FIRMSCOPE: Automatic Uncovering of Privilege-Escalation Vulnerabilities in Pre-Installed Apps in Android Firmware

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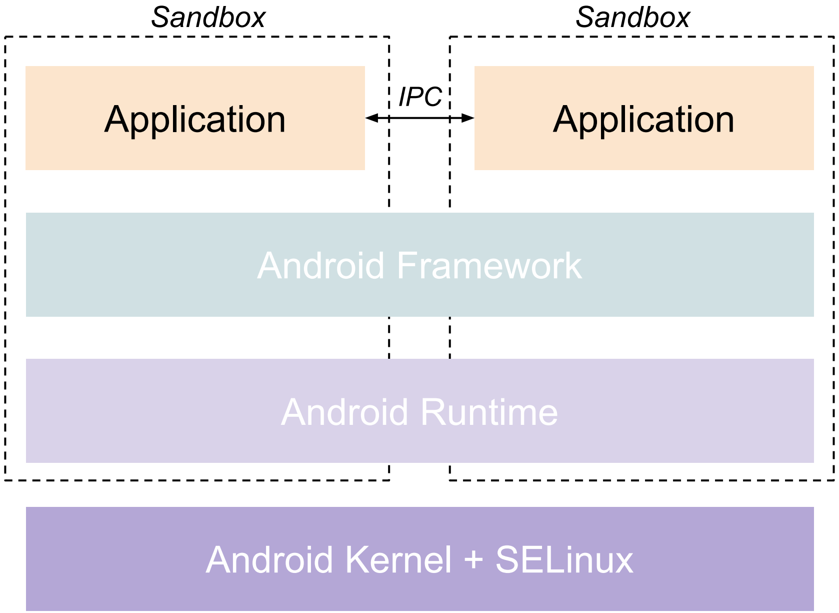
Android Application Sandbox



- Isolated process
- Isolated storage
- Secure IPC
- Restricted access to resources (permission based)

Privileged Pre-Installed Apps

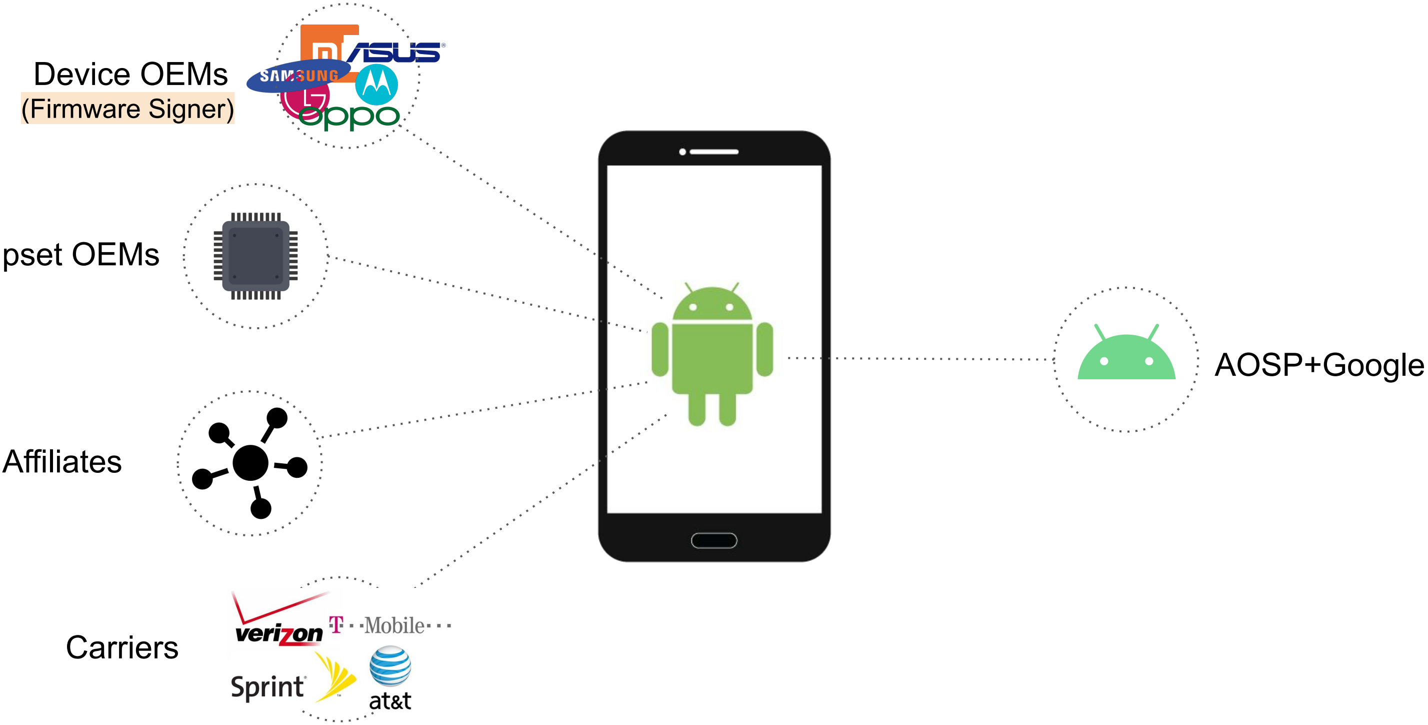
User Apps
/data/app/...

- Netflix, SnapChat, …
- User-Installed
- Low privilege
- Limited permissions
- User-granted permissions

System Apps
/system/priv-app/...

- Telephony, I/O, Package Mgmt, ...
- Pre-installed + Persistent
- High privilege
- Unrestricted permissions
- Pre-granted permissions

Pre-Installed Apps



Device OEMs
(Firmware Signer)

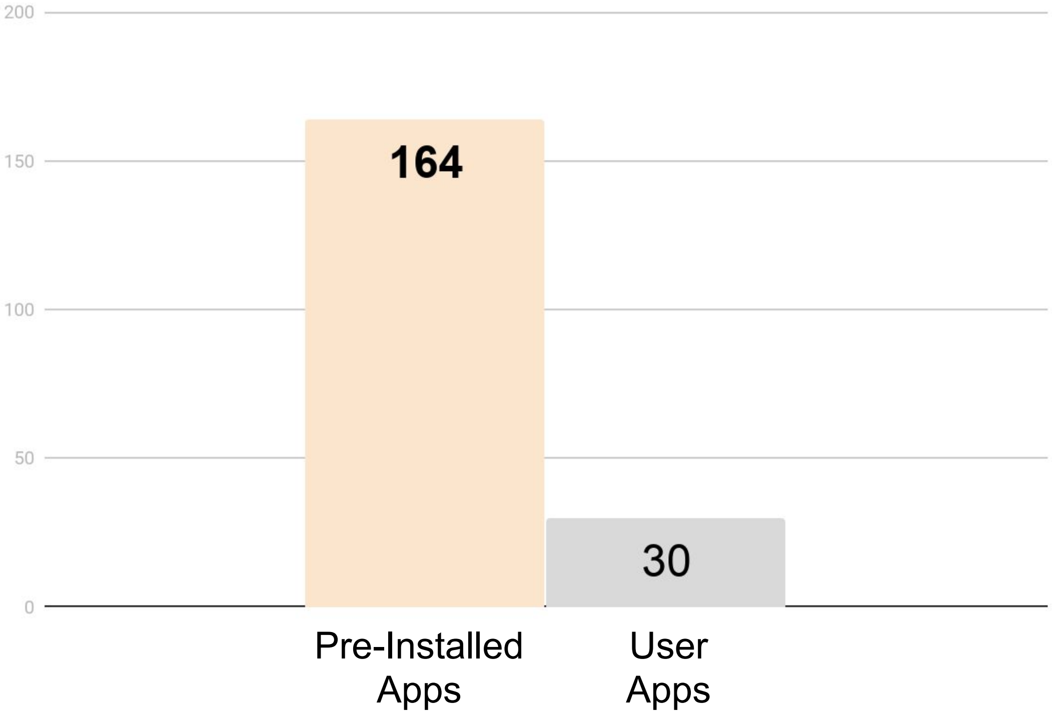
Chipset OEMs

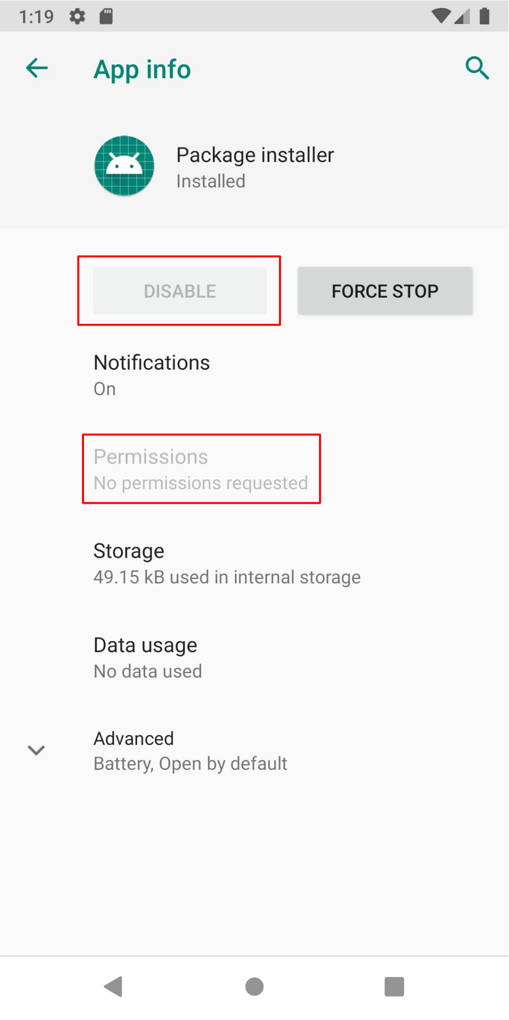
Affiliates

Carriers

AOSP+Google

Average No. Apps on an Android Phone





1:19

App info

Package installer
Installed

DISABLE

FORCE STOP

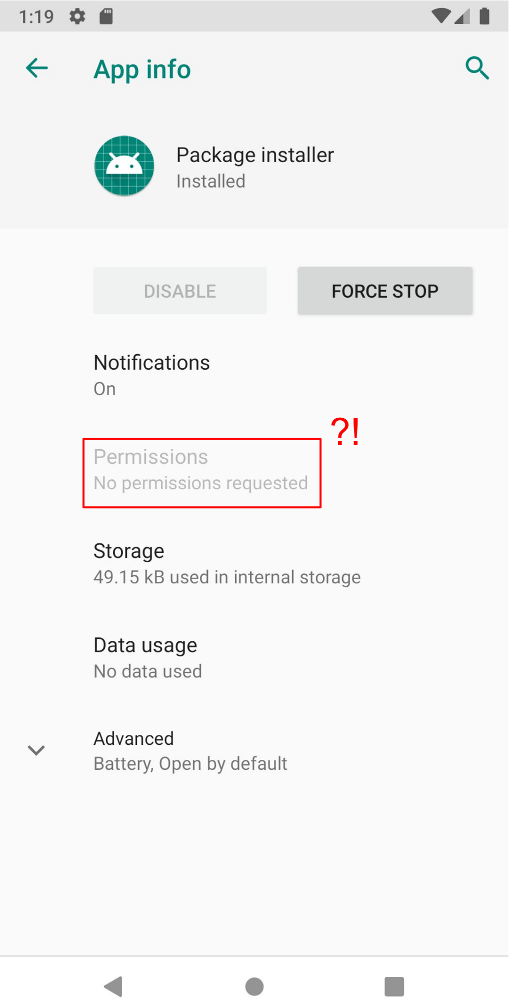
Notifications
On

Permissions
No permissions requested

Storage
49.15 kB used in internal storage

Data usage
No data used

Advanced
Battery, Open by default



Package installer
Installed

Notifications
On

?!

Permissions
No permissions requested

Storage
49.15 kB used in internal storage

Data usage
No data used

Advanced
Battery, Open by default

```
> dumpsys package com.google.android.packageinstaller
      ...
 1.   android.permission.KILL_UID: granted=true
 2.   android.permission.USE_RESERVED_DISK: granted=true
 3.   android.permission.CLEAR_APP_USER_DATA: granted=true
 4.   android.permission.INSTALL_PACKAGES: granted=true
 5.   android.permission.FOREGROUND_SERVICE: granted=true
 6.   android.permission.RECEIVE_BOOT_COMPLETED: granted=true
 7.   android.permission.INSTALL_GRANT_RUNTIME_PERMISSIONS: granted=true
 8.   android.permission.ACCESS_INSTANT_APPS: granted=true
 9.   android.permission.INTERACT_ACROSS_USERS_FULL: granted=true
10.   android.permission.READ_INSTALL_SESSIONS: granted=true
11.   android.permission.REVOKE_RUNTIME_PERMISSIONS: granted=true
12.   android.permission.MANAGE_USERS: granted=true
13.   android.permission.MANAGE_APP_OPS_RESTRICTIONS: granted=true
14.   android.permission.CLEAR_APP_CACHE: granted=true
15.   android.permission.GRANT_RUNTIME_PERMISSIONS: granted=true
16.   android.permission.HIDE_NON_SYSTEM_OVERLAY_WINDOWS: granted=true
17.   android.permission.MANAGE_APP_OPS_MODES: granted=true
18.   android.permission.WAKE_LOCK: granted=true
19.   android.permission.UPDATE_APP_OPS_STATS: granted=true
20.   android.permission.OBSERVE_GRANT_REVOKE_PERMISSIONS: granted=true
21.   android.permission.DELETE_PACKAGES: granted=true
22.   android.permission.READ_EXTERNAL_STORAGE: granted=true
```

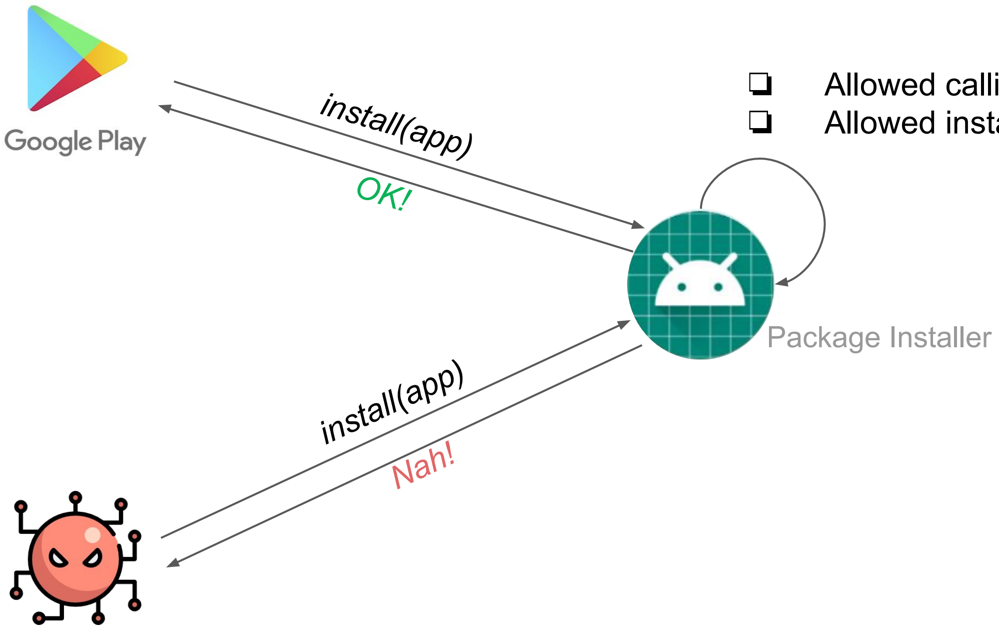
Privileged Functionality → Access Control

Authentication: Who is allowed access?

Authorization: What are they allowed to do?

Accounting: What did they do?

❏ Allowed calling me?
❏ Allowed installing apps?



Google Play

install(app)

OK!

Package Installer

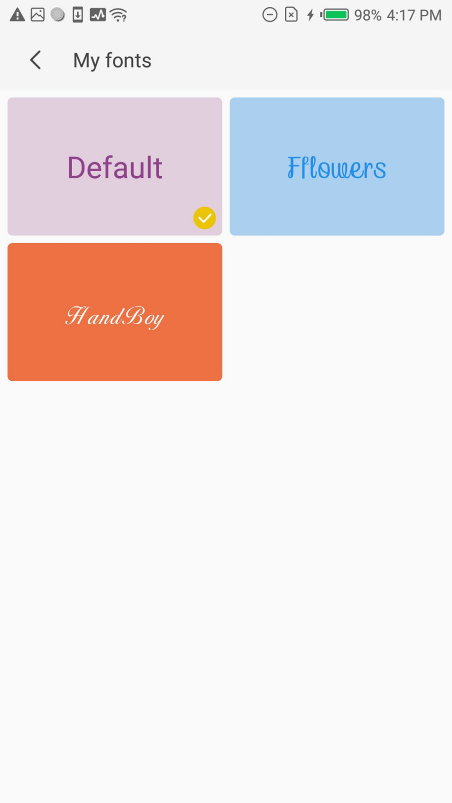
install(app)

Nah!

What We Found

Thousands of privilege-escalation vulnerabilities in Android 4 to 9
due to improper access control in pre-installed apps

Real Example: *Lovely Fonts*



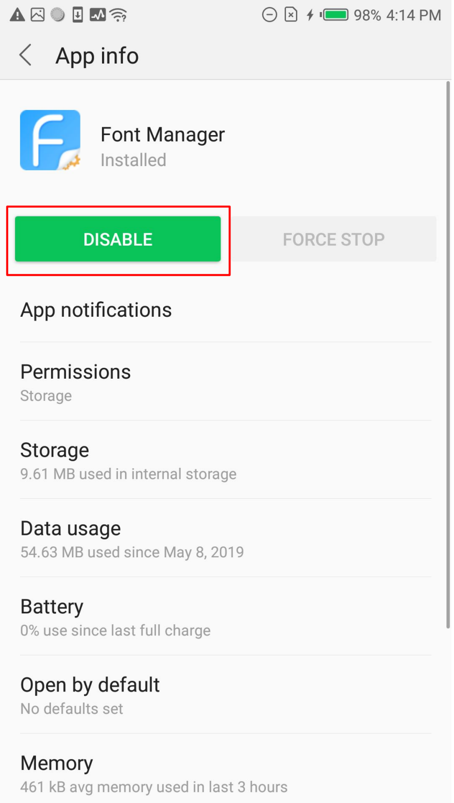
98% 4:17 PM

My fonts

Default

Fflowers

HandBoy



98% 4:14 PM

App info

Font Manager
Installed

DISABLE

FORCE STOP

App notifications

Permissions
Storage

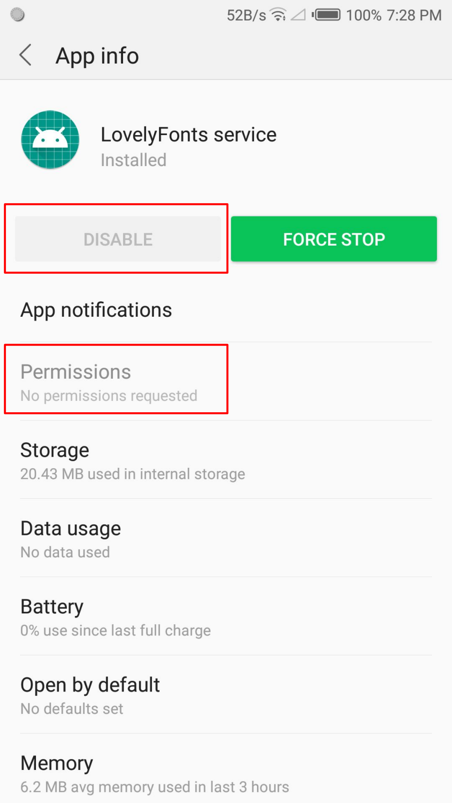
Storage
9.61 MB used in internal storage

Data usage
54.63 MB used since May 8, 2019

Battery
0% use since last full charge

Open by default
No defaults set

Memory
461 kB avg memory used in last 3 hours



52B/s 100% 7:28 PM

App info

LovelyFonts service
Installed

DISABLE

FORCE STOP

App notifications

Permissions
No permissions requested

Storage
20.43 MB used in internal storage

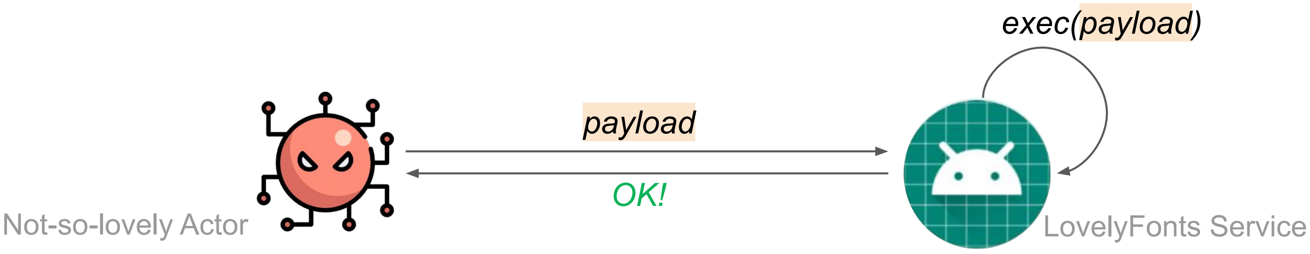
Data usage
No data used

Battery
0% use since last full charge

Open by default
No defaults set

Memory
6.2 MB avg memory used in last 3 hours

Real Example: *Lovely Fonts*

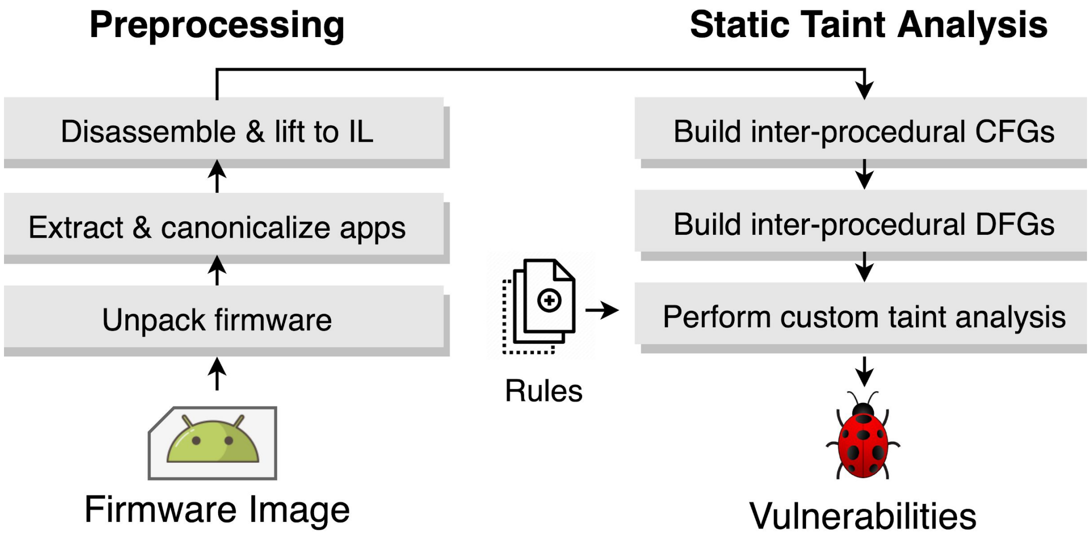


Unprivileged
+ Zero permissions
+ Local/Remote

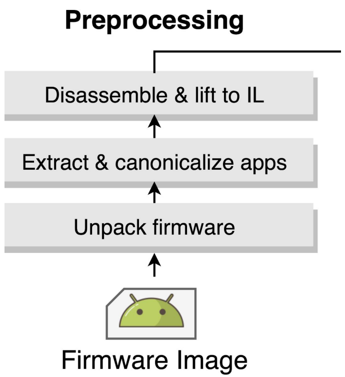
Privileged

- Local/Remote Command+Code Injection
- 40+ ROMs, 10+ Vendors, Millions of users

Automatic Discovery: FIRMSCOPE


Preprocessing
Static Taint Analysis
Disassemble & lift to IL
Extract & canonicalize apps
Unpack firmware
Firmware Image
Rules
Build inter-procedural CFGs
Build inter-procedural DFGs
Perform custom taint analysis
Vulnerabilities

Automatic Discovery: Preprocessing



Challenges:

- Non-standard image formats
- Different build/optimization settings
- Dalvik bytecode internals

Solutions:

- Unpacking heuristics
- Lift disassembly into IL

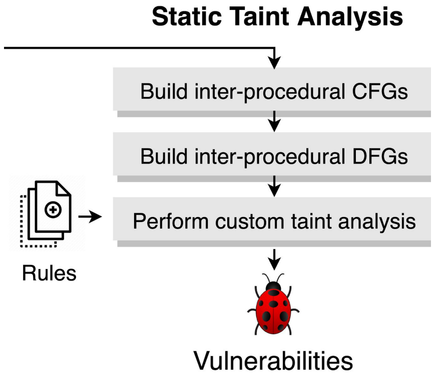
Automatic Discovery: Static Taint Analysis

Challenges:

- Flows through fields, callbacks, lifecycles, ...
- Analysis sensitivities
- Practical considerations

Solutions:

- Custom Def-Use
- Encode flows using custom gadgets


Static Taint Analysis
Build inter-procedural CFGs
Build inter-procedural DFGs
Perform custom taint analysis
Rules
Vulnerabilities

Automatic Discovery: Rules

- Command/Code Injection
- App (Un)Installation
- Audio/Video/Screen Recording
- Settings Modification
- SMS Reading, Sending
- Information Leakage
- Device Flashing/Resetting

- Source/Sink rules

Rules

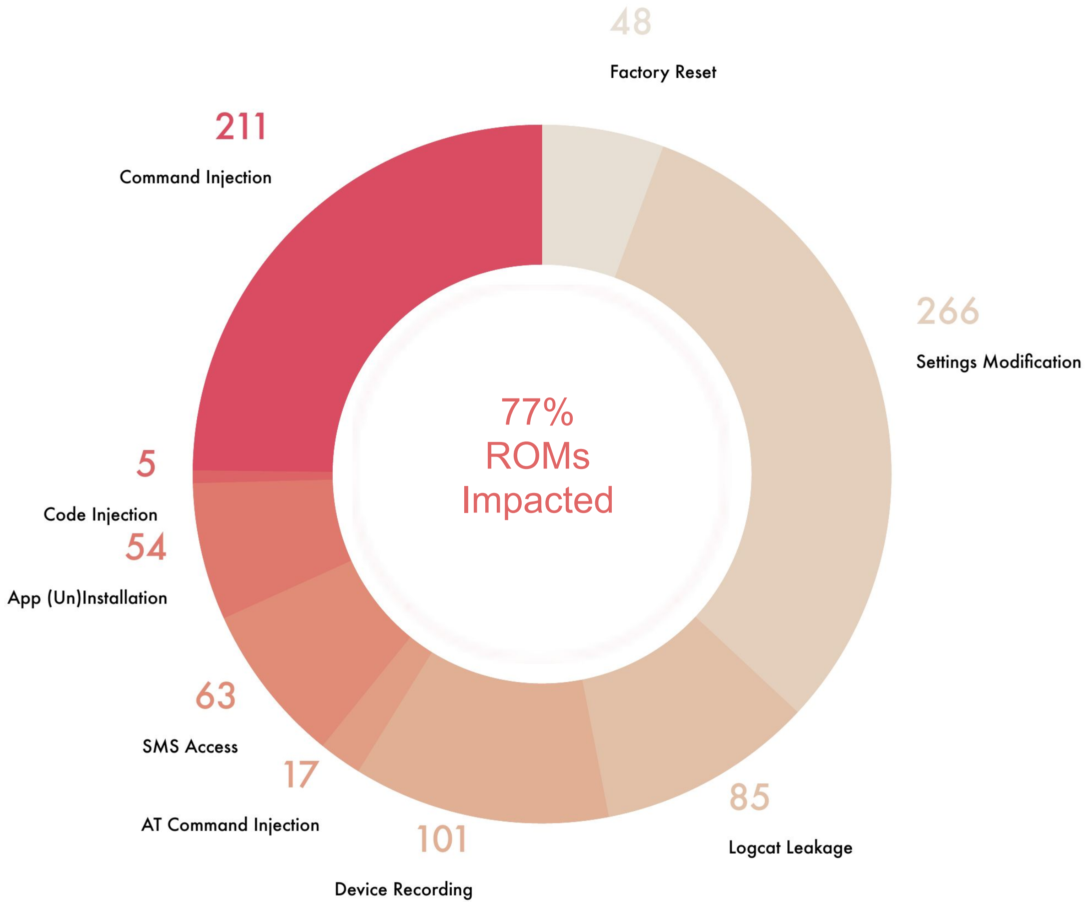
Findings Summary

- Scanned 2017 Android 4 to 9 ROMs (331k apps)

- 850 unique vulnerabilities (3k+ total)
- 77% ROMs impacted
- 41% had Command Injection

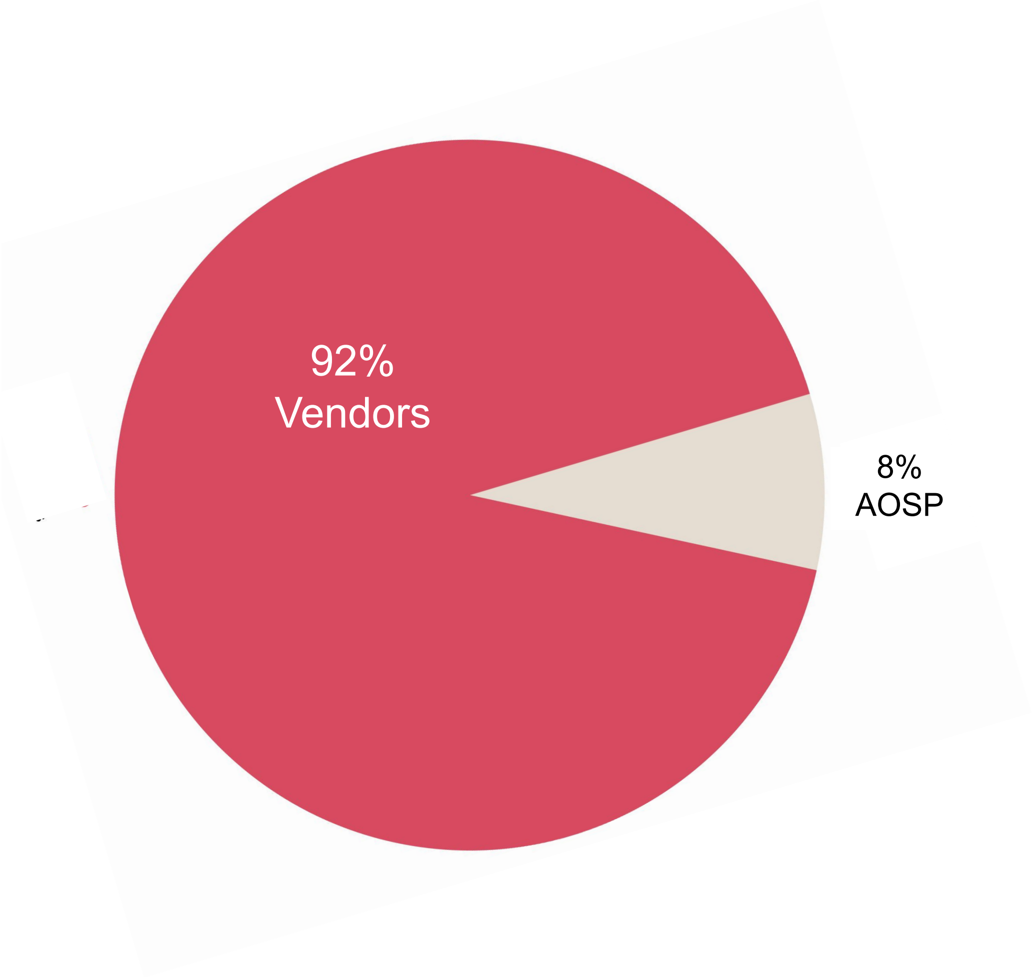
- ⅓ the findings lead to code execution

- Disclosed 370+ in Android 7,8,9
- 200+ vendor-confirmed to date



Who Is to Blame?

- Overall lax security posture by vendors
- Most flaws from custom features, factory-mode apps, OTA providers, MDM apps, helpers, ...
- AOSP-like devices were the cleanest



Runtime Performance

- 7 min per app on average (53 s median)
- 81.7 min per ROM on average (55.7 min median)
- Significantly less FPs, FNs, CPU, MEM than prior solutions

FIRMSCOPE

- Accurate, efficient, static taint analysis
- Automatic privilege-escalation vulnerabilities detection

- Scanned 2017 ROMs (331k pre-installed apps)
- Discovered 850 unique privilege-escalation vulnerabilities
- Responsible disclosures for Android 7,8,9

Thank You!

Pilots: https://www.kryptowire.com/contact-us

Courtesy: thehackernews.com