DroidScope:

Seamlessly Reconstructing the OS and Dalvik Semantic Views for Dynamic Android Malware Analysis

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Android

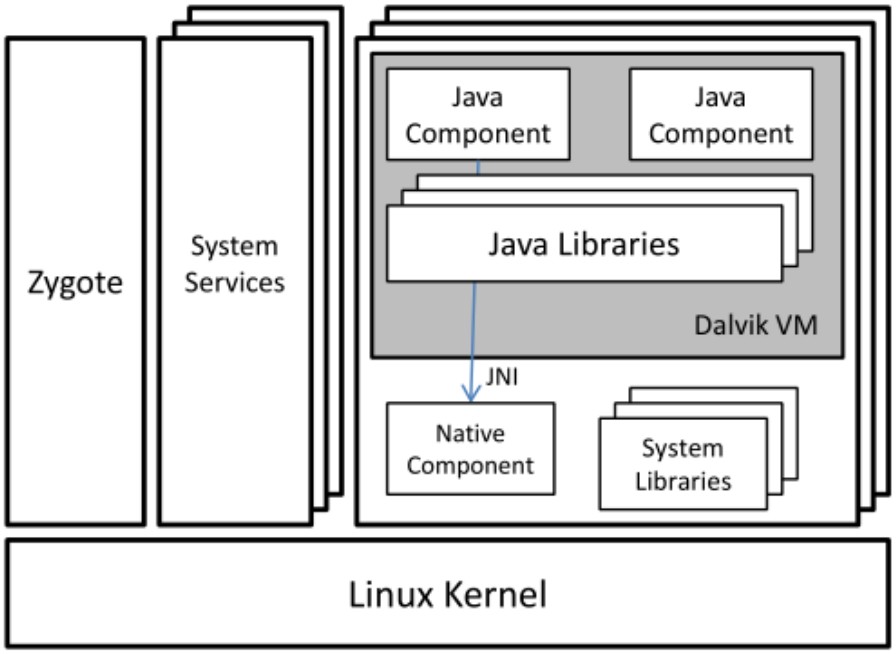
Java Components

System Services

Native Components

Apps

Android



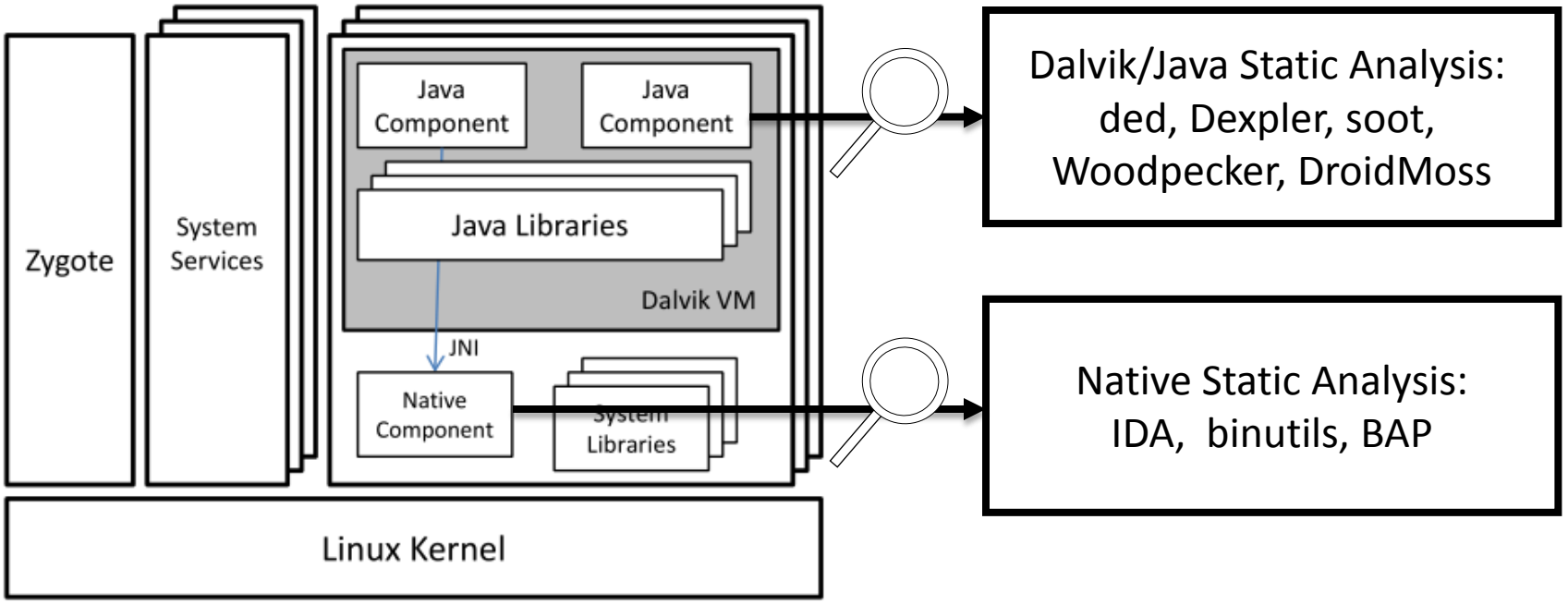
Java Components

Native Components

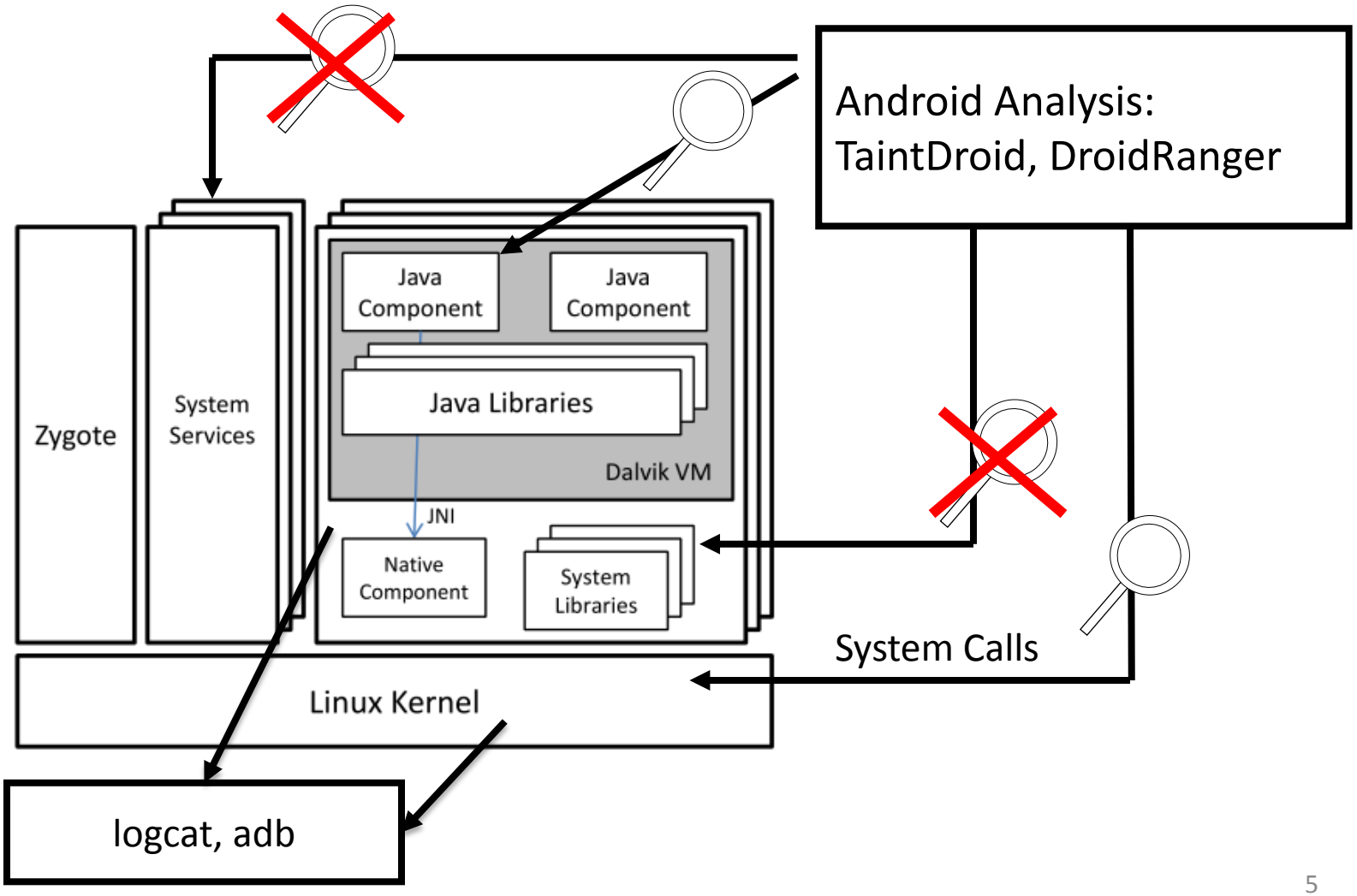
System Services

Apps

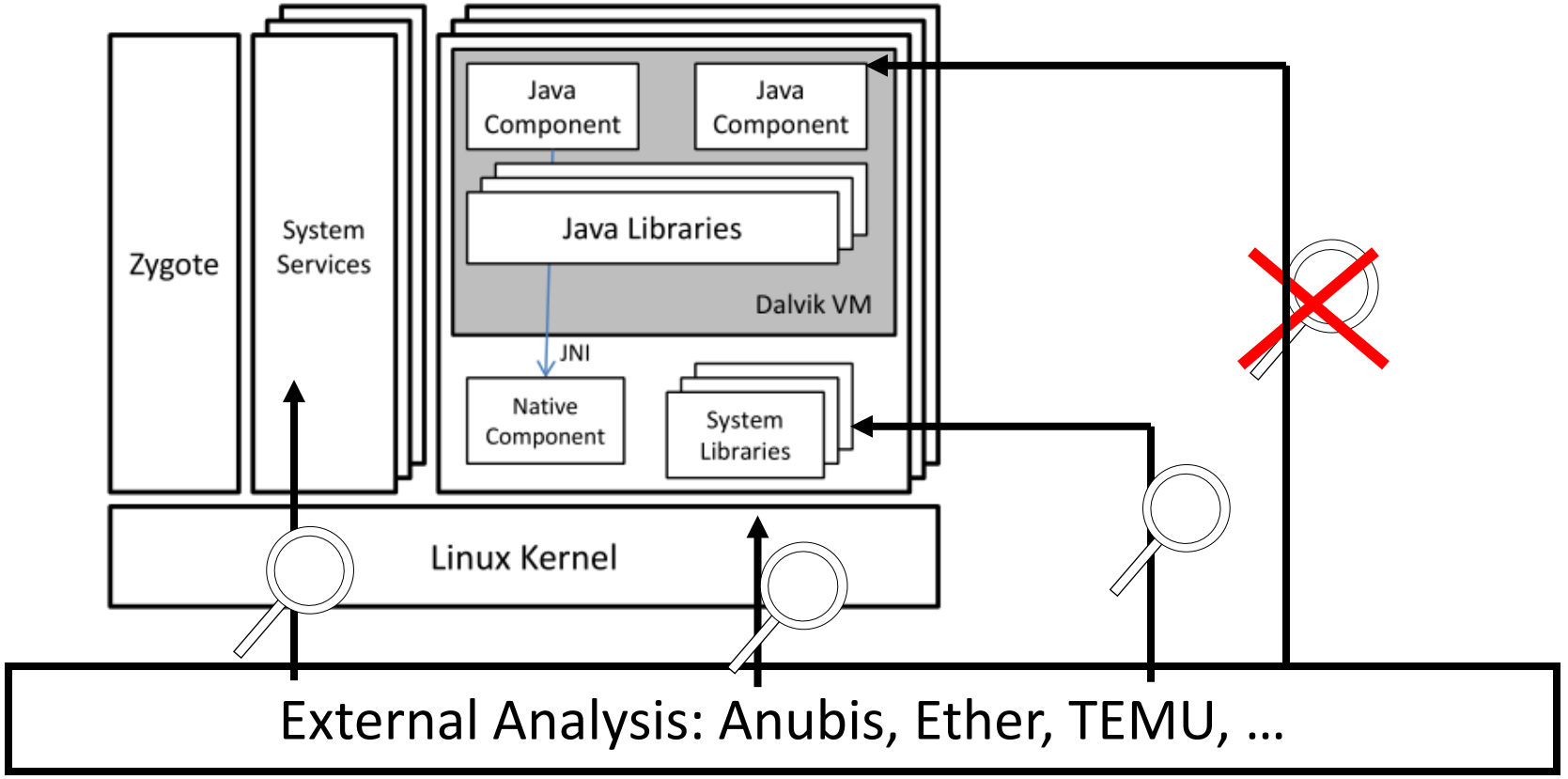
Motivation: Static Analysis



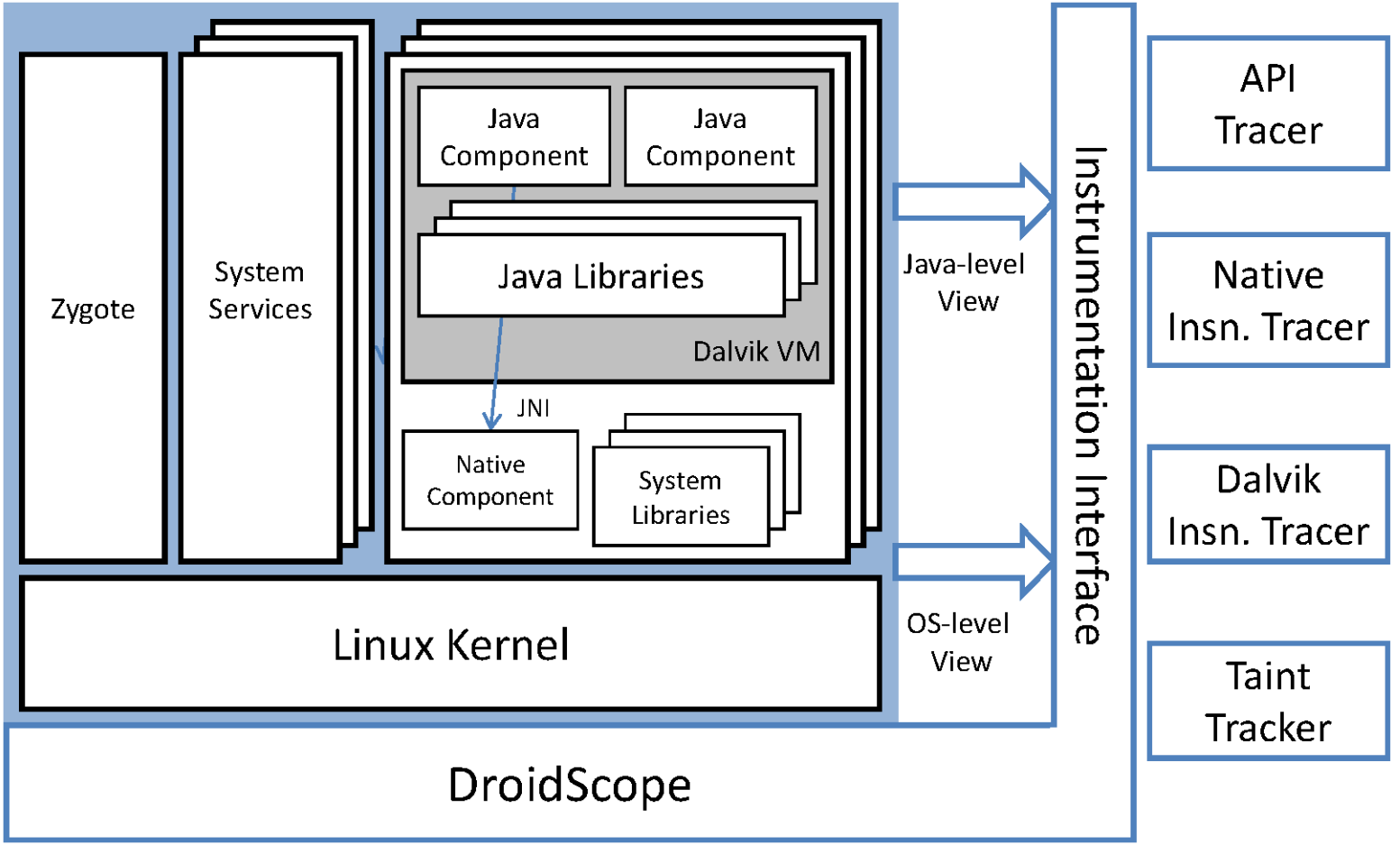
Motivation: Dynamic Analysis



Motivation: Dynamic Analysis



DroidScope Overview



Goals

- Dynamic binary instrumentation for Android
  - Leverage Android Emulator in SDK
  - No changes to Android Virtual Devices
  - External instrumentation
    - Linux context
    - Dalvik context
  - Extensible: plugin-support / event-based interface
  - Performance
    - Partial JIT support
    - Instrumentation optimization

Roadmap

- External instrumentation
  - Linux context
  - Dalvik context
- Extensible: plugin-support / event-based interface
- Evaluation
  - Performance
  - Usage

Linux Context: Identify App(s)

- Shadow task list
  - pid, tid, uid, gid, euid, egid, parent pid, pgd, comm
  - *argv[0]*
- Shadow memory map
  - Address Space Layout Randomization (Ice Cream Sandwich)
- Update on
  - *fork*, *execve*, *clone*, *prctl* and *mmap2*

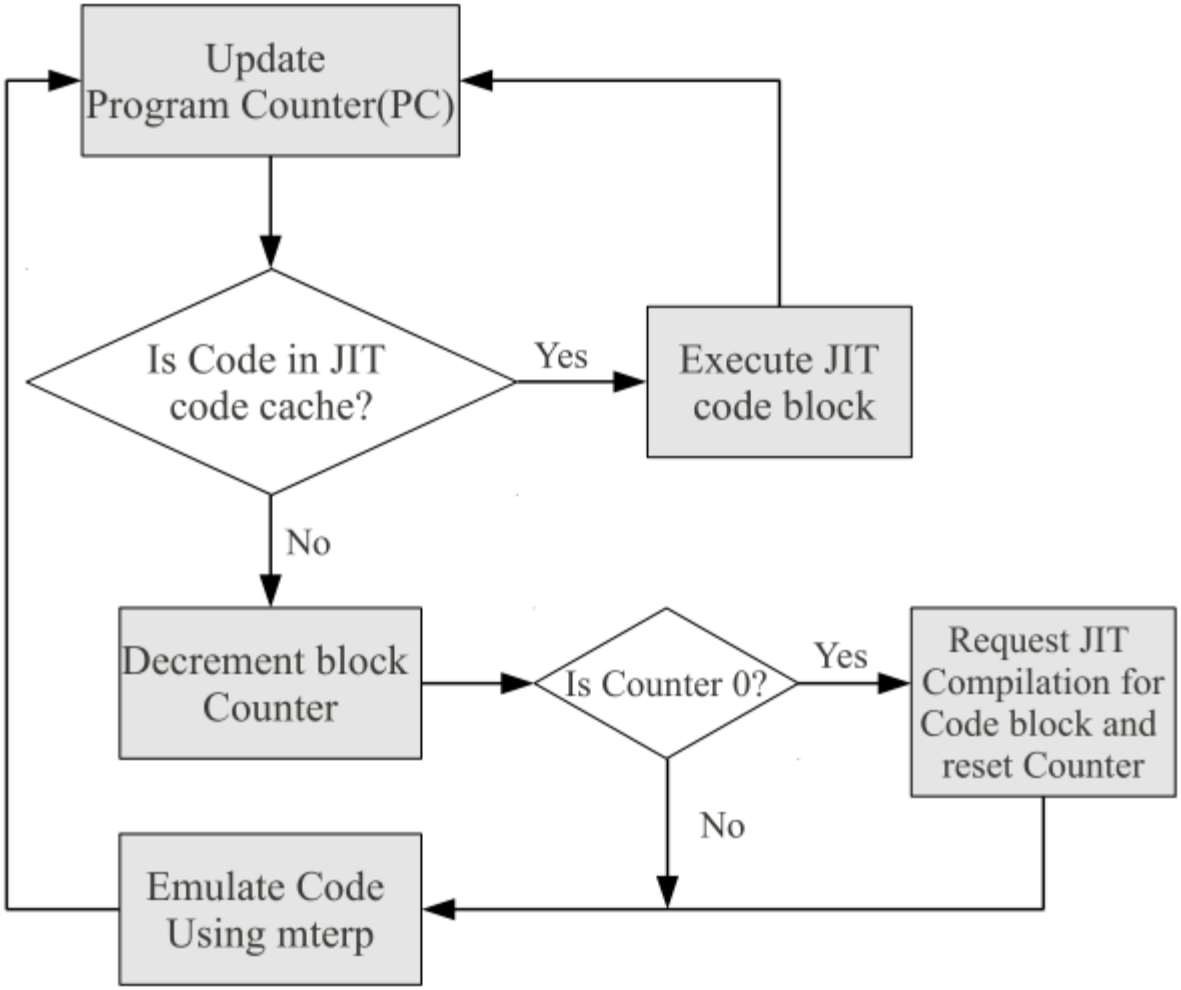
Java/Dalvik View

- Dalvik virtual machine
  - register machine (all on stack)
  - 256 opcodes
  - saved state, *glue*, pointed to by ARM R6, on stack in x86
- mterp
  - offset-addressing: *fetch opcode* then jump to *(dvmAsmInstructionStart + opcode * 64)*
  - *dvmAsmSisterStart* for emulation overflow
- Which Dalvik opcode?
  1. Locate dvmAsmInstructionStart in shadow memory map
  2. Calculate opcode = (R15 - dvmAsmInstructionStart) / 64.

Just In Time (JIT) Compiler

- Designed to boost performance
- Triggered by counter - mterp is always the default
- Trace based
  - Multiple basic blocks
  - Multiple exits or *chaining cells*
  - Complicates external introspection
  - Complicates instrumentation

Disabling JIT



Roadmap

- ✓ External instrumentation
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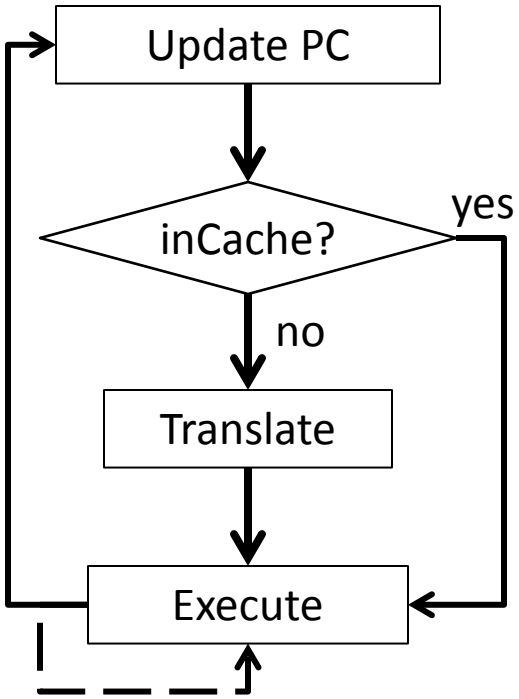
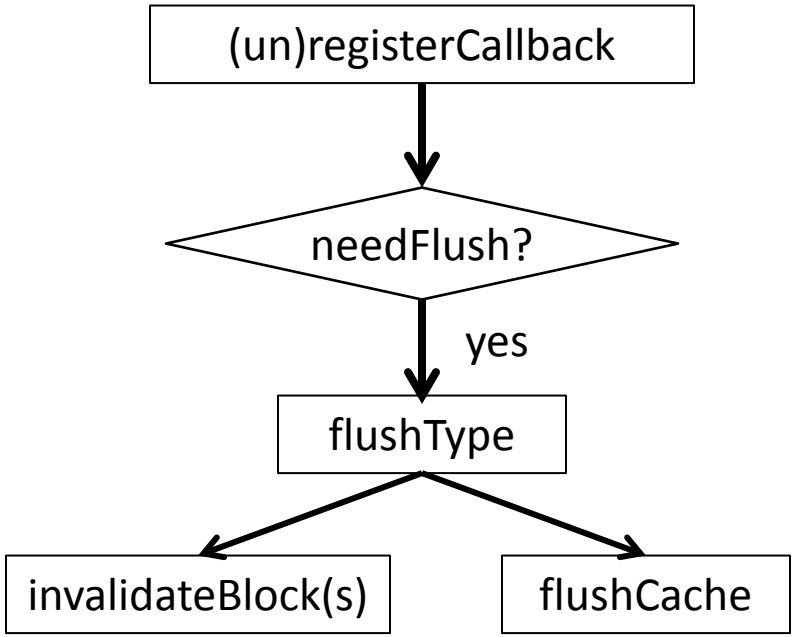
Instrumentation Design

- Event based interface
  - Execution: e.g. native and Dalvik instructions
  - Status: updated shadow task list
- Query and Set, e.g. interpret and change cpu state
- Performance
  - Example: Native instructions vs. Dalvik instructions
  - Instrumentation Optimization

Dynamic Instrumentation





Instrumentation

	NativeAPI	LinuxAPI	DalvikAPI
Events	instruction begin/end	context switch	Dalvik instruction begin
	register read/write	system call	method begin
	memory read/write	task begin/end	
	block begin/end	task updated	
		memory map updated	
Query & Set	memory read/write	query symbol database	query symbol database
	memory r/w with pgd	get current context	interpret Java object
	register read/write	get task list	get/set DVM state
	taint set/check		taint set/check objects
			disable JIT

Dalvik Instruction Tracer (Example)

```
1. void opcode_callback(uint32_t opcode) {
2.   printf("[%x] %s\n", GET_RPC, opcodeToStr(opcode));
3. }
4.
5. void module_callback(int pid) {
6.   if (bInitialized || (getIBase(pid) == 0))
7.     return;
8.
9.
10.  getModAddr(“dfk@classes.dex”, &startAddr, &endAddr);
11.  addDisableJITRange(pid, startAddr, endAddr);
12.  disableJITInit(getGetCodeAddrAddress(pid));
13.  addMterpOpcodesRange(pid, startAddr, endAddr);
14.  dalvikMterpInit(getIBase(pid));
15.  registerDalvikInsnBeginCb(&opcode_callback);
16.  bInitialized = 1;
17. }
18.
19. void _init() {
20.  setTargetByName("com.andhuhu.fengyinchuanshuo");
21.  registerTargetModulesUpdatedCb(&module_callback);
22. }
```

Plugins

- API Tracer
  - System calls
    - *open*, *close*, *read*, *write*, includes parameters and return values
  - Native library calls
  - Java API calls
    - Java Strings converted to C Strings
- Native and Dalvik Instruction Tracers
- Taint Tracker
  - Taints ARM instructions
  - One bit per byte
  - Data movement & Arithmetic instructions including barrel shifter
  - Does not support control flow tainting

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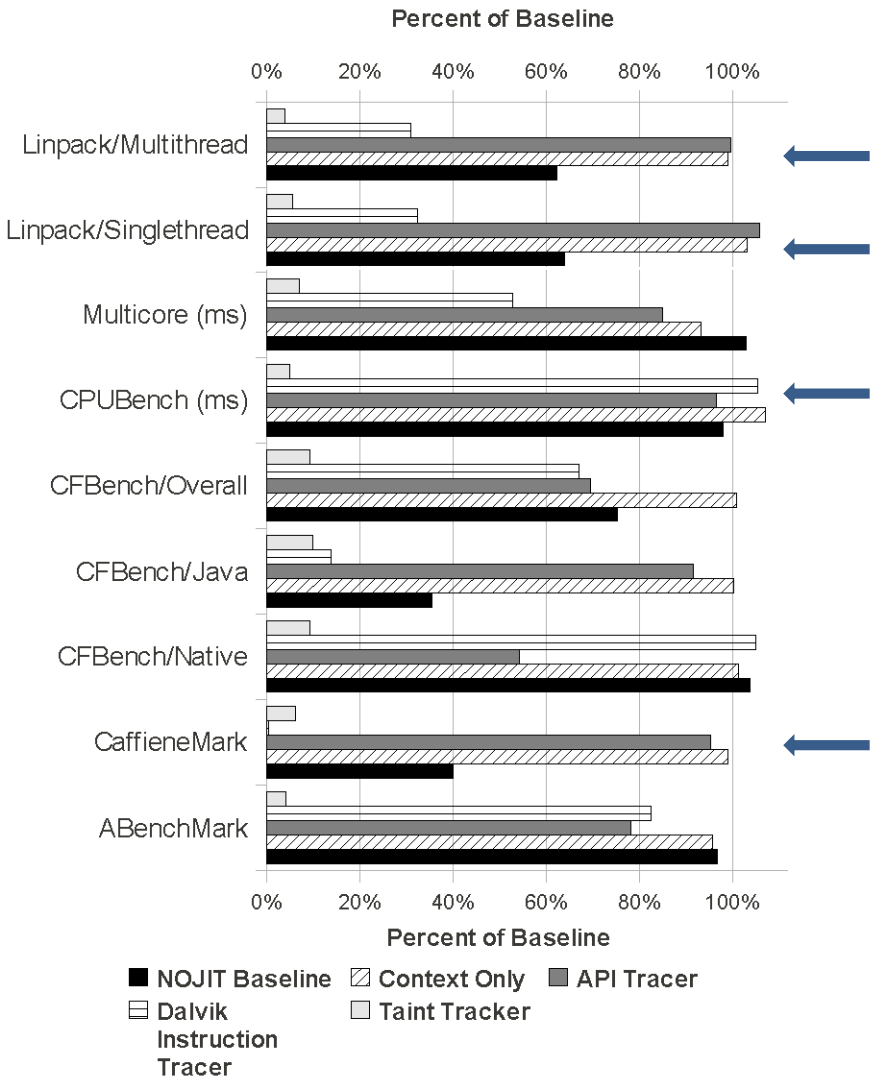
Implementation

- Configuration
  - QEMU 0.10.50 – part of Gingerbread SDK
  - Gingerbread
    - “user-eng”
    - No changes to source
  - Linux 2.6.29, QEMU kernel branch

Performance Evaluation

- Seven free benchmark Apps
  - AnTuTu Benchmark
  - (ABenchMark) by AnTuTu
  - CaffeineMark by Ravi Reddy
  - CF-Bench by Chainfire
  - Mobile processor benchmark (Multicore) by Andrei Karpushonak
  - Benchmark by Softweg
  - Linpack by GreeneComputing
- Six tests repeated five times each
  - Baseline
  - NO-JIT Baseline – uses a build with JIT disabled at runtime
  - Context Only
  - API Tracer
  - Dalvik Instruction Trace
  - Taint Tracker

Select Performance Results



APITracer vs. NOJIT

Results are not perfect

Dynamic Symbol Retrieval Overhead

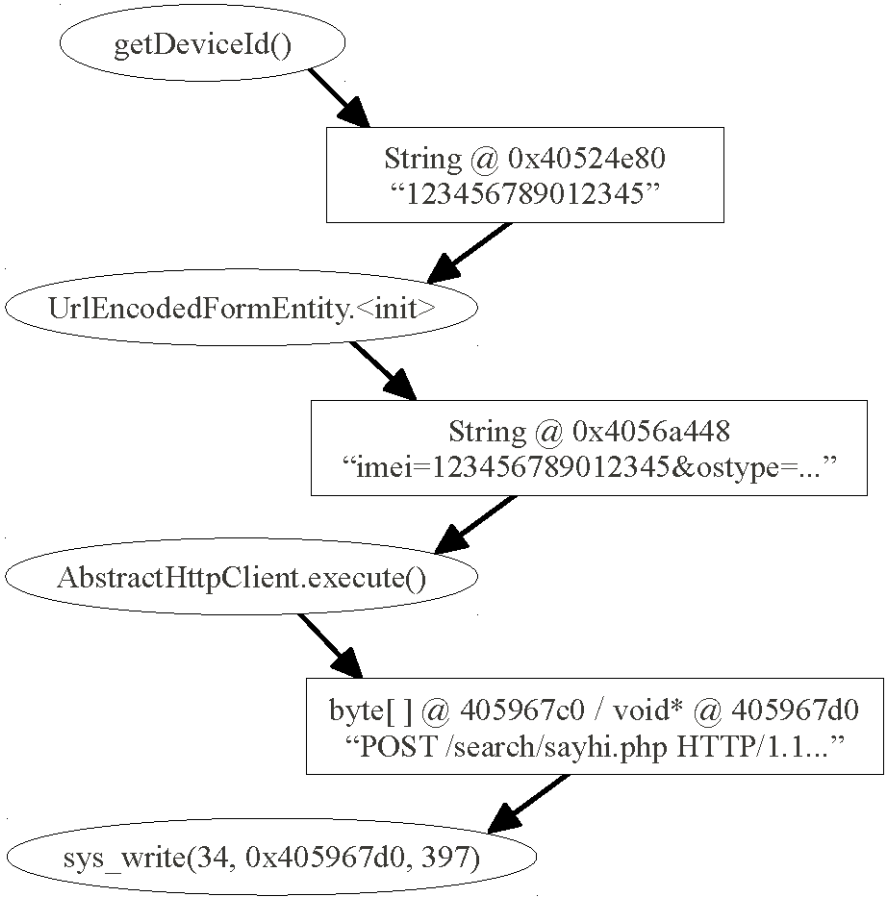
Usage Evaluation

- Use DroidScope to analyze real world malware
  - API Tracer
  - Dalvik Instruction Tracer + dexdump
  - Taint Tracker – taint IMEI/IMSI @ *move_result_object* after *getIMEI/getIMSI*
- Analyze included exploits
  - Removed patches in Gingerbread
  - Intercept system calls
  - Native instruction tracer

Droid Kung Fu

- Three encrypted payloads
  - ratc (Rage Against The Cage)
  - killall (ratc wrapper)
  - gjsvro (udev exploit)
- Three execution methods
  - piped commands to a shell (default execution path)
  - Runtime.exec() Java API (instrumented path)
  - JNI to native library terminal emulator (instrumented path)
  - Instrumented return values for *isVersion221* and *getPermission* methods

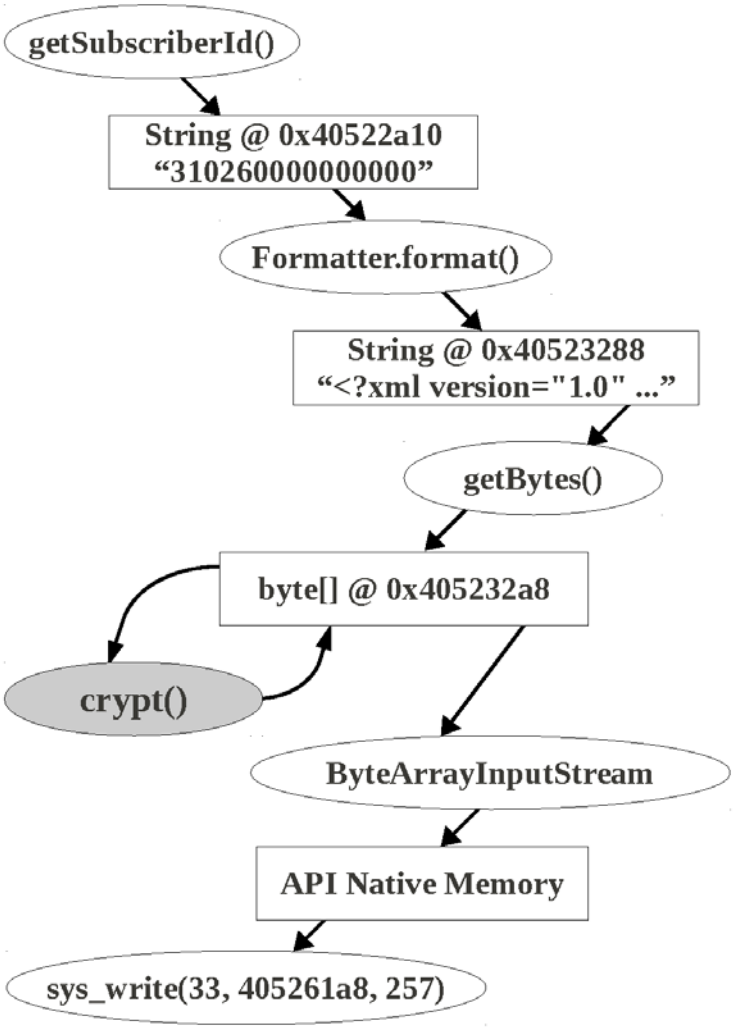
Droid Kung Fu: TaintTracker



DroidDream

- Same payloads as DroidKungFu
- Two processes
  - Normal *droiddream* process clears logcat
  - *droiddream:remote* is malicious
- xor-encrypts private information before leaking
- Instrumented *sys_connect* and *sys_write*

Droid Dream: TaintTracker



DroidDream: crypt trace

```
[43328f40] aget-byte v2(0x01), v4(0x405232a8), v0(186)
  Getting Tainted Memory: 40523372(2401372)
  Adding M@410accec(42c5cec) len = 4
[43328f44] sget-object v3(0x0000005e), KEYVALUE// field@0003
[43328f48] aget-byte v3(0x88), v3(0x4051e288), v1(58)
[43328f4c] xor-int/2addr v2(62), v3(41)
  Getting Tainted Memory: 410accec(42c5cec)
  Adding M@410accec(42c5cec) len = 4
[43328f4e] int-to-byte v2(0x17), v2(23)
  Getting Tainted Memory: 410accec(42c5cec)
  Adding M@410accec(42c5cec) len = 4
[43328f50] aput-byte v2(0x17), v4(0x405232a8), v0(186)
  Getting Tainted Memory: 410accec(42c5cec)
  Adding M@40523372(2401372) len = 1
```

Summary

- DroidScope
  - Dynamic binary instrumentation for Android
  - Built on Android Emulator in SDK
  - External Introspection & Instrumentation support
  - Four plugins
    - API Tracer
    - Native Instruction Tracer
    - Dalvik Instruction Tracers
    - TaintTracker
  - Partial JIT support

Related Works

- Static Analysis
  - ded, Dexpler, soot
  - Woodpecker, DroidMoss
- Dynamic Analysis
  - TaintDroid
  - DroidRanger
  - PIN, Valgrind, DynamoRIO
  - Anubis, TEMU, Ether, PinOS
- Introspection
  - Virtuoso
  - VMWatcher

Challenges

- JIT
  - Full JIT support
  - Flushing JIT cache
- Emulation detection
  - Real Sensors: GPS, Microphone, etc.
  - Bouncer
- Timing assumptions, timeouts, events
- Closed source systems, e.g. iOS

Questions?

Q0. Where can I get DroidScope?