# Android “OS” Internals

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A first glimpse of Android Internals

# Android Version History

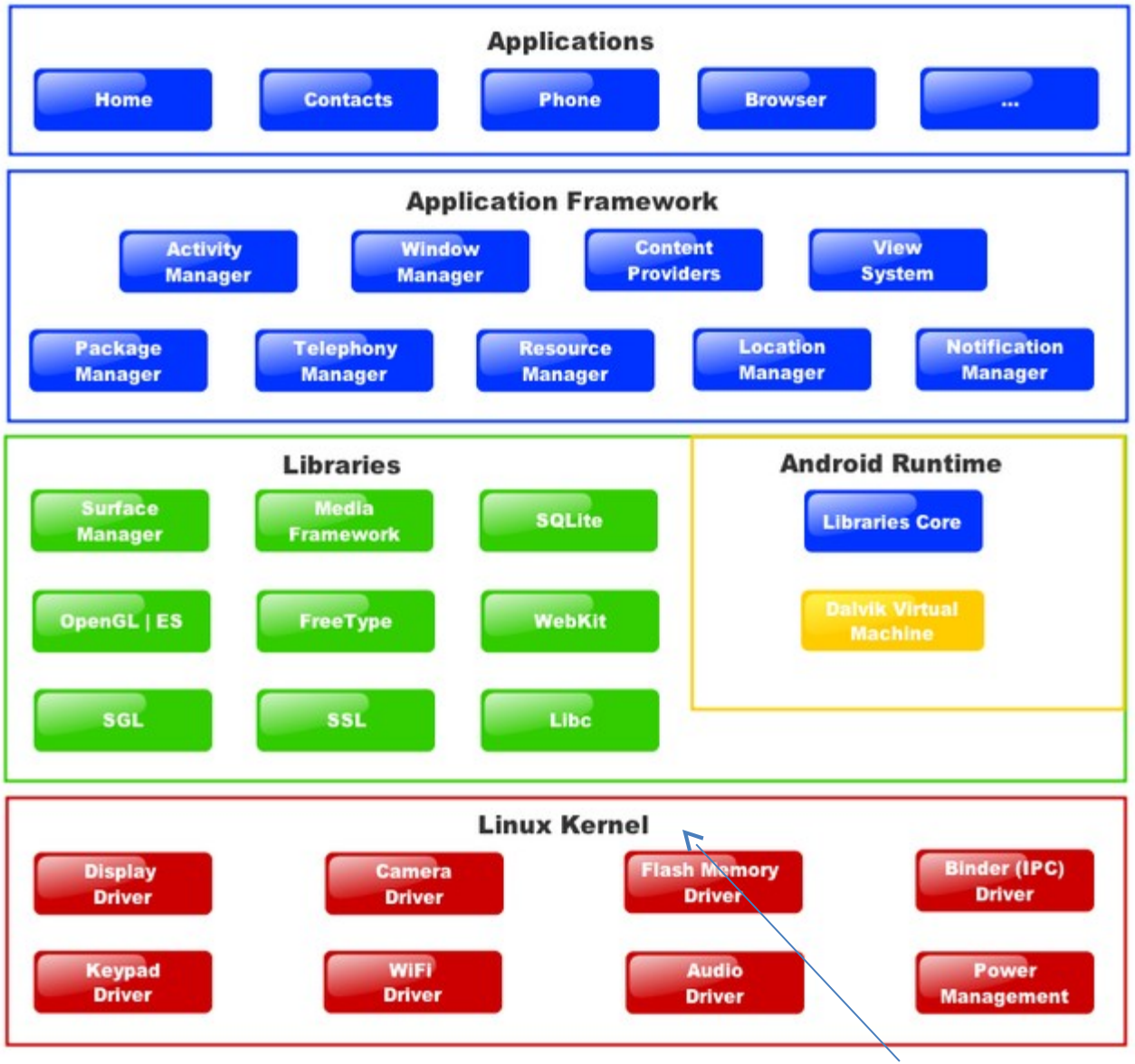
- http://en.wikipedia.org/wiki/Android_version_history

# Android System

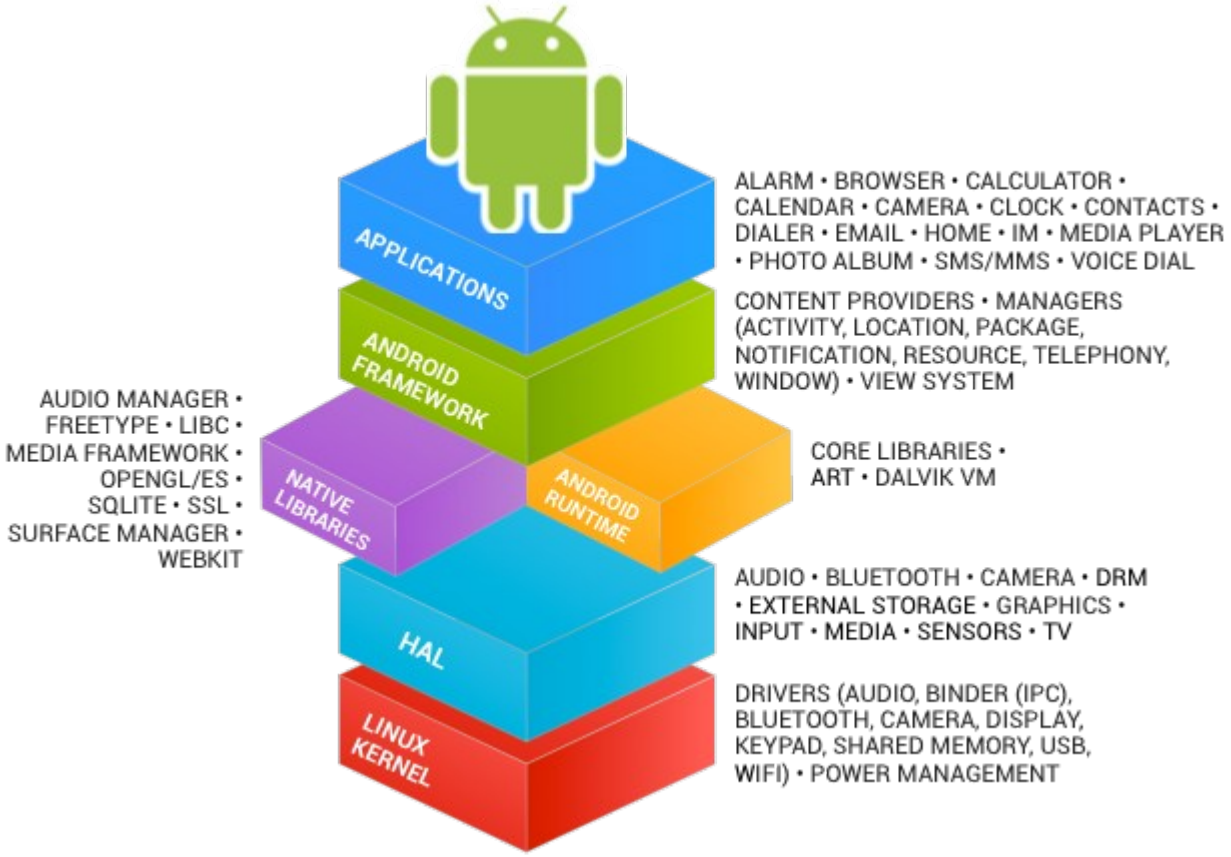
- Open software platform for mobile devices
- A complete stack – OS, Middleware, Applications
- An Open Handset Alliance (OHA) project
- Powered by Linux OS
- Application development mostly in Java
- Open source under the Apache 2 license

# Device Characteristics

- CPU: ARM 500-2600 Mhz; recently Intel Atom
- RAM available to an App is not as much as on PCs
- “Disk” (flash) access is slow cf to HDD/SSD
- Lifecycle:  Apps must pause/quit often, and restore to give the illusion that they are always running
- UI design
  - screen may be HVGA (320x480) to 1920x1080 to …
  - may be in portrait (h > w) or landscape (w > h)
  - high DPI -- small text may not be readable
  - touch resolution is low (~25 pixel)
- Network access may be slow and intermittent



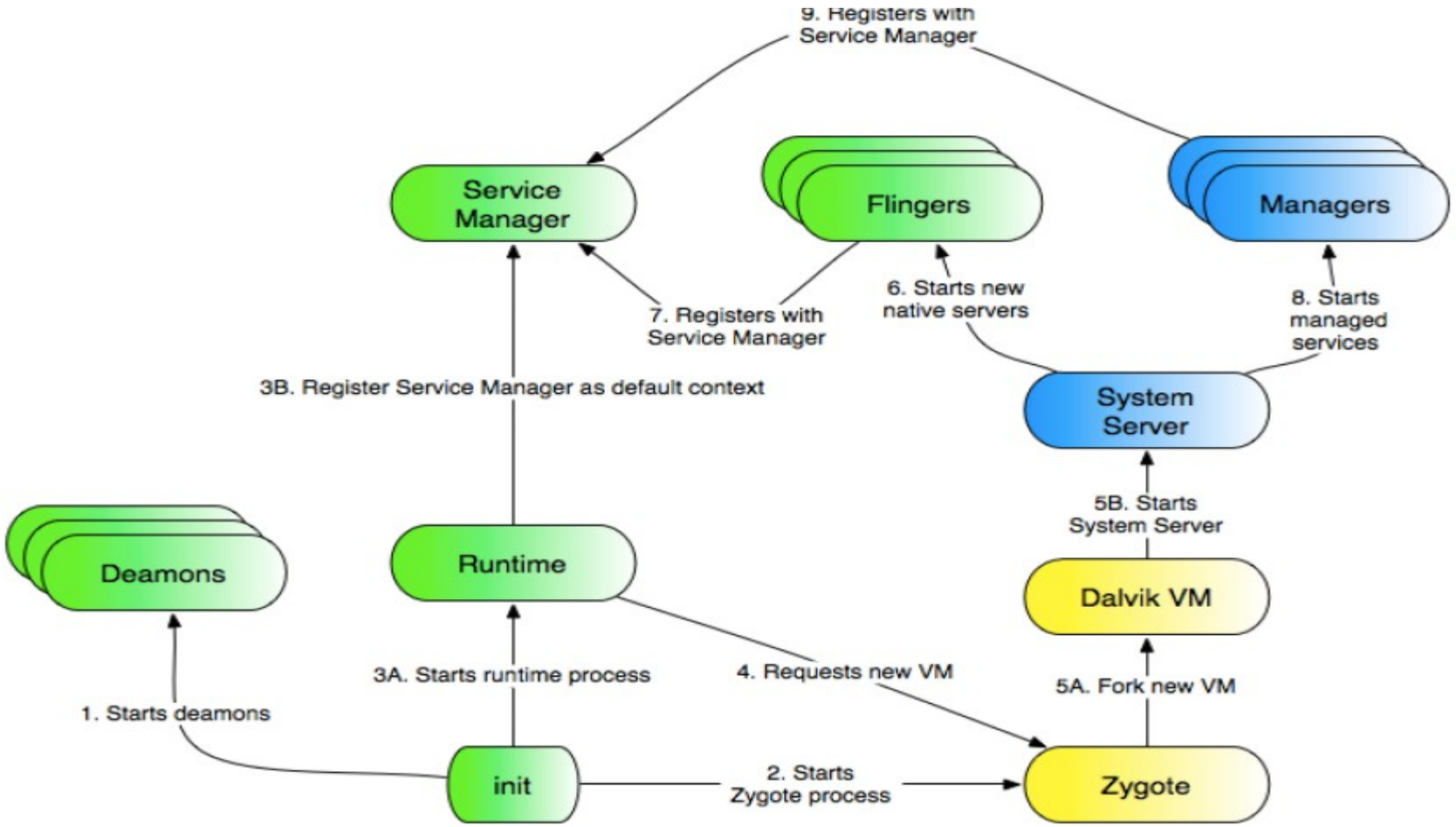

Std kernel parts not shown


APPLICATIONS
ALARM • BROWSER • CALCULATOR • CALENDAR • CAMERA • CLOCK • CONTACTS • DIALER • EMAIL • HOME • IM • MEDIA PLAYER • PHOTO ALBUM • SMS/MMS • VOICE DIAL
ANDROID FRAMEWORK
CONTENT PROVIDERS • MANAGERS (ACTIVITY, LOCATION, PACKAGE, NOTIFICATION, RESOURCE, TELEPHONY, WINDOW) • VIEW SYSTEM
NATIVE LIBRARIES
AUDIO MANAGER • FREETYPE • LIBC • MEDIA FRAMEWORK • OPENGL/ES • SQLITE • SSL • SURFACE MANAGER • WEBKIT
ANDROID RUNTIME
CORE LIBRARIES • ART • DALVIK VM
HAL
AUDIO • BLUETOOTH • CAMERA • DRM • EXTERNAL STORAGE • GRAPHICS • INPUT • MEDIA • SENSORS • TV
LINUX KERNEL
DRIVERS (AUDIO, BINDER (IPC), BLUETOOTH, CAMERA, DISPLAY, KEYPAD, SHARED MEMORY, USB, WIFI) • POWER MANAGEMENT

# Linux OS Inside

- Linux Kernel Works as a HAL
- Linux/Android Device drivers
- Linux Memory management
- Linux Process management
- Linux Networking
- Kernel from the Linux FOSS project

# Android Runtime

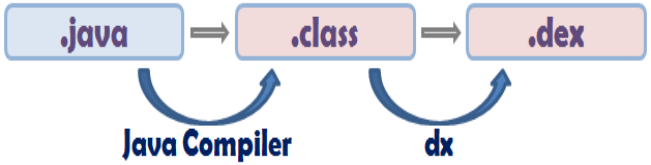


# Android Java

- Java syntax is the same.  But, not all libs are included.
- Unused: Swing, AWT, SWT, lcdgui
- Android Java =  Java SE –  AWT/Swing
  + Android API

# Dalvik Virtual Machine

- Dalvik VM is a new JVM by Google
  - Register-based versus stack-based JVM
  - Different set of Java libraries than JDK
- Dalvik VM has been optimized for mobile devices
  - not so powerful CPU
  - memory shortage
  - Dalvik Executable .dex format is compact
  - run multiple VMs efficiently.



# Dalvik Virtual Machine (Contd)

- Can have JIT enabled
- Relying on the Linux Kernel for:
  - Threading
  - Low-level memory management
- Projects for making JRuby, Groovy, and Scala first class languages for Android.

# Art Virtual Machine

- Android Run Time (ART) libart.so
- Replaces Dalvik libdvm.so (starting with 4.5?)
- Faster And Battery improvements
- https://source.android.com/devices/tech/dalvik/art.html

# Libraries

- Surface Manager: A compositing window manager similar to Compiz. Instead of drawing directly to the screen buffer, drawing commands go into off-screen bitmaps that are then combined with other bitmaps to form the display the user sees. Can create see-through windows, fancy transitions, …
- 2D and 3D graphics: Use 3D hardware or a software renderer. OpenGL.
- Media codecs: AAC, AVC (H.264), H.263, MP3, MPEG-4, …

# Libraries

- Browser engine:
  - WebKit library for rendering web pages
  - the same engine used in KDE, the Google Chrome browser, Apple's Safari browser, the iPhone, and Symbian 60.

# OpenGL ES Momentum

- **The leading 3D rendering API for mobile and embedded devices**
  - Based on desktop OpenGL – but optimized for mobile / handheld devices
  - Removes redundancy & rarely used features - adds mobile-friendly data types
  - The power of OpenGL distilled into a much smaller package
- **OpenGL ES adopted by every major handset OS**
  - Pervasive mobile 3D is evolving fast
- **OpenGL ES has become the most widely deployed 3D API**
  - Used in diverse applications, devices and markets
  - Mobile phones, games consoles, personal navigation devices, personal media players automotive systems, settop boxes

# OpenGL ES

- OpenGL ES is a subset of OpenGL graphics standard.
- OpenGL ES is a … low-level interface between software and graphics acceleration. OpenGL ES includes profiles for floating-point and fixed-point systems and the EGL™ specification ….
- OpenGL ES 1.X is for fixed function hardware and offers acceleration, image quality and performance.
- OpenGL ES 2.X enables full programmable 3D graphics.
- http://www.khronos.org/opengles/

# SQLite

- SQLite database engine
  - Provides persistent storage.
  - Also used in Firefox and the iPhone.
  - android.database.sqlite
- Application would use to manage its own private database.
- /system/xbin/sqlite3

# Background: What is a program?

- (Will add more details based on feedback.)
- Precise def will be based on OS.
- Do NOT use “program” and “process” interchangeably.
- A program is a *file*
  - *Executable* permissions
  - Structure of content rigidly defined by an executable formats
    - Linux: ELF, a.out, coff
    - Windows: com, exe
    - Java: .class files
    - Android: .dex
- Program v Object code files
  - generated by a *linker*
  - On Linux, /usr/bin/ld  (historically misnamed)
  - The compiler/IDE tool chain invokes the linker
- APK file includes
  - the .dex file
  - along with other files describing resources.
- “App” is an alternate term for a program

# Background: What is a process?

- Process is a run-time volatile entity created by an OS system call *exec*
- Processes have a virtual memory foot print.
  - Code (machine instructions)
  - Run time stack content
  - Run time heap content
  - Run time global variables
- Subject to paging and swapping
- Android details are more complex cf. Linux

# Selected root Processes

- The following examples are typical
- % ps | wc –l was 220
- root 1 /init
  root 1835 /system/bin/vold
  root 1838 /system/bin/netd
  root 1839 /system/bin/debuggerd
  root 1840 /system/bin/sh
  root 1848 zygote
  root 2479 kcryptd

- URL ps-full-list.txt

# Selected system+ Processes

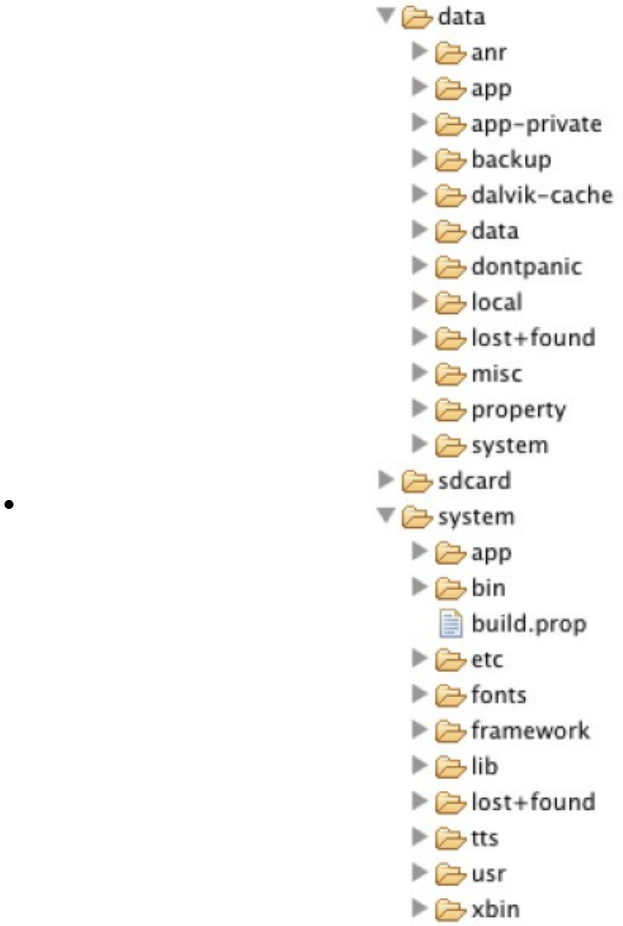
- system 1834 /system/bin/servicemanager
- system 1847 /system/bin/surfaceflinger
- gps 1855 /system/bin/gpsd
- media_rw 1880 /system/bin/sdcard
- system 2775 com.sec.android.inputmethod
- system 2824 com.sec.android.app.snotebook
- wifi 3420 /system/bin/wpa_supplicant
- dhcp 3533 /system/bin/dhcpcd
- radio 2798 com.android.phone

# Selected user Processes

- u0_a126 2656 com.android.systemui
- u0_a16 2909 com.google.process.gapps
- u0_a6 3110 android.process.acore
- u0_a16 3162 com.google.process.location
- u0_a6 3857 com.android.contacts
- u0_a101 3906 com.sec.phone
- u0_a77 4979 com.android.vending
- u0_a203 5535 org.mozilla.firefox
- u0_a236 5723 com.twitter.android
- u0_a162 7604 com.kk.launcher
- u0_a189 8461 com.devexpert.weather
- u0_a112 12143 com.sec.android.app.music
- u0_a58 12199 com.samsung.music
- u0_a226 12230 com.android.chrome
- u0_a25 29235 android.process.media
- First column is user names

# File System

- ext3, ext4 of Linux
- Mount points
  - One for system, one for the apps, and one for whatever.
- Each app has its own sandbox accessible to it. No one else can access its data.
- /sdard
- /mnt/extSdCard



# Partitions

- Example: Samsung T679
  - ARMv7 (v7l)
  - fdisk -l /dev/ block/ mmcblk0
  - lists 37 partitions.

| | |
|---|---|
| /dev/block/mmcblk0p15 | /system |
| /dev/block/mmcblk0p16 | /cache |
| /dev/block/mmcblk0p | /data |
| /dev/block/vold/179:33 | /storage/sdcard1 |
| /dev/block/vold/179:28 | /storage/sdcard0 |

# root@mako:/ # df

| Filesystem | Size | Used | Free | Blksize |
|---|---|---|---|---|
| /dev | 916.3M | 128.0K | 916.2M | 4096 |
| /sys/fs/cgroup | 916.3M | 12.0K | 916.3M | 4096 |
| /mnt/asec | 916.3M | 0.0K | 916.3M | 4096 |
| /mnt/obb | 916.3M | 0.0K | 916.3M | 4096 |
| /mnt/fuse | 916.3M | 0.0K | 916.3M | 4096 |
| /system | 826.8M | 713.1M | 113.7M | 4096 |
| /cache | 551.2M | 10.1M | 541.1M | 4096 |
| /data | 5.7G | 3.9G | 1.8G | 4096 |
| /persist | 15.7M | 4.1M | 11.6M | 4096 |
| /firmware | 64.0M | 44.4M | 19.5M | 16384 |
| /mnt/shell/emulated | 5.7G | 3.9G | 1.8G | 4096 |

(My rooted Nexus 4, May 2014)

# Commands

- /system/bin
  - mount, swap, top, adb
  - blkid, bootanimation
  - backuptool.sh
  - bugreport
  - chmod, chown
  - du, e2fsck, fsck.exfat
  - gdbserver, grep, gzip
  - iptables, kill
  - ssh*, top, ps
- /system/xbin
  - busybox
  - crond
  - dd, df, fdisk, tune2fs
  - nanddump
  - nslookup
  - nice
  - pidof, pkill, pwd
  - strace, su, sync, sha1sum
  - zip

# ls –l /proc/1 (trimmed)

```
dr-xr-xr-x root     root              2014-05-12 06:39 attr
-r--r--r-- root     root            0 2014-05-11 22:43 cmdline
lrwxrwxrwx root     root              2014-05-12 06:39 cwd -> /
-r-------- root     root            0 2014-05-12 06:39 environ
lrwxrwxrwx root     root              2014-05-12 06:39 exe -> /init
dr-x------ root     root              2014-05-12 06:39 fd
dr-x------ root     root              2014-05-12 06:39 fdinfo
-r-------- root     root            0 2014-05-12 06:39 io
-r--r--r-- root     root            0 2014-05-12 06:39 limits
-rw-r--r-- root     root            0 2014-05-12 06:39 loginuid
-r--r--r-- root     root            0 2014-05-12 06:39 maps
-rw------- root     root            0 2014-05-12 06:39 mem
-r--r--r-- root     root            0 2014-05-12 06:39 mountinfo
-r--r--r-- root     root            0 2014-05-12 06:39 mounts
-r-------- root     root            0 2014-05-12 06:39 mountstats
dr-xr-xr-x root     root              2014-05-11 22:43 net
dr-x--x--x root     root              2014-05-12 06:39 ns
-r--r--r-- root     root            0 2014-05-12 06:39 pagemap
-r--r--r-- root     root            0 2014-05-12 06:39 personality
lrwxrwxrwx root     root              2014-05-12 06:39 root -> /
-r--r--r-- root     root            0 2014-05-12 06:39 sessionid
-r--r--r-- root     root            0 2014-05-12 06:39 smaps
-r--r--r-- root     root            0 2014-05-12 06:39 stack
-r--r--r-- root     root            0 2014-05-11 22:43 stat
-r--r--r-- root     root            0 2014-05-12 06:39 statm
-r--r--r-- root     root            0 2014-05-11 22:45 status
dr-xr-xr-x root     root              2014-05-11 22:43 task
-r--r--r-- root     root            0 2014-05-12 06:39 wchan
```

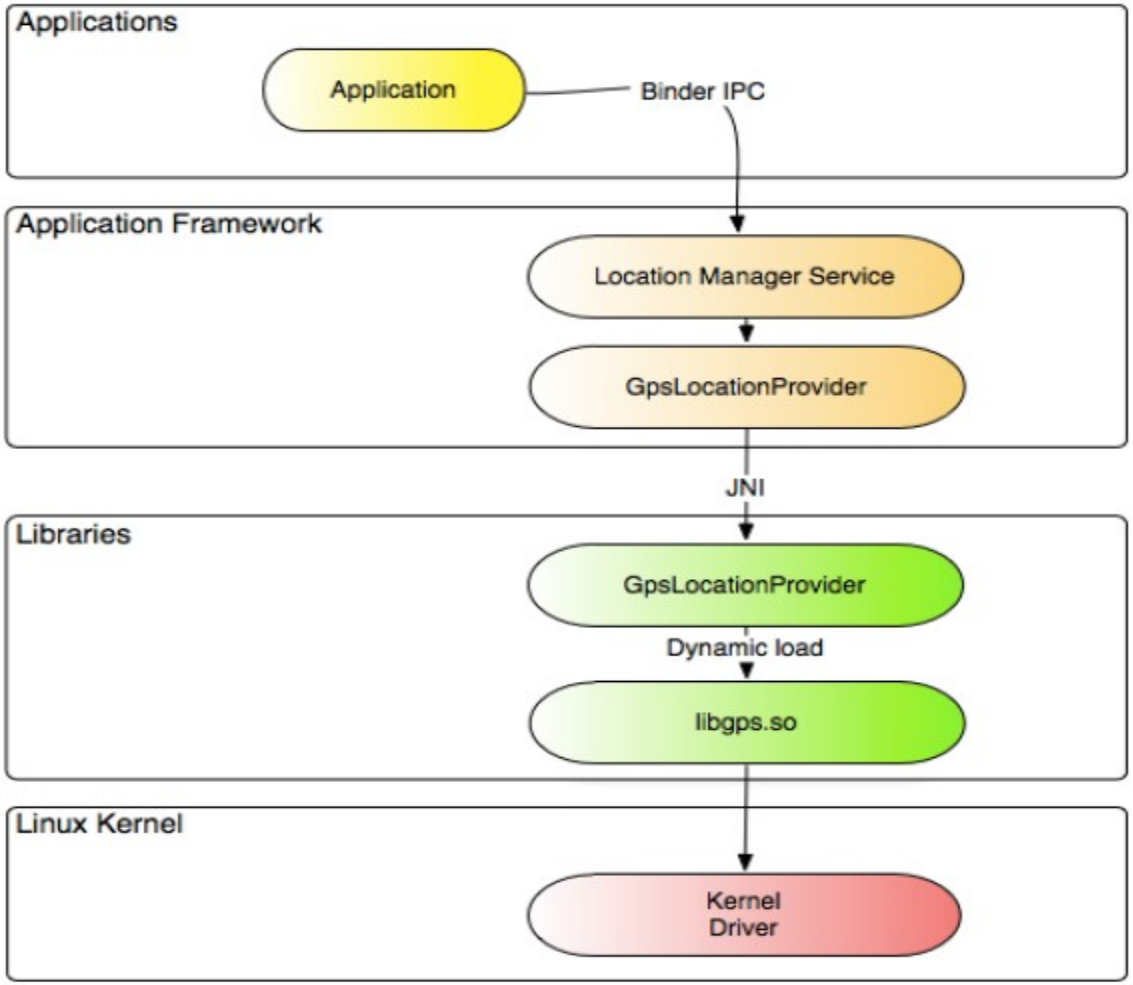
# Android Hardware Abstraction (HAL)

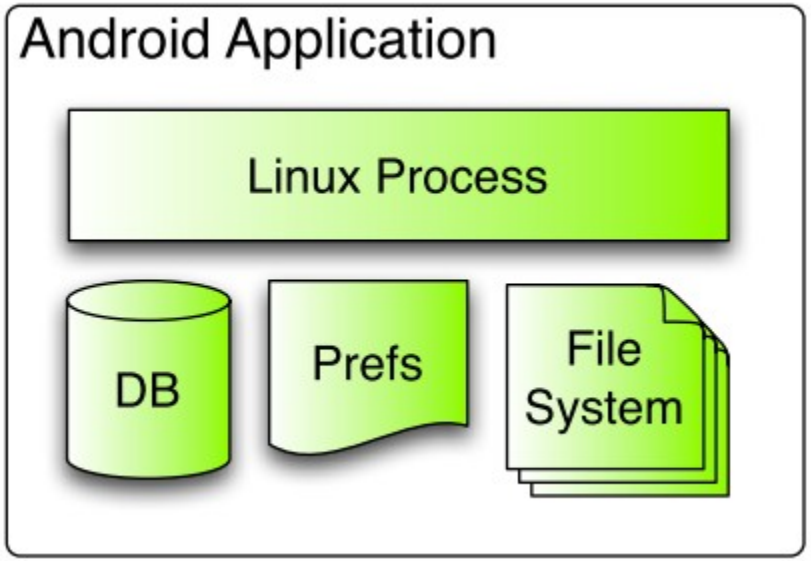
- https://source.android.com/devices/reference/files.html
- Linux originated
  - /dev/zero, /dev/null
  - /dev/random
  - /dev/input/*
  - /dev/tty
  - /dev/kmem
  - /sys/dev/block
- Mfr specific details abstracted out
  - All cameras, GPS, …
- Example /dev entries
  - Video
  - msm_camera
  - msm_dsps
  - msm_rotator
  - msm_vidc_dec
  - wcnss_wlan

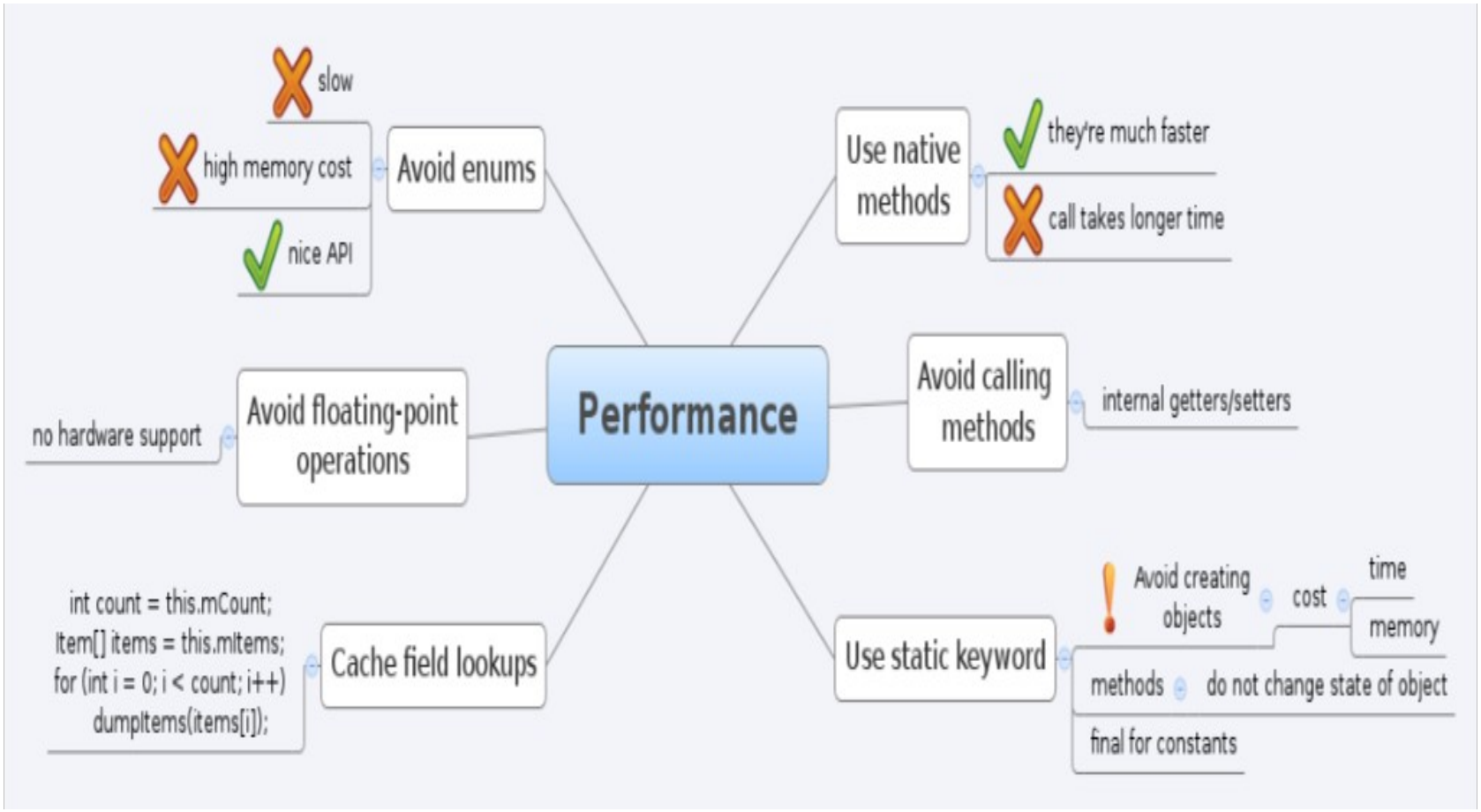
# IPC Mechanism in Android

- In GNU/Linux
  - Pipes
  - Shared Memory
  - Message Queue
- In Android
  - Binder

# App Runtime Service




Android Application
Linux Process
DB
Prefs
File System


Performance
Avoid enums
slow
high memory cost
nice API
Use native methods
they're much faster
call takes longer time
Avoid floating-point operations
no hardware support
Avoid calling methods
internal getters/setters
Cache field lookups
int count = this.mCount;
Item[] items = this.mItems;
for (int i = 0; i < count; i++)
dumpItems(items[i]);
Use static keyword
Avoid creating objects
cost
time
memory
methods
do not change state of object
final for constants

# Application Security

- Each Android application
  - own Linux process.
  - own userid.
  - own sandbox file system
  - own set of preferences
  - own database.
- Other applications cannot access any of its data, unless it is explicitly shared.
- finer-grained security features through a "permission" mechanism
- per-URI permissions for granting ad-hoc access
- More later

# /system/etc/permissions/…

- android.hardware.camera.front.xml
- android.hardware.sensor.gyroscope.xml
- android.hardware.telephony.gsm.xml
- android.hardware.usb.host.xml
- android.hardware.wifi.xml
- com.cyanogenmod.android.xml
- features.xml
- platform.xml

# How to Explore Android Internals

- Install a “terminal” app.  If your device is rooted, you can change things.  (We will discuss “root” later.)
- adb shell
- Install an ssh server on the Android device, and from Linux ssh into it.
  - Highly useful.
  - E.g., filezilla sftp client invoked on Linux
  - Some devices already have /system/bin/sshd

# References

- Karim Yaghmour, Embedded Android book