DEFInit: An Analysis of Exposed Android Init Routines

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**This work was done while interning at Kryptowire.*

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Background:

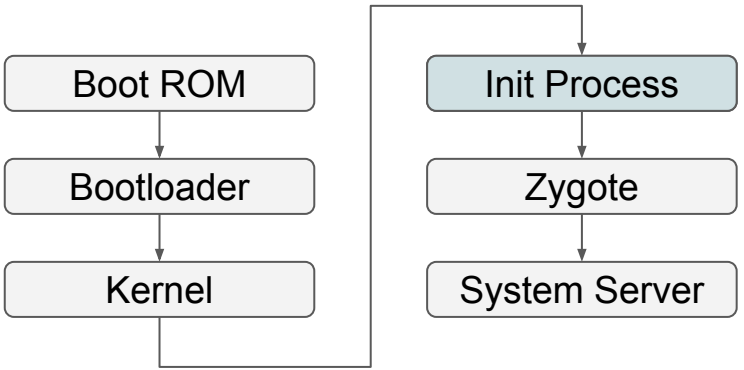
Android Init

Init Process

- Common *NIX process
- First process in user-space
- Highly-privileged process

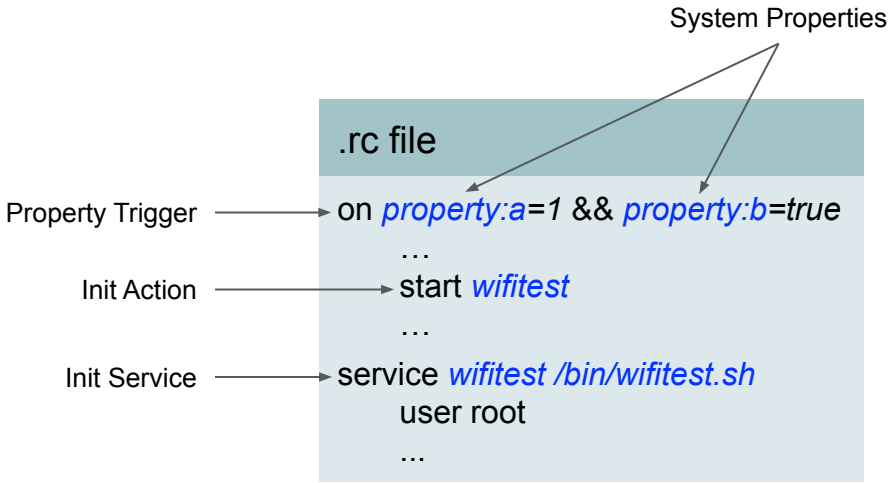
Unique in Android

- Acts as the system property store
- Supports Init Routines



Background:

Android Init Routines

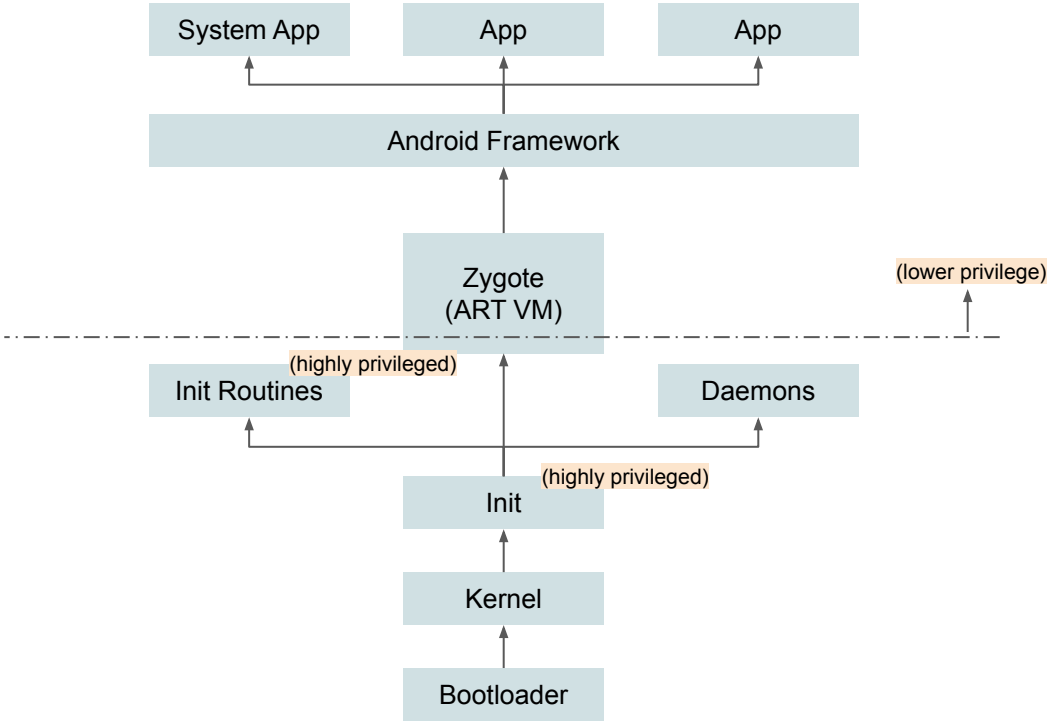


Programs executed by Android Init in response to changes to system properties

- Customizable by vendors
- Only system (privileged; pre-installed) apps/processes can set system properties

Background:

Android Init Routines



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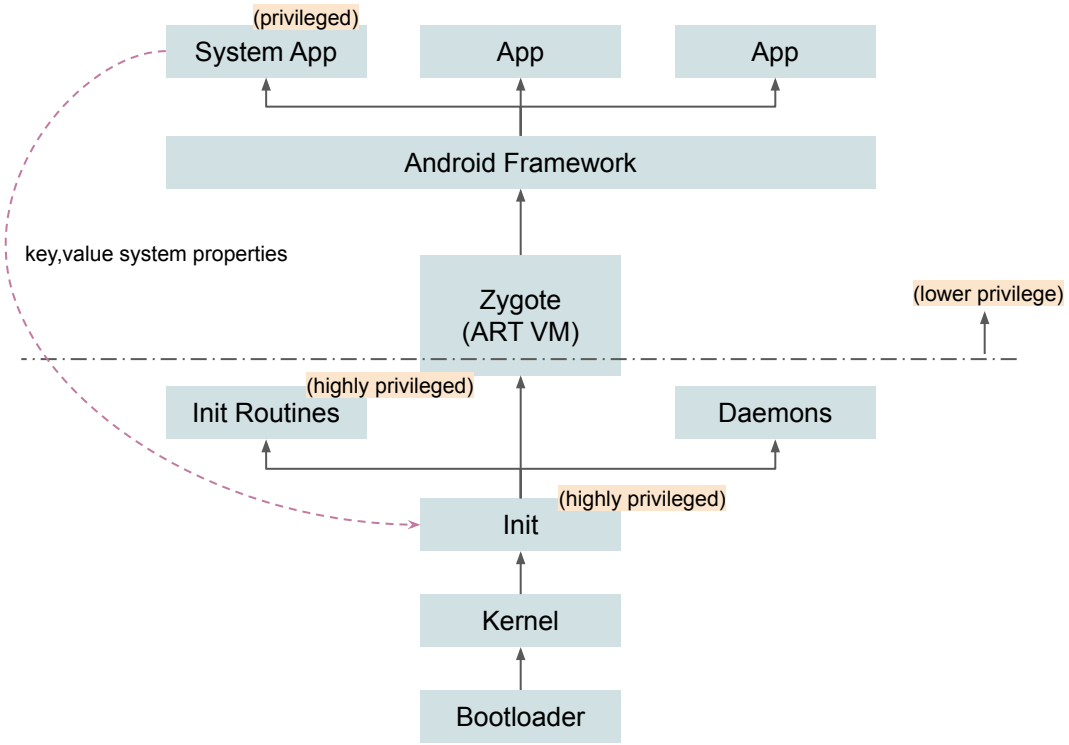
Android Init Routines



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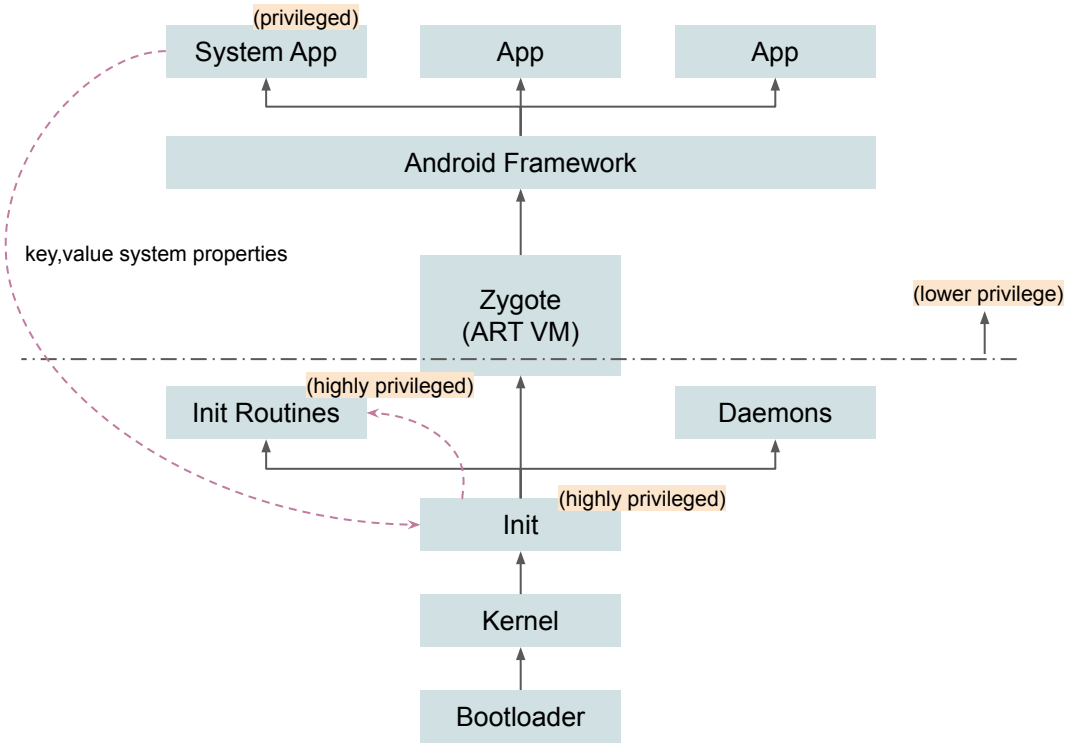
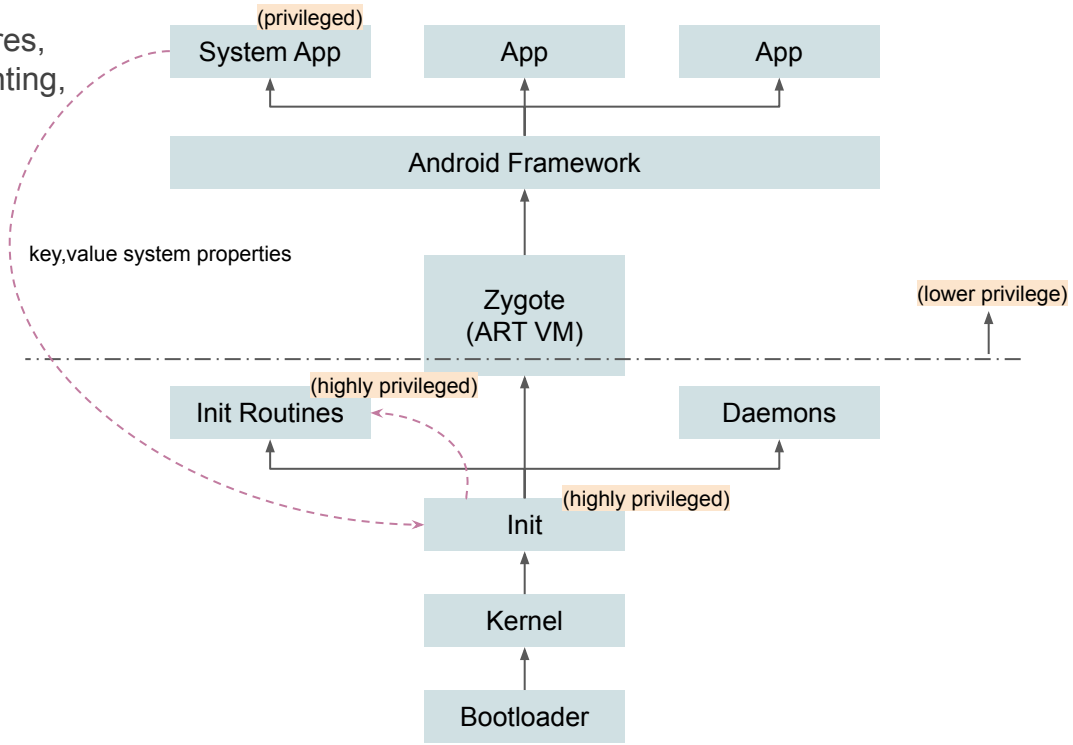
Android Init Routines



Background:

Android Init Routines

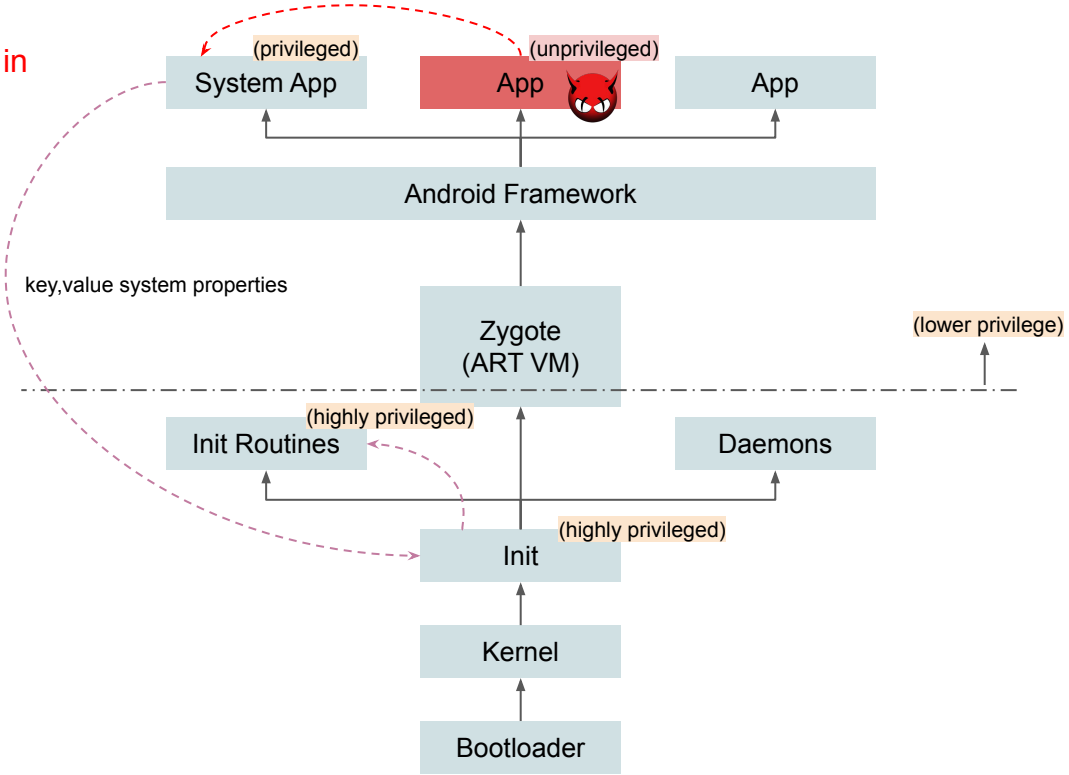
👍 Unique hardware features, diagnostics, docking, mounting, etc., that cannot be done directly in a privileged app



Background:

Android Init Routines

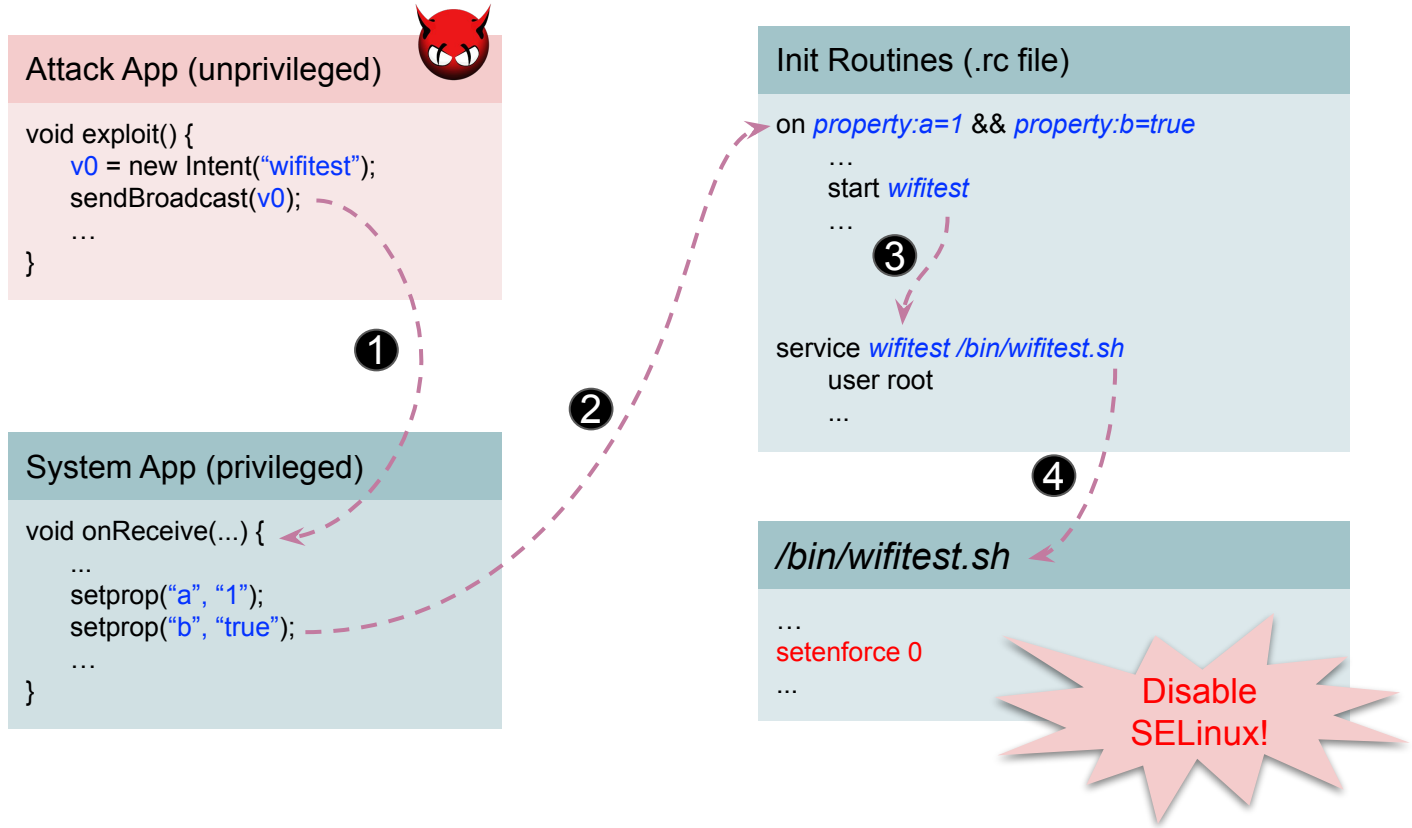
👎 Improper access control in privileged apps can expose Init Routines to unprivileged apps, resulting in crossing security boundaries!



What We Found

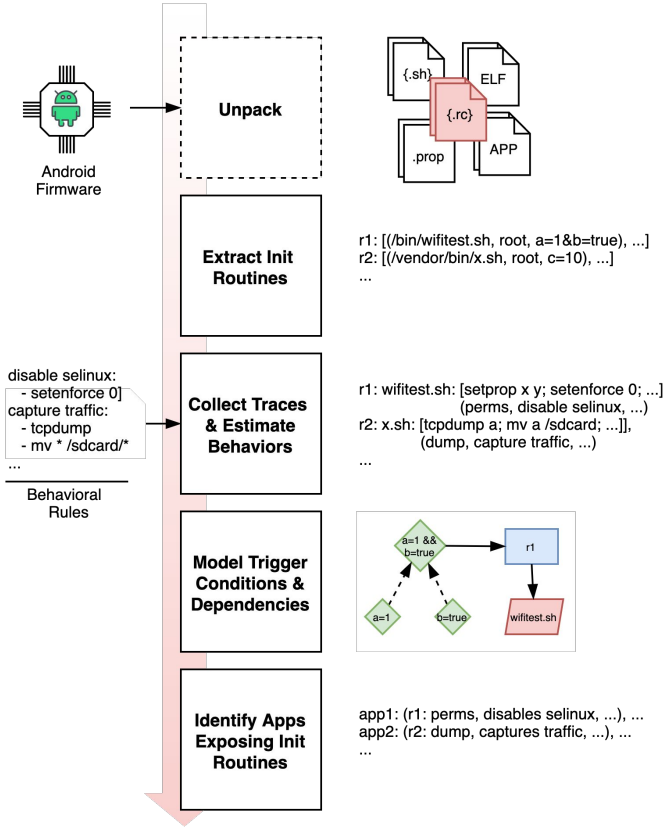
Numerous zero-day privilege-escalation vulnerabilities due to custom (added by vendors) Init routines that are exposed to unprivileged apps!

Real-World Example



Automated Discovery with DEFInit

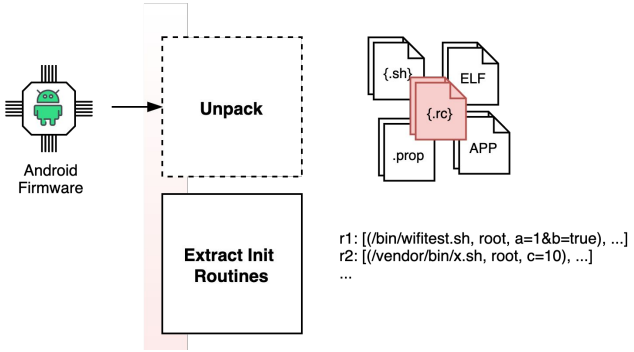
- *Automated system to identify exposed security-sensitive Init routines, their behaviors, and the apps exposing them*
- *First study* on the security impact of customized Android Init routines
- *89 High-Impact Zero-Days*
  - Disabling SELinux, sniffing network traffic, reading system logs, recording screen, *etc*.



Unpack and Extract Init Routine Definitions

Challenges:

- Multiple firmware file formats
- Dynamically load and process .rc files
- Import Init sections defined in other files
- Service and action definitions are polymorphic



Solutions:

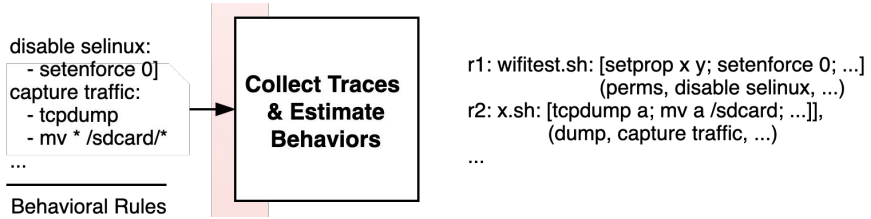
- Integrate multiple firmware file format unpackers
- Start parsing at the root /init.rc file
- Nest into imported files in depth-first order
- Keep track of merge or override options

DEFInit:

Estimate Behaviors of Init Routines

Challenges:

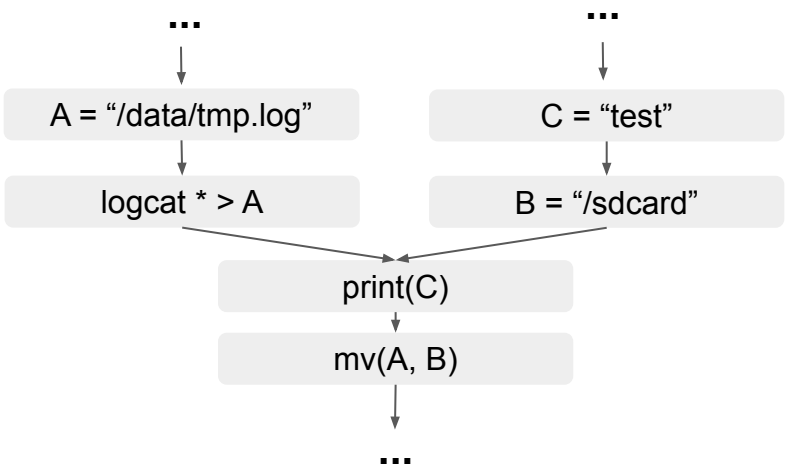
- Estimating security-relevant behavior of arbitrary programs
- Multiple formats: Init commands, ELF binaries, Shell Scripts



Estimate Behaviors of Init Routines

Solutions:

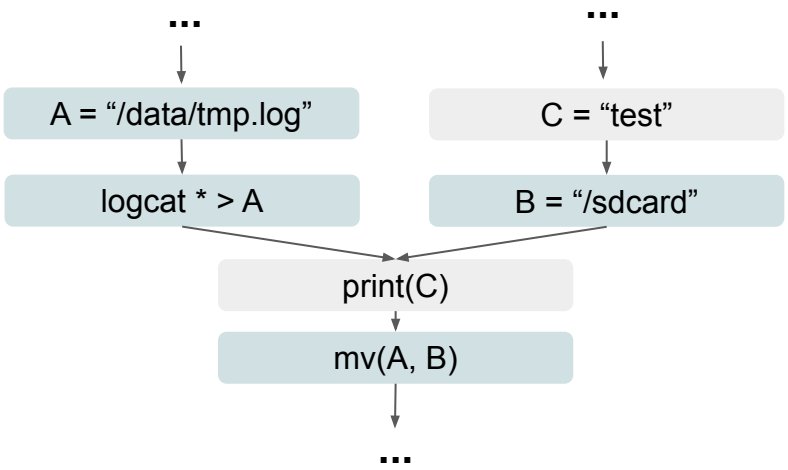
- Extract code traces
  - ELF binaries → collect static traces of called APIs along CFG paths in DFS order
  - Shell scripts → collect code traces by dry-running them in a custom shell tracer



Estimate Behaviors of Init Routines

Solutions:

- Extract code traces
  - ELF binaries → collect static traces of called APIs along CFG paths in DFS order
  - Shell scripts → collect code traces by dry-running them in a custom shell tracer
- Match interesting trace sequences using static rules



Read Logcat Logs:

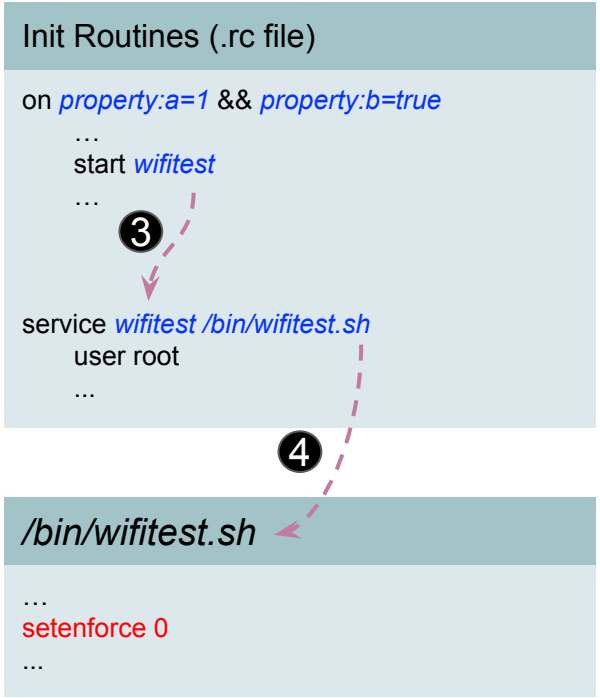
```
logcat * (-f|>) $sdcard/*
| logcat * (-f|>) *
  (mv|cp) * $sdcard/*
```

DEFInit:

Model Trigger Conditions

Challenges

- Multiple interdependencies between Init actions, services, Android commands, and APIs



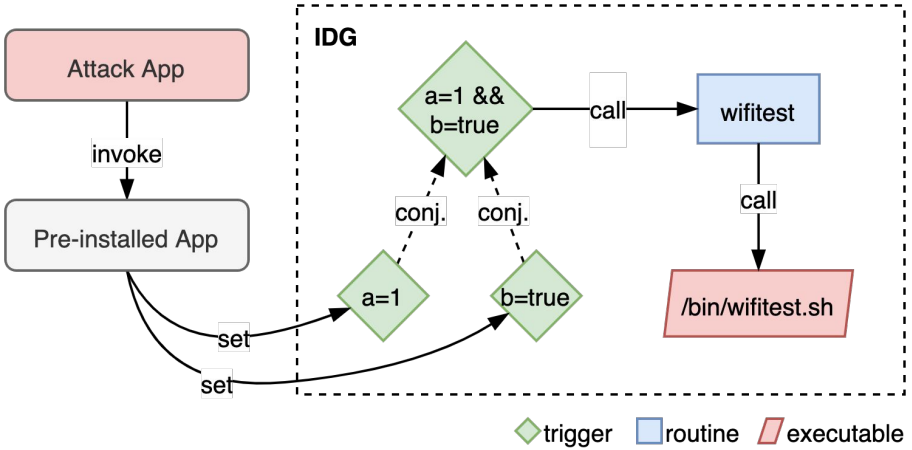
Model Trigger Conditions

Challenges

- Multiple interdependencies between Init actions, services, Android commands, and APIs

Solutions

- A novel graph structure called an Init Dependency Graph (IDG)



DEFInit:

Identify Exposed Routines and Behaviors

Challenges

- Identifying system property call sites
- Resolving argument values
- Detecting if a call site is exposed to unprivileged apps

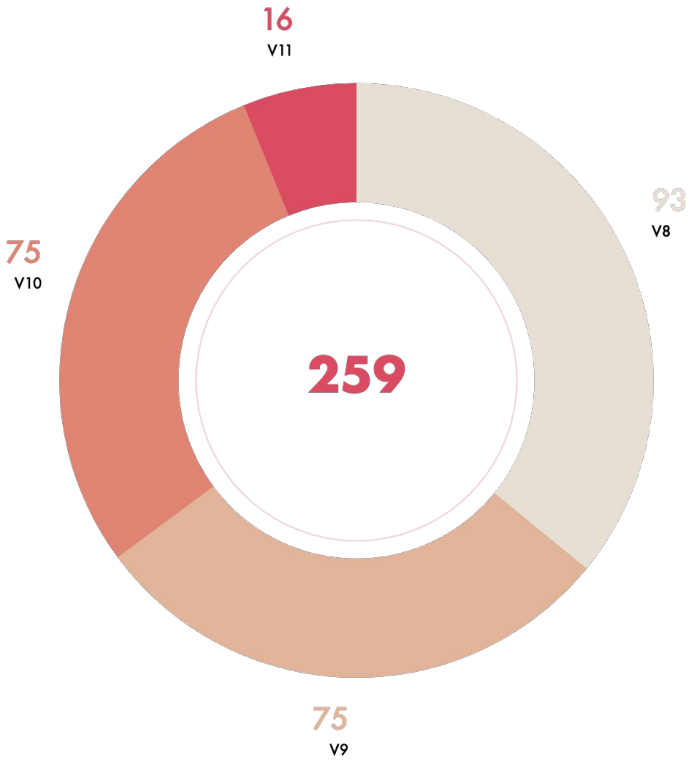
app1: (r1: perms, disables selinux, ...), ...
app2: (r2: dump, captures traffic, ...), ...
...

Solutions

- Context- and flow-sensitive property key and value extraction
- Reachability query from IPC entry points to call sites on control-flow graphs

Evaluation:

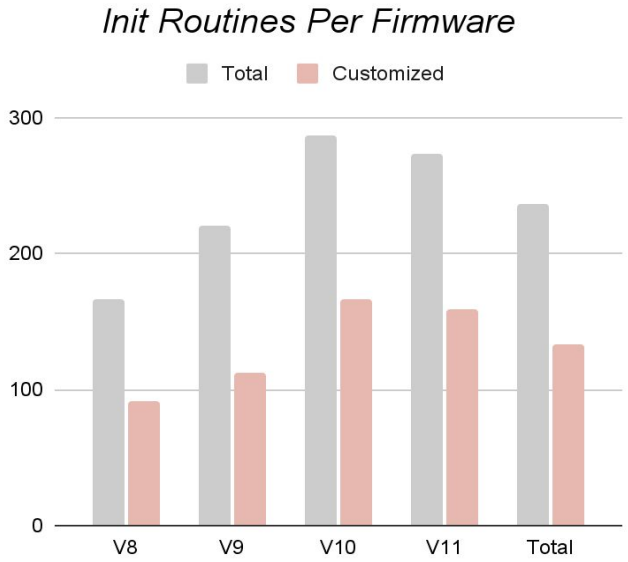
Analyzed Firmware Dataset



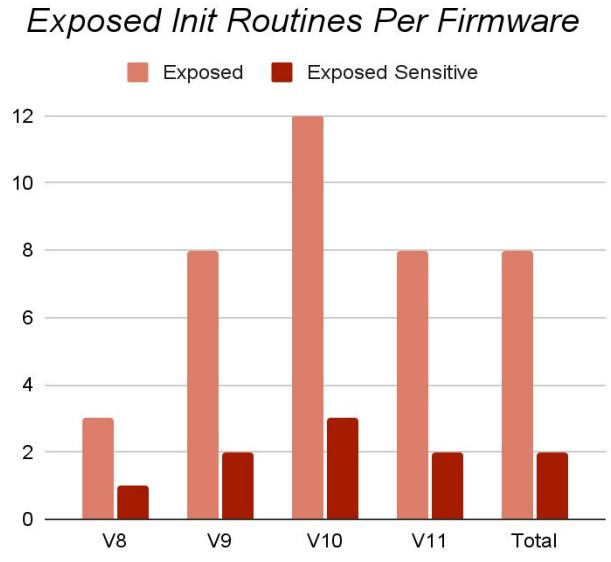
- 259 Android 8 -- 11 firmware
- 21 top vendors worldwide
- 65k system apps
  - 262 per firmware (average)

Evaluation:

Identified Init Routines



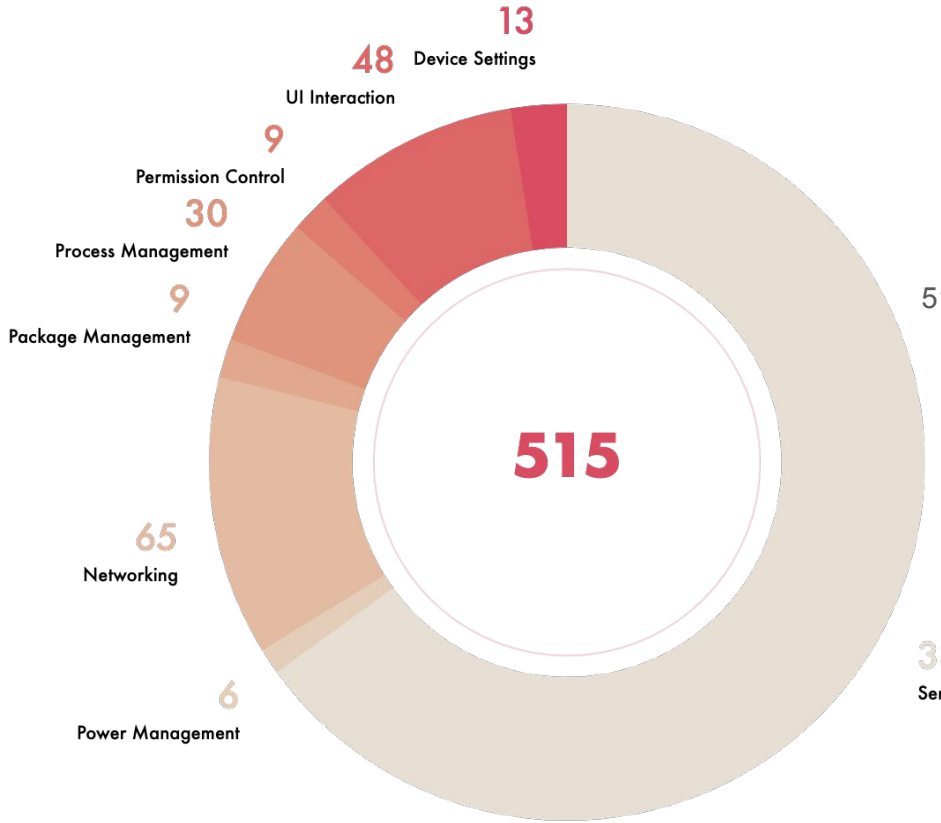
- 223 routines per firmware
- *66%* custom (added by vendors)



- *8* exposed routines per firmware
- *2* sensitive exposed routines per firmware
- *All* custom!

Evaluation:

Exposed Behaviors



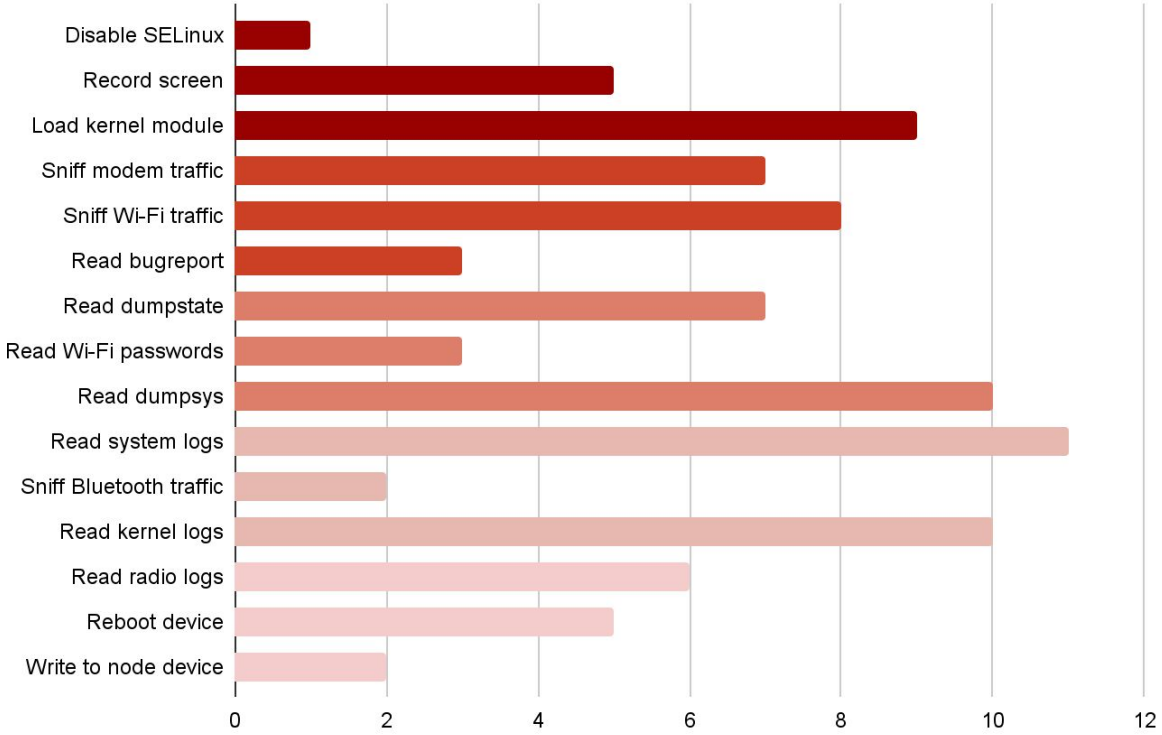
515 exposed sensitive functionalities

- 430 unique routines
- 173 unique apps
- 101 firmware
- 13 vendors

Evaluation:

Discovered Zero-Day Vulnerabilities

- Verified 89 vulnerabilities
  - 34 unique apps
  - 30 firmware
  - 6 vendors
- Developed+Tested 59 PoCs
- 49 confirmed by 3 vendors so far



Evaluation:

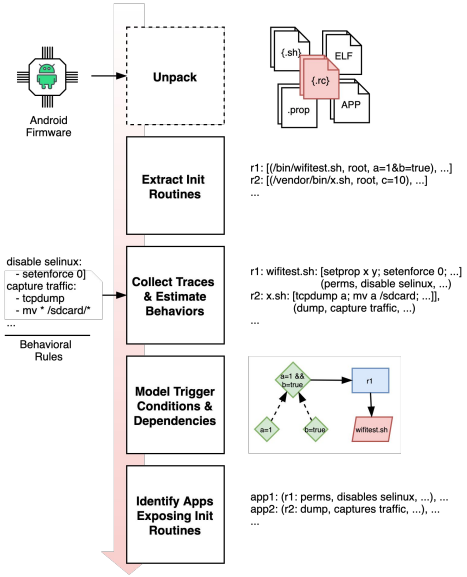
Impact of Discovered Vulnerabilities

- *Disable system-wide Mandatory Access Control*
- *Execute arbitrary code with high privileges*
- *Spy on screen content and user activity*
- *Spy on content of sent/received SMS messages and Calls*
- *Capture data transmitted using Wi-Fi and Bluetooth*
- *Capture an extensive amount of PII from numerous sources*
- *Capture information to attack other processes (mmap, open files, etc.)*
- *Prevent meaningful usage of the device (persistent DoS attack)*
- *Access stored Wi-Fi passwords*
- *...*

Courtesy: thehackernews.com

DEFInit: An Analysis of Exposed Android Init Routines

- Systematically studied security impact of Android Init routines
- Novel study and automated analysis
- Various high-impact zero-days in Android 8 -- 11 devices
- More in paper
  - Routines exposed via the GUI, rule samples, characteristics of exposed routines, commands called by exposed routines, *etc*.



Thank You!

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