Defects-in-Depth

Analyzing the Integration of Effective Defenses against One-Day Exploits in Android Kernels

Lukas Maar, Florian Draschbacher, Lukas Lamster, and Stefan Mangard

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Who am I?

Lukas Maar

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Improve system security

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Defects-in-Depth

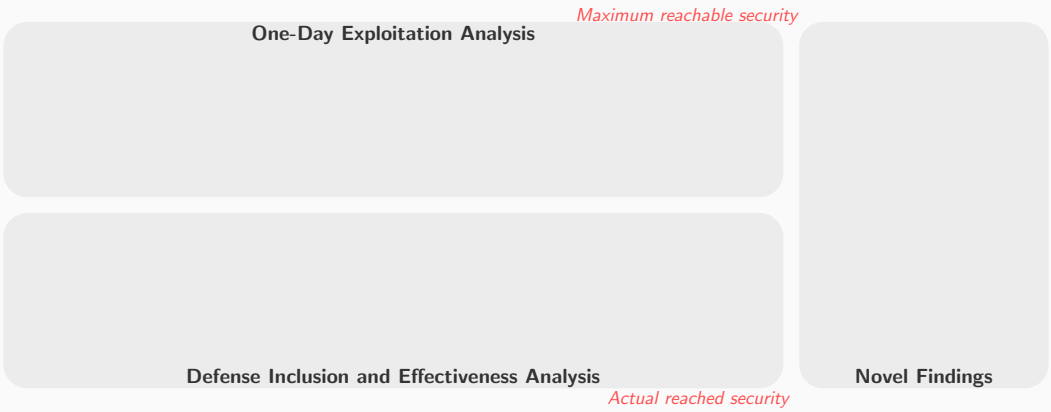
High-Level Workflow

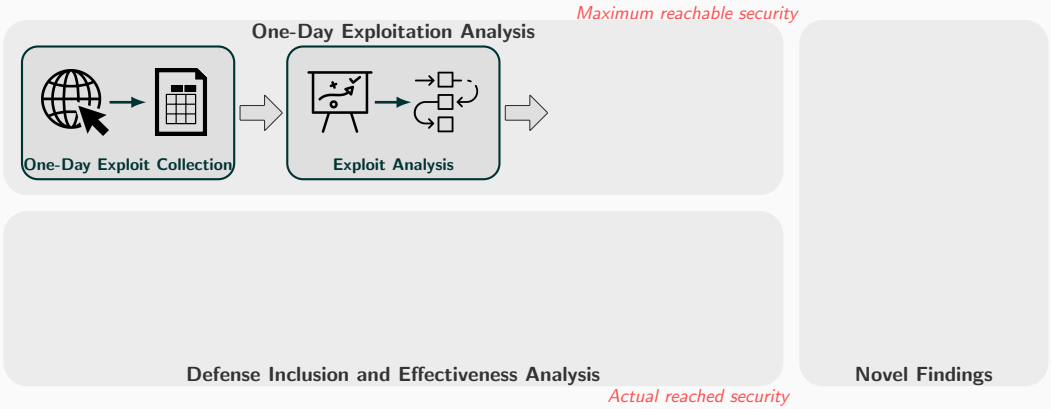
One-Day Exploitation Analysis

Defense Inclusion and Effectiveness Analysis

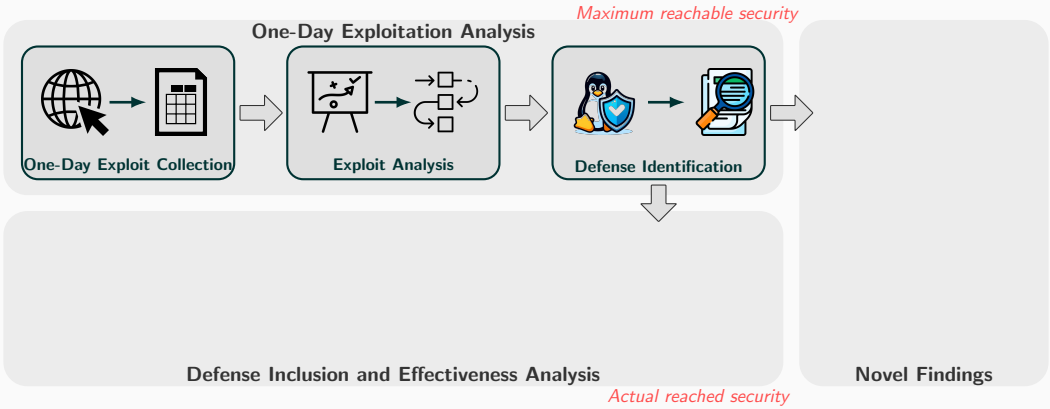
Novel Findings

High-Level Workflow




Maximum reachable security
One-Day Exploitation Analysis
One-Day Exploit Collection
Exploit Analysis
Defense Inclusion and Effectiveness Analysis
Novel Findings
Actual reached security

High-Level Workflow



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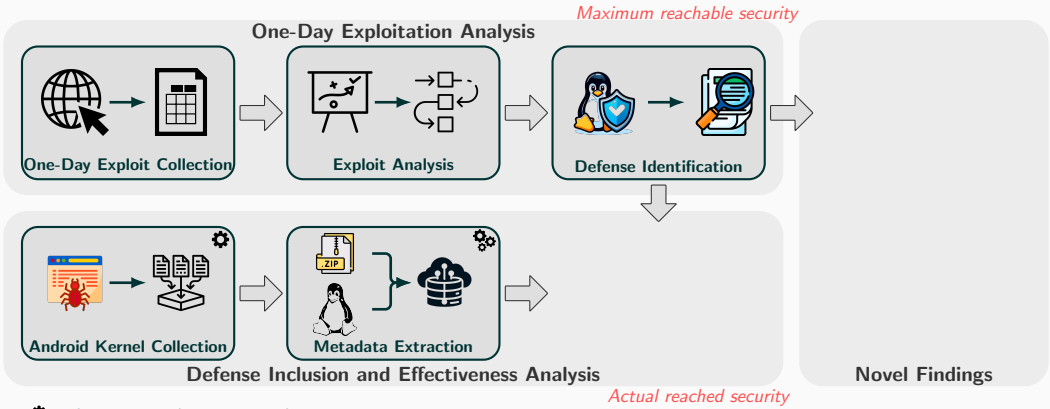

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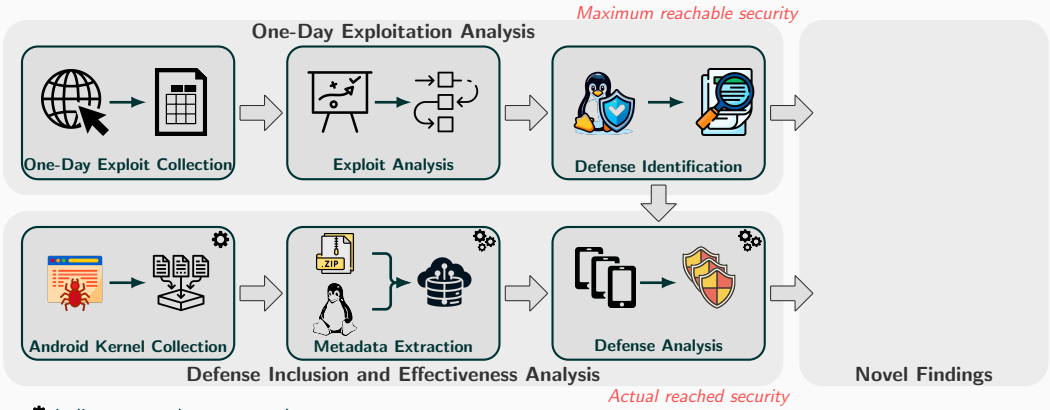

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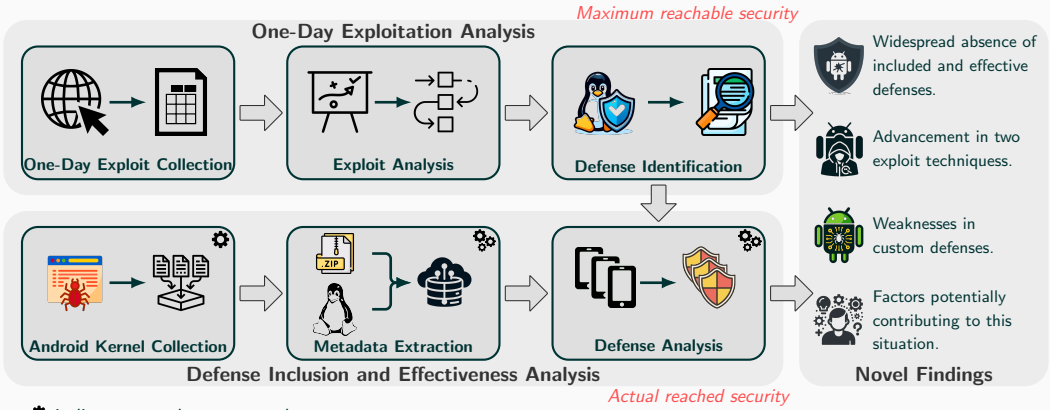
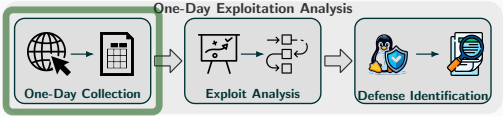
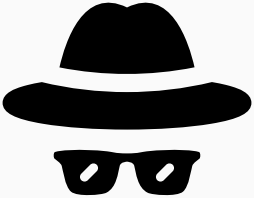
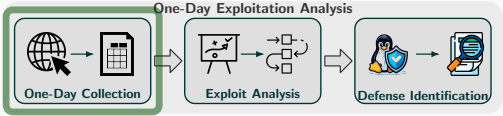


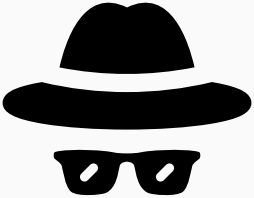
One-Day Exploitation Analysis

One-Day Exploit Collection









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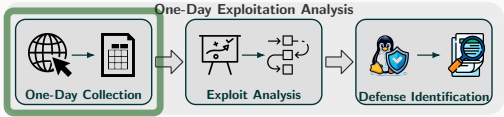

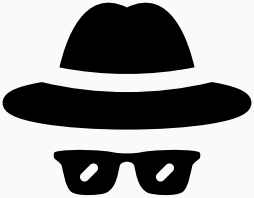

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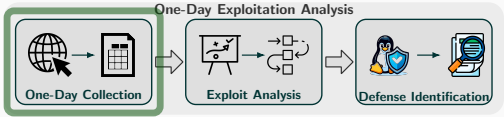

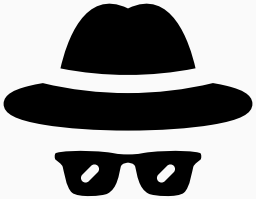

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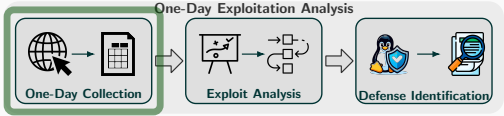

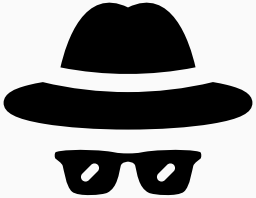

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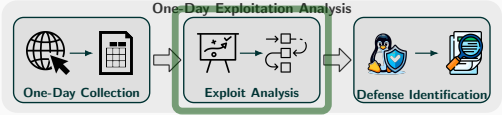

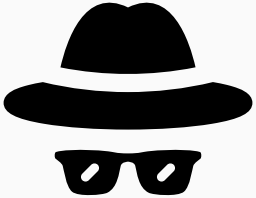

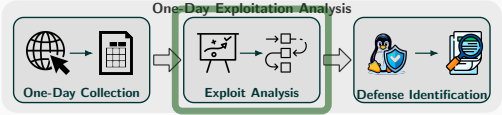

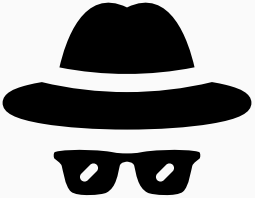

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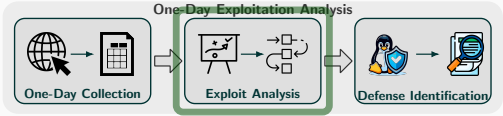

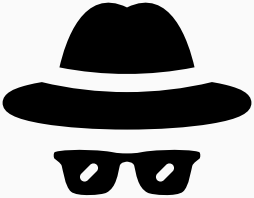

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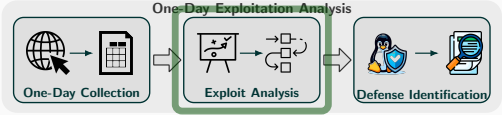

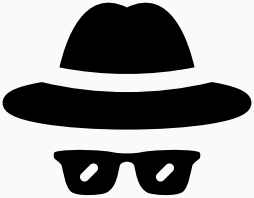

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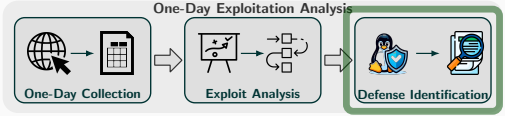
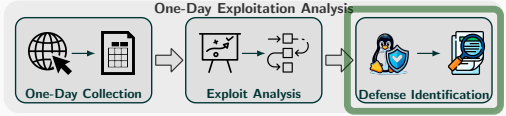
- **Analyze 26 one-day exploitation flows**
  - 10 exploit techniques


One-Day Exploitation Analysis
One-Day Collection
Exploit Analysis
Defense Identification

Maximum Reachable Security

CVE	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
CVE-2019-2215	✓	✗	✓							✓
CVE-2019-2025	✓		✓							
CVE-2020-0030	✓	✗	✓							✓
CVE-2021-1968,-1969,-1940				✓	✓				✗	
CVE-2021-0920	✓		✓							
CVE-2021-1905				✓	✓				✗	
CVE-2022-22265			✓							
CVE-2021-25369,-25370		✗	✓	✗					✗	✓
CVE-2016-3809,-2021-0399			✓	✓	✓				✗	
CVE-2022-20409			✓							
CVE-2023-21400			✓						✶	✗
CVE-2022-28350									✶	✗
CVE-2020-29661									✶	✗
CVE-2021-22600			✓							
CVE-2020-0423	✓							✗	✓	✓
CVE-2022-22057					✓			✗	✓	✓
CVE-2023-26083,-0266				✗					✗	
CVE-2020-0041	✓		✓							
CVE-2019-2205	✓		✓							
CVE-2019-2025	✓		✓					✗	✓	✓
CVE-2020-3680	✓		✓					✗	✓	✓
CVE-2022-20421			✓							
CVE-2022-0847							✓			
CVE-2021-4154										
CVE-2021-38001				✓	✓				✗	
NO_NUMBER (~2021)			✓			✓				



DM1: CONFIG_DEBUG_LIST **DM2:** CONFIG_ARM64_UAO **DM3:** kmalloc-cg-* **DM4:** CONFIG_CFI_CLANG
DM5: CONFIG_BPF_JIT_ALWAYS_ON **DM6:** CONFIG_SLAB_FREELIST_HARDENED **DM7:** CONFIG_INIT_ON_ALLOC_DEFAULT_ON
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CVE-2021-1905				✓	✓				✗	
CVE-2022-22265			✓							
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CVE-2016-3809,-2021-0399			✓	✓	✓				✗	
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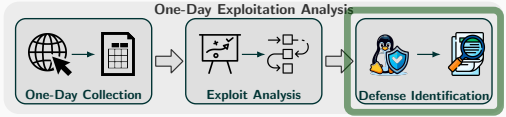

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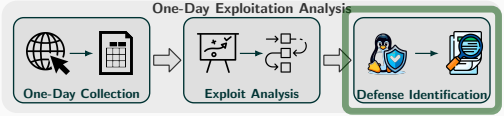
22 out of 26 one-days are preventable



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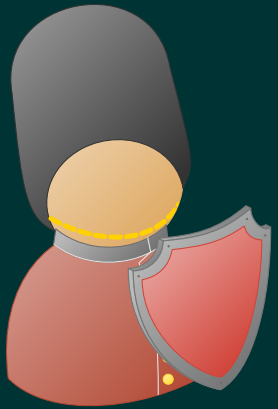
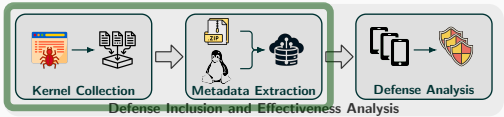
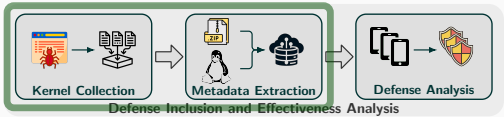


Defense Inclusion and Effectiveness Analysis



- **Goal:**
  - Determine actual security reached
  - By downstreamed Android kernels

Android Kernel Collection & Metadata Extraction



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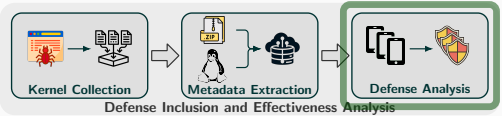
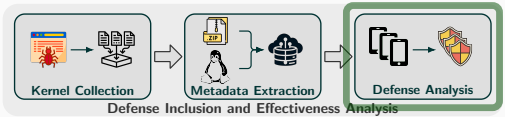
- **Android devices:**
  - 10 vendors:
    - SAMSUNG, mi, oppo, vivo, HUAWEI, R, Motorola, Google, 1+, FAIRPHONE
  - 1698 devices released between 2018 and 2023
  - We extracted 994 device kernels


Kernel Collection
Metadata Extraction
Defense Analysis
Defense Inclusion and Effectiveness Analysis



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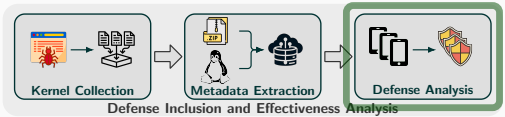

- **Source code analysis:**
  - *Manual analysis* of all kernel defenses
  - Determine their effectiveness
- **Kernel binary analysis:**
  - *Automatic analysis* of all kernel defenses
  - Depending whether the kernel includes crucial routines

    E.g., check or permission setting function
  - Determine their inclusion

Novel Findings

Level of Security reached Severely Lacking

Widespread absence of included and effective defenses.

Advancement in two exploit techniquess.

Weaknesses in custom defenses.

Factors potentially contributing to this situation.

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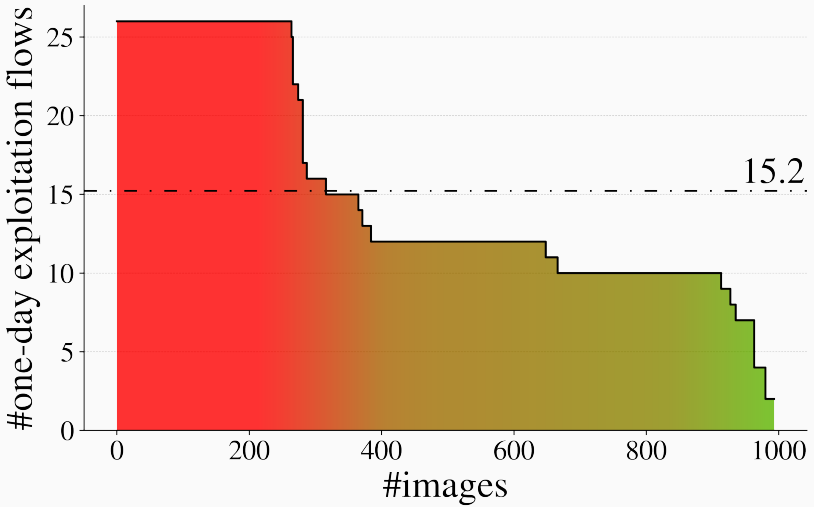

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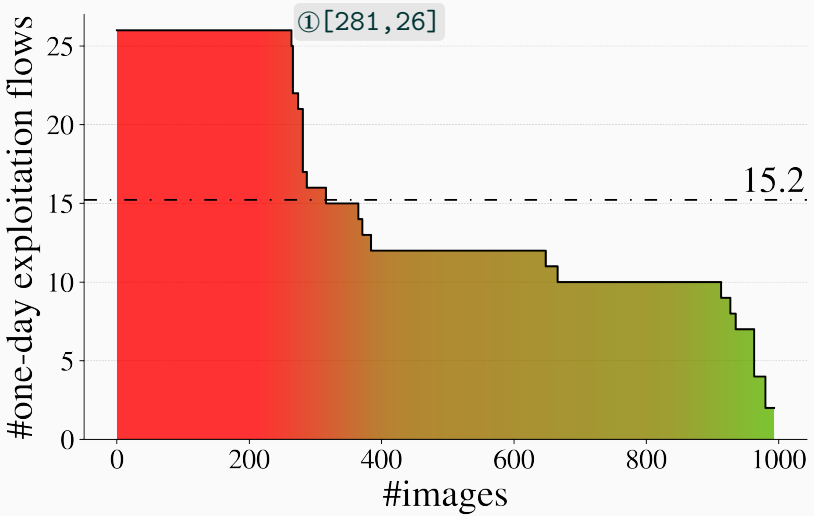

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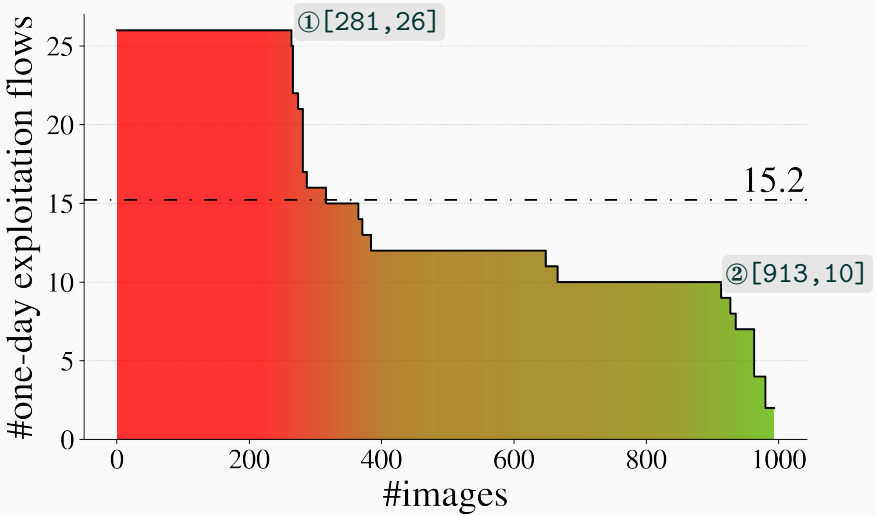

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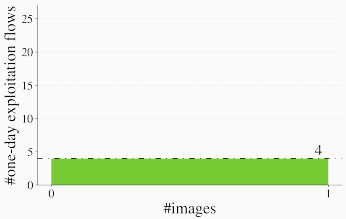
Level of Security reached Severely Lacking contd



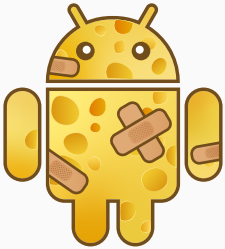
(a) Ground truth **(b)** Google

(c) Samsung **(d)** Fairphone

- Widespread absence of included and effective defenses.
- Advancement in two exploit techniquess.
- Weaknesses in custom defenses.
- Factors potentially contributing to this situation.

Novel Findings

Factors Potentially Contributing to this Situation



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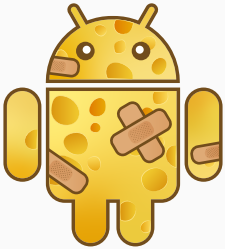

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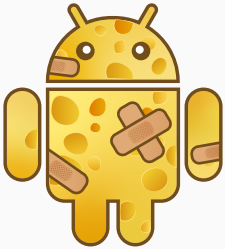

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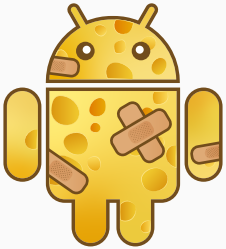

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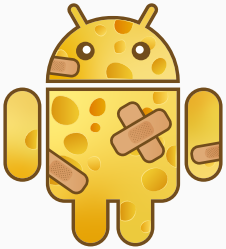

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- "Implementing certain security mitigations can lead to significant **performance costs**, e.g., `CONFIG_DEBUG_LIST` was enforced in the past but OEMs complaint about the performance hit."
- "However, considering the fact that the majority of Android devices are **low-end devices**, it's generally not possible to apply all mitigations due to the performance reasons."

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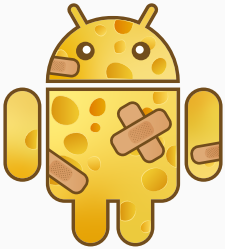
Novel Findings

Factors Potentially Contributing to this Situation contd



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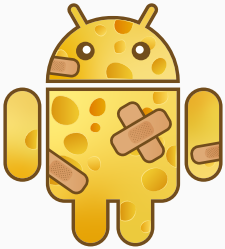

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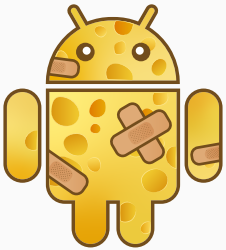

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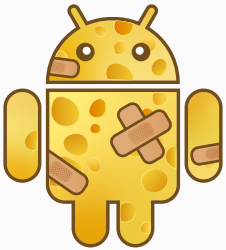

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3. 23.8 % susceptibility gap between high and low-end devices

Performance cost, especially for less powerful low-end devices

Widespread absence of included and effective defenses.

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Factors potentially contributing to this situation.

Novel Findings

Conclusion

https://lukasmaar.github.io

- **Analyzed 26 one-days targeting the Android kernel**
- **Identified defenses mitigating most of these one-days**
- **Performed a defense inclusion and effectiveness analysis**
- **Presented novel findings:**
  1. Absence of effective defenses in vendor-provided kernels
  2. Advancement in two exploitation techniques
  3. Weaknesses in defenses
  4. Potential factors that contribute to this situation

References

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