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Boxify: Full-fledged App Sandboxing for Stock Android

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Oliver Schranz, **Philipp von Styp-Rekowsky**

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Motivation

FlaskDroid
[SEC'13]

AirBag
[NDSS'14]

Apex
[ASIACCS'10]

Cells
[SOSP'11]

Dr. Android & Mr. Hide
[SPSM'12]

TaintDroid
[OSDI'10]

AppGuard
[TACAS'13]

L4Android
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MOSES
[SACMAT'12]

ASM
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I-ARM-Droid
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DroidForce
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TrustDroid
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Aurasium
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RetroSkeleton
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OS Extensions

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AppGuard [TACAS‘13]

RetroSkeleton [MobiSys‘13]

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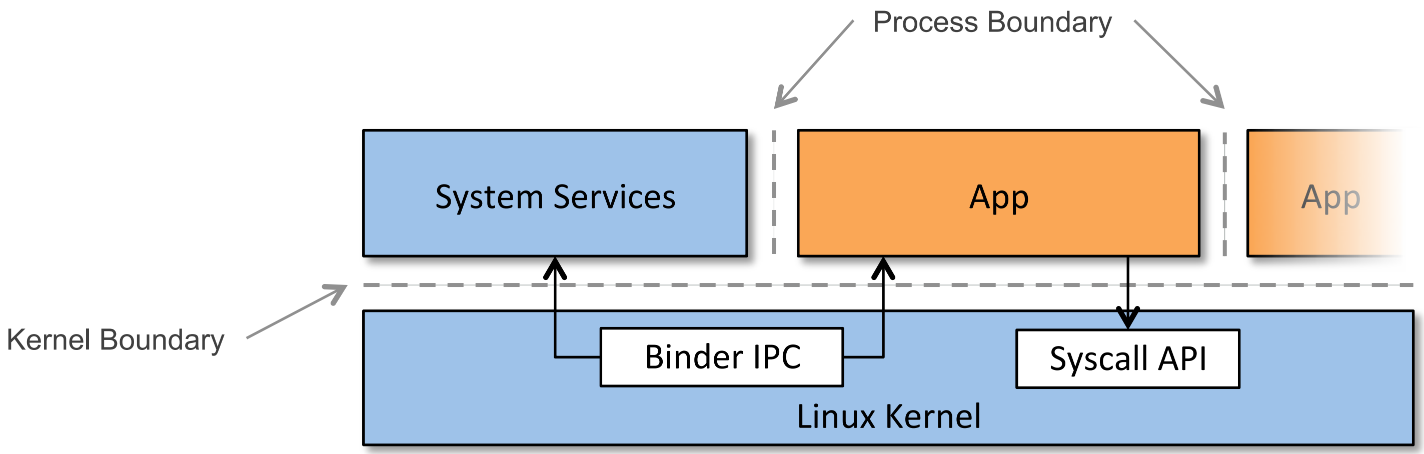
Aurasium [SEC‘12]

Application Layer Solutions

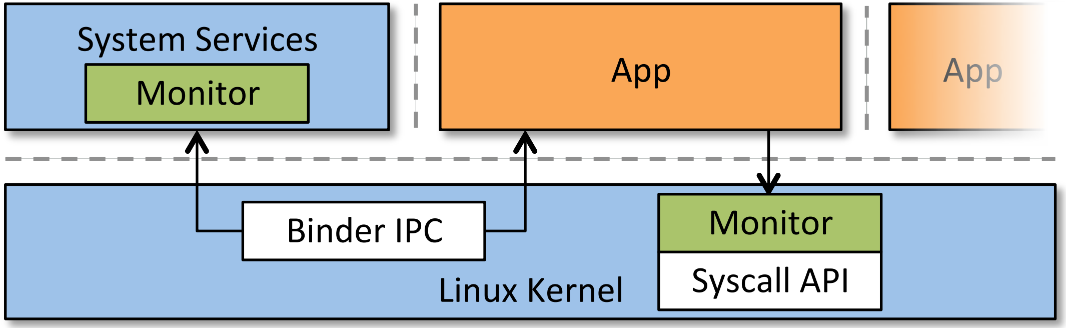
Android OS Extensions



Android OS Extensions

✓ Strong security

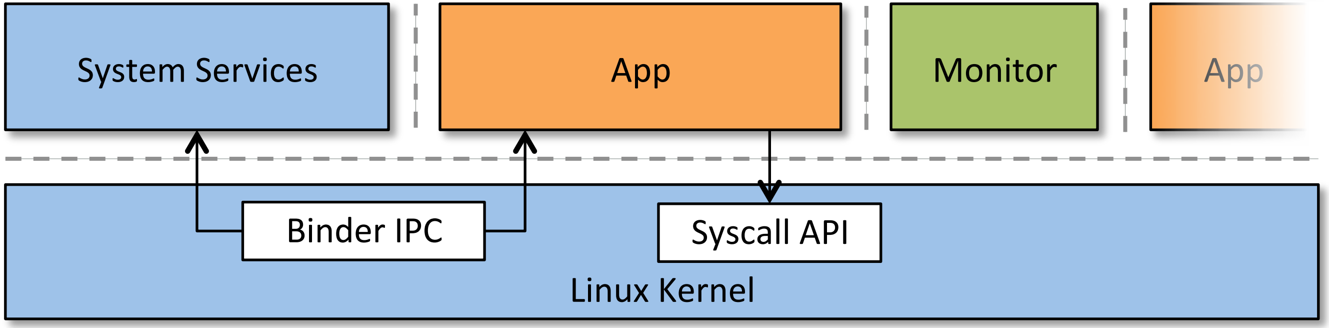
✗ Hard to deploy



Application Layer Solutions

✓ Easy to deploy

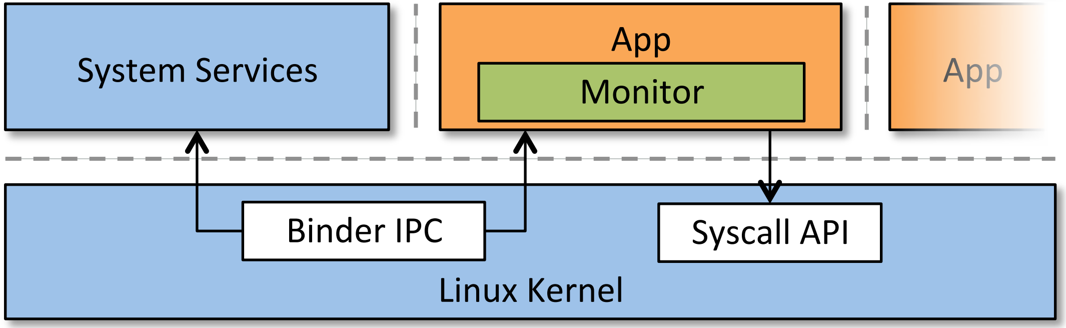
✗ No app monitoring possible



Inlined Reference Monitor

✓ Easy to deploy

✗ Weak security



Goal

OS Extensions

✖ Hard to deploy

✔ Strong security

Application Layer Solutions

✔ Easy to deploy

✖ Weak security

Goal

OS Extensions	Our Goal	Application Layer Solutions
✖ Hard to deploy	✔ Easy to deploy	✔ Easy to deploy
✔ Strong security	✔ Strong security	✖ Weak security

Objectives

Monitor and constrain untrusted applications

✓ **Easy to deploy**

- No firmware modification / root
- No application modification

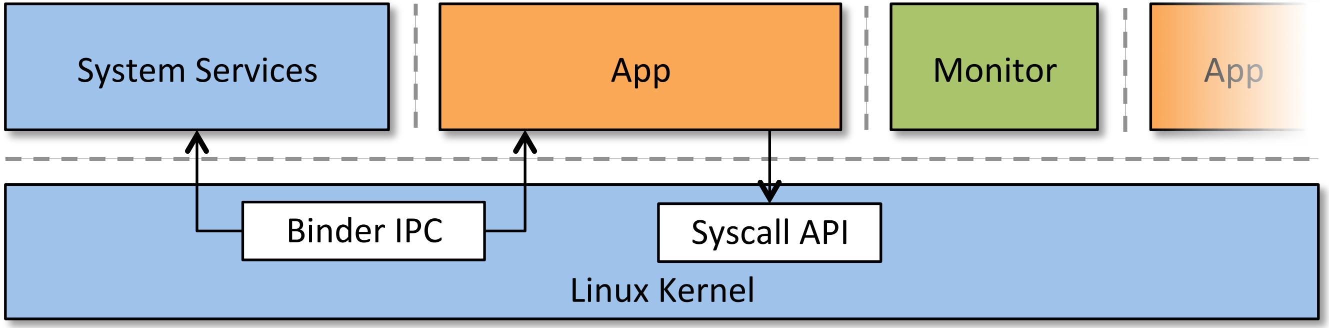
✓ **Strong security**

- Protected reference monitor
- Fail-safe defaults

Approach (1)

Objective: No firmware modification / root

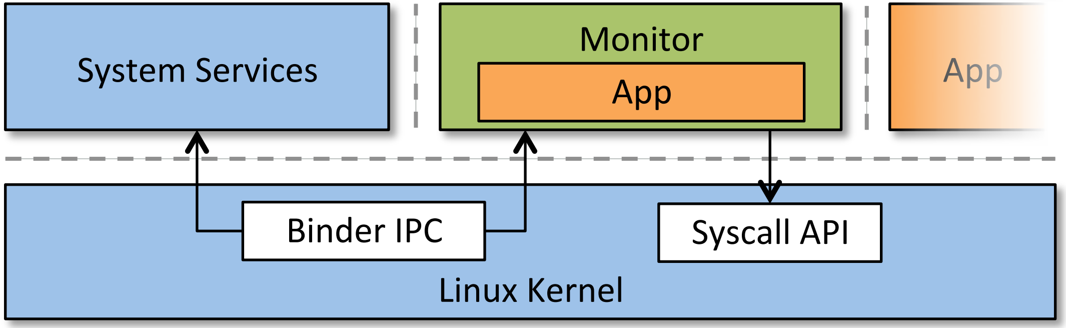
Solution: Regular user-space application



Approach (2)

Objective: No application modification

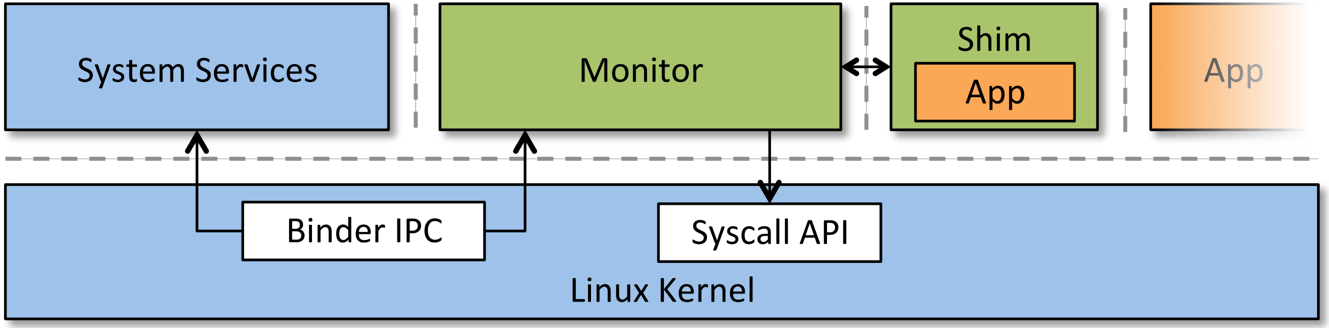
Solution: Application virtualization



Approach (3)

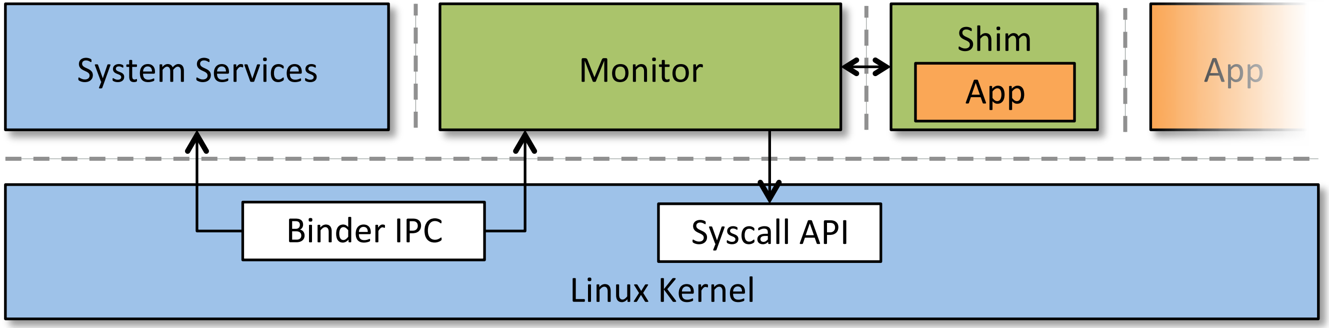
Objective: Protected reference monitor

Solution: Separate process



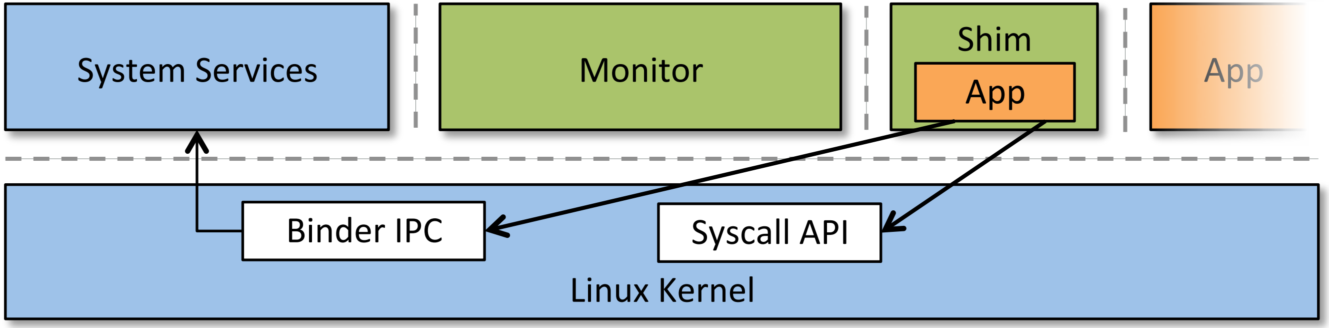
Approach (4)

Objective: Fail-safe defaults



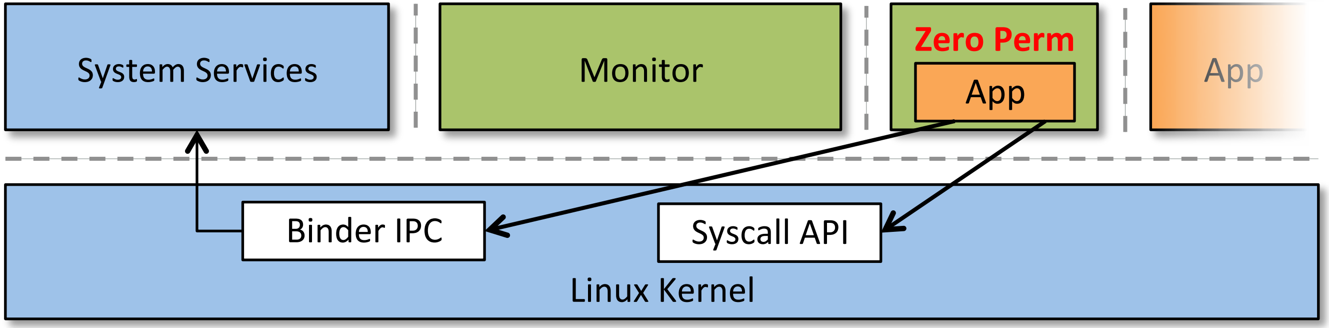
Approach (4)

Objective: Fail-safe defaults



Approach (4)

Objective: Fail-safe defaults



Approach (4)

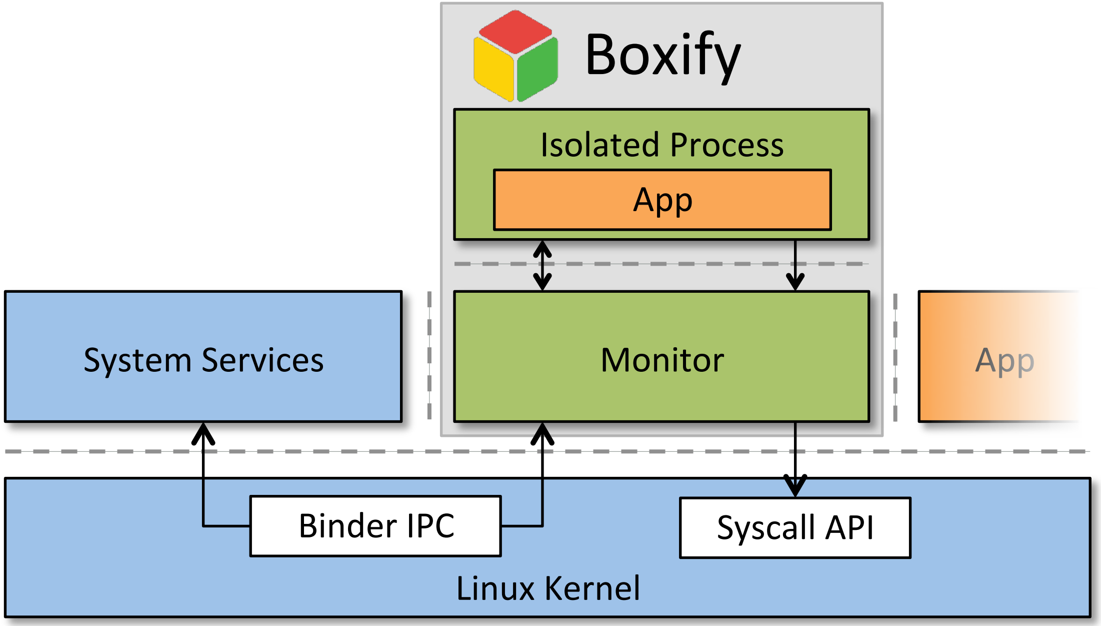
Objective: Fail-safe defaults

Solution: Isolated process

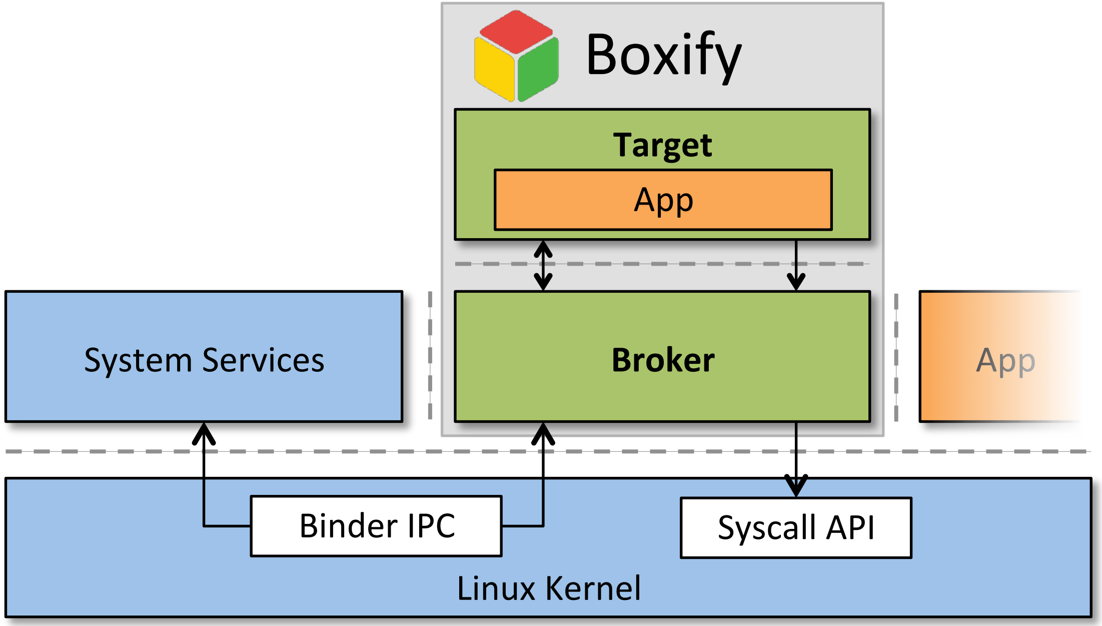
Isolated Process

- Allows *service components* to run isolated from the rest of the application
- Isolated processes
  - Have zero permissions
  - Have no access to system services
  - Run with a distinct, transient UID
  - Cannot write to the filesystem

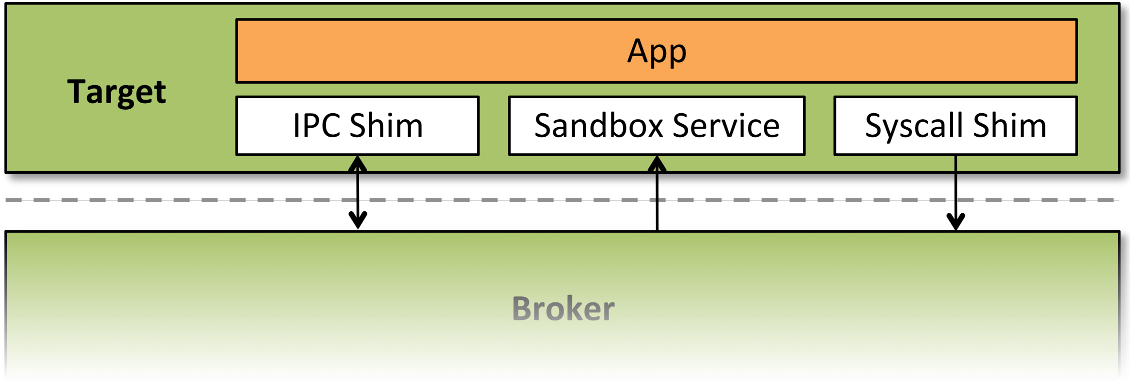
Architecture



Architecture



Target



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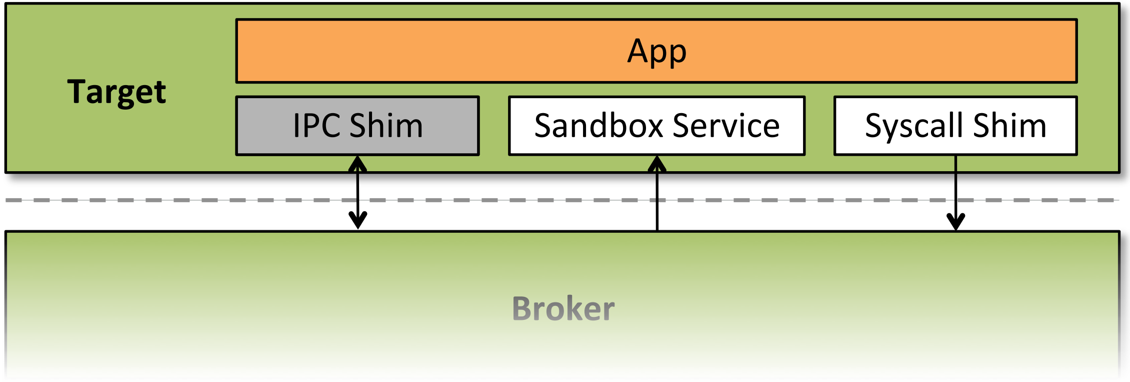
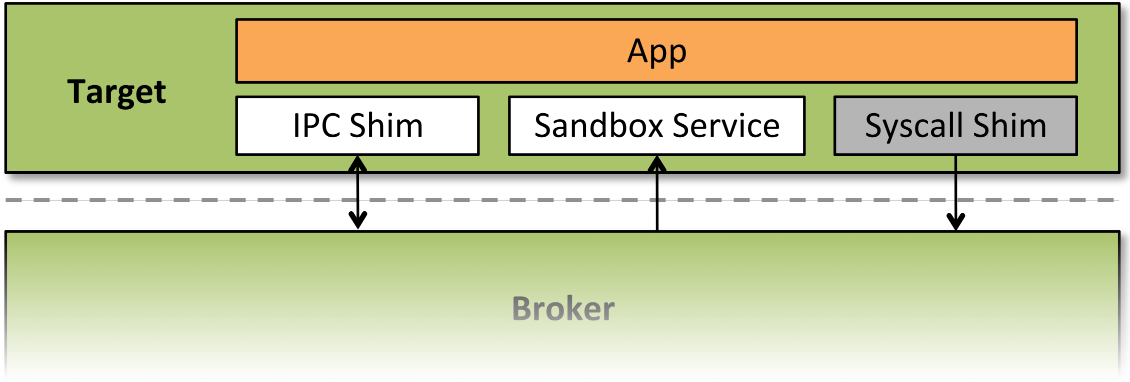


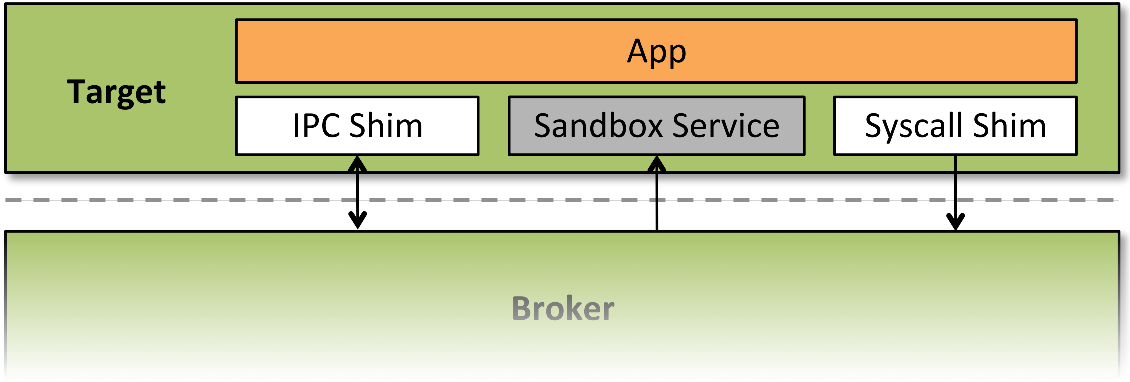
Divert Binder IPC to Broker

Target



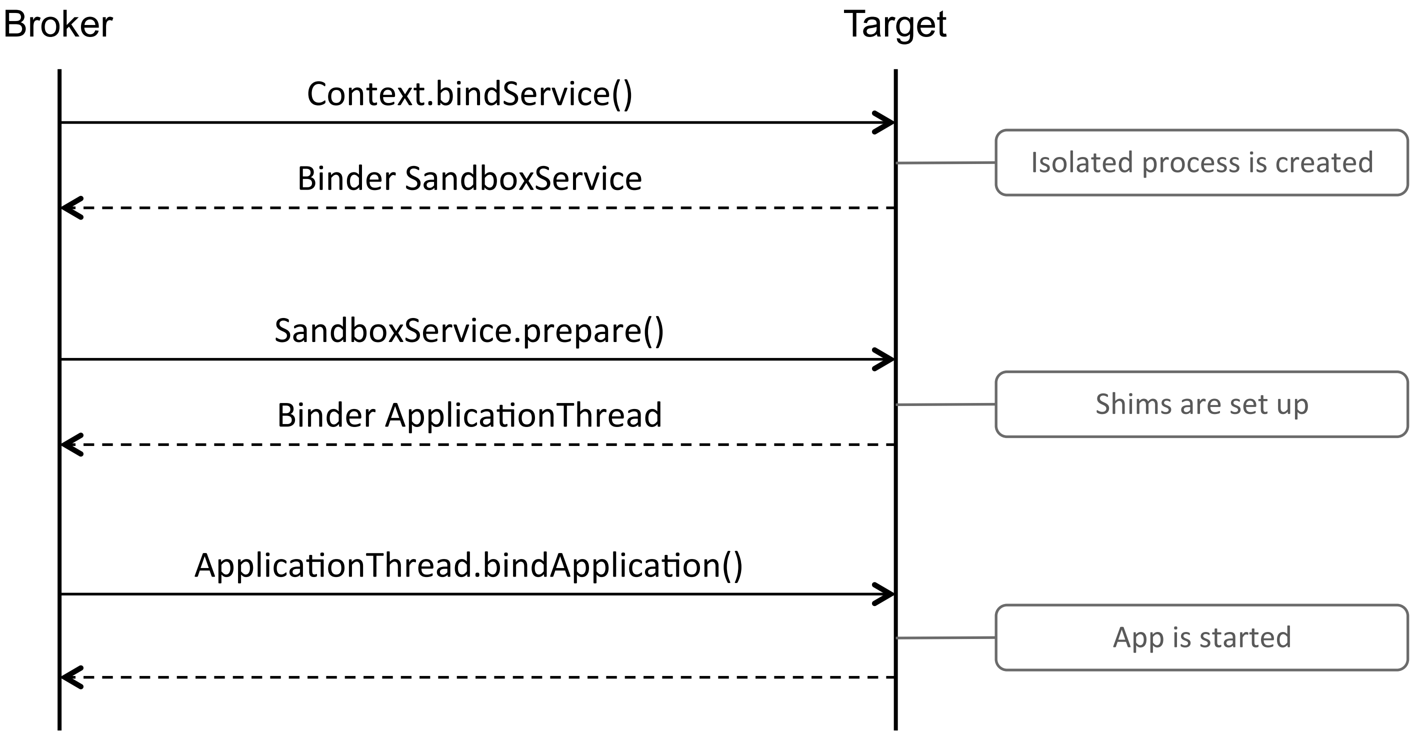
Divert Syscalls to Broker

Target

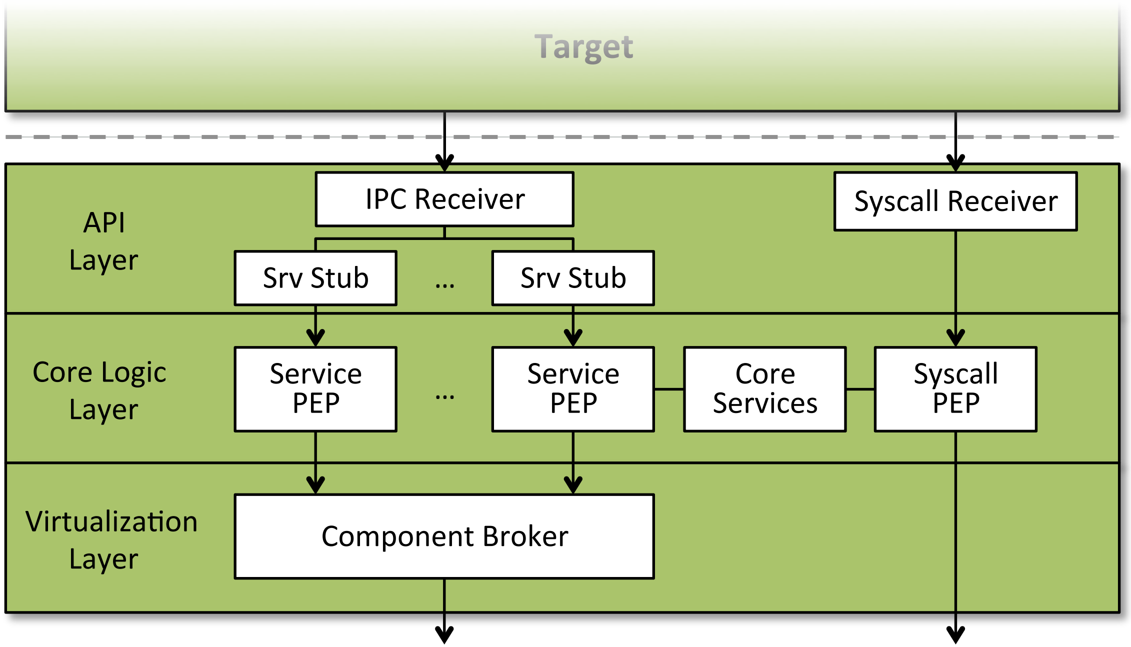


Control channel for loading/terminating apps

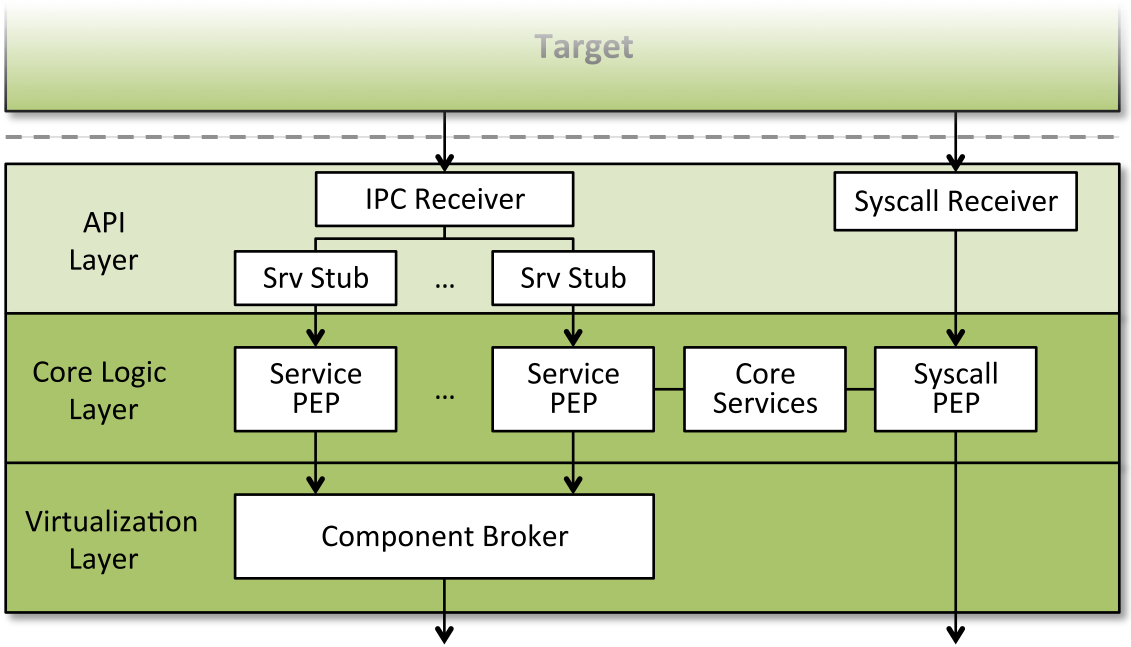
Loading an app



Broker

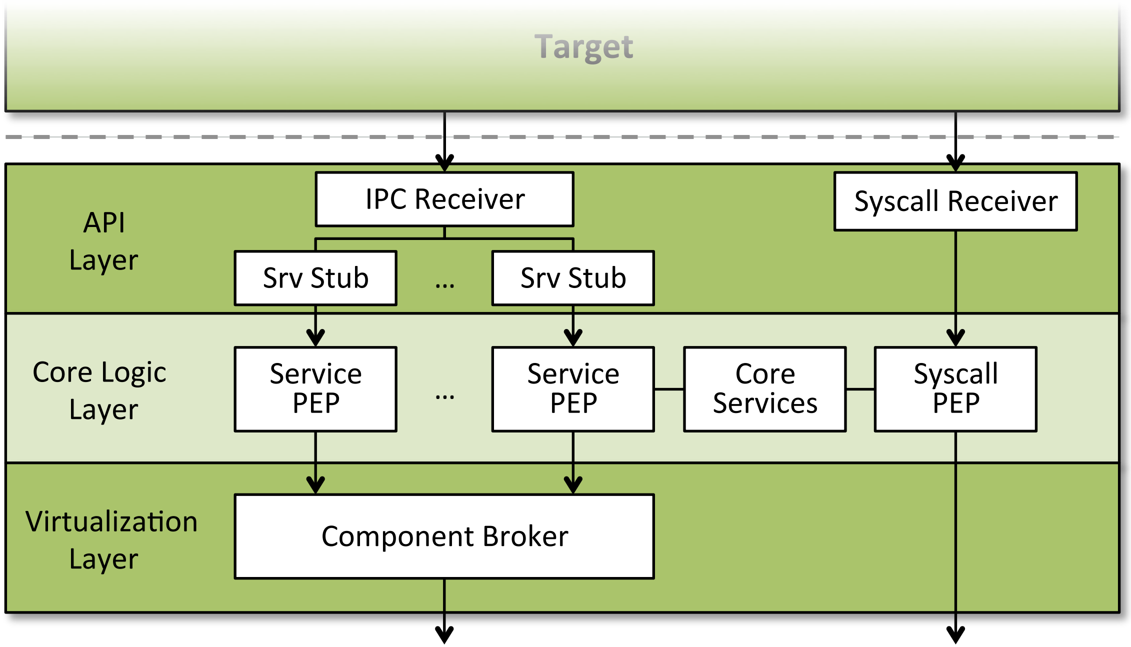

Target
API Layer
IPC Receiver
Syscall Receiver
Srv Stub
…
Srv Stub
Core Logic Layer
Service PEP
…
Service PEP
Core Services
Syscall PEP
Virtualization Layer
Component Broker

API Layer



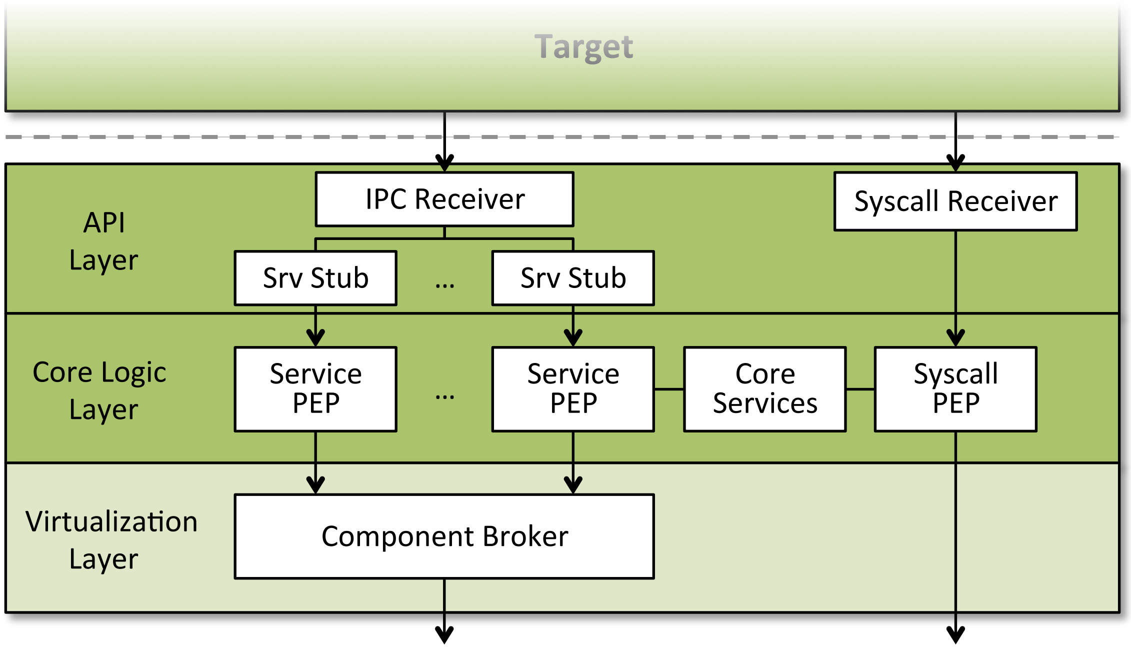
Establish compatibility across Android versions

Core Logic Layer



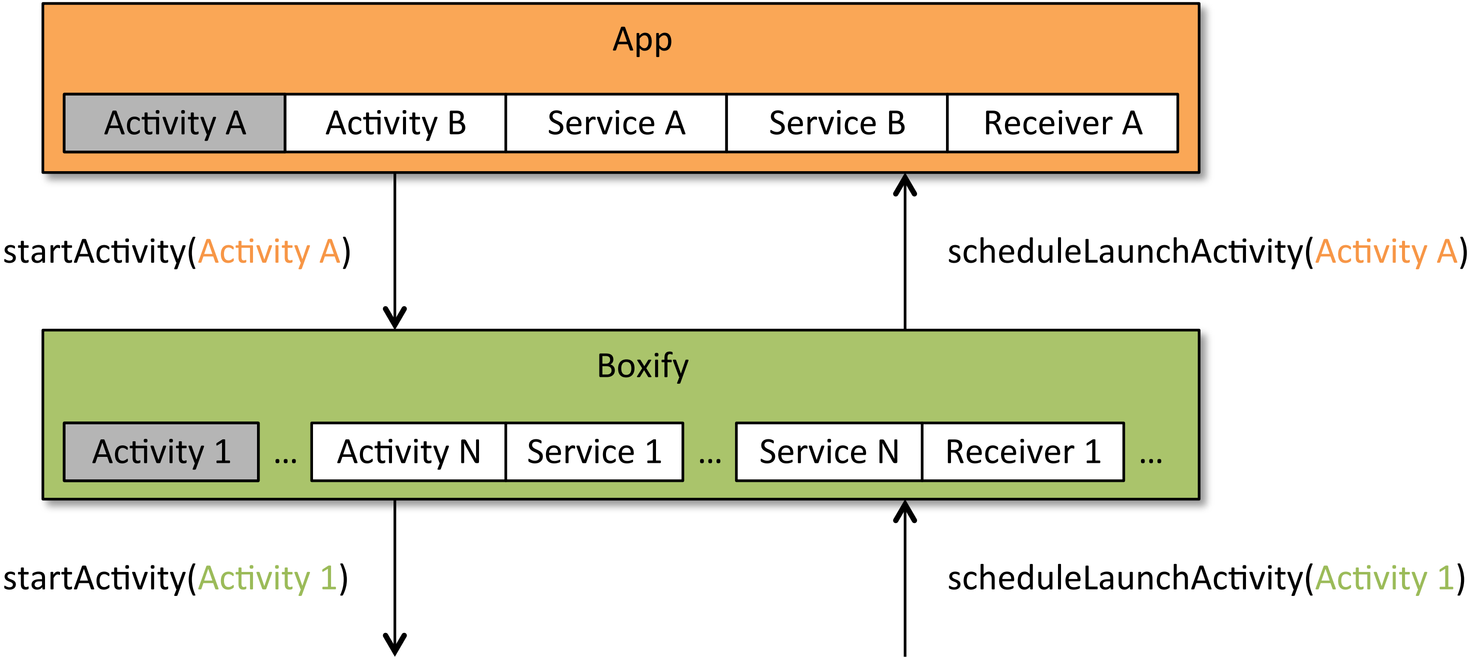
Baseline enforcement & virtual system services

Virtualization Layer



Translate between Boxify and Android system

Virtualization Layer

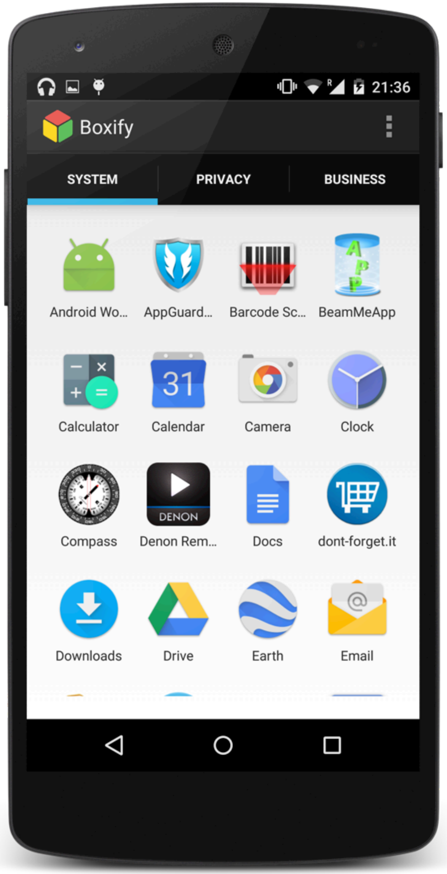


App
Activity A
Activity B
Service A
Service B
Receiver A
startActivity(Activity A)
scheduleLaunchActivity(Activity A)
Boxify
Activity 1
…
Activity N
Service 1
…
Service N
Receiver 1
…
startActivity(Activity 1)
scheduleLaunchActivity(Activity 1)

System Integration

- Launching apps
  - Dedicated Activity

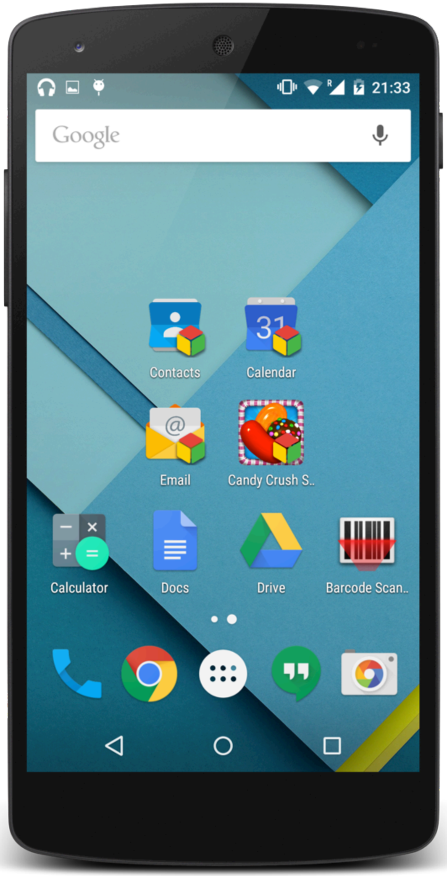
- Installing/Updating apps



System Integration

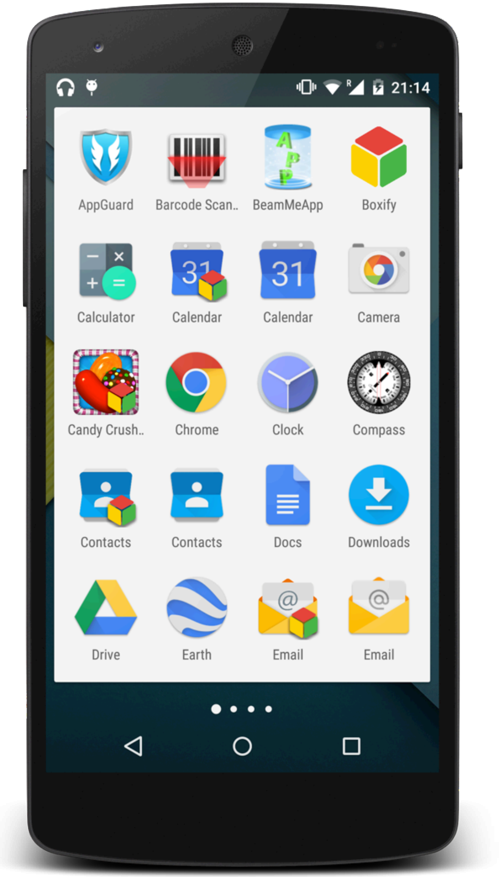
- Launching apps
  - Dedicated Activity
  - Shortcuts on Home Screen

- Installing/Updating apps



System Integration

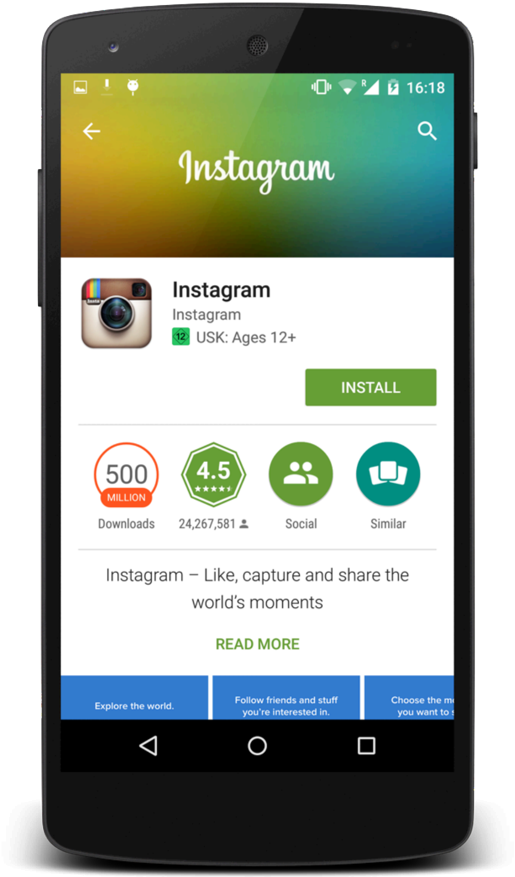
- Launching apps
  - Dedicated Activity
  - Shortcuts on Home Screen
  - Virtualized Launcher
- Installing/Updating apps



System Integration

- Launching apps
  - Dedicated Activity
  - Shortcuts on Home Screen
  - Virtualized Launcher

- Installing/Updating apps
  - Directly via App Stores



Instagram
Instagram
USK: Ages 12+

Instagram – Like, capture and share the world's moments

Performance

Middleware Microbenchmark

API Call	Native	On Boxify	Overhead
Open Camera	103.24 ms	104.48 ms	1.24 ms (1.2%)
Query Contacts	7.63 ms	8.55 ms	0.92 ms (12.0%)
Insert Contacts	66.49 ms	67.51 ms	1.02 ms (1.5%)
Delete Contacts	75.86 ms	76.81 ms	0.95 ms (0.9%)

Performance

Syscall Microbenchmark

System Call	Native	On Boxify	Overhead
`create`	47.2 µs	162.4 µs	115.2 µs
`open`	9.5 µs	122.7 µs	113.2 µs
`remove`	49.5 µs	159.6 µs	110.1 µs
`mkdir`	88.4 µs	199.4 µs	111.0 µs

Performance

Benchmark Tools

Tool	Native	On Boxify	Loss
CF Bench	16082 Pts	15376 Pts	4.3%
Geekbench	1649 Pts	1621 Pts	1.6%
PassMark	3674 Pts	3497 Pts	4.8%
Quadrant	7820 Pts	7532 Pts	3.6%

Discussion & Limitations

- Cancels Android‘s own access control checks
- Violates *Principle of Least Privilege*
- Full kernel attack surface available
- Presence of Boxify detectable

Use Cases

- Instantiate OS extensions at application layer
  - Fine-grained access control
  - Information flow control
  - Dual-persona, BYOD
  - Dynamic analysis
  - Automated testing
  - Xposed
  - …

Conclusion

- Lightweight application virtualization for stock Android
- No root or app modification required
- Low runtime performance overhead
- Wide range of applications

Thank you!