A Component-based Environment for Android Apps

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Smartphone Trust Challenges
Privilege Escalation

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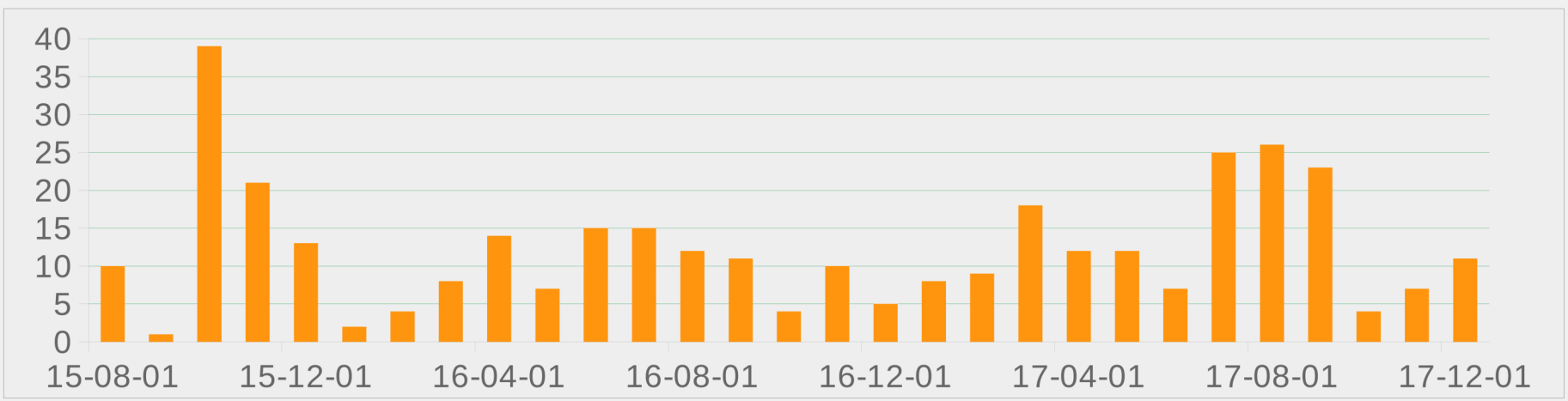
- Stagefright (July 2015)
  - Specially crafted media data
  - Remote code execution, privilege escalation
- Problem not solved since:



Media-related Android vulnerabilities (Critical/high, based on https://source.android.com/security/bulletin/)

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Media Frameworks are not getting simpler.
How do we avoid such fatal errors?

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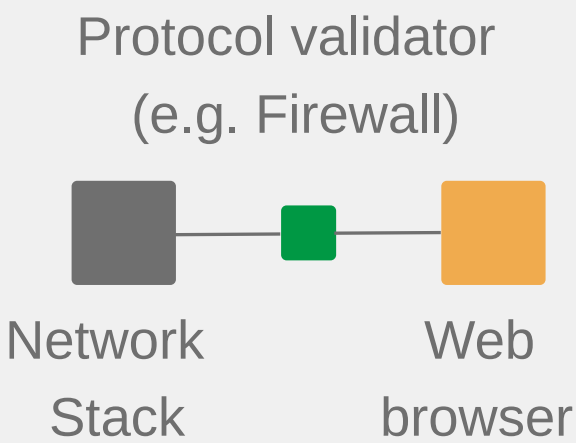
- Can’t reimplement everything
- **Solution: software reuse**
  - Untrusted software (gray)
  - Policy object (green)
  - Client software (orange)
- **Policy object**
  - Establishes assumptions of client
  - Sanitizes
  - Enforces additional policies



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Information Flow

Correctness

Trustworthy Systems
Information Flow: Genode OS Framework

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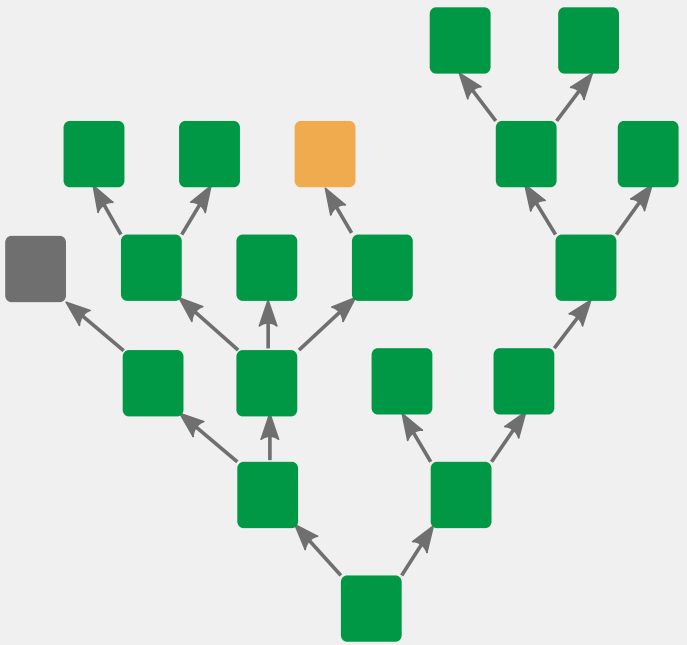
- **Recursive system structure**
  - Root: Microkernel
  - Parent: Responsibility + control
  - Isolation is default
  - Strict communication policy
- **Everything is a user-process**
  - Application
  - File systems
  - Drivers, Network stacks
- *Stay here for the next 2 talks for details (13:00)*

- **Hierarchical System Architecture**



Trustworthy Systems
Correctness: SPARK

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- **Programming Language**
  - Based on Ada
  - Compilable with GCC and LLVM
  - Customizable runtimes
  - Contracts (preconditions, postconditions, invariants)
- **Verification Toolset**
  - Absence of runtime errors
  - Functional correctness

- **Applications**
  - Avionics
  - Defense
  - Air Traffic Control
  - Space
  - Automotive
  - Medical Devices
  - Security

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Applying this Approach to Android Apps

GART Project
Objectives

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- Unmodified Android Apps
- On top of Genode OS Framework
- Formally-verified policy objects

GART Project
Elements

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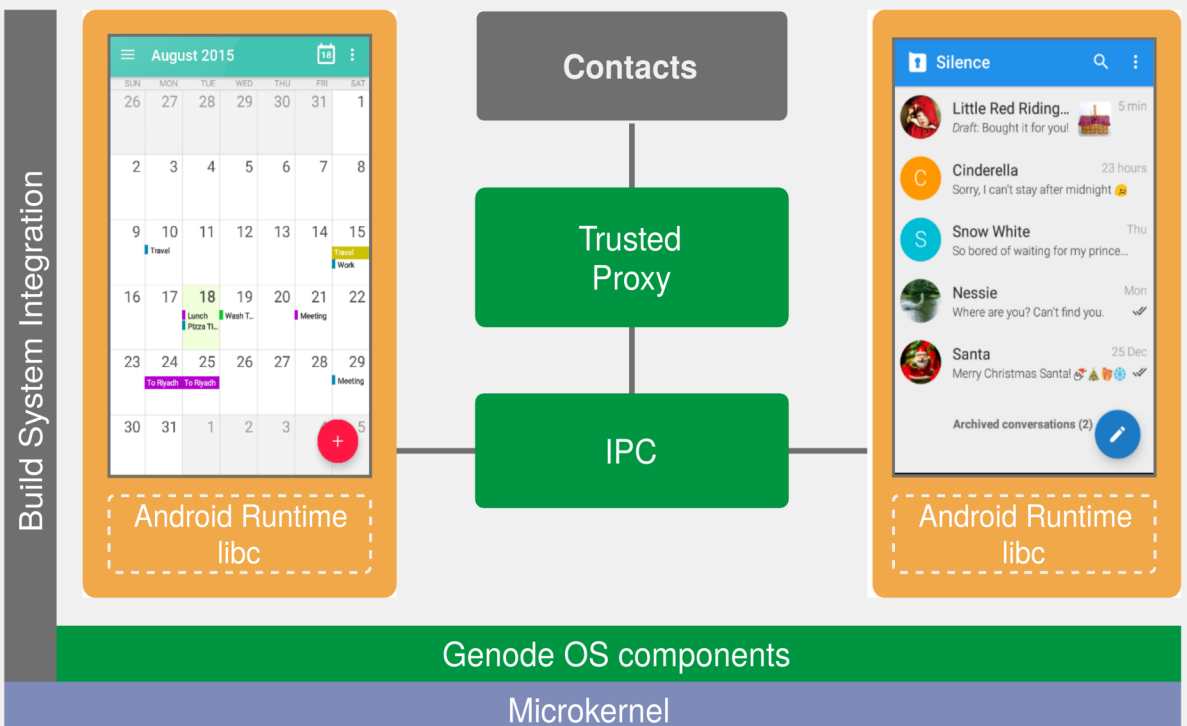
- Build system
- Android Runtime
- Trusted Proxies
- IPC



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Build System Integration

Build System Integration
Android Build Files

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- *Soong* replaced old make-based build system in Oreo (8.0)
- JSON-like blueprint files
- Purely declarative – no conditionals, no control flow
- Complex cases handled in Go application
- Manifests for the *Ninja* build system are generated

```
cc_binary {
    name: "gzip",
    srcs: ["src/test/minigzip.c"],
    shared_libs: ["libz"],
    stl: "none",
}
```

Build System Integration
Translating Android Build Files

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```
$ gnoos -b android -i libnativehelper/Android.bp -o libnativehelper.mk -p LIBNATIVEHELPER_ \
'/cc_library[@name=libnativehelper]'
$ cat libnativehelper.mk
LIBNATIVEHELPER_CFLAGS = -Werror -fvisibility=protected
LIBNATIVEHELPER_EXPORT_HEADER_LIB_HEADERS = jni_headers jni_platform_headers libnativehelper_header_only
LIBNATIVEHELPER_EXPORT_INCLUDE_DIRS = include
LIBNATIVEHELPER_HEADER_LIBS = jni_headers jni_platform_headers libnativehelper_header_only
LIBNATIVEHELPER_HOST_SUPPORTED = True
LIBNATIVEHELPER_NAME = libnativehelper
LIBNATIVEHELPER_SHARED_LIBS = liblog
LIBNATIVEHELPER_SRCS = JNIHelp.cpp JniConstants.cpp JniInvocation.cpp toStringArray.cpp
```

Build System Integration
Integrating Android Build Files (1)

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- Gnoos has been integrated into Genode build system
- Consistent with regular Genode applications
  - Library build files are in `lib/mk`
  - Library import files are in `lib/import`
  - Applications have a `target.mk`

Build System Integration
Integrating Android Build Files (2)

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- Porting native Android applications is easy
- With run script, they can be run as every other Genode application
- `gart_gtest_main` makes porting Android tests a one-liner

```
$ make -C build/arm_v8a run/test/libutils
 ...
[init → libutils_test] Note: Google Test filter = -VectorTest.SetCapacity_Overflow:VectorTest._grow_OverflowSize
[init → libutils_test] :VectorTest._grow_OverflowCapacrstr16EmptyTarget_bug:SystemClock.SystemClock
[init → libutils_test] [==========] Running 61 tests from 9 test cases.
[init → libutils_test] [----------] Global test environment set-up.
[init → libutils_test] [----------] 3 tests from VectorTest
[init → libutils_test] [ RUN      ] VectorTest.CopyOnWrite_CopyAndAddElements
[init → libutils_test] [       OK ] VectorTest.CopyOnWrite_CopyAndAddElements (2 ms)
 ...
[init → libutils_test] [ PASSED ] 61 tests.
[init] child "libutils_test" exited with exit value 0
Run script execution successful.
make: Leaving directory 'build/arm_v8a'
```

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Android Runtime

Android Runtime
Dependencies

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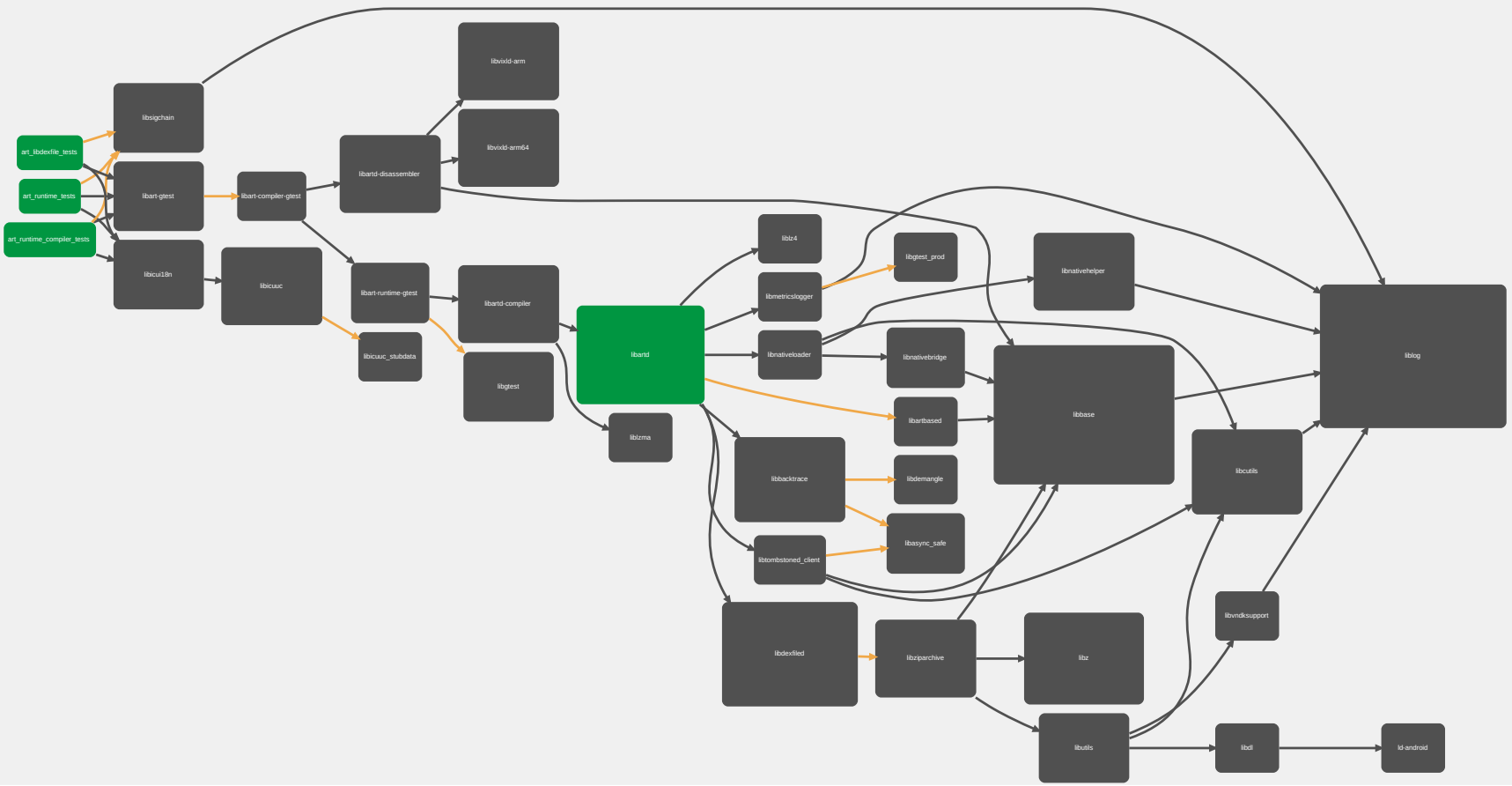

Android Runtime
Components

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- **dalvikvm**
  - Only ~200 LOC
  - Linked with only few libraries – `libsigchain`, `libnativehelper`, `libc`
    - `libsigchain`: interception layer for signals
    - `libnativehelper`: helpers for Java/native interface
- **libart**
  - Actual Java Virtual Machine
  - Loaded dynamically by dalvikvm
  - > 50 dependencies that needed to be ported

Android Runtime
Current State

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- **dalvikvm and libart ported to Genode**
  - The ~1000 tests cases of dependencies succeed
  - Most of the ~500 ART test cases succeed
  - Runtime fully initializes and starts Java program on Genode/arm_v8a (and then crashes, see below ;)
- **Open issues**
  - Concurrency bugs due to missing futex implementation
  - Probably some more due to differences between Genodes libc and Linux
  - Runtime-compiler basically ported, but still has issues

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Trusted Proxies

Trusted Proxies
Component Environment

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- **Downsized SPARK/Ada runtime**
  - Optimized for critical low-complexity components
  - No allocators, no exception handlers, no implicit dynamic code, no tasking...
  - Support for Genode, Muen and Linux
  - Easy to customize and port to new (embedded) environments

- **Gneiss component library**
  - Fully asynchronous, event-driven and platform-independent
  - Support for Genode, Muen and Linux
  - Only constructs that are formally verifiable with SPARK proof tools
  - Generic interfaces: Log, timer, block device, message, shared memory
- *See recordings of previous talk by Johannes Kliemann for details*

Trusted Proxies
Verified Binary Parsers

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- **RecordFlux**
  - DSL and toolset for formal specification of binary messages
  - Model verification (absence of contradictions, reachability, ...)
  - Generation of verifiable binary parsers
  - Generation of message generators
- *See recording of Tobias Reihers talk for details (Saturday, 11:30, security devroom)*

```
package TLV is
   type Tag is (Msg_Data  ⇒ 1,
                Msg_Error ⇒ 3) with Size ⇒ 2;
   type Length is mod 2**14;

   type Message is
      message
         Tag    : Tag
            then Length
               if Tag = Msg_Data,
            then null
               if Tag = Msg_Error;
         Length : Length
            then Value
               with Length ⇒ Length * 8;
         Value  : Payload;
       end message;
end TLV;
```

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Future Work / Next Up:
Android IPC

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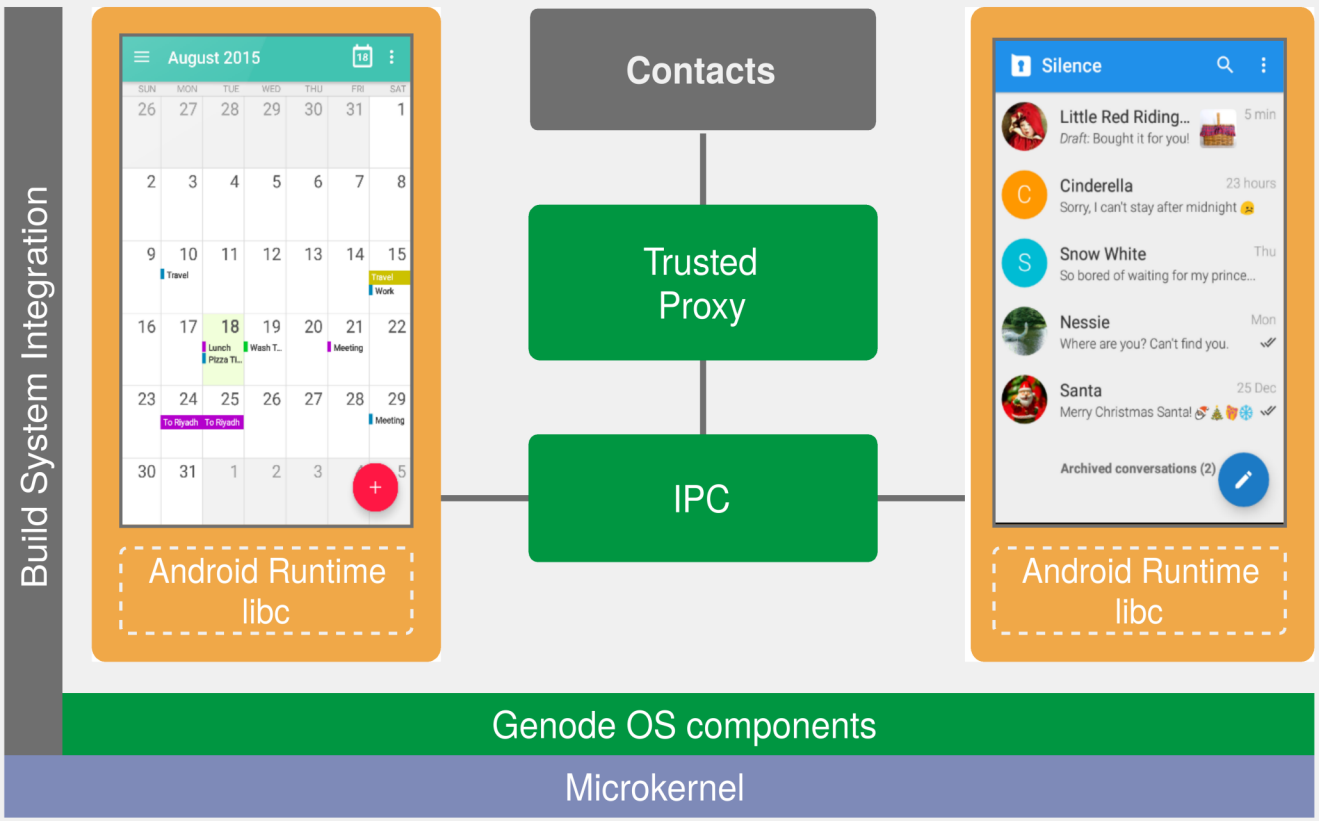
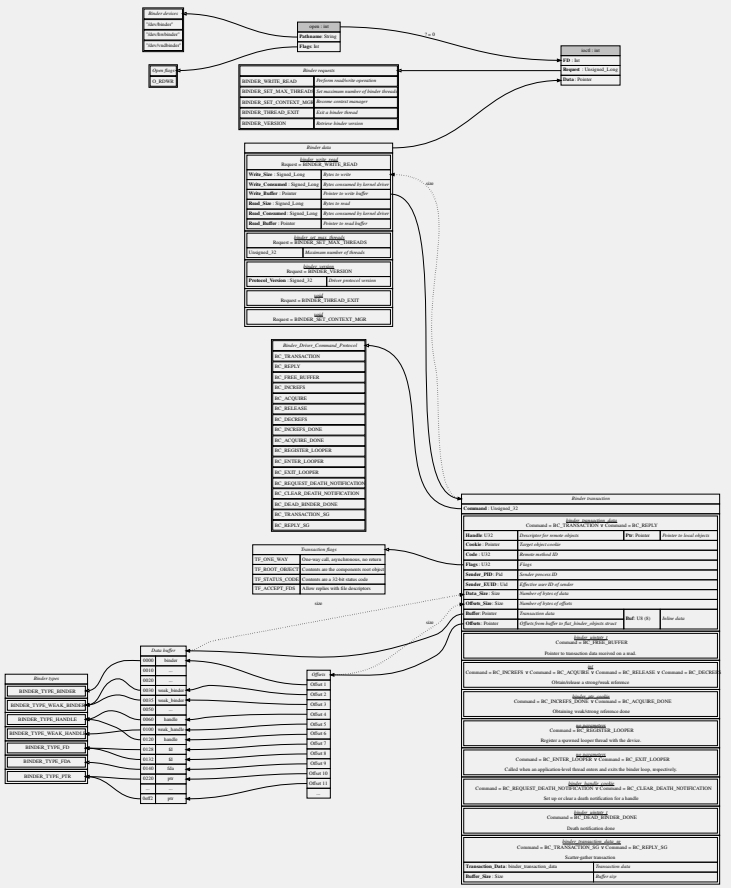


Android IPC
Binder device

- Linux device node `/dev/[vnd|hw|]binder`
  - Interaction through `ioctl()` interface
  - Blocking or non-blocking
  - Send and/or receive phase
- Data is passed via linked data structure
  - Local/remote objects with reference counting
  - Special objects
  - File-descriptor passing
  - Linux kernel copies between processes
  - Name-service application (ServiceManager)



Android IPC
Idea: User-level message broker

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- **Verified broker component to handle binder transactions**
  - Android apps are client of broker using message passing
  - Clients share memory region with broker
  - Broker implements name service and copies between clients
- **Pros**
  - No additional complexity in the kernel
  - Enables filter components / policies
- **Cons**
  - At least 3 copies per transaction (Android kernel needs 1)

Conclusions

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- **Conclusions**
  - Rehosting Android Runtime to Genode is feasible
  - Easy porting due to declarative nature of Androids build system
  - Googles extensive test suite is extremely helpful
  - Environment for trustworthy formally verified filters exists

- **Future Work**
  - User-level binder IPC on Genode
  - Porting or emulation of required Android services
  - Integration into Genodes Nitpicker UI subsystem
  - Trusted filters (e.g. encrypted / tagged calendar entries)
  - Test complex, unmodified Android applications on Genode

Questions?

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