Practice of Android Reverse Engineering

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Myself

was a Kaffe Developer

- Threaded Interpreter, JIT, AWT for embedded system, robustness

was a GCJ (Java Frontend for GCC) and GNU Classpath Developer

is an AOSP (Android Open Source Project) contributror

- 30+ patches are merged officially
- bionic libc, ARM optimizations

Not Only for Cracking

(1) Sometimes, it takes __time__ to obtain source code than expected. → Taiwanese ODM

(2) Post-optimizations over existing Android applications

(3) “Borrow" something good to produce "goods"

Background Knowledge (and Thank you!)

- The Code Injection and Data Protection of Android, Thinker Li @HITcon2011
- Reversing Android Malware,

  Mahmud ab Rahman @HITcon2011

- My focus would be the practice.
  - Hack Android applications for Beginners

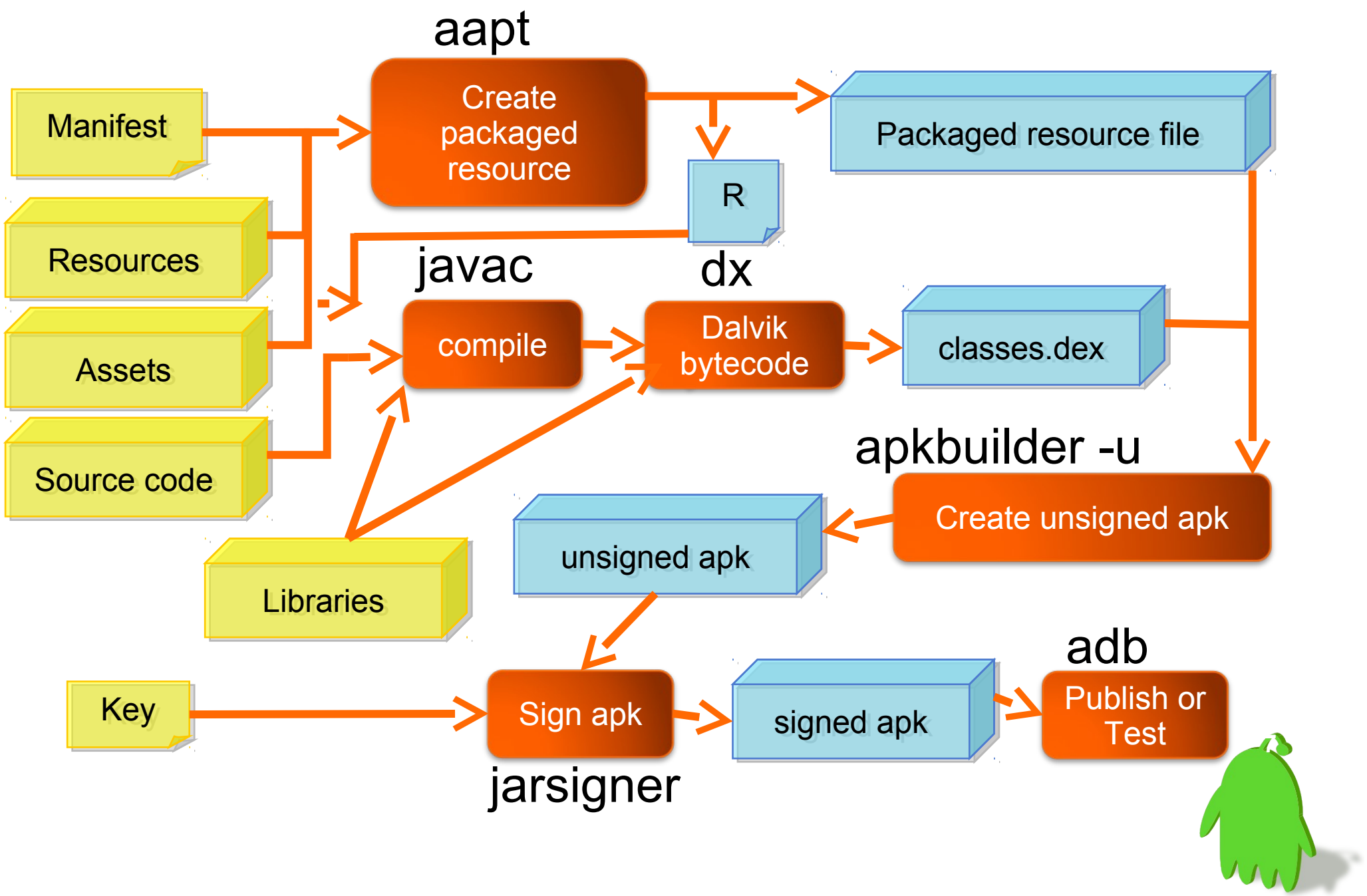
Agenda

(1) Development Flow

(2) Reverse Practice

(3) Real world tasks

Android Application Development Flow



APK content

```
$ unzip Angry+Birds.apk
Archive:  Angry+Birds.apk
...
  inflating: AndroidManifest.xml
 extracting: resources.arsc
 extracting: res/drawable-hdpi/icon.png
 extracting: res/drawable-ldpi/icon.png
 extracting: res/drawable-mdpi/icon.png
  inflating: classes.dex
  inflating: lib/armeabi/libangrybirds.so
  inflating: lib/armeabi-v7a/libangrybirds.so
  inflating: META-INF/MANIFEST.MF
  inflating: META-INF/CERT.SF
  inflating: META-INF/CERT.RSA
```

Dalvik DEX

JNI

manifest + signature

APK content

```
$ unzip Angry+Birds.apk
Archive:  Angry+Birds.apk
...
  inflating: AndroidManifest.xml
```

```
Name: classes.dex

SHA1-Digest: I9Vne//i/5Wyzs5HhBVu9dIoHDY=

Name: lib/armeabi/libangrybirds.so
SHA1-Digest: pSdb9FYauyfjDUxM8L6JDmQk4qQ=
```

```
  inflating: classes.dex
  inflating: lib/armeabi/libangrybirds.so
  inflating: lib/armeabi-v7a/libangrybirds.so
  inflating: META-INF/MANIFEST.MF
  inflating: META-INF/CERT.SF
  inflating: META-INF/CERT.RSA
```

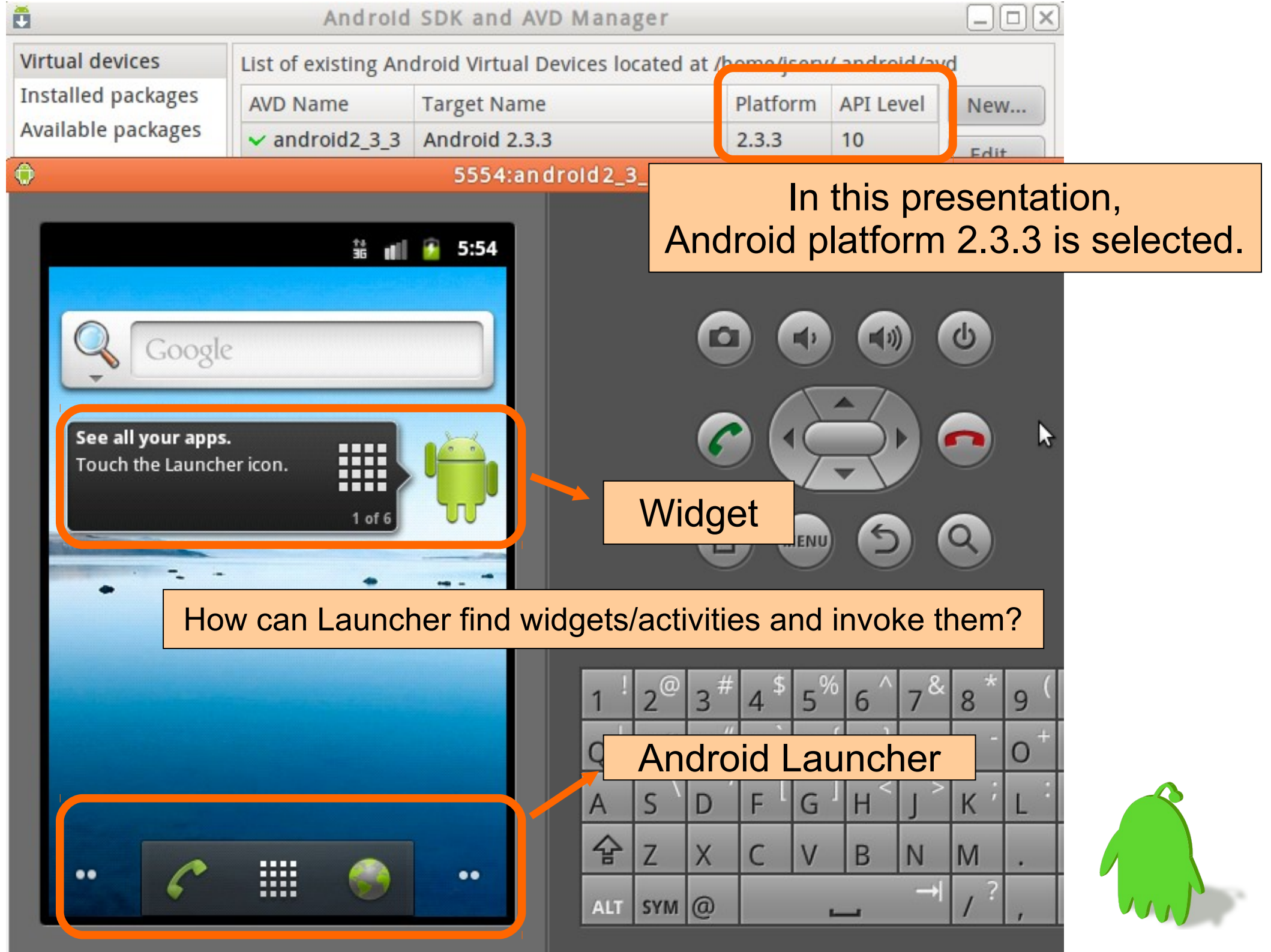
AndroidManifest


```
$ unzip Angry+Birds.
Archive:  Angry+Bird
...
...
  inflating: AndroidManifest.xml
 extracting: resources.arsc
```

```
$ file AndroidManifest.xml
AndroidManifest.xml: DBase 3 data file (2328 records)

$ apktool d ../AngryBirds/Angry+Birds.apk
I: Baksmaling...
I: Loading resource table...
...
I: Decoding file-resources...
I: Decoding values*/* XMLs...
I: Done.
I: Copying assets and libs...
$ file Angry+Birds/AndroidManifest.xml
Angry+Birds/AndroidManifest.xml: XML  document text
```

so

Before performing reverse engineering, let's observe how Android system works


Android SDK and AVD Manager
Virtual devices
Installed packages
Available packages
List of existing Android Virtual Devices located at
AVD Name
Target Name
Platform
API Level
New...
Edit...
android2_3_3
Android 2.3.3
2.3.3
10
5554:android2_3_
In this presentation,
Android platform 2.3.3 is selected.
5:54
Google
See all your apps.
Touch the Launcher icon.
1 of 6
Widget
How can Launcher find widgets/activities and invoke them?
Android Launcher

When installing FrozenBubble.apk

```
$ adb logcat -c
$ adb install -r FrozenBubble.apk
1222 KB/s (499568 bytes in 0.399s)
pkg: /data/local/tmp/FrozenBubble.apk
Success
$ adb logcat
D/AndroidRuntime(  329):
D/AndroidRuntime(  329): >>>>>>
AndroidRuntime START
com.android.internal.os.RuntimeInit <<<<<<
D/PackageParser(   60): Scanning
package: /data/app/vmdl10628918.tmp
...
```

Download the whole package: http://0xlab.org/~jserv/dex-dis-example.tar.bz2

APK Installation Procedure

D/AndroidRuntime(329):

D/AndroidRuntime(329): >>>>>> AndroidRuntime START com.android.internal.os.RuntimeInit <<<<<<

D/PackageParser(60): Scanning package: /data/app/vmdl10628918.tmp

I/PackageManager(60): Removing non-system package:org.jfedor.frozenbubble

I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

D/PackageManager(60): Scanning package org.jfedor.frozenbubble

I/PackageManager(60): Package org.jfedor.frozenbubble codePath changed from /data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk; Retaining data and using new

I/PackageManager(60): Unpacking native libraries for /data/app/org.jfedor.frozenbubble-1.apk

D/installd(34): DexInv: --- BEGIN '/data/app/org.jfedor.frozenbubble-1.apk' ---

D/dalvikvm(340): DexOpt: load 54ms, verify+opt 137ms

D/installd(34): DexInv: --- END '/data/app/org.jfedor.frozenbubble-1.apk' (success) ---

W/PackageManager(60): Code path for pkg : org.jfedor.frozenbubble changing from /data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk

W/PackageManager(60): Resource path for pkg : org.jfedor.frozenbubble changing from /data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk

D/PackageManager(60): Activities: org.jfedor.frozenbubble.FrozenBubble

I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

I/installd(34): move /data/dalvik-cache/data@app@org.jfedor.frozenbubble-1.apk@classes.dex -> /data/dalvik-cache/data@app@org.jfedor.frozenbubble-1.apk@classes.dex

D/PackageManager(60): New package installed in /data/app/org.jfedor.frozenbubble-1.apk

I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

I/installd(34): unlink /data/dalvik-cache/data@app@org.jfedor.frozenbubble-2.apk@classes.dex

D/AndroidRuntime(329): Shutting down VM

D/jdwp (329): adbd disconnected

APK Installation Procedure

D/AndroidRuntime(329)
D/AndroidRuntime(329)

Android Runtime performs init

D/PackageParser(60):
I/PackageManager(60)

Package Manager detects APK and installs

I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

D/PackageManager(60): Scanning package org.jfedor.frozenbubble

I/PackageManager(60): Package org.jfedor.frozenbubble codePath changed from /data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk; Retaining data and using new

I/PackageManager(60): Unpacking native libraries for /data/app/org.jfedor.frozenbubble-1.apk

D/installd(34): DexInv: --- BEGIN '/data/app/org.jfedor.frozenbubble-1.apk' ---

D/dalvikvm(340): DexOpt:
D/installd(34): DexInv: ---

DexOpt
(verify and optimize all of the classes in the DEX file)

W/PackageManager(60):
/data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk

W/PackageManager(60): Resource path for pkg : org.jfedor.frozenbubble changing from /data/app/org.jfedor.frozenbubble-2.apk to /data/app/org.jfedor.frozenbubble-1.apk

D/PackageManager(60): Activities: org.jfedor.frozenbubble.FrozenBubble

I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

I/installd(
/data/dalvi

Activities: ***org.jfedor.frozenbubble.FrozenBubble***

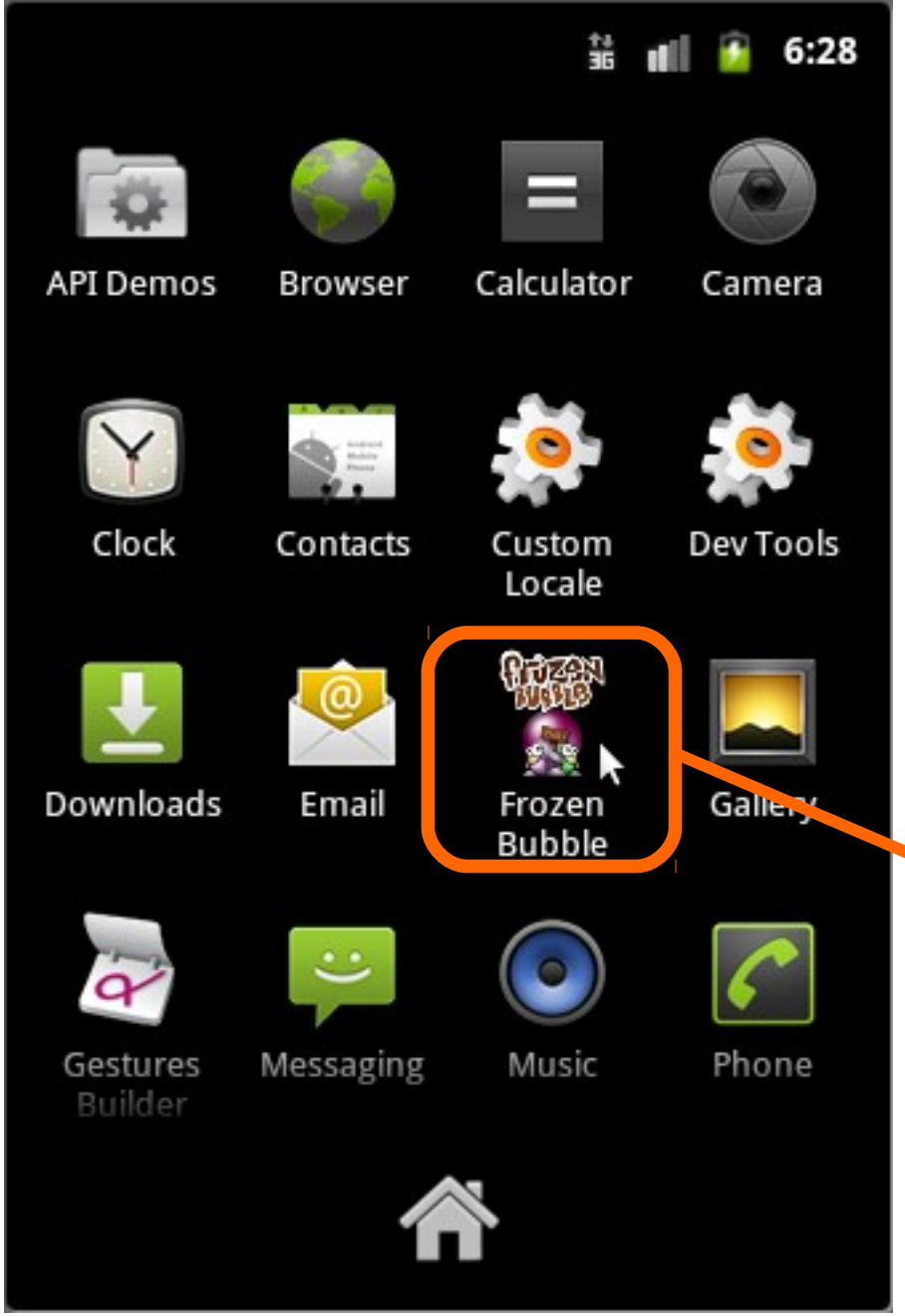
D/PackageManager(60): New package installed in /data/app/org.jfedor.frozenbubble-1.apk

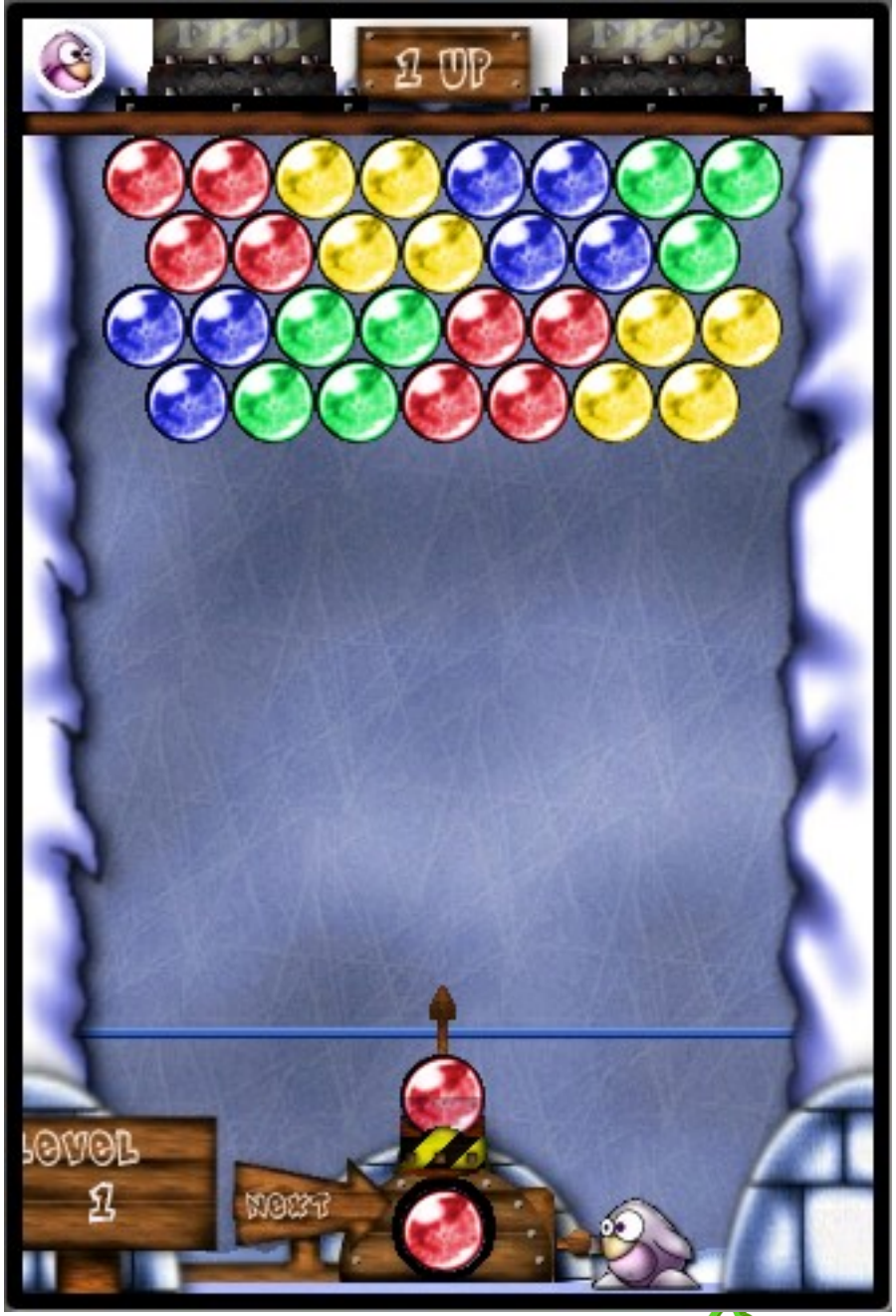
I/ActivityManager(60): Force stopping package org.jfedor.frozenbubble uid=10034

I/installd(34): unlink /data/dalvik-cache/data@app@org.jfedor.frozenbubble-2.apk@classes.dex

D/AndroidRuntime(329): Shutting down VM

D/jdwp (329): adbd disconnected



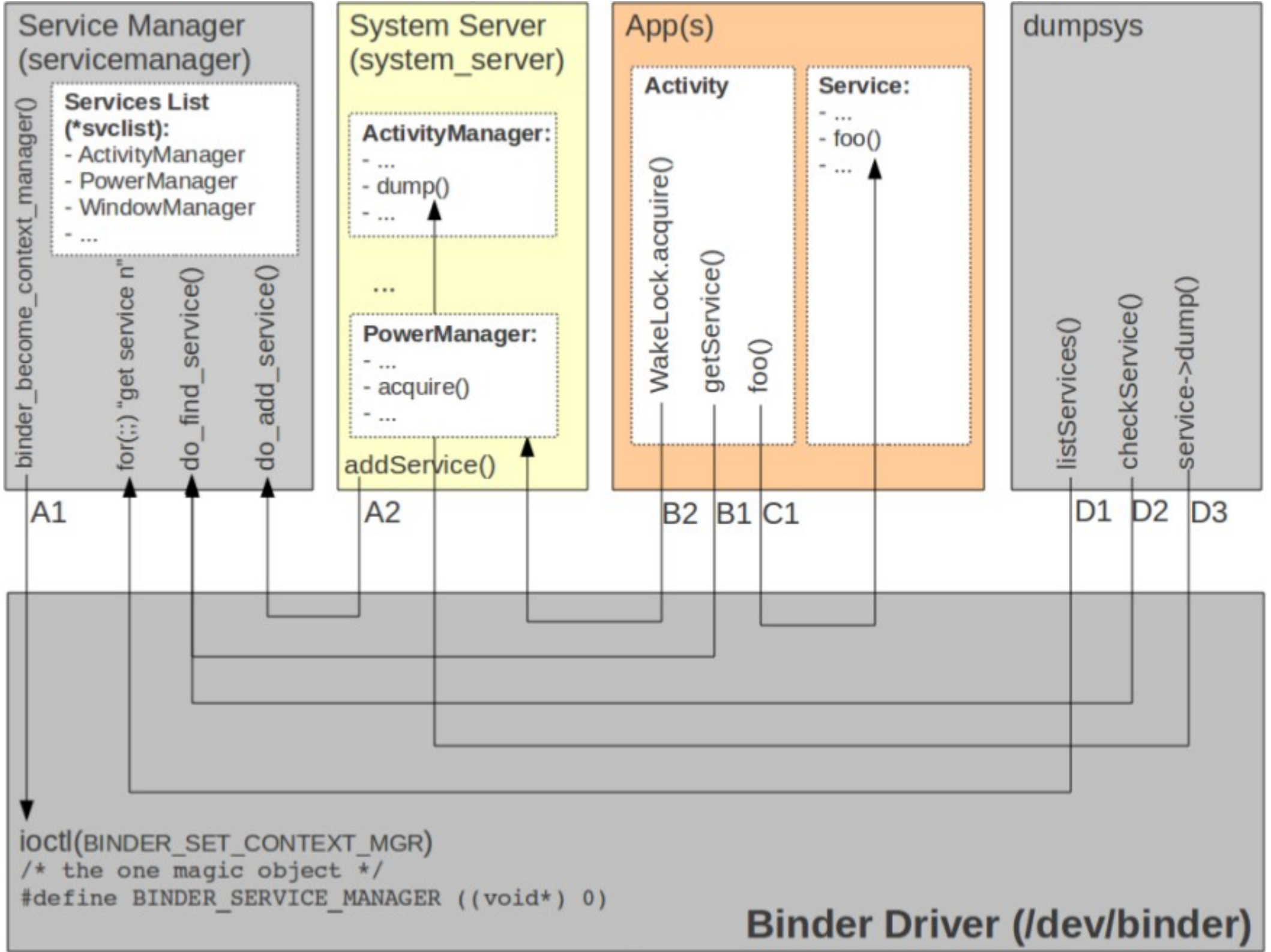


I/ActivityManager(60): Start proc org.jfedor.frozenbubble for activity org.jfedor.frozenbubble/.FrozenBubble: pid=356 uid=10034 gids={}

I/ActivityManager(60): Displayed org.jfedor.frozenbubble/.FrozenBubble: +2s899ms

Execute FrozenBubble from Android Launcher

```
$ adb shell am start \
  -e debug true \
  -a android.intent.action.MAIN \
  -c android.intent.category.LAUNCHER \
  -n org.jfedor.frozenbubble/.FrozenBubble
Starting: Intent
{ act=android.intent.action.MAIN
cat=[android.intent.category.LAUNCHER]
cmp=org.jfedor.frozenbubble/.FrozenBubb
le (has extras)
```


Service Manager
(servicemanager)
Services List
(*svclist):
- ActivityManager
- PowerManager
- WindowManager
- ...
binder_become_context_manager()
for(;;) "get service n"
do_find_service()
do_add_service()
System Server
(system_server)
ActivityManager:
- ...
- dump()
- ...
...
PowerManager:
- ...
- acquire()
- ...
addService()
App(s)
Activity
WakeLock.acquire()
getService()
foo()
Service:
- ...
- foo()
- ...
dumpsys
listServices()
checkService()
service->dump()
A1
A2
B2
B1
C1
D1
D2
D3
ioctl(BINDER_SET_CONTEXT_MGR)
/* the one magic object */
#define BINDER_SERVICE_MANAGER ((void*) 0)
Binder Driver (/dev/binder)

Execute FrozenBubble

```
$ adb shell dumpsys | grep -i bubble
```

name=org.jfedor.frozenbubble/org.jfedor.frozenbubble.FrozenBubble

Intent { act=android.intent.action.PACKAGE_ADDED dat=package:org.jfedor.frozenbubble flg=0x10000000 (has extras) }

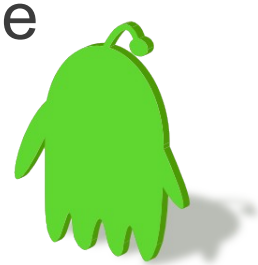
* TaskRecord{40744ad0 #4 A org.jfedor.frozenbubble}

affinity=org.jfedor.frozenbubble

intent={act=android.intent.action.MAIN cat=[android.intent.category.LAUNCHER] flg=0x10200000 cmp=org.jfedor.frozenbubble/.FrozenBubble}

realActivity=org.jfedor.frozenbubble/.FrozenBubble

...



ActivityManager

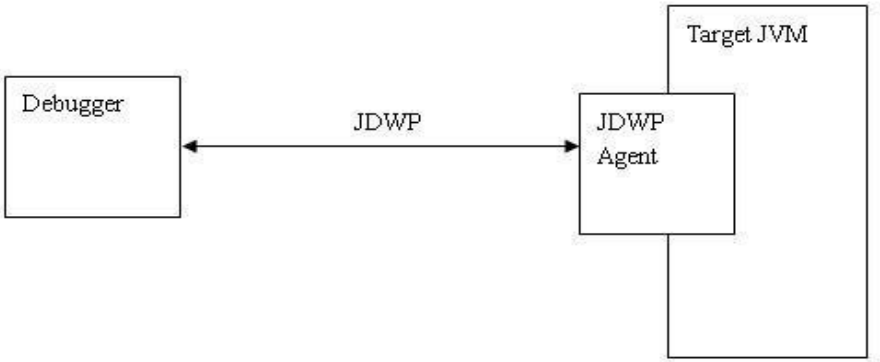
- Start new Activities and Services
- Fetch Content Providers
- Intent broadcasting
- OOM adj. Maintenance
- ANR (Application Not Responding)
- Permissions
- Task management
- Lifecycle management

ActivityManager

- starting new app from Launcher:
  - onClick(Launcher)
  - startActivity
  - <Binder>
  - ActivityManagerService
  - startViaZygote(Process.java)
  - <Socket>
  - Zygote

Use JDB to Trace Android Application

```
#!/bin/bash
adb wait-for-device
adb shell am start \
    -e debug true \
    -a android.intent.action.MAIN \
    -c android.intent.category.LAUNCHER \
    -n org.jfedor.frozenbubble/.FrozenBubble &
debug_port=$(adb jdwp | tail -1);
adb forward tcp:29882 jdwp:$debug_port &
jdb -J-Duser.home=. -connect \
com.sun.jdi.SocketAttach:hostname=localhost,port=29882 &
```



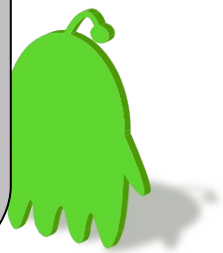
In APK manifest, `debuggable="true"`

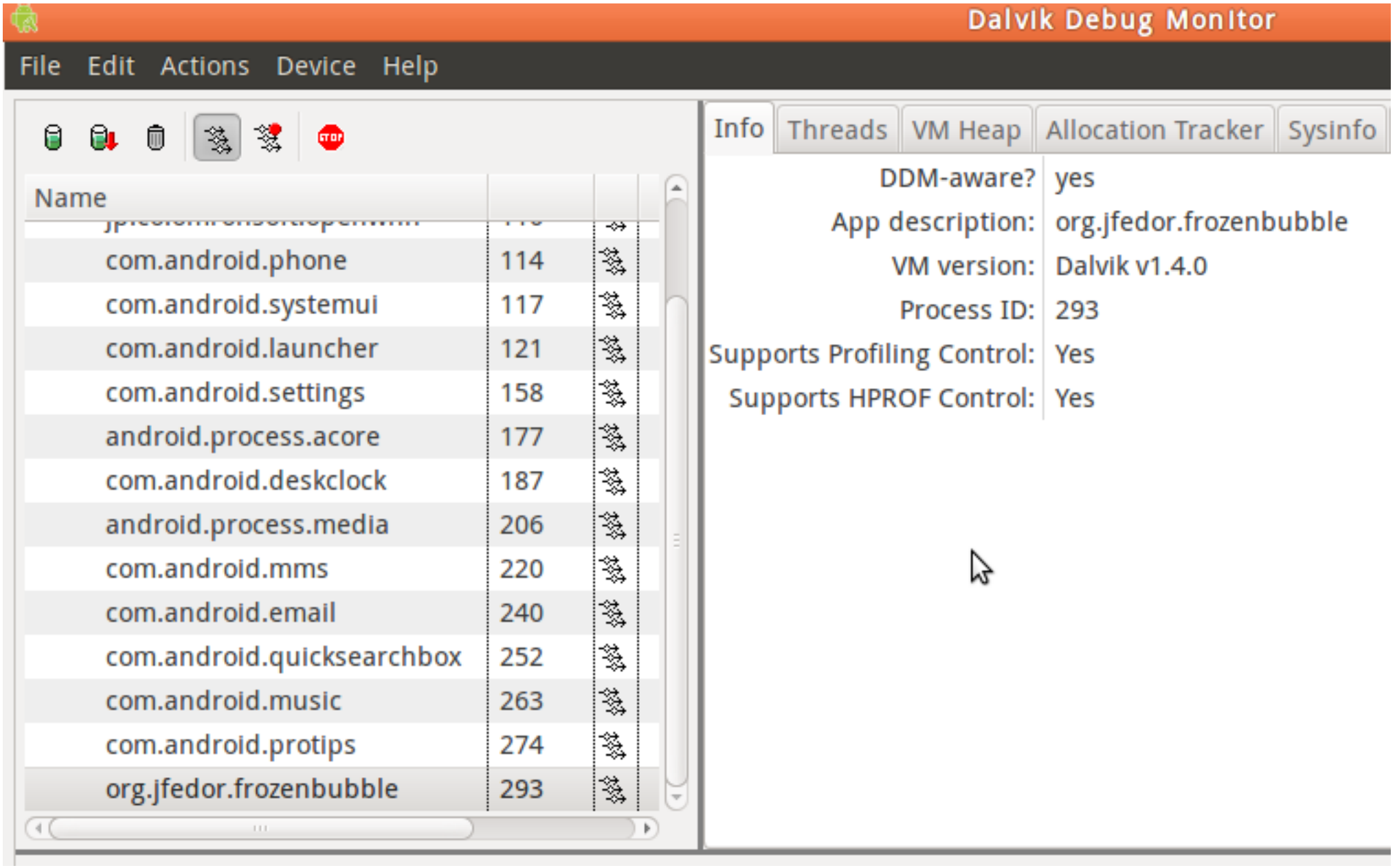
JDWP: Java Debug Wire Protocol

JDB usage

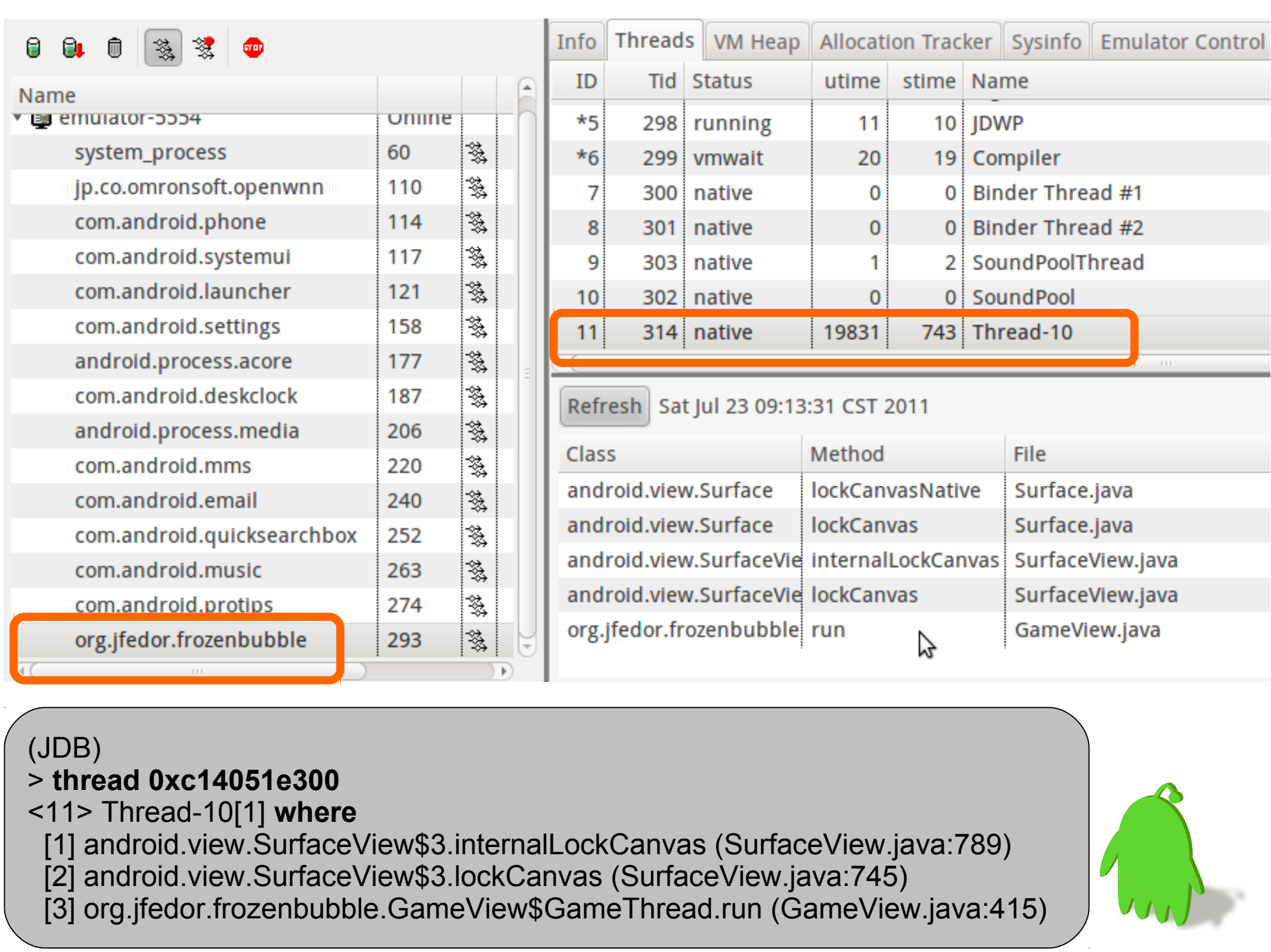
```
> threads
Group system:
  (java.lang.Thread)0xc14050e388  <6> Compiler          cond. Waiting
  (java.lang.Thread)0xc14050e218  <4> Signal Catcher    cond. waiting
  (java.lang.Thread)0xc14050e170  <3> GC                cond. waiting
  (java.lang.Thread)0xc14050e0b8  <2> HeapWorker        cond. waiting
Group main:
  (java.lang.Thread)0xc14001f1a8  <1> main              running
  (org.jfedor.frozenbubble.GameView$GameThread)0xc14051e300
                                  <11> Thread-10        running
  (java.lang.Thread)0xc14050f670  <10> SoundPool        running
  (java.lang.Thread)0xc14050f568  <9> SoundPoolThread   running
  (java.lang.Thread)0xc140511db8  <8> Binder Thread #2  running
  (java.lang.Thread)0xc140510118  <7> Binder Thread #1  running
```

```
> suspend 0xc14051e300
> thread 0xc14051e300
<11> Thread-10[1] where
  [1] android.view.SurfaceView$3.internalLockCanvas (SurfaceView.java:789)
  [2] android.view.SurfaceView$3.lockCanvas (SurfaceView.java:745)
  [3] org.jfedor.frozenbubble.GameView$GameThread.run (GameView.java:415)
```



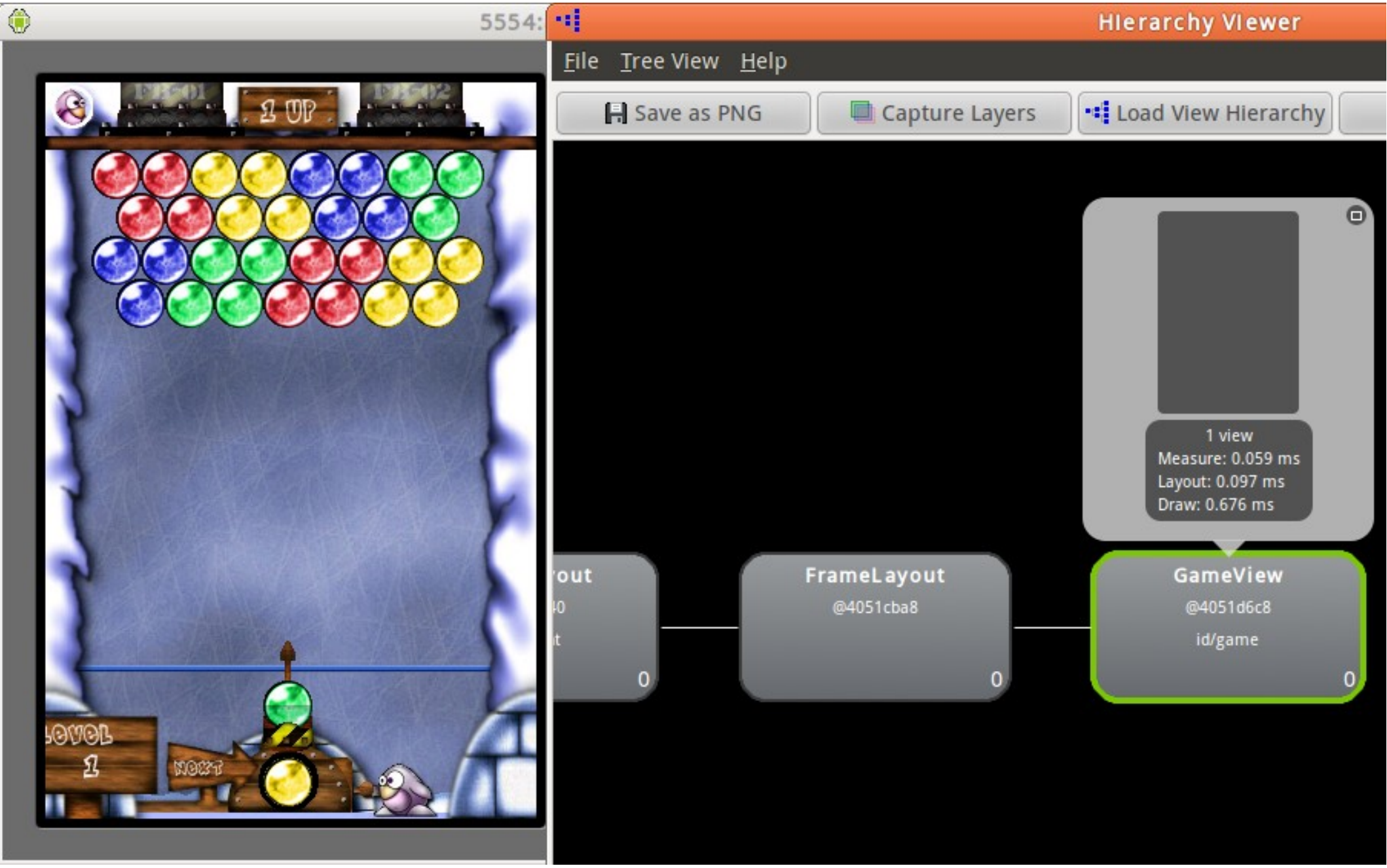


DDMS = Dalvik Debug Monitor Server




```
(JDB)
> thread 0xc14051e300
<11> Thread-10[1] where
  [1] android.view.SurfaceView$3.internalLockCanvas (SurfaceView.java:789)
  [2] android.view.SurfaceView$3.lockCanvas (SurfaceView.java:745)
  [3] org.jfedor.frozenbubble.GameView$GameThread.run (GameView.java:415)
```

hierarchyviewer: Traverse widgets



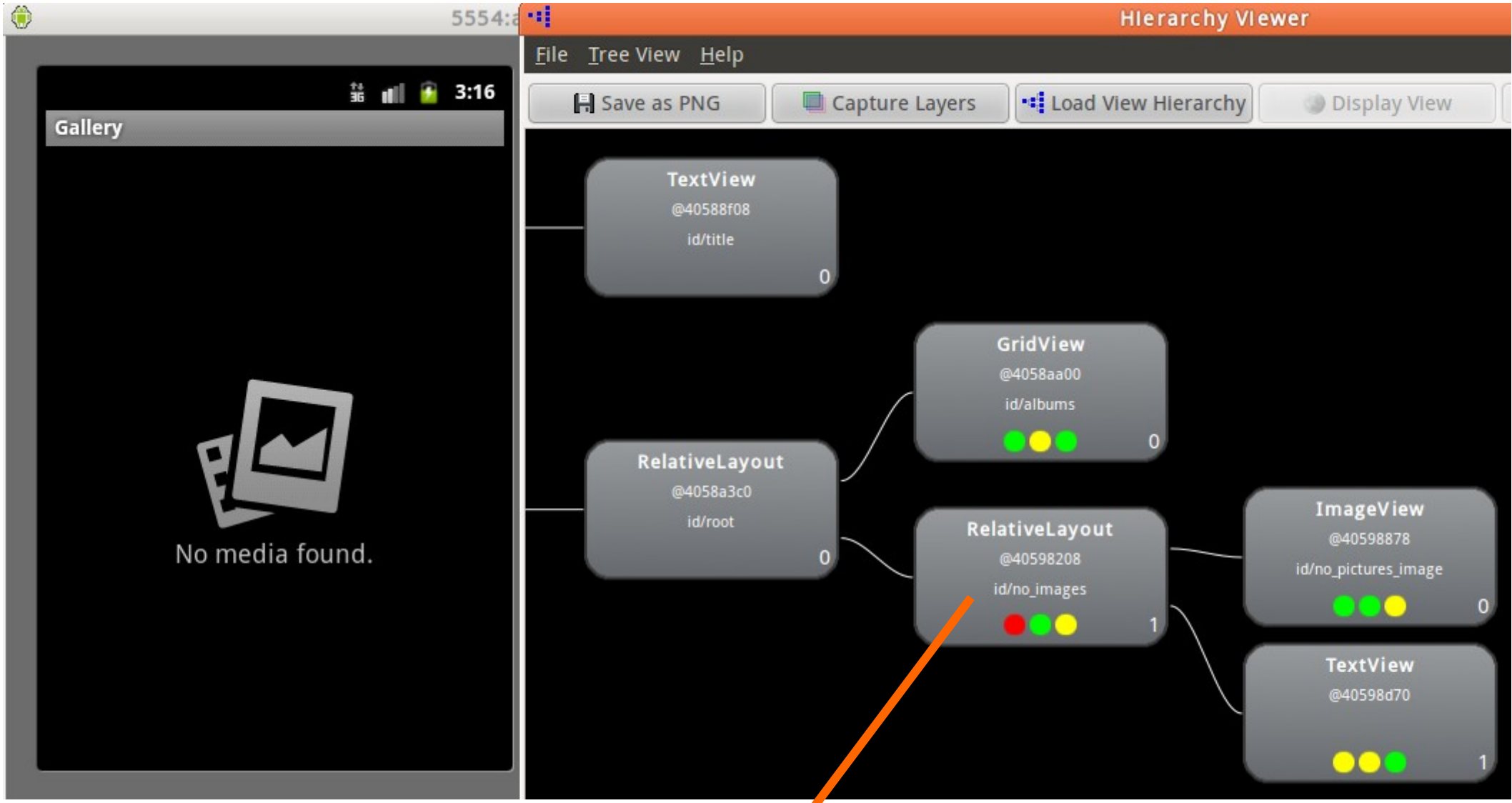
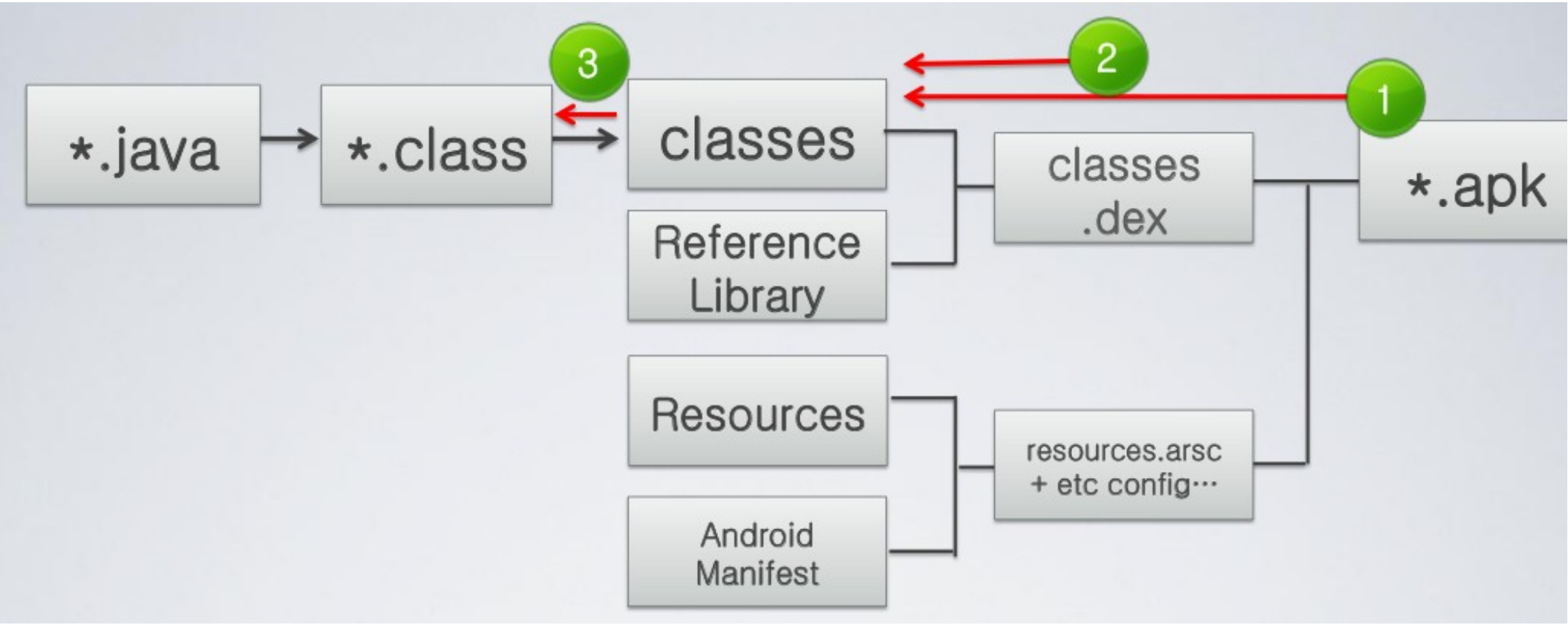


Figure out the association between APK resources and runtime behavior.

Decompile / Disassembly

- apktool: http://code.google.com/p/android-apktool/
- dex2jar: http://code.google.com/p/dex2jar/
- Jad / jd-gui: http://java.decompiler.free.fr/



smali : assembler/disassembler for Android's dex format

- http://code.google.com/p/smali/
- smali: The assembler
- baksmali: The disassembler
- Fully integrated in apktool

```
$ apktool d ../AngryBirds/Angry+Birds.apk
I: Baksmaling...
I: Loading resource table...
...
I: Decoding file-resources...
I: Decoding values*/* XMLs...
I: Done.
I: Copying assets and libs...
```

Java bytecode vs. Dalvik bytecode

(stack vs. register)

```
public int method( int i1, int i2 ) {
    int i3 = i1 * i2;
    return i3 * 2;
}
```

```
.var 0 is "this"
.var 1 is argument #1
.var 2 is argument #2

method public method(II)I
    iload_1
    iload_2
    imul
    istore_3
    iload_3
    iconst_2
    imul
    ireturn
.end method
```

Java

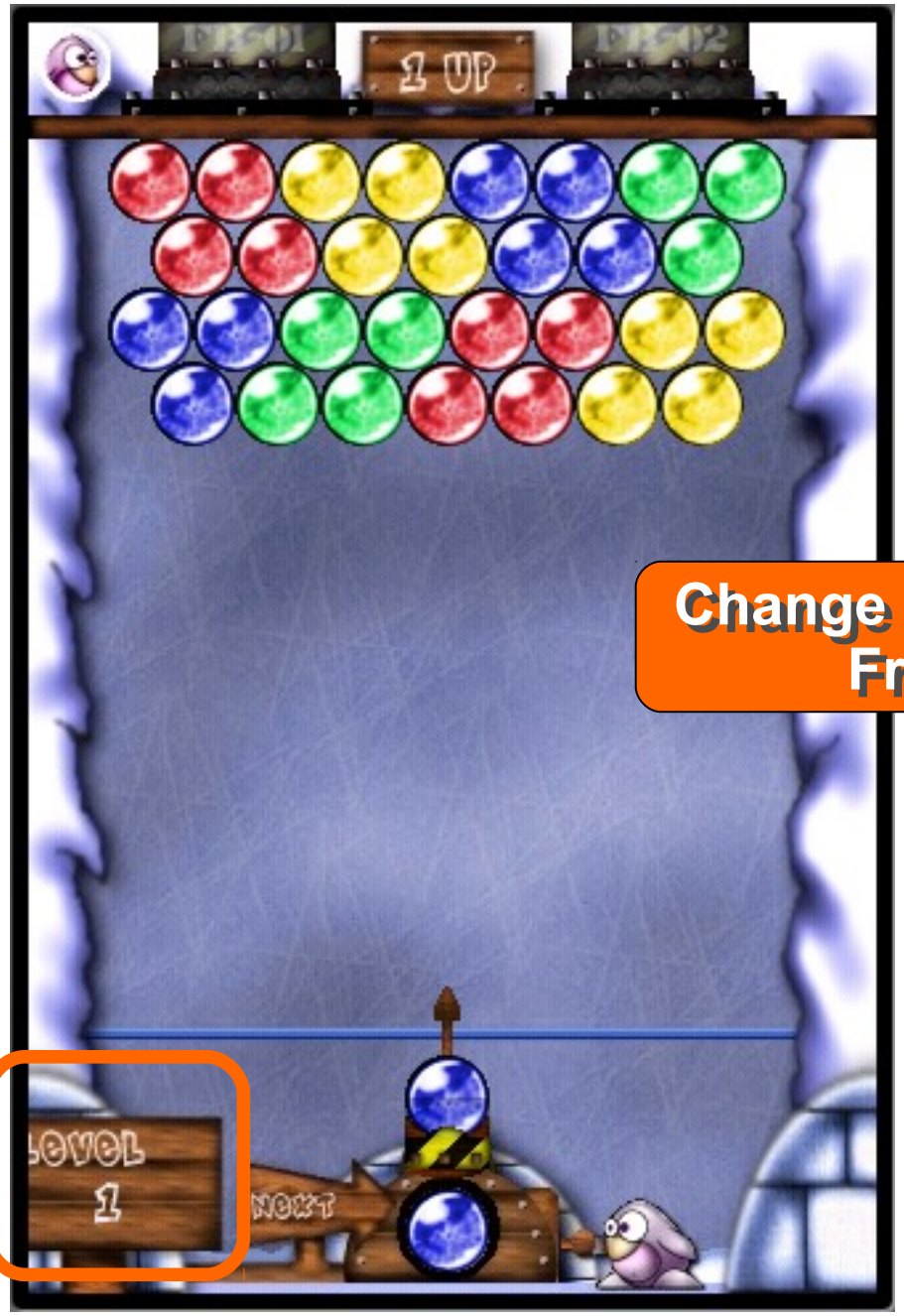
```
this: v1 (Ltest2;)
parameter[0] : v2 (I)
parameter[1] : v3 (I)

.method public method(II)I
    mul-int v0,v2,v3
    mul-int/lit-8 v0,v0,2
    return v0
.end method
```

Dalvik

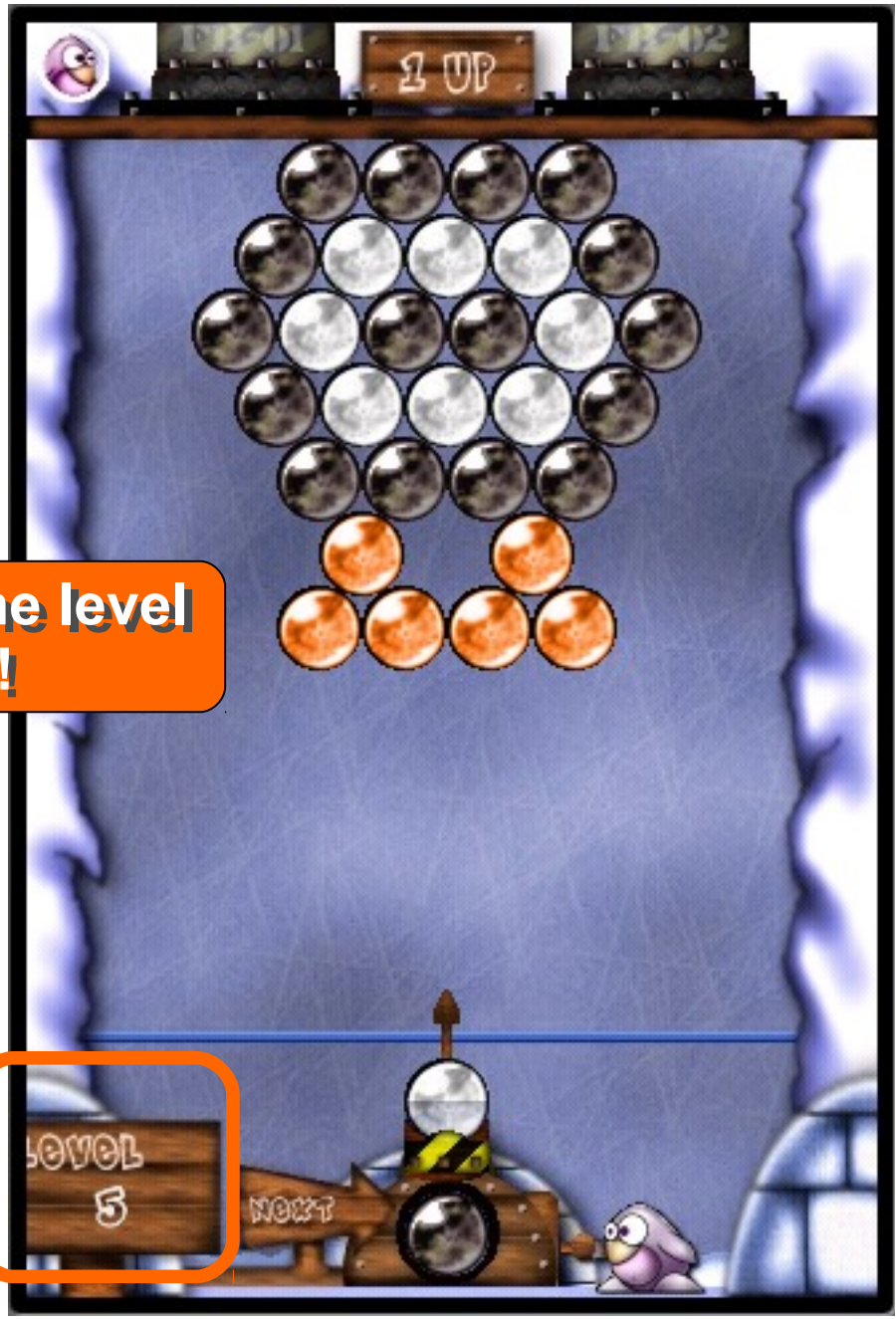
Dalvik Register frames

- Dalvik registers behave more like local variables
- Each method has a fresh set of registers.
- Invoked methods don't affect the registers of invoking methods.

Practice: Level Up



Change initial game level
From 1 to 5 !



Disassembly

```
$ mkdir workspace smali-src
$ cd workspace
$ unzip ../FrozenBubble-orig.apk
Archive:  ../FrozenBubble-orig.apk
  inflating: META-INF/MANIFEST.MF
  inflating: META-INF/CERT.SF
  inflating: META-INF/CERT.RSA
  inflating: AndroidManifest.xml
...
extracting: resources.arsc
$ bin/baksmali -o smali-src workspace/classes.dex
```

Output

org.jfedor.frozenbubble/.FrozenBubble

```
smali-src$ find
./org/jfedor/frozenbubble/FrozenBubble.smali
./org/jfedor/frozenbubble/R$id.smali
./org/jfedor/frozenbubble/GameView.smali
./org/jfedor/frozenbubble/SoundManager.smali
./org/jfedor/frozenbubble/LaunchBubbleSprite.smali
./org/jfedor/frozenbubble/Compressor.smali
./org/jfedor/frozenbubble/R$attr.smali
./org/jfedor/frozenbubble/BubbleFont.smali
./org/jfedor/frozenbubble/PenguinSprite.smali
./org/jfedor/frozenbubble/GameView$GameThread.smali
./org/jfedor/frozenbubble/LevelManager.smali
./org/jfedor/frozenbubble/BubbleSprite.smali
./org/jfedor/frozenbubble/R$string.smali
...
```

Generated from resources

Output

```
smali-src$ grep "\.method"
org/jfedor/frozenbubble/LevelManager.smali
.method public constructor <init>([BI)V
.method private getLevel(Ljava/lang/String;)[[B
.method public getCurrentLevel()[[B
.method public getLevelIndex()I
.method public goToFirstLevel()V
.method public goToNextLevel()V
.method public restoreState(Landroid/os/Bundle;)V
.method public saveState(Landroid/os/Bundle;)V
```

List the methods implemented in class LevelManager

Dalvik::Types

```
.method private getLevel(Ljava/lang/String;)[[B
    → private byte[][] getLevel(String data)

.method public goToNextLevel()V
    → public void goToNextLevel();
```

- Base types
  - I : int / J : long / S : short
  - Z : boolean
  - D : double / F : float
  - C : char
  - V : void (when return value)
- Classes: Ljava/lang/Object;
- Arrays: [I, [Ljava/lang/Object;, [[I

Dalvik::Methods

- Rich meta-information is assigned to Dalvik methods
- Method meta-information:
  - Signature
  - Try-catch information
  - Annotations
  - Number of registers used
  - Debug information
    - Line numbers
    - Local variable lifetime

Output

```
smali-src$ grep -r goToFirstLevel *
org/jfedor/frozenbubble/GameView$GameThread.smali:
invoke-virtual {v2},
  Lorg/jfedor/frozenbubble/LevelManager;->goToFirstLevel()V
org/jfedor/frozenbubble/LevelManager.smali:
.method public goToFirstLevel()V
```

That the first argument of the method invocation is “this” as this is a non-static method.

GameView$GameThread.smali

```
.method public newGame()V
        . . .
    move-object/from16 v0, p0

    iget-object v0, v0,
Lorg/jfedor/frozenbubble/GameView$GameThread;-
>mLevelManager:Lorg/jfedor/frozenbubble/LevelManager;

    move-object v2, v0

    invoke-virtual {v2},
Lorg/jfedor/frozenbubble/LevelManager;->goToFirstLevel ()V
```

Equals to Java:
`objLevelManager.goToFirstLevel();`

LevelManager.smali

```
.method public goToFirstLevel()V
    .registers 2

    .prologue
    .line 175
    const/4 v0, 0x0

    iput v0, p0,
 Lorg/jfedor/frozenbubble/LevelManager;->currentLevel:I

    .line 176
    return-void
.end method
```

Equals to Java:

```
public class LevelManager {
    ...
    public void goToFirstLevel() {
        currentLevel = 0;
    }
    ...
}
```

Equals to Java:

```
currentLevel = 0;
```

Constants to registers: const/4, const/16, const, const/high16, const-wide/16, const-wide/32, const-wide, const-wide/high16, const-string, const-class

Modify constructor of GameView::GameThread()

- Look up output in GameView$GameThread.smali

```
.class Lorg/jfedor/frozenbubble/GameView$GameThread;
.super Ljava/lang/Thread;
.annotation system Ldalvik/annotation/InnerClass;
    accessFlags = 0x0
    name = "GameThread"
.end annotation

# direct methods
.method public constructor
<init>(Lorg/jfedor/frozenbubble/GameView;Landroid/view/SurfaceHol
der;[BI)V
```

Modify constructor of GameView::GameThread()

- Look up output in GameView$GameThread.smali

  # direct methods

  .method public constructor <init>(Lorg/jfedor/frozenbubble/GameView;Landroid/view/SurfaceHolder;[BI)V

Equals to Java:

```
class GameView ??? {
    class GameThread extends Thread {
        public GameThread(SurfaceHolder s,
                          byte[] b,
                          int I) {
```

GameView.smali

- Look up output in GameView.smali

  .class Lorg/jfedor/frozenbubble/GameView;

  .super Landroid/view/SurfaceView;

  # interfaces

  .implements Landroid/view/SurfaceHolder$Callback;

- Look up output in GameView$GameThread.smali

.class Lorg/jfedor/frozenbubble/GameView$GameThread;

.super Ljava/lang/Thread;

Equals to Java:

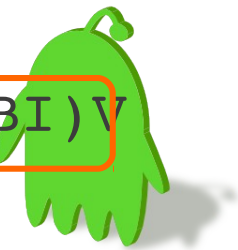
```
class GameView extends SurfaceView
                implements SurfaceHolder.Callback {
  class GameThread extends Thread {
```

Implementation of GameView::GameThread()

- Check GameView::public GameThread(SurfaceHolder s, byte[] b, int I)

```
const-string v3, "level"
const/4 v4, 0x0
move-object/from16 v0, v25
move-object v1, v3
move v2, v4
invoke-interface {v0, v1, v2},
Landroid/content/SharedPreferences;-
>getInt(Ljava/lang/String;I)I
move-result p4
new-instance v3, Lorg/jfedor/frozenbubble/LevelManager;
move-object v0, v3
move-object/from16 v1, v22
move/from16 v2, p4 invoke-direct {v0, v1, v2},
Lorg/jfedor/frozenbubble/LevelManager;-><init>([BI)V
```

Invoke constructor of LevelManager



Register v1 related code

```
const-string v3, "level"
const/4 v4, 0x0
move-object/from16 v0, v25
move-object v1, v3
move v2, v4
invoke-interface {v0, v1, v2},
Landroid/content/SharedPreferences;-
>getInt(Ljava/lang/String;I)I
move-result p4
new-instance v3,
Lorg/jfedor/frozenbubble/LevelManager;
move-object v0, v3
move-object/from16 v1, v22
move/from16 v2, p4
invoke-direct {v0, v1, v2},
Lorg/jfedor/frozenbubble/LevelManager;-><init>([BI)V
```

Register v2 related code

```
const-string v3, "level"
const/4 v4, 0x0
move-object/from16 v0, v25
move-object v1, v3
move v2, v4
invoke-interface {v0, v1, v2},
Landroid/content/SharedPreferences;-
>getInt(Ljava/lang/String;I)I
move-result p4
new-instance v3,
Lorg/jfedor/frozenbubble/LevelManager;
move-object v0, v3
move-object/from16 v1, v22
move/from16 v2, p4
invoke-direct {v0, v1, v2},
Lorg/jfedor/frozenbubble/LevelManager;-><init>([BI)V
```

"0x0" is passed to LevelManager's constructor as parameter

Recall the grep results

```
smali-src$ grep "\.method"
org/jfedor/frozenbubble/LevelManager.smali
.method public constructor <init>([BI)V
.method private getLevel(Ljava/lang/String;)[[B
.method public getCurrentLevel()[[B
.method public getLevelIndex()I
.method public goToFirstLevel()V
.method public goToNextLevel()V
.method public restoreState(Landroid/os/Bundle;)V
.method public saveState(Landroid/os/Bundle;)V
```

Equals to Java:

```
public class LevelManager {
    ...
    public LevelManager(byte[] b, int i)
```

Register v2 related code

```
const-string v3,
const/4 v4, 0x0
move-object/from16 v0, v25
move-object v1, v3
move v2, v4
invoke-interface {v0, v1, v2},
Landroid/content/SharedPreferences;-
>getInt(Ljava/lang/String;I)I
move-result p4
new-instance v3,
Lorg/jfedor/frozenbu
move-object v0, v3
move-object/from16 v1, v22
move/from16 v2, p4
invoke-direct {v0, v1, v2},
Lorg/jfedor/frozenbubble/LevelManager;-><init>([BI)V
```

p4 reserve the result after method invocation.

Therefore, v2 has return value of method android.content.Shared.Preference.getInt()

Modify!!!

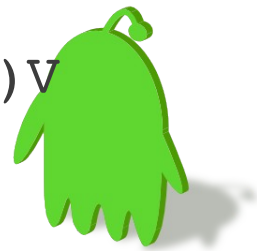
- Check GameView::public GameThread(SurfaceHolder s, byte[] b, int I)

```
const-string v3, "level"
const/4 v4, 0x0
move-object/from16 v0, v25
move-object v1, v3
move v2, v4
invoke-interface {v0, v1, v2},
Landroid/content/SharedPreferences;->getInt(Ljava/lang/String;I)I
move-result p4
new-instance v3, Lorg/jfedor/frozenbubble/LevelManager;
move-object v0, v3
move-object/from16 v1, v22
move/from16 v2, p4
invoke-direct {v0, v1, v2},
Lorg/jfedor/frozenbubble/LevelManager;-><init>([BI)V
```

Change value from 0x0 to 0x4

Remove!

Remove!



Real World Tasks

Tasks

- ODEX (Optimized DEX)
  - platform-specific optimizations:
    - specific bytecode
    - vtables for methods
    - offsets for attributes
    - method inlining
- JNI
  - JNIEnv
- Native Activity
- Key signing

DEX Optimizations

- Before being executed by Dalvik, DEX files are optimized.
  - Normally it happens before the first execution of code from the DEX file
  - Combined with the bytecode verification
  - In case of DEX files from APKs, when the application is launched for the first time.
- Process
  - The dexopt process (which is actually a backdoor of Dalvik) loads the DEX, replaces certain instructions with their optimized counterparts
  - Then writes the resulting optimized DEX (ODEX) file into the /data/dalvik-cache directory
  - It is assumed that the optimized DEX file will be executed on the same VM that optimized it. ODEX files are NOT portable across VMs.

dexopt: Instruction Rewritten

- Virtual (non-private, non-constructor, non-static methods)

  invoke-virtual <symbolic method name> → **invoke-virtual-quick** <vtable index>

  Before:

  invoke-virtual {v1,v2},java/lang/StringBuilder/append;append(Ljava/lang/String;)Ljava/lang/StringBuilder;

  After:

  invoke-virtual-quick {v1,v2},vtable #0x3b

- Frequently used methods

  invoke-virtual/direct/static <symbolic method name> → execute-inline <method index>

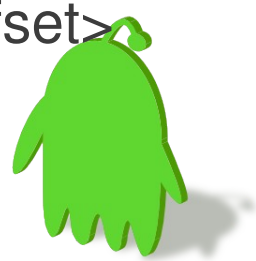
  – Before:

  invoke-virtual {v2},java/lang/String/length

  – After:

  execute-inline {v2},inline #0x4

- instance fields: iget/iput <field name> → iget/iput-quick <memory offset>
  – Before: iget-object v3,v5,android/app/Activity.mComponent
  – After: iget-object-quick v3,v5,[obj+0x28]



Meaning of DEX Optimizations

- Sets byte ordering and structure alignment
- Aligns the member variables to 32-bits / 64-bits
- boundary (the structures in the DEX/ODEX file itself are 32-bit aligned)
- Significant optimizations because of the elimination of symbolic field/method lookup at runtime.
- Aid of Just-In-Time compiler

JNI specificities can ease reversing

- 1- get the function signature in Java
- 2- use IDA to generate a TIL file from jni.h
- 3- assign the structure to the right variable
- 4- see function calls directly
- 5- do the same in Hex-Rays

Reverse: JNI

1

```
.text:0000173C    MOV     R8, R3
.text:0000173E    MOVS    R3, 0x2A4
.text:00001742    LDR     R3, [R2,R3]
.text:00001744    MOV     R9, R1
.text:00001746    MOVS    R2, #0
.text:00001748    LDR     R1, [SP,#0x1D0+var_1BC]
.text:0000174A    MOVS    R7, R0
.text:0000174C    BLX     R3
```

2

```
.text:0000173E    MOVS    R3, 0x
.text:00001742    LDR     R3, [R
.text:00001744    MOV     R9, R1
.text:00001746    MOVS    R2, #0
.text:00001748    LDR     R1, [S
.text:0000174A    MOVS    R7, R0
.text:0000174C    BLX     R3
.text:0000174E    LDR     R3, =(
```

Chart of xrefs from
JNINativeInterface.GetStringUTFChars
Use standard symbolic constant
676 H
01244
0b1010100100 B

3

```
.text:0000173C    MOV     R8, R3
.text:0000173E    MOVS    R3, JNINativeInterface.GetStringUTFChars
.text:00001742    LDR     R3, [R2,R3]
.text:00001744    MOV     R9, R1
.text:00001746    MOVS    R2, #0
.text:00001748    LDR     R1, [SP,#0x1D0+var_1BC]
.text:0000174A    MOVS    R7, R0
.text:0000174C    BLX     R3
```

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Reverse: JNI with Hex-Rays

```
v13 = strlen(v23);
8j3zIX(&v25, v23, v13, 0);
8j3zIX(&v25, v36, 32, 0);
sdlHj(&v25, &v32);
v22 = &v32;
((void (__fastcall *)(JNIEnv *, int, _DWORD, signed int))(*jnienv_)->SetByteArrayRegion)(jnienv_, v24, 0, 32);
i = 0;
do
{
  v26[i] = v33[i] ^ v36[i & 7];
  ++i;
}
while ( i != 17 );
v27 = v26[0] ^ 0x31;
v28 = v26[1] ^ 0x2C;
v29 = v26[2] ^ 0x59;
v30 = v26[3] ^ 0x2F;
v15 = ((int (__fastcall *)(JNIEnv *, unsigned __int8 *))(*jnienv_)->FindClass)(jnienv_, v26);
```

```
(*jnienv_)->SetByteArrayRegion)(jnienv_, v24, 0, 32);
```

ANSSI

Further Considerations

- Optimizing, Obfuscating, and Shrinking your Android Applications with ProGuard
  http://www.androidengineer.com/2010/07/optimizing-obfuscating-and-shrinking.html
- Missions:
  - Obfuscation
  - Optimizing
- ProGuard

```
<target name="-dex" depends="compile,optimize">
<target name="-post-compile">
  <antcall target="optimize"/>
</target>
```

- Google's License Verification Library (LVL)

```
-keep class com.android.vending.licensing.ILicensingService
```

Reference

- Analysis of Dalvik Virtual Machine and Class Path Library, Security Engineering Research Group, Institute of Management SciencesPeshawar, Pakistan (2009)

  http://serg.imsciences.edu.pk
- Android: forensics and reverse engineering, Raphaël Rigo – ANSSI (2010)
- http://code.google.com/p/dex2jar/
- http://java.decompiler.free.fr/

http://0xlab.org