Makes own hot sauce - cause why not?
- @timstrazz
- github.com/strazzere

CLOUDFLARE



WHY ARE WE HERE

More importantly - why should you care?

- Threat Intel is important!
- Used for many purposes:
    - What are people researching now?
    - What should you research next?
    - Anticipate attack patterns.
    - Avoid overlap with others!
- We like drinking…

THE TAKE AWAYS

What should you learn from us today?

- How to fingerprint Android compilers
- Abnormalities in AXML / DEX structure
- Why fingerprinting compilers is useful
- Sophisticated agents
- Related PC stuff
  - F.L.I.R.T. - https://www.hex-rays.com/products/ida/tech/flirt/index.shtml
  - PEID - http://www.aldeid.com/wiki/PEiD

CURRENT ANDROID TOOL LANDSCAPE

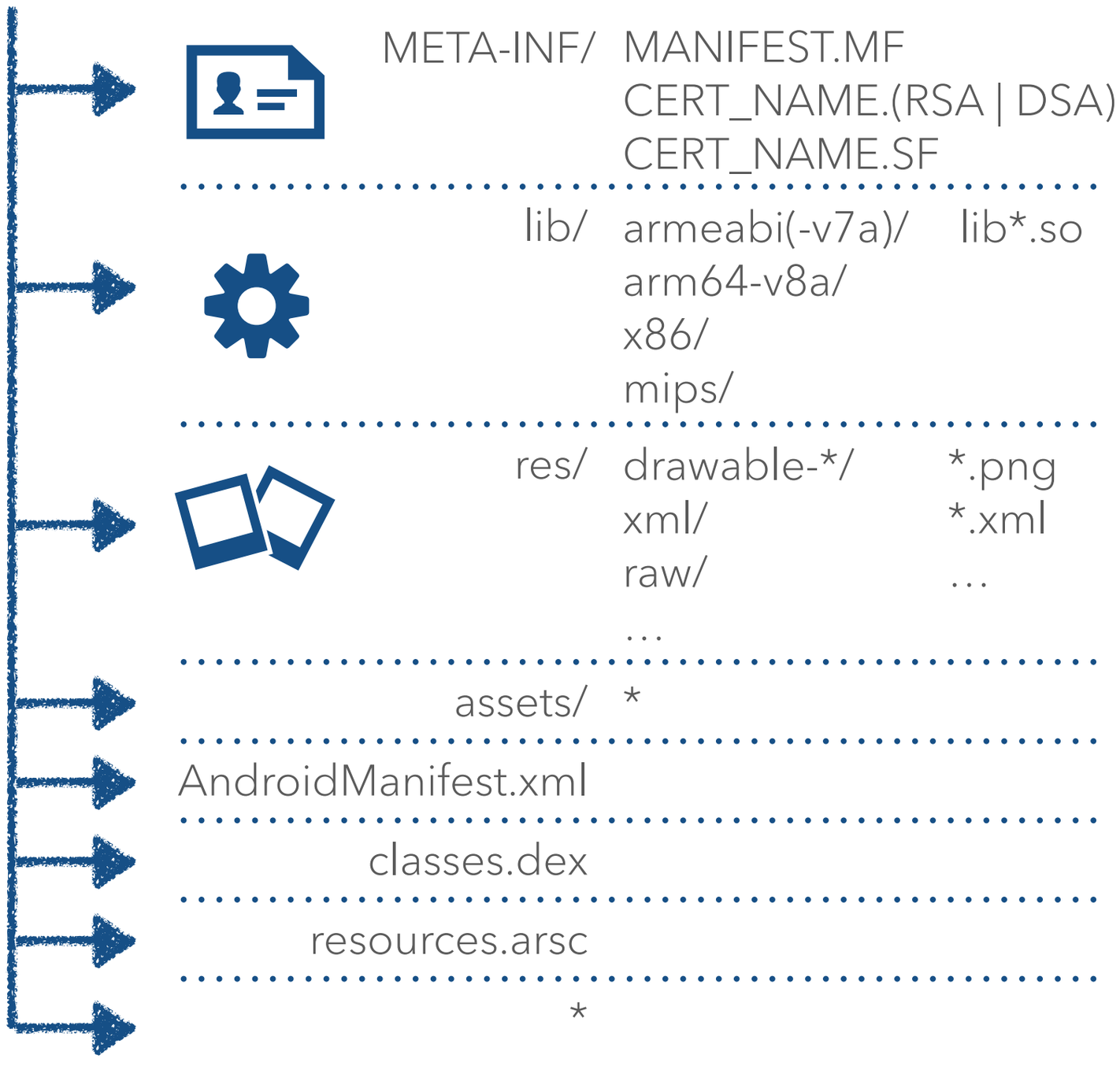
Tools and Evolution

REDNAGA

ANDROID APPLICATION PACKAGING (APK)

application/vnd.android.package-archive

Blah.apk



ANDROID APPLICATION PACKAGING (APK)

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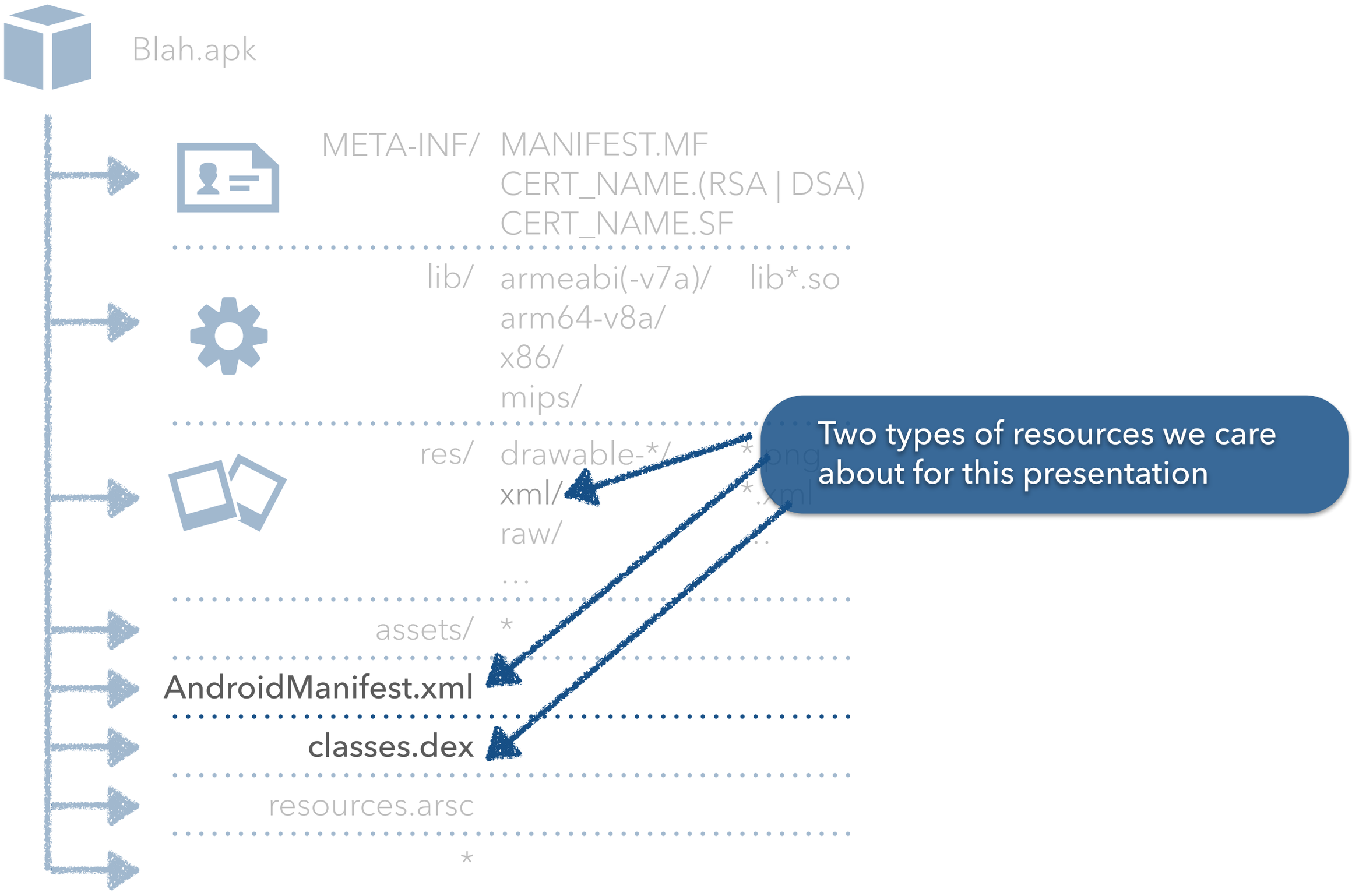

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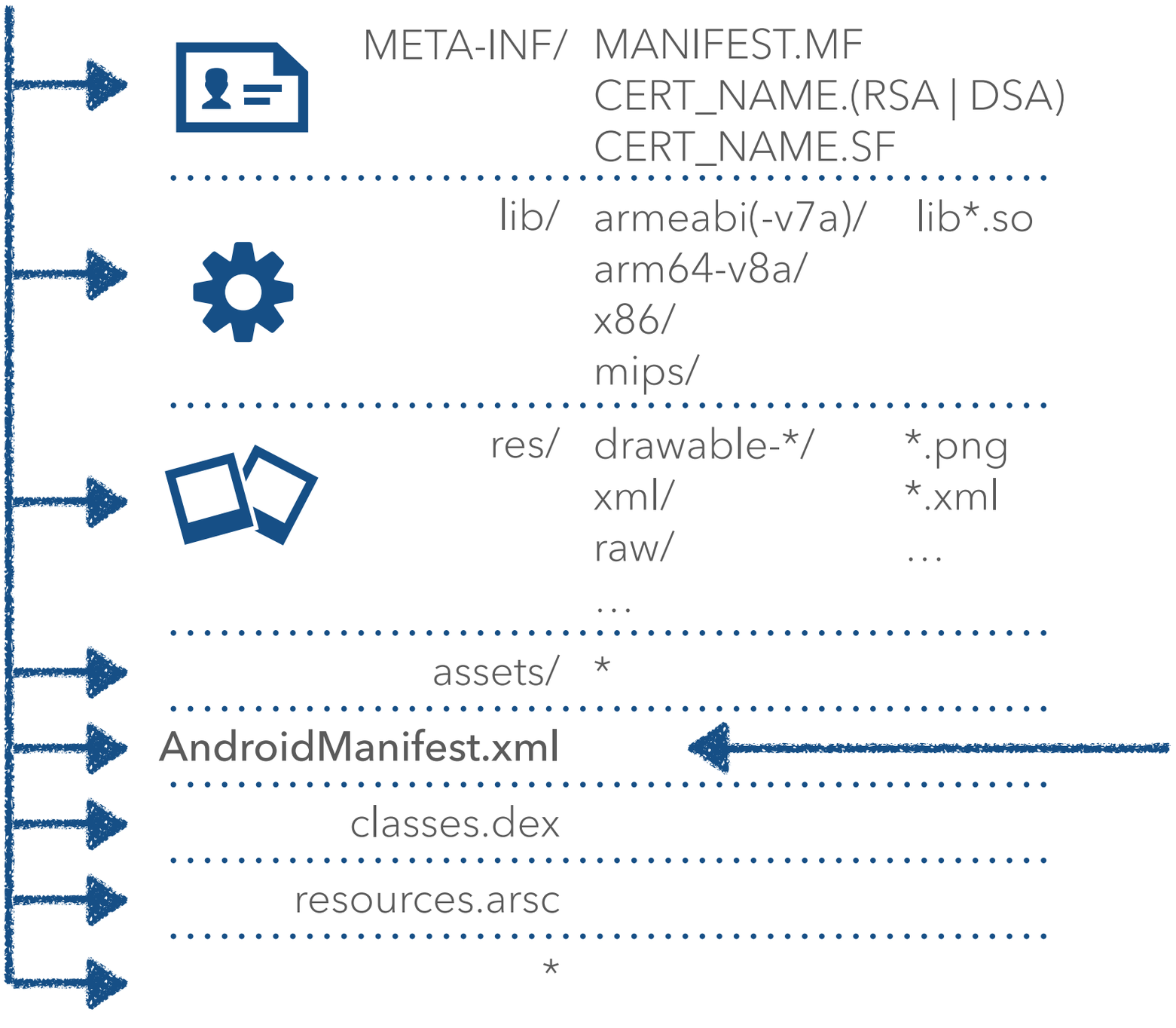
Blah.apk



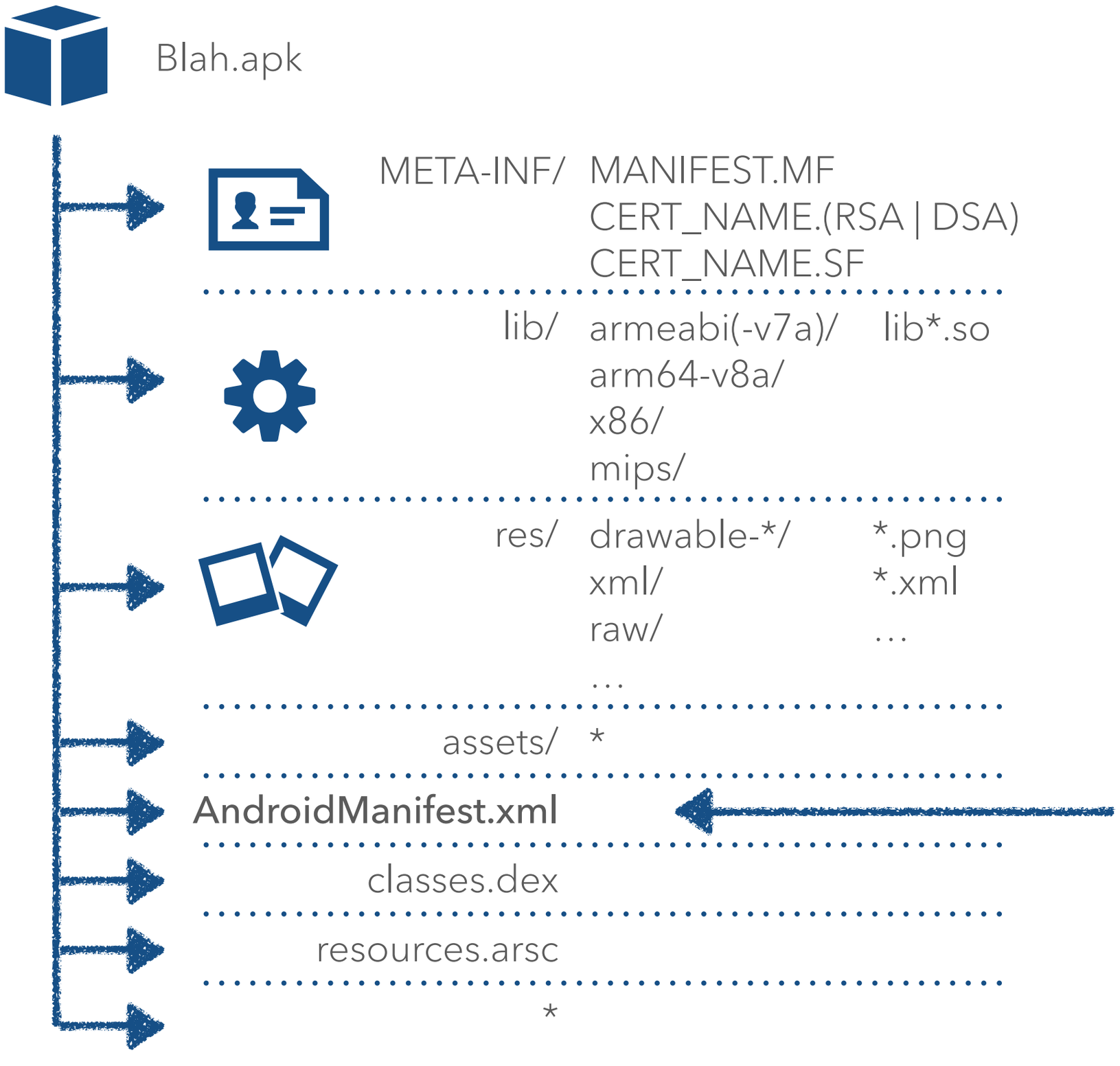
Android Manifest
Compiled AndroidXML

Contains:
- **entry points for app**
  - Activities
  - Services
  - Receivers
  - Intents
  - …
- **app permissions**
- **app meta-data**
  - package name
  - version code/name
  - debuggable
- **referenced libraries**

Reverse with:
- axmlprinter2
- apktool
- jeb / jeb2
- androguard
- 010Editor Templates

ANDROID APPLICATION PACKAGING (APK)

application/vnd.android.package-archive



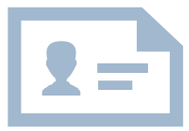
Android Manifest
Compiled AndroidXML

Created by:
aapt
axmlprinter2 (new ver)
apktool
(axmlprinter2 mod)
random Python scripts

ANDROID APPLICATION PACKAGING (APK)

application/vnd.android.package-archive

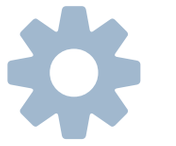
Blah.apk



META-INF/ MANIFEST.MF
CERT_NAME.(RSA | DSA)
CERT_NAME.SF

lib/ armeabi(-v7a)/ lib*.so
arm64-v8a/
x86/
mips/

Used by normal devs



res/ drawable-*/ *.png
xml/ *.xml
raw/ …
…

assets/ *

AndroidManifest.xml

classes.dex

resources.arsc

*

Android Manifest
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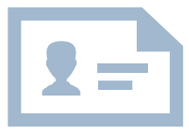

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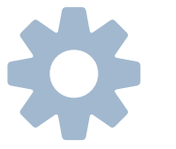

Used by normal devs

res/ drawable-*/ *.png
xml/ *.xml
raw/
...

Used by “abnormal” devs

- Security tools
- “injection” tools

Almost all used for
post-compilation modification

AndroidManifest.xml

classes.dex

resources.arsc

*

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Blah.apk

META-INF/ MANIFEST.MF
CERT_NAME.(RSA | DSA)
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lib/ armeabi/ *.so
arm64-v8a/
x86/

All of these things are “interesting”
depending on how you look at it...

New malware?
New security tool (ab)using the system?
Play Store APKs look different than in the wild binaries?

res/ *.xml
raw/ *

assets/ *

AndroidManifest.xml

classes.dex

resources.arsc

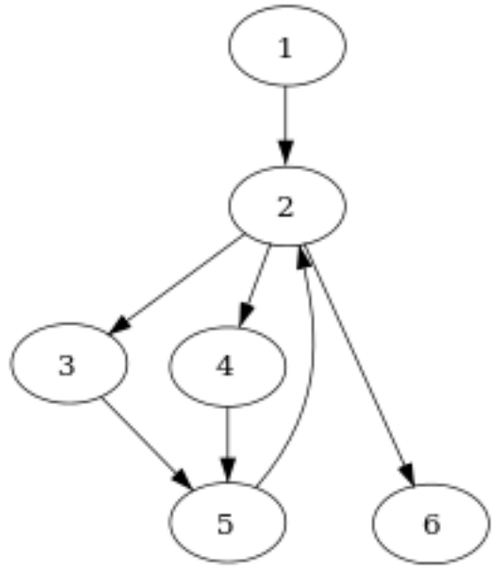
*

AXML OPEN SOURCE CYCLE

Who is using what?

AXMLPrinter2 is a very, very old project with bugs...

- Was the standard which people found breakages in
- Code used by APKTool (licenses appear stripped)
- JEB imported APKTool (seen in licenses)
- JEB author back ported fixed into APKTool
- Library to break them all! (until jeb2)



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- Was the standard which people found breakages in
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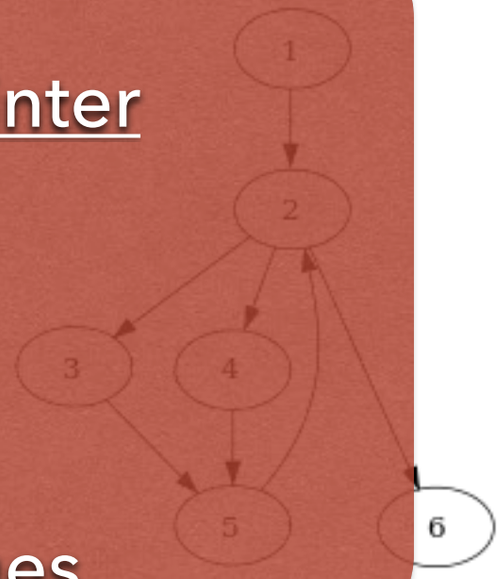
FOSS remake released;
https://github.com/rednaga/axmlprinter

~85% TCC
Allows reading / writing AXML
Avoids previous breakages
Can be used to detect these changes



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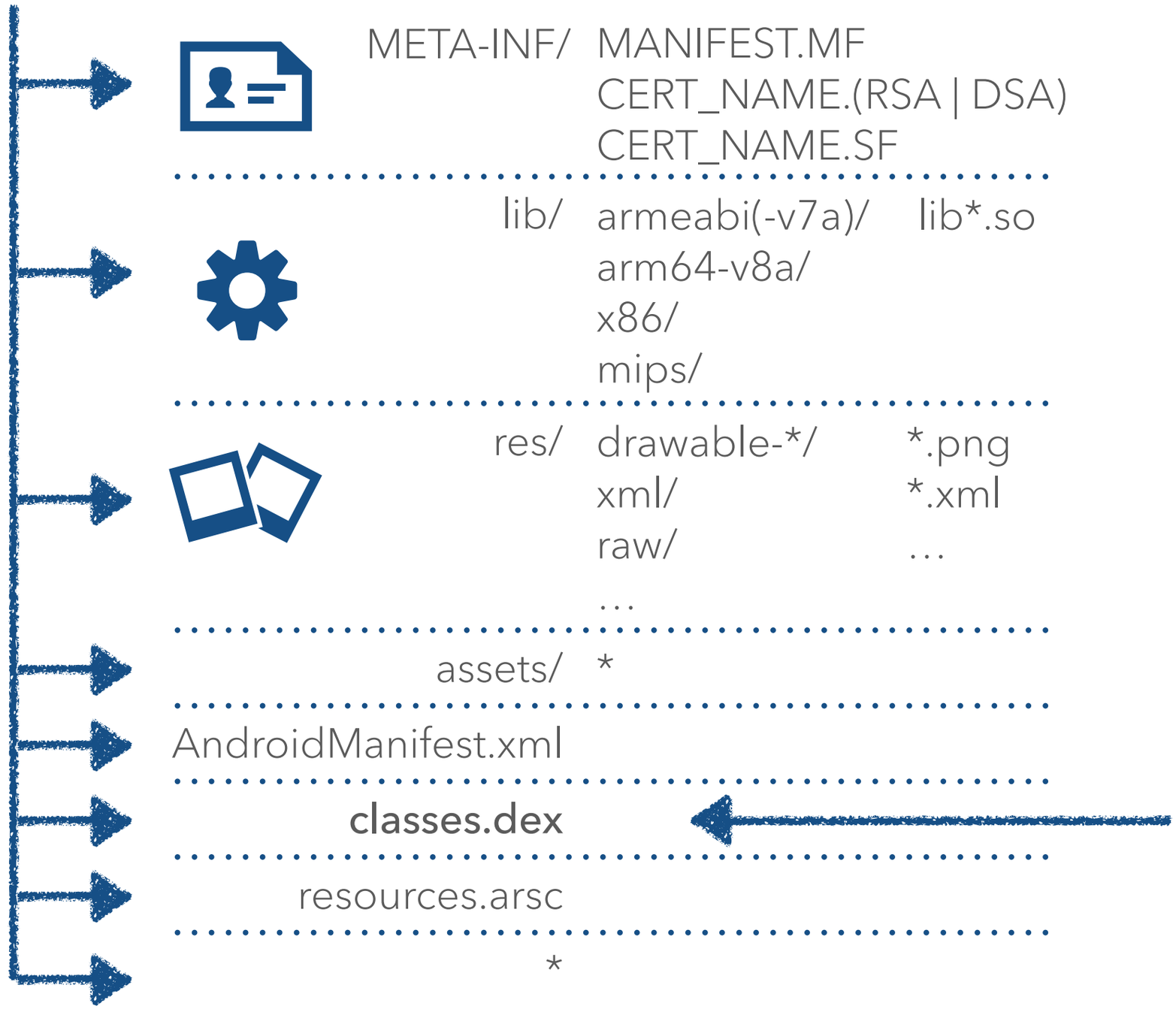

Dalvik Executable
Compiled classes for DVM

Contains executable Dalvik code

Optimized on install to:
- ODEX for DVM runtime
- OAT for ART runtime

Reverse with:
- smali / apktool
- IDA Pro
- jeb / jeb2
- androguard
- enjarify
- dex2jar + jad/jd
- jadx
- radare
- 010Editor Templates

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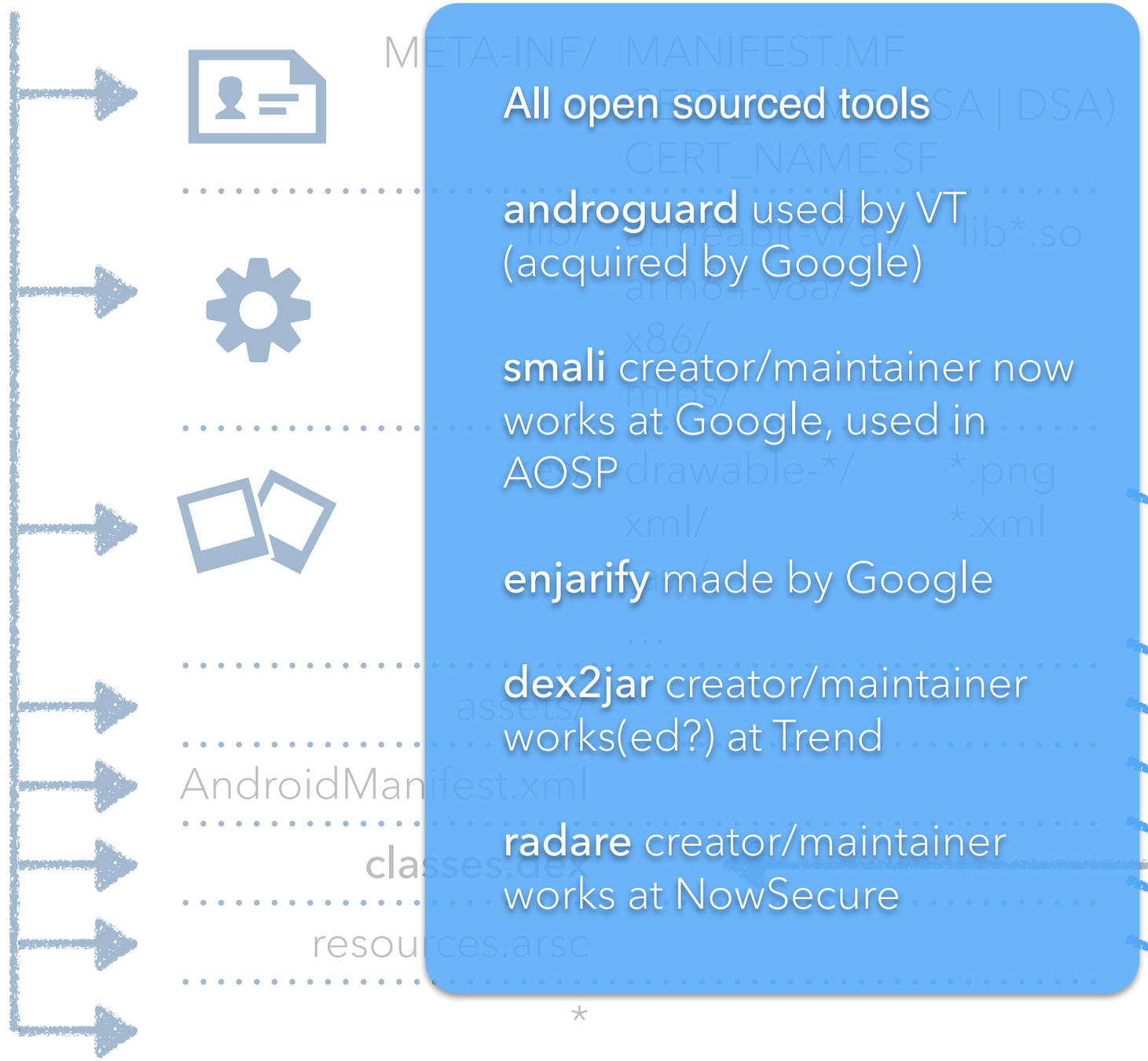

All open sourced tools

androguard used by VT (acquired by Google)

smali creator/maintainer now works at Google, used in AOSP

enjarify made by Google

dex2jar creator/maintainer works(ed?) at Trend

radare creator/maintainer works at NowSecure

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Blah.apk

META-INF/ MANIFEST.MF
CERT_NAME.(RSA | DSA)
CERT_NAME.SF

lib/ armeabi(-v7a)/ lib*.so

res/ drawable-*/ *.png
xml/ *.xml
raw/

assets/

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apktool used original **axmlprinter2** code, now mostly refactored out

jeb (maybe **jeb2**?) originally used **apktool** for resource parsing and back ported patches for resources which broke the non-free tool

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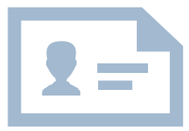

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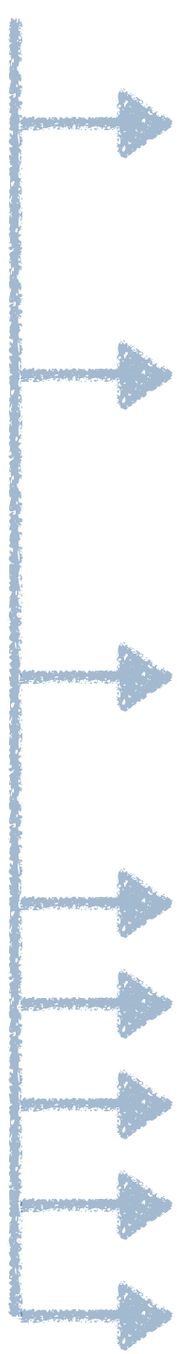

Contains or is a **disassembler** which can provide a more direct translation to what the Android VM will see.

Usually requires learning simple Jasmin like language syntax.

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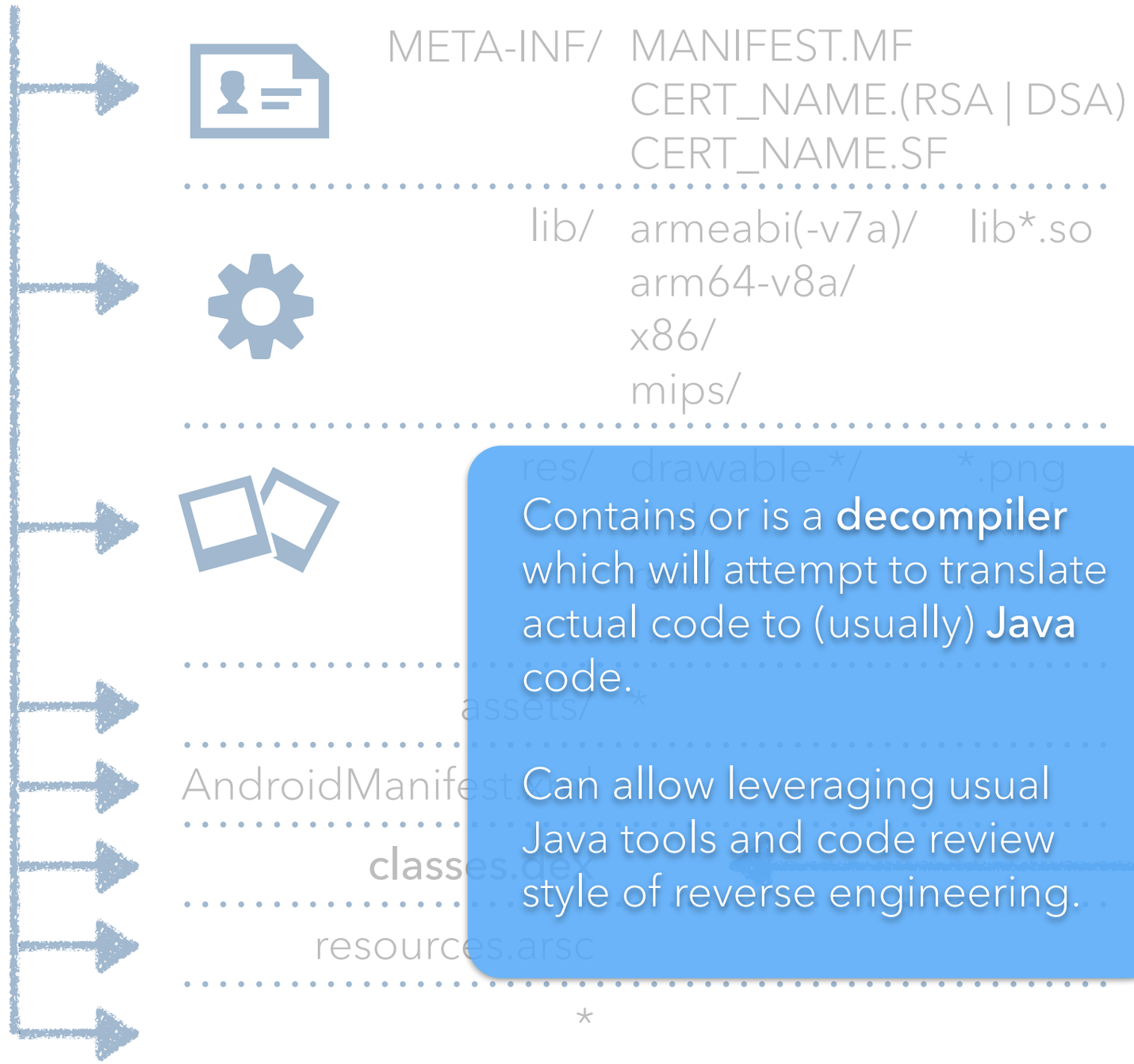

Contains or is a **decompiler** which will attempt to translate actual code to (usually) **Java** code.

Can allow leveraging usual Java tools and code review style of reverse engineering.

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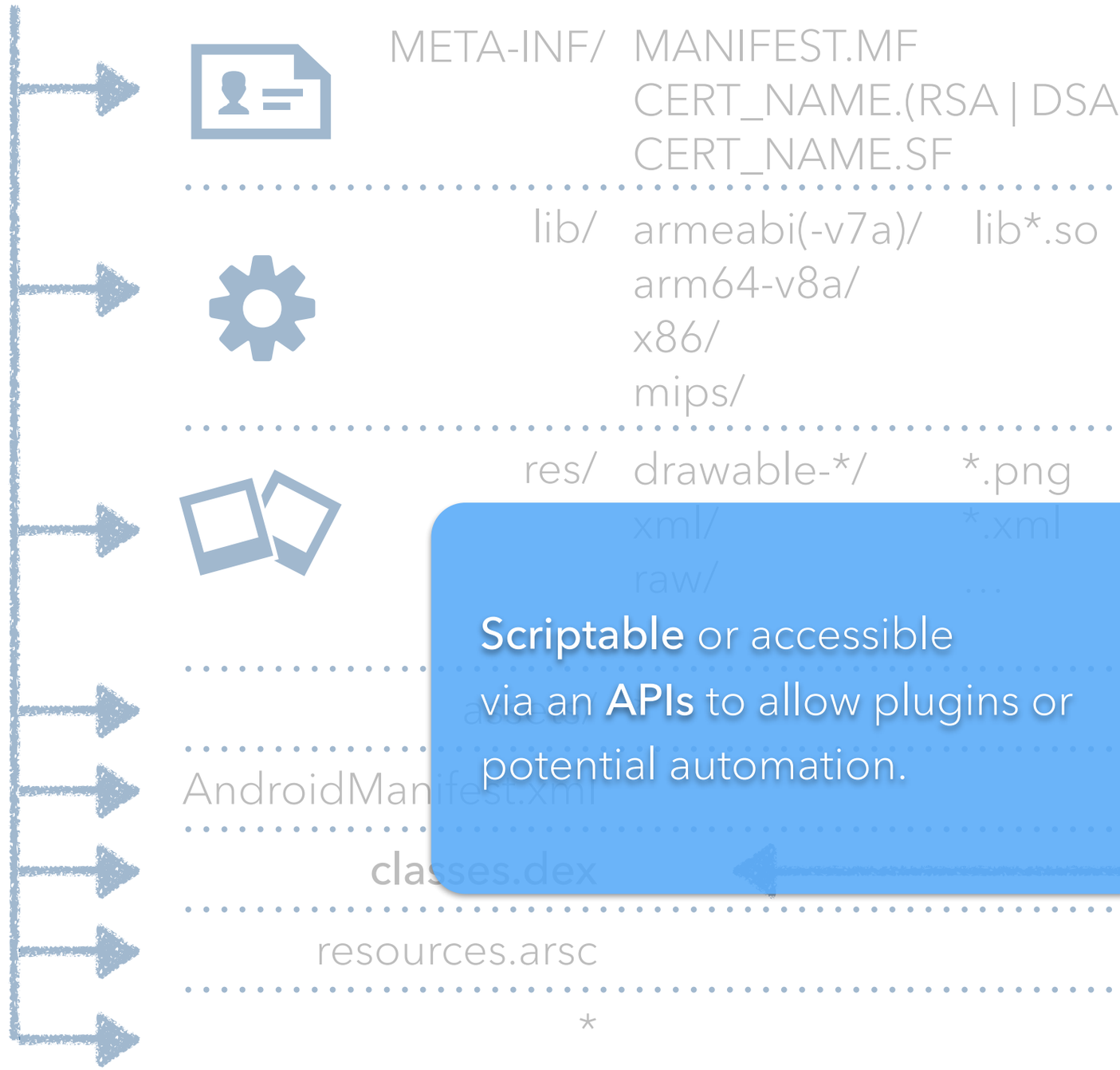

Scriptable or accessible via an **APIs** to allow plugins or potential automation.

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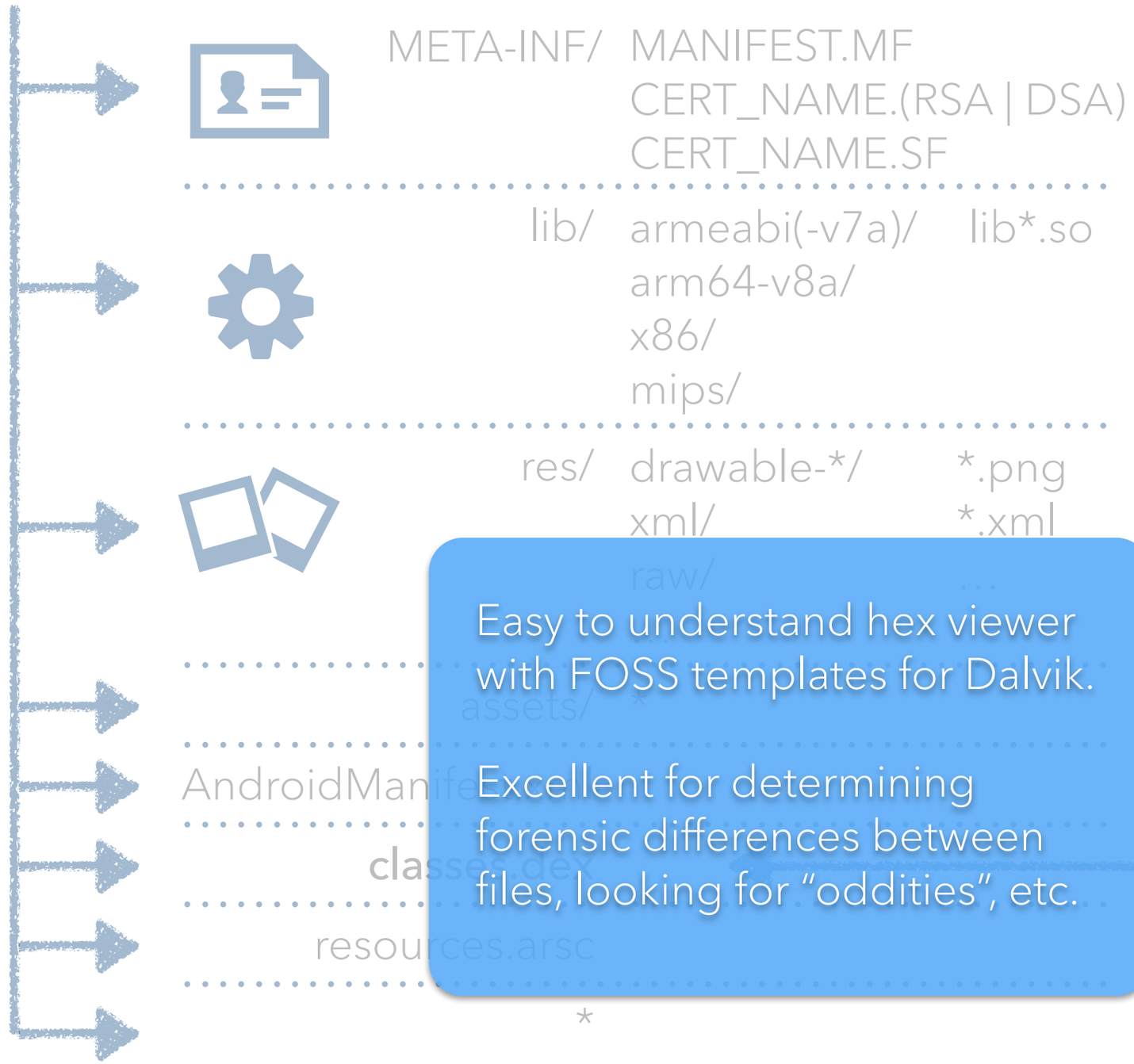

Easy to understand hex viewer with FOSS templates for Dalvik.

Excellent for determining forensic differences between files, looking for “oddities”, etc.

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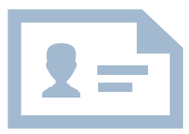
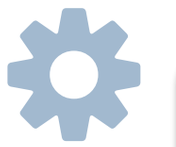


META-INF/ MANIFEST.MF
CERT_NAME.(RSA | DSA)
CERT_NAME.SF

lib/ armeabi(-v7a)/ lib*.so
arm64-v8a/
x86/
x86_64/



assets/ *

AndroidManifest.xml

resources.arsc

*

"Official" / standard tools included in the Android SDK

dx compiles Java .class to .dex

dexmerge combines .dex files and is used by some IDEs for "incremental builds"

Java **A**ndroid **C**ompile **K**it compiles Java .class to .dex

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Created with:
dexmerge
dx
jack
smali (dexlib1/2/2beta)
apktool (dexlib)

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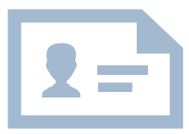
application/vnd.android.package-archive

Blah.apk



META-INF/ MANIFEST.MF
CERT_NAME.(RSA | DSA)
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lib/ armeabi(-v7a)/ lib*.so
arm64-v8a/
x86/
mips/

res/ drawable-*/ *.png
xml/ *.xml
raw/ ...

assets/ *

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Used by everything else,
post compilation modification.

Sec tools / injections / etc

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Created with:
dexmerge
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smali (dexlib1/2/2beta)
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COMPILER FINGERPRINTING

diff / caleb

REDNAGA

LOW TECH ANALOGY

Multiple valid ways to “compile” clothes

Small differences in how each person does it

Can “fingerprint” these differences to win arguments

LEFT VS RIGHT HANDED

Caleb’s technique
(left handed)

Wife’s technique
(right handed)

PHYSICAL ORDERING

"Flexible" sorting
(constant insert, O(N) lookup)

Color-based sorting
(unnecessarily complex for small N)

SUMMARY

- Each way produces “valid” clothes compilation
- Subtle but distinguishable differences
- Same with Android compilers; each produce valid executables but slightly different files
- Person1: “Where did you put my jacket?”
  Person2: “I didn’t touch it. I have no idea.”
  Person1: “I found it hung up right-handed; must have been you. **Clothes fingerprinting!**”
  (⚠️ Person1 is right, but now Person2 wants a divorce ⚠️)

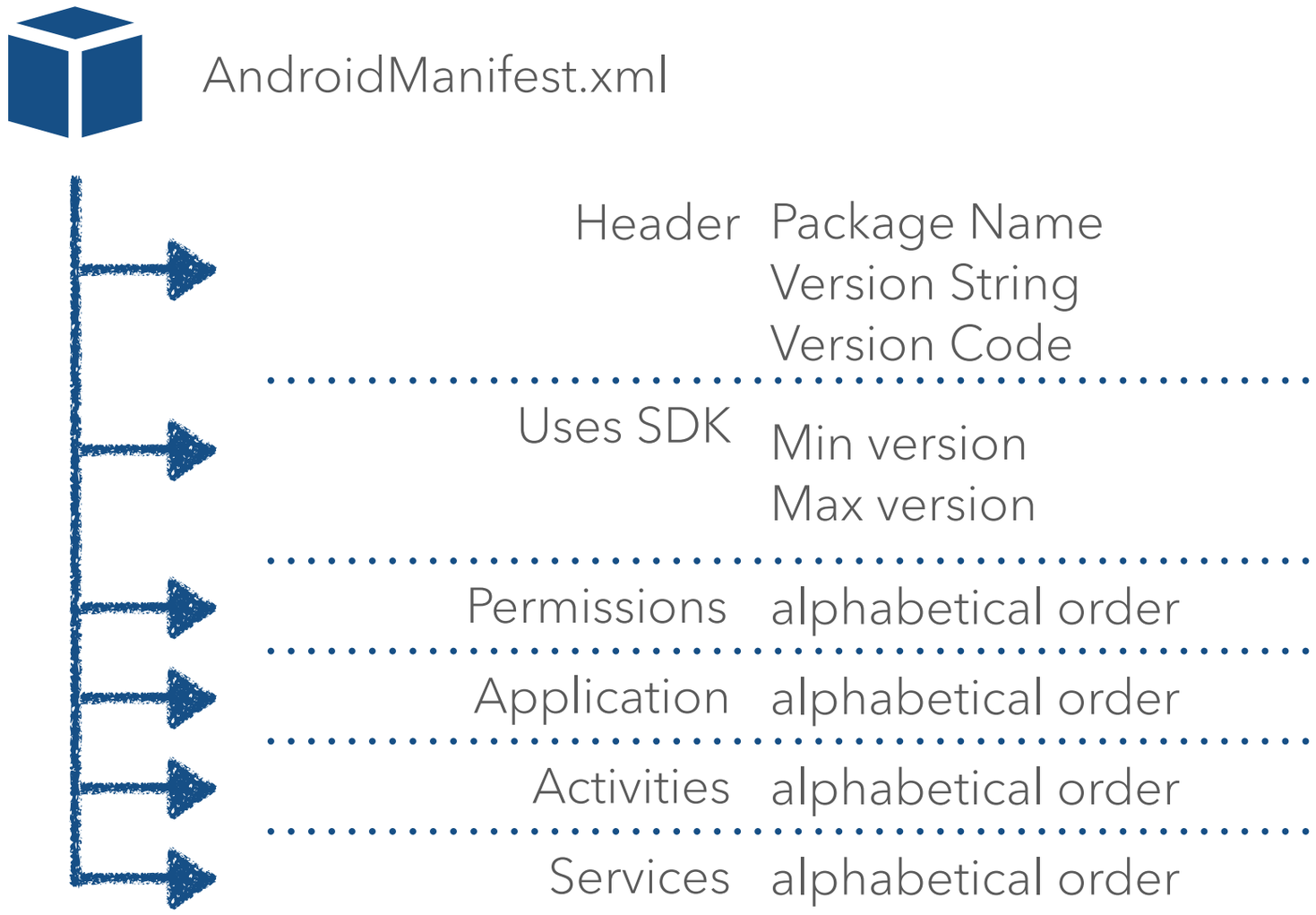
AXML FILES

Relatively Simplistic…

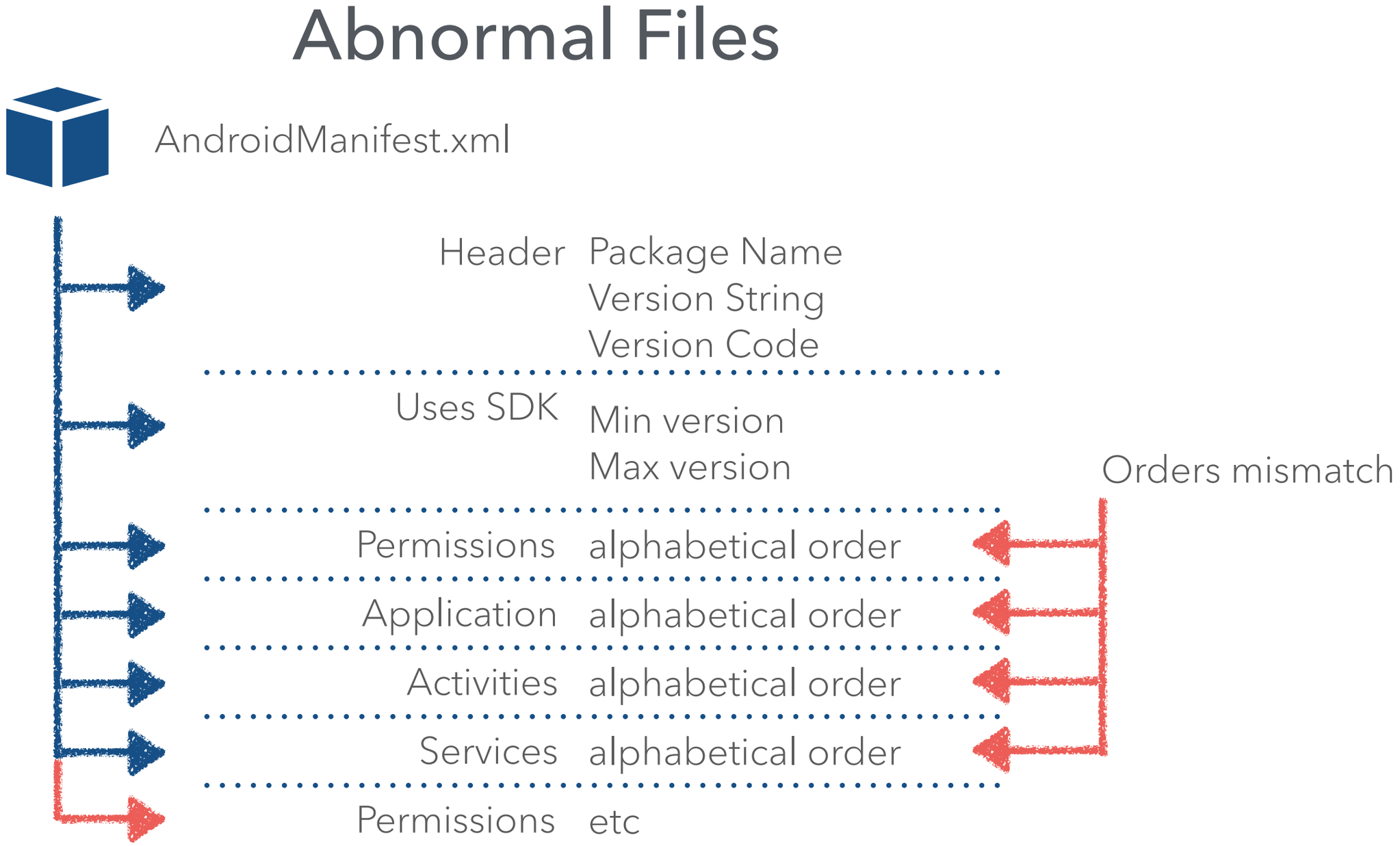
- Normal tools create AXML file in a simple order
- AXML files don’t need to be in a specific order
- Most tools **append** new structures to the file

AXML FILES

Normal Files

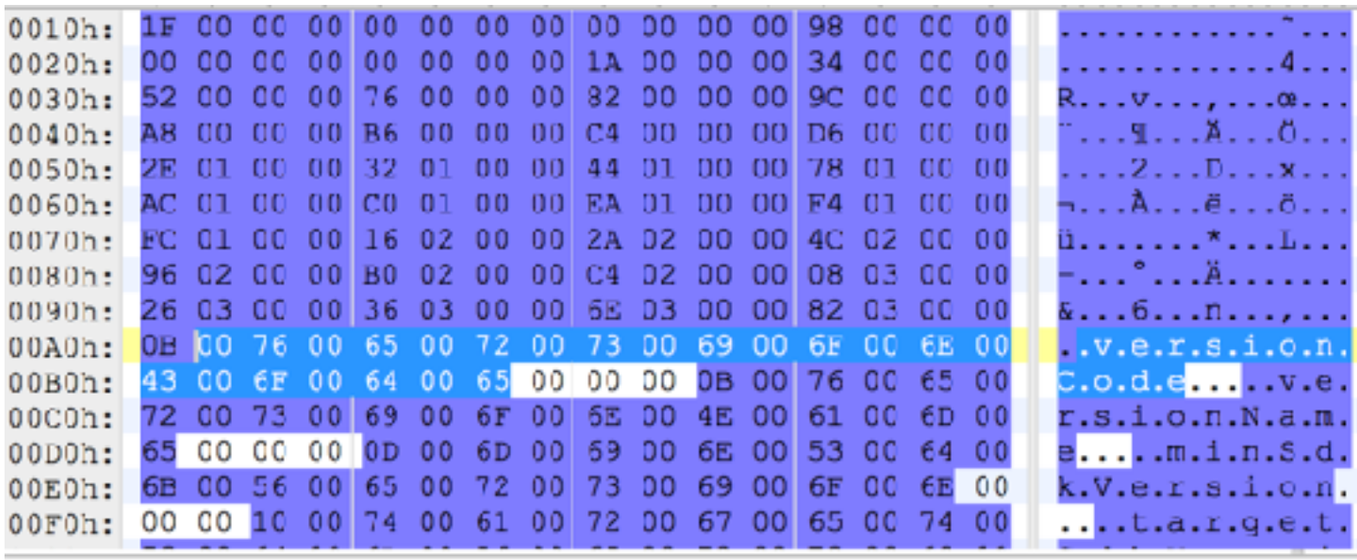


AXML FILES


Abnormal Files
AndroidManifest.xml
Header
Package Name
Version String
Version Code
Uses SDK
Min version
Max version
Permissions
alphabetical order
Application
alphabetical order
Activities
alphabetical order
Services
alphabetical order
Permissions
etc
Orders mismatch

AXML FILES

Normal Files



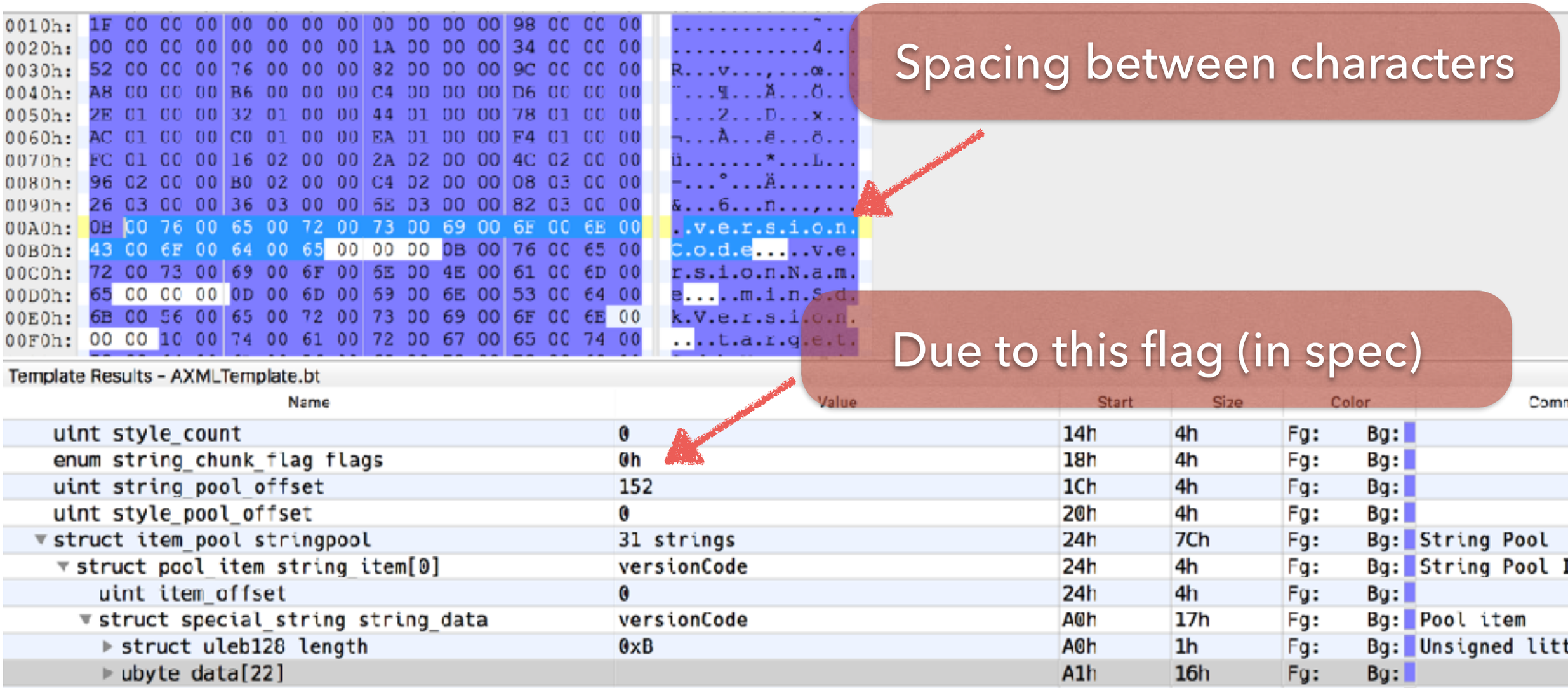
```
0010h: 1F 00 CC 00 00 00 00 00 00 00 00 00 98 00 CC 00   ............˜...
0020h: 00 00 CC 00 00 00 00 00 1A 00 00 00 34 00 CC 00   ............4...
0030h: 52 00 CC 00 76 00 00 00 82 00 00 00 9C 00 CC 00   R...v...,...œ...
0040h: A8 00 00 00 B6 00 00 00 C4 00 00 00 D6 00 00 00   ¨...¶...Ä...Ö...
0050h: 2E 01 00 00 32 01 00 00 44 01 00 00 78 01 00 00   ....2...D...x...
0060h: AC 01 00 00 C0 01 00 00 EA 01 00 00 F4 01 00 00   ¬...À...ê...ô...
0070h: FC 01 00 00 16 02 00 00 2A 02 00 00 4C 02 00 00   ü.......*...L...
0080h: 96 02 00 00 B0 02 00 00 C4 02 00 00 08 03 00 00   –...°...Ä.......
0090h: 26 03 00 00 36 03 00 00 6E 03 00 00 82 03 00 00   &...6...n...,...
00A0h: 0B 00 76 00 65 00 72 00 73 00 69 00 6F 00 6E 00   ..v.e.r.s.i.o.n.
00B0h: 43 00 6F 00 64 00 65 00 00 00 0B 00 76 00 65 00   C.o.d.e.....v.e.
00C0h: 72 00 73 00 69 00 6F 00 5E 00 4E 00 61 00 6D 00   r.s.i.o.n.N.a.m.
00D0h: 65 00 00 00 0D 00 6D 00 69 00 6E 00 53 00 64 00   e.....m.i.n.S.d.
00E0h: 6B 00 56 00 65 00 72 00 73 00 69 00 6F 00 6E 00   k.V.e.r.s.i.o.n.
00F0h: 00 00 10 00 74 00 61 00 72 00 67 00 65 00 74 00   ....t.a.r.g.e.t.
```

Template Results - AXMLTemplate.bt

Name	Value	Start	Size	Color	Comm
uint style_count	0	14h	4h	Fg: Bg:	
enum string_chunk_flag flags	0h	18h	4h	Fg: Bg:	
uint string_pool_offset	152	1Ch	4h	Fg: Bg:	
uint style_pool_offset	0	20h	4h	Fg: Bg:	
▼ struct item_pool stringpool	31 strings	24h	7Ch	Fg: Bg:	String Pool
▼ struct pool_item string_item[0]	versionCode	24h	4h	Fg: Bg:	String Pool I
uint item_offset	0	24h	4h	Fg: Bg:	
▼ struct special_string string_data	versionCode	A0h	17h	Fg: Bg:	Pool item
▶ struct uleb128 length	0xB	A0h	1h	Fg: Bg:	Unsigned litt
▶ ubyte data[22]		A1h	16h	Fg: Bg:	

AXML FILES

Normal Files



AXML FILES

Abnormal files which broke old AXMLPrinter2 lib

```
00B0h: 43 01 00 00 50 01 00 00 59 01 C0 00 62 01 00 C0  C...P...Y...b...
00C0h: 6B 01 00 00 74 01 00 00 7D 01 C0 00 86 01 00 C0  k...t...}...†...
00D0h: 8F 01 00 00 98 01 00 00 A1 01 C0 00 AA 01 00 C0  ....˜...¡...ª...
00E0h: B3 01 00 00 BC 01 00 00 C7 01 C0 00 CD 01 00 C0  ³...¼...Ç...Í...
00F0h: DA 01 00 00 E1 01 00 00 E6 01 C0 00 ED 01 00 C0  Ú...á...æ...í...
0100h: F2 01 00 00 F8 01 00 00 00 02 C0 00 08 02 00 C0  ò...ø...........
0110h: 1C 02 00 00 18 02 00 00 20 02 C0 00 28 02 00 C0  ........ ...(...
0120h: 04 04 6E 61 6D 65 00 06 06 64 65 76 69 63 65 C0  ..name...device.
0130h: 07 07 41 6E 64 72 6F 69 64 00 C4 04 69 74 65 6D  ..Android..Ätem
0140h: 0C 04 04 6E 6F 6E 65 00 01 01 30 00 09 09 73 63  ...none....0...sc
0150h: 72 65 65 6E 2E 6F 6E 00 03 03 31 30 30 00 10 10  reen.on...100...
0160h: 62 6C 75 65 74 6F 6F 74 68 2E 61 63 74 69 76 65  bluetooth.active
0170h: 0C 03 03 31 34 32 00 0C 0C 62 6C 75 65 74 6F 6F  ...142...bluetoo
0180h: 74 68 2E 6F 6E 00 03 03 30 2E 33 00 0C 0C 62 6C  th.on...0.3...bl
0190h: 75 65 74 6F 6F 74 68 2E 61 74 00 05 05 33 35 36  uetooth.at...356
```

No spacing between characters

Due to this flag (in spec)

Template Results - AXMLTemplate.bt

Name	Value	Start	Size	Color	Comme
uint style_count	0	14h	4h	Fg: Bg:	
enum string_chunk_flag flags	UTF8_FLAG (100h)	18h	4h	Fg: Bg:	
uint string_pool_offset	280	1Ch	4h	Fg: Bg:	
uint style_pool_offset	0	20h	4h	Fg: Bg:	
▼ struct item_pool stringpool	63 strings	24h	FCh	Fg: Bg:	String Pool
▼ struct pool_item string_item[0]	name	24h	4h	Fg: Bg:	String Pool It
uint item_offset	0	24h	4h	Fg: Bg:	
▶ struct special_string string_data	name	120h	6h	Fg: Bg:	Pool item

This was back ported from JEB to APKTOOL...

AXML FILES

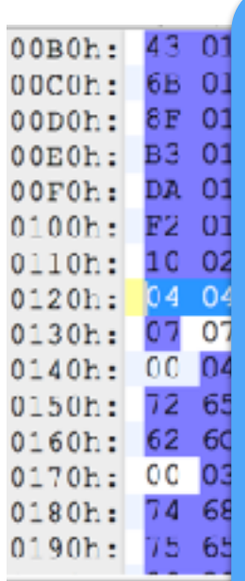
Abnormal files which broke old AXMLPrinter2 lib

```
rule axml_non_standard_flags {
  condition:
    axml.resources_header.flags != 0 and axml.resources_header.flags != 256
}

rule axml_uses_utf8_strings {
  condition:
    axml.resources_header.flags == 256
}
```

aracters

ec)



Template Result

Comme

uint sty						
enum string_chunk_flag flags	UTF8_FLAG (100h)	18h	4h	Fg:	Bg:	
uint string_pool_offset	280	1Ch	4h	Fg:	Bg:	
uint style_pool_offset	0	20h	4h	Fg:	Bg:	
▼ struct item_pool stringpool	63 strings	24h	FCh	Fg:	Bg:	String Pool
▼ struct pool_item string_item[0]	name	24h	4h	Fg:	Bg:	String Pool It
uint item_offset	0	24h	4h	Fg:	Bg:	
▶ struct special_string string_data	name	120h	6h	Fg:	Bg:	Pool item

This was back ported from JEB to APKTOOL...

AXML FILES

Abnormal files which broke old AXMLPrinter2 lib

```
rule axml_non_standard_flags {
  condition:
    axml.resources_header.flags != 0 and axml.resources_header.flags != 256
}

rule axml_uses_utf8_strings {
  condition:
    axml.resources_header.flags == 256
}
```

aracters

ec)

Asking the question of **~85k** APKs (randomly pulled)

~20 utilized UTF8_FLAG

~3 utilized SORTED_FLAG

This w

AXML FILES

Protectors / Anti* tricks

```
[42%]diff@rocksteady:[axml_tests] $ axml power_profile.xml
<?xml version="1.0" encoding="utf-8"?>
java.lang.ArrayIndexOutOfBoundsException: 140
        at android.content.res.StringBlock.getShort(StringBlock.java:231)
        at android.content.res.StringBlock.getString(StringBlock.java:91)
        at android.content.res.AXmlResourceParser.getName(AXmlResourceParser.java:140)
        at test.AXMLPrinter.main(AXMLPrinter.java:56)
```

AXML FILES

Protectors / Anti* tricks

Expects certain values to be present

```
[42%]diff@rocksteady:[axml_tests] $ axml power_profile.xml
<?xml version="1.0" encoding="utf-8"?>
java.lang.ArrayIndexOutOfBoundsException: 140
        at android.content.res.StringBlock.getShort(StringBlock.java:231)
        at android.content.res.StringBlock.getString(StringBlock.java:91)
        at android.content.res.AXmlResourceParser.getName(AXmlResourceParser.java:140)
        at test.AXMLPrinter.main(AXMLPrinter.java:56)
```

AXML FILES

Protectors / Anti* tricks

```
[52%]diff@rocksteady:[crisis-hunt] $ axml contents/AndroidManifest.xml
<?xml version="1.0" encoding="utf-8"?>
<manifest
        xmlns:android="http://schemas.android.com/apk/res/android"
        android:versionCode="1"
        ="1.0"
        package="com.android.deviceinfo"
        >
        <uses-permission
                ="android.permission.RECEIVE_BOOT_COMPLETED"
                >
        </uses-permission>
        <uses-permission
                ="android.permission.WRITE_EXTERNAL_STORAGE"
                >
        </uses-permission>
        <uses-permission
                ="android.permission.WRITE_SMS"
                >
        </uses-permission>
        <uses-permission
                ="android.permission.VIBRATE"
                >
        </uses-permission>
        <uses-permission
                ="android.permission.SEND_SMS"
                >
```

Tools expected name tags

Originally found by dexguard, didn’t work on all Android versions

Replicated by malware

AXML FILES

APKTOOL Specifics… easy, easy

```
[36%]diff@rocksteady:[soplayer] $ axml AndroidManifest.xml
<?xml version="1.0" encoding="utf-8"?>
<manifest
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:versionCode="9"
    android:versionName="1.0"
    package="com.android.h5play"
    platformBuildVersionCode="21"
    platformBuildVersionName="APKTOOL"
    >
```

AXML FILES

APKTOOL Specifics… easy, easy

```
[36%]diff@rocksteady:[soplayer] $ axml AndroidManifest.xml
<?xml version="1.0" encoding="utf-8"?>
<manifest
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:versionCode="9"
    android:versionName="1.0"
    package="com.android.h5play"
    platformBuildVersionCode="21"
    platformBuildVersionName="APKTOOL"
    >
```

Uhhh, thanks?

DEX FILES

- DEX format is … flexible
- Only a few different compilers
- Slight variations between each one
- Obfuscators do really weird stuff too

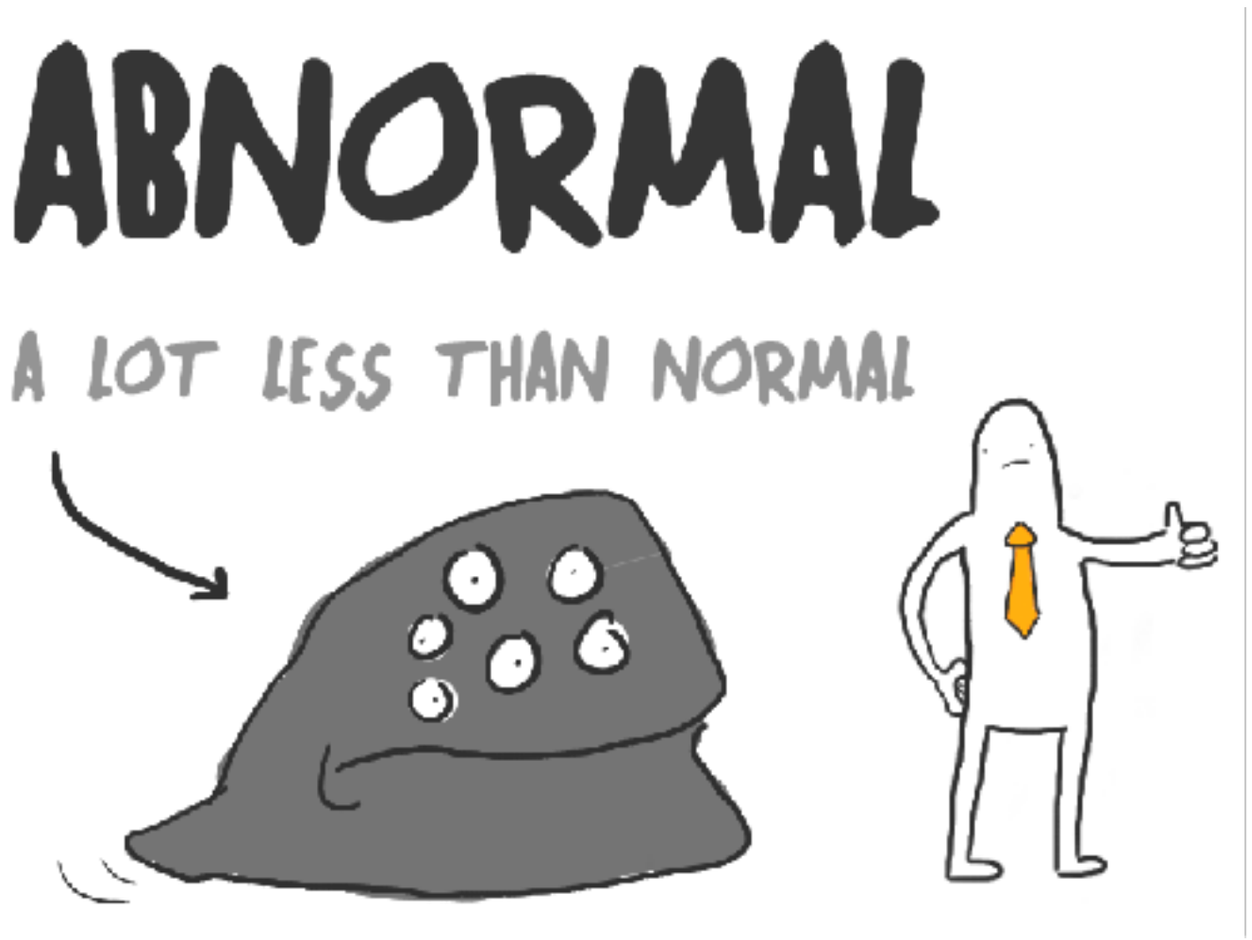
INVESTIGATION

- Built lots of DEX files with different tools
- Compared files with 010Editor
- Found some differences but wanted to know **all** of them
- Read DEX format specification
- Gave up since it doesn't include enough detail
- Very carefully read the source code
- Found many fingerprintable "characteristics"

CHARACTERISTICS

These may be abnormal...

1. Class interfaces
2. Class paths
3. Endian tag
4. Header size
5. Link section
6. String sorting
7. Map type order
8. Section contiguity



ABNORMAL_CLASS_INTERFACES

- Implies: early dexlib 2.x (smali)

classes.dex

```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F  0  1  2  3  4  5  6  7  8  9
115Eh: 23 00 95 00 00 00 3C 00 24 00 95 00 00 00 3C 00 25 00 95 00 00 00 3C 00 1E 00
1178h: 6C 01 00 00 3D 00 40 00 1B 01 00 00 3D 00 40 00 1D 01 00 00 3E 00 19 00 DB 00
1192h: 00 00 3E 00 1E 00 F3 00 00 00 3E 00 4A 00 08 01 00 00 3E 00 3E 00 5A 01 00 00
11ACh: 3E 00 44 00 60 01 00 00 40 00 4E 00 C8 00 00 00 40 00 28 00 F1 00 00 00 40 00
11C6h: 45 00 6F 01 00 00 41 00 2D 00 17 00 00 00 42 00 4A 00 FE 00 00 00 42 00 15 00
11E0h: 2B 01 00 00 43 00 41 00 17 00 00 00 43 00 4A 00 FF 00 00 00 43 00 1E 00 2C 01
11FAh: 00 00 44 00 1E 00 F3 00 00 00 44 00 05 00 FD 00 00 00 45 00 40 00 17 00 00 00
1214h: 45 00 29 00 CE 00 00 00 45 00 2C 00 ED 00 00 00 45 00 10 00 F0 00 00 00 45 00
122Eh: 2B 00 F2 00 00 00 15 00 00 00 01 00 00 00 37 00 00 00 AC 27 00 00 1A 00 00 00
1248h: 00 00 00 00 48 4A 00 00 00 00 00 00 16 00 00 00 01 00 00 00 05 00 00 00 AC 27
1262h: 00 00 1B 00 00 00 00 00 00 00 9E 4A 00 00 00 00 00 00 17 00 00 00 01 00 00 00
127Ch: 05 00 00 00 AC 27 00 00 23 00 00 00 00 00 00 00 C4 4A 00 00 00 00 00 00 18 00
1296h: 00 00 01 00 00 00 20 00 00 00 AC 27 00 00 7C 00 00 00 F4 28 00 00 D2 4A 00 00
12B0h: 00 00 00 00 19 00 00 00 01 00 00 00 37 00 00 00 AC 27 00 00 80 00 00 00 0C 29
12CAh: 00 00 EA 4A 00 00 00 00 00 00 1A 00 00 00 01 00 00 00 06 00 00 00 AC 27 00 00
12E4h: 7E 00 00 00 00 00 00 00 8B 4B 00 00 00 00 00 00 1B 00 00 00 01 00 00 00 06 00
12FEh: 00 00 AC 27 00 00 7E 00 00 00 00 00 00 00 00 9F 4B 00 00 00 00 00 00 1C 00 00 00
```

Template Results - DEXTemplate.bt

Name	Value
▼ struct class_def_item_list dex_class_defs	9 classes
▼ struct class_def_item class_def[0]	public com.secapk.wrapper.ACall
uint class_idx	(0x15) com.secapk.wrapper.ACall
enum ACCESS_FLAGS access_flags	(0x1) ACC_PUBLIC
uint superclass_idx	(0x37) java.lang.Object
uint interfaces_off	10156

If class has no interface, dx uses
interfaces_off = 0
dexlib gives offset to address
with null bytes (10156 is null)

ABNORMAL_CLASS_PATH

- Implies: anti-decompiler

▼ struct class_def_item_list dex_class_defs	317 classes
▶ struct class_def_item class_def[0]	public final android.media.AmrInputStream
▶ struct class_def_item class_def[1]	public final o.if
▶ struct class_def_item class_def[2]	public final o.Con
▶ struct class_def_item class_def[3]	public abstract o.á§
▶ struct class_def_item class_def[4]	public abstract o.CON
▶ struct class_def_item class_def[5]	public final o.Ő
▶ struct class_def_item class_def[6]	final o.áµ
▶ struct class_def_item class_def[7]	public final o.áµ¢
▶ struct class_def_item class_def[8]	public abstract o.â±
▶ struct class_def_item class_def[9]	public final o.ï¹¶
▶ struct class_def_item class_def[10]	public abstract o.á¨
▶ struct class_def_item class_def[11]	public final o.ï¹³

Decompilers output filenames based on class name

Invalid Windows filenames:
CON, PRN, AUX, CLOCK$, NUL
COM1, COM2, COM3, COM4
LPT1, LPT2, LPT3, LPT4

ABNORMAL_CLASS_PATH

- Implies: anti-decompiler

▼ struct class_def_item class_def[377]	public final com.maxmpz.audioplayer.data.ÑLKwlekljkj5w3lkjkljkJlOWEIMmNWHEHKSPIJLNWLHNWLHJDKWPWISJNNNHBHWKEWYHEYWPWW
uint class_idx	(0x2E8) com.maxmpz.audioplayer.data.ÑLKwlekljkj5w3lkjkljkJlOWEIMmNWHEHKSPIJLNWLHNWLHJDKWPWISJNNNHBHWKEWYHEYWPWWKEL
enum ACCESS_FLAGS access_flags	(0x11) ACC_PUBLIC ACC_FINAL
uint superclass_idx	(0x79A) java.lang.Object
uint interfaces_off	0
uint source_file_idx	(0x19B) ""
uint annotations_off	0
uint class_data_off	1648319
▶ struct class_data_item class_data	2 static fields, 0 instance fields, 6 direct methods, 0 virtual methods
uint static_values_off	0

"com.maxmpz.audioplayer.data.ÑLKwlekljkj5w3lkjkljkJlOWEIMmNWHEHKSPIJLNWLHNWLHJDKWPWISJNNNHBHWKEWYHEYWPWWKELWJEKWEWNELWJEJHWELKWEWUEWIEKWLRJFKWNENWKJEJKWHEKWJEJHWKEWJHRKLWHJEKWJEJHWJEHWHEKWEHWHEHjehhwkjrhwerwnbewnrwemnrwkjh5n4m4mwn54mnkhjJNdenrrrr3453nmNMEWERTENRNERMERJEJRNNWKJEWNEWWKEJWEĐ¯"

Looks legit!

Class name used for filename!
Too long for Windows
Most Linux file systems have no limit
NTFS limited to 255 characters per part

ABNORMAL_ENDIAN_MAGIC

- Implies: weird, shouldn't run on any Android device

classes.dex

	00	02	04	06	08	0A	0C
0000h:	64 65 78 0A	30 33 35 00	8F 8D C1 B5	6F 4B			
0021h:	0C 06 00 70	00 00 00 78	56 34 12 00	00 00			
0042h:	00 00 B8 2D	00 00 87 02	00 00 1C 37	00 00			
0063h:	00 F0 BE 00	00 F0 25 05	00 90 E6 00	00 90			
0084h:	A2 E6 00 00	A8 E6 00 00	AB E6 00 00	AF E6			
00A5h:	E6 00 00 D1	E6 00 00 D7	E6 00 00 DC	E6 00			
00C6h:	00 00 33 E7	00 00 3A E7	00 00 43 E7	00 00			
00E7h:	00 84 E7 00	00 8D E7 00	00 94 E7 00	00 A7			
0108h:	C8 E7 00 00	CB E7 00 00	D3 E7 00 00	21 E8			
0129h:	E8 00 00 03	E9 00 00 26	E9 00 00 45	E9 00			

Template Results - DEXTemplate.bt

Name	
struct header_item dex_header	
struct dex_magic magic	dex 035
uint checksum	B5C18D8Fh
SHA1 signature[20]	6F4B5F3279B
uint file_size	396416
uint header_size	112
uint endian_tag	12345678h

Big Endian
(Weird)

reverse_endian.dex

	00	02	04	06	08	0A	0C
0000h:	64 65 78 0A	30 33 35 00	0D EE 21 FD	61 1A			
0021h:	00 01 08	00 00 00 70	12 34 56 78	00 00 00			
0042h:	00 02	00 00 00 78	00 00 00 00	00 00 00 00			
0063h:	01 00 00 00	80 00 00 00	68 00 00 00	A0 00			
0084h:	00 00 00 00	00 00 00 00	00 00 00 00	FF FF			
00A5h:	79 3B 00	12 4C 6A 61	76 61 2F 6C	61 6E 67			
00C6h:	00 01	00 00 00 00	00 01 00 00	00 00 00 02			
00E7h:	00 00 00 00	01 00 00 00	80 20 02	00 00 00			
0108h:							

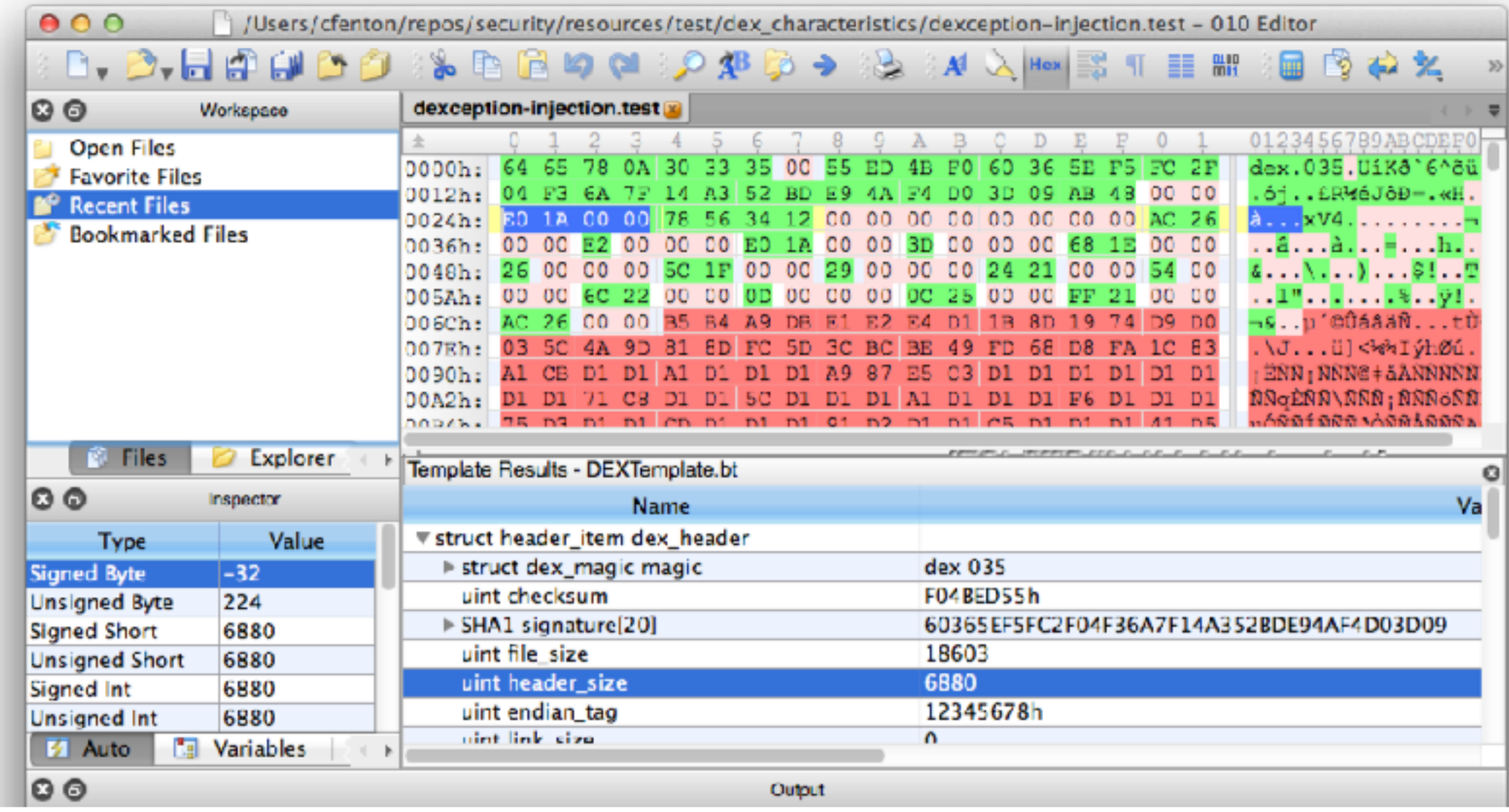
Template Results - DEXTemplate.bt

Name	
struct header_item dex_header	
struct dex_magic magic	dex 035
uint checksum	FD21EE0Dh
SHA1 signature[20]	611AEAB853E
uint file_size	134283264
uint header_size	1879048192
uint endian_tag	78563412h

Little Endian
(Normal)

ABNORMAL_HEADER_SIZE

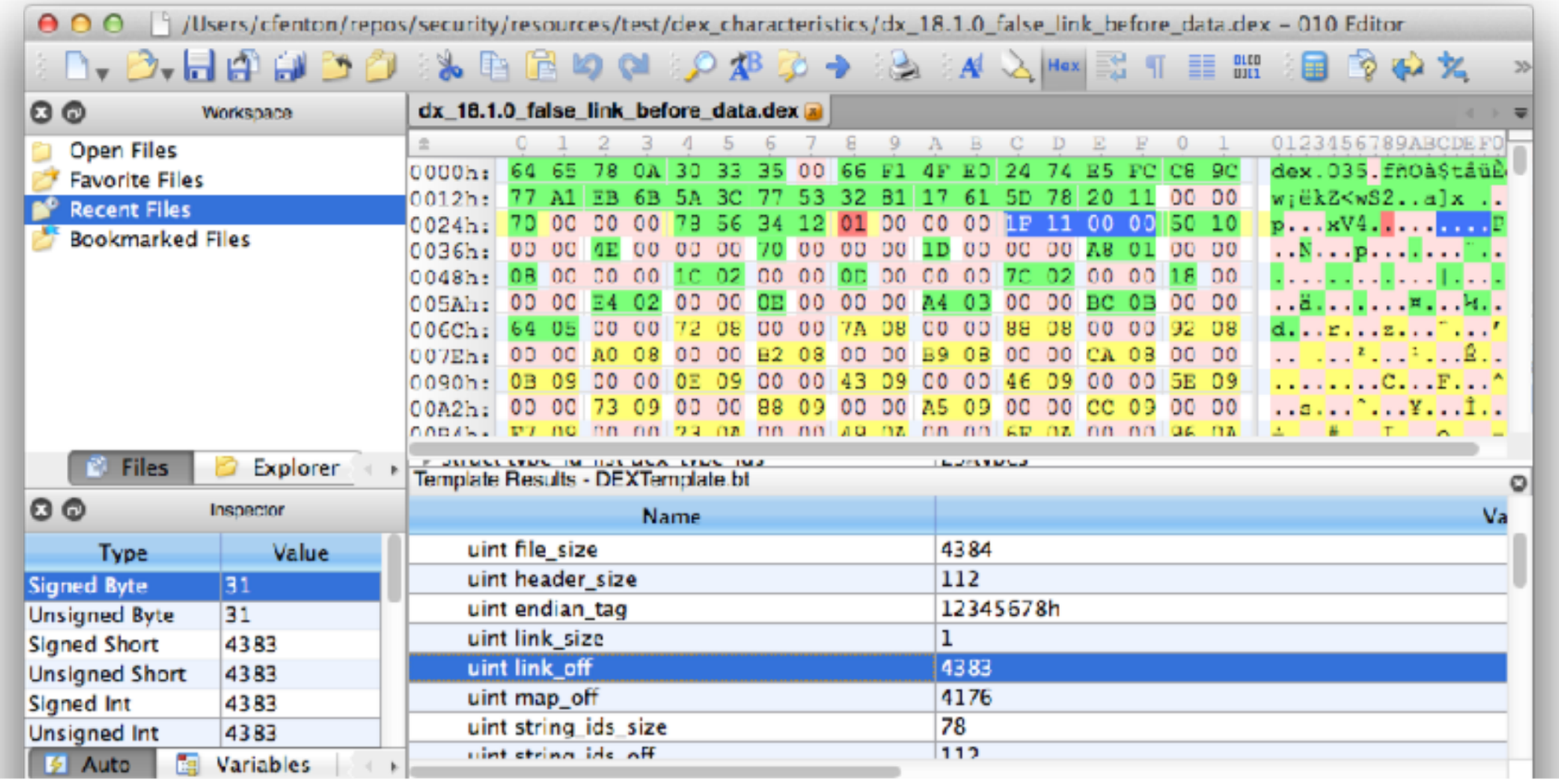
- Implies: weird, possibly hiding data after header before string table



header_size normally
0x70 (112) bytes

ABNORMAL_LINK_SECTION

- Implies: anti-decompiler



link_offset and size
always **0**
in DEX files

ABNORMAL_STRING_SORT

- Implies: dexlib 1.x

Normal

▼ struct string_id_list dex_string_ids	78 strings
▼ struct string_id_item string_id[0]	<init>
uint string_data_off	2162
▶ struct string_item string_data	
▼ struct string_id_item string_id[1]	AppBaseTheme
uint string_data_off	2170
▶ struct string_item string_data	
▶ struct string_id_item string_id[2]	AppTheme
▶ struct string_id_item string_id[3]	Arrakis.java
▶ struct string_id_item string_id[4]	BuildConfig.java
▶ struct string_id_item string_id[5]	DEBUG
▶ struct string_id_item string_id[6]	EnterMentatMode

string[0] starts @2162
string[1] starts immediately after string[0]

Abnormal

▼ struct string_id_list dex_string_ids	77 strings
▼ struct string_id_item string_id[0]	<init>
uint string_data_off	2234
▶ struct string_item string_data	
▼ struct string_id_item string_id[1]	AppBaseTheme
uint string_data_off	3427
▶ struct string_item string_data	
▶ struct string_id_item string_id[2]	AppTheme
▶ struct string_id_item string_id[3]	Arrakis.java
▶ struct string_id_item string_id[4]	BuildConfig.java
▶ struct string_id_item string_id[5]	DEBUG
▶ struct string_id_item string_id[6]	EnterMentatMode
▶ struct string_id_item string_id[7]	Highly organized research is guaranteed to produce nothing new.

string[1] starts way after string[0]
2234 + len("<init>") != 3427

ABNORMAL_TYPE_ORDER

- Implies: something other than dx or dexmerge

dx Map Item Order

1. HEADER_ITEM
2. STRING_ID_ITEM
3. TYPE_ID_ITEM
4. PROTO_ID_ITEM
5. FIELD_ID_ITEM
6. METHOD_ID_ITEM
7. CLASS_DEF_ITEM
8. ANNOTATION_SET_REF_LIST
9. ANNOTATION_SET_ITEM
10. CODE_ITEM
11. ANNOTATIONS_DIRECTORY_ITEM
12. TYPE_LIST
13. STRING_DATA_ITEM
14. DEBUG_INFO_ITEM
15. ANNOTATION_ITEM
16. ENCODED_ARRAY_ITEM
17. CLASS_DATA_ITEM
18. MAP_LIST

▼ struct map_list_type dex_map_list	17 items
uint size	17
▼ struct map_item list[17]	
▶ struct map_item list[0]	TYPE_HEADER_ITEM
▶ struct map_item list[1]	TYPE_STRING_ID_ITEM
▶ struct map_item list[2]	TYPE_TYPE_ID_ITEM
▶ struct map_item list[3]	TYPE_PROTO_ID_ITEM
▶ struct map_item list[4]	TYPE_FIELD_ID_ITEM
▶ struct map_item list[5]	TYPE_METHOD_ID_ITEM
▶ struct map_item list[6]	TYPE_CLASS_DEF_ITEM
▶ struct map_item list[7]	TYPE_STRING_DATA_ITEM
▶ struct map_item list[8]	TYPE_TYPE_LIST
▶ struct map_item list[9]	TYPE_ENCODED_ARRAY_ITEM
▶ struct map_item list[10]	TYPE_ANNOTATION_ITEM
▶ struct map_item list[11]	TYPE_ANNOTATION_SET_ITEM
▶ struct map_item list[12]	TYPE_ANNOTATIONS_DIRECTORY_ITEM
▶ struct map_item list[13]	TYPE_DEBUG_INFO_ITEM
▶ struct map_item list[14]	TYPE_CODE_ITEM
▶ struct map_item list[15]	TYPE_CLASS_DATA_ITEM
▶ struct map_item list[16]	TYPE_MAP_LIST

not made with **dx** or **dexmerge,** probably **dexlib** because TYPE_STRING_DATA_ITEM comes after TYPE_CLASS_DEF_ITEM

dexmerge Map Item Order

1. HEADER_ITEM
2. STRING_ID_ITEM
3. TYPE_ID_ITEM
4. PROTO_ID_ITEM
5. FIELD_ID_ITEM
6. METHOD_ID_ITEM
7. CLASS_DEF_ITEM
8. MAP_LIST
9. TYPE_LIST
10. ANNOTATION_SET_REF_LIST
11. ANNOTATION_SET_ITEM
12. CLASS_DATA_ITEM
13. CODE_ITEM
14. STRING_DATA_ITEM
15. DEBUG_INFO_ITEM
16. ANNOTATION_ITEM
17. ENCODED_ARRAY_ITEM
18. ANNOTATIONS_DIRECTORY_ITEM

NON_CONTIGUOUS_SECTION

- Implies: weird, maybe dexmerge

uint type_ids_size	61
uint type_ids_off	7784
uint proto_ids_size	38
uint proto_ids_off	12124

proto_ids should come after type_ids

type_id_item size = 4 bytes
type_ids_size * 4 = 244
type_ids_off + 244 = 8028
proto_ids actually starts 12124! weird!

MALWARE AND PIRACY DETECTION

caleb

REDNAGA

? THE QUESTION

Four main compilers:

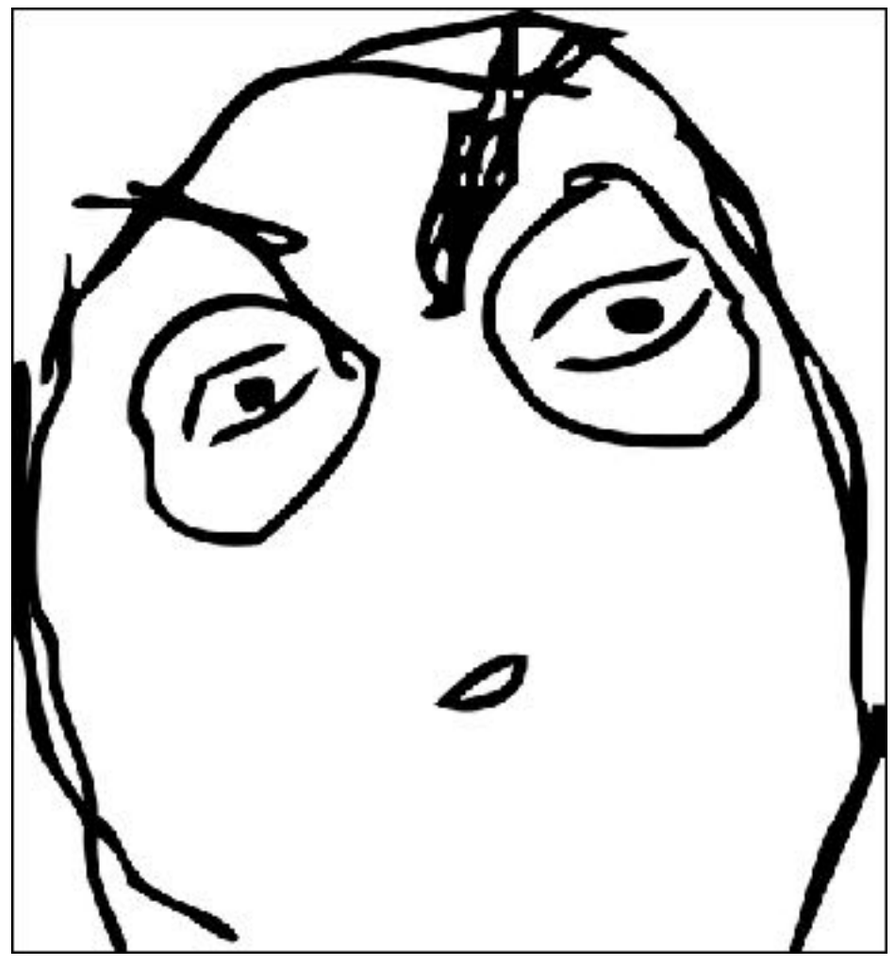
1. dx ← Java .class files (source code)
2. Jack ← Java .java files (source code)
3. dexmerge ← Not used manually, only by IDEs (source code)
4. smali (dexlib) ← DEX files (**not source code**)

Why would a legitimate developer ever need to use smali?

They have the source.

THE HYPOTHESIS

- If app compiled with dexlib, probably tampered
- If tampered, probably not by the developer
- Tampered apps are likely either:
  - 🔓 pirated / cracked
  - 💀 malicious



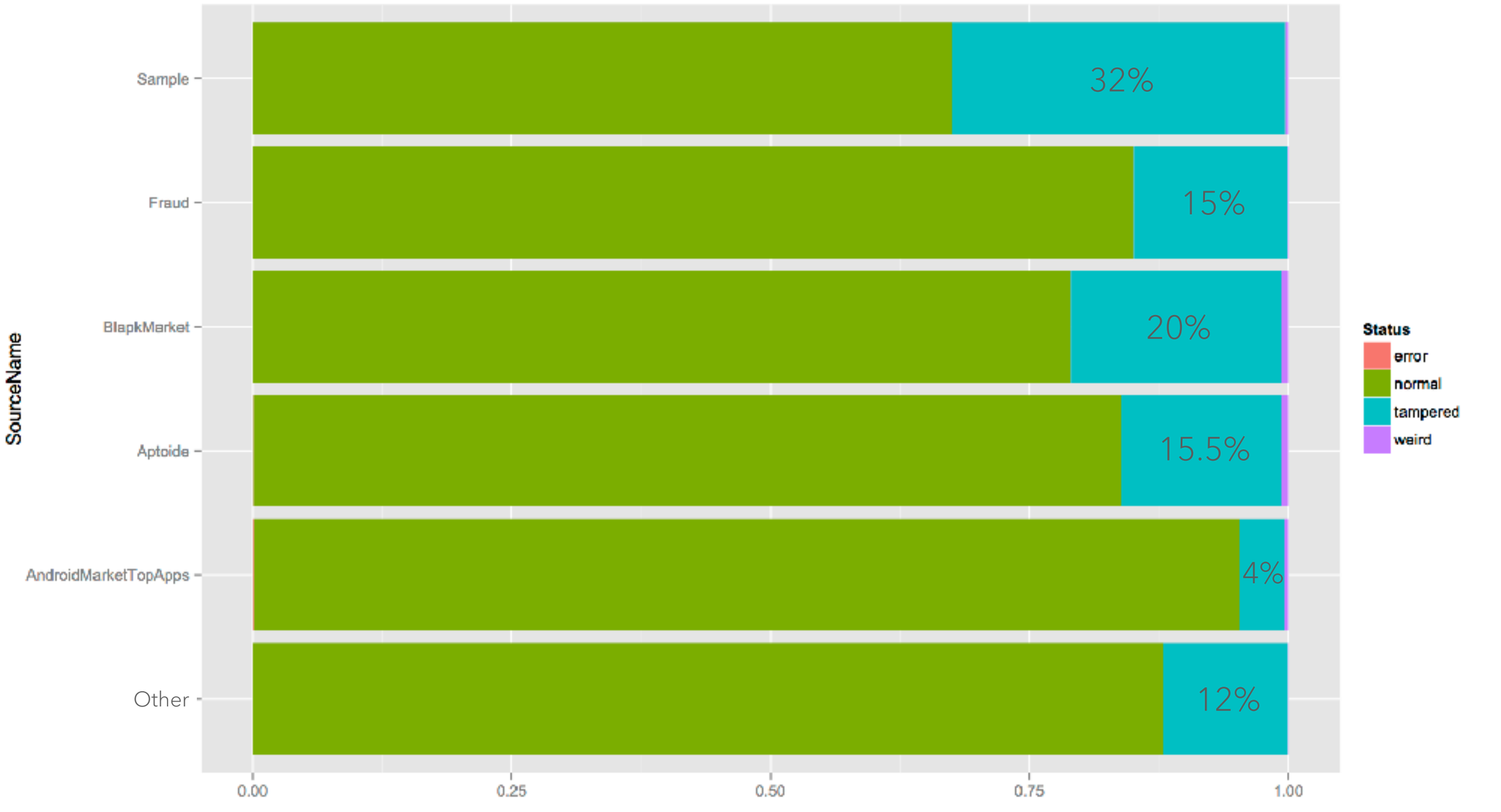
🐛 SAMPLE SET

- 20,000 APKs from each market
  - Top Play Apps, Aptoide, BlapkMarket, etc.
- 10,000 highest scoring “fraudulent” apps
  - Scored by experimental, in-house model
  - Real fraud may just modify the AXML, not DEX
- Up to 10 APKs per variant of all malware families

THE METHOD

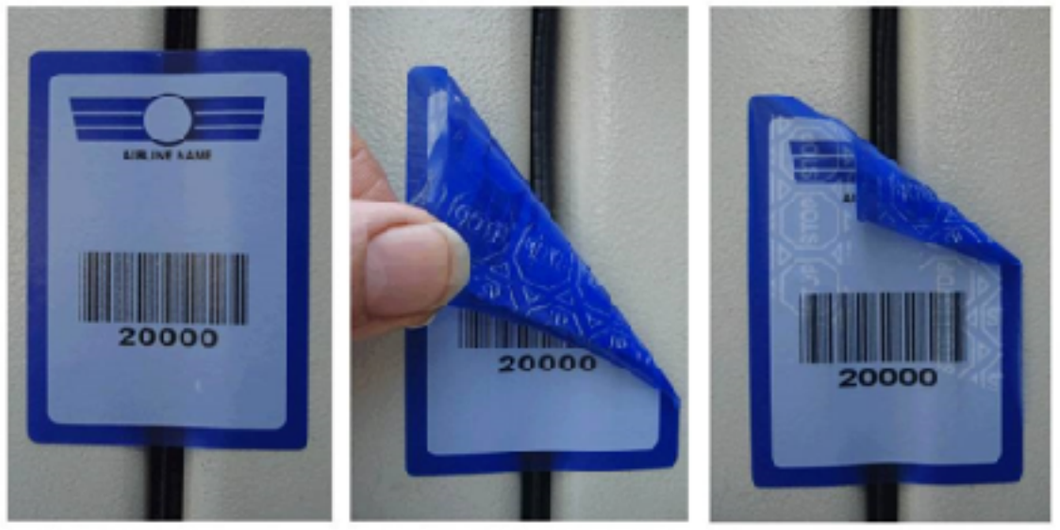
- Scanned DEX of each APK
- Didn’t scan AXML files
- Tampered means:
  - abnormal string sort, class path, type order
- Weird means:
  - abnormal endian magic, header size, type descriptor, class path

RESULTS: SOURCE TAMPERING



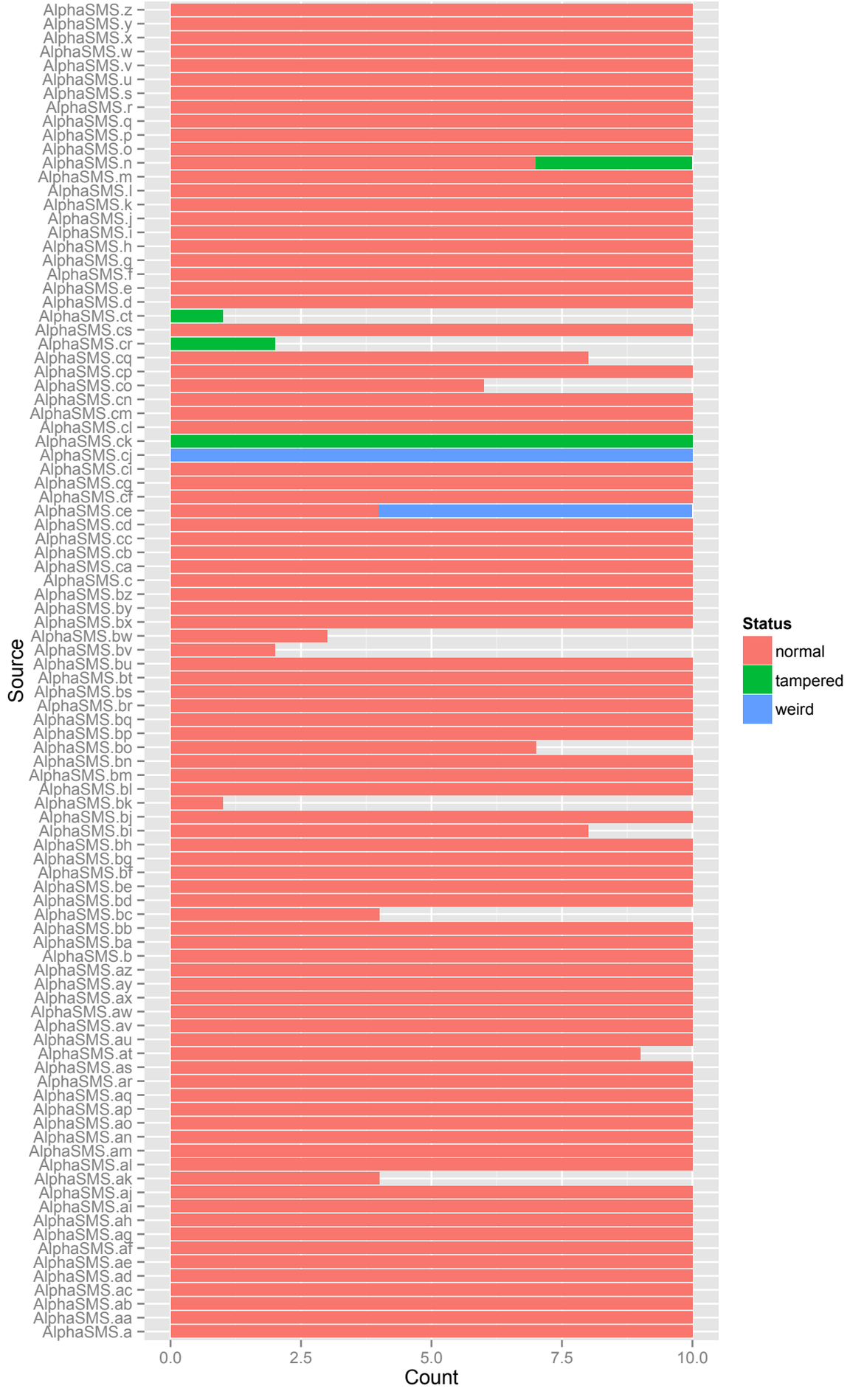
RESULTS: MALWARE TAMPERING

- 756 malware families (many variants each)
- 17508 malicious APKs
- 50% families have some tampering
- 50% families have no tampering
- 85 families are 100% tampered
- Each family has a tampering profile



100% TAMPERED FAMILIES

AdultFreedom Alsalah AncientSMSThief AppleService AvariceYY BadSerial
BadSub Badaccents BankMirage Bgserv BiggBoss CastilStyle CataChar
CnSky CoinKrypt DeCerTasks DidStall DirtyAir DoubleZero EasyPine
EdeFraud EmmentalCrupt ErrthangSms Euroxbox ExplicitHorse FadeSMS
FakeActivate FakeKakao FastUninstallRepackaged FineFocusAds
FlaccidForest GauerCloud Geinimi GoGuangGo Gone60 ImAdPush KHSms
Kakabet KhpowSms KrabBot Krysanec LidLocker LoveMii MMarketPay
MaClickFraud MirvspySMS MixedSmoke MmsMore MocheYY Moghava
Obad OccupyYourPrivacy PVAFraud PhoXinhSms PicSysCom PirateShame
PlusTV PopTest RootSmart RuSms Samsapo SandroRat SimpleTemai
SixPointFourSMS SlyInstall SmsMonitur SneakyBeeSMS Stask Stoqx
StorgeSMS SwfScam SwiftLogger Taotobo Tornika
UniversalAndrootRepackaged VDLoader Vchargelet VideoBoss
VservSubscription WinAdOffers WrongPath XSider Xybot YobaSMS ZxtdPay


Source
AlphaSMS.z
AlphaSMS.y
AlphaSMS.x
AlphaSMS.w
AlphaSMS.v
AlphaSMS.u
AlphaSMS.s
AlphaSMS.r
AlphaSMS.q
AlphaSMS.p
AlphaSMS.o
AlphaSMS.n
AlphaSMS.m
AlphaSMS.l
AlphaSMS.k
AlphaSMS.j
AlphaSMS.i
AlphaSMS.h
AlphaSMS.g
AlphaSMS.f
AlphaSMS.e
AlphaSMS.d
AlphaSMS.ct
AlphaSMS.cs
AlphaSMS.cr
AlphaSMS.cq
AlphaSMS.cp
AlphaSMS.co
AlphaSMS.cn
AlphaSMS.cm
AlphaSMS.cl
AlphaSMS.ck
AlphaSMS.cj
AlphaSMS.ci
AlphaSMS.cg
AlphaSMS.cf
AlphaSMS.ce
AlphaSMS.cd
AlphaSMS.cc
AlphaSMS.cb
AlphaSMS.ca
AlphaSMS.c
AlphaSMS.bz
AlphaSMS.by
AlphaSMS.bx
AlphaSMS.bw
AlphaSMS.bv
AlphaSMS.bu
AlphaSMS.bt
AlphaSMS.bs
AlphaSMS.br
AlphaSMS.bq
AlphaSMS.bp
AlphaSMS.bo
AlphaSMS.bn
AlphaSMS.bm
AlphaSMS.bl
AlphaSMS.bk
AlphaSMS.bj
AlphaSMS.bi
AlphaSMS.bh
AlphaSMS.bg
AlphaSMS.bf
AlphaSMS.be
AlphaSMS.bd
AlphaSMS.bc
AlphaSMS.bb
AlphaSMS.ba
AlphaSMS.b
AlphaSMS.az
AlphaSMS.ay
AlphaSMS.ax
AlphaSMS.aw
AlphaSMS.av
AlphaSMS.au
AlphaSMS.at
AlphaSMS.as
AlphaSMS.ar
AlphaSMS.aq
AlphaSMS.ap
AlphaSMS.ao
AlphaSMS.an
AlphaSMS.am
AlphaSMS.al
AlphaSMS.ak
AlphaSMS.aj
AlphaSMS.ai
AlphaSMS.ah
AlphaSMS.ag
AlphaSMS.af
AlphaSMS.ae
AlphaSMS.ad
AlphaSMS.ac
AlphaSMS.ab
AlphaSMS.aa
AlphaSMS.a
0.0
2.5
5.0
7.5
10.0
Count
Status
normal
tampered
weird

CONCLUSION

- Few legitimate apps are tampered
- Tampering good signal for malware / piracy
- Better able to understand malware family evolution

APKID DEMO

REDNAGA

BONUS: THE JUDGE

REDNAGA

THE JUDGE

- **judge.rednaga.io** - upload some APKs ;)
- Detects malware using machine learning
- Provides results of analysis (including APKiD output)
- Model trained with 170k samples (50% malware)
- Cross-validation shows 97% accuracy, so not perfect
- Has JSON API

WEBSITE DESIGN IS HARD

Judge

Android malware scanner and app analyser

DASHBOARD ABOUT STATISTICS REDNAGA BLOG

Judge

Search

APK hash (SHA256, SHA1, MD5) Search

Upload APK

APK must be signed, have a manifest, and fewer than 100mb.

Choose File No file chosen Upload

News

03/10/2017 - Initial release

This site was launched as part of RedNaga's talk on compiler fingerprinting. Hope it's useful or interesting!

Submission Stats:

Benign: 1791

Malicious: 1145

Unknown: 41

Total: 2977

Recent Submissions

dc577ab81e6fb5013a9b6d95fe37de23435402c641b2b1c71b5a35f386448c9c

cc7f54e55149c870bca9dadfc0b5d879c708019b3a4f6e7119962fdf17c91ddd

dbf27a78aec6cd33df5596532a9940bd4c7a99a002bd391b1c49b4f5df71cb8b

1247f9b93d274d31598573cca6b45ddb5b6996d25d1b8876ec7fd70c7339e39e

6cd1f1cba31aa18a34785c53008f98e0607d48b266240f6bccd01c3293a58161

a72f7af2a90ece931c3ef68aba3f051369f5ddcdd52a83dd8e258a1aab4a8958

a84458ea0ebc8050f5c8ef8fb68f11876f687718138e2cddee73048c4905240e

3b09cb30098ef09d630976f20b458cc26e7296626fc4903616076825 1e97f55d

3a69316a98cc658312ff1d65d182da4edd9b659b32729f7af94ffe7d0904aee6

EXTENDED READING

https://github.com/rednaga/training

http://www.strazzere.com/papers/DexEducation-PracticingSafeDex.pdf

https://github.com/strazzere/anti-emulator/tree/master/slides

https://github.com/strazzere/android-unpacker/blob/master/AHPL0.pdf

http://www.droidsec.org/wiki/#whitepapers

http://calebfenton.github.io/

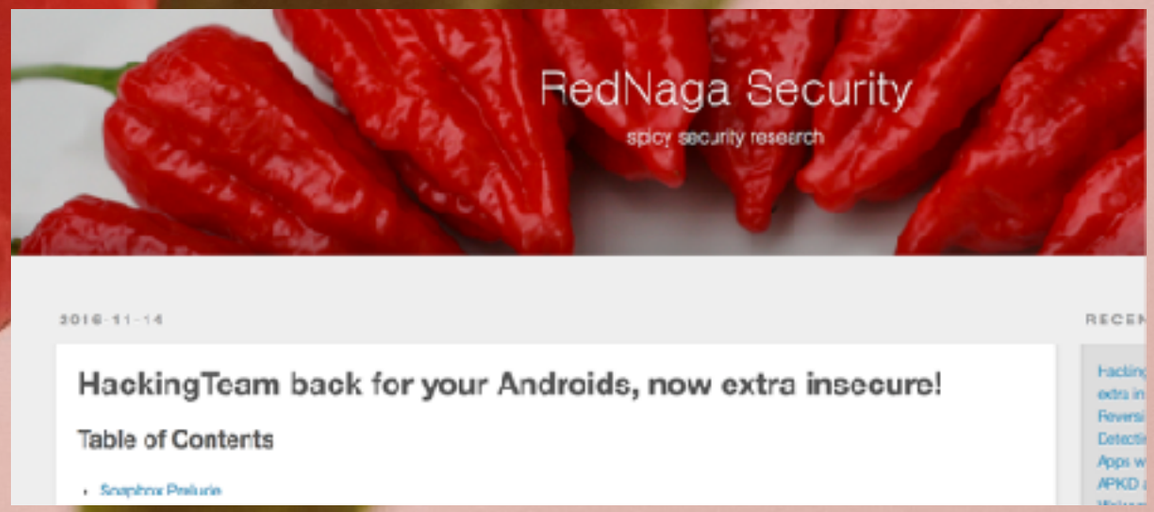
http://androidcracking.blogspot.com/

SHARING IS CARING

Need help? Ask!

^- Totally legit big data projects

Send a drive, get ~8tb of APKS



^- Send us your implants so we can

burn the baddies to the ground together!

REDNAGA

THANKS!

TIM “DIFF” STRAZZERE
@TIMSTRAZZ

CALEB FENTON
@CALEB_FENTON

Special Thanks for Jacob Soo and Mikachu for all your assistance!

Join use on Freenode on #droidsec and #rednaga

Good people to follow on Twitter for
Android / reversing / malware / hacking information:
@_jsoo_ @droidsec @jcase @marcwrogers @msolnik
@PatrickMcCanna @rotlogix @snare @tamakikusu @trimosx
@cryptax @virqdroid @WataShiva @againsthimself @collinrm
@michalmalik @utkan0s @malataz @LukasStefanko @ACKFlags
#MalwareMustDie

03.10.2017

Android Security Symposium

REDNAGA