Static Analysis for Extracting Permission Checks of a Large Scale Framework: The Challenges And Solutions for Analyzing Android

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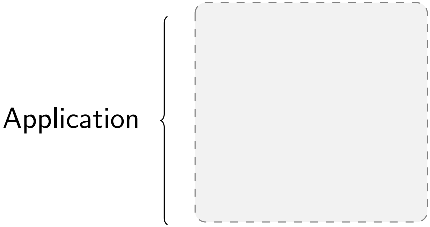
Static Analysis of a Permission-Based Security System



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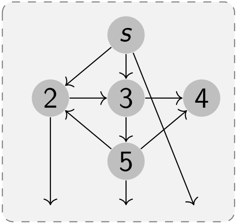
Application



The application declares permissions p_1 and p_2

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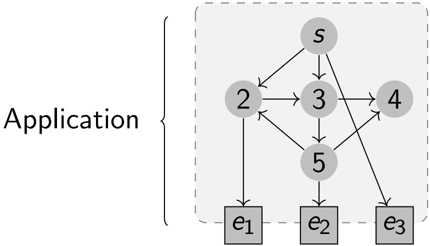

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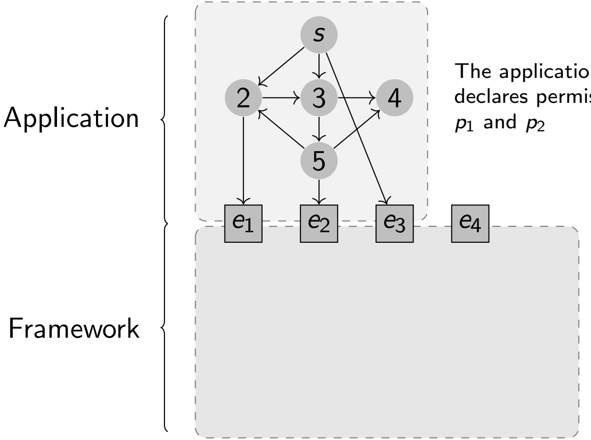

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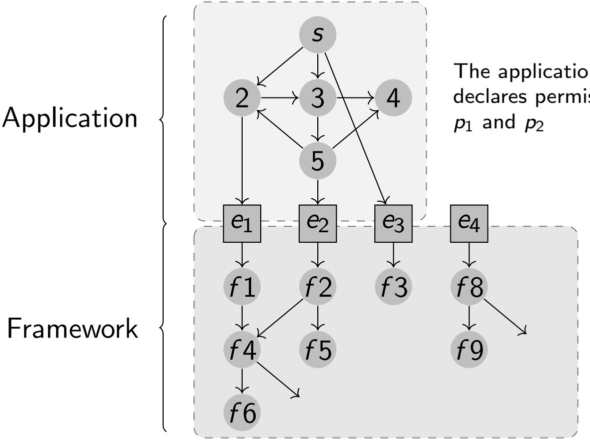

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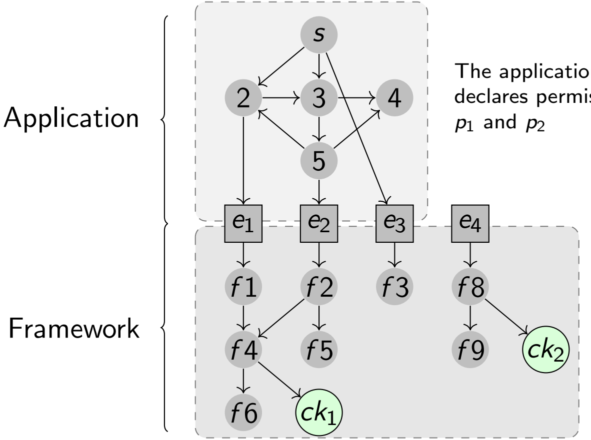

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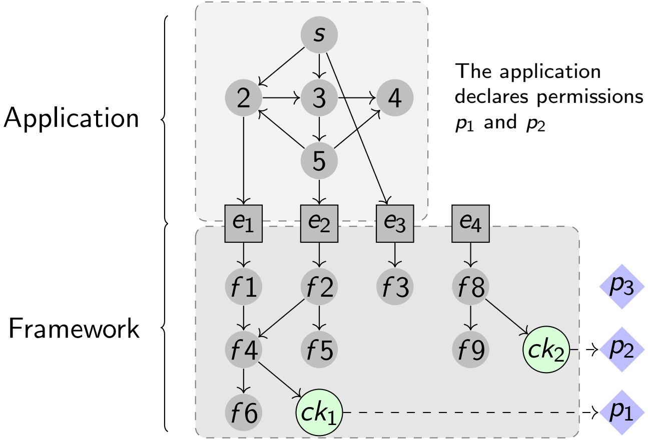

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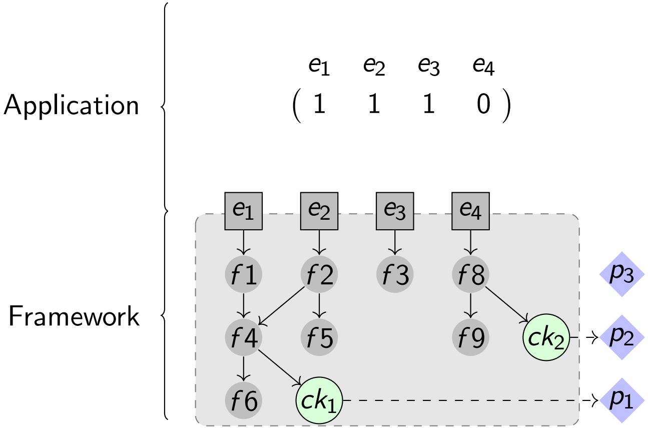

Static Analysis of a Permission-Based Security System

$$\text{Application}\left\{\quad \begin{array}{cccc} e_1 & e_2 & e_3 & e_4 \\ \end{array} \atop \begin{pmatrix} 1 & 1 & 1 & 0 \end{pmatrix}\right.$$

$$\text{Framework}\left\{\quad \begin{array}{c|c} & \begin{array}{ccc} p_1 & p_2 & p_3 \end{array} \\ \begin{array}{c} e_1 \\ e_2 \\ e_3 \\ e_4 \end{array} & \begin{pmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \end{array}\right.$$

Methodology to Compute Permission Set (Step 1/3)

Step 1: Extract Framework Permission Matrix

$$M = \begin{array}{c} \\ e_1 \\ e_2 \\ e_3 \\ e_4 \end{array} \begin{array}{c} \begin{array}{ccc} p_1 & p_2 & p_3 \end{array} \\ \begin{pmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \end{array}$$

This step is only done *once* (for a given framework).

Methodology to Compute Permission Set (Step 2/3)

Step 2: Extract Application Access Vector

$$\begin{array}{cc} & \begin{array}{cccc} e_1 & e_2 & e_3 & e_4 \end{array} \\ AV_{app} = & \begin{pmatrix} 1 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

This step is done *for every application*.

Methodology to Compute Permission Set (Step 3/3)

Step 3: Infer Permission Set of the Application

$$
\begin{aligned}
IP_{app} &= \begin{pmatrix} 1 & 1 & 1 & 0 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \\
IP_{app} &= \begin{pmatrix} 1 & 0 & 0 \end{pmatrix}
\end{aligned}
$$

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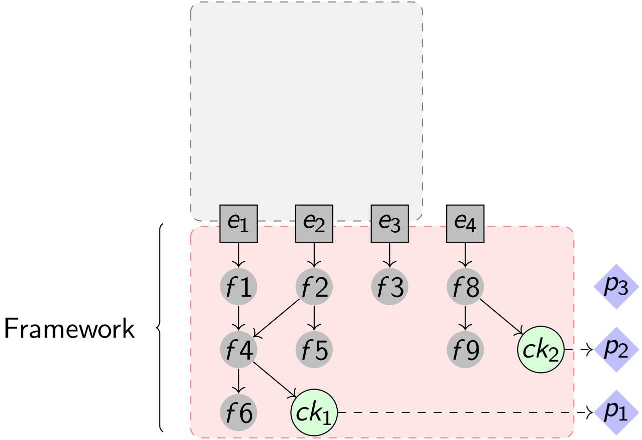
Android Framework Call Graph Construction



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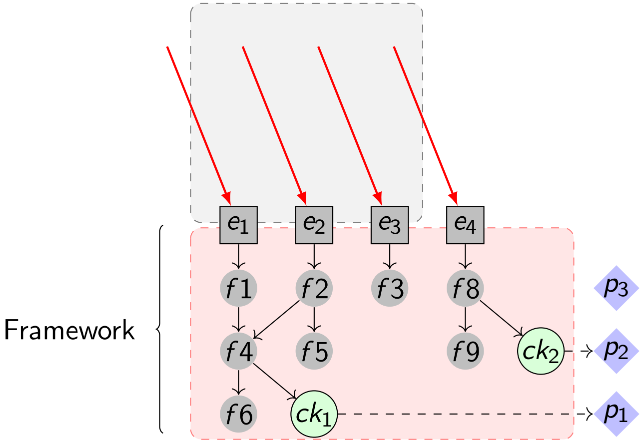

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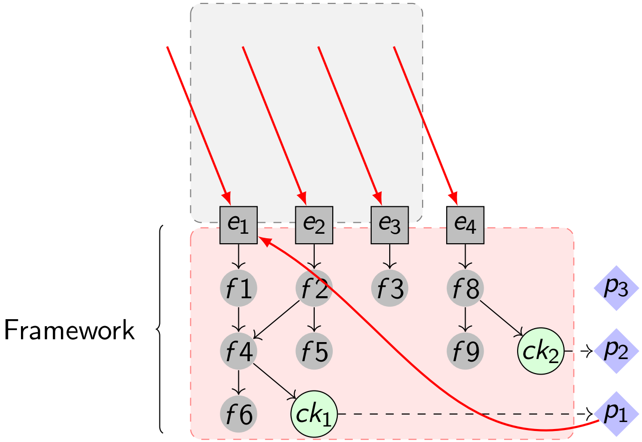

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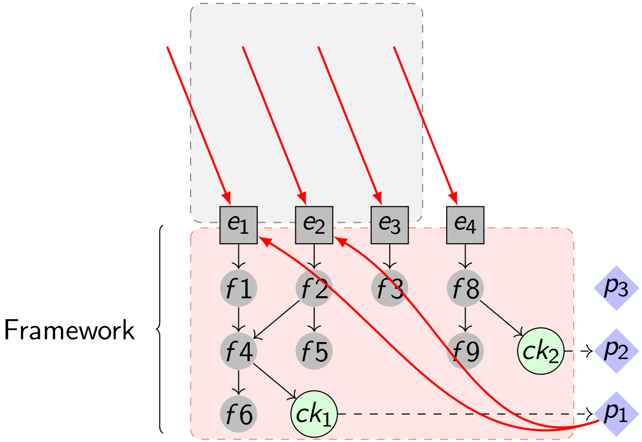

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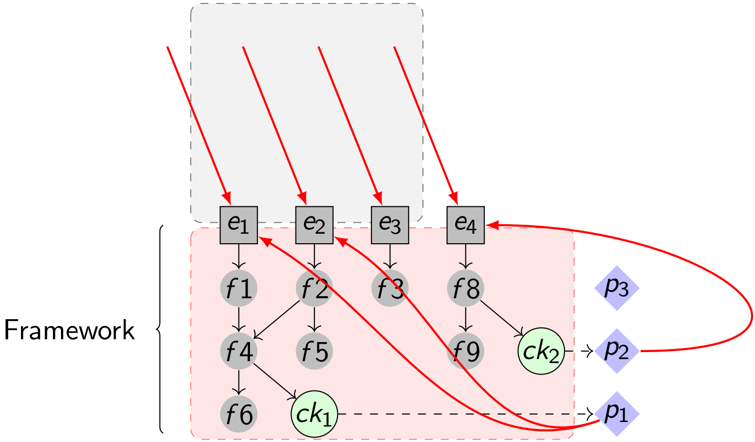

Call Graph Construction Techniques for Java

- Not precise: CHA (based on class hierarchy)
  - CHA essential (1/4)
  - CHA intelligent (2/4)
- Field sensitive: Spark
  - Spark naive (3/4)
  - Spark intelligent (4/4)

CHA Essential (1/4)

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with 0 permissions	31,791 (64%)
with 1 permissions	1 ($<$ 0.01%)
with 105 permissions	18,237 (36%)
	50,029 (100%)

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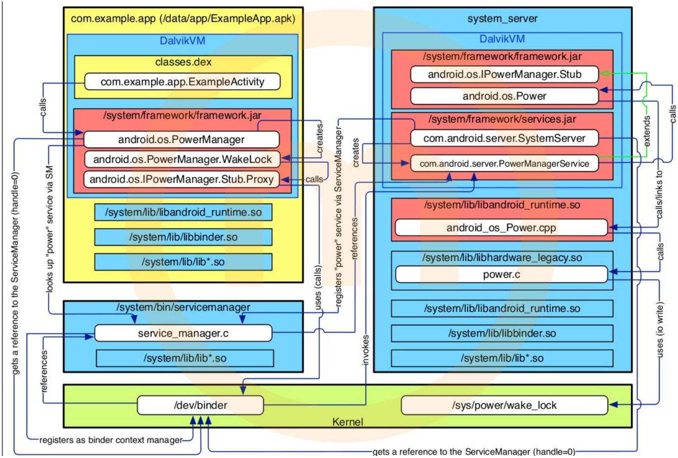
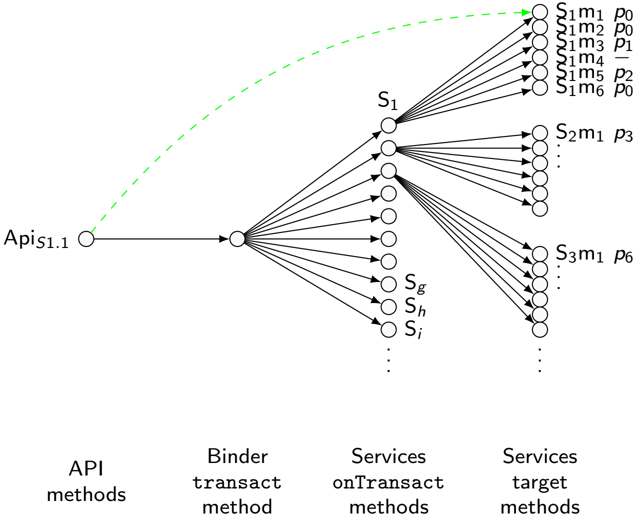
- Why explosion of permission set size?
  - Call graph goes through binder code

CHA Essential (1/4): The Real World System with Multiple Software Layers



(source: Gargenta, 2012)

CHA Essential (1/4): The Reason of the Explosion



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- Finds check methods in the call graph
- Extracts names of checked permissions
- Handles system service communication through the "Binder"

CHA Intelligent (2/4): Handling Binder

Application Code

Service Call

```
r = getSystemService()
p = r.getPassword()
```

Account System Service

```
getPassword() {
 checkPermission();
 return password;
}
```

Binder (Linux module)

CHA Intelligent (2/4): Handling Binder

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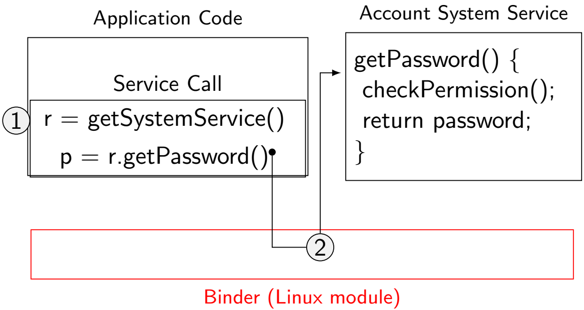

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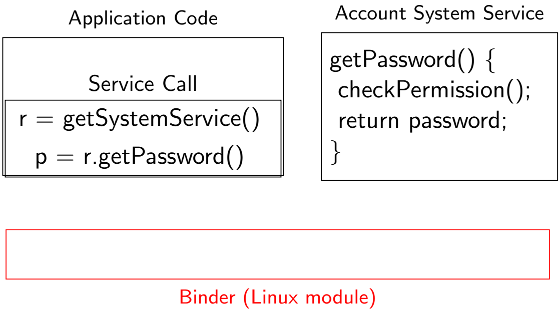

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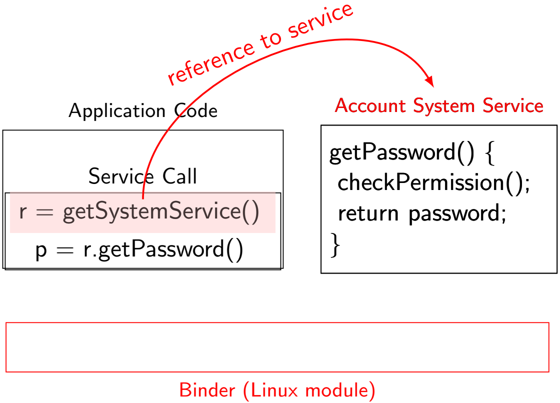

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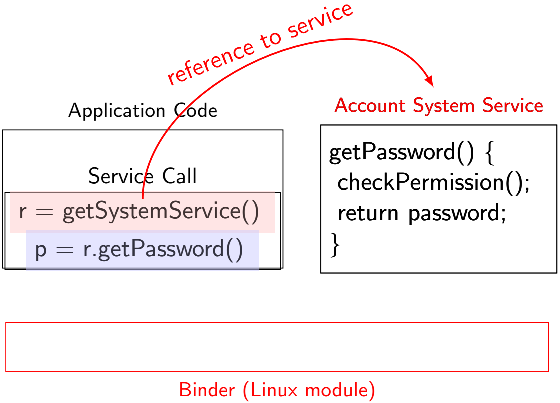

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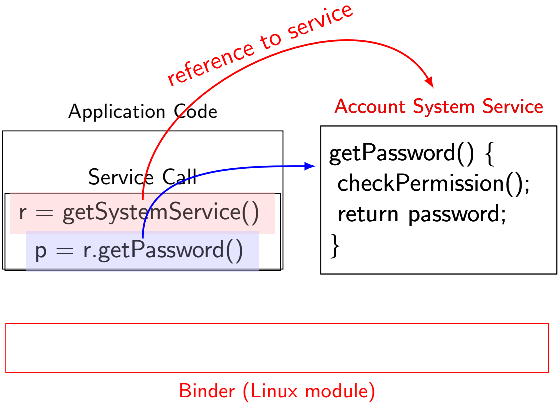

CHA Intelligent Results (2/4)

Permission Set	# entry points (CHA Intelligent)	# entry points (CHA Essential)
with 0 permissions	32,924 (65.8%)	32,924 (64%)
with 1 permissions	39 (0.08%)	1 ($<$ 0.01%)
with 2 permissions	55 (0.12%)	0 (0%)
with $>$ 65 permissions	17,011 (34.0%)	18,237 (36%)
	50,029 (100%)	50,029 (100%)

Spark Naive (3/4)

- Off-the-shelf

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$\rightarrow$ generate entry point "wrappers" to initialize objects

Spark Intelligent (4/4)

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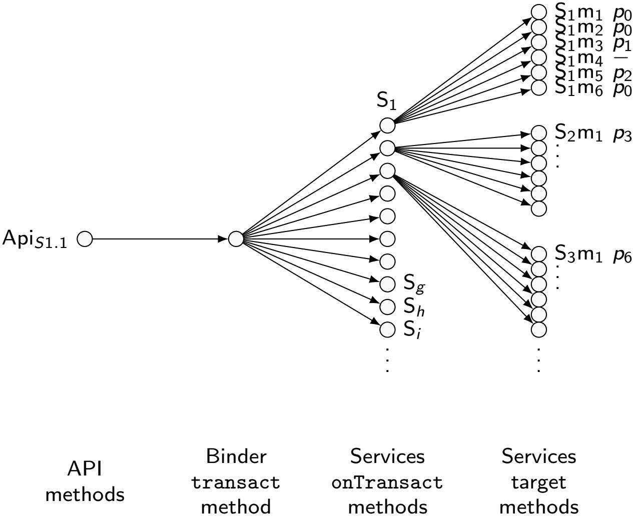
- Generates entry point wrappers
- Handles system services initialization and managers initialization

Spark Intelligent (4/4)



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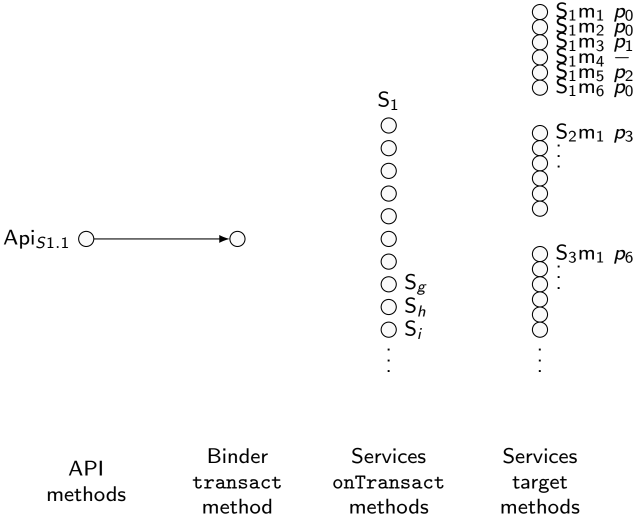

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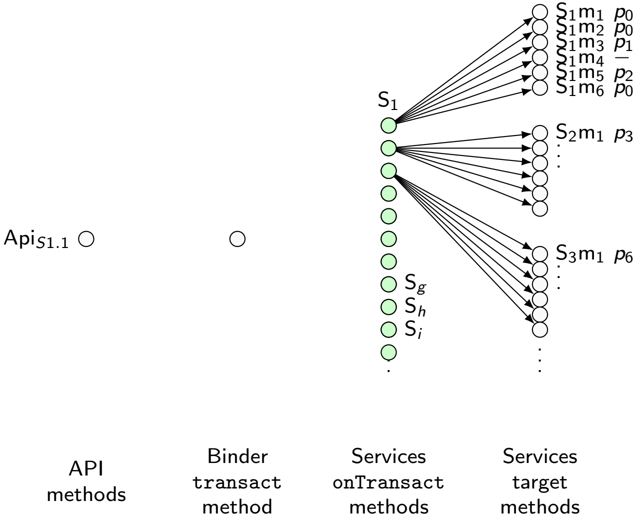

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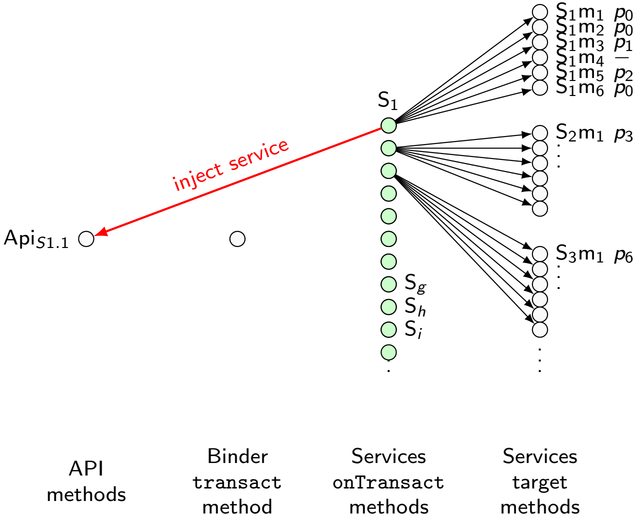

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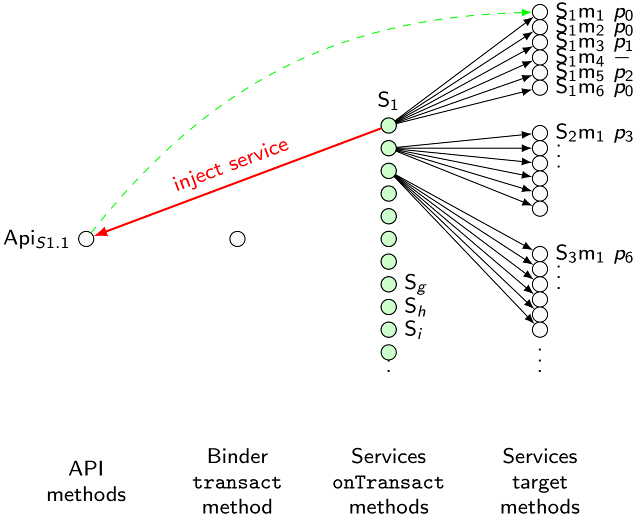

Spark Intelligent Results (4/4)

Permission Set	# entry points (Spark Intelligent)	# entry points (CHA Intelligent)	# entry points (CHA Essential)
with 0 permissions	42,895 (98.77%)	32,924 (65.8%)	32,924 (64%)
with 1 permissions	471 (1.08%)	39 (0.08%)	1 ($<$ 0.01%)
with 2 permissions	48 (0.11%)	55 (0.12%)	0 (0%)
with 3 permissions	10 (0.01%)	0 (0%)	0 (0%)
with $>$ 3 permissions	3 (0.02%)	17,011 (34.0%)	18,237 (36%)
	43,427 (100%)	50,029 (100%)	50,029 (100%)

Spark Intelligent Results (4/4)

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classes are removed to speed up the experiment

Evaluation (1/3): Android 4

Comparison Spark Intelligent vs. PScout [1]

[1] K. W. Y. Au, Y. F. Zhou, Z. Huang, and D. Lie. Pscout: analyzing the android permission specification. In Proceedings of the 2012 ACM conference on Computer and communications security, 2012.

Evaluation (1/3): Android 4

Comparison Spark Intelligent vs. PScout [1]

Permission set	Number of Methods
#API Methods in Spark and PScout	468 (100%)
Identical	289 (61.75%)
we find less permission checks	176 (37.60%)
we find more permission checks	3 (0.64%)

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- We are less precise: we not analyze some modules (ex: non-Java code)

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Evaluation (2/3): Android 2.2

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↳ Static (2) Analysis yields an over-approximation.
↳ Combining the (1) and (2) to have "correct" results?

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Evaluation (3/3): Permission Gaps in Real World Applications

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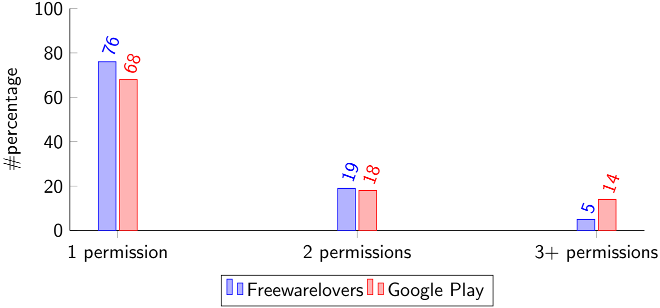

Contributions Summary

- Empirically demonstrated that off-the-shelf static analysis can not address the extraction of permissions in Android
- Static analysis of Android requires inner knowledge of the stack
- Static analysis components must be put together:
  1. Entry point initialization
  2. String analysis
  3. Service initialization
  4. Service redirection

Contributions Summary

- **Alexandre Bartel**, Jacques Klein, Martin Monperrus, and Yves Le Traon. Automatically Securing Permission-Based Software by Reducing the Attack Surface: An Application to Android. In *Proceedings of the 27th IEEE/ACM International Conference On Automated Software Engineering (ASE)*, 2012. Short paper. [cication count: 26]
- **Alexandre Bartel**, Jacques Klein, Martin Monperrus, and Yves Le Traon. Static Analysis for Extracting Permission Checks of a Large Scale Framework: The Challenges And Solutions for Analyzing Android. In *IEEE Transactions on Software Engineering (TSE)*, 2014.