香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Taming Android Fragmentation: Characterizing and Detecting Compatibility Issues for Android Apps

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05 September 2016

Android: Popular and Fast-Evolving System

- Fast-evolving: multiple releases every year

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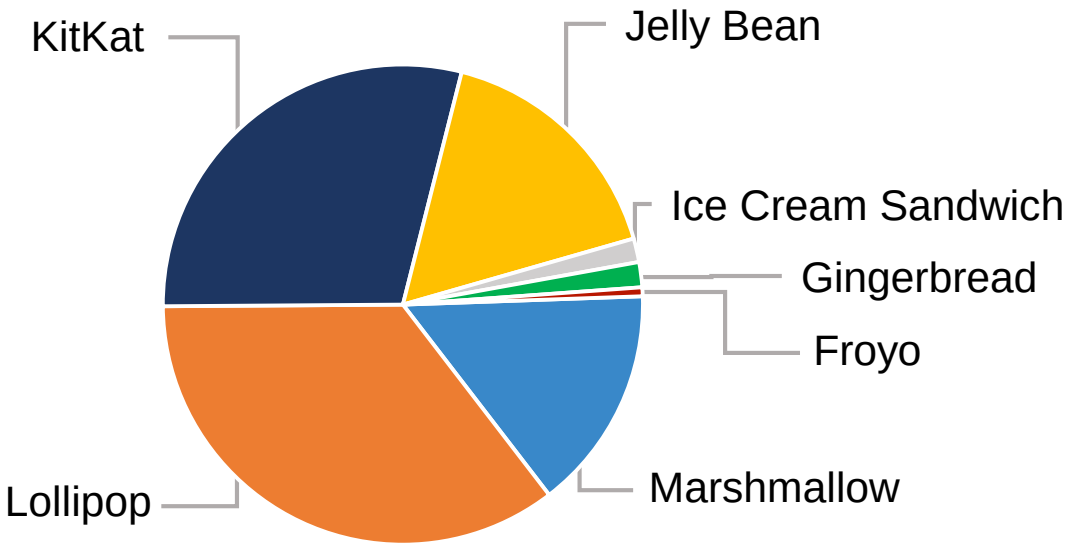
- Many different system versions in use:

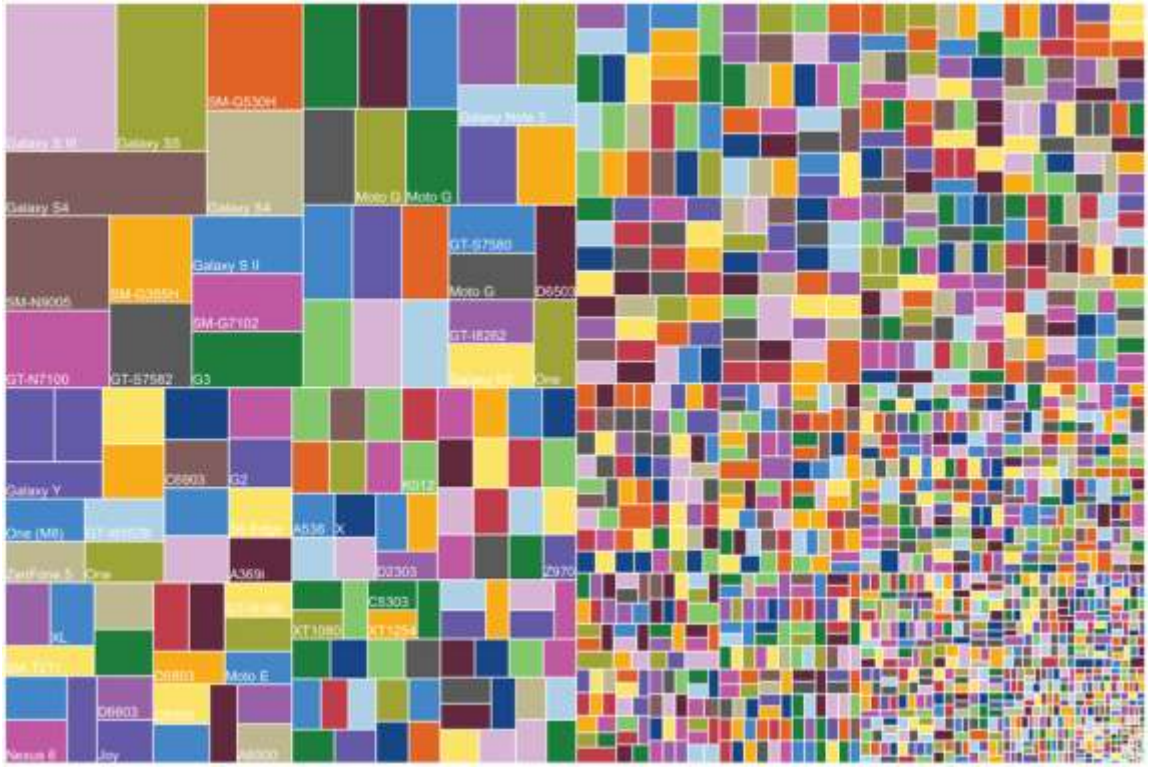


https://developer.android.com/about/dashboards/index.html


android
open source project
htc
ZTE
Lenovo
acer
SONY
HUAWEI
DELL
SAMSUNG
motorola
LG
ASUS

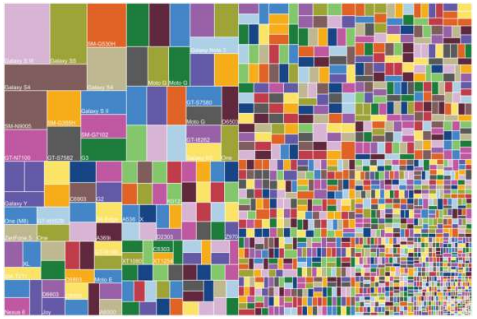
Huge Number of Device Models

Over 24,000 distinct device models (Aug. 2014 – Aug.2015)



http://opensignal.com/reports/2015/08/android-fragmentation/

Fragmented Android Ecosystem



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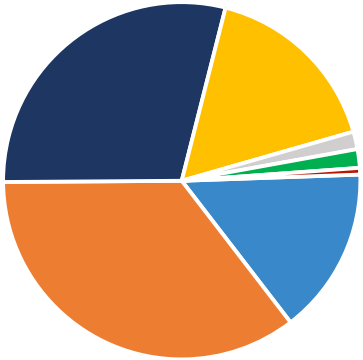

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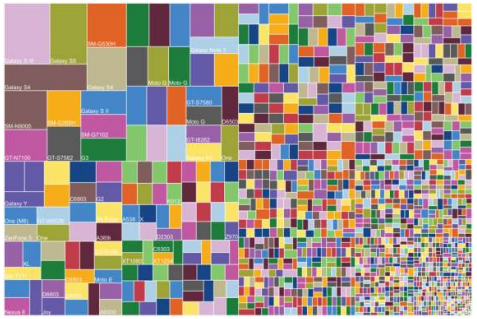

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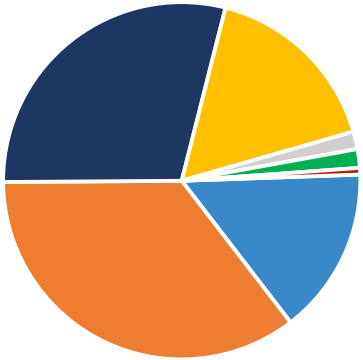

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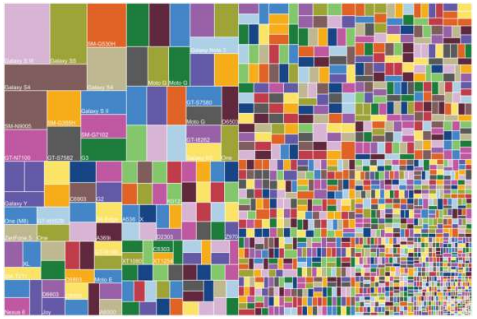

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- App developers have to optimize UI of their apps to fit diversified screen sizes

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Fragmentation-induced compatibility issues

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Testing Compatibility Issues

- To fully test compatibility issues is difficult with huge search space
  - Combination of **three dimensions**

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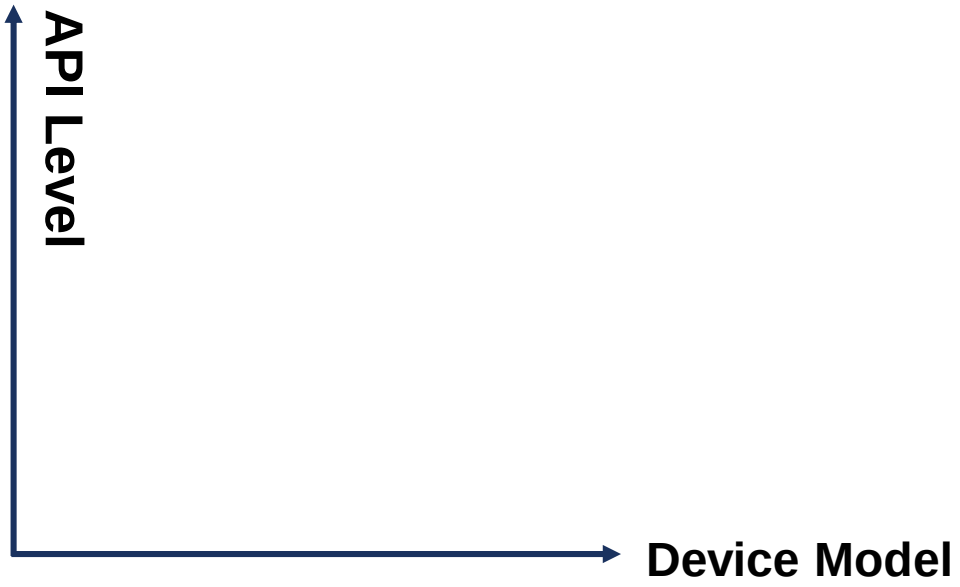

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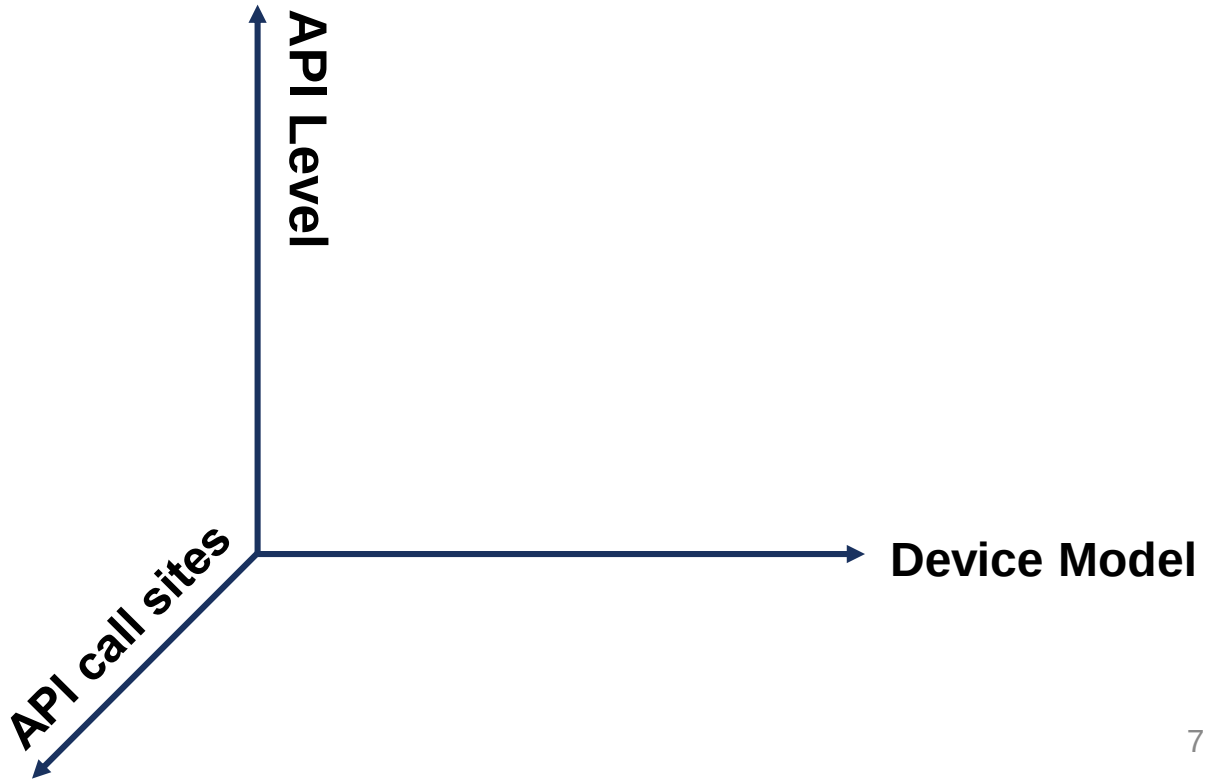

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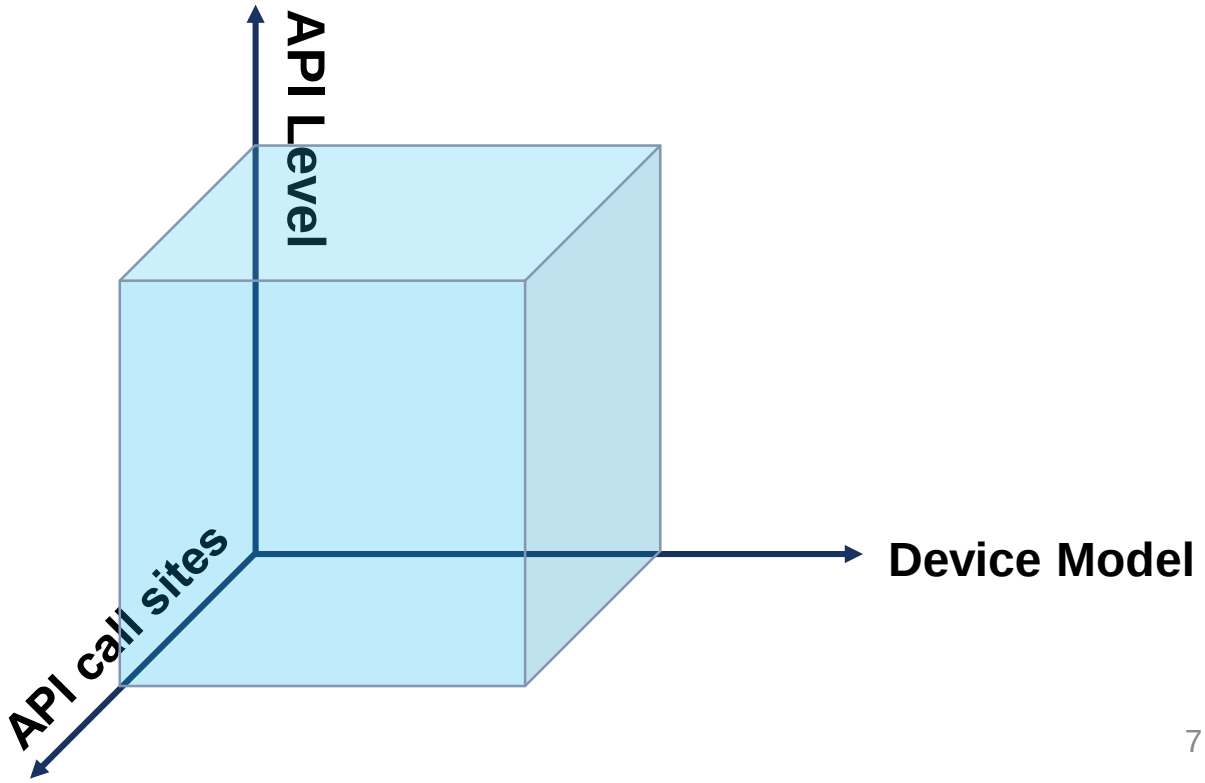

Existing Work

- Understanding Android fragmentation
  - D. Han et al. [WCRE’ 2012]
  - T. McDonnell et al. [ICSM’ 2013]
- Prioritize devices to test on:
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None of the existing studies dug into the code level:

- To understand compatibility issues
- To detect compatibility issues

Our Goal

Understand compatibility issues at code level

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Understand compatibility issues at code level

Detect compatibility issues

Research Questions

- **RQ1: Issue type and root cause**
  - What are the common types of compatibility issues in Android apps? What are their root causes?

Research Questions

- **RQ1: Issue type and root cause**
  - What are the common types of compatibility issues in Android apps? What are their root causes?
- **RQ2: Issue fixing**
  - How do Android developers fix compatibility issues in practice? Are there any common patterns?

Dataset Collection

27 **popular**, **large-scale**, **well-maintained** candidate apps, which have **public issue tracking systems**

Dataset Collection

27 **popular**, **large-scale**, **well-maintained** candidate apps, which have **public issue tracking systems**

Apps satisfying these criterion are:

- More likely to be affected by different kinds of compatibility issues
- With traceable issue fix and discussions to study

Keyword Search

device	compatible	compatibility	samsung
lge	sony	moto	lenovo
asus	zte	google	htc
huawei	xiaomi	android.os.build	

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VLC r-8e31d57:

Blind fix for mountpoint issues with some **Samsung** devices

```
   if(line.contains("vfat") || line.contains("exfat") ||
-      line.contains("/mnt") || line.contains("/Removable")) {
+       line.contains("sdcardfs") || line.contains("/mnt") ||
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```

CSipSimple r-af0ceea:

Fixes issue 498.

```
+   //HTC evo 4G
+   if(android.os.Build.PRODUCT.equalsIgnoreCase("htc_supersonic"))
+       return true;
```

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All 27 apps contain potential revisions related to compatibility issues

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Five apps with top number of potential issue-related code revisions

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Five apps with top number of potential issue-related code revisions

Over **1800 code revisions** found in the five apps need to be manually inspected

Dataset Collection

27 **popular**, **large-scale**, **well-maintained** candidate apps, which have **public issue tracking systems**

Five apps with top number of potential issue-related code revisions **(>1800 revisions)**

191 compatibility issues

Selected Apps

App Name	Category	Rating	Downloads	KLOC	#Revisions
CSipSimple	Communication	4.3/5.0	1M - 5M	59.2	1,778
AnkiDroid	Education	4.5/5.0	1M - 5M	58.1	8,282
K-9 Mail	Communication	4.3/5.0	5M - 10M	86.7	6,116
VLC	Media & Video	4.3/5.0	10M - 50M	28.3	6,868
AnySoftKeyboard	Tools	4.3/5.0	1M - 5M	70.7	2,788

Data Analysis

Identified the issue-inducing APIs

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Recovered links between revisions and reports

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Identified the issue-inducing APIs

Recovered links between revisions and reports

Collected related discussions from online forums

RQ1: Issue Type and Root Cause

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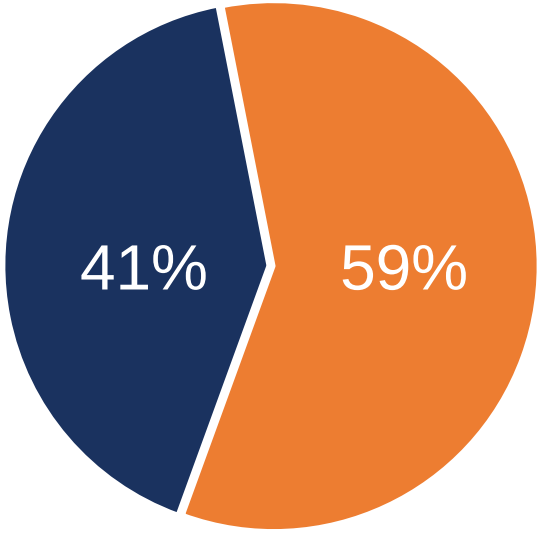
- Device-specific issues
  - Compatibility issues can only be triggered on certain device models
- Non-device-specific issue
  - Compatibility issues can be triggered under certain API level independent from device model

RQ1: Issue Type and Root Cause



Non-device-specific issues
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Device-specific issues
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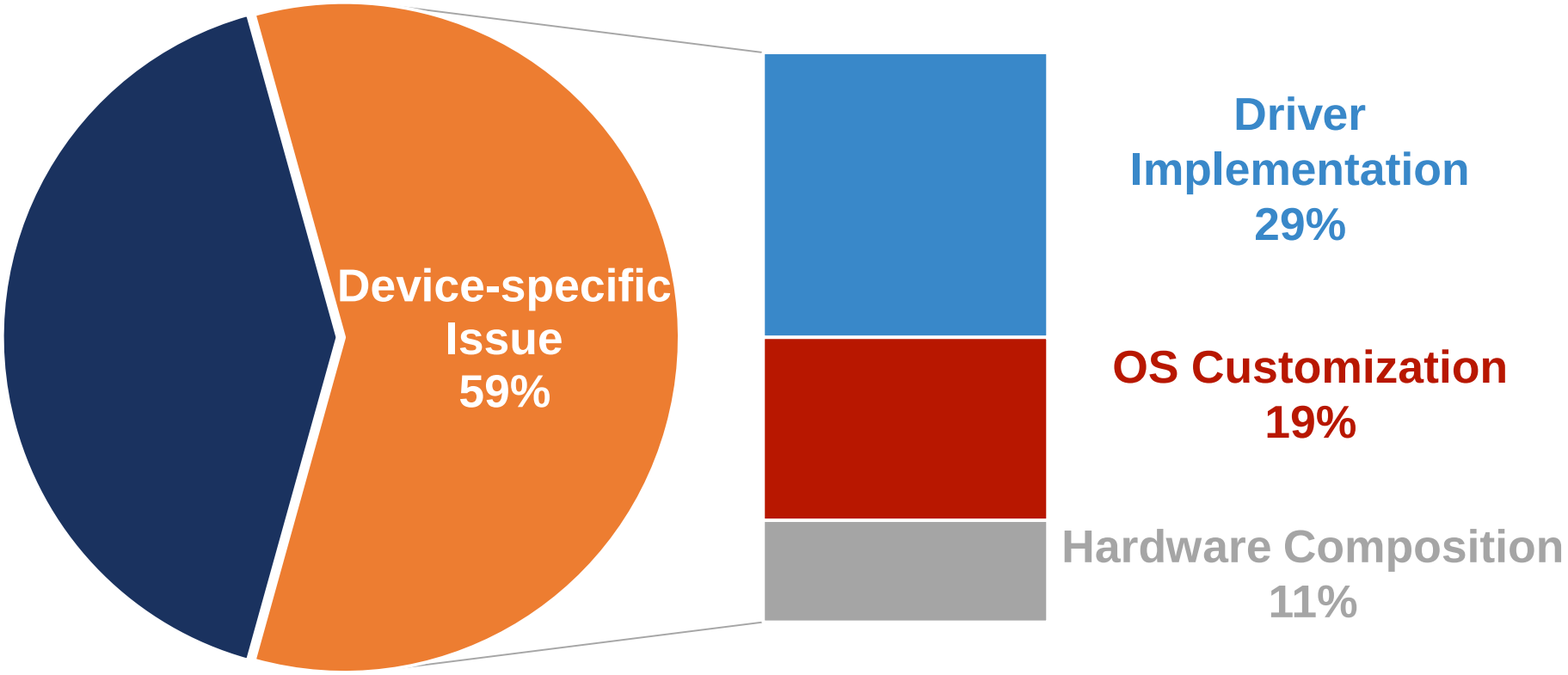
Device-Specific Issue



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- Problematic driver implementation
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- OS customization
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- Hardware composition
  - Diversified hardware composition of different device models can cause compatibility issues

Device-Specific Issues

- Problematic driver implementation
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Proximity sensor: Report the distance between device and its surrounding object

Device-Specific Issues

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An Android client app for internet calls

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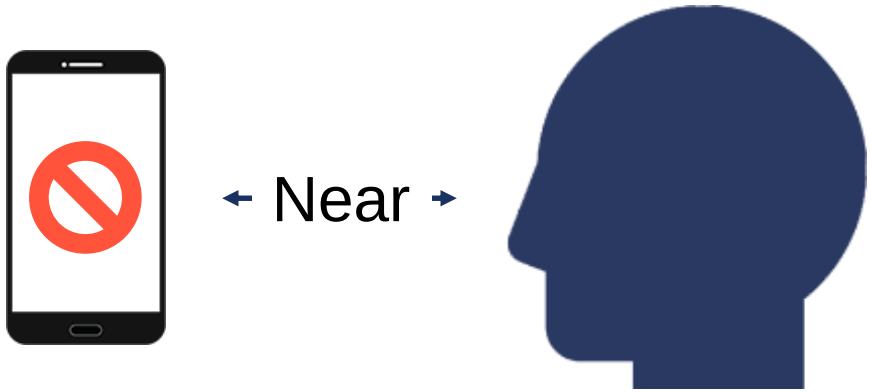

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SD card variations

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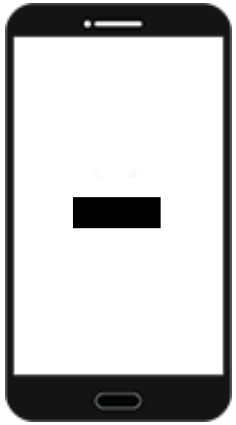

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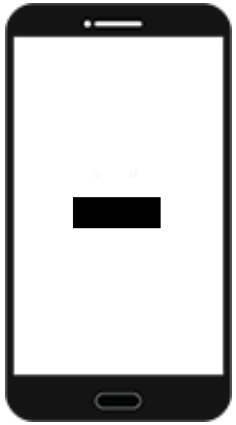

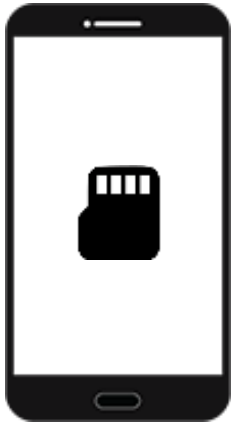

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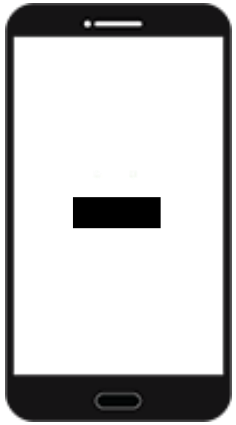

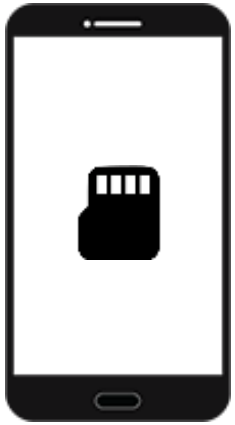

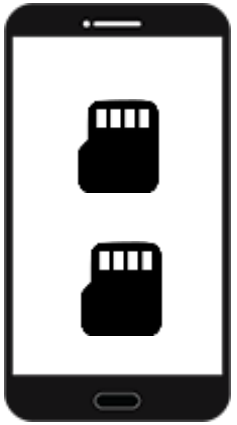

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SD card variations

Mount points vary across devices

Device-Specific Issues

VLC:
A popular Android video player

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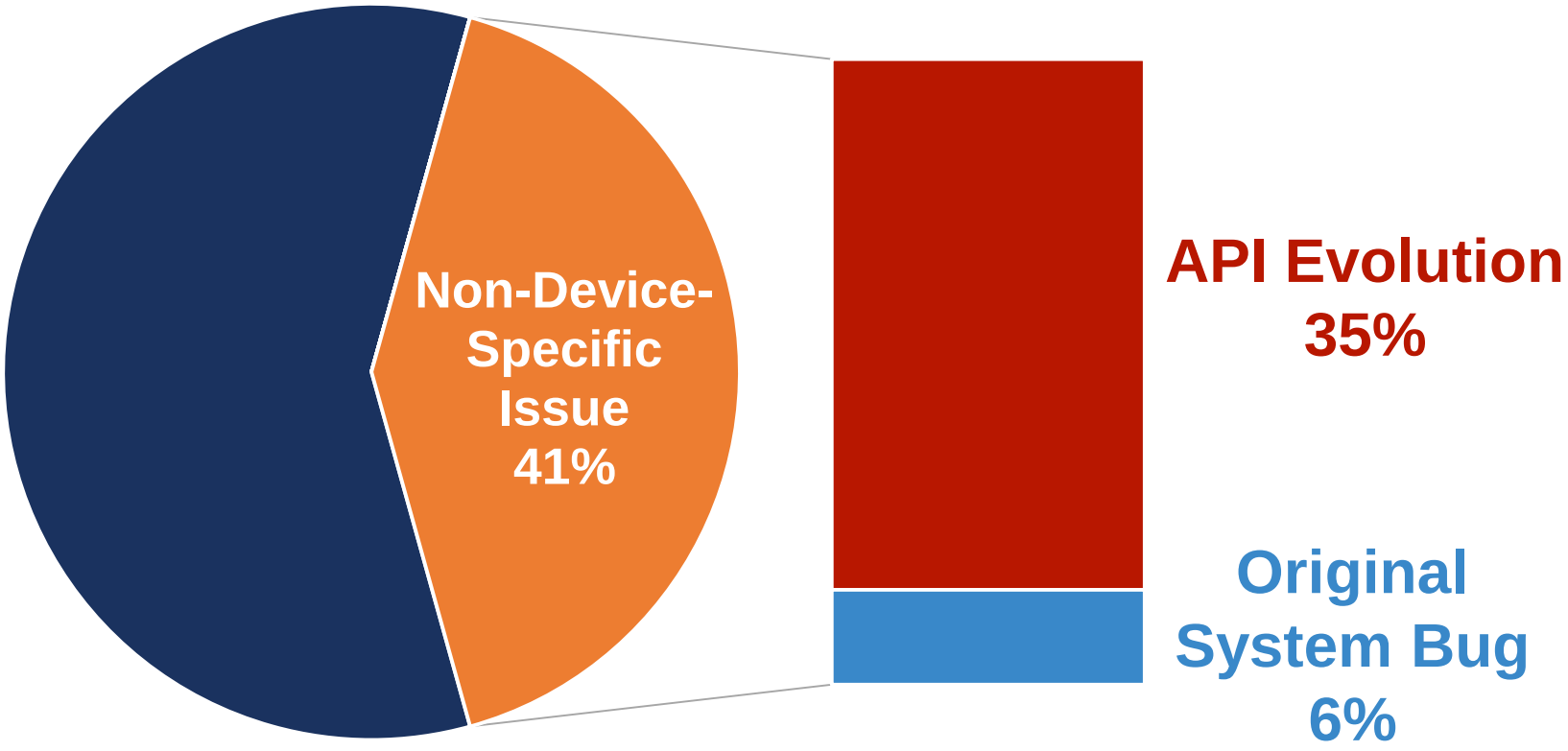
VLC specifically handle the SD card variations to ensure support of different device models

Non-Device-Specific Issue



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- Android platform API evolution
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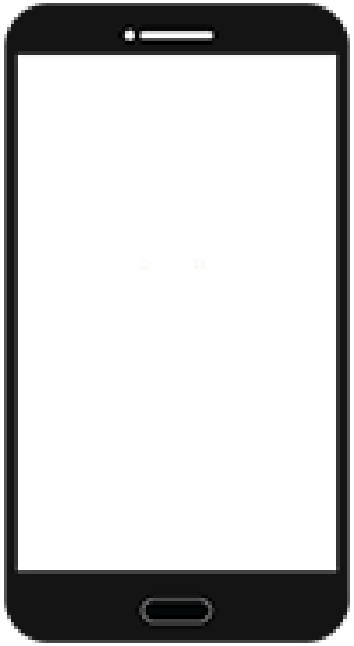
Non-Device-Specific Issues

- Android platform API evolution
  - Evolving Android system with API introduction, deprecation and behavior modification causes compatibility issues
- Original Android system bugs
  - Bugs in the system got fixed in newer version while still existing in older versions can cause compatibility issues.

Non-Device-Specific Issues

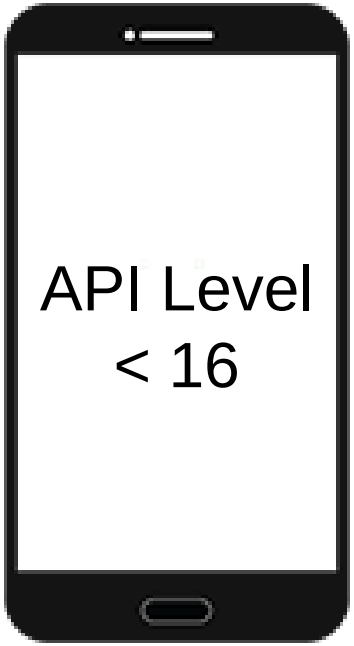
AnkiDroid pull request 130



API (Added in API Level 16):
SQLiteDatabase.disableWriteAheadLogging()

Non-Device-Specific Issues

AnkiDroid pull request 130



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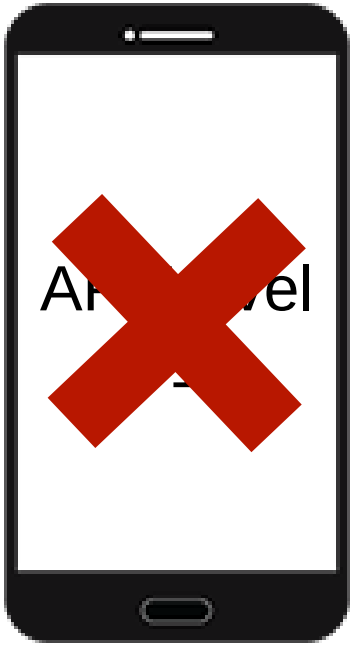

API (Added in API Level 16):
SQLiteDatabase.disableWriteAheadLogging()

RQ2: Issue Fixing

- Patch Complexity
- Common Patching Patterns

RQ2: Issue Fixing

- Patch Complexity
  - Simple
  - Small

```
1.  +    if (android.os.Build.VERSION.SDK_INT >= 16) {
2.                   sqLiteDatabase.disableWriteAheadLogging();
3.  +    }
```

RQ2: Issue Fixing

- Patch Complexity
  - To debug and find a valid fix is not easy

CSipSimple issue 2436:

“HTC has closed source this contact/call log app which makes things almost impossible to debug for me."

RQ2: Issue Fixing

- Common patching patterns
  - Check device information (71.7%)

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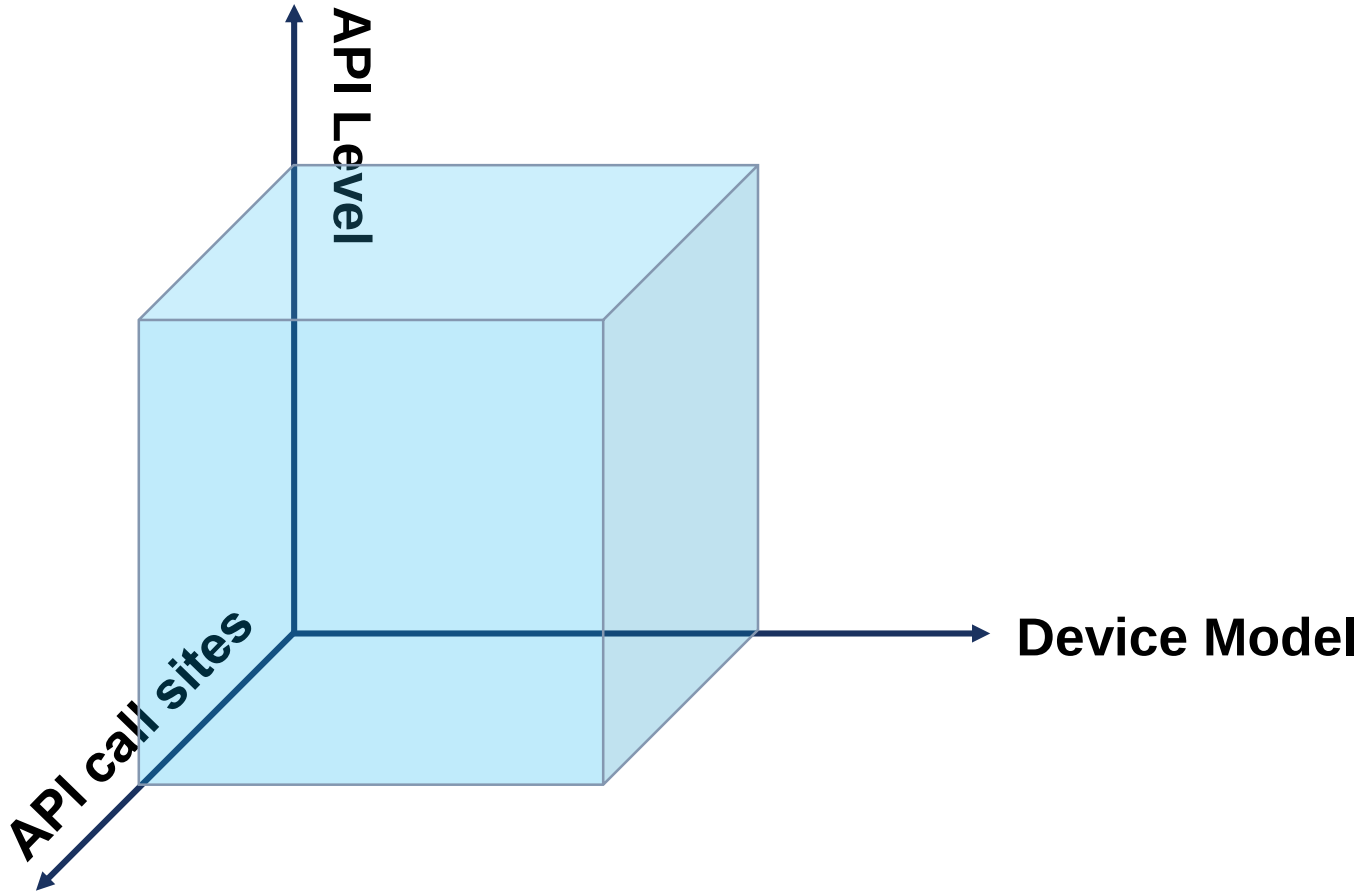
Locating the root cause of compatibility issues is difficult. Whereas, issue fixes are usually simple and demonstrate common patterns.

Applications of the Empirical Findings

- Prioritize testing efforts



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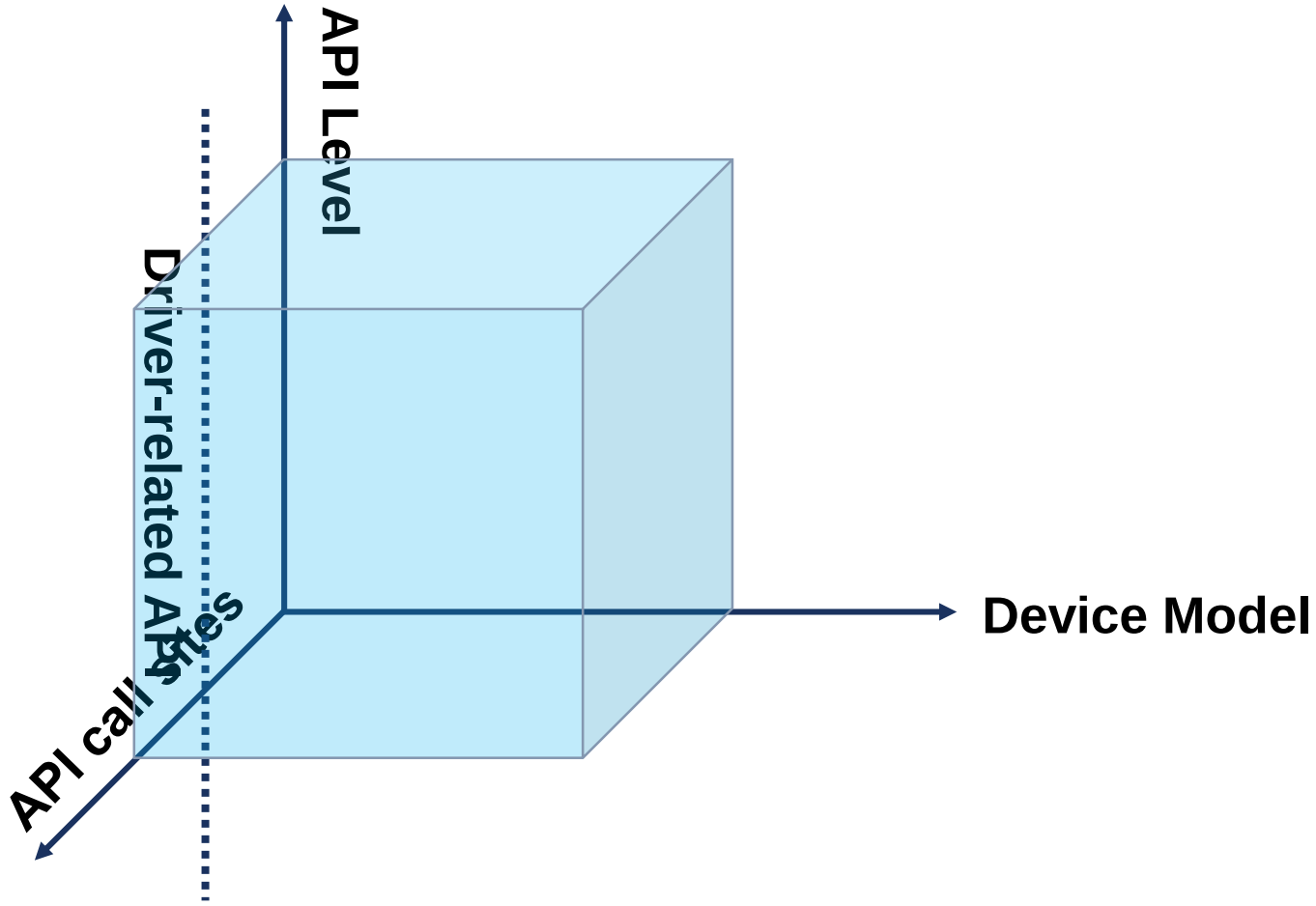

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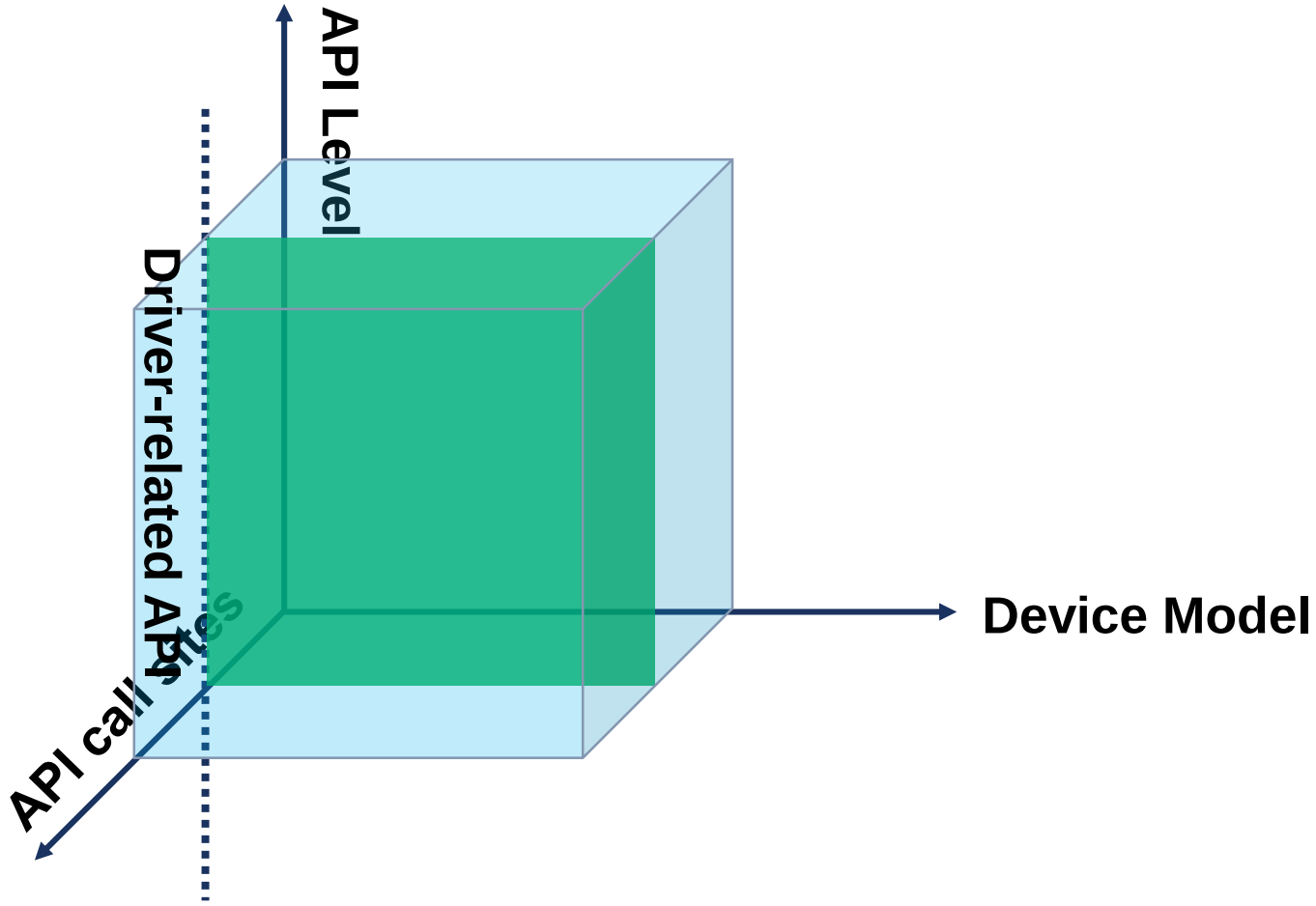
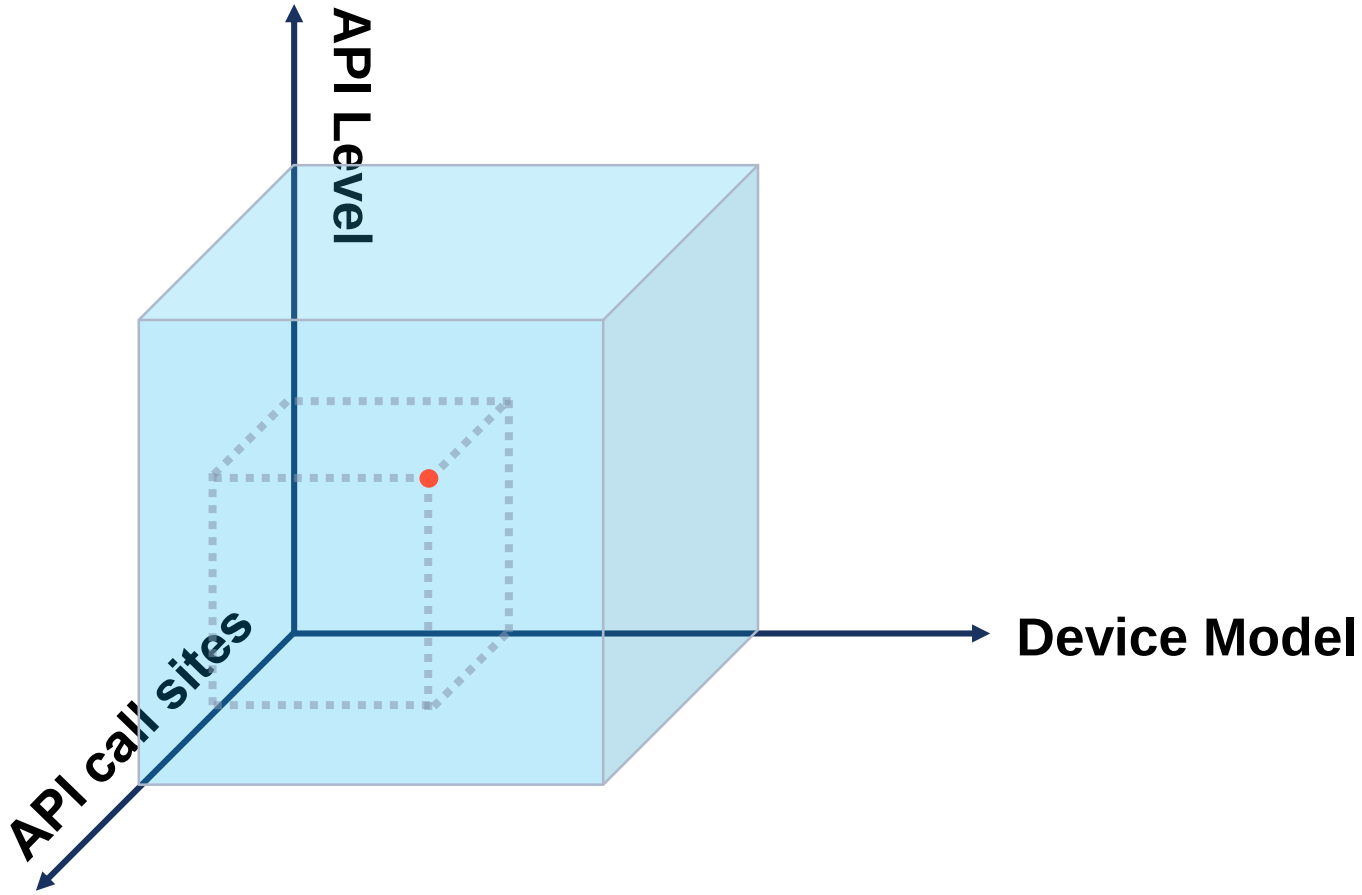


Applications of the Empirical Findings

- Detect compatibility issues



API-Context Pair Model

- Common compatibility issue pattern

Compatibility issues are triggered by the improper use of an Android API **(issue-inducing API)** in a problematic software or hardware environment **(issue-triggering context)**

API-Context Pair Model

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API-Context Pair Model:
Each pattern of compatibility issue is modeled as a pair of **issue-inducing API** and **issue-triggering context**

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Context: conjunction of device model, device brand or API level, etc.

API-Context Pair Model

- Common compatibility issue pattern

API-Context Pair Model:
Each pattern of compatibility issue is modeled as a pair of **issue-inducing API** and **issue-triggering context**

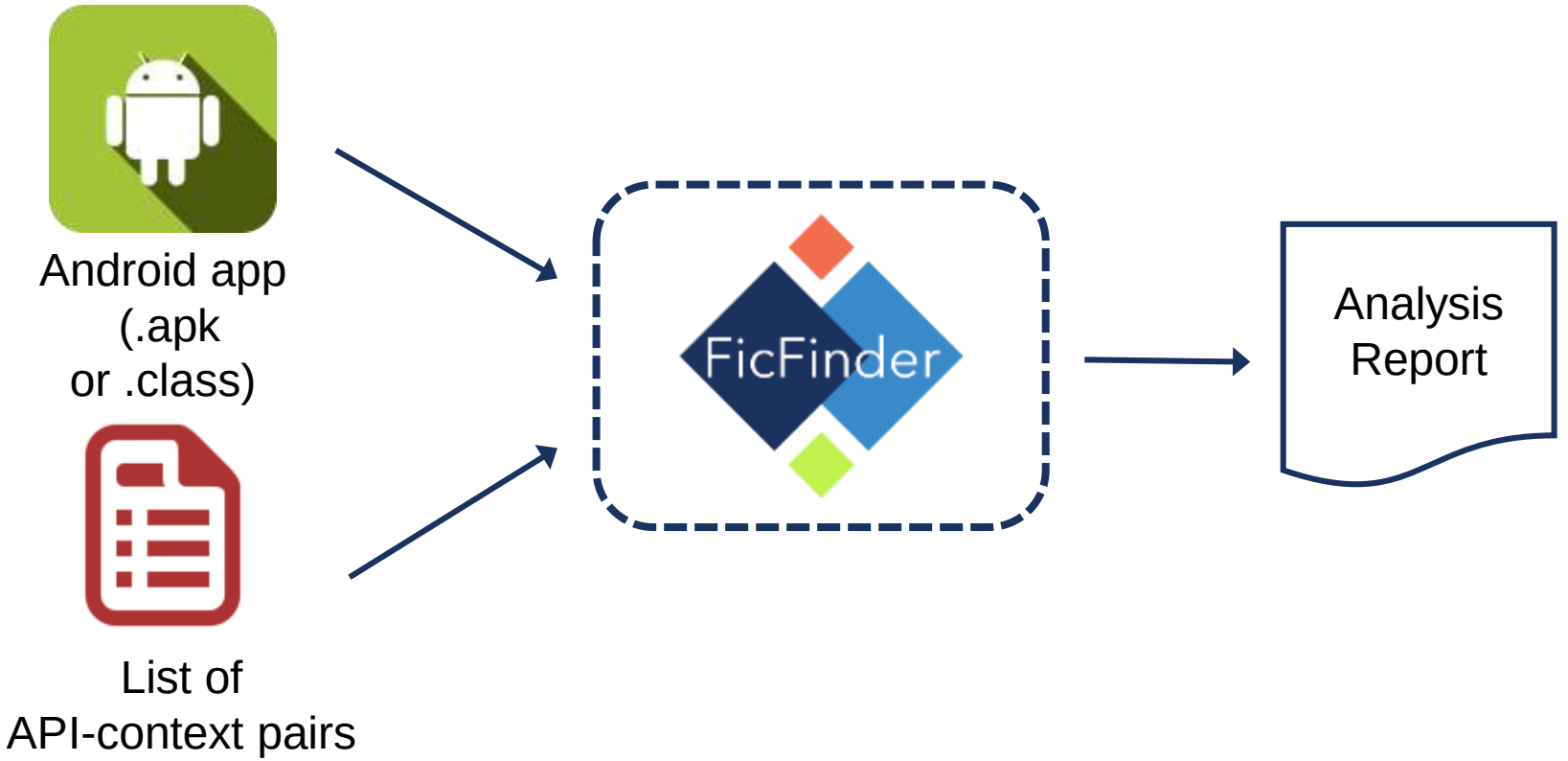
API: SQLiteDatabase.disableWriteAheadLogging()
Context: API_level < 16 ∧ Dev_model != "Nook HD"

FicFinder: Detecting Compatibility Issues

FicFinder:

Fragmentation-**I**nduced **C**ompatibility Issue Finder

FicFinder: Detecting Compatibility Issues



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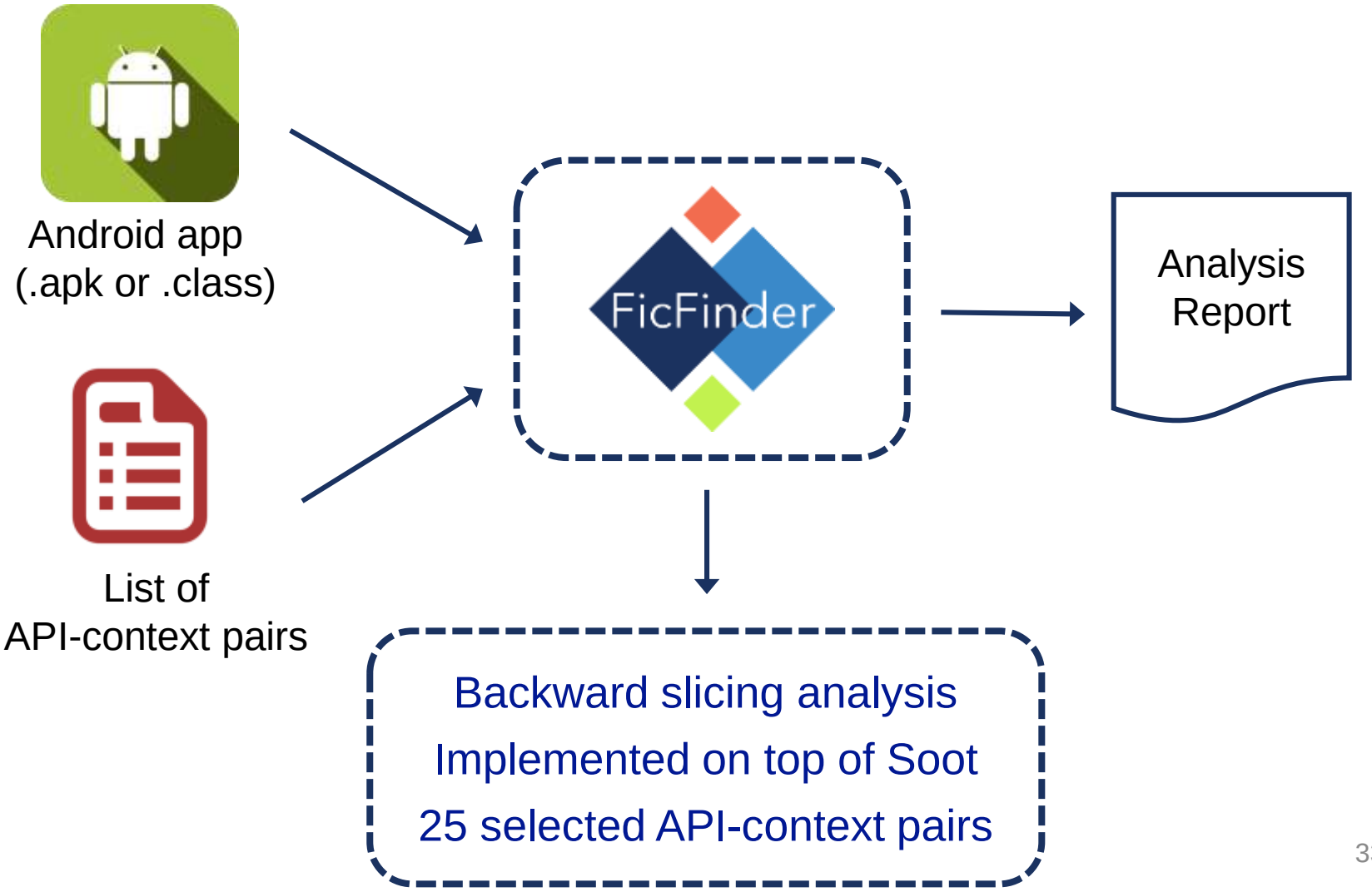

Example

```
void disableWAL() {
    SQLiteDatabase db = getDatabase();
    if (db.inTransaction()) {
        db.endTransaction();
    }

    db.disableWriteAheadLogging();

}
```

API: SQLiteDatabase.disableWriteAheadLogging()
Context: API_level < 16 ∧ Dev_model != "Nook HD"

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Slice:

db.disableWriteAheadLogging()

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Slice:

db.disableWriteAheadLogging()

API: SQLiteDatabase.disableWriteAheadLogging()
Context: API_level < 16 ∧ Dev_model != "Nook HD"

Example

```
void disableWAL() {
    SQLiteDatabase db = getDatabase();
    if (db.inTransaction()) {
        db.endTransaction();
    }

    db.disableWriteAheadLogging();

}
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void disableWAL() {
    SQLiteDatabase db = getDatabase();
    if (db.inTransaction()) {
        db.endTransaction();
    }
    if (isJellyBeanOrLater() || isNookHD) {
        db.disableWriteAheadLogging();
    }
}
boolean isJellyBeanOrLater() {
    return android.os.Build.SDK_VERSION >= 16;
}
boolean isNookHD {
    return android.os.Build.BRAND.equals("NOOK")
      && android.os.Build.PRODUCT.equals("HDplus")
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Evaluation

- Subject apps: latest version of 27 popular, actively-maintained Android apps
  - Covering 10 different categories
  - At least 5K downloads

App name	Category	KLOC	Rating	Downloads
ConnectBot	Communication	23.0	4.6	1M – 5M
AntennaPod	Media & Video	65.0	4.5	100K – 500K
c:geo	Entertainment	78.8	4.4	1M – 5M
AnySoftKeyboard	Tools	70.7	4.4	1M – 5M
…	…	…	…	…

Effectiveness of FicFinder

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46 of the 51 warnings are true positives
(Precision: 90.2%)

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  - Bug reports included **issue-related discussions**, **API guides** and **possible fixes** in the bug reports to help developers diagnose the issues

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  - Bug reports included **issue-related discussions**, **API guides** and **possible fixes** in the bug reports to help developers diagnose the issues

8 of the 14 bug reports were acknowledged by app developers.
5 issues were quickly fixed.

Usefulness of FicFinder

- Knowledge of API-context pairs extracted from our empirical study can be transferred across different apps

AnySoftKeyboard Issue 639:
Rule originally extracted from **K9 Mail**

K9 Mail Issue 1237:
Rule originally extracted from **CSipSimple**

Usefulness of FicFinder

- **4** of the 5 fixed issues were fixed by adopting our suggested fixes.

iSsO (1Sheeld developer)

Thanks, we will do it as you proposed in out next release. :)
Please let us know if you found more of these issues.

Usefulness of FicFinder

- **4** of the 5 fixed issues were fixed by adopting our suggested fixes.
- The other issue was fixed with an alternative patch, which was **semantically equivalent** to our suggested one.

iSsO (1Sheeld developer)

Thanks, we will do it as you proposed in out next release. :)
Please let us know if you found more of these issues.

Conclusion

- First large-scale empirical study of Android compatibility issues at code level
- API-context pair to model compatibility issues
- A static analysis tool, FicFinder, to detect fragmentation-induced compatibility issues

Future Work

- Automate API-context pair extraction
- Continue to improve the effectiveness of FicFinder

Thank you!

More information can be found in our paper

Or visit FicFinder's homepage:

http://sccpu2.cse.ust.hk/ficfinder/