# Inside Android's UI

**AnDevCon V**

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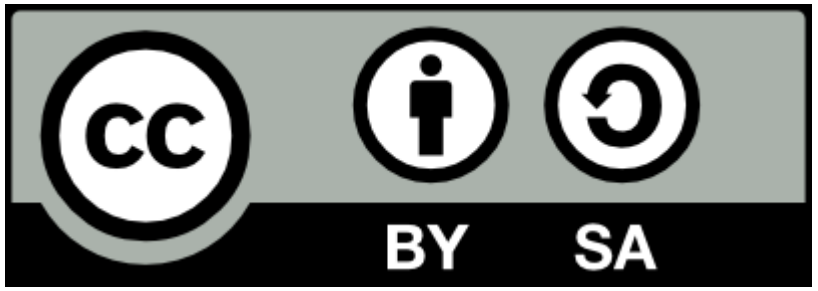




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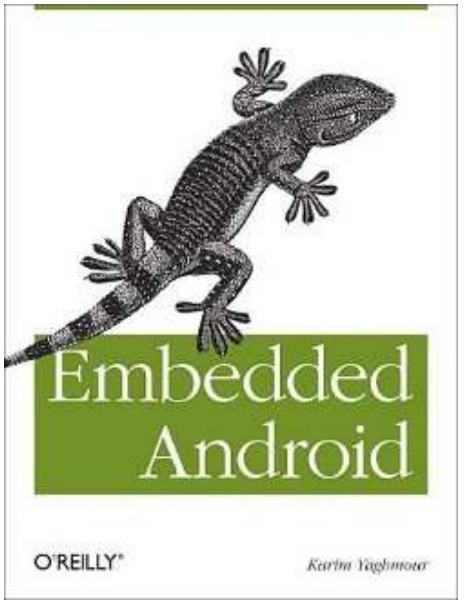
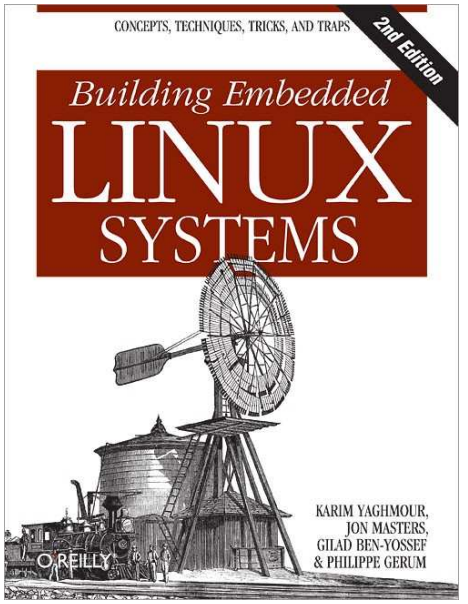
# About

- Author of:




- Introduced Linux Trace Toolkit in 1999
- Originated Adeos and relayfs (kernel/relay.c)
- Training, Custom Dev, Consulting, ...

# Agenda

- Android's UI, what's that?
- Architecture Basics
- Display Core
- OpenGL
- Input Layer
- Relevant Apps and Services
- System Startup
- References and Pointers

# 1. Android's UI, what's that?



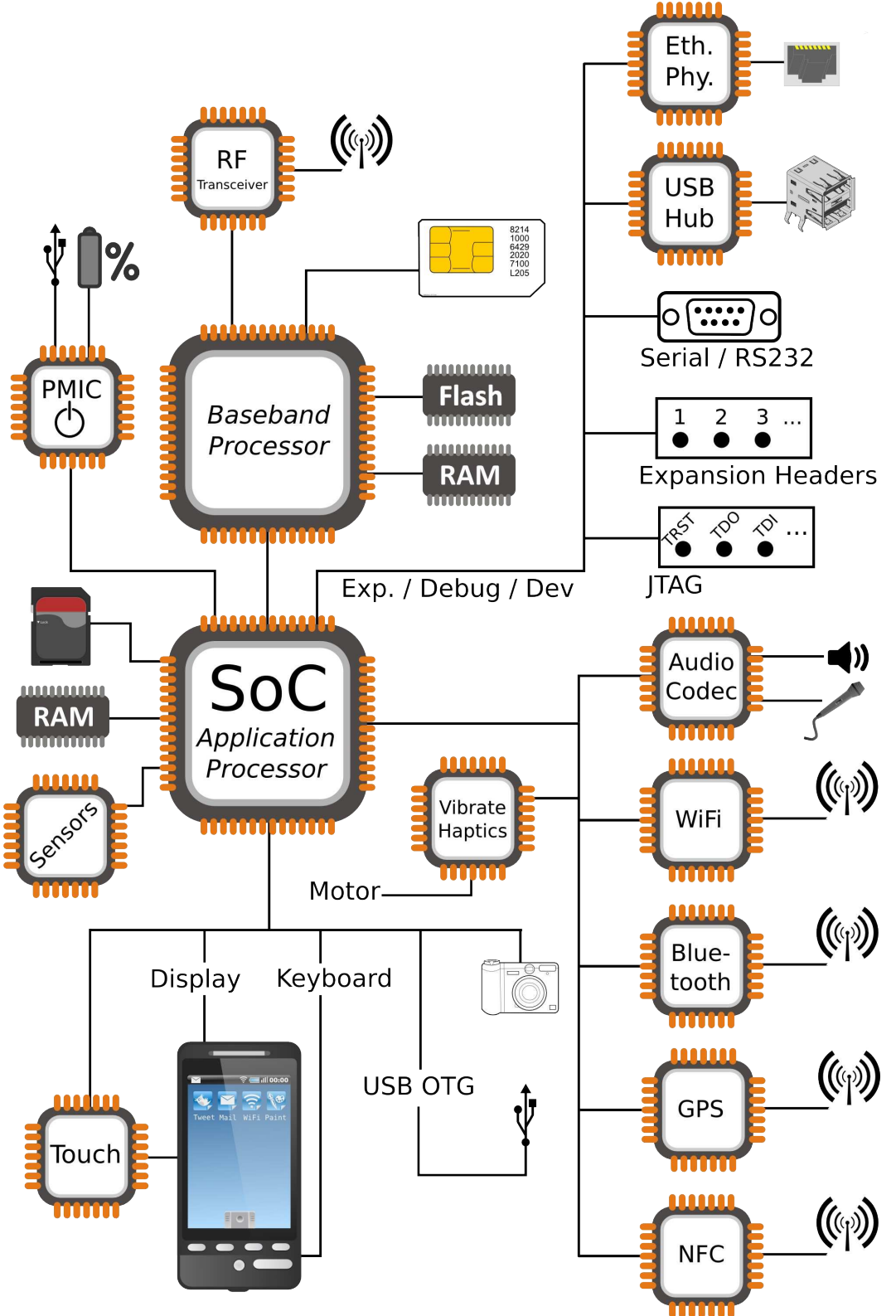
- **SoC / GPU**
- **Touch input**
- **LCD**
- **Keyboard**

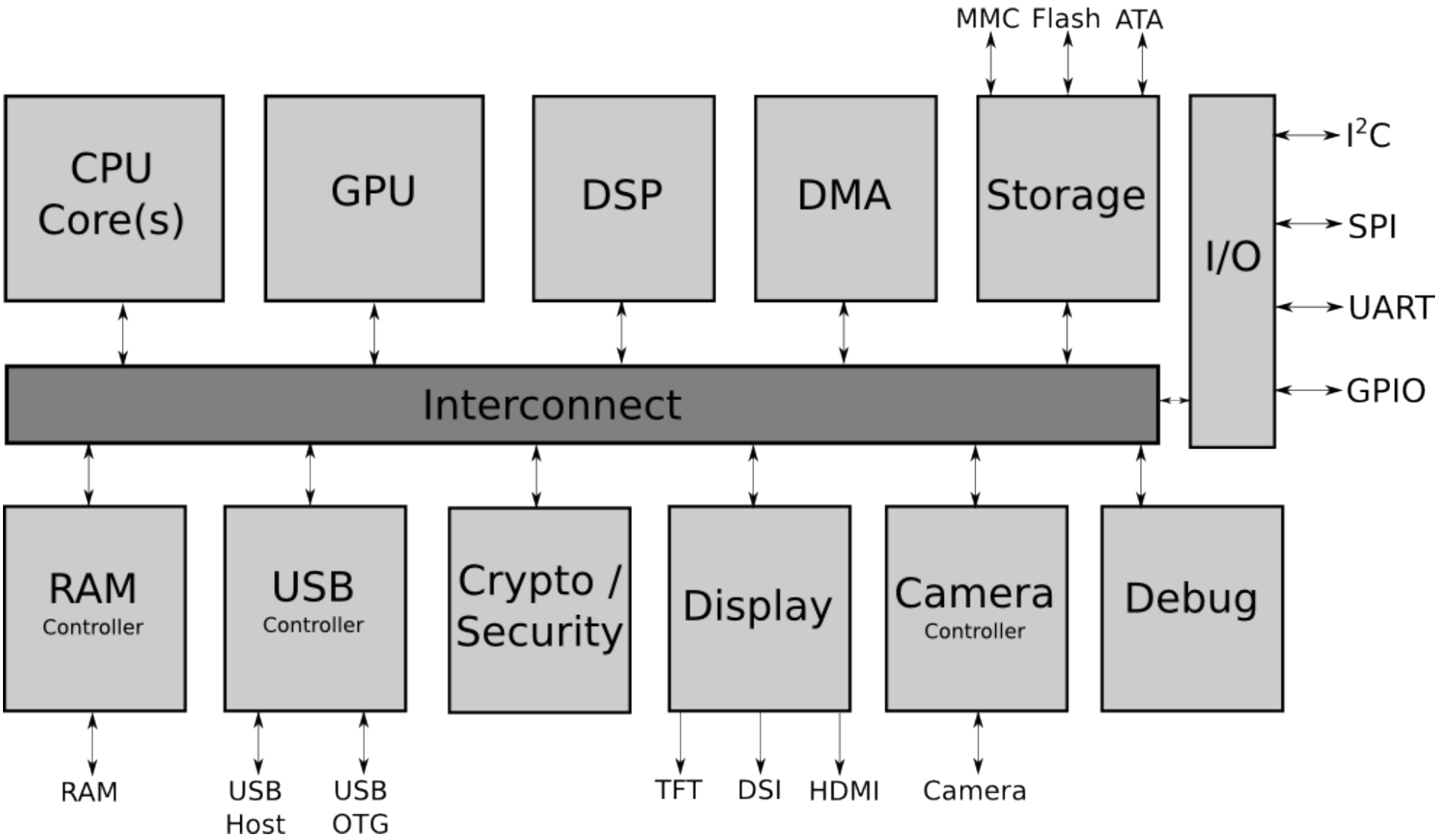
# 1.1. What I'm NOT covering

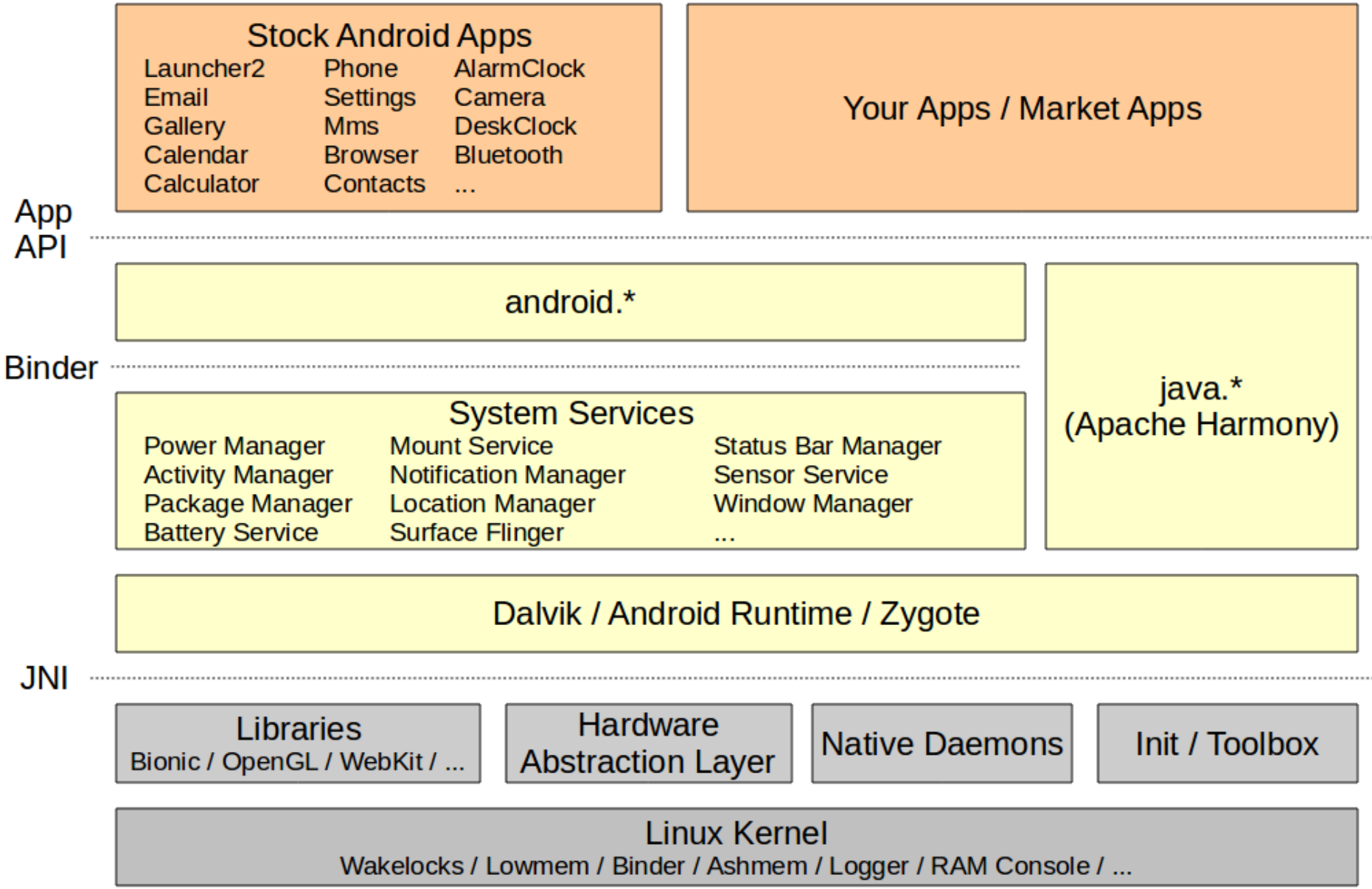
- Media layer
- StageFright
- Video playback
- Camera
- DRM
- Etc.

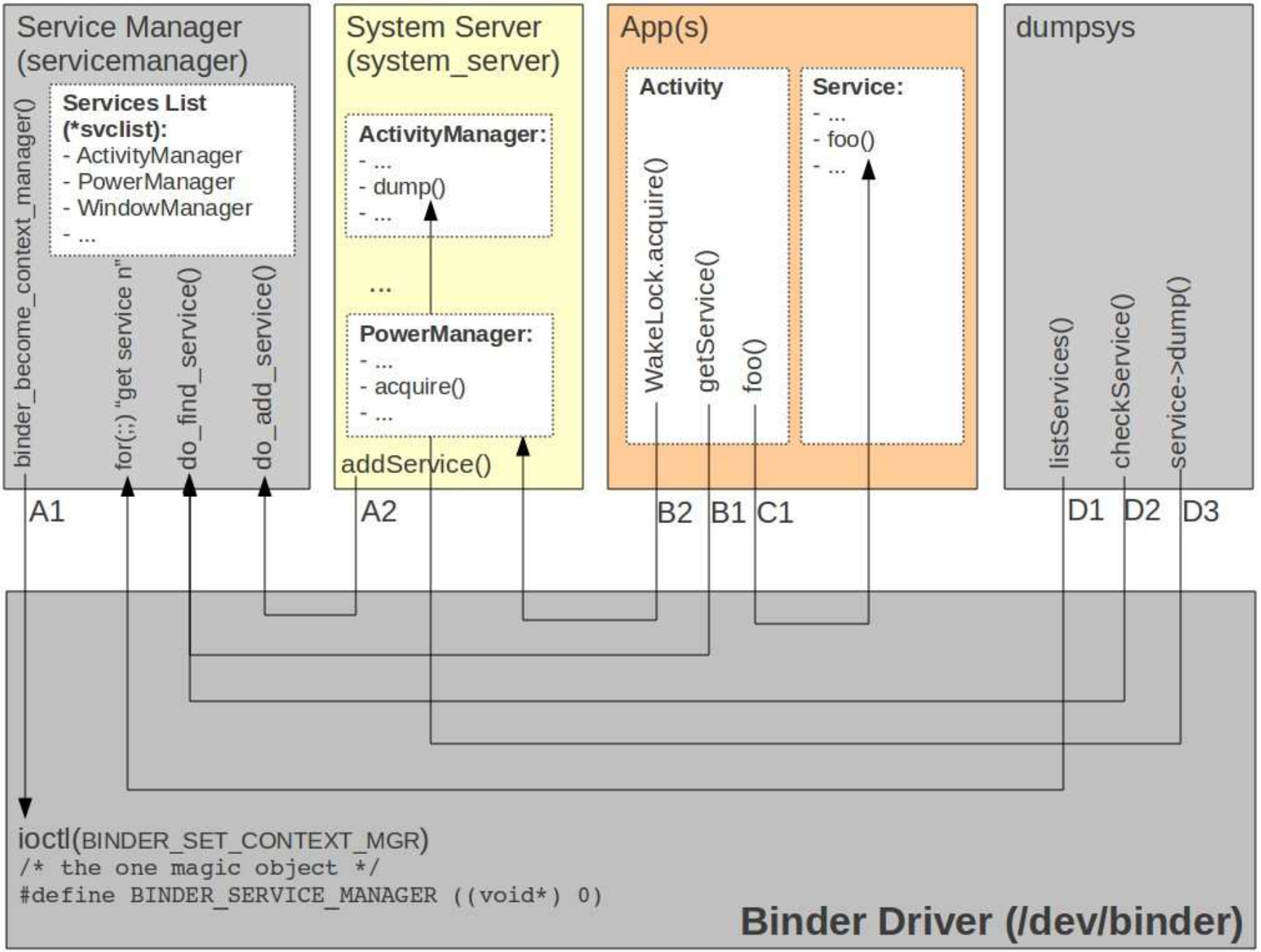
# 2. Architecture Basics

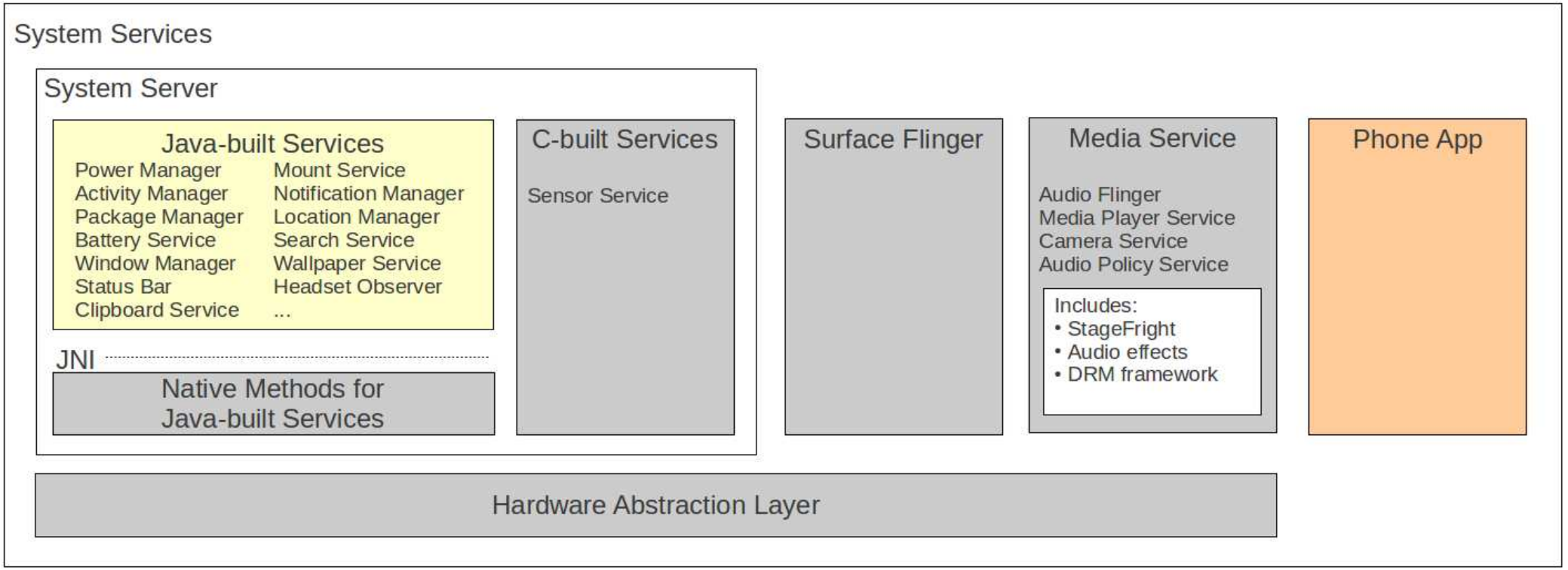
- Hardware used to run Android
- AOSP
- Binder
- System Services
- HAL

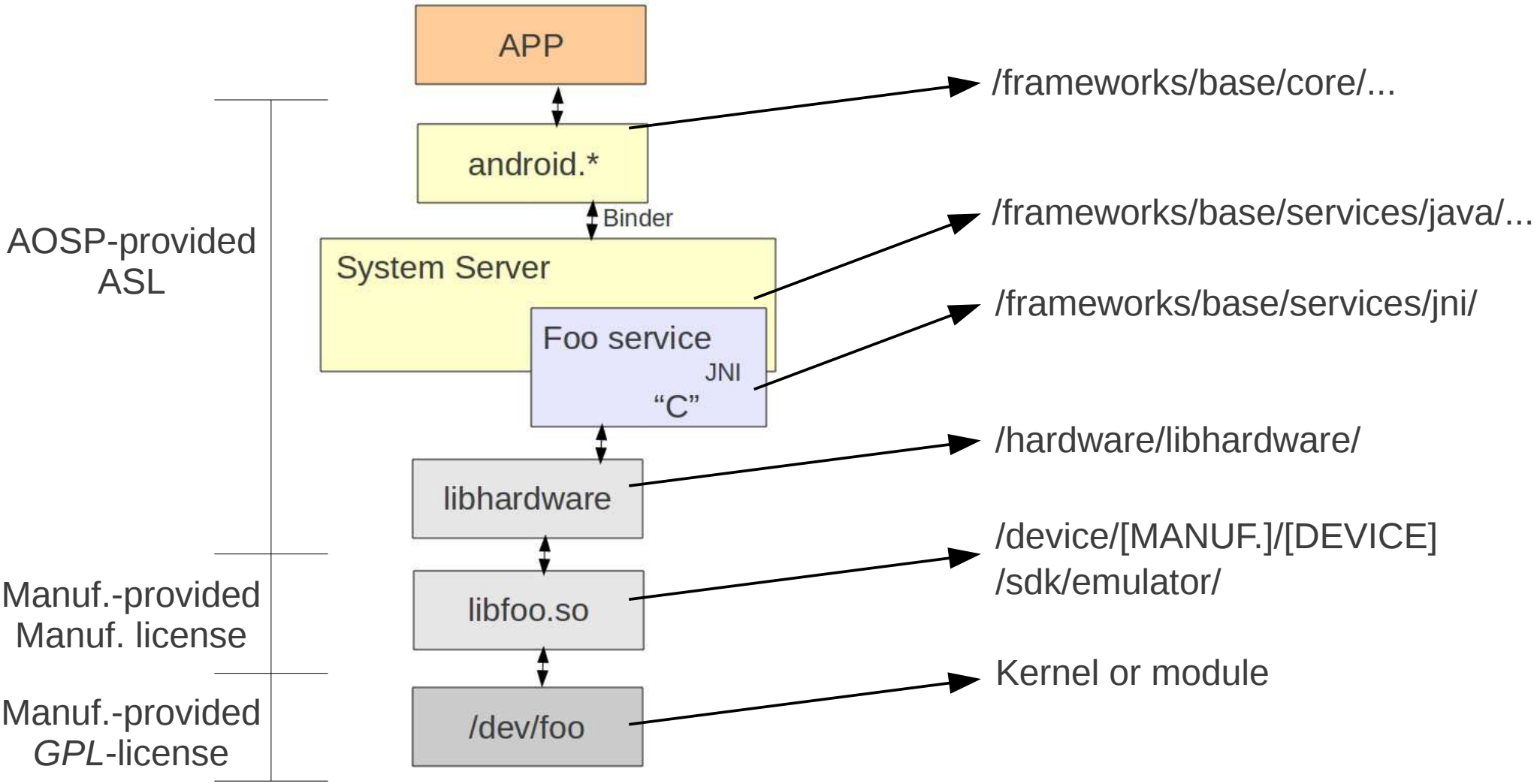

Eth.
Phy.
RF
Transceiver
USB
Hub
8214
1000
6429
2020
7100
L205
PMIC
Baseband
Processor
Flash
RAM
Serial / RS232
1 2 3 ...
Expansion Headers
TRST TDO TDI ...
JTAG
Exp. / Debug / Dev
SoC
Application
Processor
RAM
Sensors
Audio
Codec
Vibrate
Haptics
WiFi
Motor
Blue-
tooth
Display
Keyboard
GPS
Touch
USB OTG
NFC


MMC
Flash
ATA
CPU Core(s)
GPU
DSP
DMA
Storage
I/O
I²C
SPI
UART
GPIO
Interconnect
RAM Controller
USB Controller
Crypto / Security
Display
Camera Controller
Debug
RAM
USB Host
USB OTG
TFT
DSI
HDMI
Camera


Stock Android Apps
Launcher2 Phone AlarmClock
Email Settings Camera
Gallery Mms DeskClock
Calendar Browser Bluetooth
Calculator Contacts ...
Your Apps / Market Apps
App API
android.*
Binder
System Services
Power Manager Mount Service Status Bar Manager
Activity Manager Notification Manager Sensor Service
Package Manager Location Manager Window Manager
Battery Service Surface Flinger ...
java.*
(Apache Harmony)
Dalvik / Android Runtime / Zygote
JNI
Libraries
Bionic / OpenGL / WebKit / ...
Hardware Abstraction Layer
Native Daemons
Init / Toolbox
Linux Kernel
Wakelocks / Lowmem / Binder / Ashmem / Logger / RAM Console / ...


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)

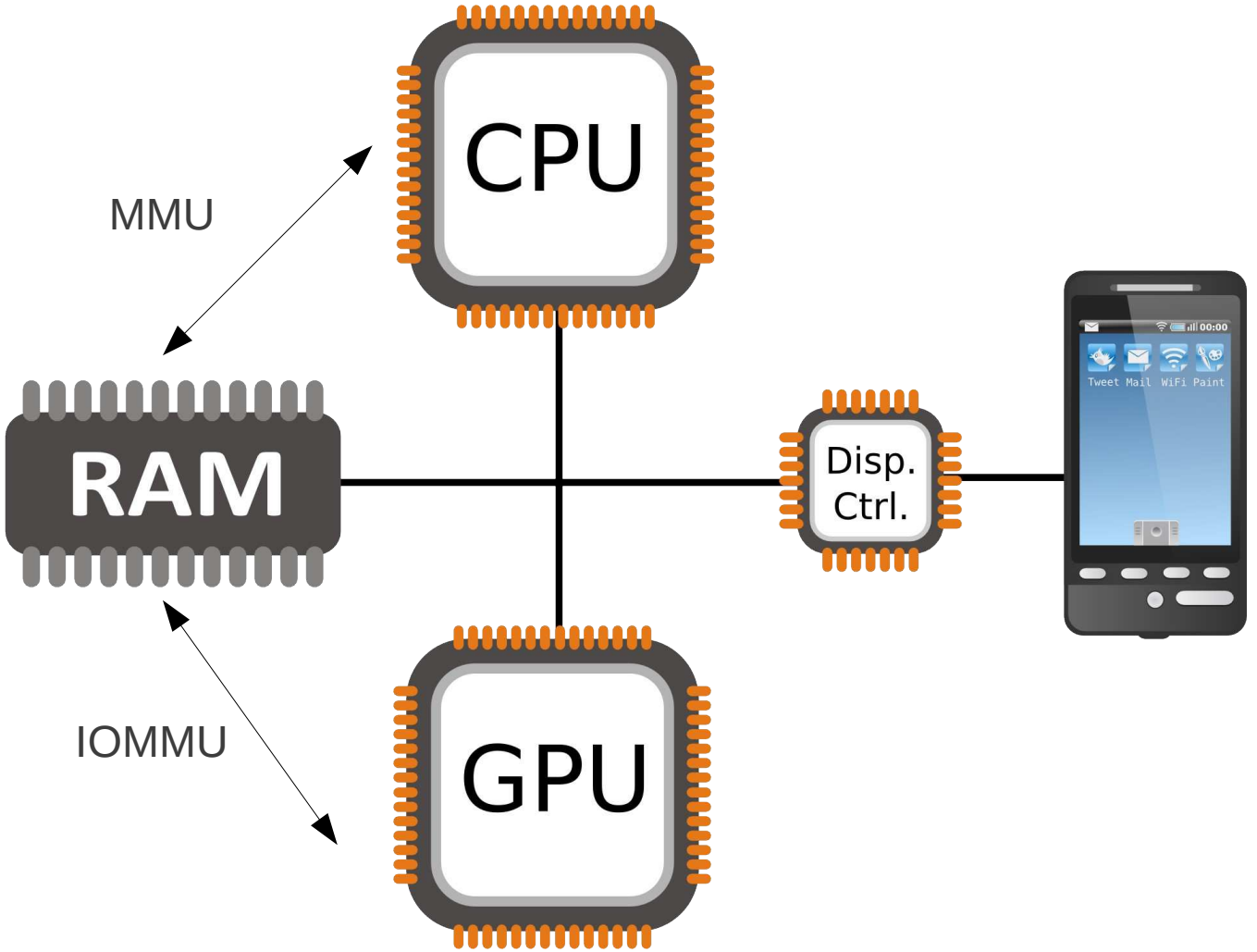

System Services
System Server
Java-built Services
Power Manager
Activity Manager
Package Manager
Battery Service
Window Manager
Status Bar
Clipboard Service
Mount Service
Notification Manager
Location Manager
Search Service
Wallpaper Service
Headset Observer
...
JNI
Native Methods for Java-built Services
C-built Services
Sensor Service
Surface Flinger
Media Service
Audio Flinger
Media Player Service
Camera Service
Audio Policy Service
Includes:
• StageFright
• Audio effects
• DRM framework
Phone App
Hardware Abstraction Layer


APP
android.*
Binder
System Server
Foo service
JNI
"C"
libhardware
libfoo.so
/dev/foo
/frameworks/base/core/...
/frameworks/base/services/java/...
/frameworks/base/services/jni/
/hardware/libhardware/
/device/[MANUF.]/[DEVICE]
/sdk/emulator/
Kernel or module
AOSP-provided
ASL
Manuf.-provided
Manuf. license
Manuf.-provided
*GPL*-license

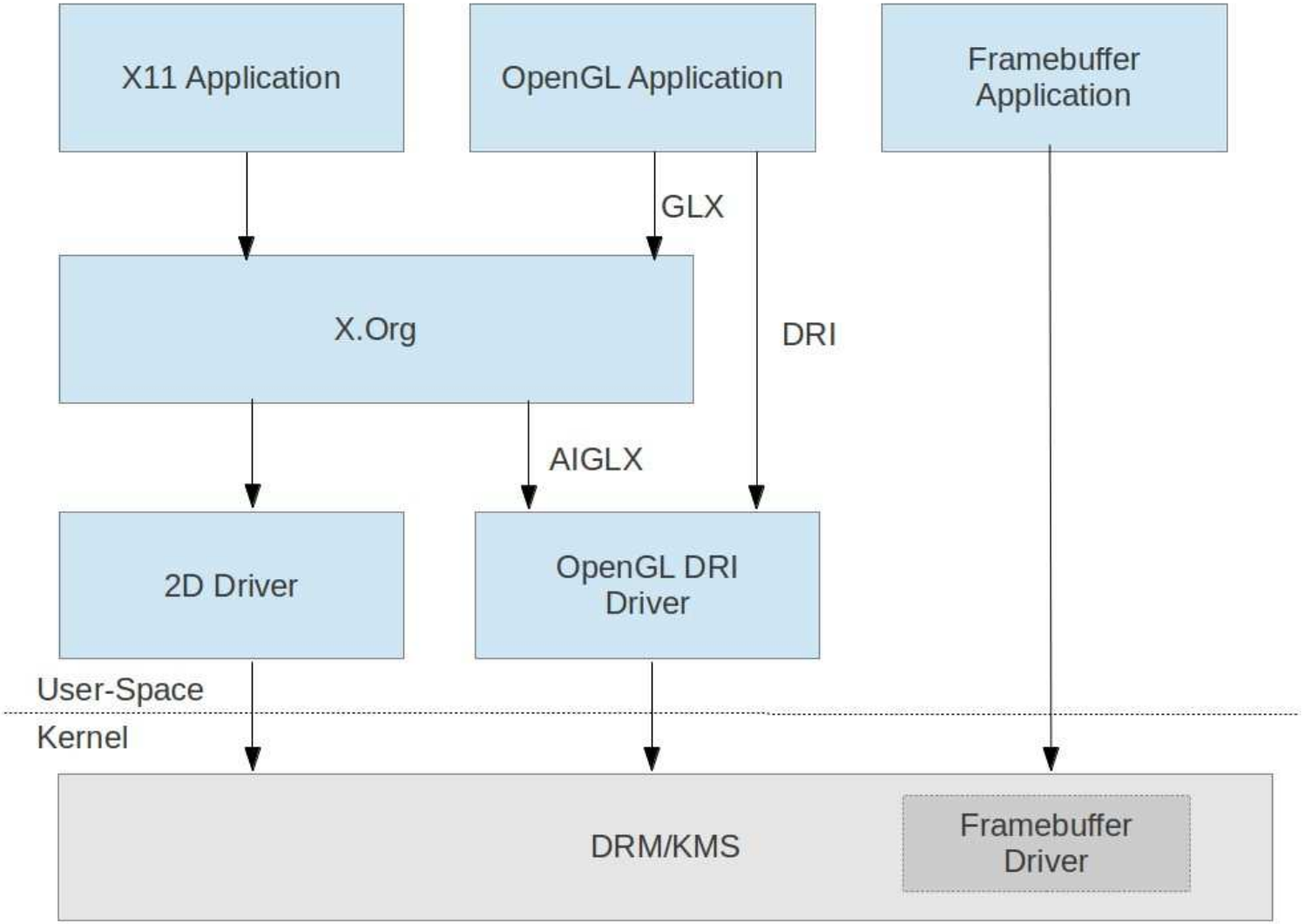
# 3. Display Core

- Display Hardware
- Classic Linux display stack
- Display stack in Android
- Kernel driver
- HAL definition
- HAL module
- Surface Flinger
- Window Manager
- Walkthrough

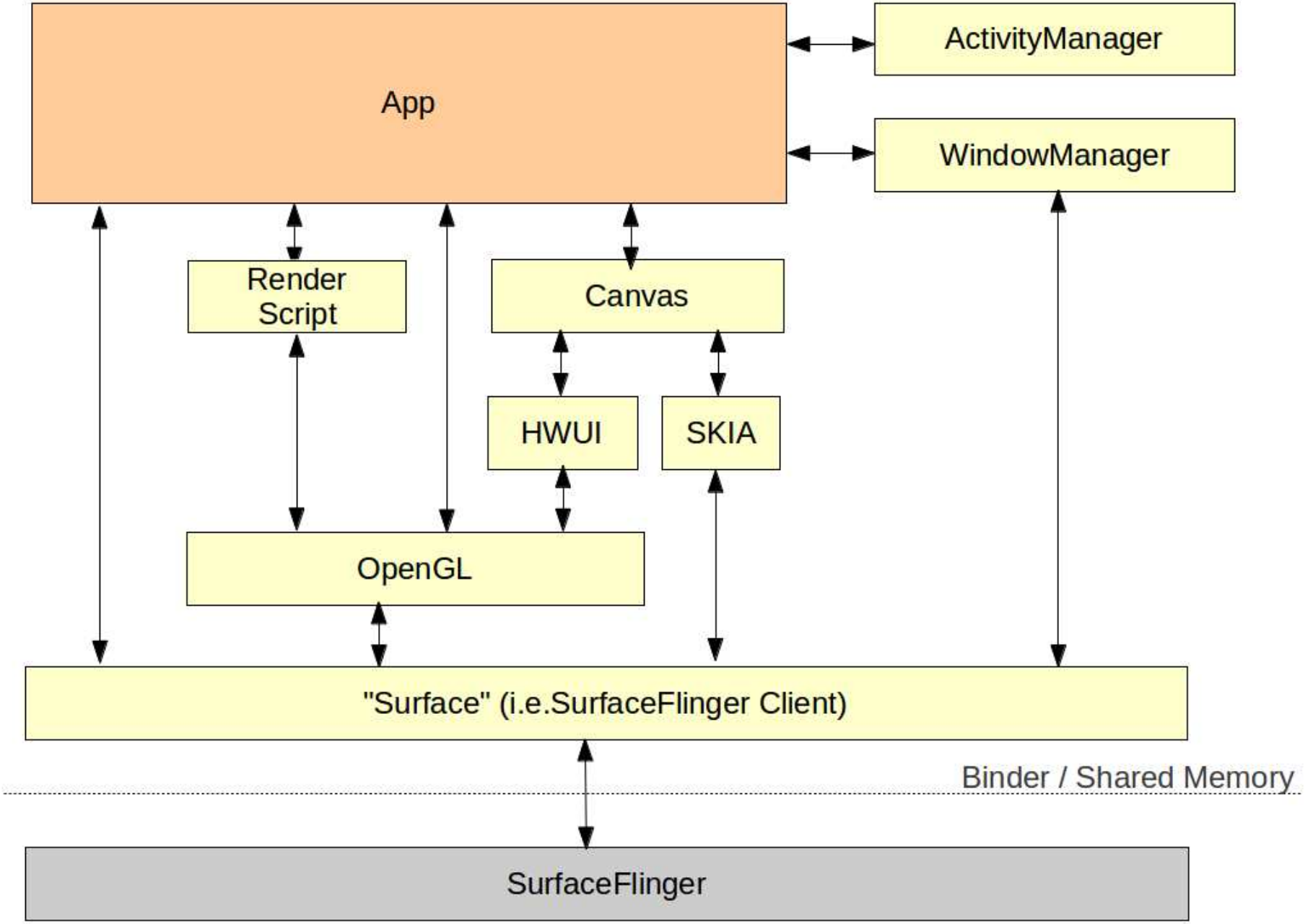
# 3.1. Display Hardware

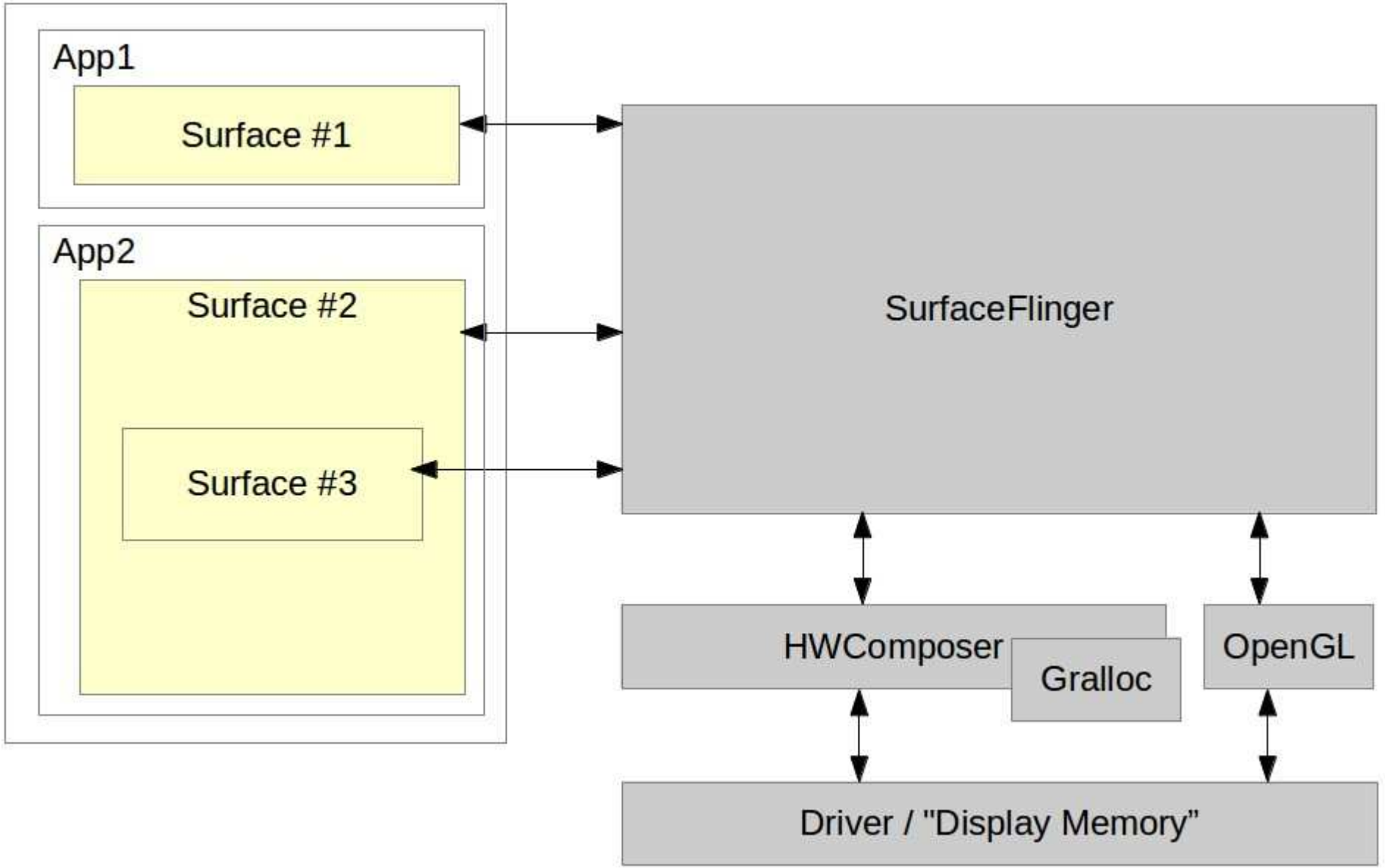


# 3.2. Classic Linux display stack



# 3.3. Display stack in Android




App1
Surface #1
App2
Surface #2
Surface #3
SurfaceFlinger
HWComposer
Gralloc
OpenGL
Driver / "Display Memory"

# 3.4. Kernel driver

- Video memory management
- Mode setting
- Checking of parameters
- Motorola Xoom:
  - /dev/nvhdcp1
  - /dev/nvhost-ctrl
  - /dev/nvhost-display
  - /dev/nvhost-dsi
  - /dev/nvhost-gr2d
  - /dev/nvhost-gr3d
  - /dev/nvhost-isp
  - /dev/nvhost-mpe
  - /dev/nvhost-vi
  - /dev/nvmap
  - /dev/tegra-crypto
  - /dev/tegra_avp
  - /dev/tegra_camera
  - /dev/tegra_fuse
  - /dev/tegra_rpc
  - /dev/tegra_sema
- ... whatever hides in hwcomposer HAL module

# 3.5. HAL Definition

- /hardware/libhardware/include/hardware/hwcomposer.h
- struct hwc_procs:
  - invalidate()
  - vsync()
- struct hwc_composer_device:
  - prepare()
  - set()
  - dump()
  - registerProcs()
  - query()
  - *()

# 3.6. HAL module

- Skeleton /hardware/libhardware/modules/hwcomposer.cpp
- /system/lib/hw/hwcomposer.BOARD.so
- /system/lib/hw/gralloc.BOARD.so
- Ex. - Mot Xoom:
  - hwcomposer.tegra.so
  - gralloc.tegra.so
- Surface Flinger hook:
  - /frameworks/native/services/surfaceflinger/DisplayHardware
    - HWComposer.cpp
    - Provides fake vsync if none is provided in HW

# 3.7. Surface Flinger

- Actual server:
  - /frameworks/native/services/surfaceflinger
- Client side:
  - /frameworks/native/libs/gui
- Client / Server interface:
  - ISurfaceComposerClient.cpp
  - ISurfaceComposer.cpp
- This is NOT an aidl'ed service
- All communication is manually marshalled/unmarshalled

# 3.8. Window Manager

- Server side:
  - /frameworks/base/services/java/com/android/server/wm/
    - WindowManagerService.java
    - Session.java
- Client side:
  - /frameworks/base/core/java/android/view/
    - WindowManager.java
    - WindowManagerImpl.java
    - ViewRootImpl.java
- Interfaces:
  - IWindowManager.aidl
  - IWindowSession.aidl
- Parameters (incl. z-order):
  - See WindowManager.java

# 3.9. Walkthrough

- Activity Manager relies on Activity Thread
- AT calls on attach() and makeVisible()
- makeVisible does wm.addView()
- wm.addView() - this also called by StatusBar to display itself
  - Creates a new ViewRootImpl
  - Call on its setView()
- setView() calls on mWindowSession.addToDisplay(...)
- This results in call to WM's addWindow()
- ViewRootImpl's performTraversals()
  - Calls on relayoutWindow()
  - Calls to WM session's relayout()
  - Call to WM's relayoutWindow()
  - Call to createSurfaceLocked()
  - new Surface(...)

frameworks/base/core/java/android/*/*

LocalActivityManager.java: startActivity()

- moveToState()
  - startActivityNow()

ActivityThread.java: startActivityNow()

- performLaunchActivity()
  - attach() -- gets AM handle and ties to it
- handleResumeActivity()
  - makeVisible()

Activity.java: makeVisible()

  - wm.addView()

WindowManagerGlobal.java: addView()

  - root = new ViewRootImpl()
  - root.setView()

ViewRootImpl.java: setView()

  - mWindowSession.addToDisplay()

IWindowSession.aidl: addToDisplay()

frameworks/base/services/java/com/android/server/wm/*
Session.java: addToDisplay()
- mService.addWindow()
WindowManagerService.java: addWindow()
...

frameworks/base/core/java/android/*/*
ViewRootImpl.java: performTraversals()
- relayoutWindow()
  - mWindowSession.relayout()

frameworks/base/services/java/com/android/server/wm/*
Session.java: relayoutWindow()
- mService.relayoutWindow()
WindowManagerService.java: relayoutWindow()
- surface = winAnimator.createSurfaceLocked();
WindowStateAnimator.java: createSurfaceLocked()
- new Surface();

# 4. OpenGL

- What's OpenGL?
- What's in a modern-day GPU?
- Software layers involved
- Kernel driver
- EGL libs
- Native interface
- Java interface
- Software GL implementation

# 4.1. What's OpenGL?

- It's just an API ... nothing but an API ...
- Check out Wikipedia
- Multiple versions out
- “ES” versions for embedded use
- Up to ES 3.0
- Android support up to ES 2.0

# 4.2. What's in a modern-day GPU?

- A tremendous amount of parallel processing units
- “SIMD”-like instruction set
- Video decoding/encoding capabilities
- ...

# 4.3. Software layers involved

- Kernel driver
- GL libraries
- Native GL API
- Java GL API

# 4.4. Kernel driver

# 4.5. EGL libs

- /frameworks/base/native/opengl/libs
- Entry point: /system/lib/libEGL.so
- Looks for /system/lib/egl/egl.cfg
- /system/lib/egl - Mot Xoom:
  - egl.cfg
  - libEGL_perfhud.so
  - libEGL_tegra.so
  - libGLES_android.so
  - libGLESv1_CM_perfhud.so
  - libGLESv1_CM_tegra.so
  - libGLESv2_perfhud.so
  - libGLESv2_tegra.so
- elg.cfg:

  0 0 tegra

# 4.6. Native interface

- /frameworks/native/opengl/include
  - EGL
  - ETC1
  - GLES
  - GLES2
  - KHR

# 4.7. Java interface

- GL libs required by libandroid_runtime.so
- /frameworks/base/opengl/java/android/opengl:
  - ...

# 4.8. Software GL implementation

- /frameworks/native/opengl/libagl

# 5. Input Layer

- Kernel side - “std” Linux input layer:
  - /dev/input/*
- No HAL use
- Native lib:
  - libinput
  - /frameworks/base/services/input
- Input Manager Service:
  - /frameworks/base/services/java/com/android/server/input
  - Started and directly tied to Window Manager
- Specific config files (see source.android.com)
- Soft keyboard:
  - /frameworks/base/core/java/android/inputmethodservice
- Input methods:
  - /packages/inputmehods
  - http://developer.android.com/guide/topics/text/creating-input-method.html

# 6. Relevant Apps and Services

- Launcher
- StatusBar
- Wallpaper Manager Service
- Notification Service
- App Widgets

# 6.1. Launcher

- An app like any other
- See /packages/app/Launcher2

# 6.2. StatusBar

- A unique app
- See /frameworks/base/packages/SystemUI
- Connects to Status Bar Manager and gives an interface it can use to call back into Status Bar
- Can use setIcon() to display icons on the right
- Provides a CPU usage add-on that renders straight on rest of display using higher z-order

# 6.3. Wallpaper Manager Service

- See /frameworks/base/services/java/com/android/server/WallpaperManagerService.java

# 6.4. Notification Service

- Toasts
- Status bar notifications
- Gets handle to Status Bar Service at instantiation
- Uses handle to communicate with Status Bar

# 6.5. App Widgets

- See /frameworks/base/services/java/com/android/server/AppWidgetService.java

# 7. System Startup

- Kernel
- Init
- Boot animation
- Launcher

# 7.1. Boot animation

- Started by Surface Flinger
- “bootanim” binary
- /frameworks/base/cmds/bootanimation
- Relies on bootanimation.zip w/ PNGs (nothing but)
- See https://github.com/CyanogenMod/android_vendor_cm/tree/jellybean/prebuilt/common/bootanimatino
- Must contain a desc.txt:

  <width> <height> <fps>

  p <count> <pause> <path>

  p <count> <pause> <path>

# 8. References and Pointers

- “Use the source, Luke”
- Jim Huang's “Android Graphics”
- Benjamin Zores' “Linux Magazine / France” articles
- MIPS article on graphics internals:

  http://developer.mips.com/2012/04/11/learning-about-android-graphics-subsystem/
- Stéphane Marchesin's “Linux Graphics Drivers: an Introduction”

  http://source.android.com/tech/input/index.html

Thank you ...

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