Northeastern University
Systems Security Lab

PatchDroid: Third Party Security Patches for Android

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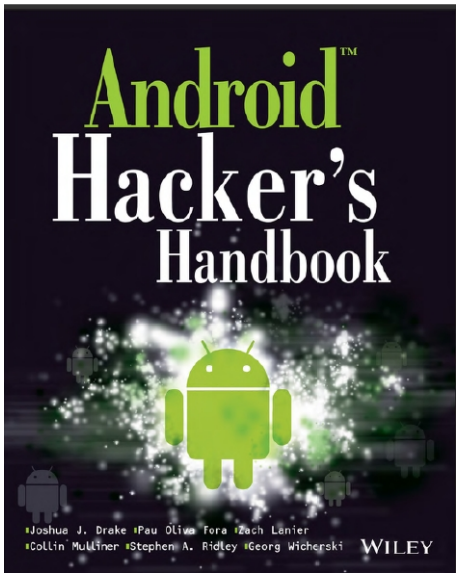
- 'postdoc' Security Researcher
  - $HOME = Northeastern University, Boston, MA, USA
  - `cat .plan`
    specialized in mobile handset security

- `cat .project`
  - OS and software security
  - Android security
  - SMS and MMS security
    (mostly handset related)
  - Early work on NFC phone security



Android Security

- Android platform contains security vulnerabilities
  - New vulnerabilities are discovered all the time
- Android has built-in update mechanism
  - Over-the-Air (OTA) updates
  - No desktop computer needed
- Google patches a bug
  - Update arrive at Nexus devices (Google devices)
  - Patches are pushed to AOSP
  - Manufacturers are notified

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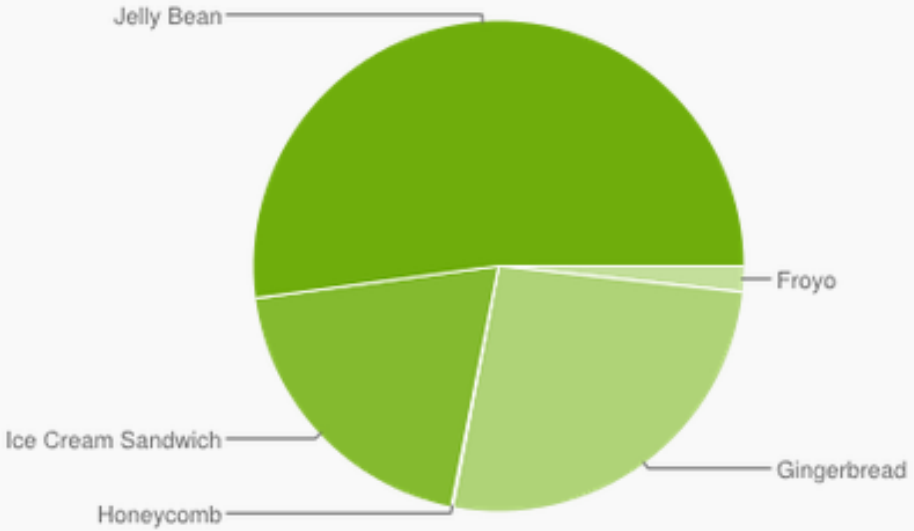
  - Patches are pushed to AOSP
  - Manufacturers are notified
- **Unfortunately, only few devices receive updates!**

Missing Updates

- Manufacturer
  - Stop supporting devices after about 18 months
  - Manufacturer specific bugs
- Carrier
  - Customize firmware
  - Delay updates due to customization efforts
  - Do not update at all
- Result → many devices run out of date software
  - Software that contains publicly known vulnerabilities

Android Platform Version Diversity

Version	Codename	API	Distribution
2.2	Froyo	8	1.7%
2.3.3 - 2.3.7	Gingerbread	10	26.3%
3.2	Honeycomb	13	0.1%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	19.8%
4.1.x	Jelly Bean	16	37.3%
4.2.x		17	12.5%
4.3		18	2.3%



Source: Google (Nov. 1, 2013)

Patching Vulnerabilities on Android Devices

- Overlooked problem until now
  - Google and manufacturers' duty
- Only solution so far is 3rd party firmware
  - Available for limited number of devices only
  - Manual process, limited follow-up updates
- Platform diversity is the key problem
  - Large number of different devices + software versions
  - Any solution has to address these problems

Challenges

- No access to source code
  - AOSP ≠ code running on devices
  - Modifications by the manufacturer
- Issue with modification of system files and partitions
  - Modified binaries might prevent system from booting
  - Cannot add/replace files on signed partitions
- Scalability vs. Testing
  - Too many different devices and OS versions
  - Patches need to be decoupled from the source code

Contributions

- **PatchDroid**: third-party security patches for Android
  - Includes attack detection and warning mechanism
- Scalable
  - Independent from device and Android version
  - Support for managed Dalvik bytecode and native code
- Reliable
  - No permanent modification (no bricked devices)
- Usable in practice
  - No noticeable overhead (no device slow down)
  - Does not rely on access to source code

Contributions

- **PatchDroid**: third-party security patches for Android
  - Includes attack detection and warning mechanism

- Scalable
  - Independent from device and Android version
  - Support for managed DalvikVM bytecode and native code
- Transparent
  - No permanent modification (no bricked devices)

- Usable in practice
  - No noticeable overhead (no device slow down)
  - Does not rely on access to source code

PatchDroid: Scalable Third-Party Security Patches for Android Devices
Collin Mulliner, Jon Oberheide, William Robertson, Engin Kirda
In the Proceedings of the 29th Annual Computer Security Applications Conference (ACSAC), Dec. 2013

Overview

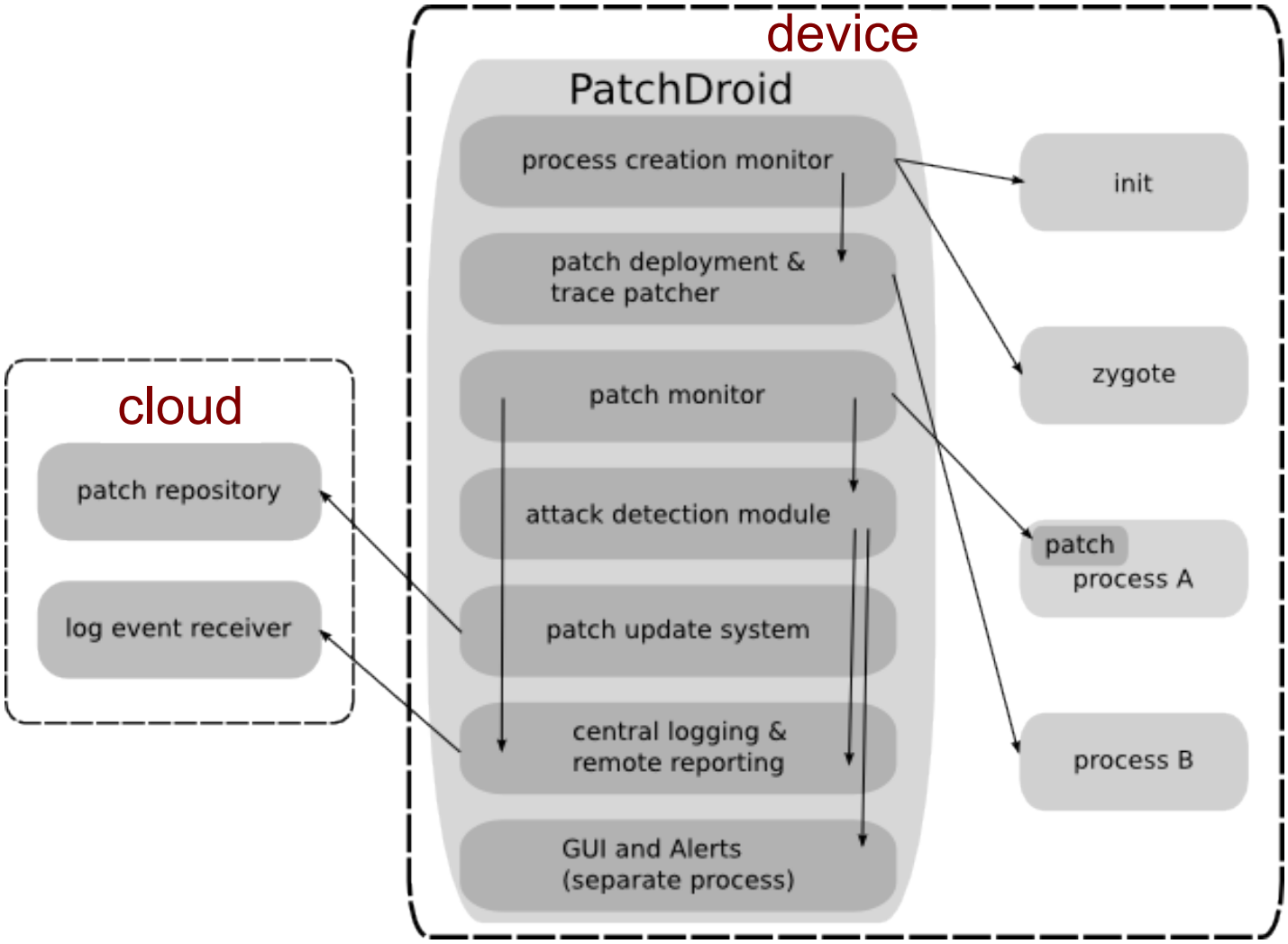
- Design
- Patches and Patching
- Implementation
- Technical Insights
- System Evaluation
- Case Study: Master Key bug(s)

The PatchDroid System

- In-memory patching at runtime
  - Need to patch processes at startup
    - Before process executes vulnerable code
    - Monitor system for new processes
  - No need to modify system files or system partitions

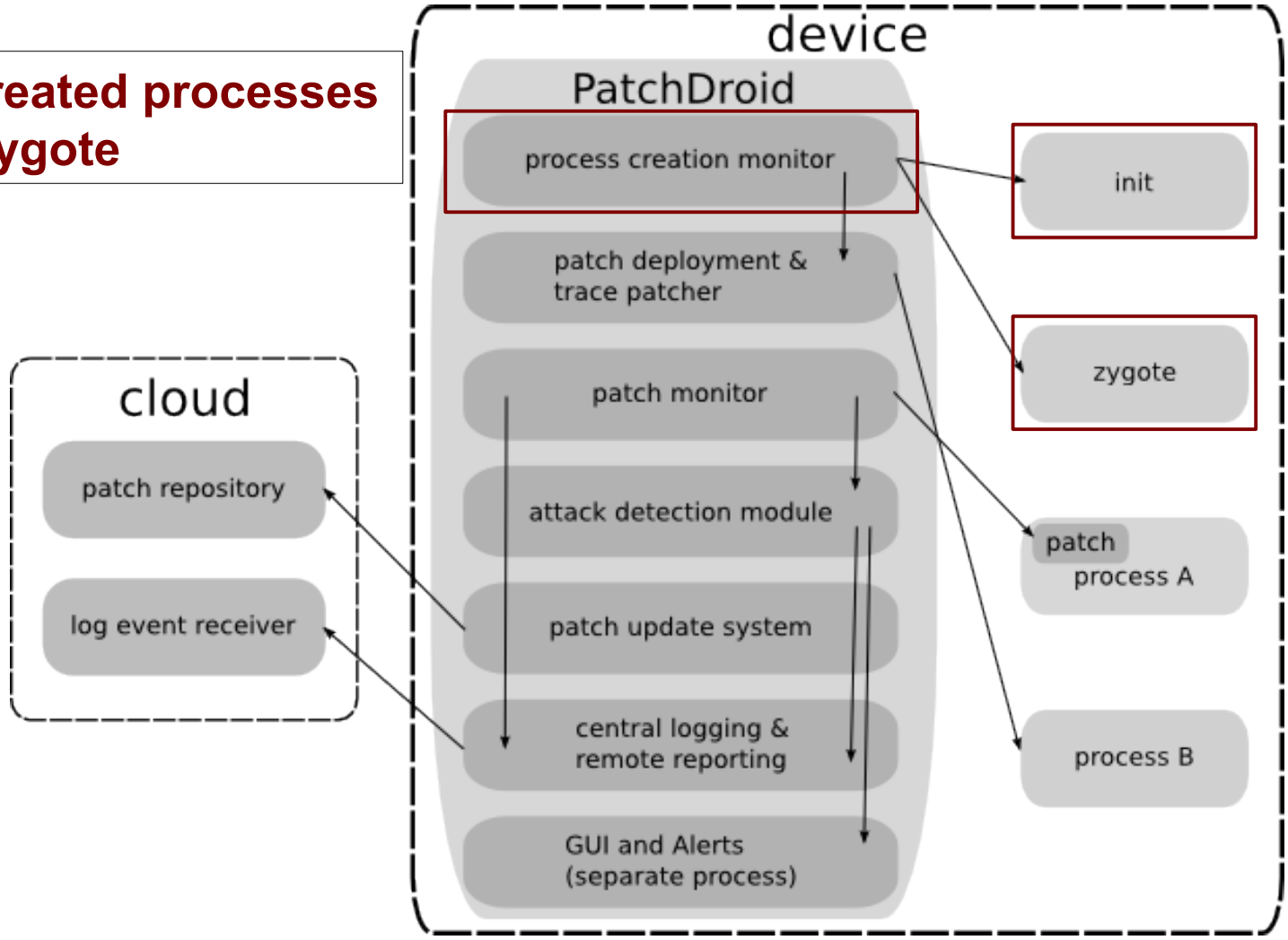
- Patches as independent code
  - Self-contained shared library
  - Patching via function hooking
  - No access to original source code required
  - Scale across different OS versions

PatchDroid : Architecture



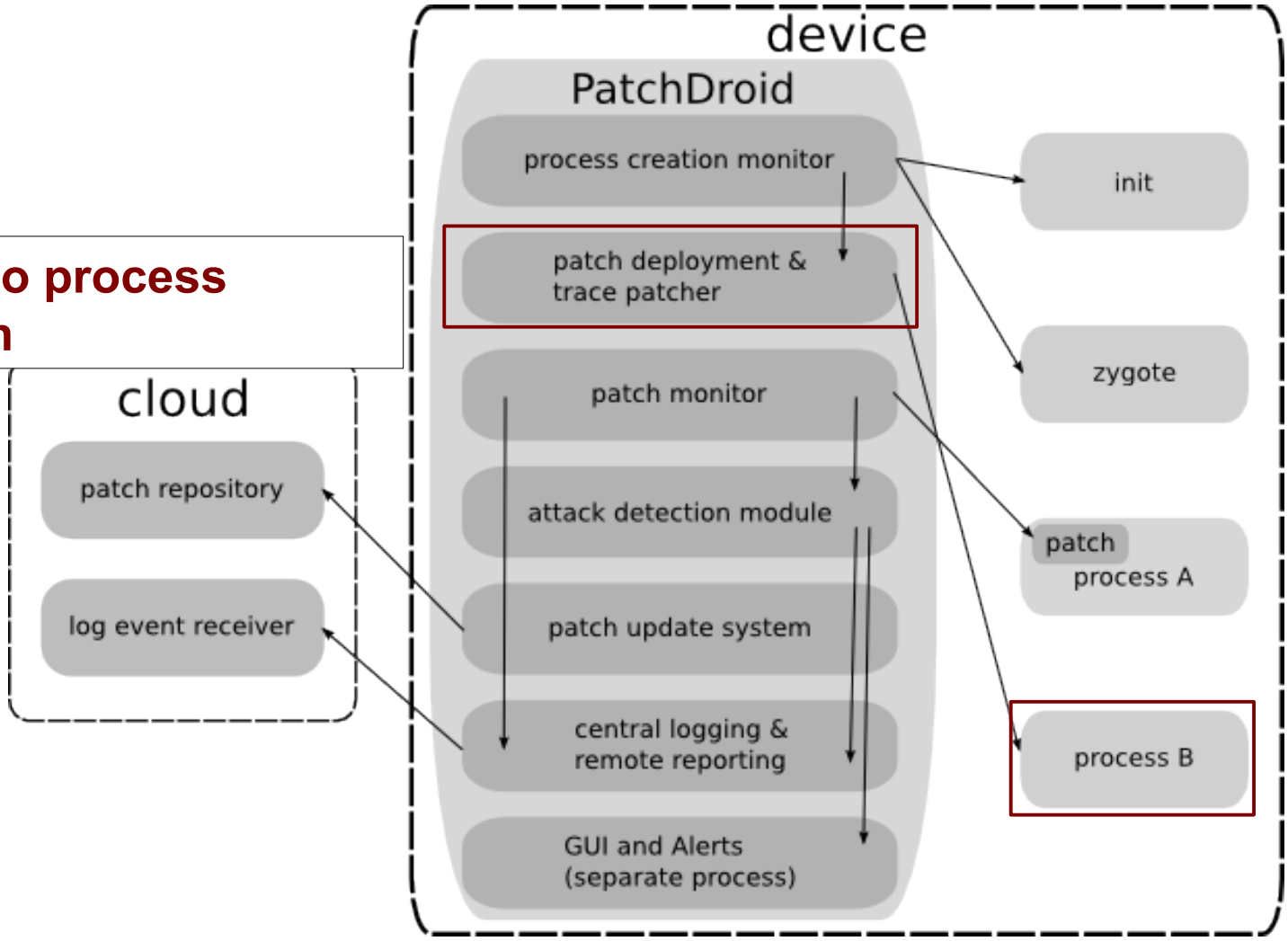
PatchDroid : Architecture

Identify newly created processes - trace init and zygote



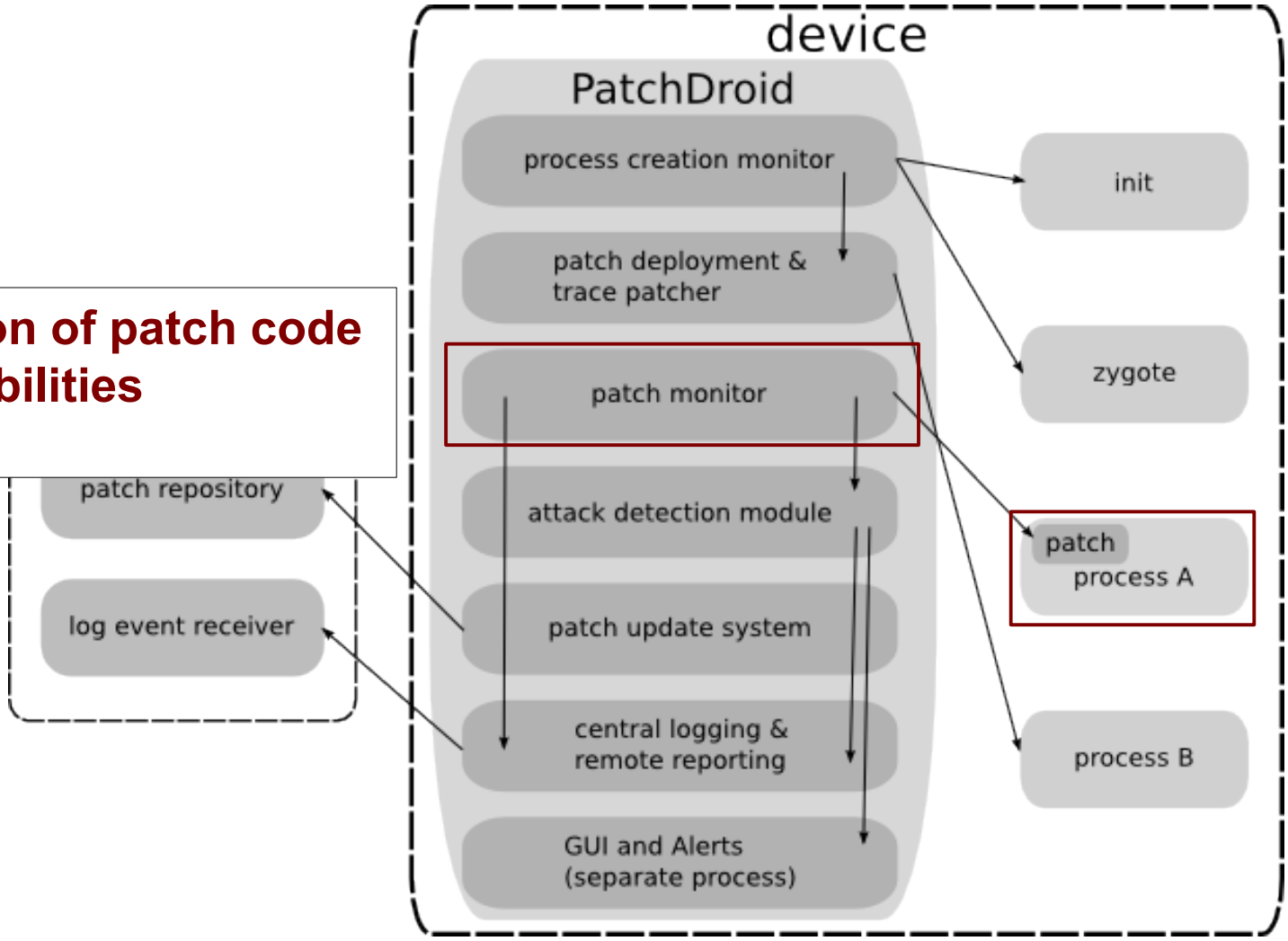
PatchDroid : Architecture

Deploy patch into process
- library injection

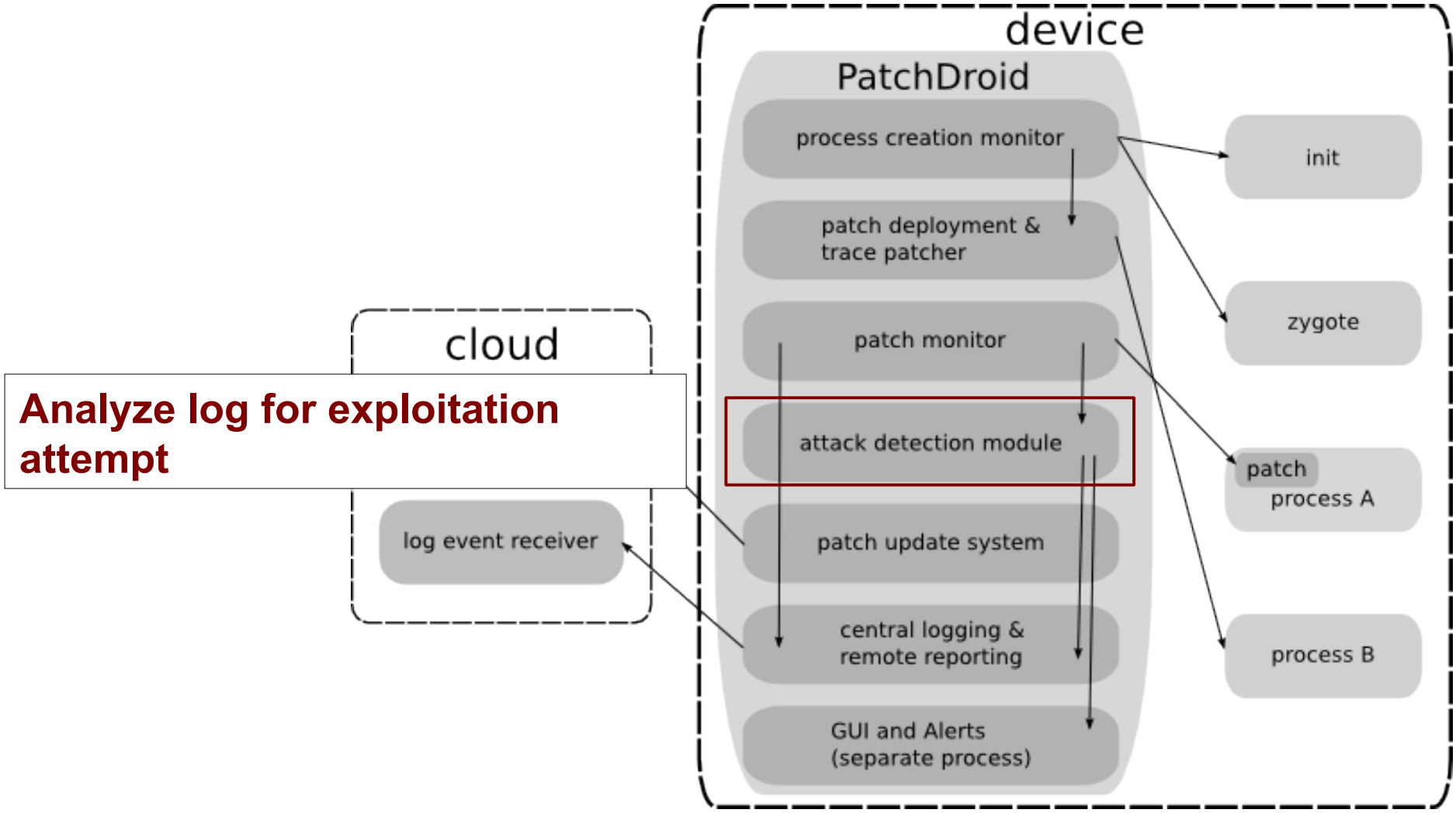


PatchDroid : Architecture

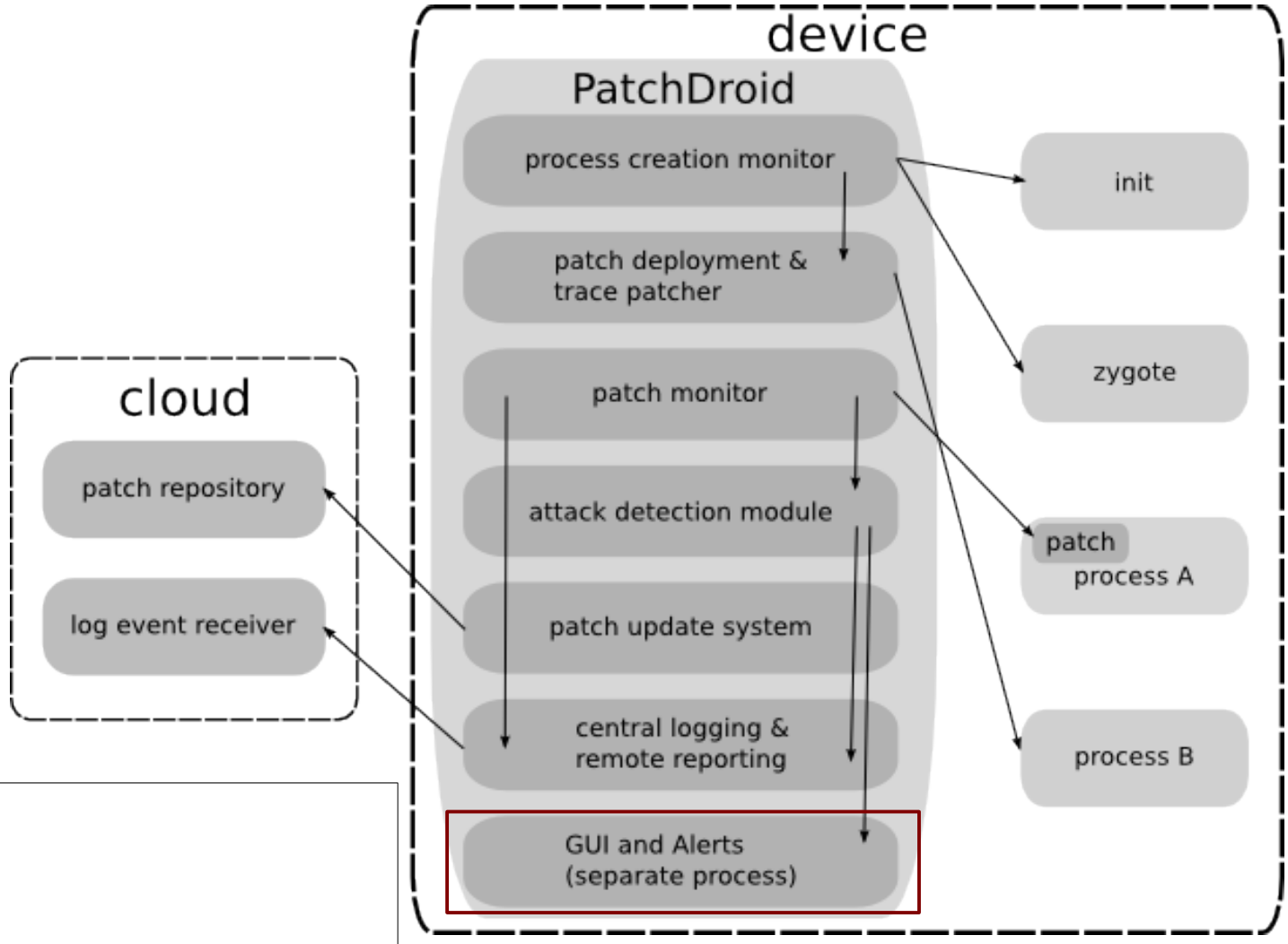
Monitor execution of patch code
- check for instabilities
- collect logs



PatchDroid : Architecture



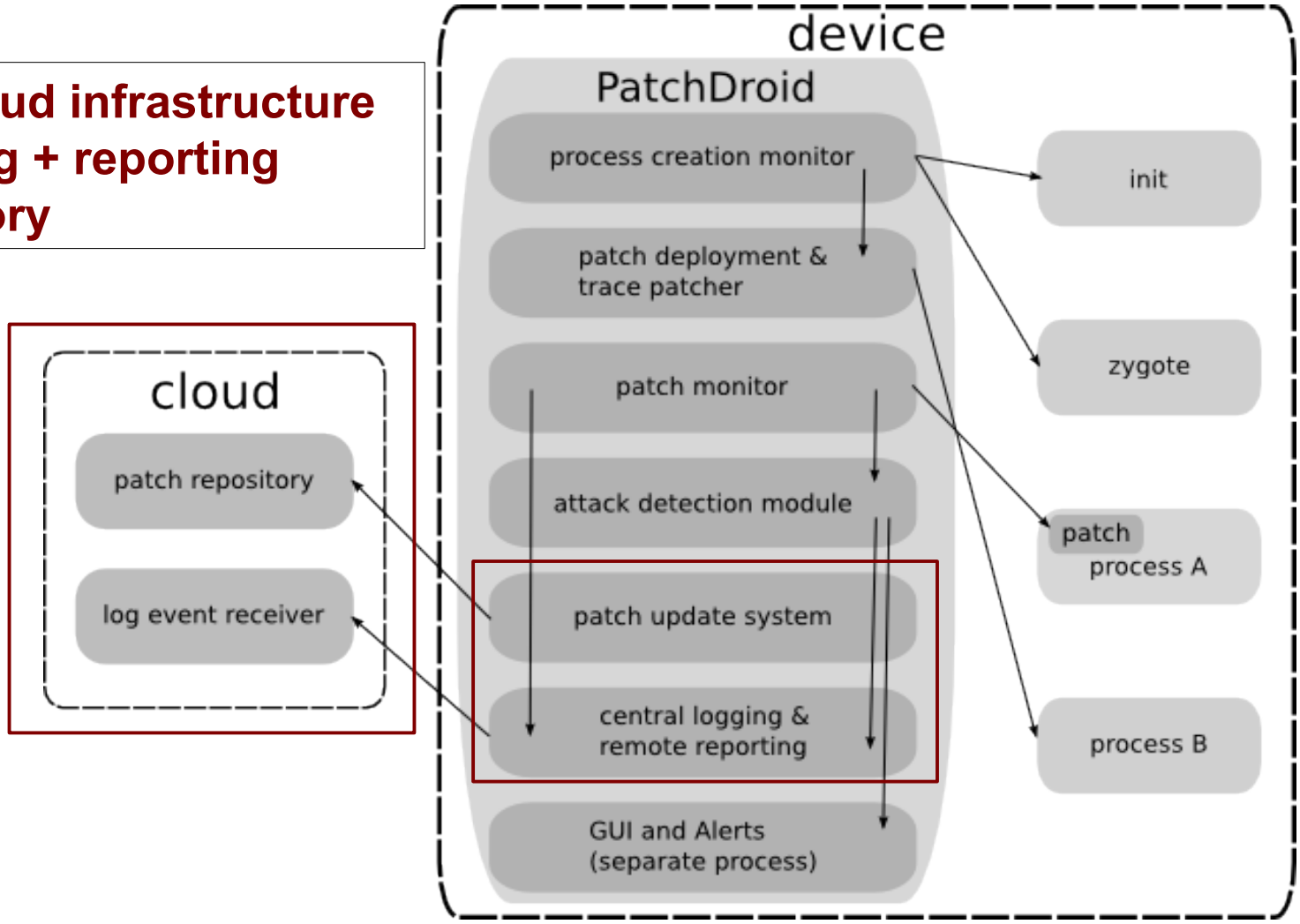
PatchDroid : Architecture



PatchDroid App
-GUI
-display alerts

PatchDroid : Architecture

PatchDroid cloud infrastructure
-central logging + reporting
-patch repository

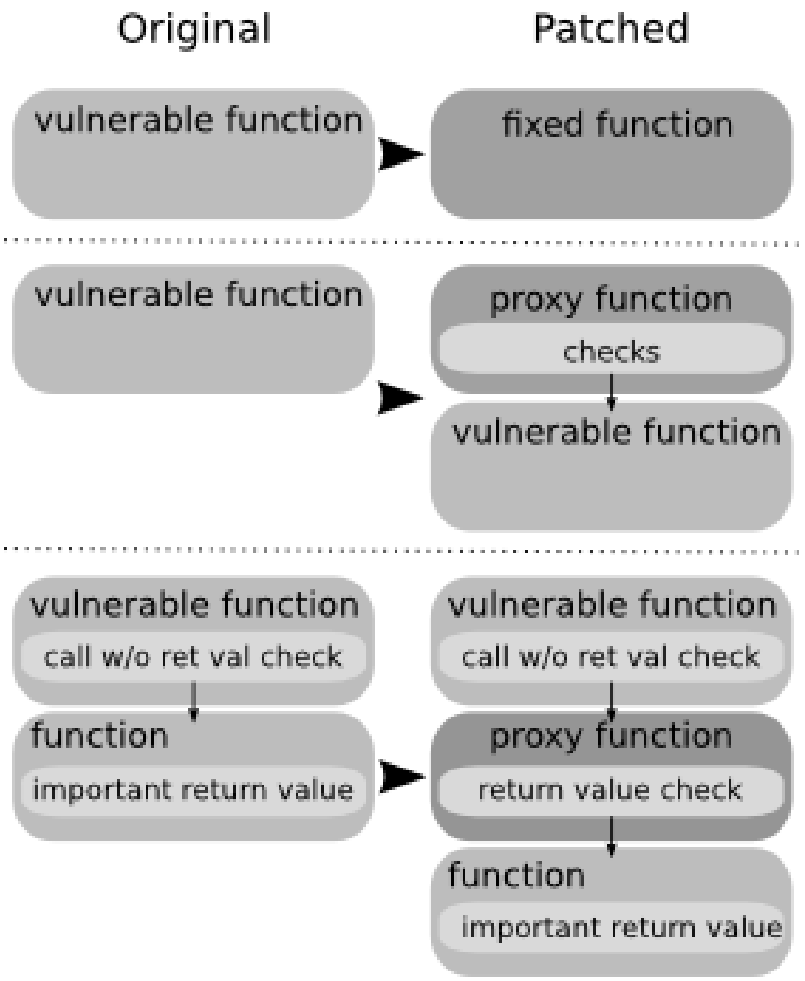


Anatomy of a Patch

- Replacement for vulnerable function
  - Equivalent code that does not contain the vulnerability
  - Wrapper that adds input/output sanitization
- Installation
  - Hook vulnerable function(s)
    (original function needs to be kept in working condition)
- Communication link
  - Read configuration parameters
  - Write log messages

Patching Strategies

- Function replacement
- Proxy function
- Failed return value check

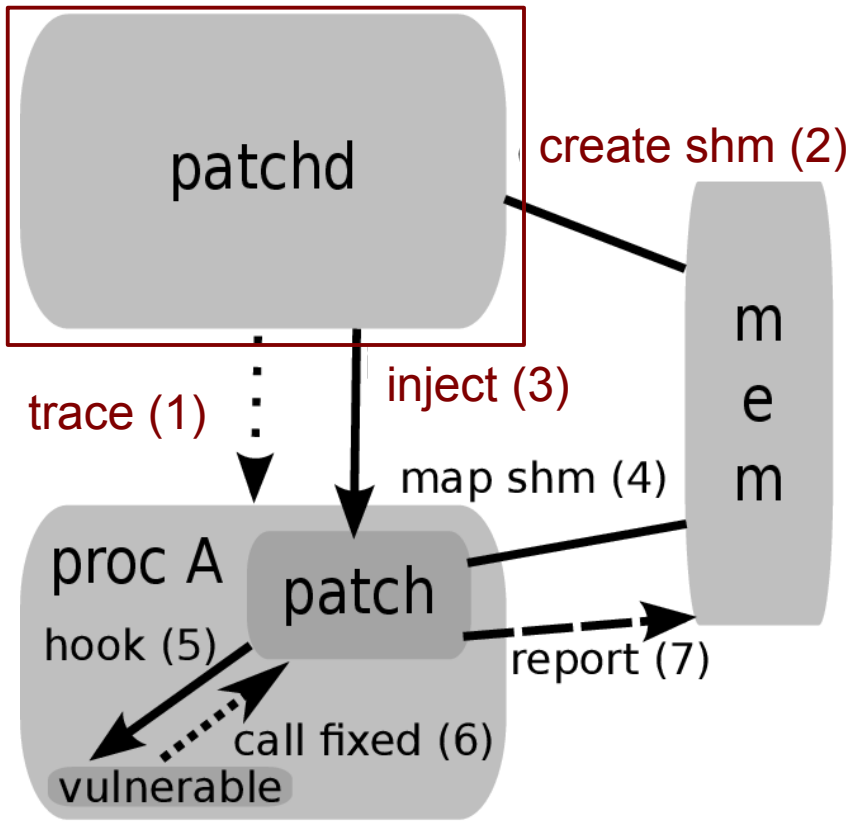


Example: Failed return value check

- int res = setuid(nobody);
  - res == 0 → success, privileges dropped
  - res == -1 → failure, privileges NOT dropped
- Missing check of result in zygote (zimperlich exploit)
  - fork() until setuid() failed due to resource limit
    → new process stays root!
- Patch: wrap setuid()
  - check result
  - terminate if res != 0

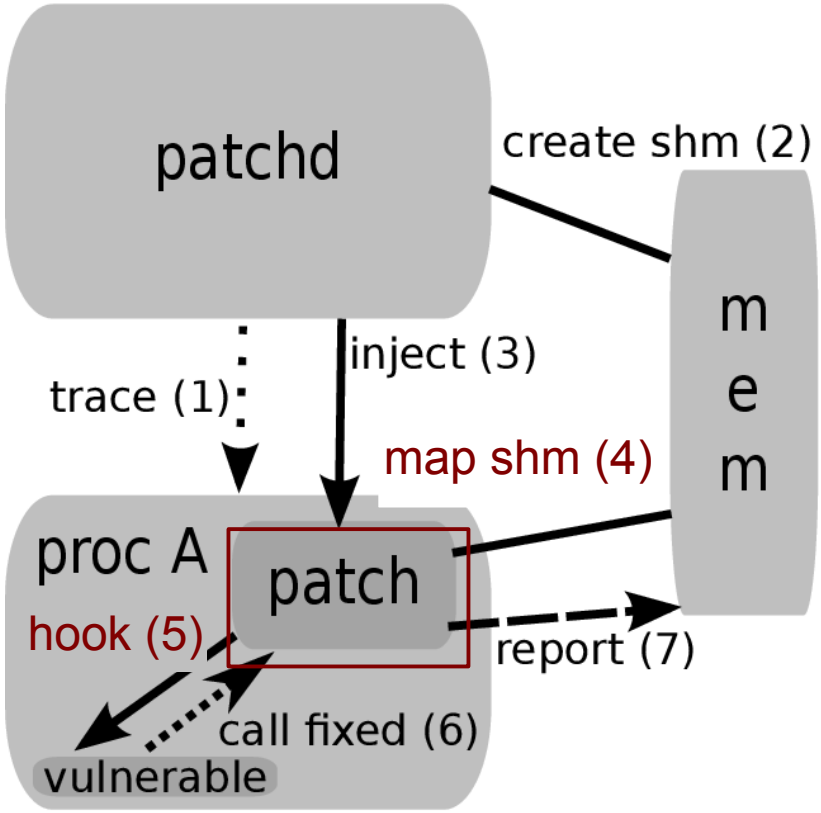
Patch Life Cycle

- Deployment
  - trace target process
  - setup communication
  - inject patch library



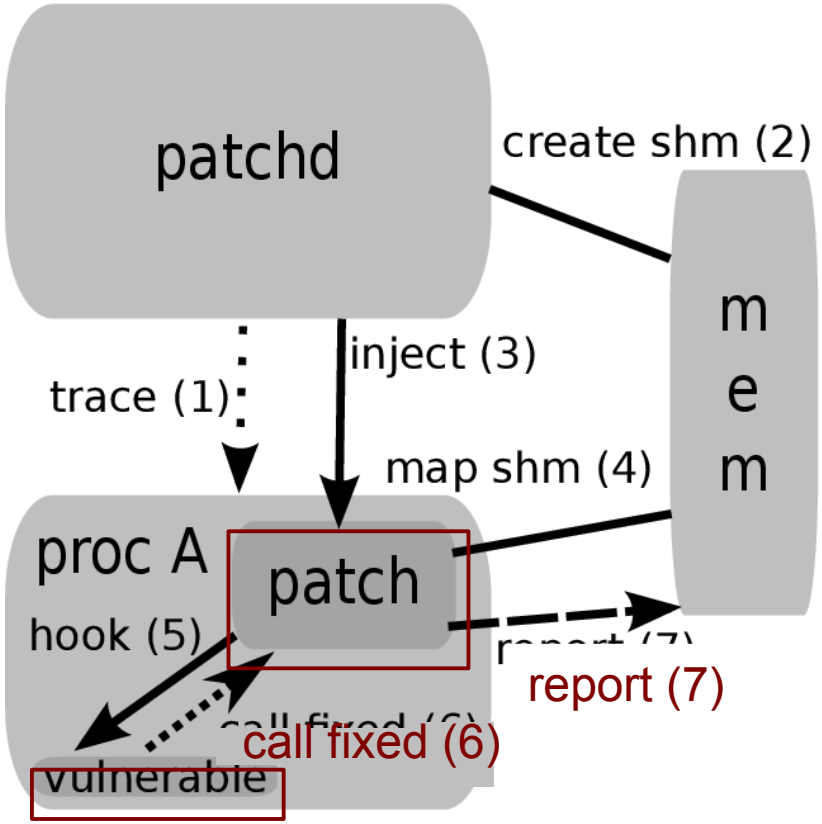
Patch Life Cycle

- Installation
  - connect communication
  - hook function



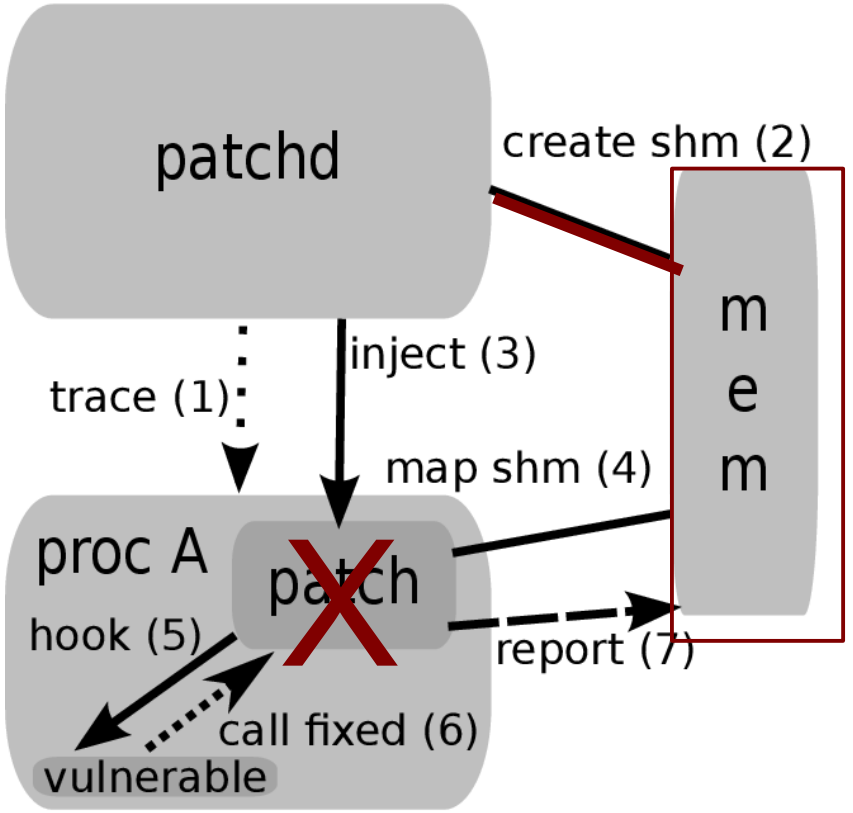
Patch Life Cycle

- Fixed function is called
  - log and report attack
  - collect patch telemetry
  - (call original function)



Patch Life Cycle

- Patch failure
  - detected using telemetry
  - failing patch is removed from system



- Enables scalable testing of patches in the field

Implementation

- *patchd:* the patch daemon
  - Monitor system for newly created processes
  - Inject patches into processes
  - Monitor patched processes
- PatchDroid Application
  - User interface
  - Helper service
  - Attack notification
- Patches
  - 3 patches for privilege escalation (native code)
  - 2 patches for bugs in managed code (Dalvik code)

Technical Insights

- patchd
  - uses `ptrace()` API for monitoring and injection
  - **requires root access**

- PatchDroid operates in /data/../com.patchdroid.patchdroid
  - no need to modify 'system' FS
    - system FS could be signed
  - secure against other non root apps
  - can be removed like any other app (reliable)

- patchd + PatchDroid (dalvik) app
  - Need both to stimulate system services
    - e.g., get process unstuck while patching it

Technical Insights cont.

- Patch
  - Shared library
  - Self-contained → no external dependencies
  - Shared memory region to communicate with patchd

```
drwxr-xr-x system   system            2014-03-05 20:42 lib
-r-xr-xr-x app_69   app_69       71104 2014-03-05 20:43 patchd
-rw-rw---- root     root            10 2014-03-07 14:40 checks
-rw-r--r-- app_69   app_69       37932 2014-03-05 20:43 libvoldmeta.so
-rw-r--r-- app_69   app_69       37932 2014-03-05 20:43 libsetuid.so
-rw-r--r-- app_69   app_69       37932 2014-03-05 20:43 libsmsperms.so
-rw-r--r-- app_69   app_69       37932 2014-03-05 20:43 libzipentry.so
-rw-r----- root     root             8993 2014-03-07 14:45 log
```

```
App_69    1602  ... com.patchdroid.patchdroid
Root      1613  ... /data/data/com.patchdroid.patchdroid/patchd
Root      1619  ... /data/data/com.patchdroid.patchdroid/patchd
```

Patch 'Technology'

- Dynamic instrumentation techniques
  - Mainly hooking functions
  - Need to preserve original function

- Native Code hooks
  - based on ADBI (http://github.com/crmulliner/adbi)

- Dalvik Code
  - based on DDI (http://github.com/crmulliner/ddi)

Patch Creation

- Extract patch from AOSP and **transform** to PatchDroid
  - Apply patch strategy best suited for vulnerability

- Develop custom patch
  - Bug known but no patch available

Patch Creation

- Extract patch from AOSP and **transform** to PatchDroid
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- Develop custom patch
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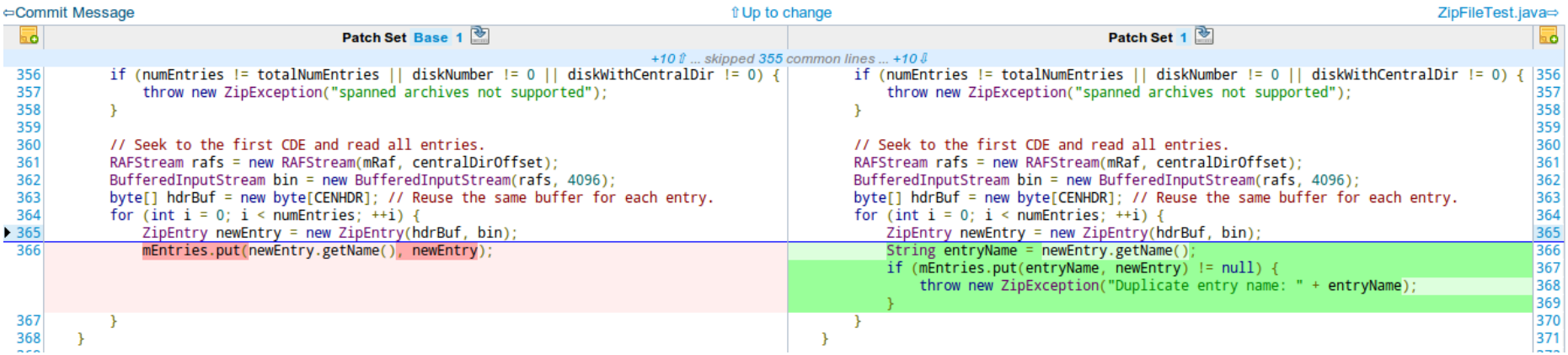
- **Walkthrough for creating a patch using source code**

Source Patch → PatchDroid Patch

- Source level patch

luni/src/main/java/java/util/zip/ZipFile.java



- Missing return value check:
  - `mEntries.put()` returns Non null if hash already has an entry with given key
- Duplicate key → multiple Zip entries with same name

Source Patch → PatchDroid Patch cont.

- Hook: `java.lang.LinkedHashMap.put()`
  - call original `put` method
  - check return value, throw exception if result != null
- But hashmap is used in other places how do we not break it?
  - Only hook it when used by ZipFile code
- Hook: `java.util.zip.ZipFile.readCentralDir()`
  - install hook for `LinkedHashMap`
  - call original `readCentralDir` method
  - unhook `LinkedHashMap`

Patch Deployment

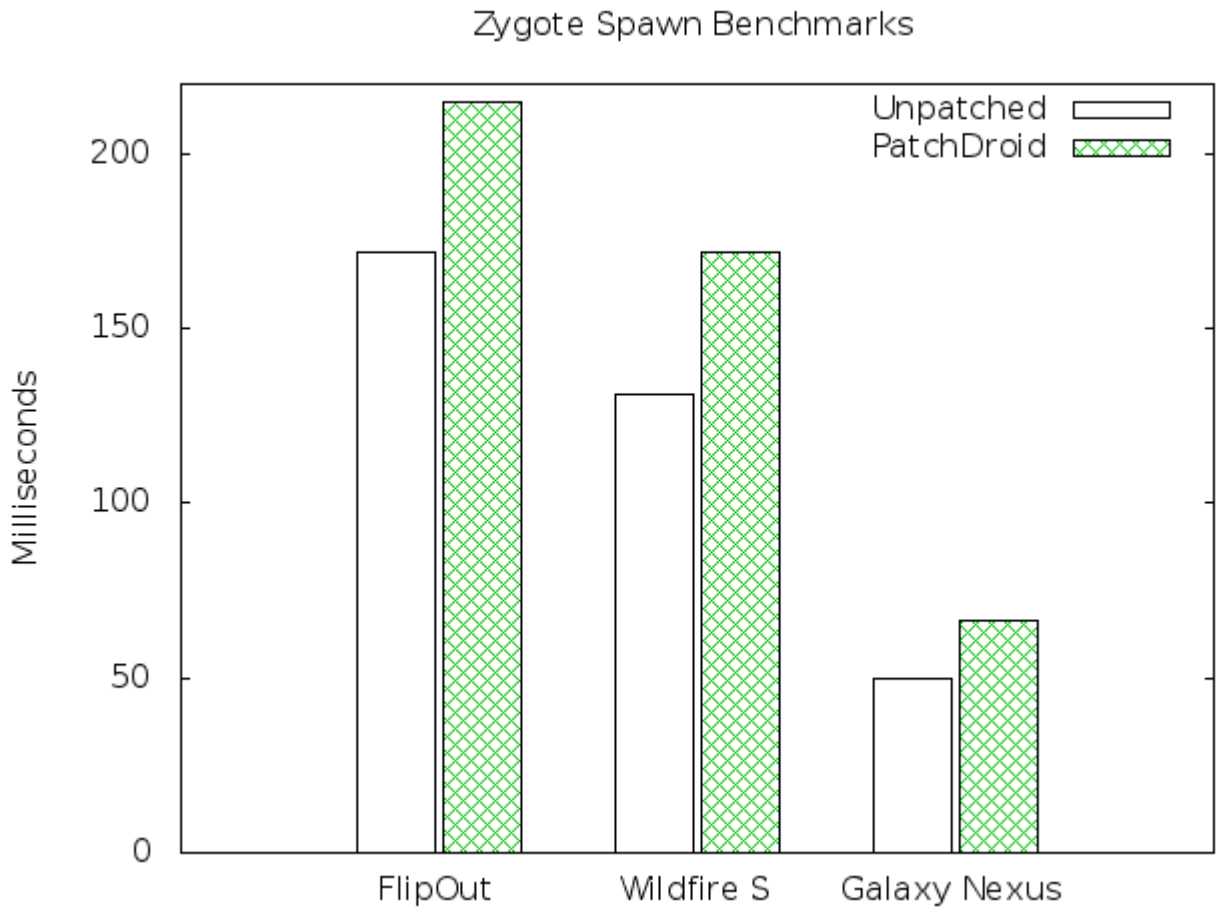
- PatchDroid injects patches into processes
  - Patches need a mapping to a process
- Service processes
  - vold, adbd
- Android framework is separated into a number of processes
  - zygote (base VM)
  - system_server (runs most of the framework code)
- The ZipFile class is used by APK installer
  - Code is part of the Android runtime framework

Evaluation

- System performance
  - Low overhead during process creation
  - No runtime overhead
- Functional testing
  - Patch vs Exploit
- User trials
  - Users run PatchDroid
  - Try exploiting known vulnerabilities (details in the PatchDroid paper)

Overhead – creating new process

- One time hit at process creation



Patch vs Exploit

- Privilege escalation vulnerabilities (root exploits)
  - Zimperlich
  - GingerBreak
  - ZergRush
- Permission leak
  - local SMS spoofing (Dalvik)
- APK processing
  - MasterKey series of bugs (Dalvik)
- All patches prevent exploitation on the affected devices
  - PatchDroid warns the user about attack

Patch vs Exploit

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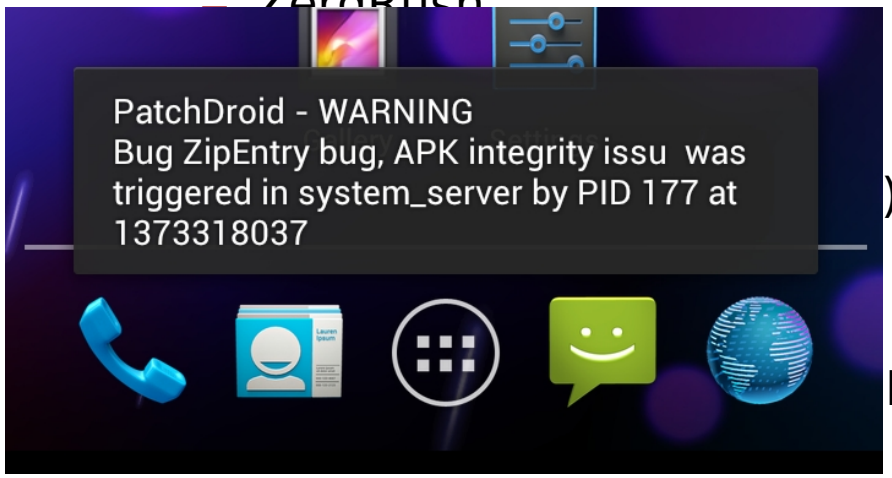

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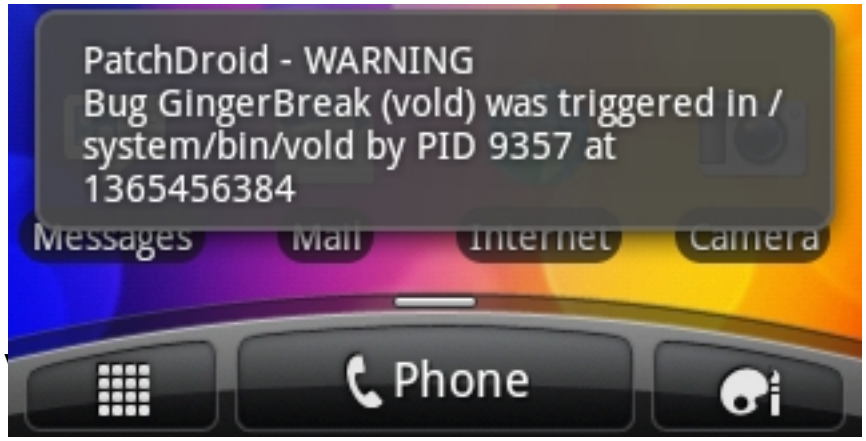

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Case Study: MasterKey Bug(s)

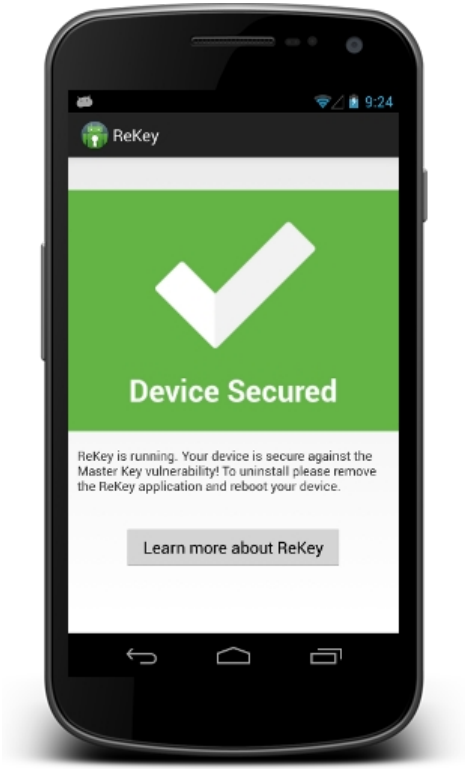
- Bug(s) in handling of APK files
  - APK can be modified w/o breaking the signature
- MasterKey can be used for privilege escalation
  - Modify APK signed with platform/manufacturer key
  - Works on all devices from manufacturer
- Bug in manifested in Dalvik bytecode
  - First privilege escalation vulnerability in Dalvik code
- Present in AOSP before version 4.3
  - Affected almost all Android devices at the time

Patching MasterKey

- Multiple bugs → multiple patches
  - Different strategies, fix via:
    - return value check
    - input sanitization
- Fast implementation and testing
  - Initial version took only three (3) hours
- We wanted to release the patch to the general public
  - Provide possibility to protect user's devices

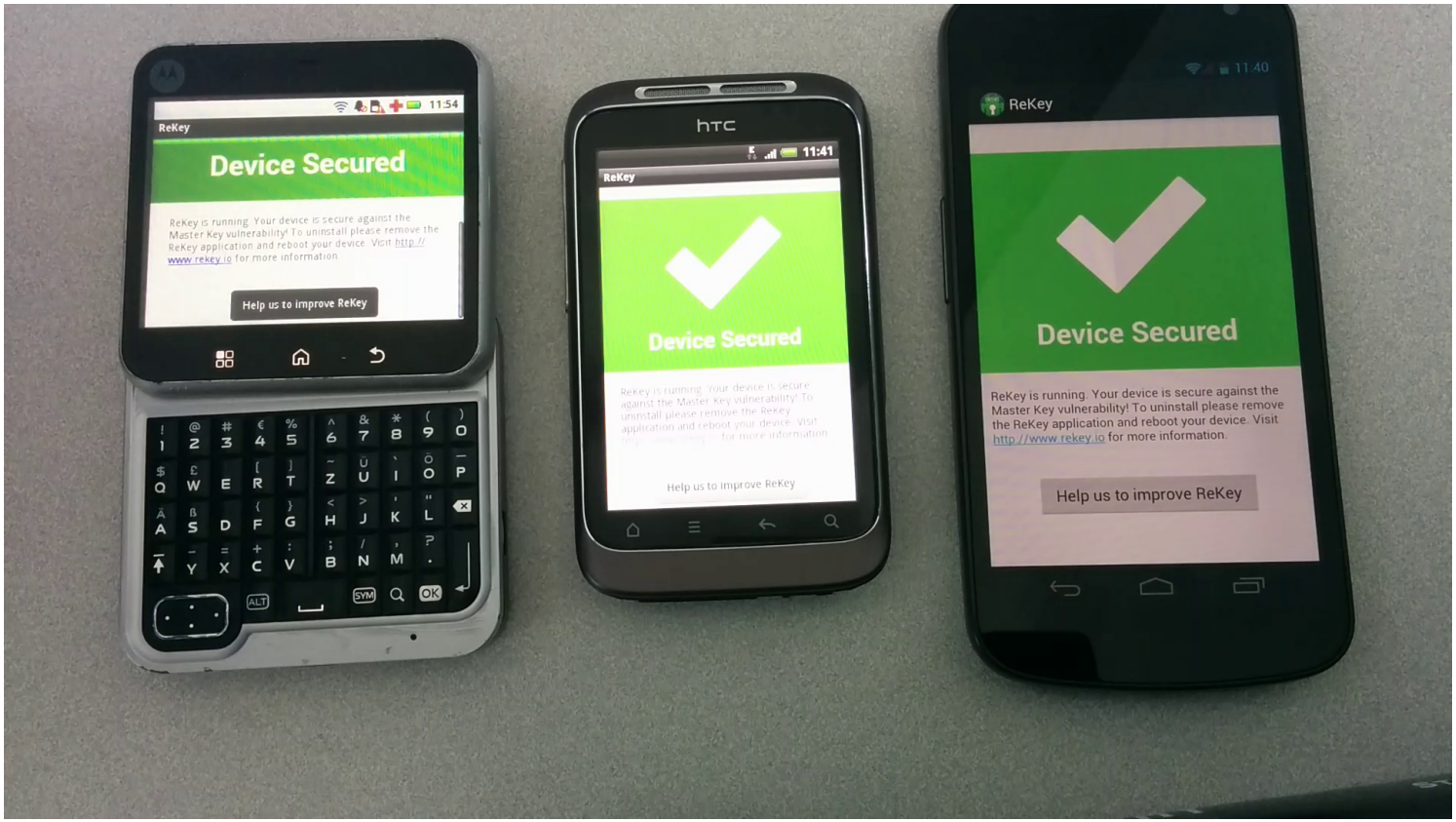
ReKey

- Limited version of the PatchDroid system
  - Only the MasterKey bug(s)
- Released ReKey on the Google Play store
  - July 16th, 2013
- +32K installs on play store
  - Only works on rooted devices!
- ReKey your device!
  - **http://www.rekey.io**



PatchDroid / ReKey - Demo Video

This version of ReKey contains all PatchDroid patches



Conclusions

- We are the first to address security patching on Android

- With PatchDroid we show that
  - third-party patching is possible without source code
  - patch development scales across different devices

- **PatchDroid**
  - supports Dalvik and native code
  - no noticeable performance overhead
  - no impact on device stability
  - safe against accidentally “bricking” devices

- Public release of ReKey was a huge success

EOF

Thank you!

Questions?

http://www.patchdroid.com