Kratos: Discovering Inconsistent Security Policy Enforcement in the Android Framework

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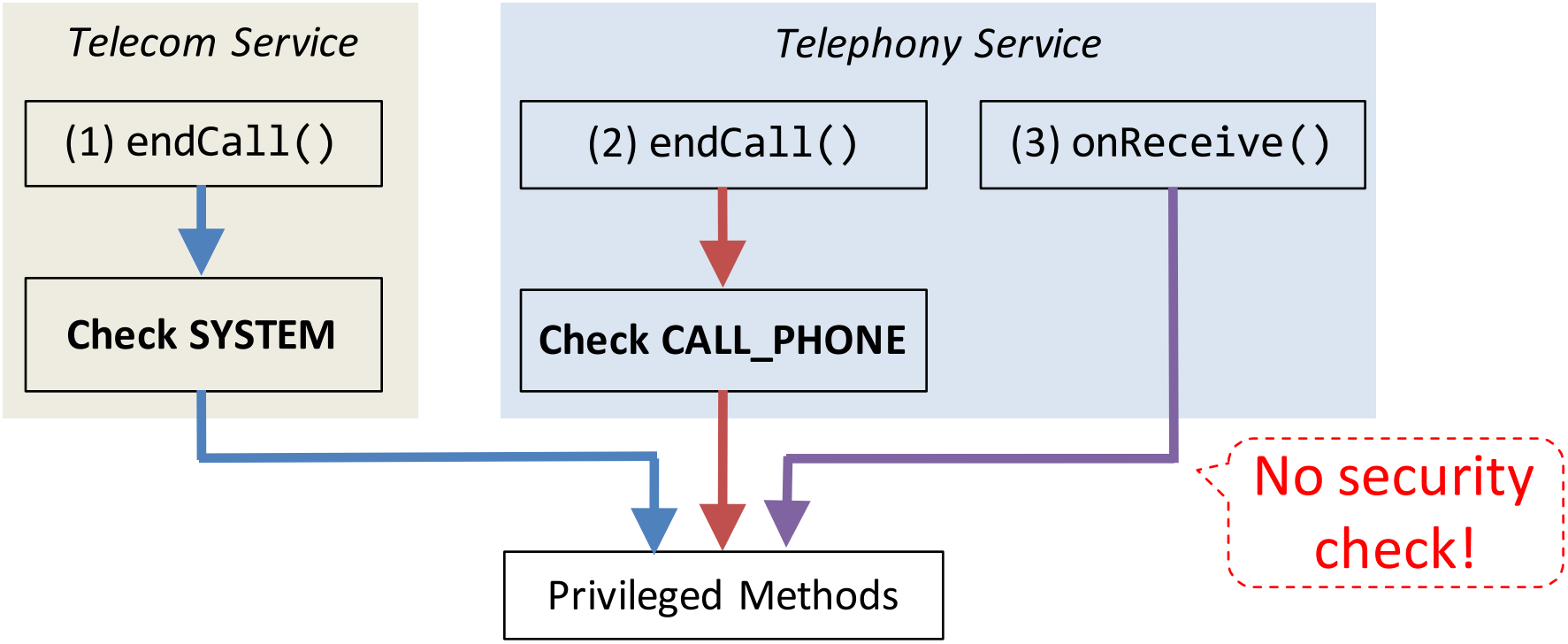
Security Policy Enforcement

- Security policies regulate access to
  - Sensitive data
  - System resources
  - Privileged operations
- Policies need to be correctly enforced

Inconsistencies exist

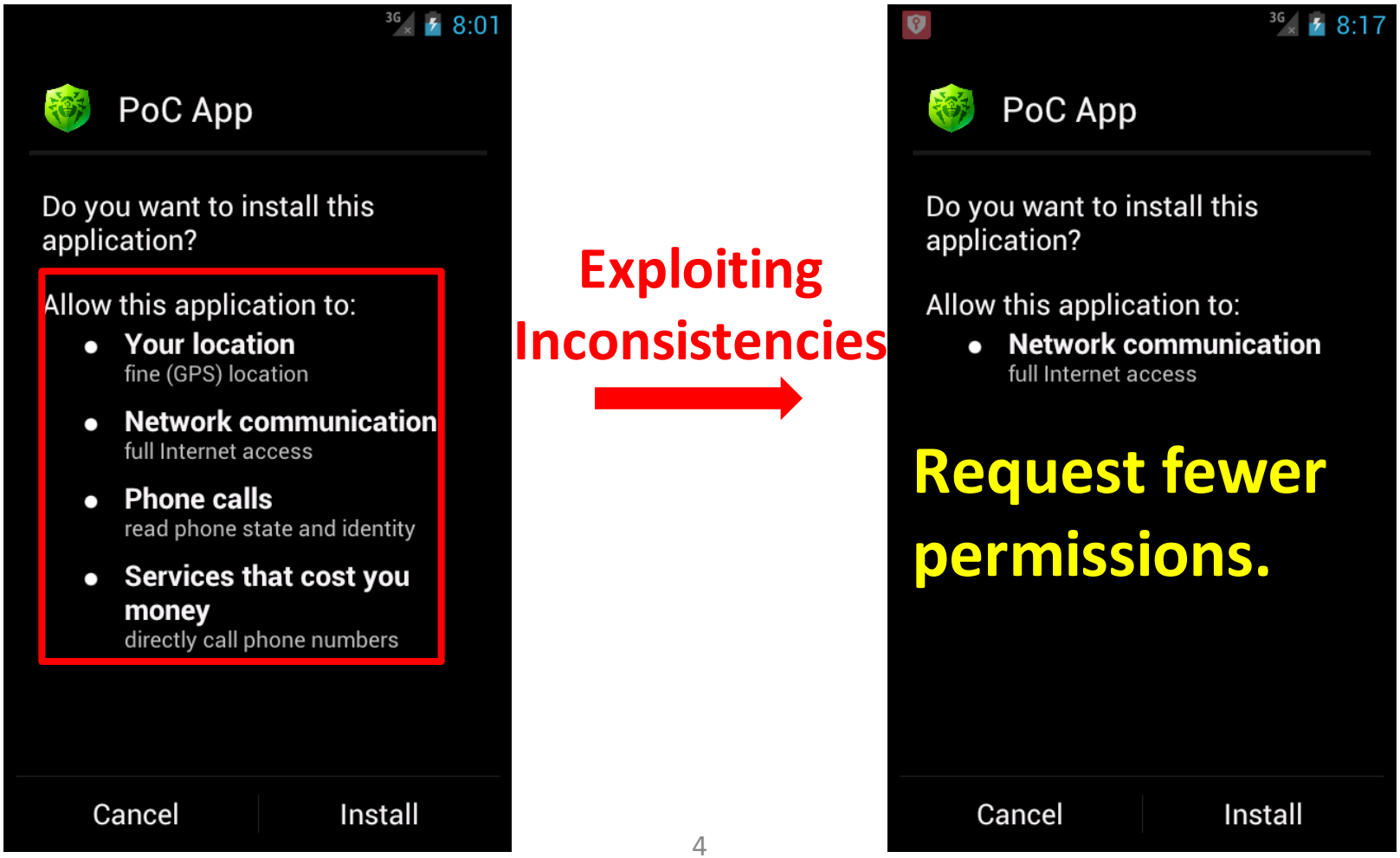
- According to the Android documentation
  - apps that hold a *CALL_PHONE* permission can end phone calls



The enforcement of a security policy on different code paths can be inconsistent

Security implication

- Privilege escalation



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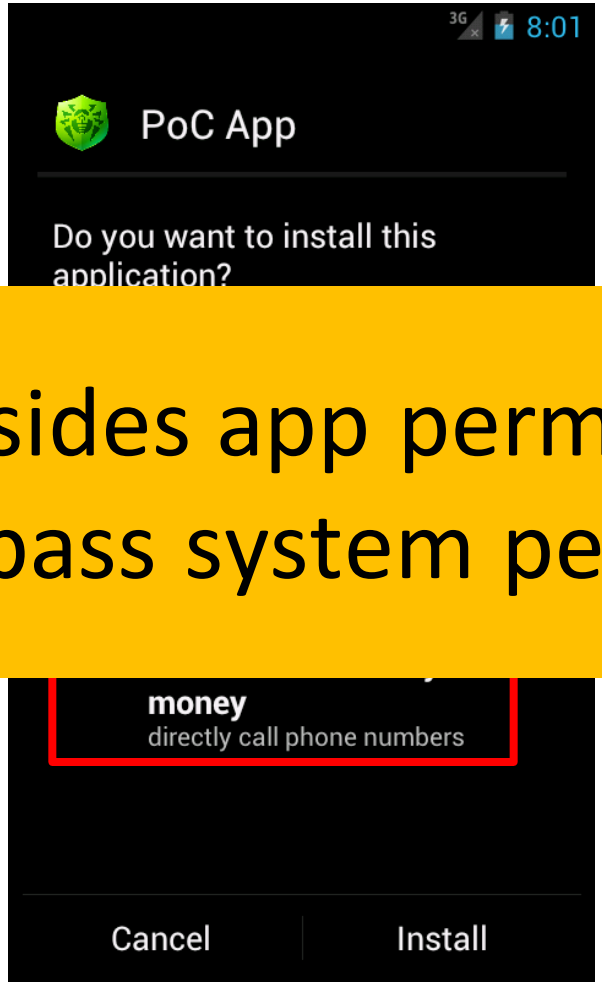
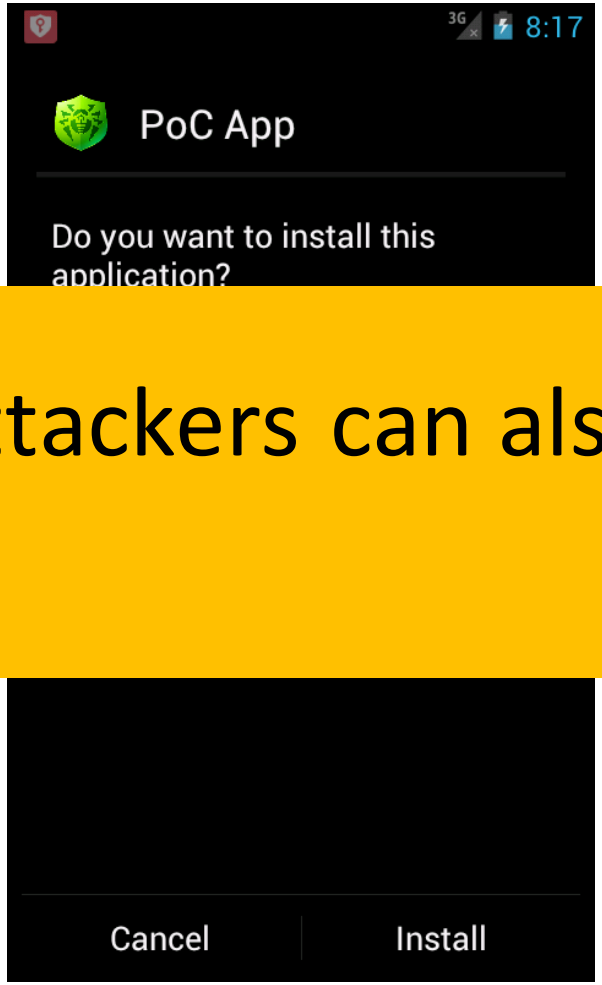




Besides app permissions, attackers can also bypass system permissions

Inconsistent security policy enforcement

- Also found in SELinux and Xen[1]
  - Unauthorized user account access
  - Permanent data loss
- No solution for the Android framework
  - Prior work is OS specific
  - Android has no explicitly defined policies

[1] Lin Tan et al. AutoISES: Automatically Inferring Security Specification and Detecting Violations. USENIX Security 2008.

Problem statement

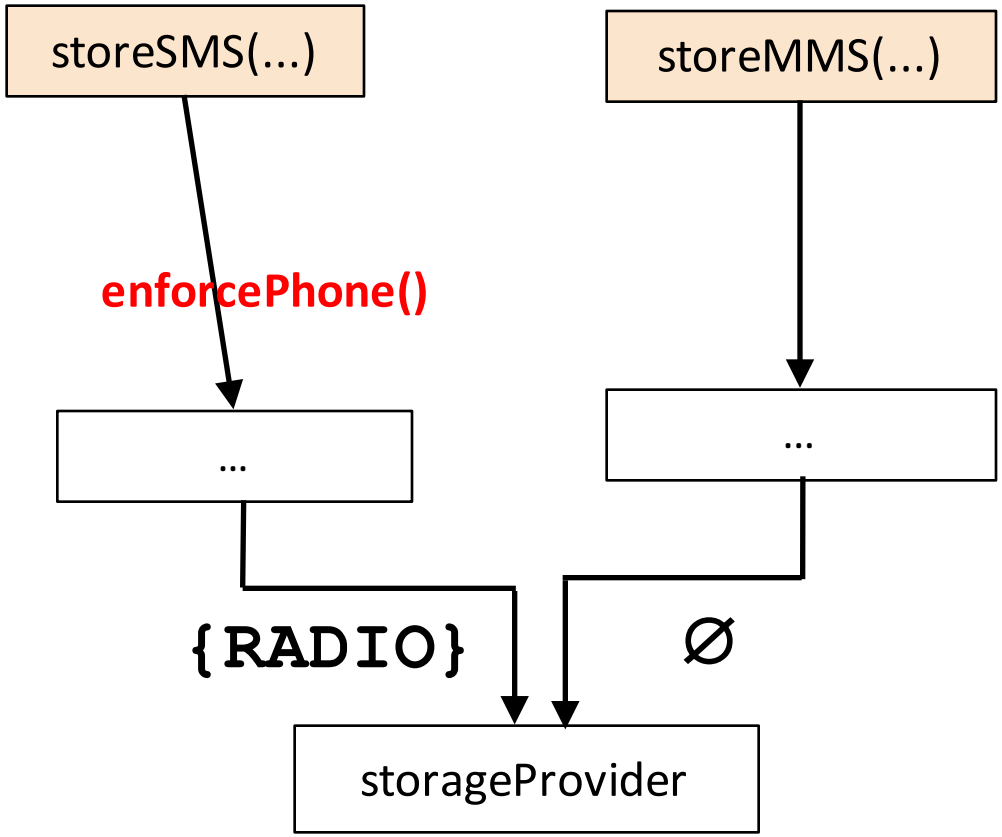
- Focusing on the Android framework, we answer the following question:
  - How can we systematically detect inconsistent security policy enforcement without any knowledge of the policies?

Our approach

- Discover app-accessible service interfaces that have overlaps in functionality
  - They're expected to have consistent security enforcement

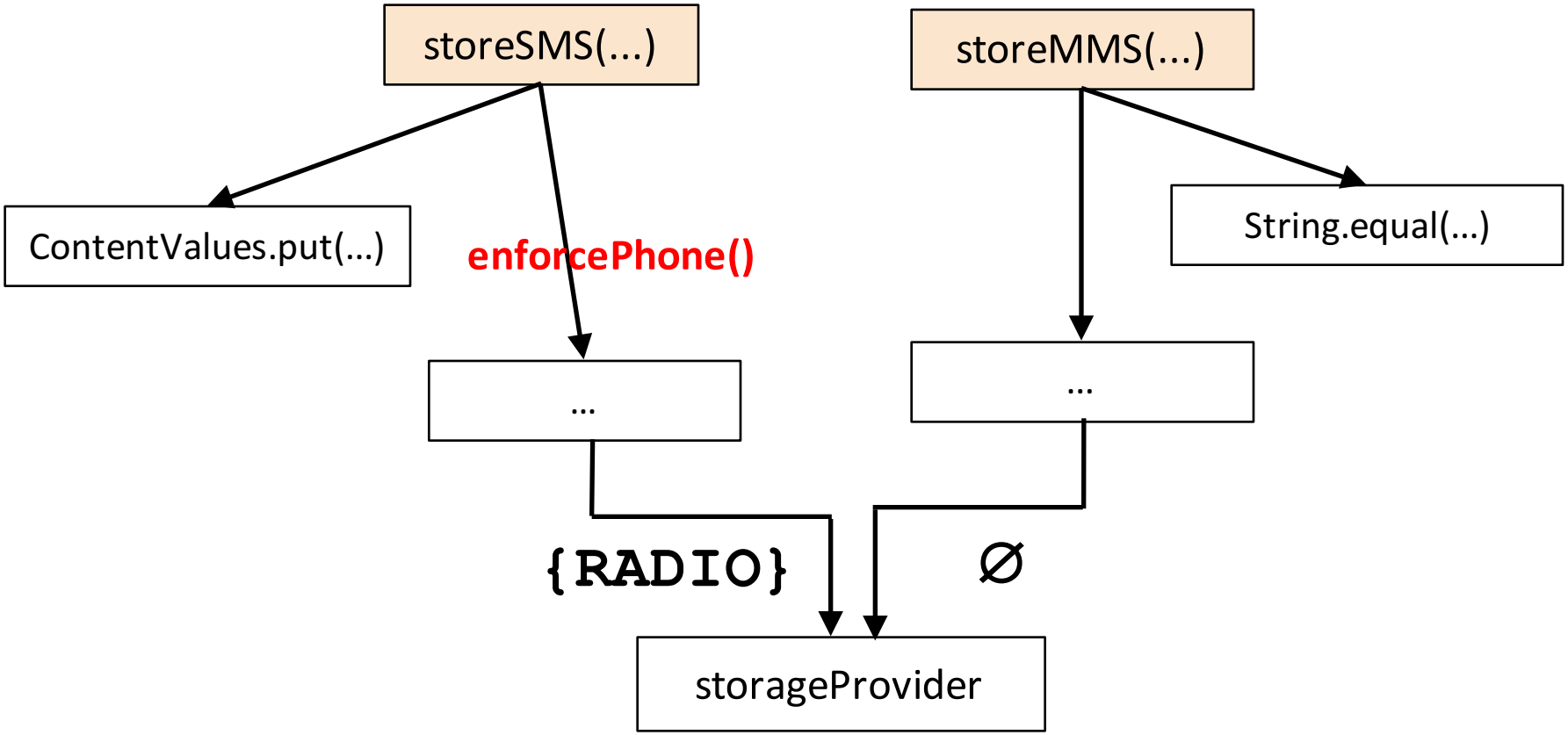
- Perform a ***differential analysis*** on security checks that two overlapping interfaces employ

Differential analysis



`enforcePhone()` checks if the caller's UID is 1001 (RADIO)

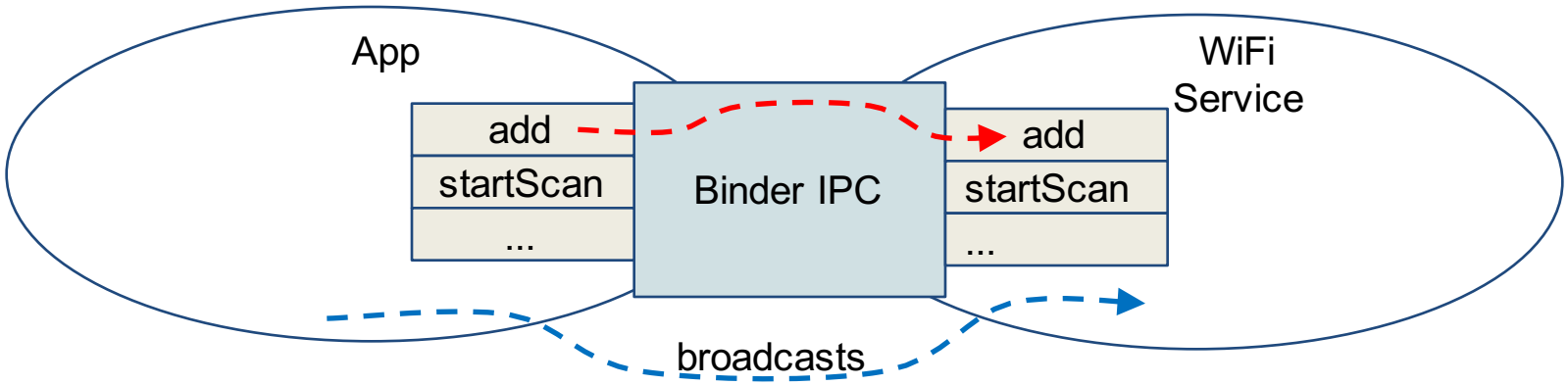
Pruning



`enforcePhone()` checks if the caller's UID is 1001 (RADIO)

App-accessible service interfaces

- Analysis scope: system services
  - System services perform enforcement
- Service interfaces
  - AIDL methods
  - Broadcast receivers

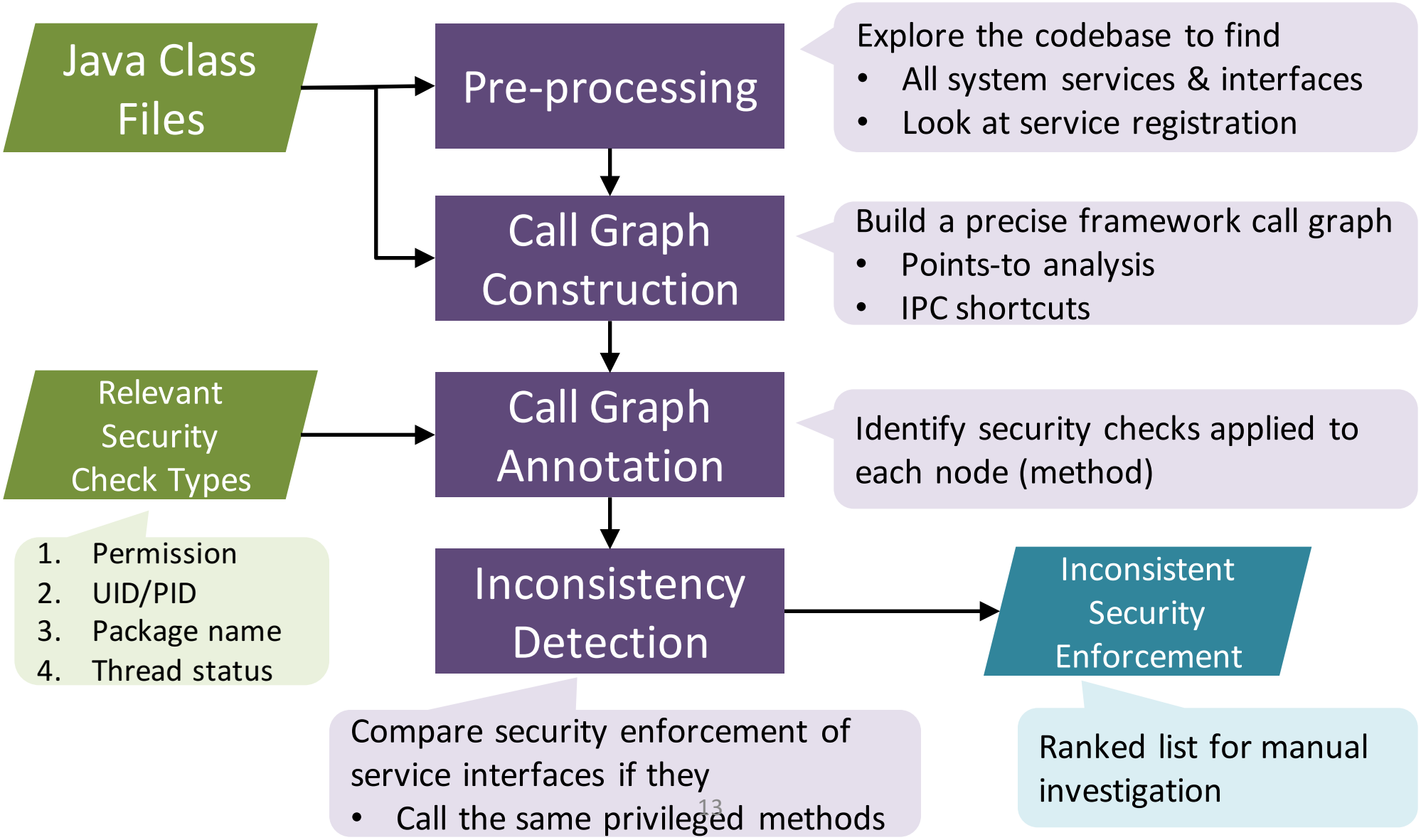


AIDL: Android interface definition language

Security checks

- Security enforcement: a set of security checks
- We formulate four types of checks
  - Permission check
  - UID/PID check
  - Package name check
  - Thread status check

Kratos Design



Implementation

- Support AOSP and customized frameworks
  - Obtain Java classes from
    - Intermediate building output (AOSP)
    - Decompiled dex files (customized)
- Build a precise framework call graph
  - Points-to analysis using Spark
  - An artificial, static entry point including all app-accessible service interfaces
- Perform data flow analysis
  - Identify security check methods
  - Collect system services

Evaluation

- 6 different Android codebases
  - AOSP 4.4, 5.0, 5.1 and M Preview
  - HTC One, Samsung Galaxy Note 3
- Accuracy

Codebase	# Inconsistencies	# TP	# FP	Precision	# Exploitable
Android 4.4	21	16	5	76.2%	8
Android 5.0	61	50	11	82.0%	11
Android 5.1	63	49	14	77.8%	10
M Preview	73	58	15	79.5%	8
AT&T HTC One	29	20	9	69.0%	8
T-Mobile Samsung Galaxy Note 3	128	102	26	79.7%	10

False positive and exploitability

- False positives exist
  - Two interfaces are not equivalent in functionality
  - Points-to analysis produces over-approximated results
- Not all inconsistencies are exploitable
  - Difficult to construct valid arguments
  - Difficult to trigger particular privileged methods

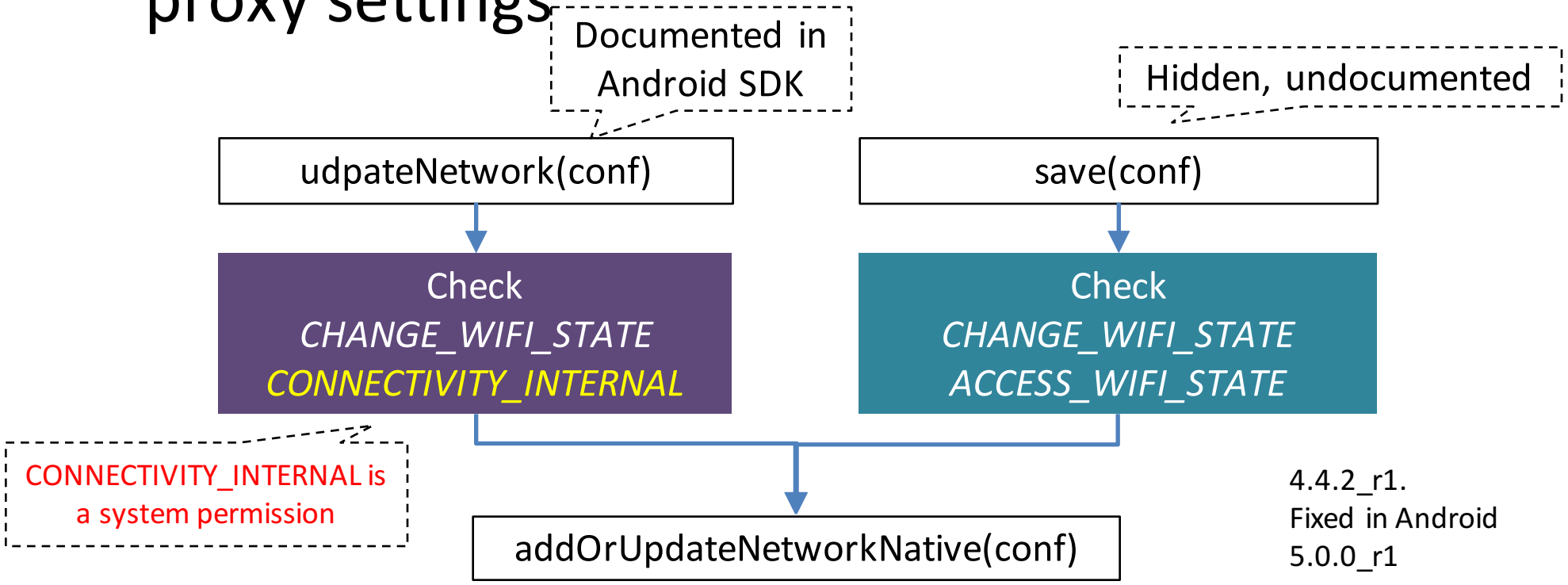
Vulnerabilities discovered

- We found 14 vulnerabilities

- 5 out of 14 affect all codebases
- Bug reports confirmed by Google
  - Results website: http://tinyurl.com/kratos15

Case study 1

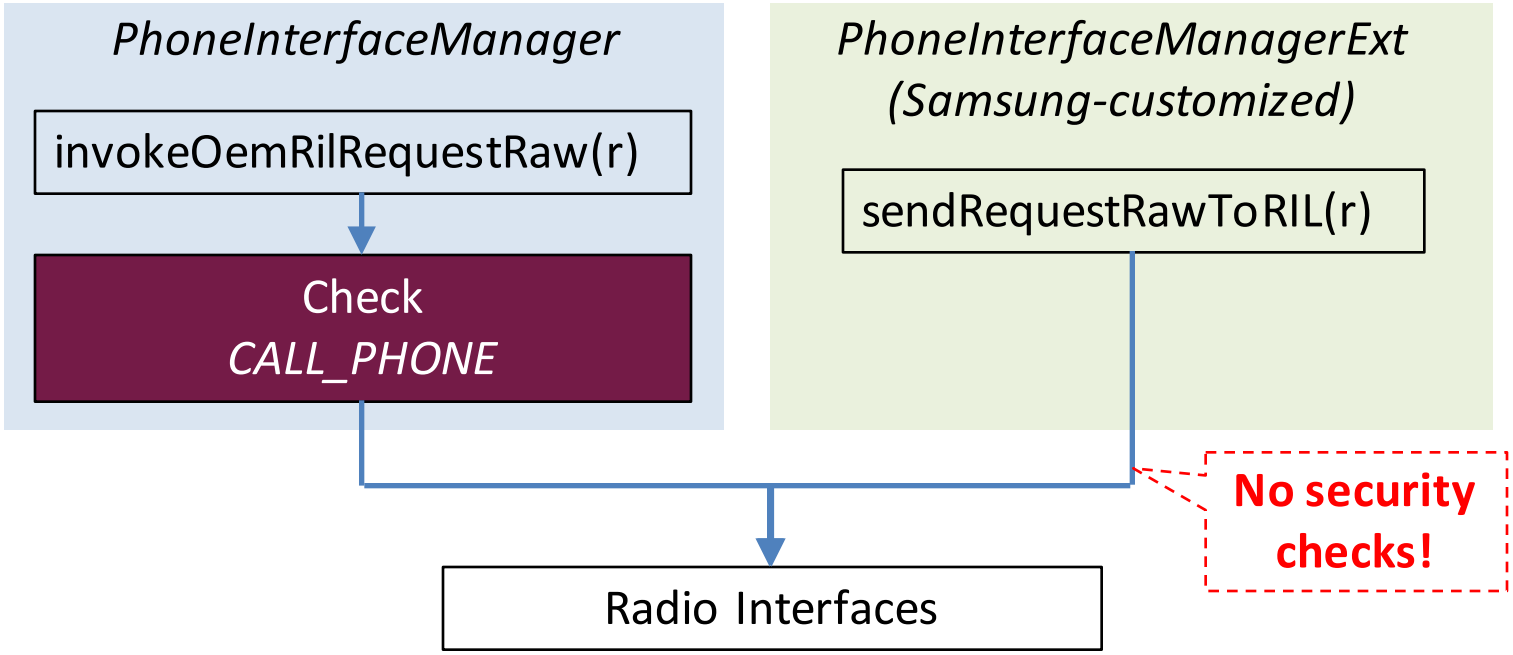
- Bypass system permission to change HTTP proxy settings



- Allows attackers to bypass the system permission
- MITM, eavesdropping, traffic interception, …

Case study 2

- Send arbitrary requests to the radio hardware without any permissions



- Allows attackers to send arbitrary requests to radio on vulnerable Samsung phones
- Send SMS, make phone calls, …

Other observations

- 11 vulnerable interfaces are hidden to apps
  - Not available in the Android SDK
  - Invoke using Java reflection
- AOSP frameworks
  - New system services introduce new inconsistencies, leading to new vulnerabilities
- Customized frameworks
  - Samsung added many system services
    - Introduced 2 additional vulnerabilities
    - One present in AOSP was fixed

Conclusions

- Inconsistent security policy enforcement gives rise to many vulnerabilities
- Our tool is practical and useful for AOSP, vendors, and carriers
- Our approach is general and can be applied to other systems
- To ensure system security, the implementation must faithfully realize the design

Q&A

- Thank you!