Android Anatomy and Physiology

Agenda

- Android Anatomy
  - Linux Kernel
  - Native Libraries
  - Android Runtime
  - Application Framework
- Android Physiology
  - Start-up Walkthrough
  - Layer Interaction

Android Anatomy

Applications

Home | Dialer | SMS/MMS | IM | Browser | Camera | Alarm | Calculator

Contacts | Voice Dial | Email | Calendar | Media Player | Albums | Clock | ...

Application Framework

Activity Manager | Window Manager | Content Providers | View System | Notification Manager

Package Manager | Telephony Manager | Resource Manager | Location Manager | ...

Libraries

Surface Manager | Media Framework | SQLite

OpenGL|ES | FreeType | WebKit

SGL | SSL | Libc

Android Runtime

Core Libraries

Dalvik Virtual Machine

Linux Kernel

Display Driver | Camera Driver | Bluetooth Driver | Shared Memory Driver | Binder (IPC) Driver

USB Driver | Keypad Driver | WiFi Driver | Audio Drivers | Power Management

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Linux Kernel

- Android is built on the Linux kernel, but Android is not Linux
- No native windowing system
- No glibc support
- Does not include the full set of standard Linux utilities

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Linux Kernel

- Standard Linux 2.6.24 Kernel
- Patch of “kernel enhancements” to support Android

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Why Linux Kernel?

- Great memory and process management
- Permissions-based security model
- Proven driver model
- Support for shared libraries
- It's already open source!

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Kernel Enhancements

- Alarm
- Ashmem
- Binder
- Power Management
- Low Memory Killer
- Kernel Debugger
- Logger

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Binder: Problem

- Applications and Services may run in separate processes but must communicate and share data
- IPC can introduce significant processing overhead and security holes

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Binder: Solution

- Driver to facilitate inter-process communication (IPC)
- High performance through shared memory
- Per-process thread pool for processing requests
- Reference counting, and mapping of object references across processes
- Synchronous calls between processes

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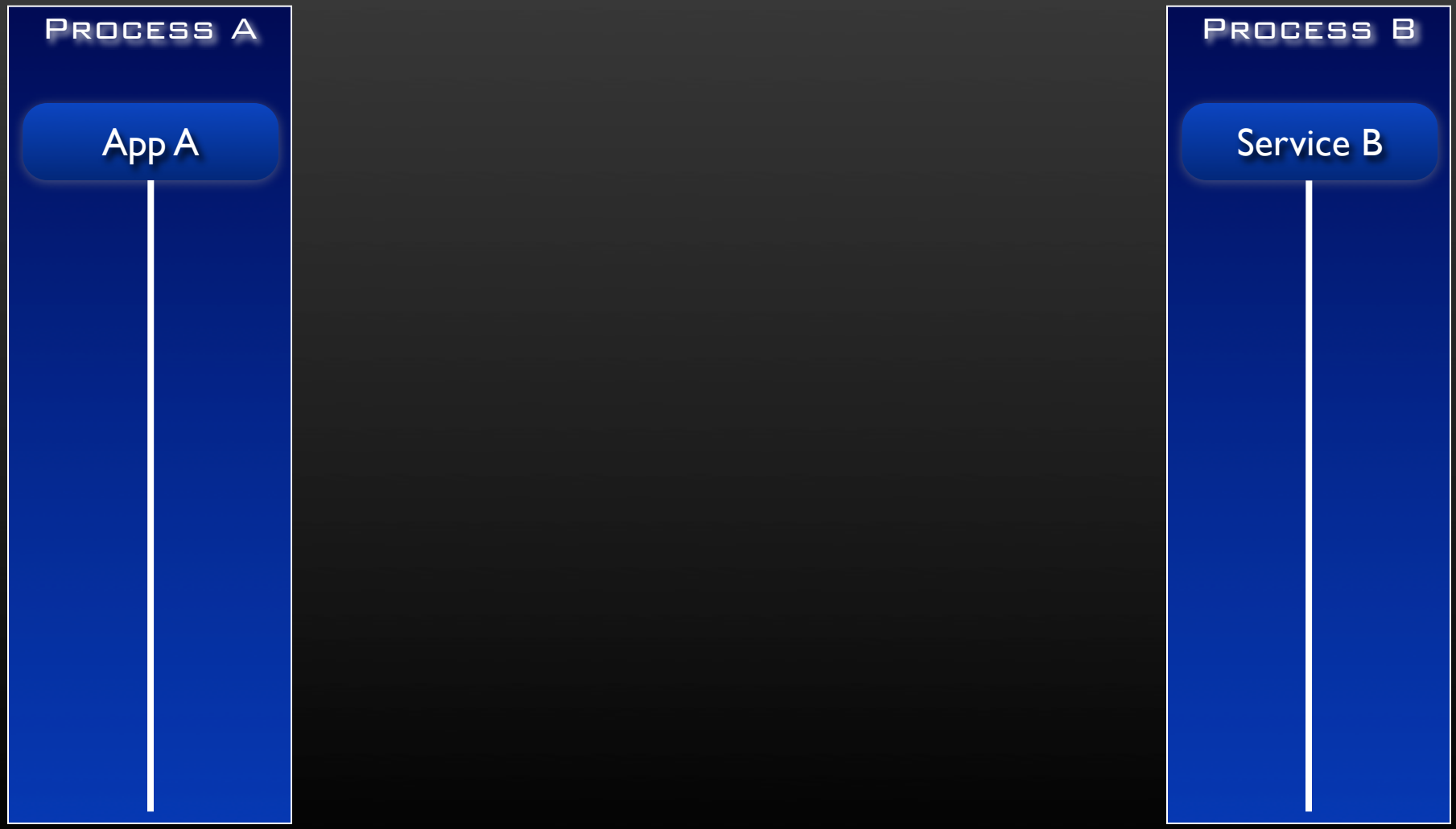
Binder in Action



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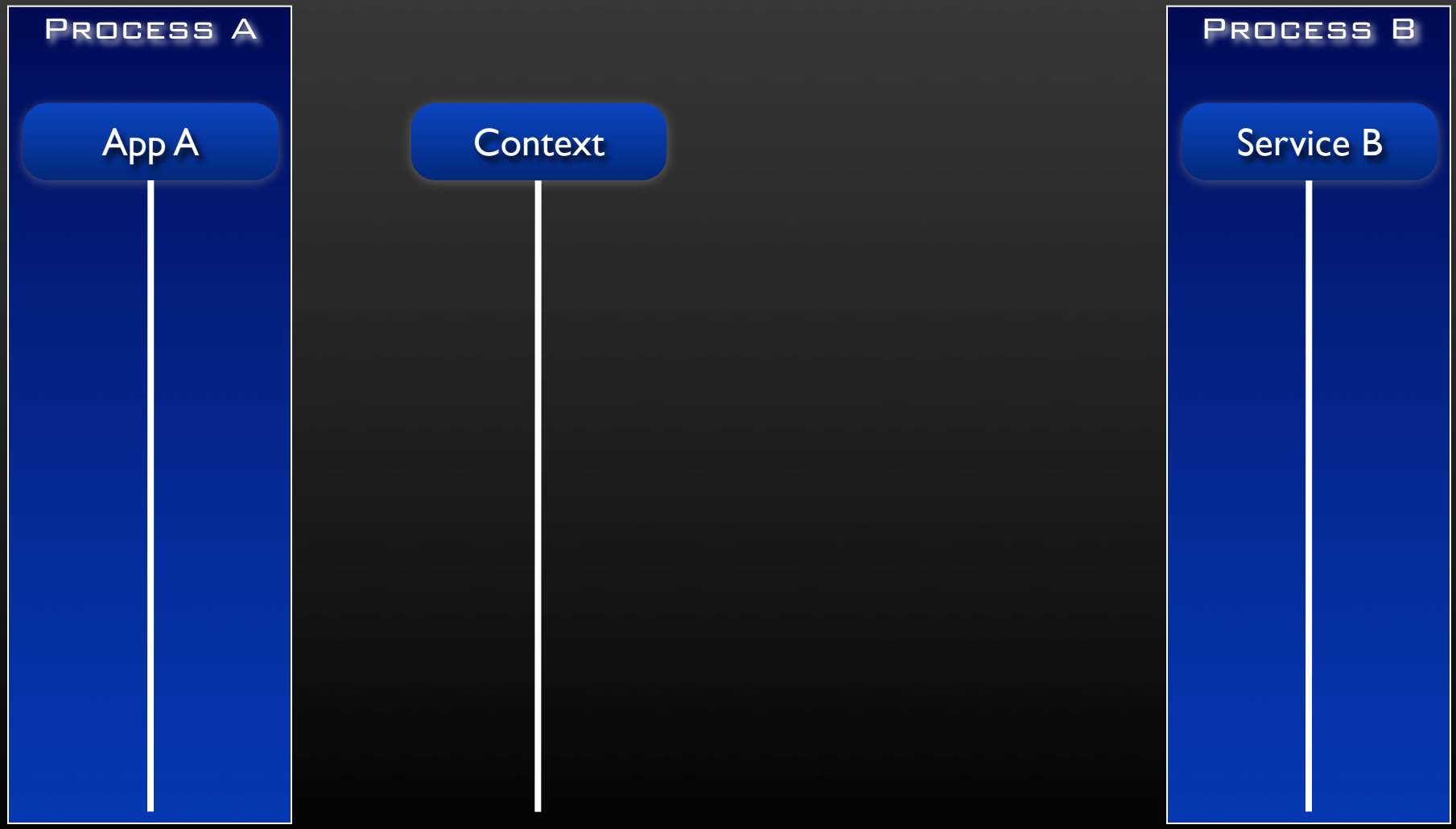

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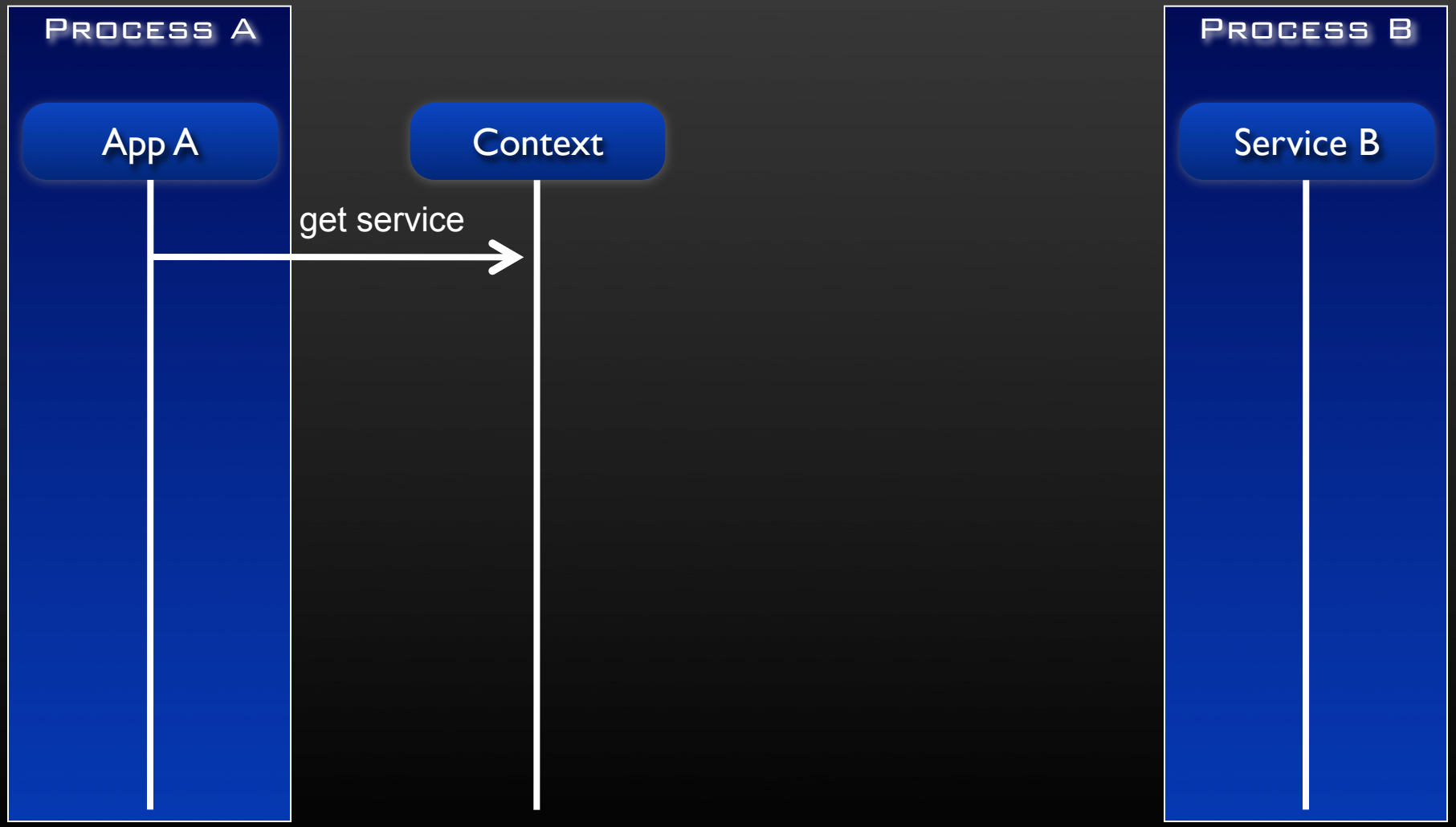

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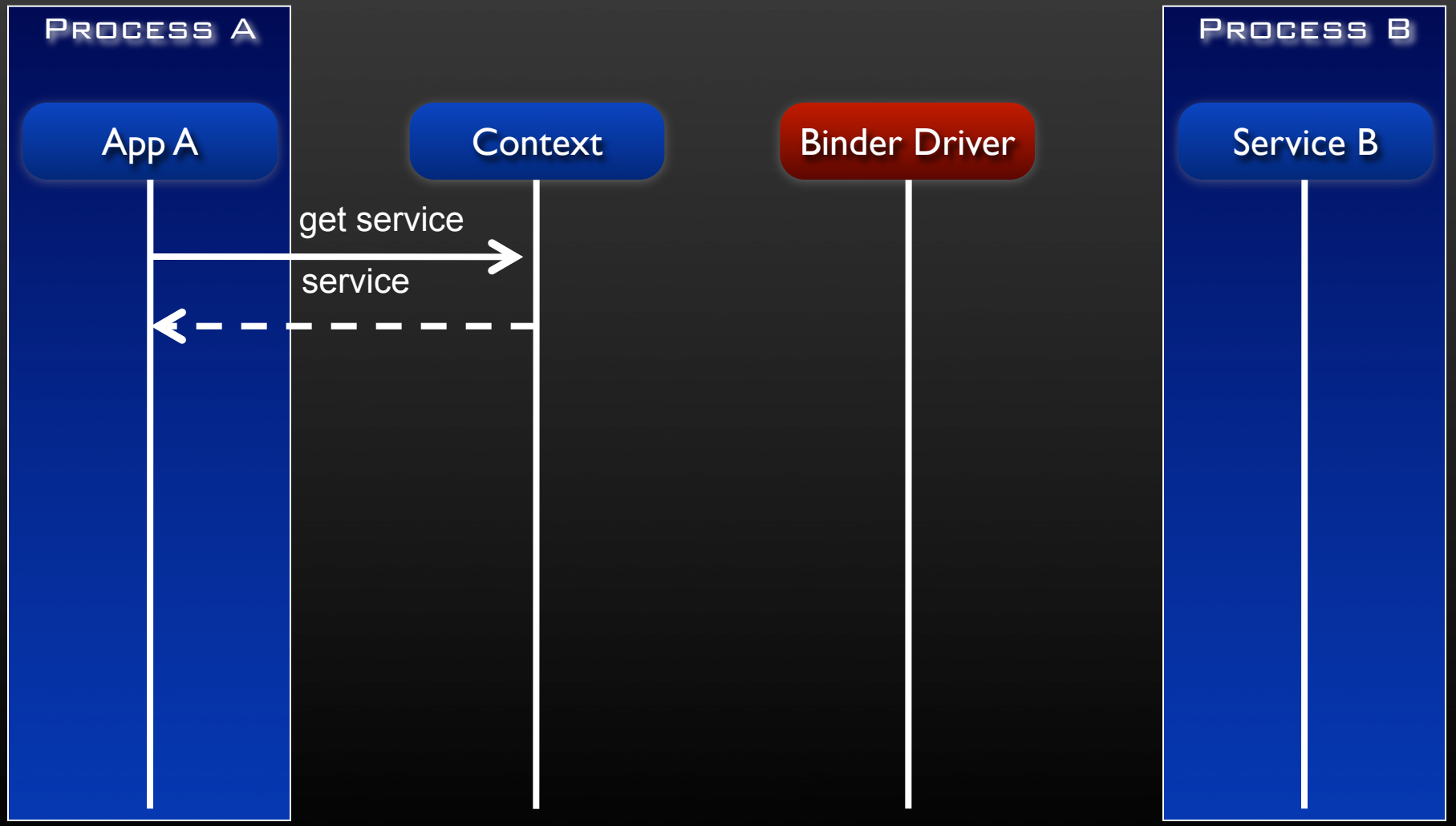

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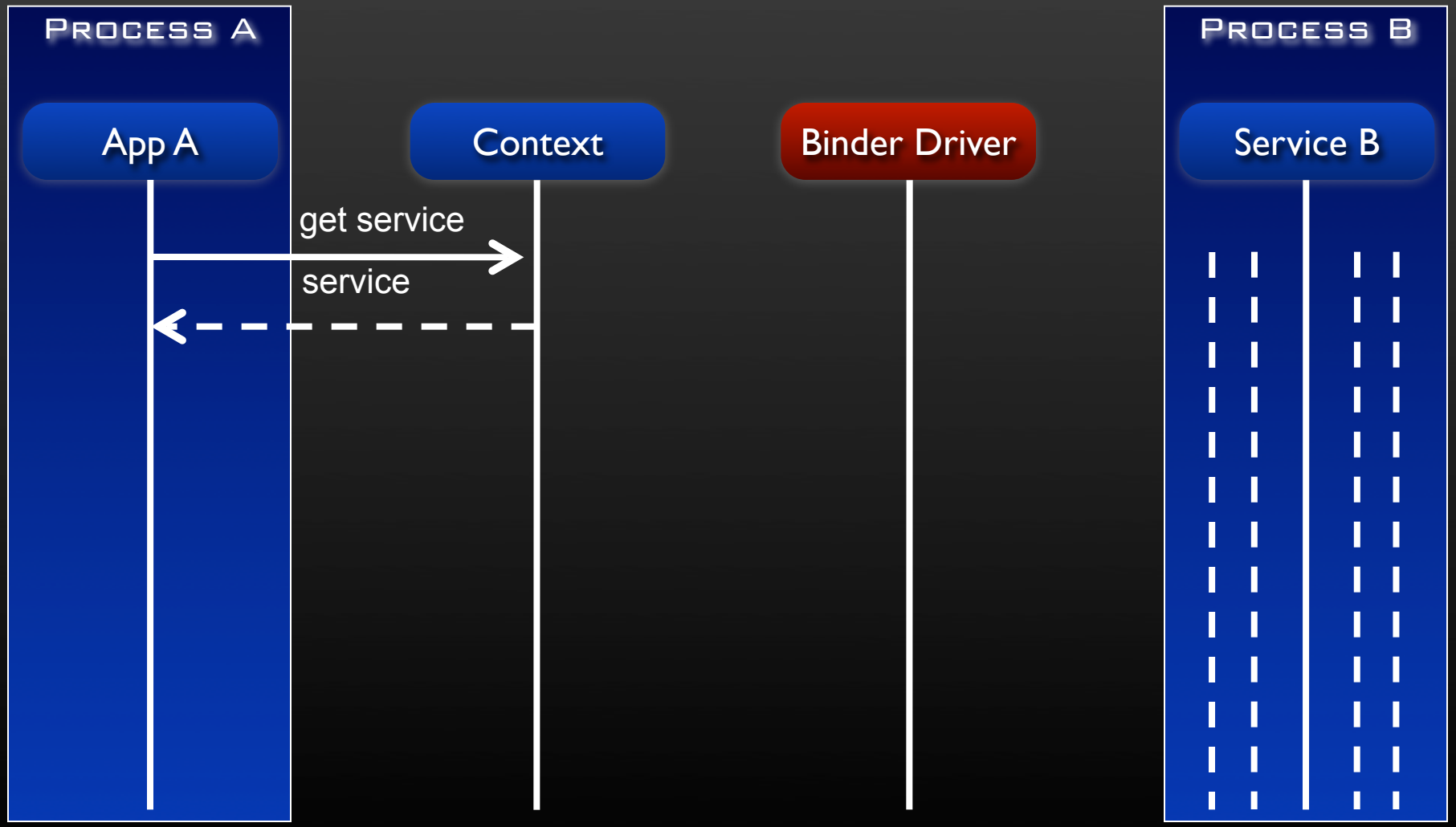

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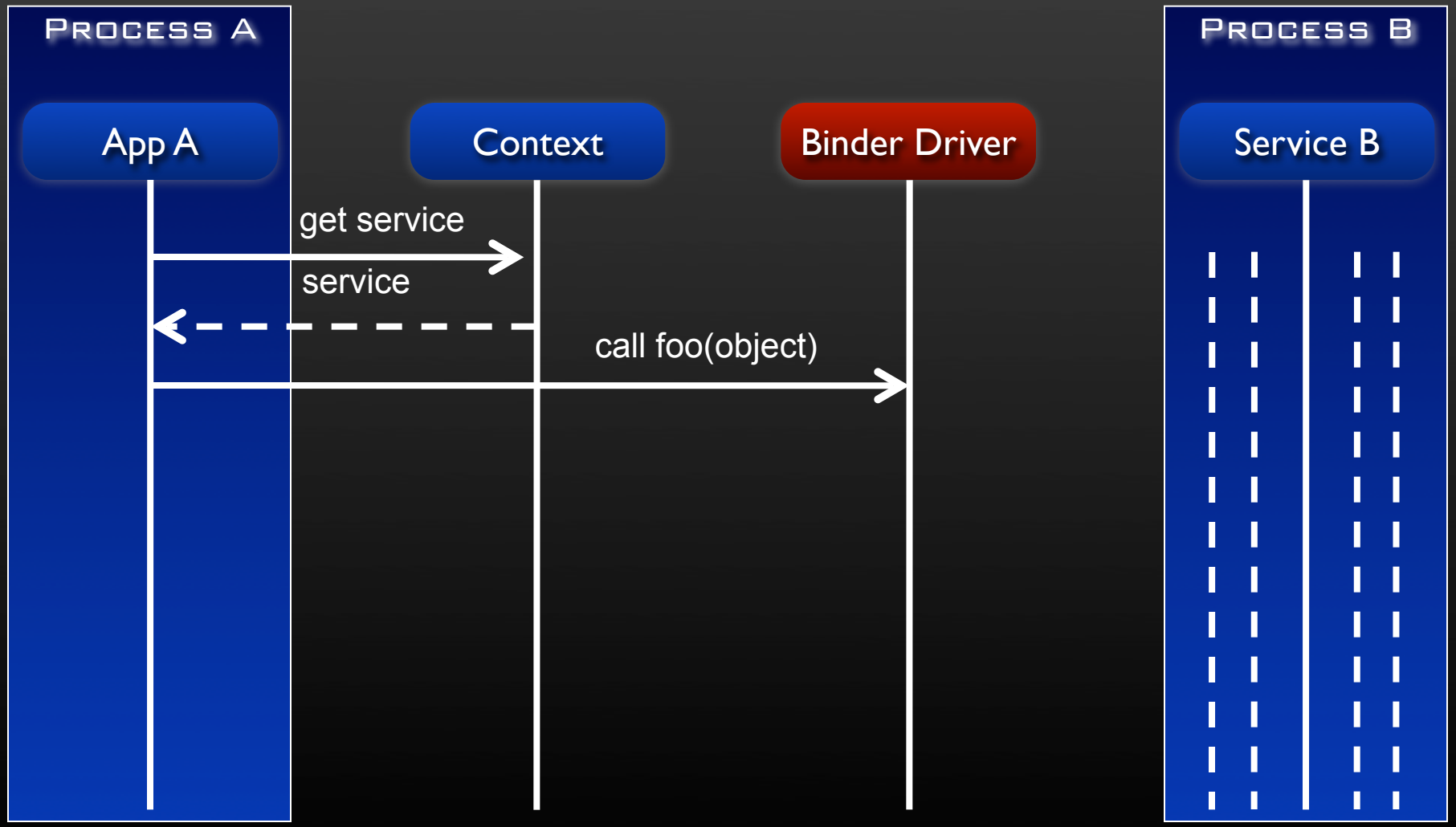

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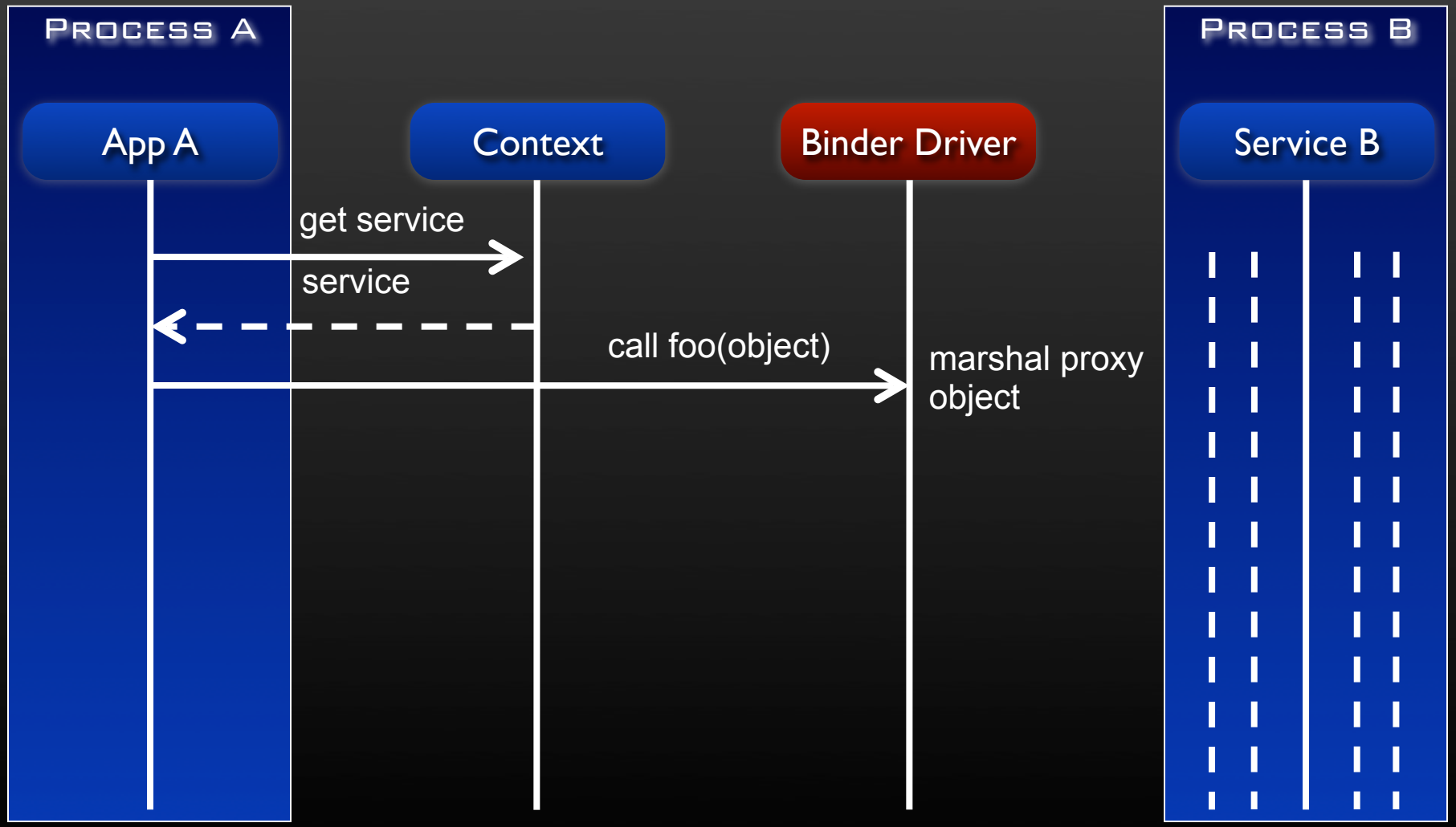

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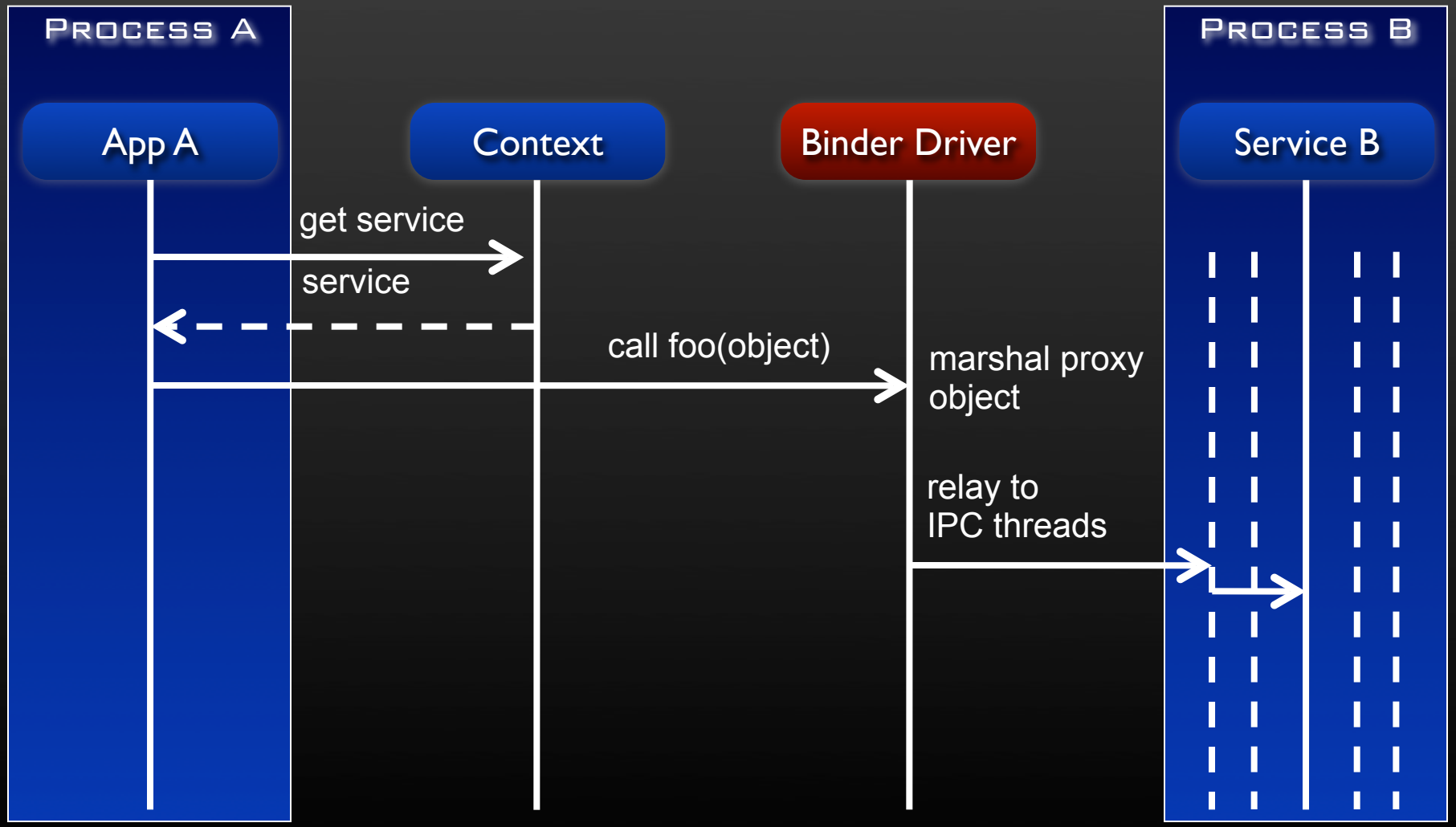

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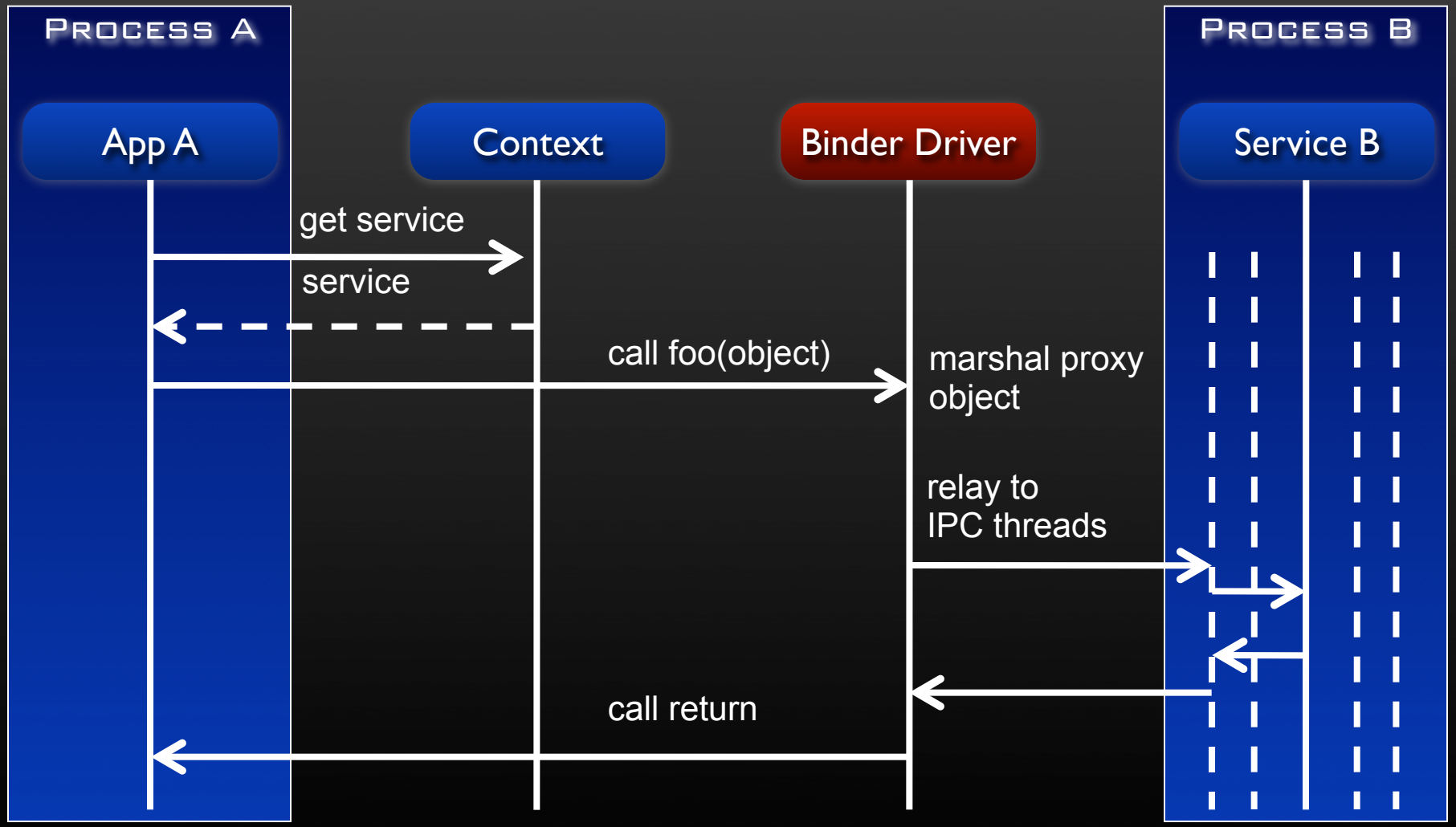
Binder in Action



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Binder

Android Interface Definition Language (AIDL)

- http://code.google.com/android/reference/aidl.html

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PM Problem

- Mobile devices run on battery power
- Batteries have limited capacity

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PM Solution

- Built on top of standard Linux Power Management (PM)
- More aggressive power management policy
- Components make requests to keep the power on through *“wake locks”*
- Supports different types of wake locks

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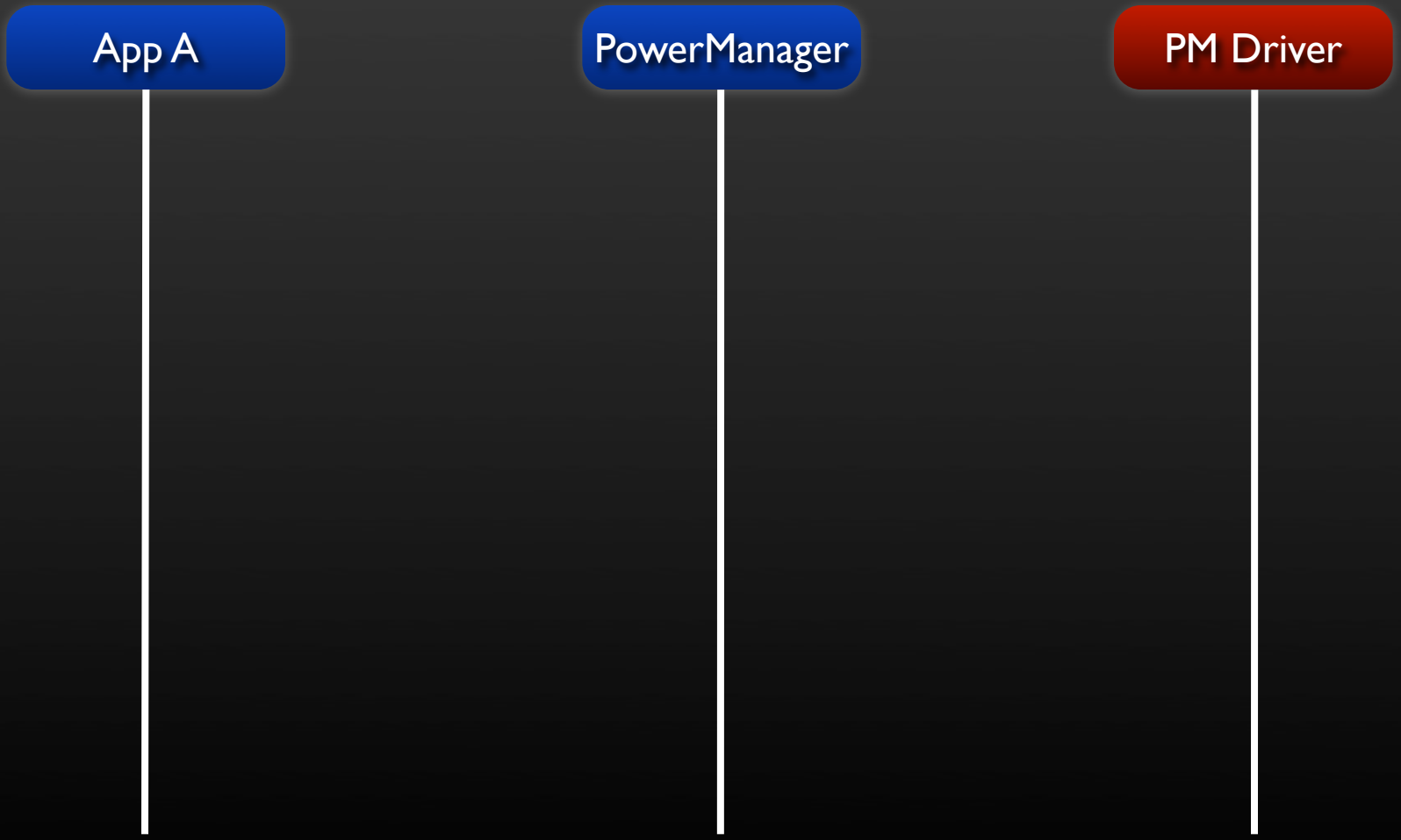
Android PM in Action



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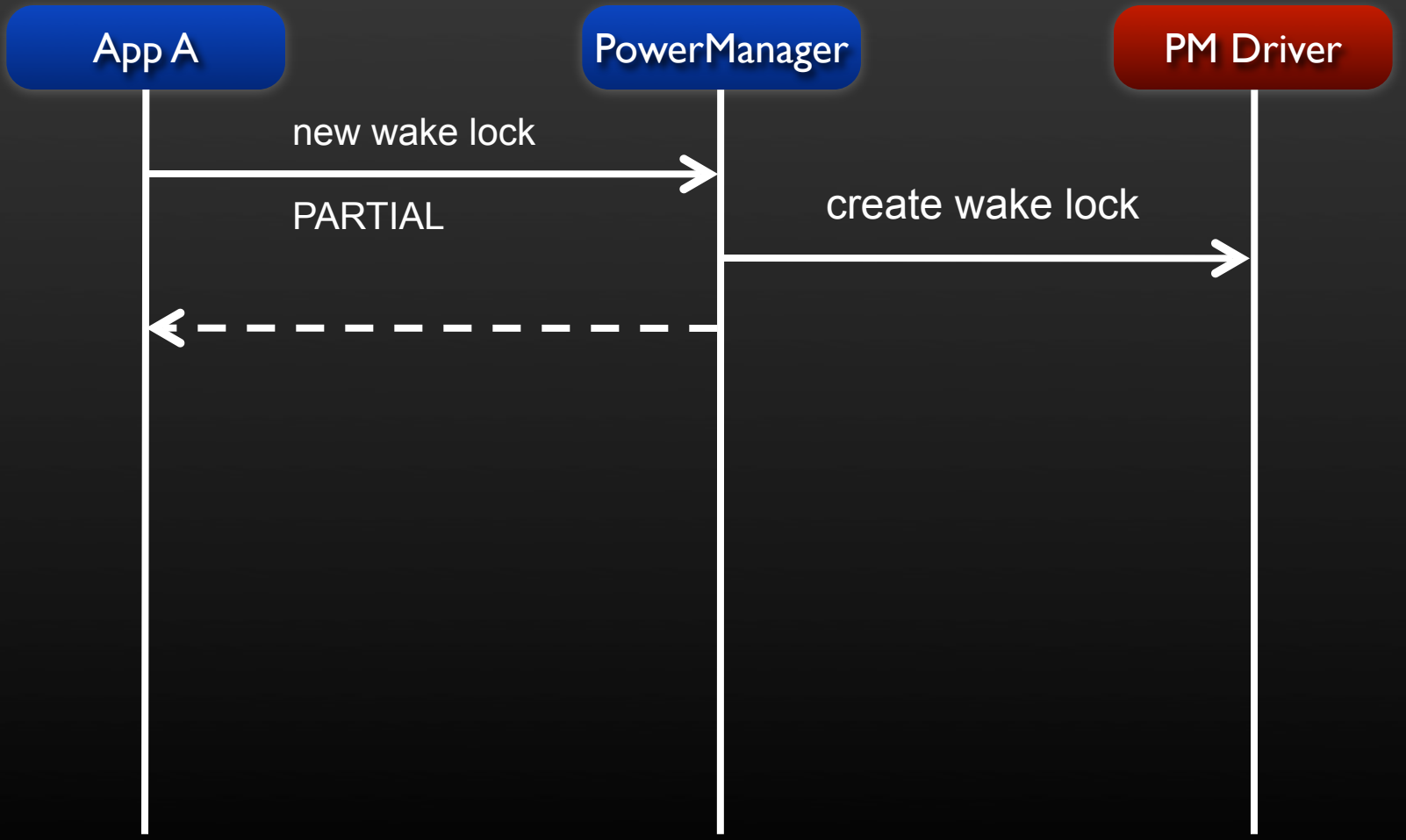
Android PM in Action

Android PM in Action



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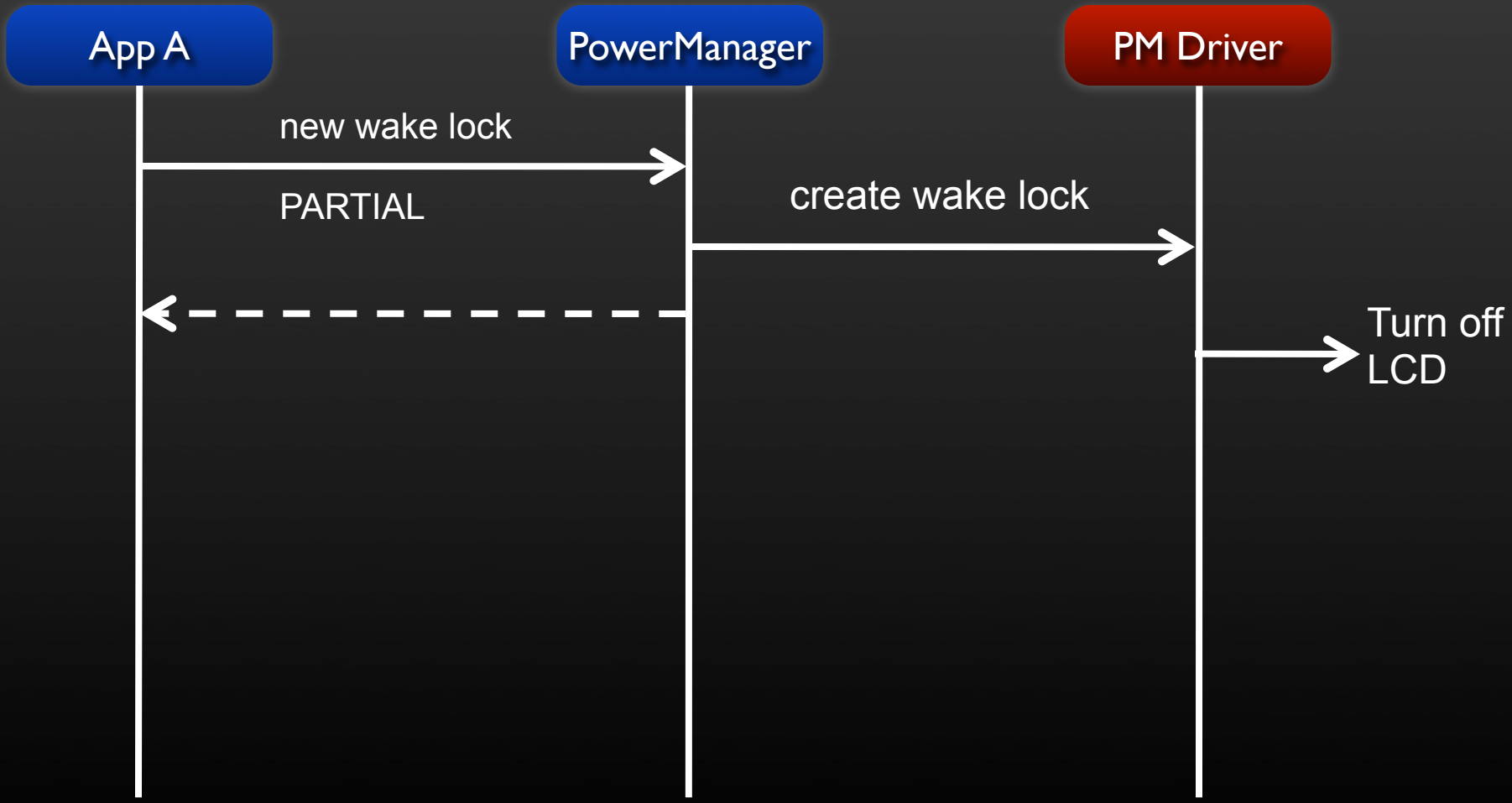
Android PM in Action



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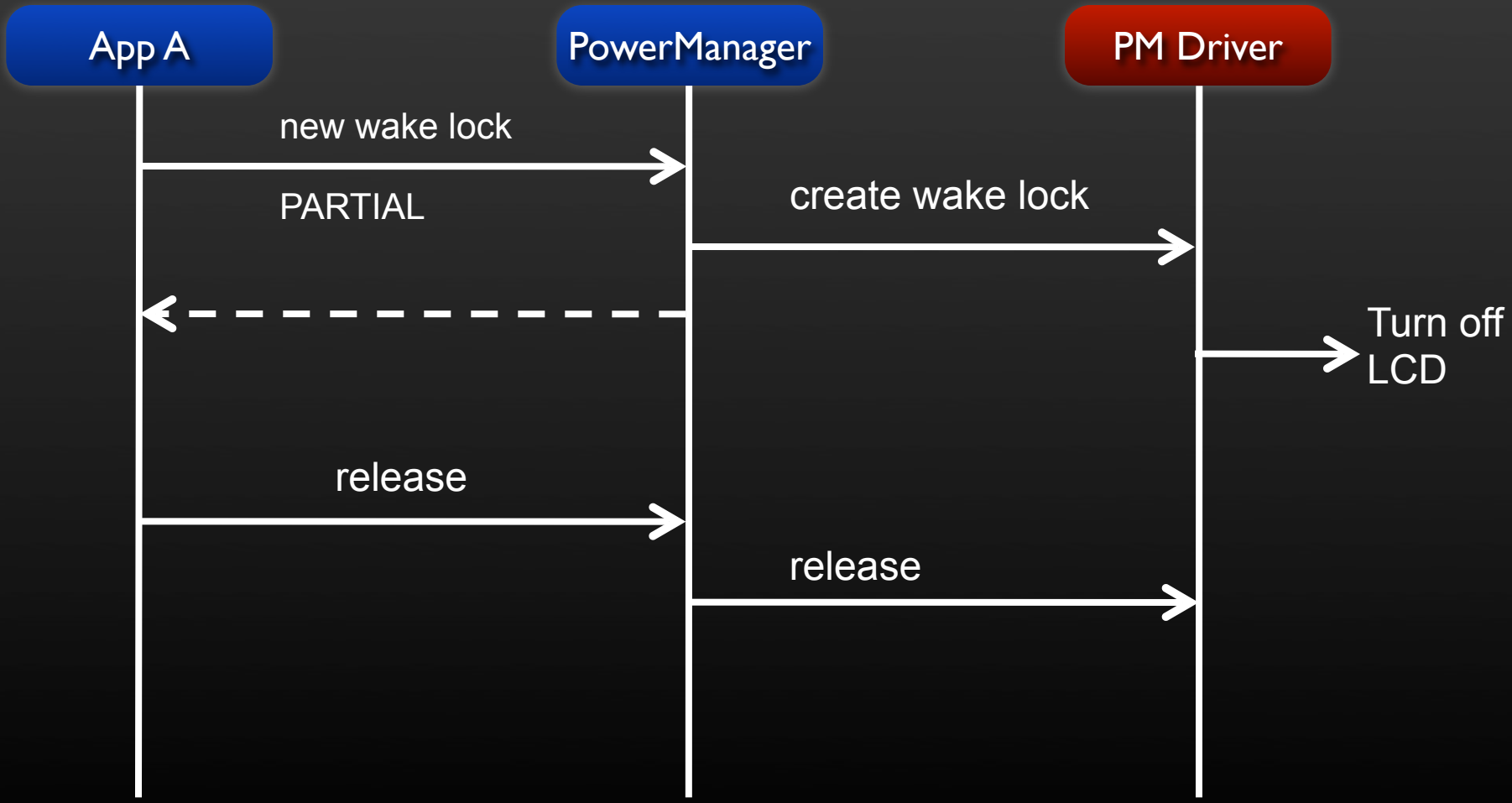
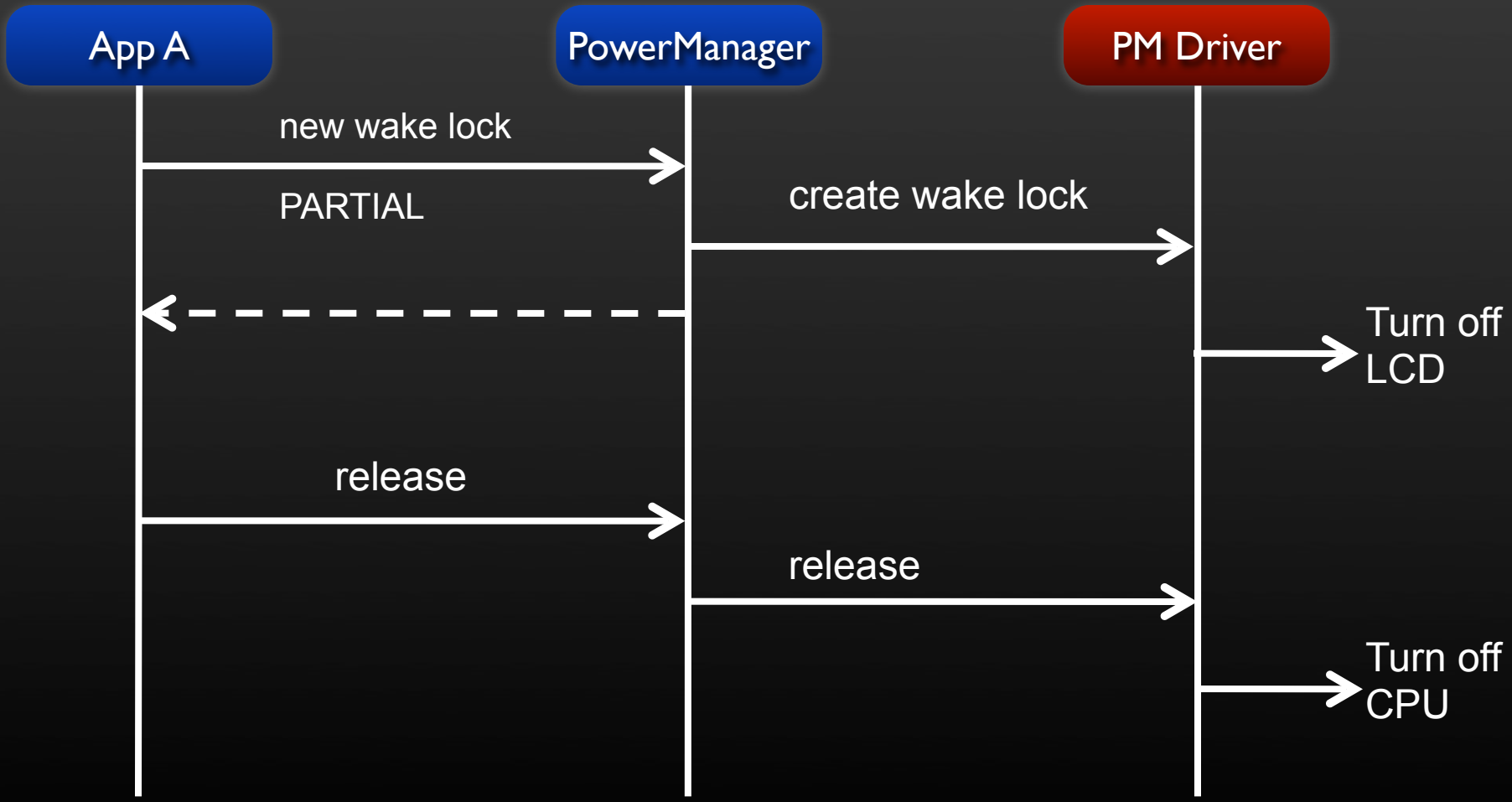
Android PM in Action



Android PM in Action



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Android PM

android.os.PowerManager

- Use wake locks carefully!

- `userActivity(long when, …);`

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Kernel

The Android kernel source is available today at:

http://git.android.com

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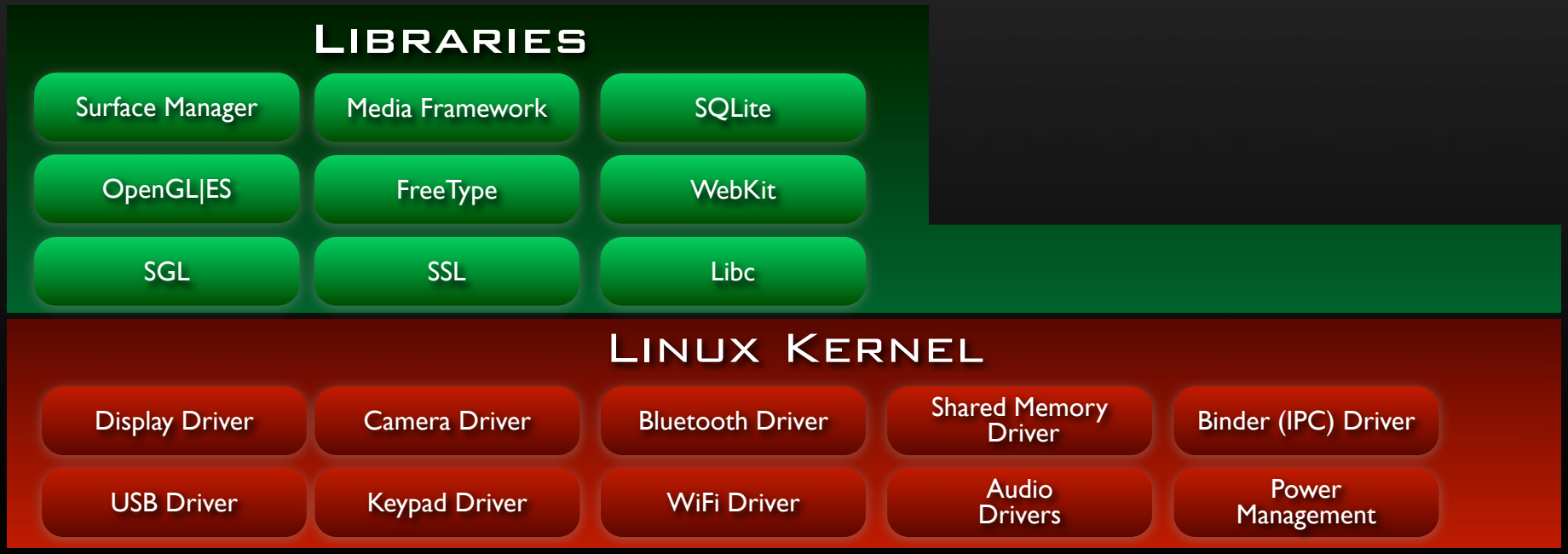
  - Start-up Walkthrough
  - Layer Interaction

Android Anatomy



Native Libraries

- Bionic Libc
- Function Libraries
- Native Servers
- Hardware Abstraction Libraries

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Native Libraries

- Bionic Libc
- Function Libraries
- Native Servers
- Hardware Abstraction Libraries

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What is Bionic?

- What is bionic?
  - Custom libc implementation, optimized for embedded use.

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Why Bionic?

Why build a custom libc library?

- License: we want to keep GPL out of user-space
- Size: will load in each process, so it needs to be small
- Fast: limited CPU power means we need to be fast

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Bionic libc

- BSD License
- Small size and fast code paths
- Very fast and small custom pthread implementation

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Bionic libc

- Built-in support for important Android-specific services
  - system properties

```
getprop("my.system.property", buff, default);
```

  - log capabilities

```
LOGI("Logging a message with priority 'Info'");
```

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Bionic libc

- Doesn't support certain POSIX features
- Not compatible with Gnu Libc (glibc)
- All native code must be compiled against bionic

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Native Libraries

- Bionic Libc
- Function Libraries
- Native Servers
- Hardware Abstraction Libraries

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WebKit

- Based on open source WebKit browser: http://webkit.org
- Renders pages in full (desktop) view
- Full CSS, Javascript, DOM, AJAX support
- Support for single-column and adaptive view rendering

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Media Framework

- Based on PacketVideo OpenCORE platform
- Supports standard video, audio, still-frame formats
- Support for hardware / software codec plug-ins

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SQLite

- Light-weight transactional data store
- Back end for most platform data storage

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Native Libraries

- Bionic Libc
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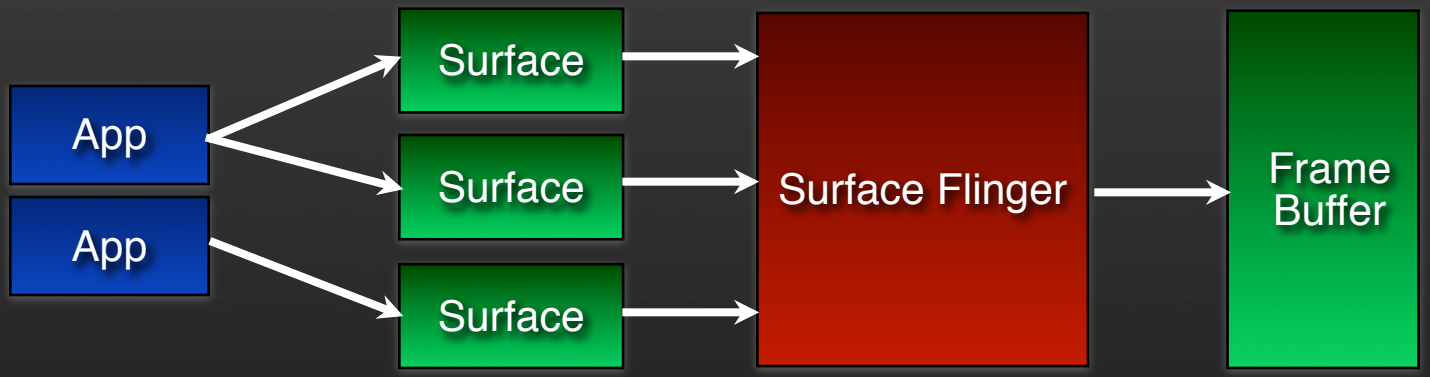
Surface Flinger



- Provides system-wide surface “composer”, handling all surface rendering to frame buffer device
- Can combine 2D and 3D surfaces and surfaces from multiple applications

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Surface Flinger

- Surfaces passed as buffers via Binder IPC calls
- Can use OpenGL ES and 2D hardware accelerator for its compositions
- Double-buffering using page-flip

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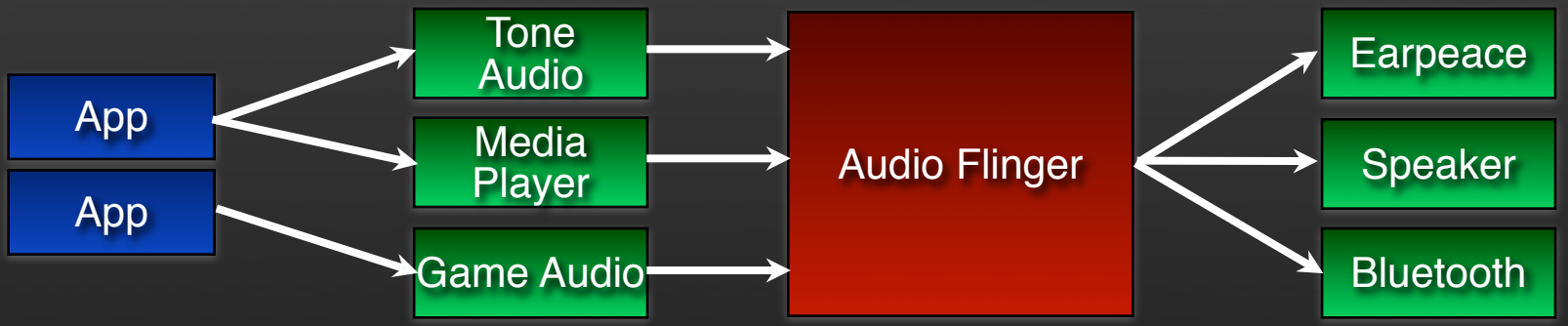
Audio Flinger



- Manages all audio output devices
- Processes multiple audio streams into PCM audio out paths
- Handles audio routing to various outputs

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Native Libraries

- Bionic Libc
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- Native Servers
- Hardware Abstraction Libraries

ANDROID

Hardware Abstraction Layer

Applications

Home | Dialer | SMS/MMS | IM | Browser | Camera | Alarm | Calculator

Contacts | Voice Dial | Email | Calendar | Media Player | Photo Album | Clock | ...

Application Framework

Activity Manager | Window Manager | Content Providers | View System | Notification Manager

Package Manager | Telephony Manager | Resource Manager | Location Manager | ...

Libraries

Surface Manager | Media Framework | SQLite | WebKit | Libc

OpenGL|ES | Audio Manager | FreeType | SSL | ...

Android Runtime

Core Libraries

Dalvik Virtual Machine

Hardware Abstraction Layer

Graphics | Audio | Camera | Bluetooth | GPS | Radio (RIL) | WiFi | ...

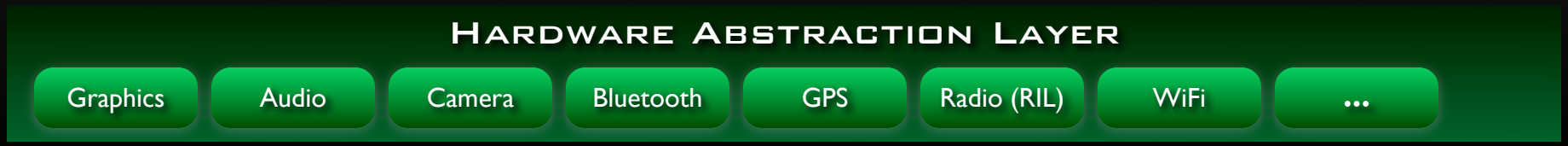
Linux Kernel

Display Driver | Camera Driver | Bluetooth Driver | Shared Memory Driver | Binder (IPC) Driver

USB Driver | Keypad Driver | WiFi Driver | Audio Drivers | Power Management

Hardware Abstraction Libraries

- User space C/C++ library layer
- Defines the interface that Android requires hardware “drivers” to implement
- Separates the Android platform logic from the hardware interface



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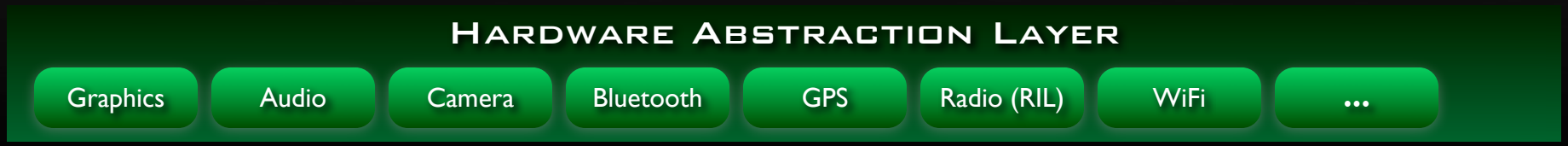
Hardware Abstraction Libraries

Why do we need a user-space HAL?

- Not all components have standardized kernel driver interfaces
- Kernel drivers are GPL which exposes any proprietary IP
- Android has specific requirements for hardware drivers



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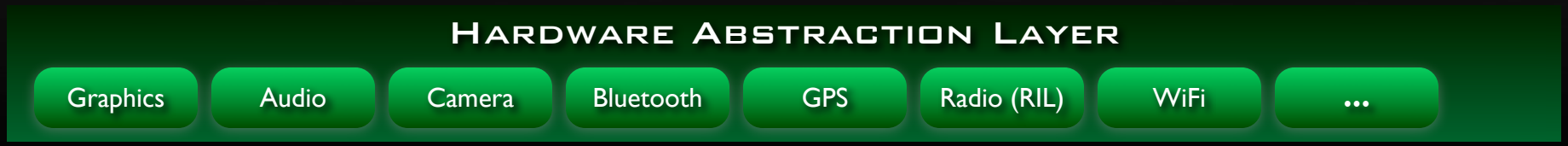
HAL Header Example

```
// must be provided by each Acme hardware implementation
typedef struct {
    int   (*foo)( void );
   char  (*bar)( void );
   …

} AcmeFunctions;


const AcmeFunctions *Acme_Init(const struct Env *env, int argc, char
   **argv);
```



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Hardware Abstraction Libraries

- Libraries are loaded dynamically at runtime as needed

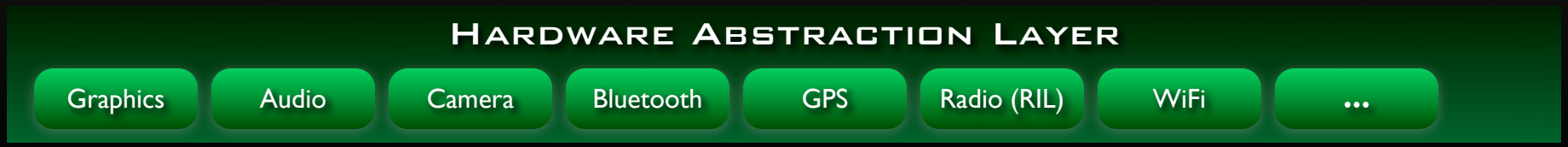
```
dlHandle = dlopen("/system/lib/libacme.so", RTLD_NOW);

...

acmeInit = (const AcmeFunctions *(*)(const struct Env *,
   int, char **))dlsym(dlHandle, "Acme_Init");

...

acmeFuncs = acmeInit(&env, argc, argv);
```



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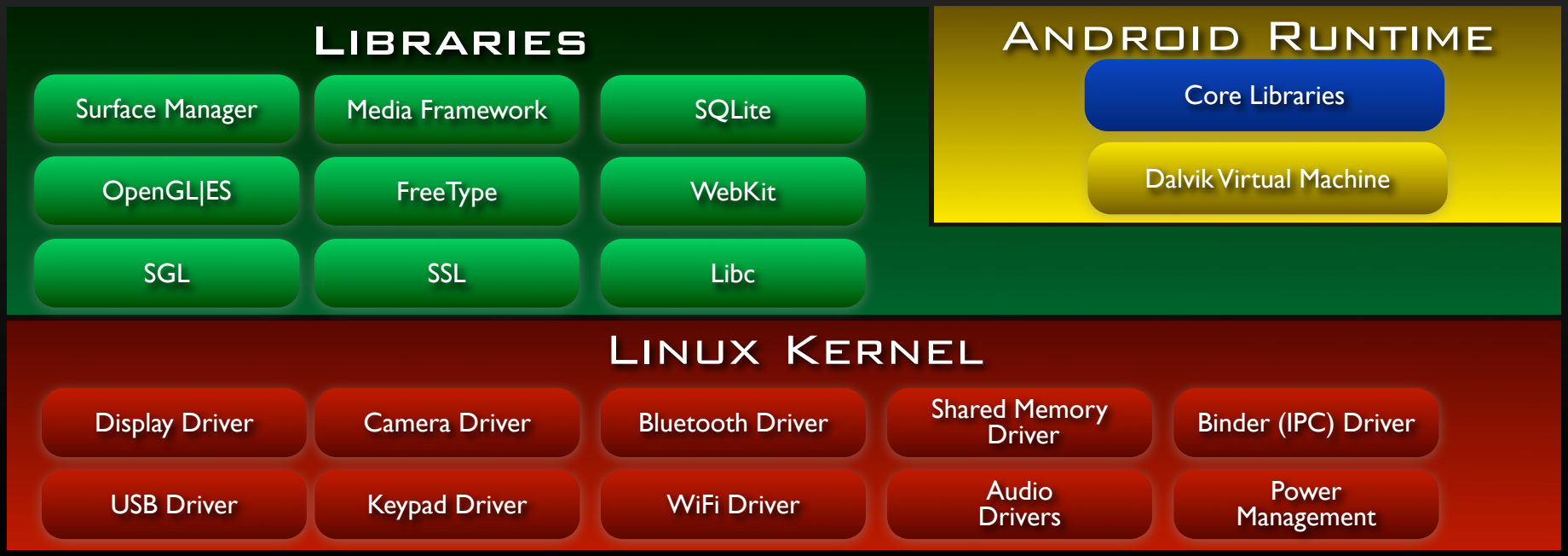
Android Anatomy



Dalvik Virtual Machine

- Android's custom clean-room implementation virtual machine
  - Provides application portability and runtime consistency
  - Runs optimized file format (.dex) and Dalvik bytecode
  - Java .class / .jar files converted to .dex at build time

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Dalvik Virtual Machine

- Designed for embedded environment
  - Supports multiple virtual machine processes per device
  - Highly CPU-optimized bytecode interpreter
  - Uses runtime memory very efficiently

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Core Libraries

- Core APIs for Java language provide a powerful, yet simple and familiar development platform
  - Data structures
  - Utilities
  - File access
  - Network Access
  - Graphics
  - …

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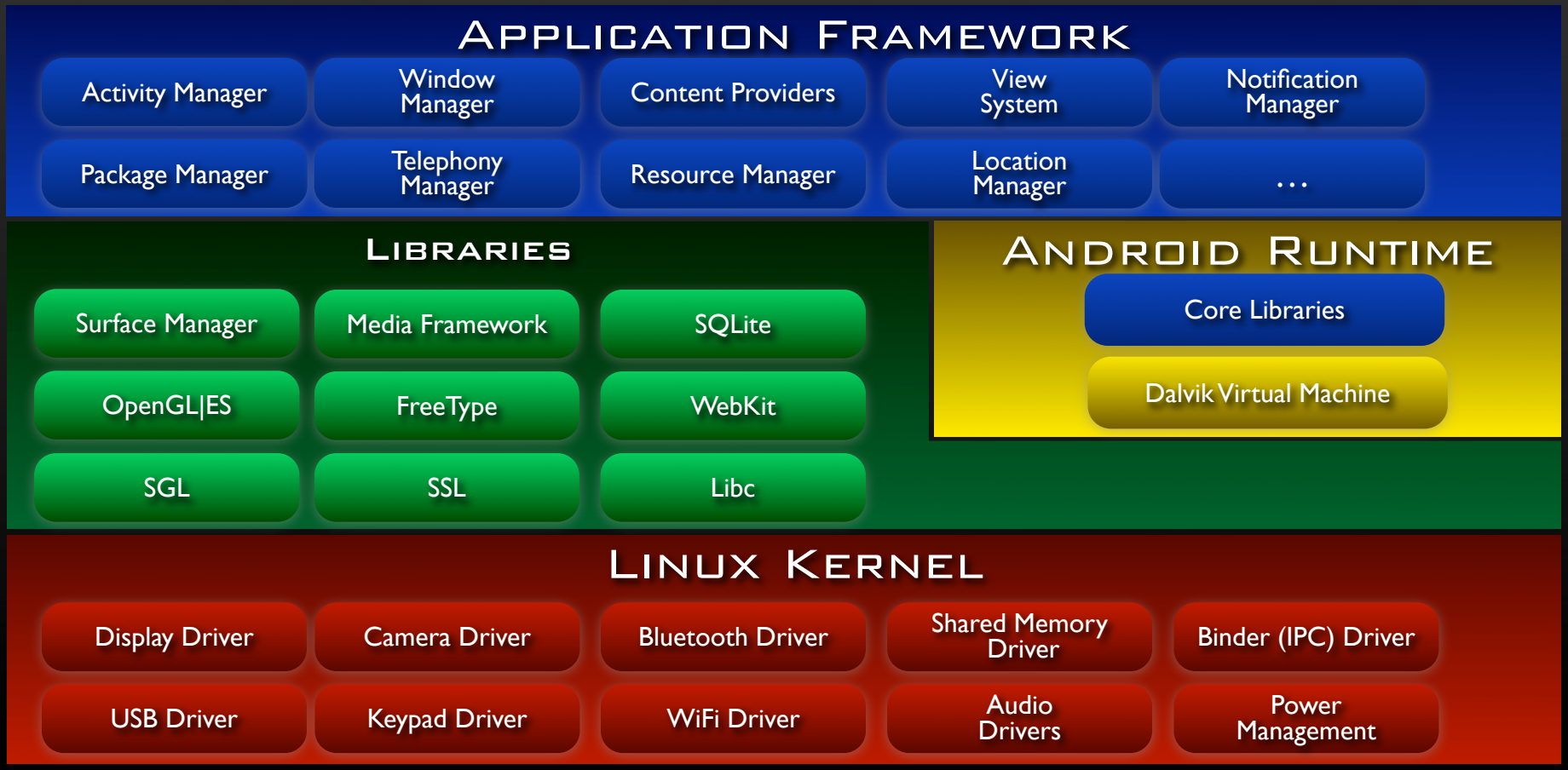

Core Platform Services

- Services that are essential to the Android platform
- Behind the scenes - applications typically don't access them directly

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Core Platform Services

- Activity Manager

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Core Platform Services

- Activity Manager
- Package Manager

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Core Platform Services

- Activity Manager
- Package Manager
- Window Manager

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Core Platform Services

- Activity Manager
- Package Manager
- Window Manager
- Resource Manager

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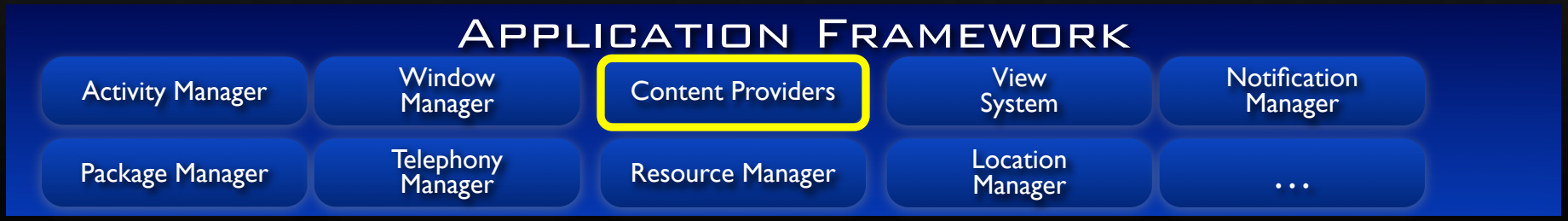
Core Platform Services

- Activity Manager
- Package Manager
- Window Manager
- Resource Manager
- Content Providers



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Core Platform Services

- Activity Manager
- Package Manager
- Window Manager
- Resource Manager
- Content Providers
- View System

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Hardware Services

- Provide access to lower-level hardware APIs

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Hardware Services

- Provide access to lower-level hardware APIs
- Typically accessed through local *Manager* object

```
LocationManager lm = (LocationManager)
   Context.getSystemService(Context.LOCATION_SERVICE);
```

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Hardware Services

- Telephony Service

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Hardware Services

- Telephony Service
- Location Service

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Hardware Services

- Telephony Service
- Location Service
- Bluetooth Service

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Hardware Services

- Telephony Service
- Location Service
- Bluetooth Service
- WiFi Service

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Hardware Services

- Telephony Service
- Location Service
- Bluetooth Service
- WiFi Service
- USB Service

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Hardware Services

- Telephony Service
- Location Service
- Bluetooth Service
- WiFi Service
- USB Service
- Sensor Service

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Application Framework

More Information

- At Google I/O
  - “Inside the Android Application Framework”
- Online
  - http://code.google.com/android

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Android Anatomy

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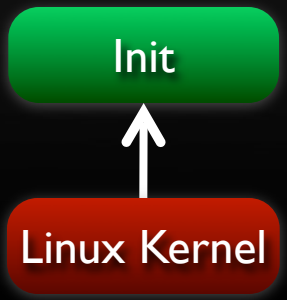
Runtime Walkthrough

It all starts with init…

Similar to most Linux-based systems at startup, the bootloader loads the Linux kernel and starts the init process.



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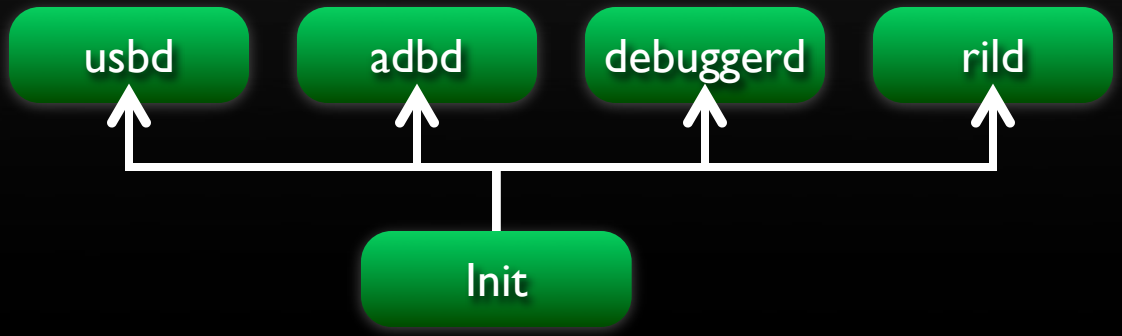
Runtime Walkthrough

Init starts Linux daemons, including:

- USB Daemon (usbd) to manage USB connections
- Android Debug Bridge (adbd) to manage ADB connections
- Debugger Daemon (debuggerd) to manage debug processes requests (dump memory, etc.)
- Radio Interface Layer Daemon (rild) to manage communication with the radio



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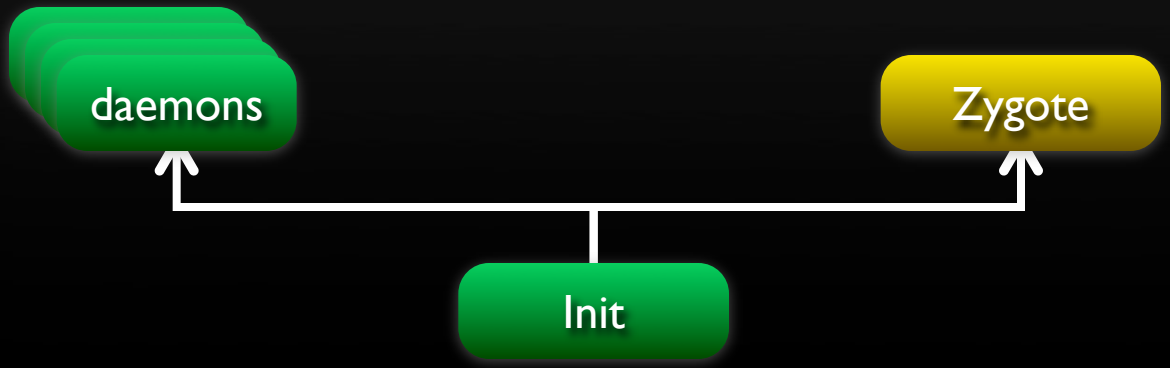
Runtime Walkthrough

Init process starts the zygote process:

- A nascent process which initializes a Dalvik VM instance
- Loads classes and listens on socket for requests to spawn VMs
- Forks on request to create VM instances for managed processes
- Copy-on-write to maximize re-use and minimize footprint



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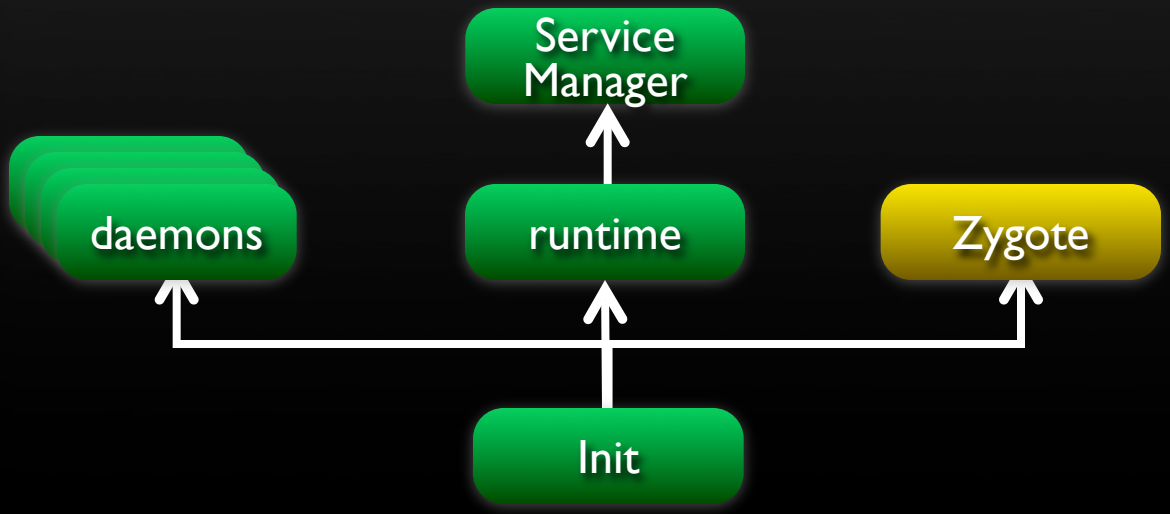
Runtime Walkthrough

Init starts runtime process:

- Initializes Service Manager – the context manager for Binder that handles service registration and lookup
- Registers Service Manager as default context manager for Binder services



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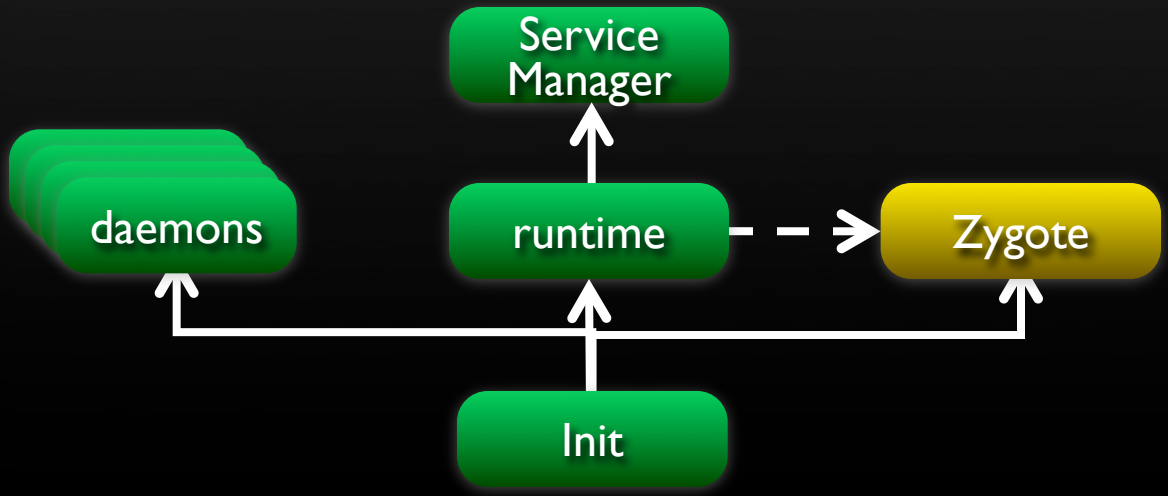
Runtime Walkthrough

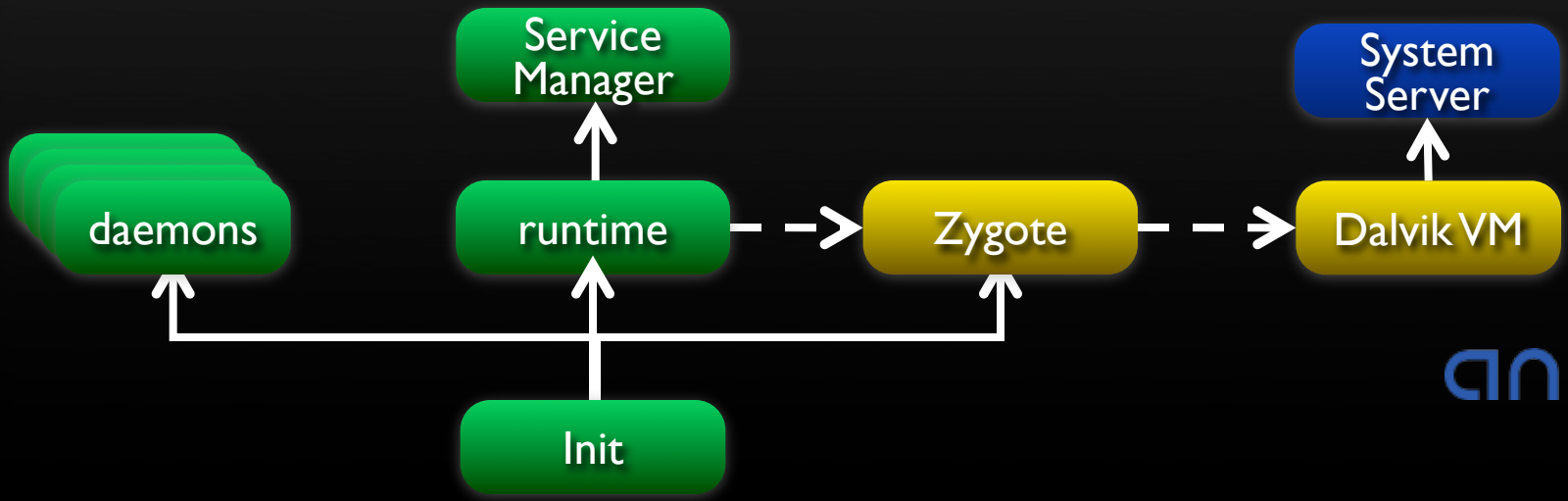
Runtime process sends request for Zygote to start System Service



Runtime Walkthrough

Runtime process sends request for Zygote to start System Server

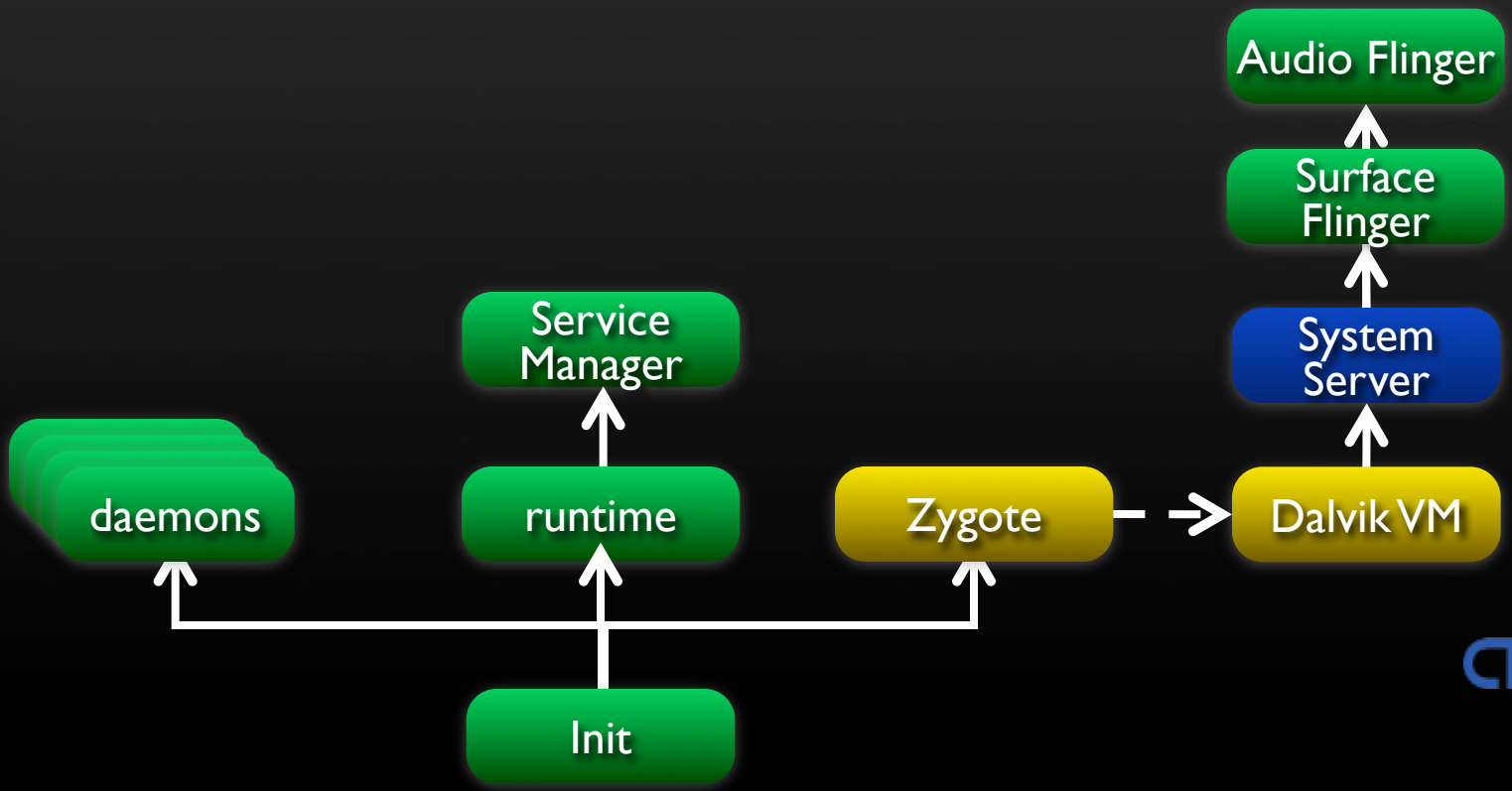
- Zygote forks a new VM instance for the System Service process and starts the service



Runtime Walkthrough

System Service starts the native system servers, including:

- Surface Flinger
- Audio Flinger



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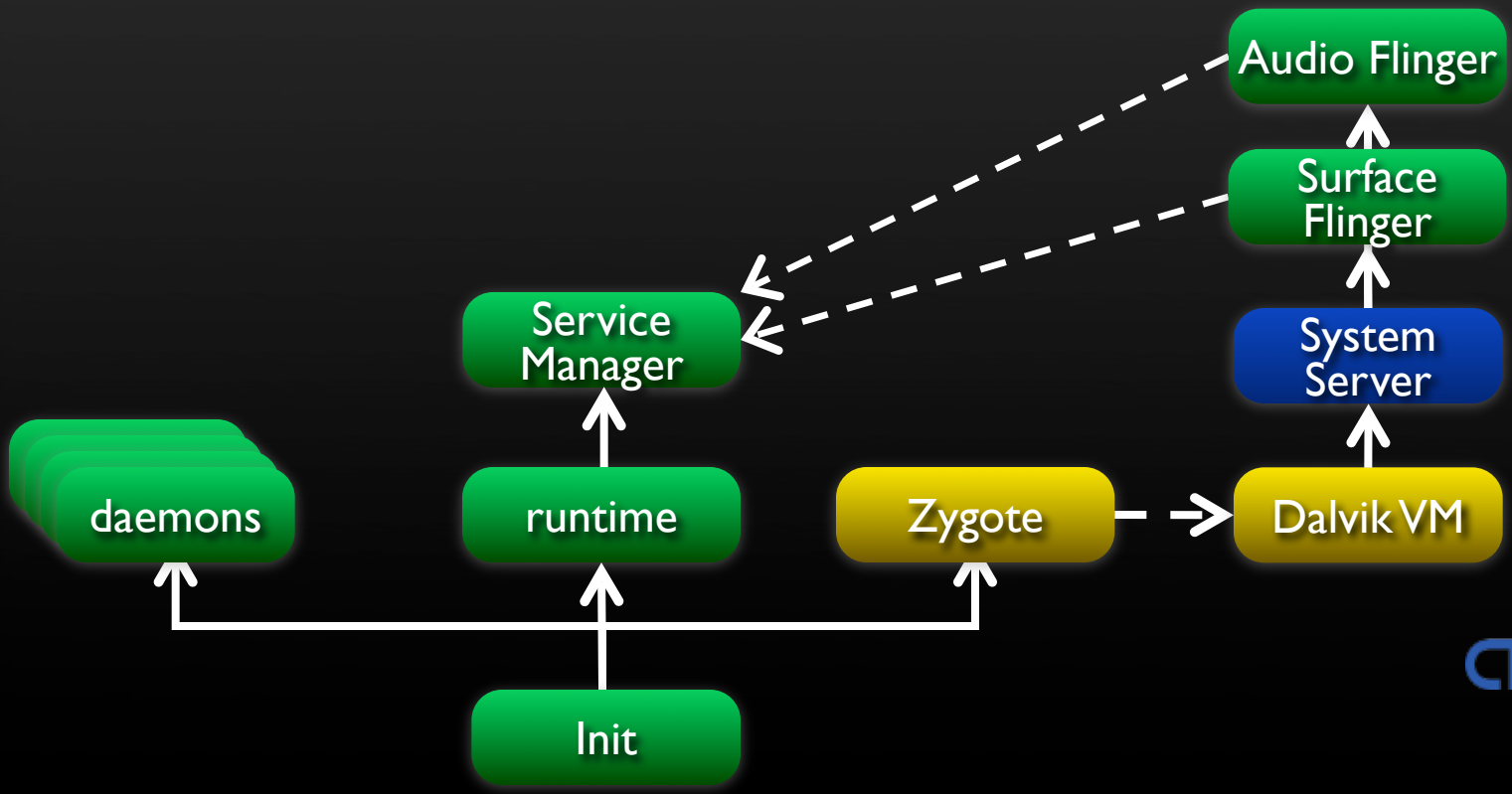
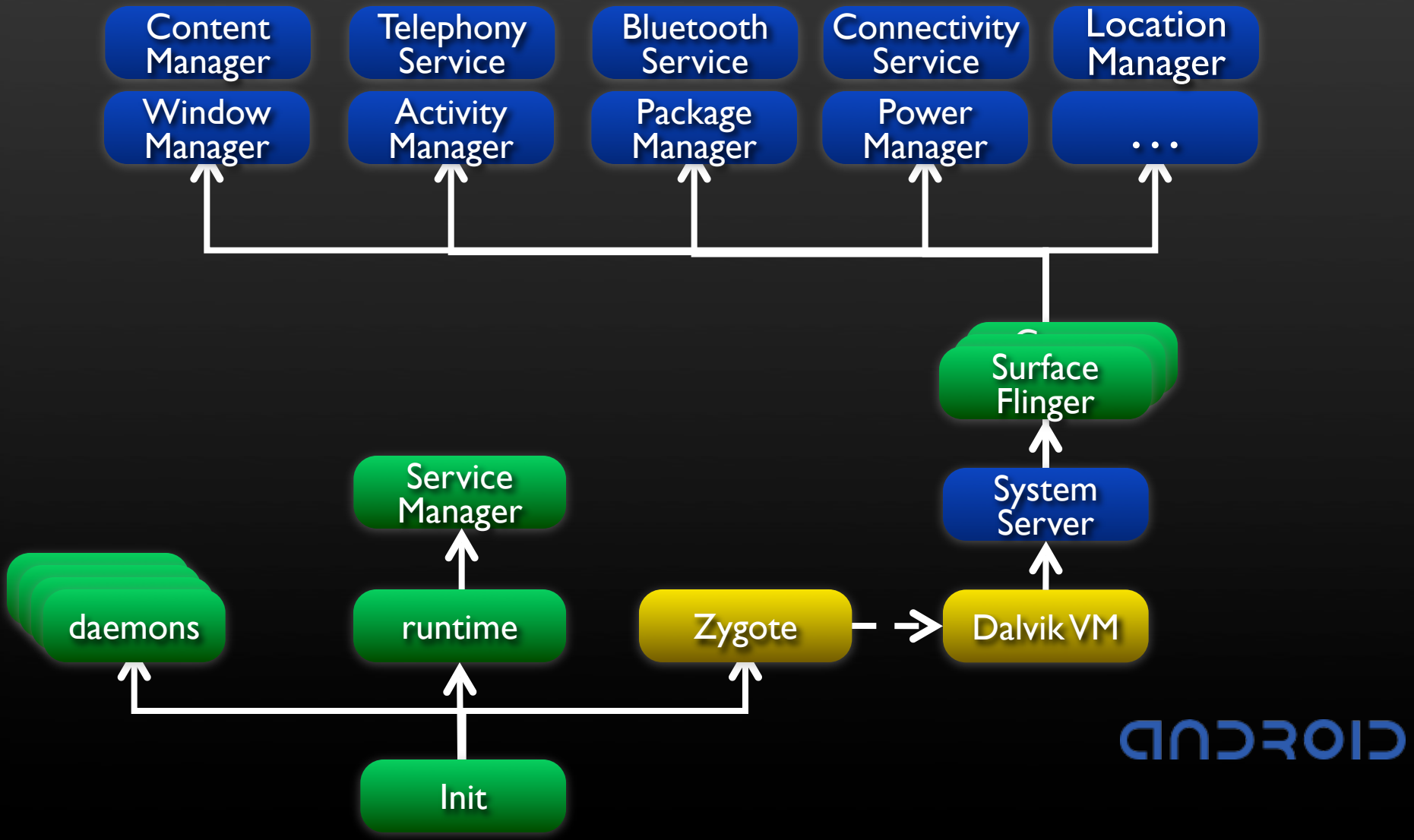
Runtime Walkthrough

Native system servers register with Service Manager as IPC service targets:



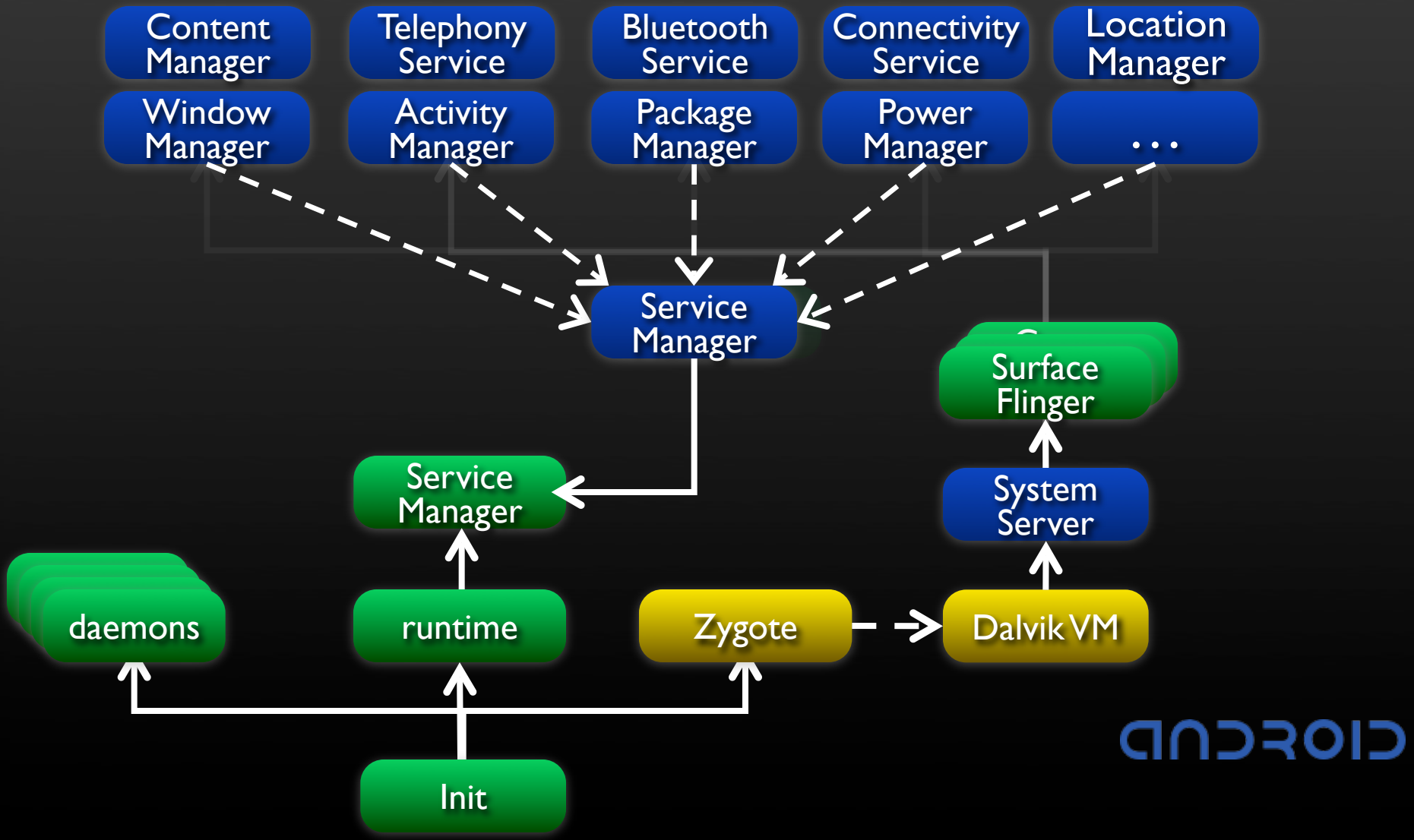
Runtime Walkthrough

System Service starts the Android managed services:

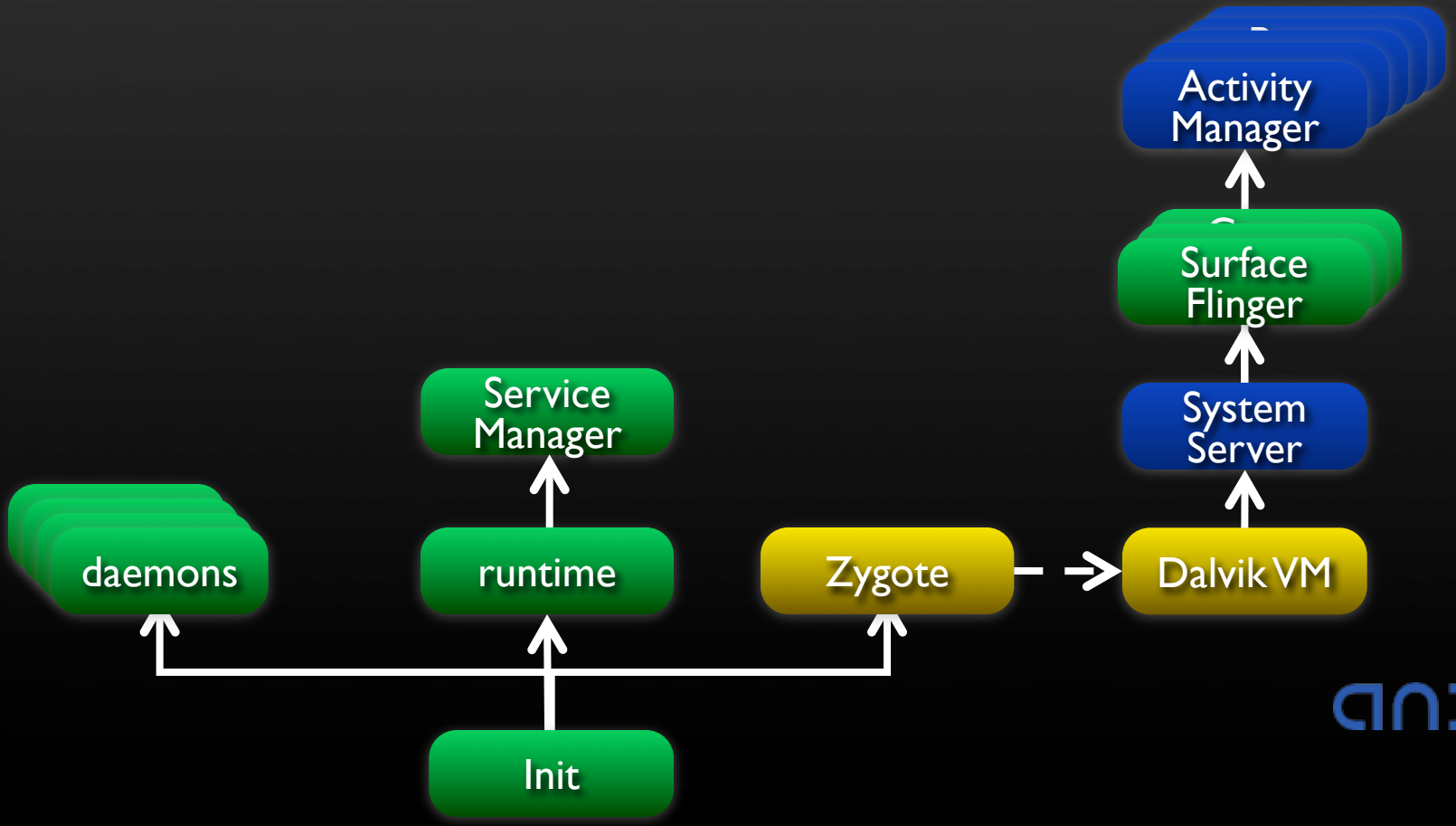


Runtime Walkthrough

Android managed Services register with Service Manager:



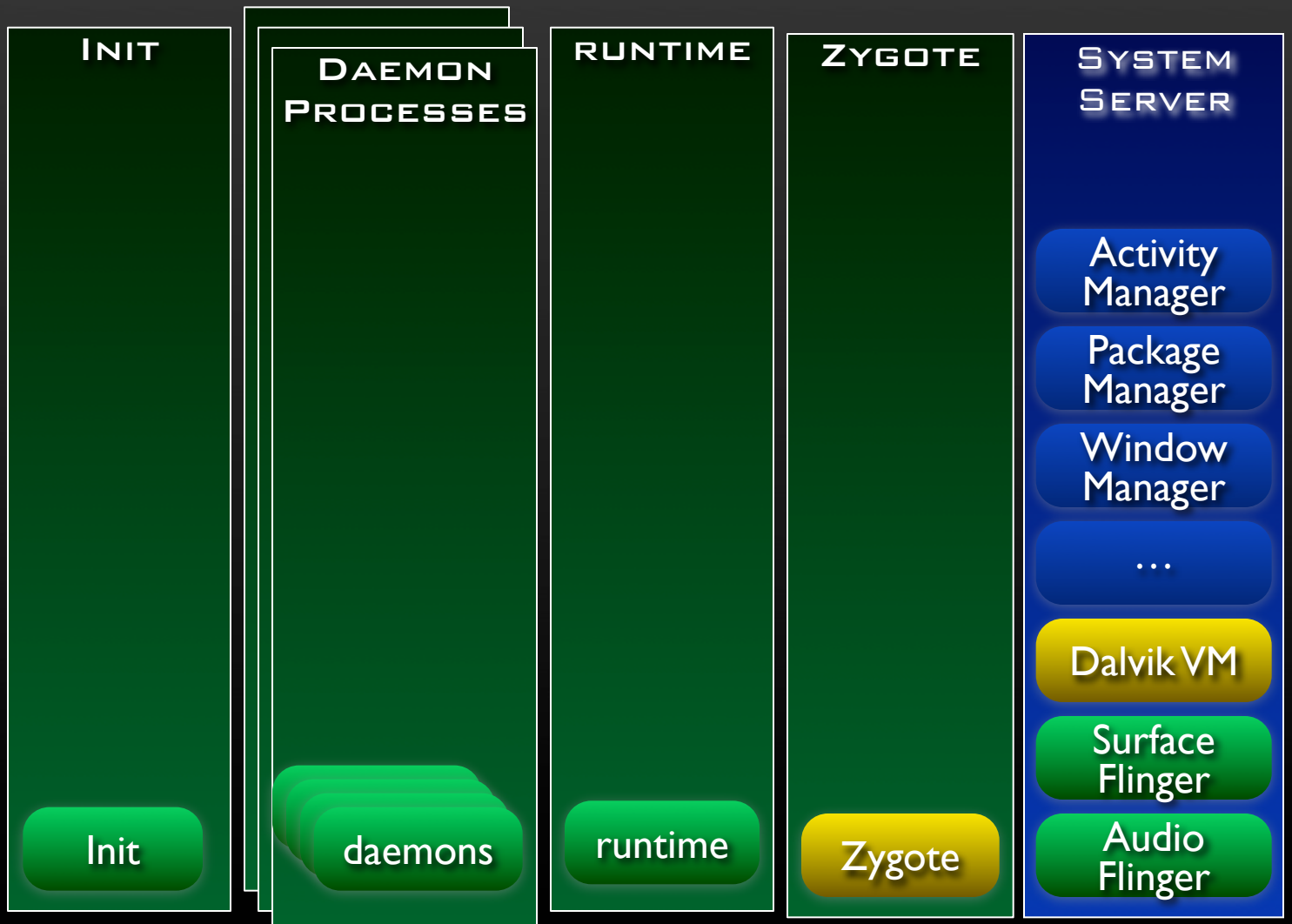
Runtime Walkthrough



android

Runtime Walkthrough

After system server loads all services, the system is ready…



Runtime Walkthrough

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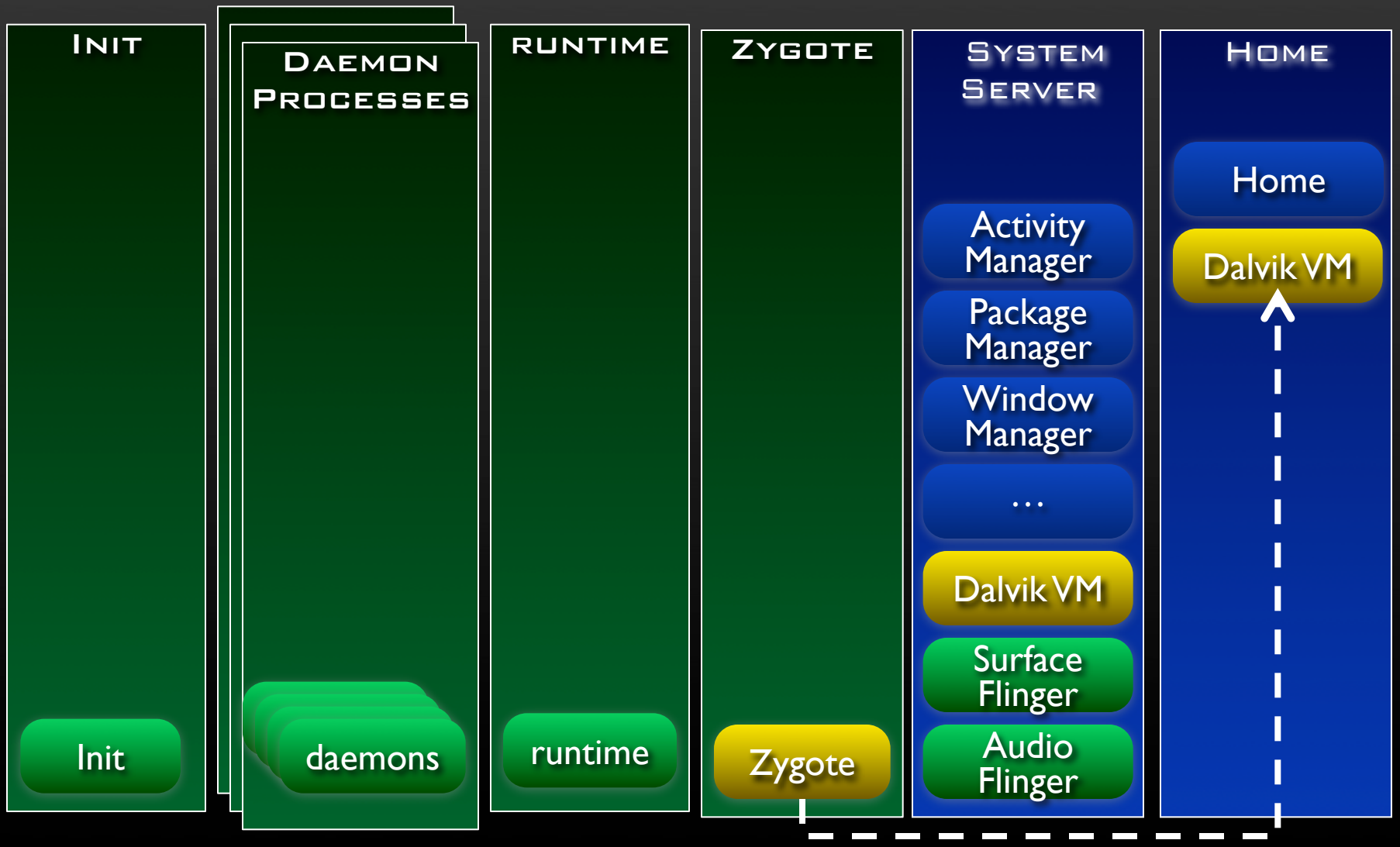

Runtime Walkthrough

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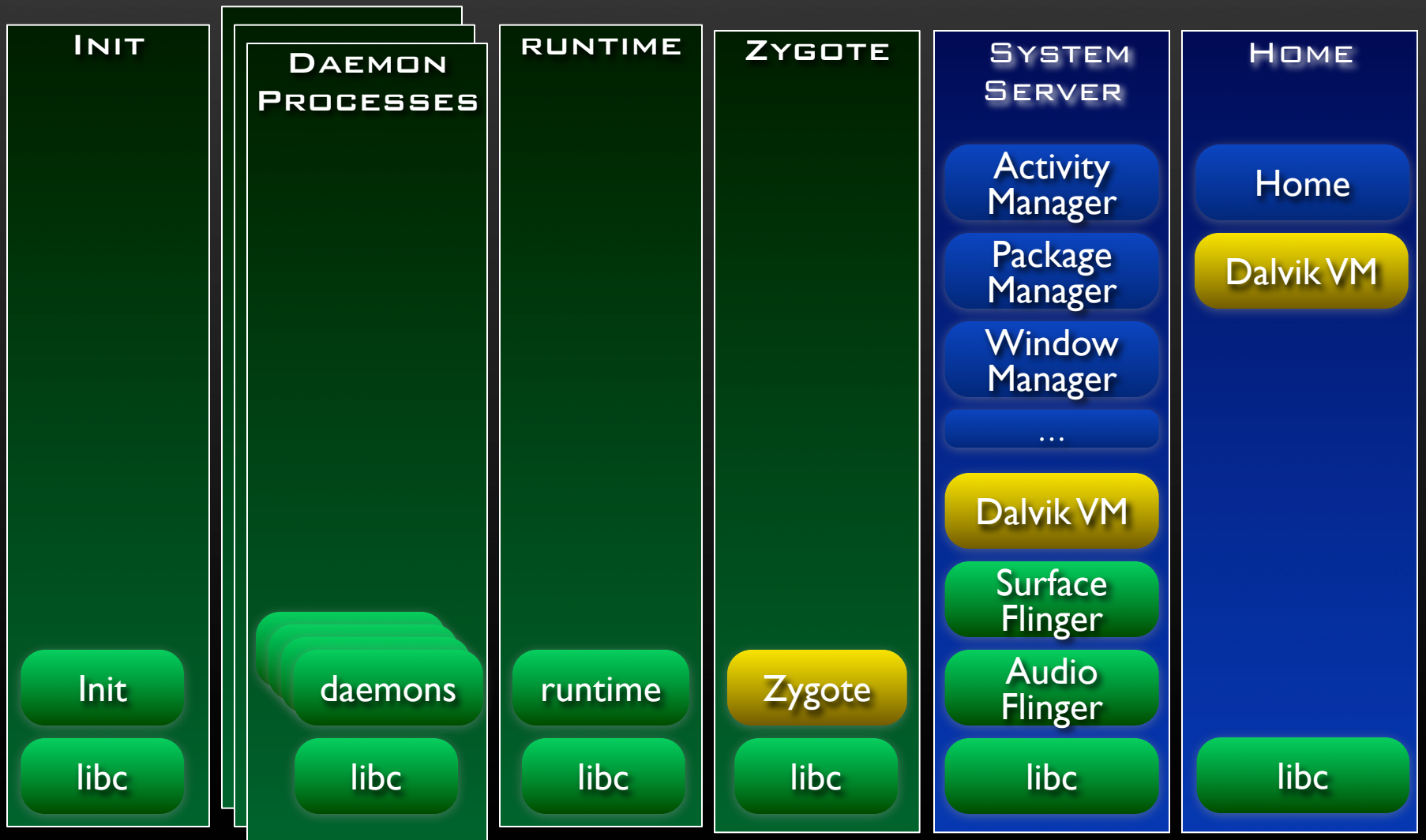

Runtime Walkthrough

Each subsequent application is launched in it's own process

Agenda

- Android Anatomy
  - Linux Kernel
  - Native Libraries
  - Framework Services
- Android Physiology
  - Start-up Walkthrough
  - Layer Interaction

Layer Interaction

There are 3 main flavors of Android layer cake:

- App → Runtime Service → lib
- App → Runtime Service → Native Service → lib
- App → Runtime Service → Native Daemon → lib

ANDROID

Layer Interaction

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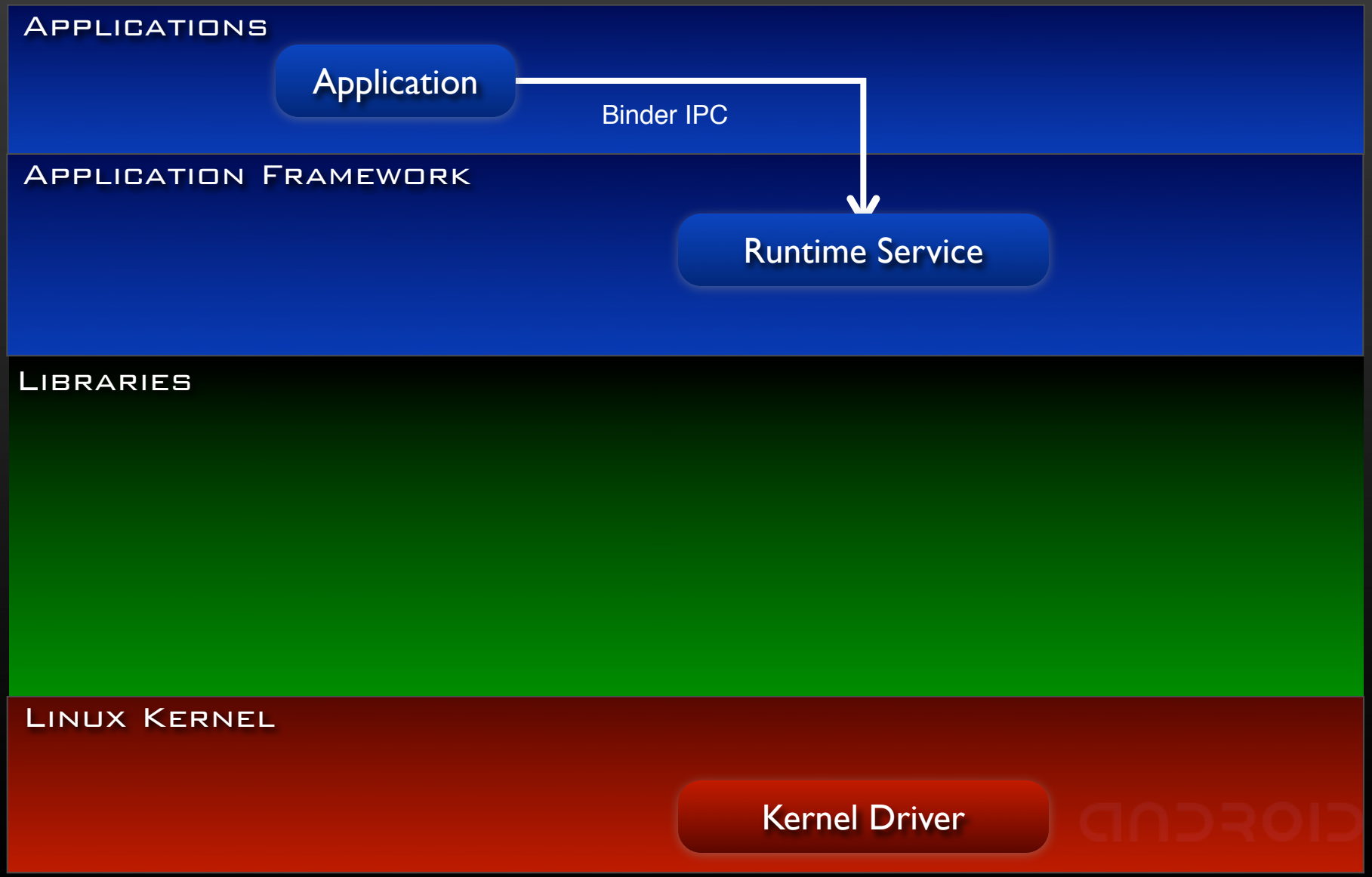
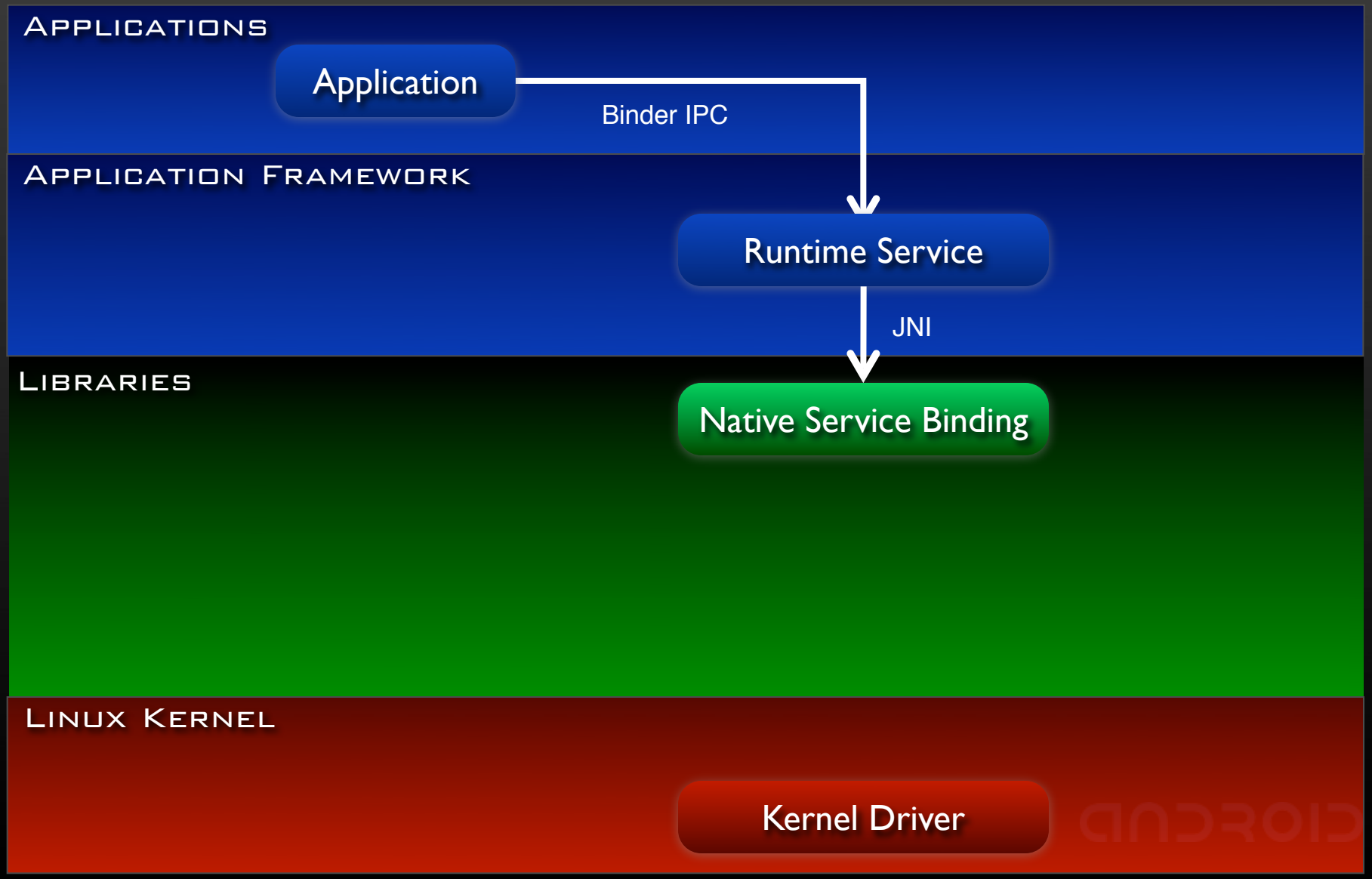
android

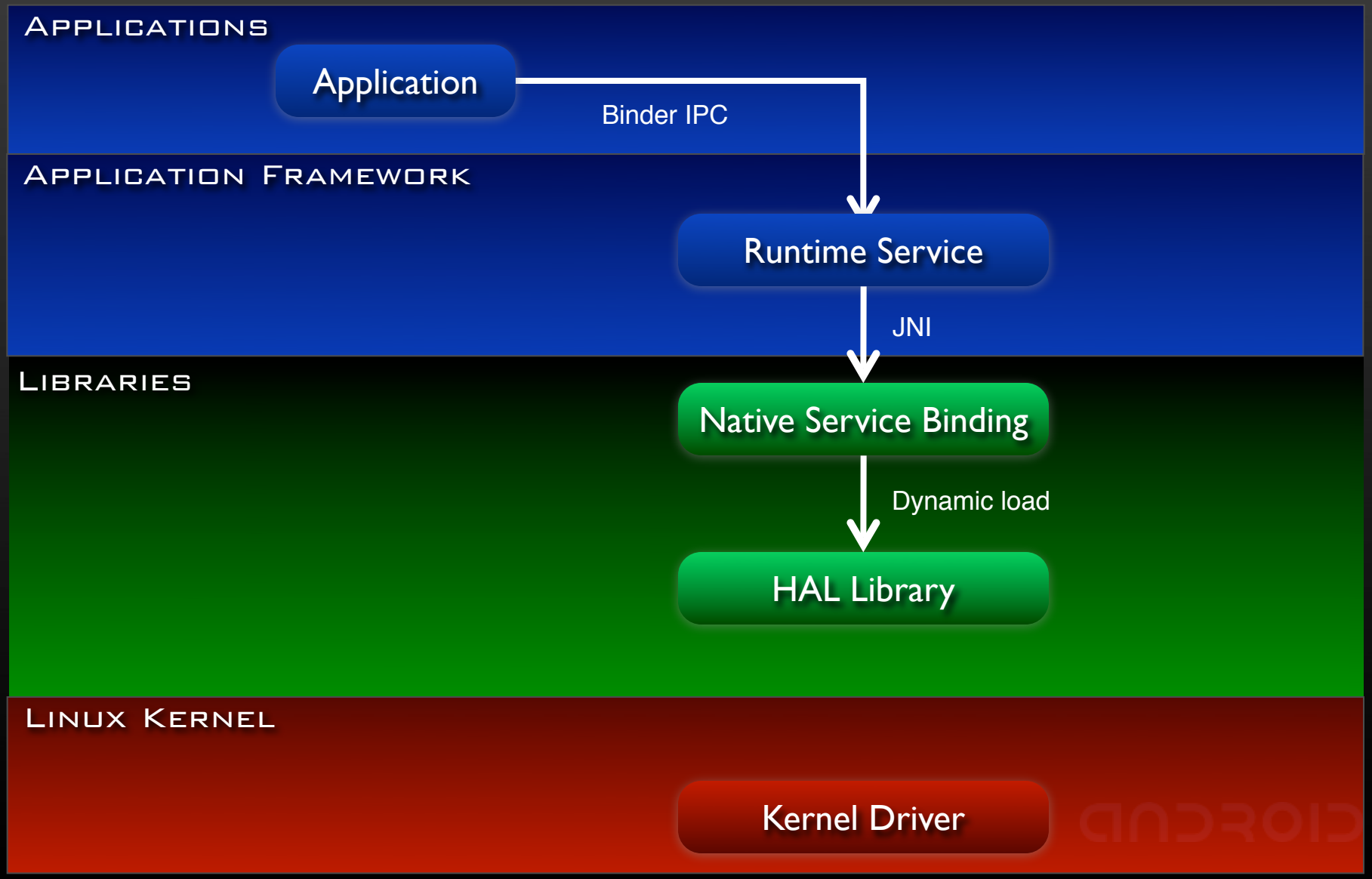
Android Runtime Services



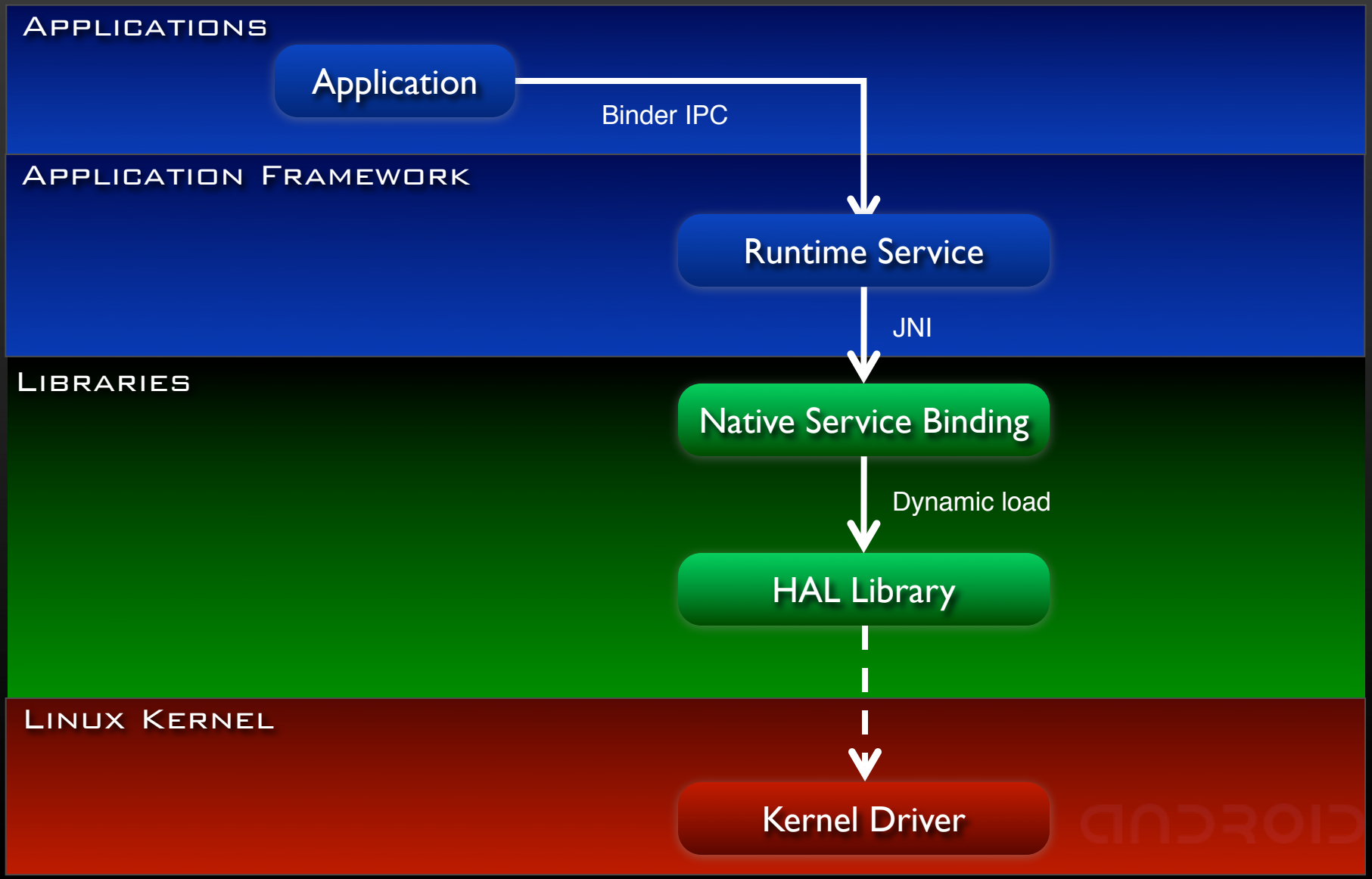
Android Runtime Services



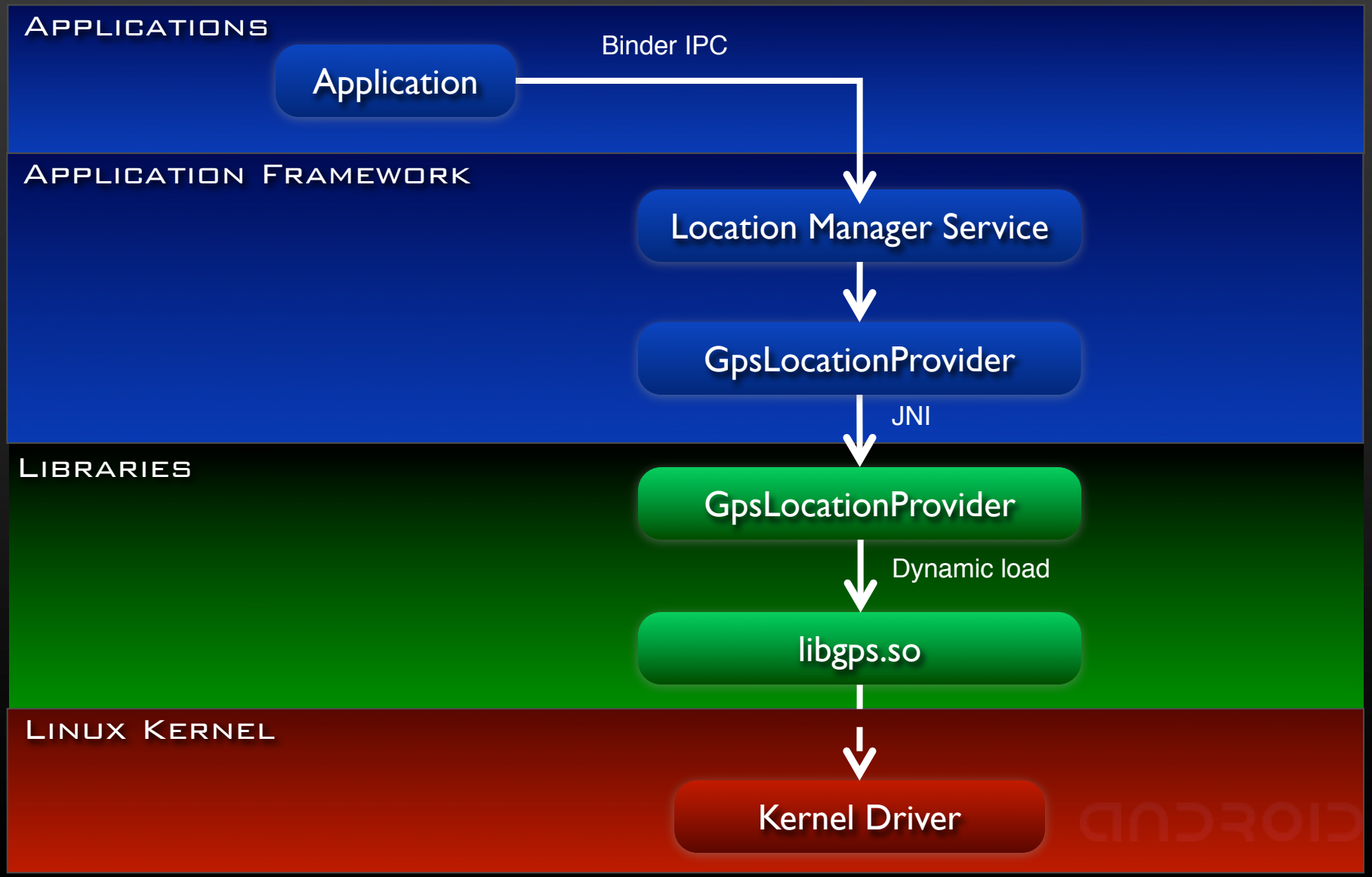
Android Runtime Services



Android Runtime Services



Example: Location Manager



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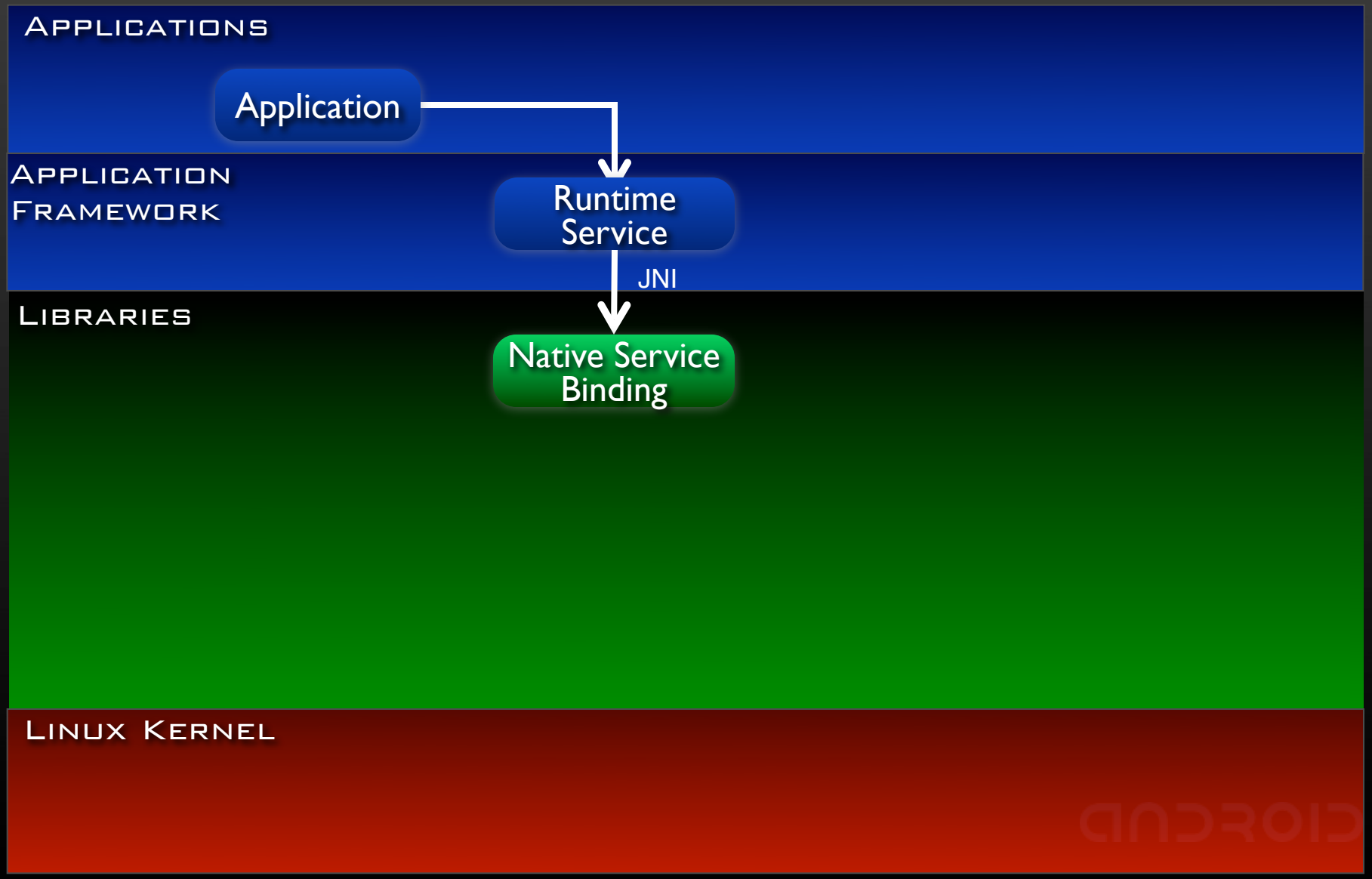
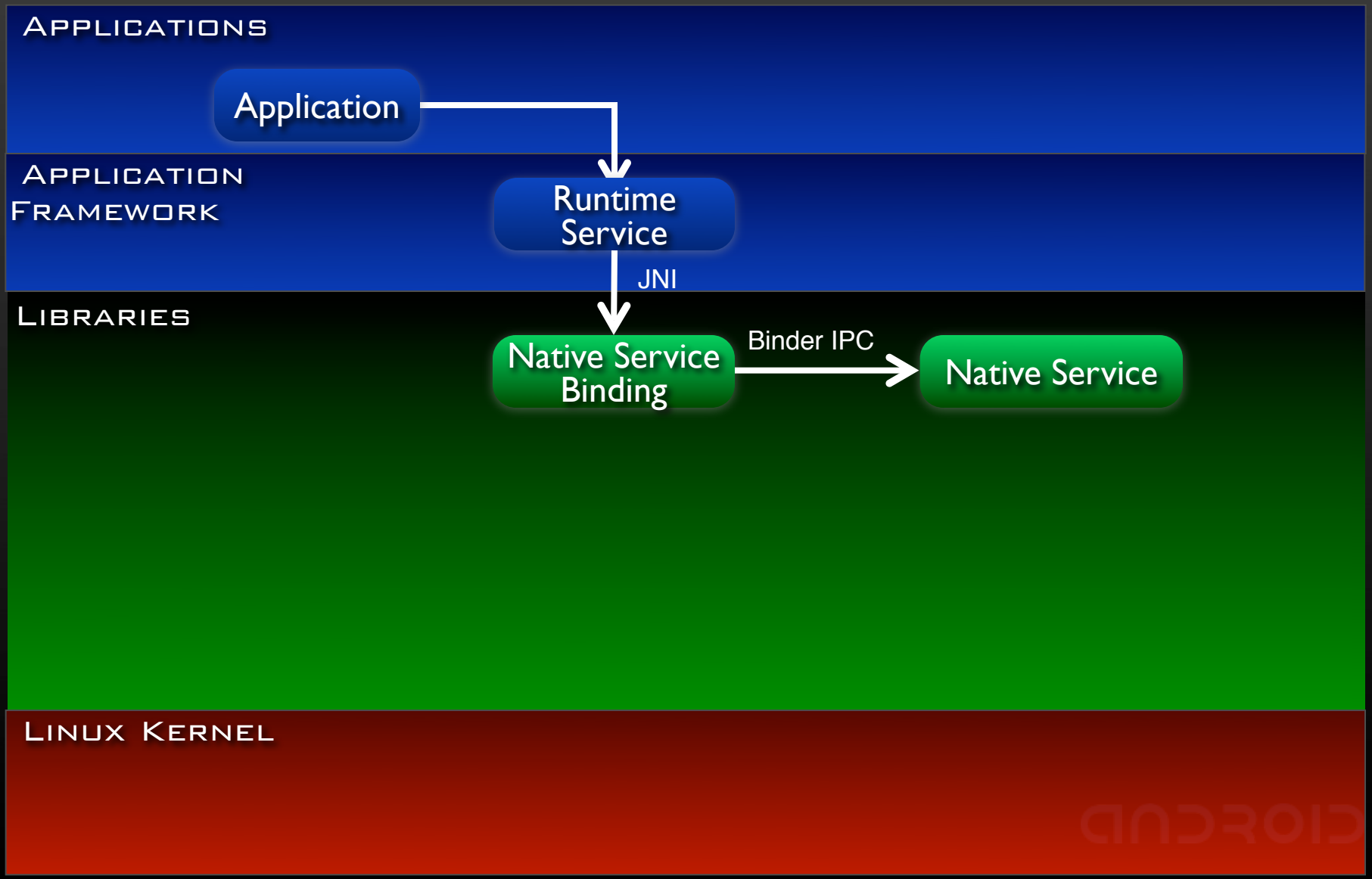
android

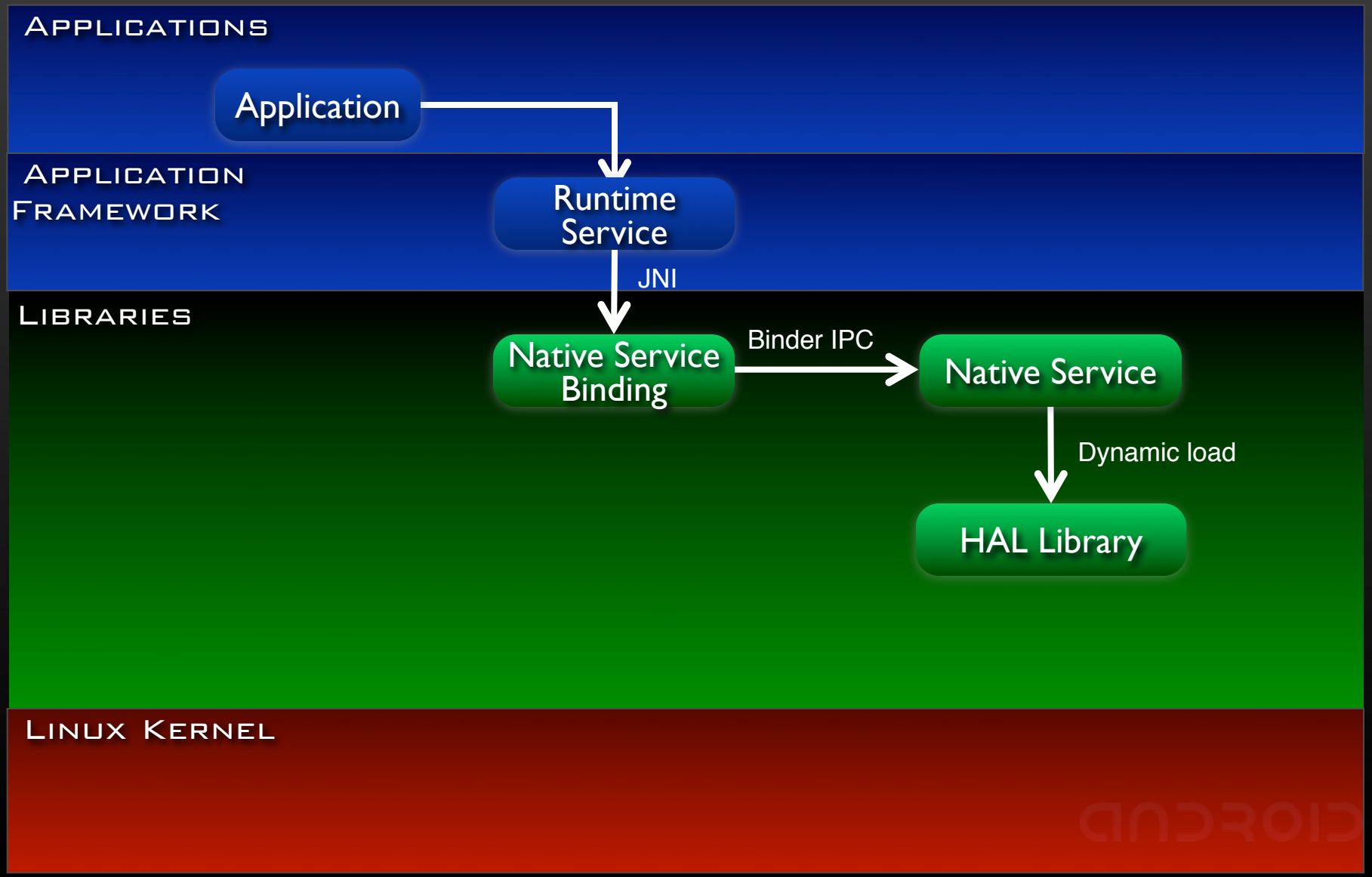
Android Native Services



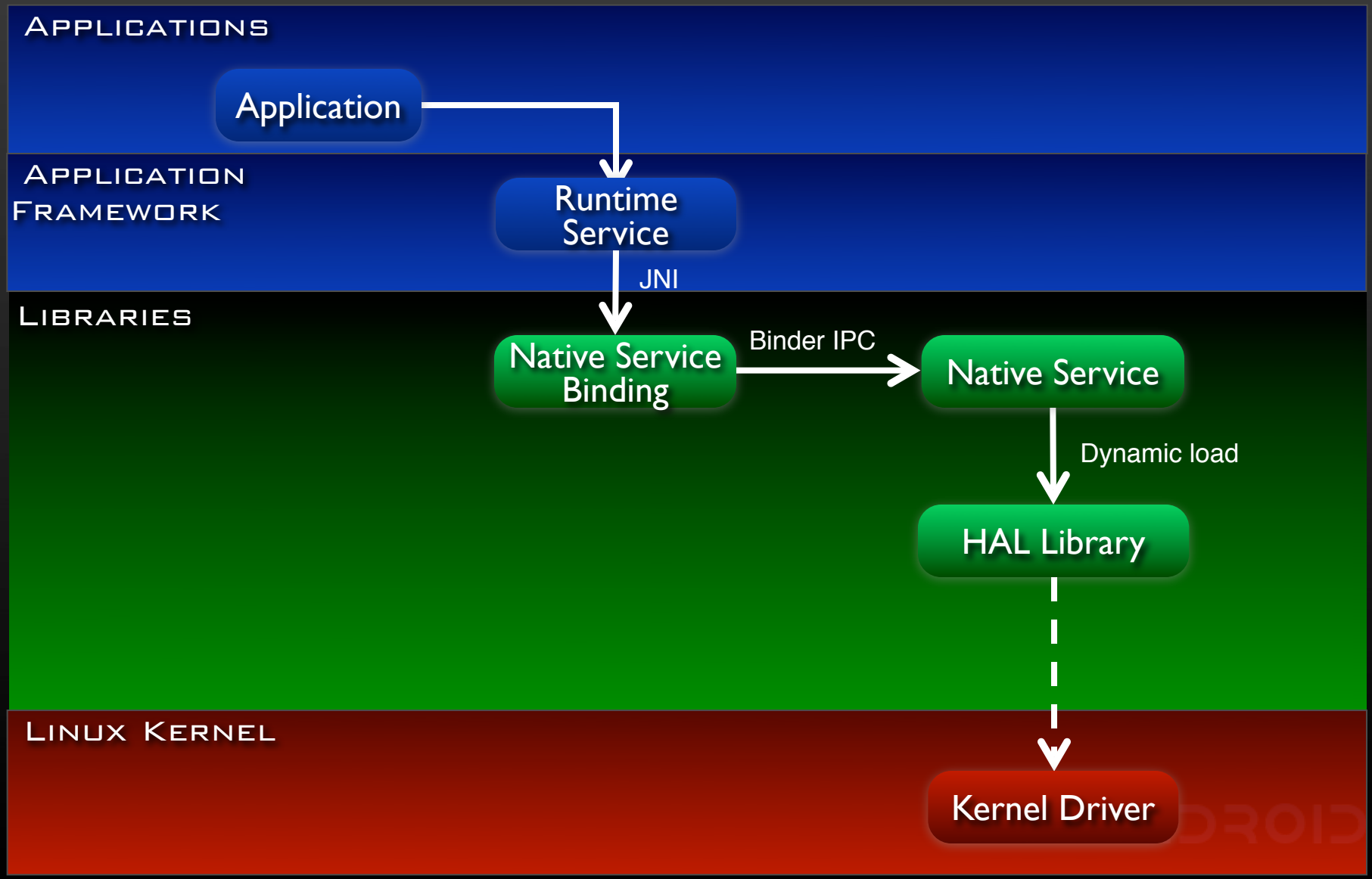
Android Native Services



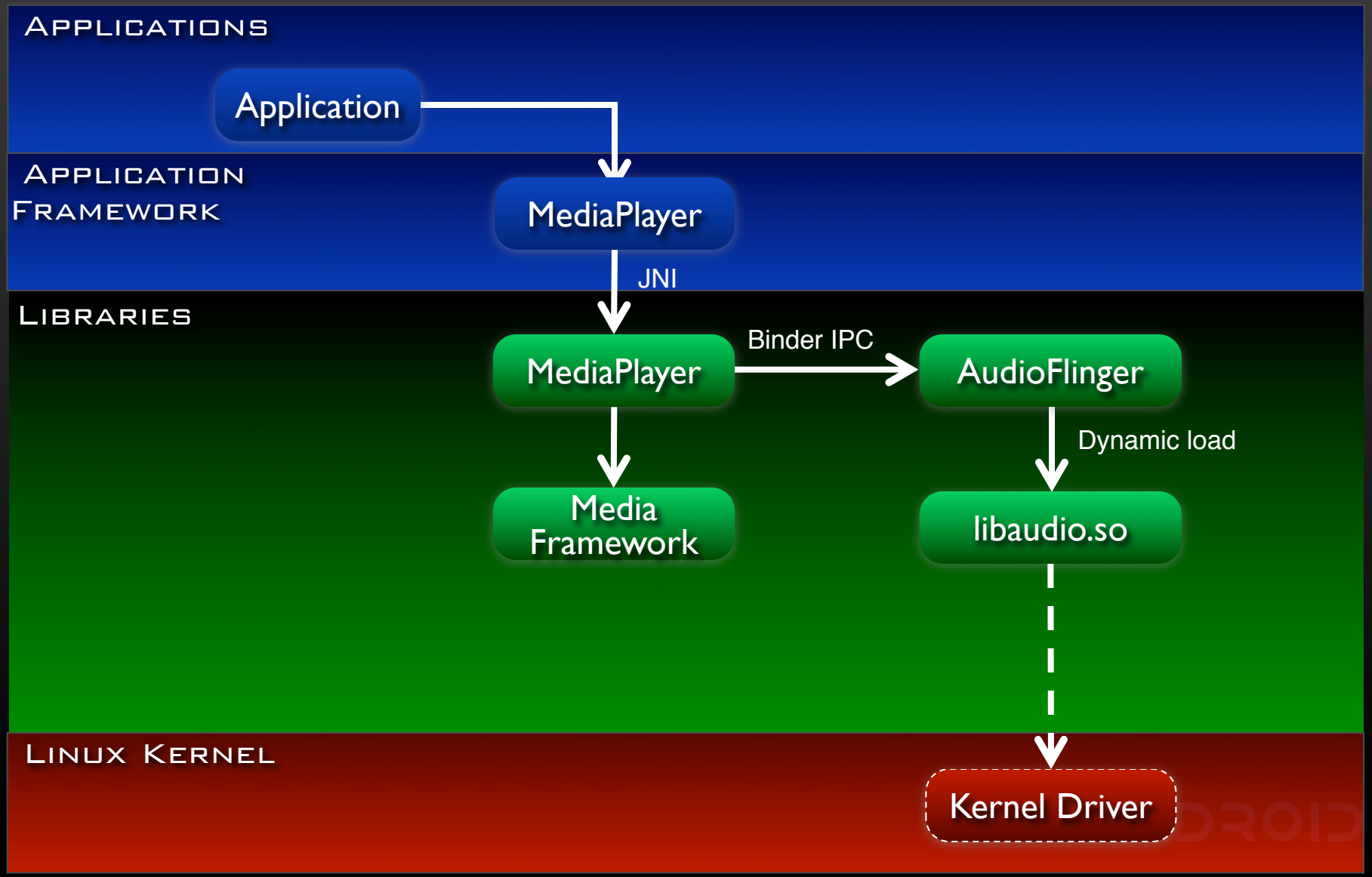
Android Native Services



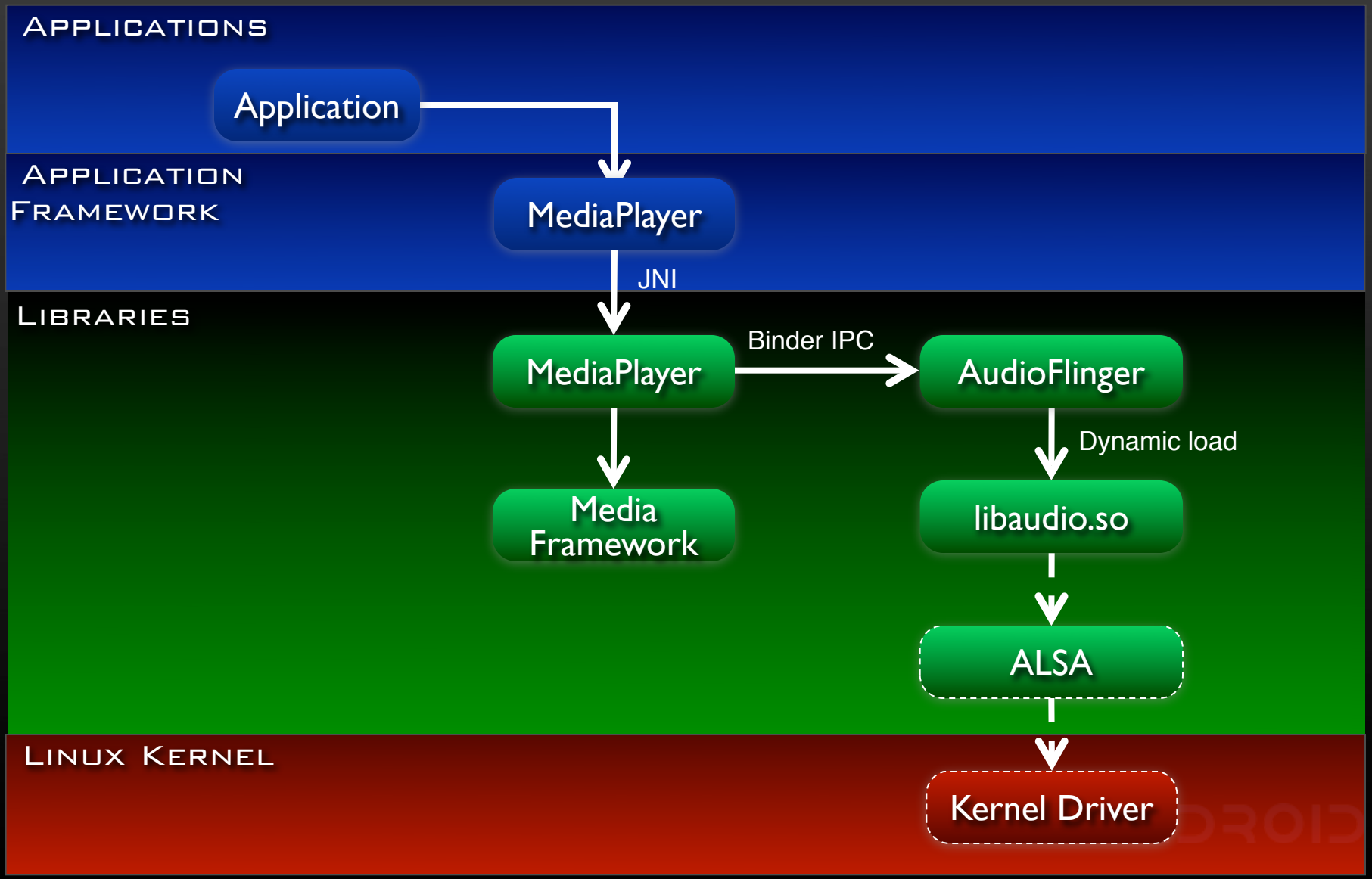
Android Native Services



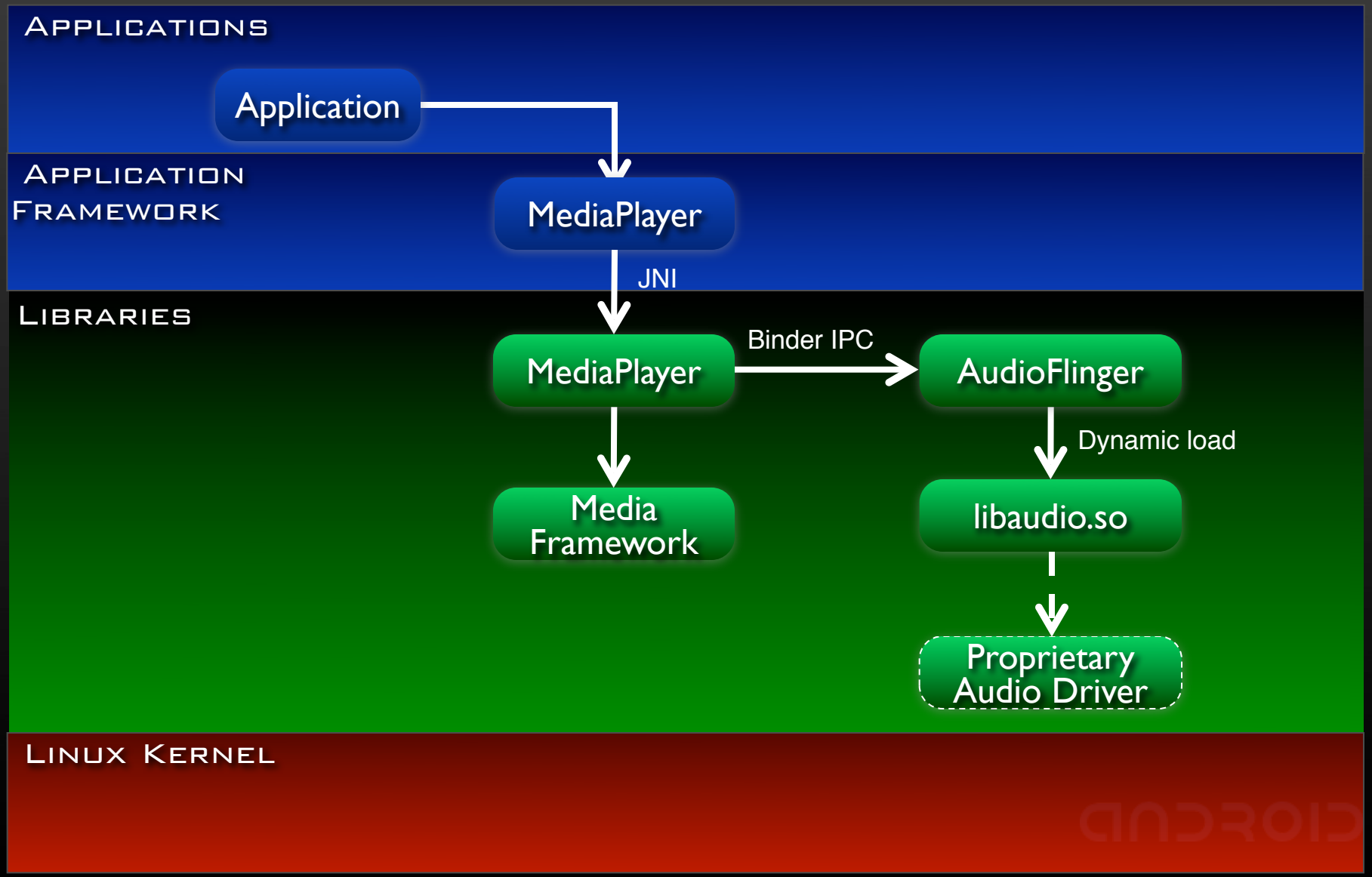
Android Native Services



Android Native Services



Android Native Services



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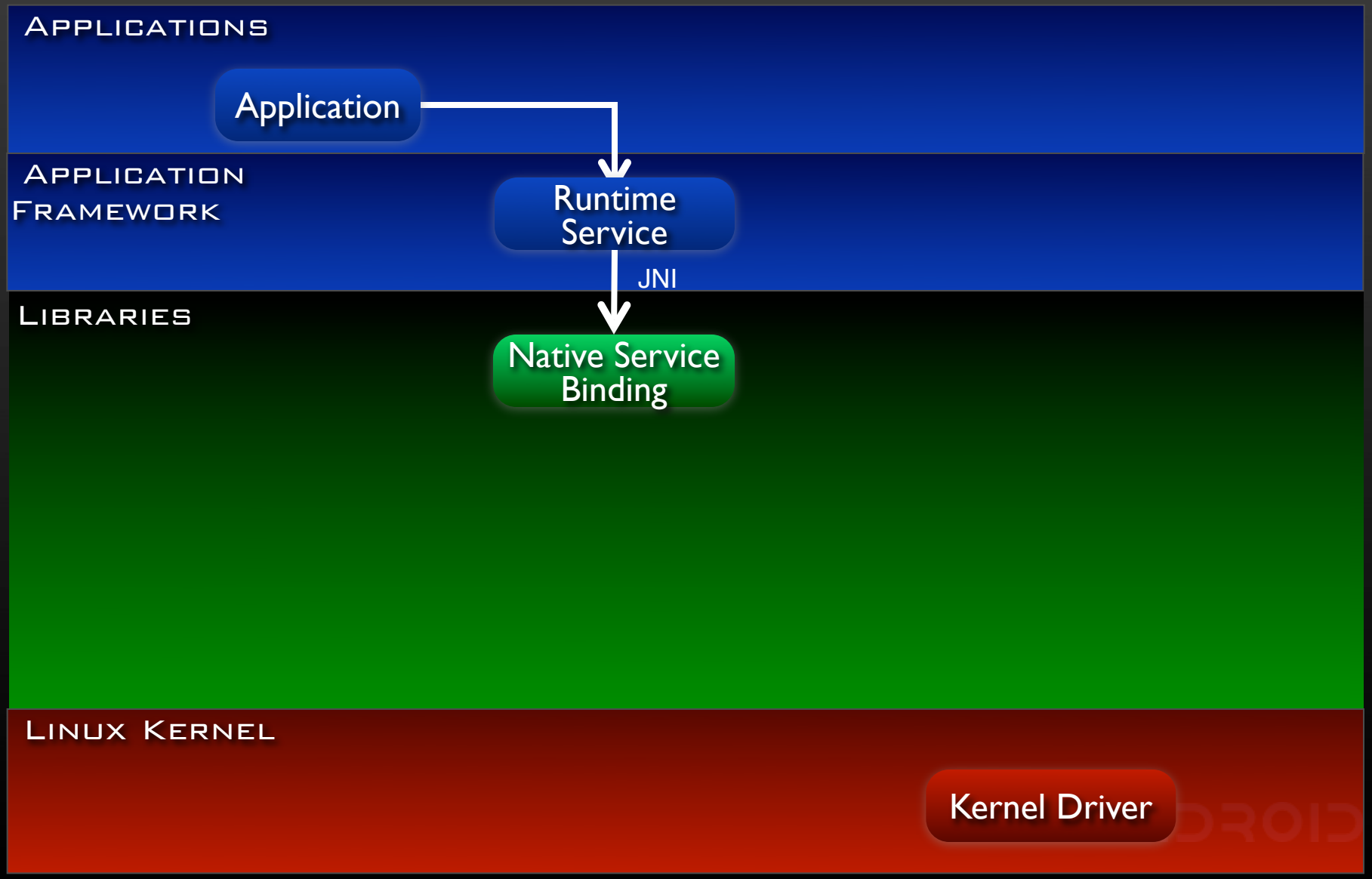
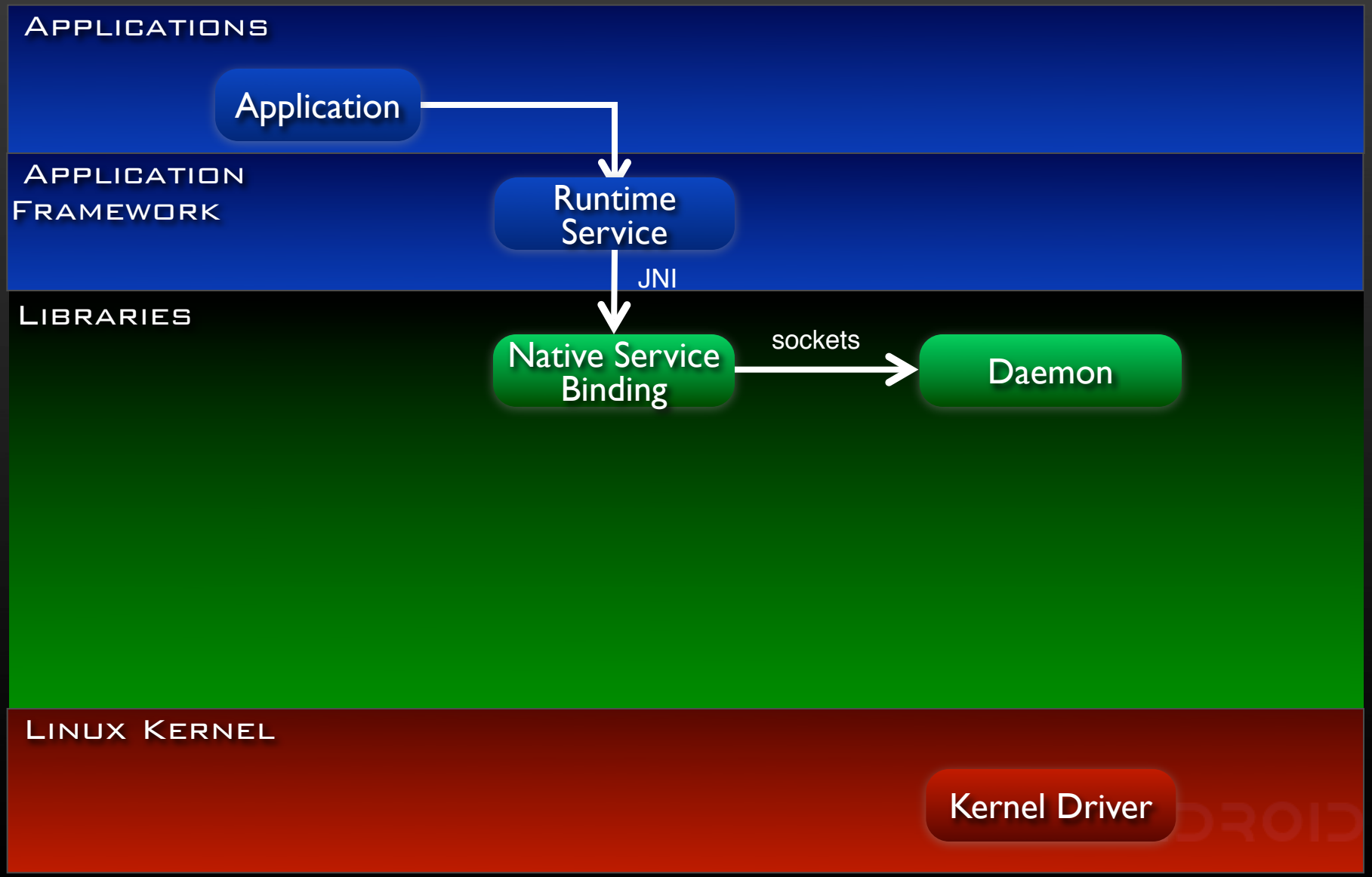
android

Daemon Connection



Daemon Connection



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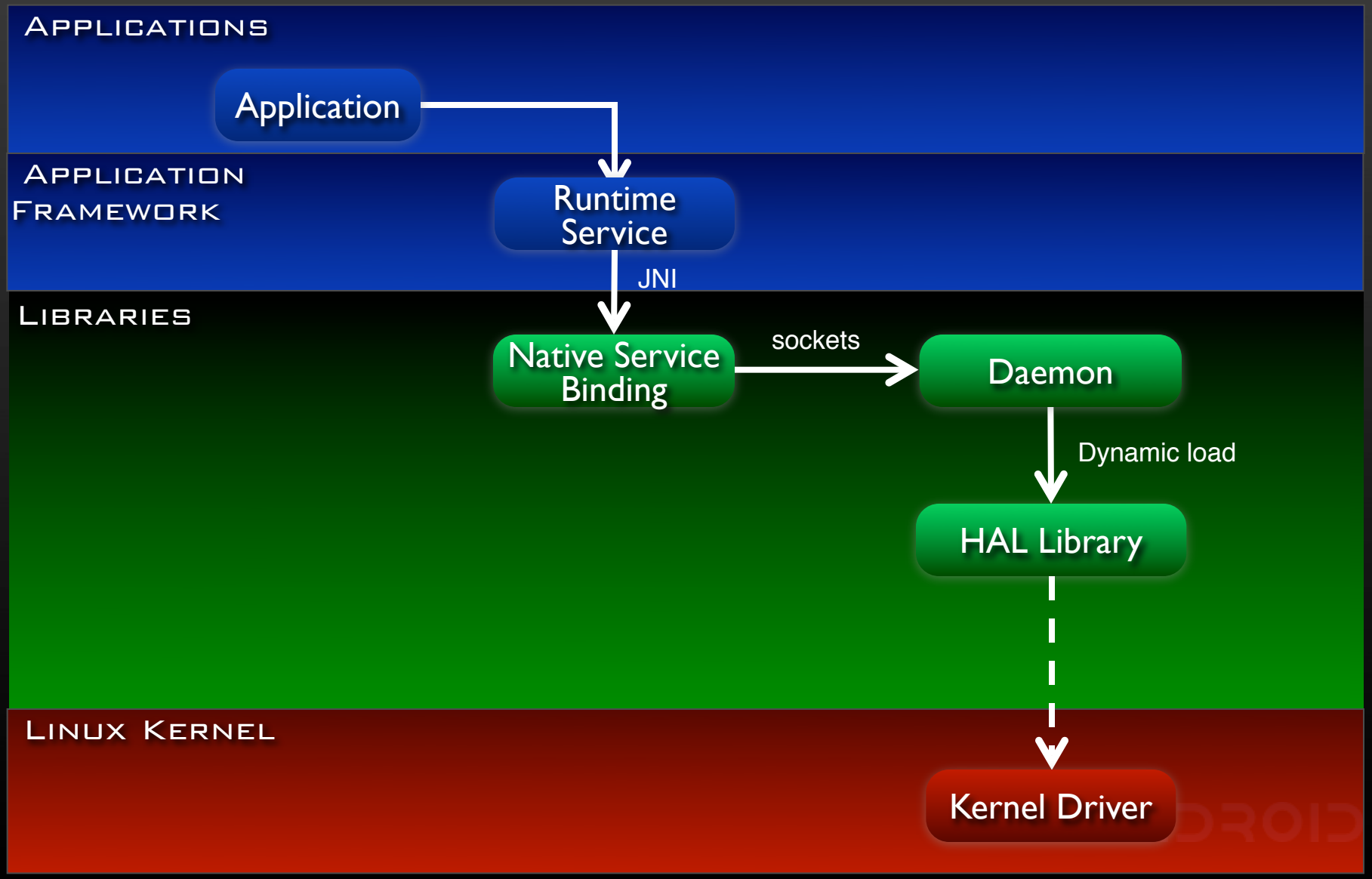
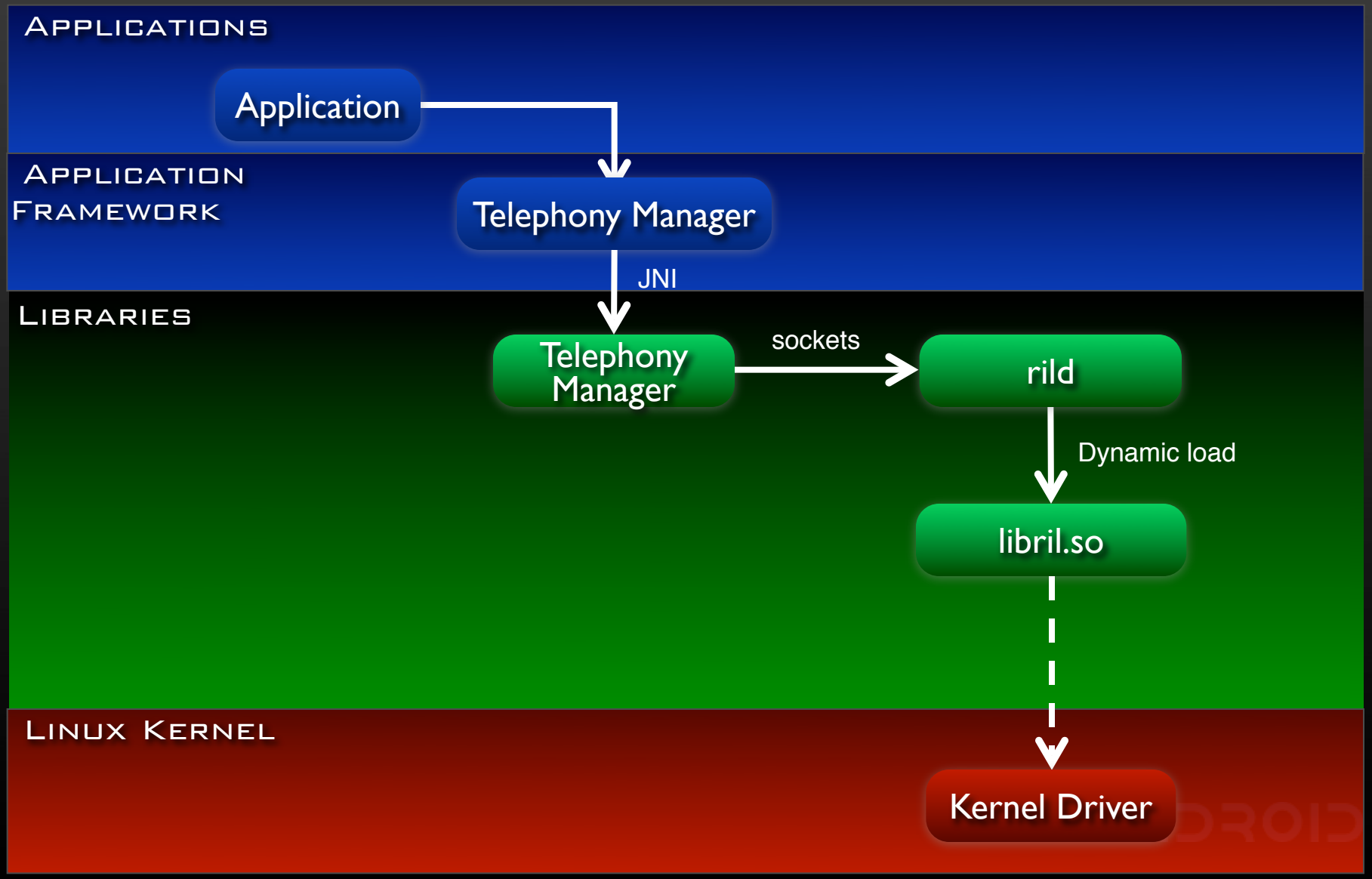


Daemon Connection



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ANDROID

Android Anatomy

Applications

Home | Dialer | SMS/MMS | IM | Browser | Camera | Alarm | Calculator

Contacts | Voice Dial | Email | Calendar | Media Player | Albums | Clock | ...

Application Framework

Activity Manager | Window Manager | Content Providers | View System | Notification Manager

Package Manager | Telephony Manager | Resource Manager | Location Manager | ...

Libraries

Surface Manager | Media Framework | SQLite

OpenGL|ES | FreeType | WebKit

SGL | SSL | Libc

Android Runtime

Core Libraries

Dalvik Virtual Machine

Linux Kernel

Display Driver | Camera Driver | Bluetooth Driver | Shared Memory Driver | Binder (IPC) Driver

USB Driver | Keypad Driver | WiFi Driver | Audio Drivers | Power Management

The End

code.google.com

Questions

Q&A