Low Level View of Android System Architecture

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Rights to copy

Low Level Android ?!

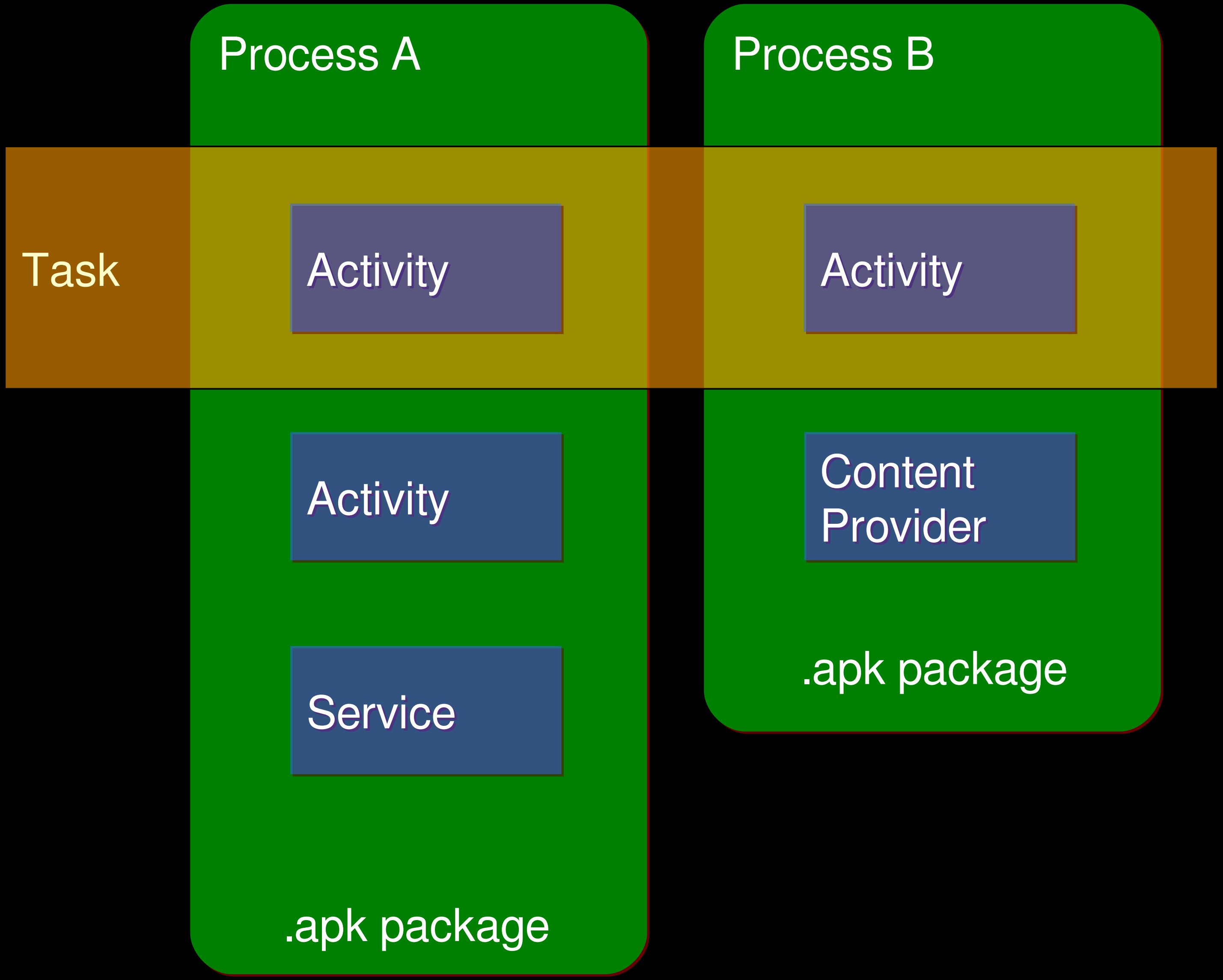
It means...

the hidden part!

Binder IPC: The heart of Android

NOTE: This presentation only covers Android 4.0

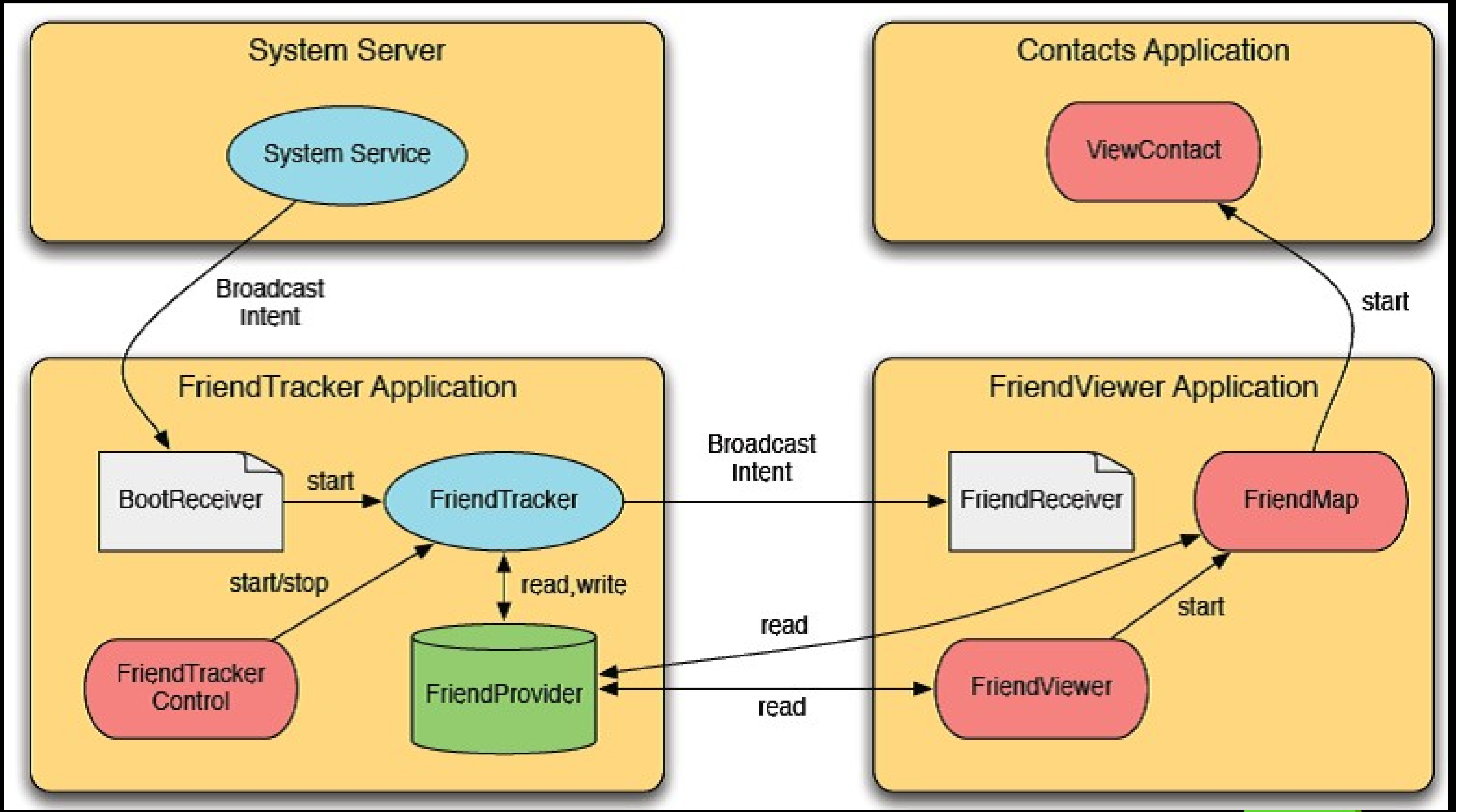
Android Tasks



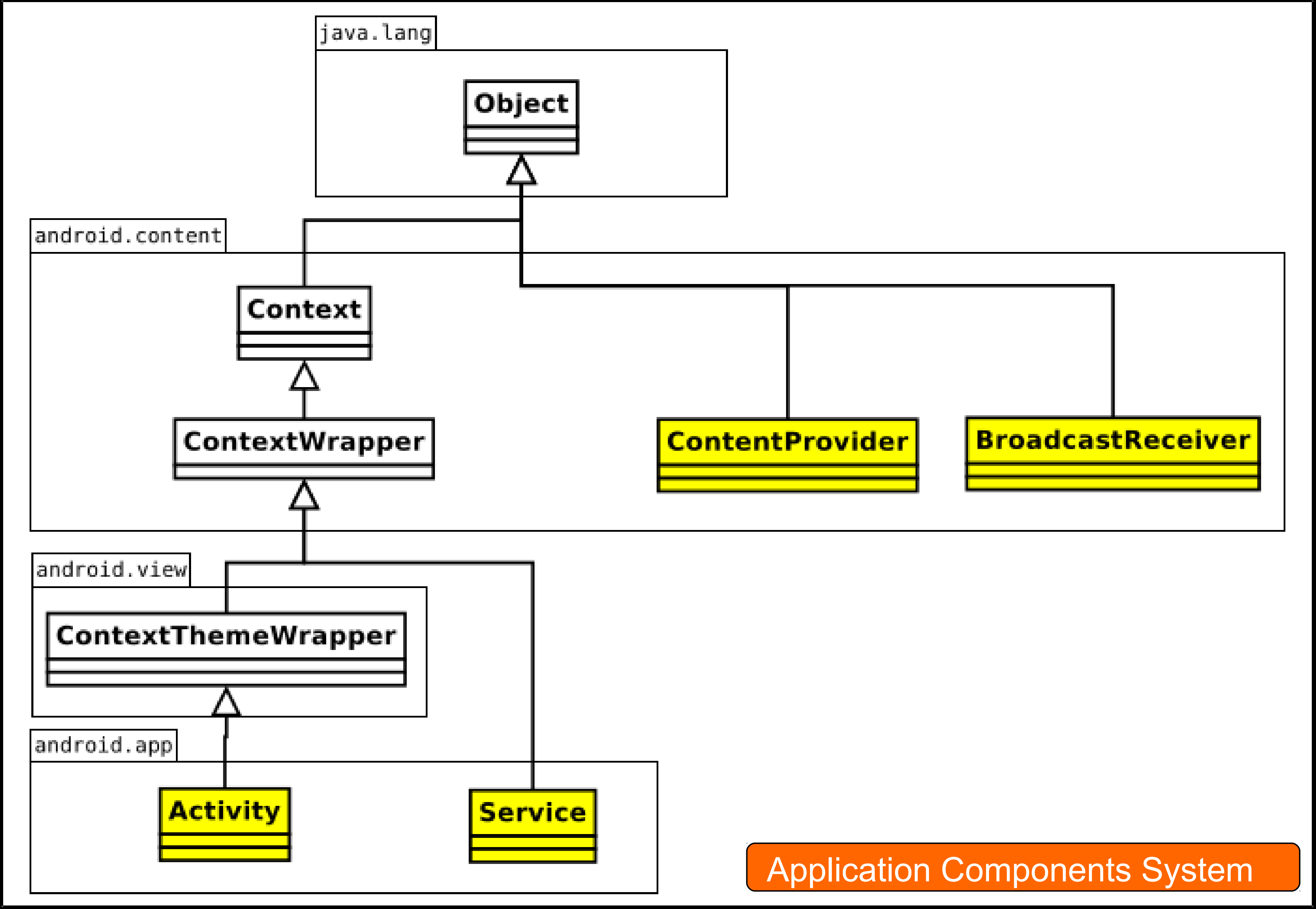
Our focus is the interaction among Android Activities.

Component View

- Different component types
  - Activity
  - Service
  - Content Provider
  - Broadcast Receiver



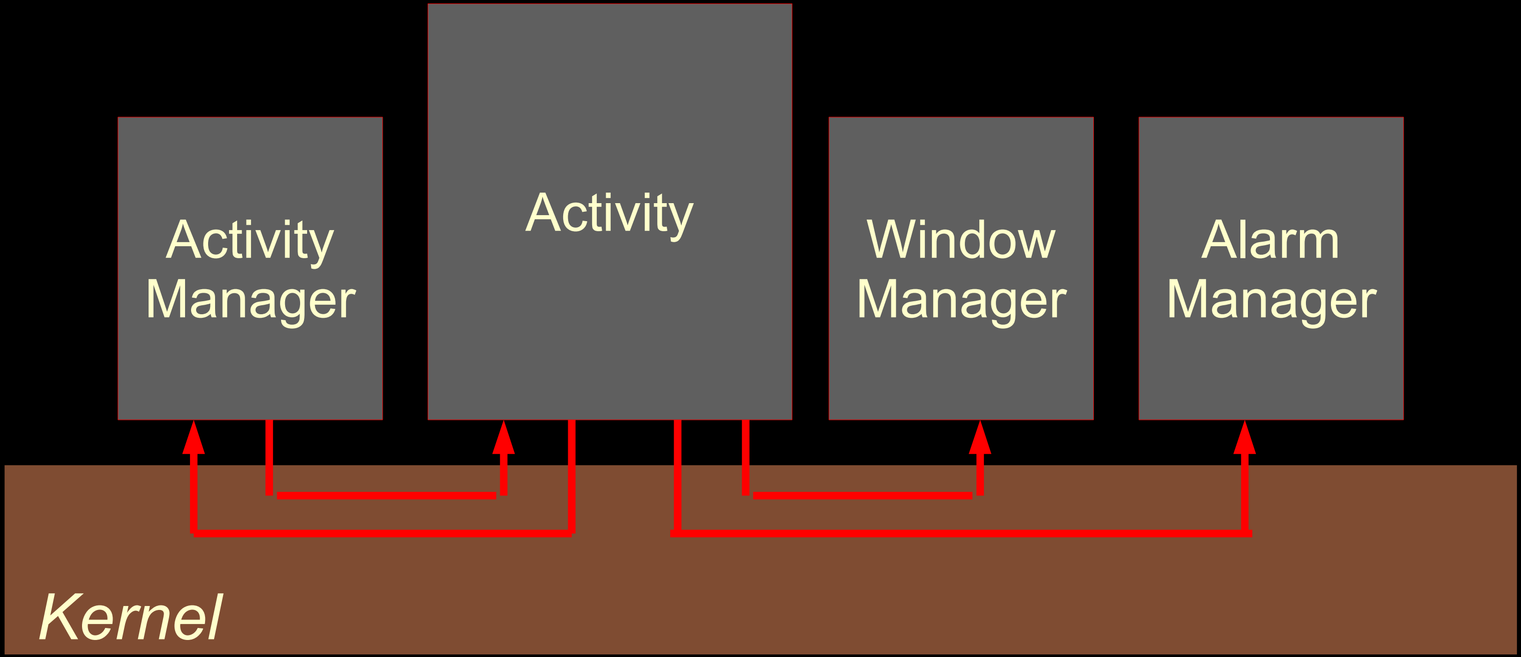
Let's recall the behavior of Android Framework.



Please check 4 major component types in the object hierarchy.
Context is tricky because it is indeed the abstraction of Android View and Activity/Service.

The interaction is not boring as it implies once if you find the right objects.

IPC = Inter-Process Communication

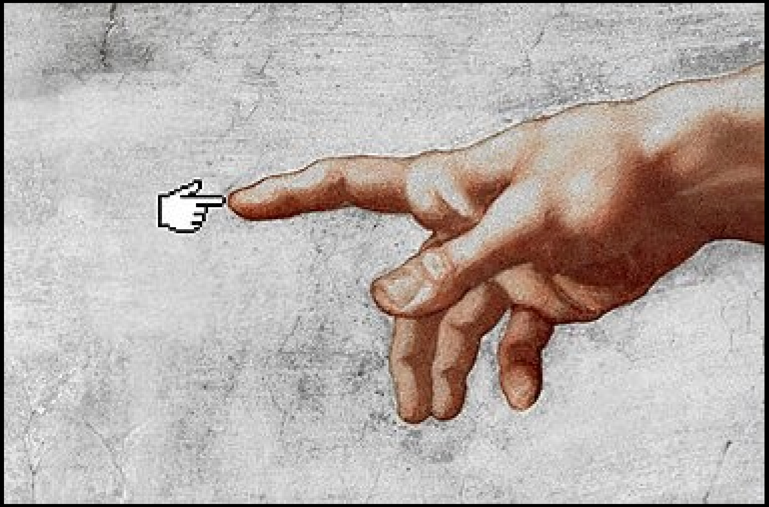


Let's get back to Binder IPC. What is the essential working model?

Why IPC?

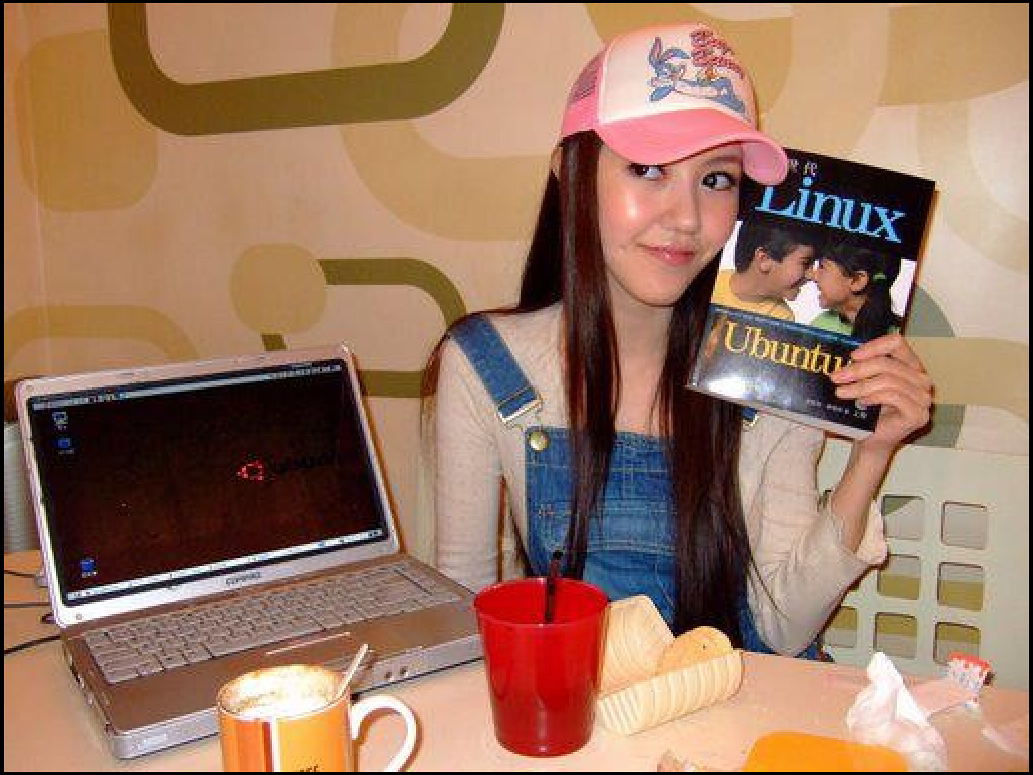
- Each process has its own address space
- Provides data isolation
- Prevents harmful direct interaction between two different processes

  Sometimes, communication between processes is required for modularization



IPC Mechanisms

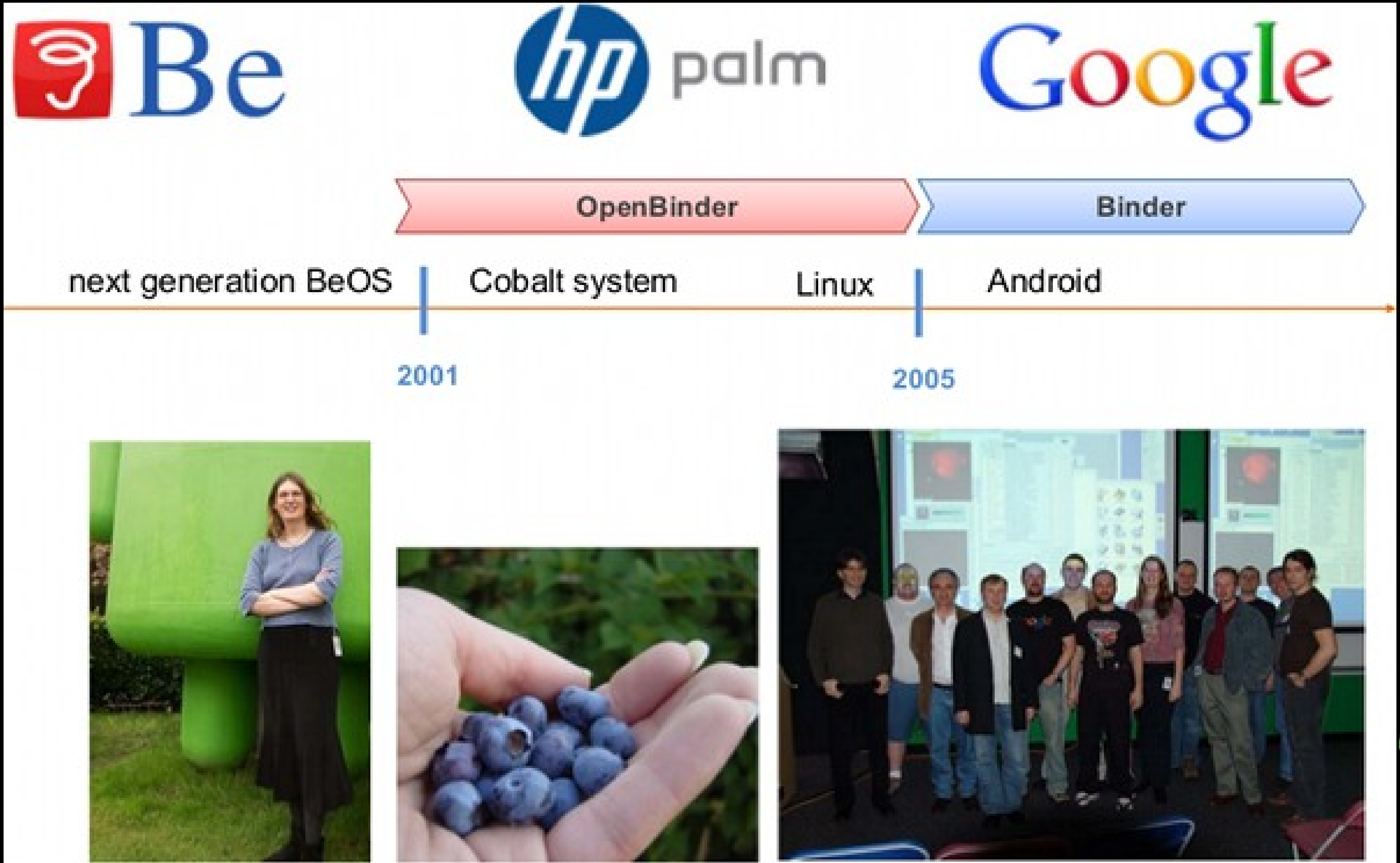
- In GNU/Linux
  - Signal
  - Pipe
  - Socket
  - Semaphore
  - Message queue
  - Shared memory



- In Android
  - Binder: lightweight RPC (Remote Procedure Communication) mechanism

Binder History

- Developed under the name OpenBinder by Palm Inc. under the leadership of Dianne Hackborn
- Android Binder: customized and reduced re-implementation of OpenBinder, providing bindings to functions/data from one execution env to another



Background Problems

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

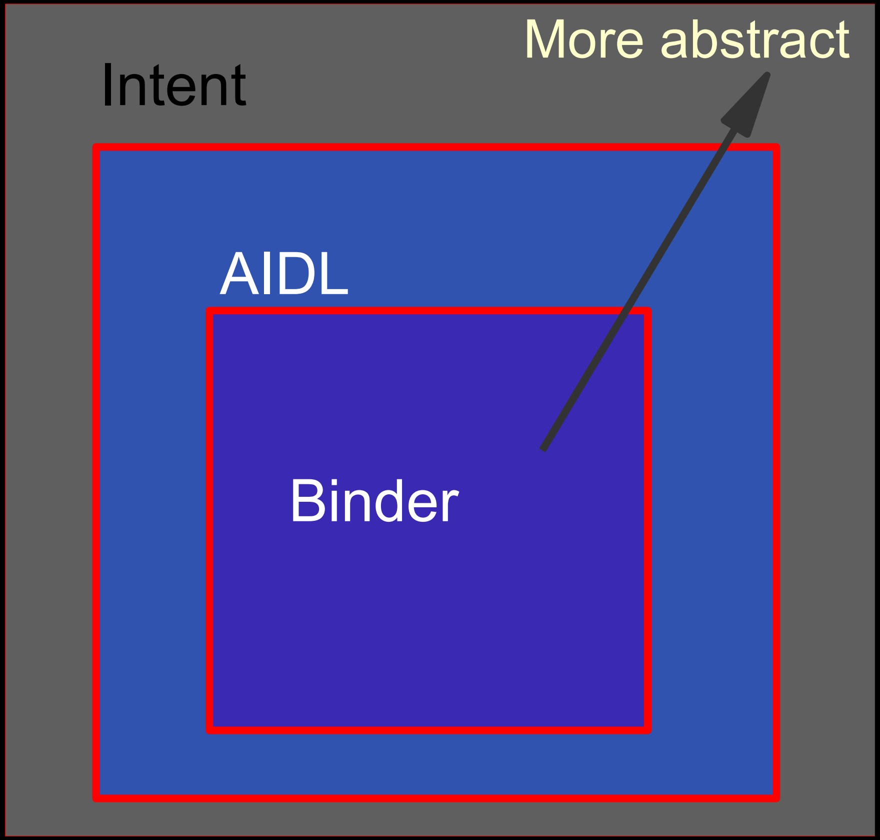
D-Bus does suffer from such issues if socket backend is used.

Binder: Android's Solution

- Driver to facilitate inter-process communication
- 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

"In the Android platform, the binder is used for nearly everything that happens across processes in the core platform. " – Dianne Hackborn
`https://lkml.org/lkml/2009/6/25/3`

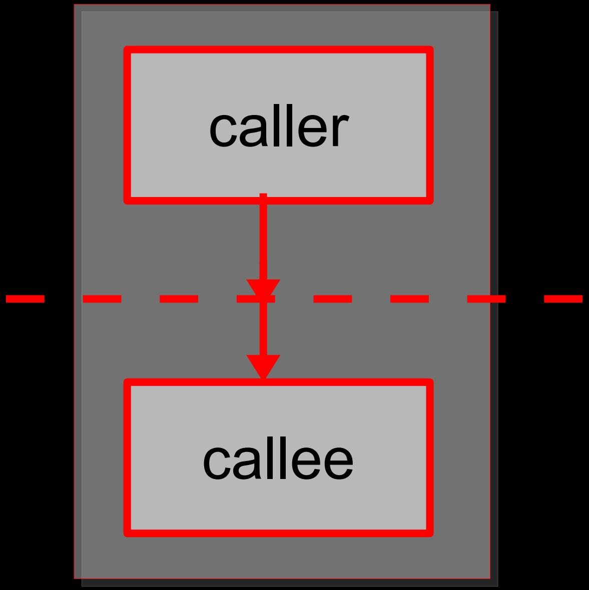
IPC Abstraction



- Intent
  - The highest level abstraction
- Inter process method invocation
  - **AIDL**: Android Interface Definition Language
- binder: kernel driver
- ashmem: shared memory

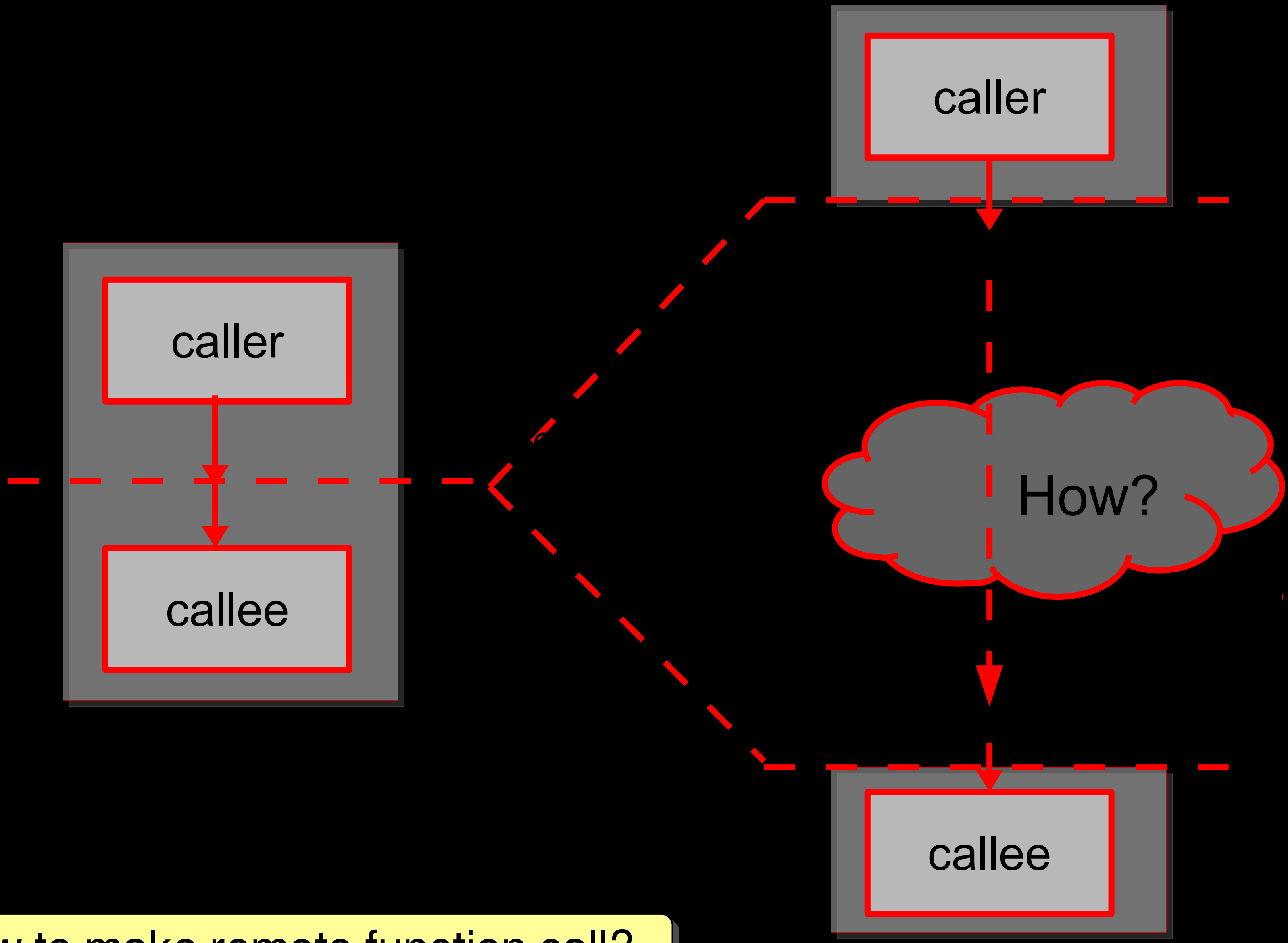
Level of abstraction: Binder $\rightarrow$ AIDL $\rightarrow$ Intent

Method invocation



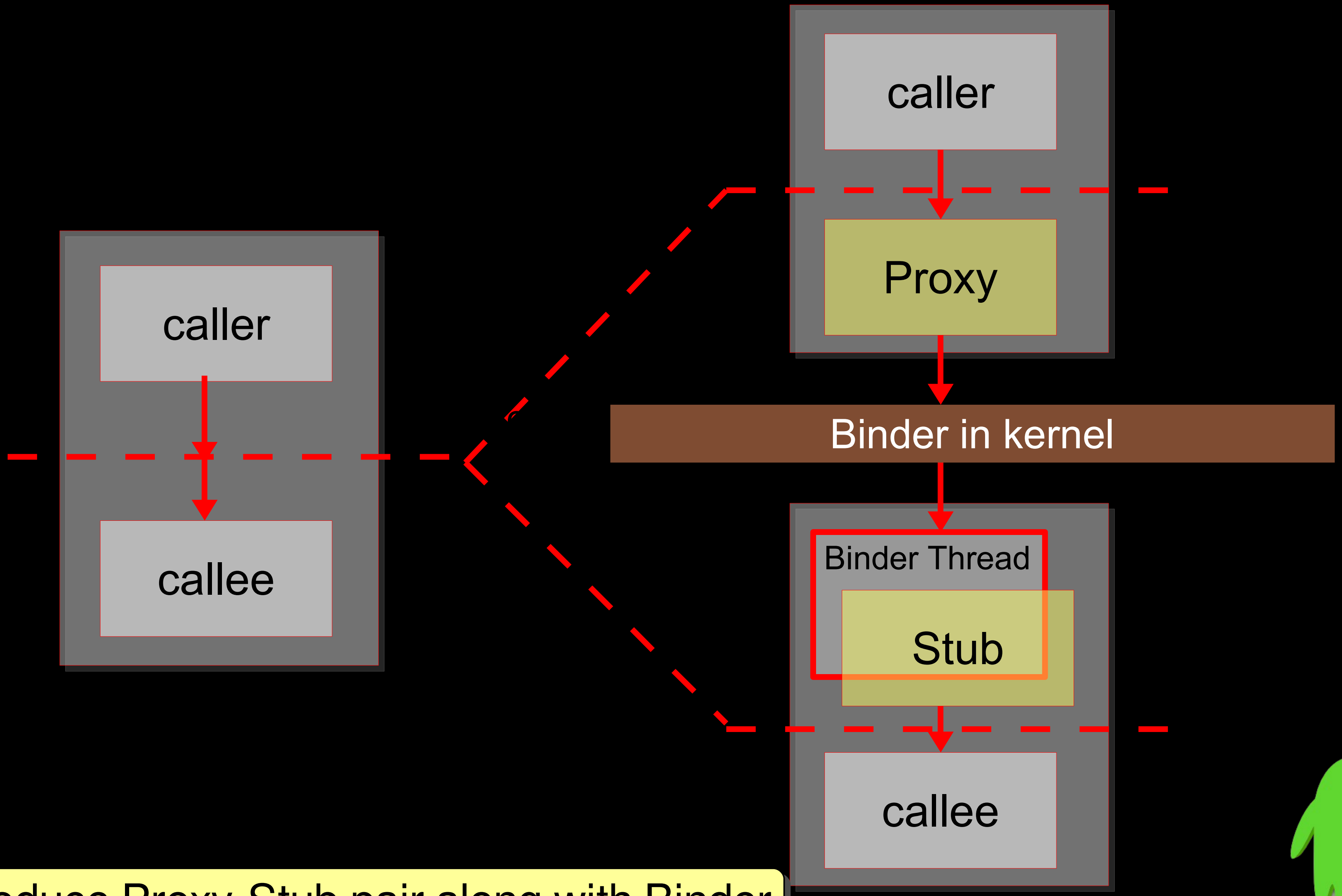
Think of how the typical function call works:
caller (call somebody) + callee (somebody called)

Inter-process method invocation



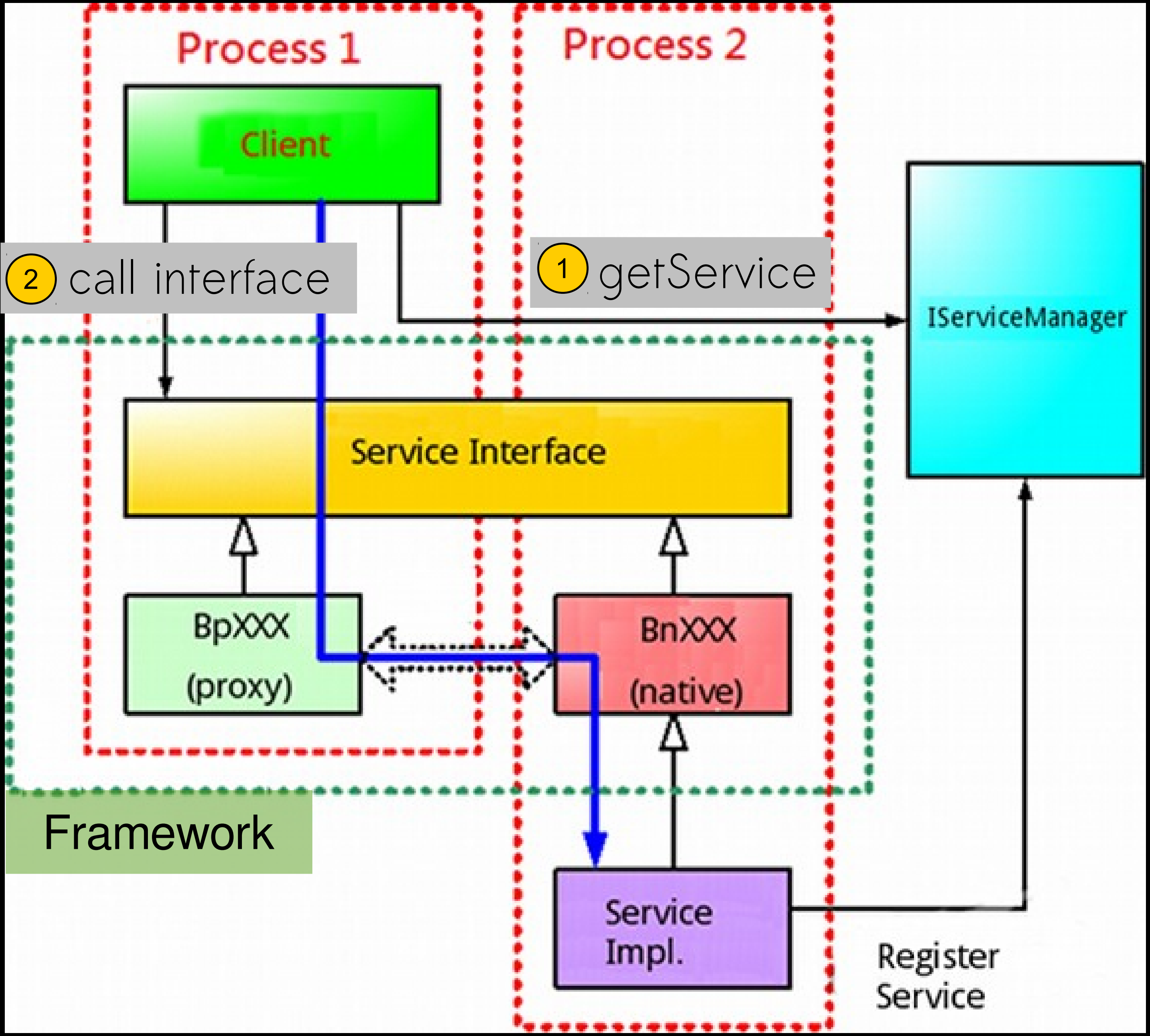
How to make remote function call?

Inter-process method invocation



Introduce Proxy-Stub pair along with Binder

IPC Interaction in Android

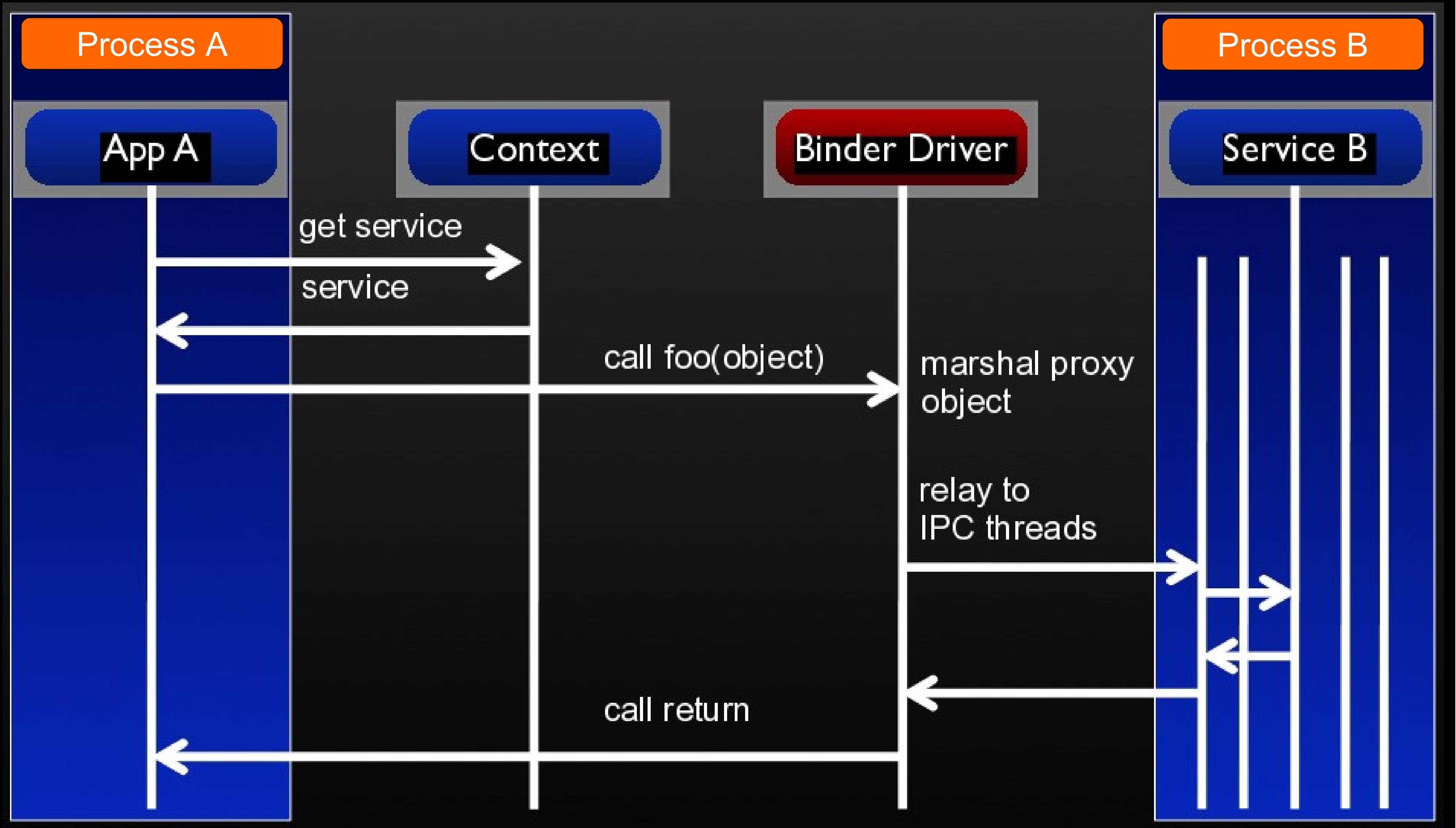


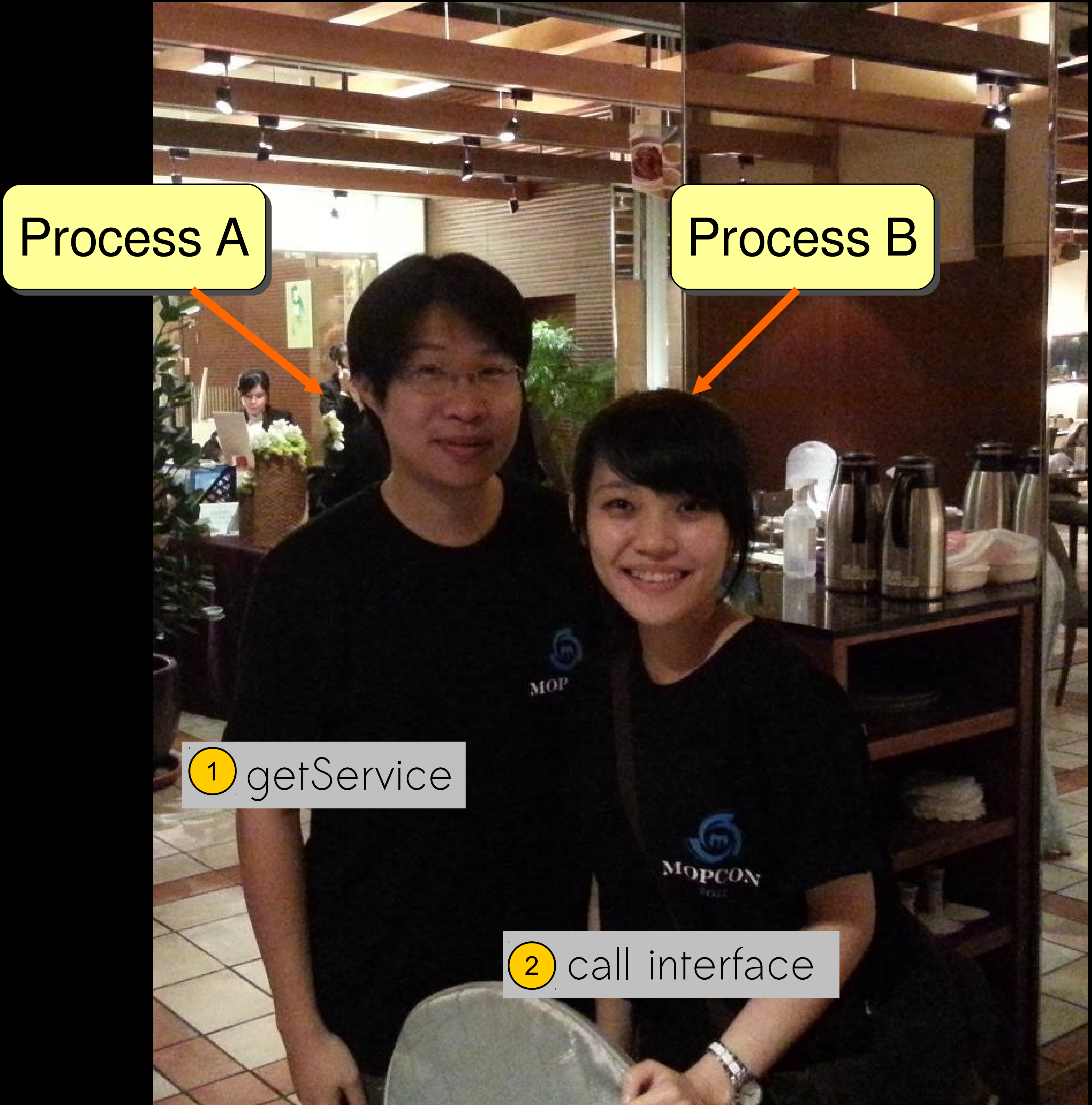
(Application View)

3 parts:

- BnXXX: native
- BpXXX: proxy
- Client
  Invoke BpXXX

Binder in Action




Process A
Process B
MOP
MOPCON
1 getService
2 call interface

Binder Internals

Binder Terminology

- Binder
- Binder Object

  an instance of a class that implements the Binder interface.

  One Binder object can implement multiple Binders
- Binder Protocol
- IBinder Interface

  is a well-defined set of methods, properties and events that a Binder can implement.
- Binder Token

  A numeric value that uniquely identifies a Binder

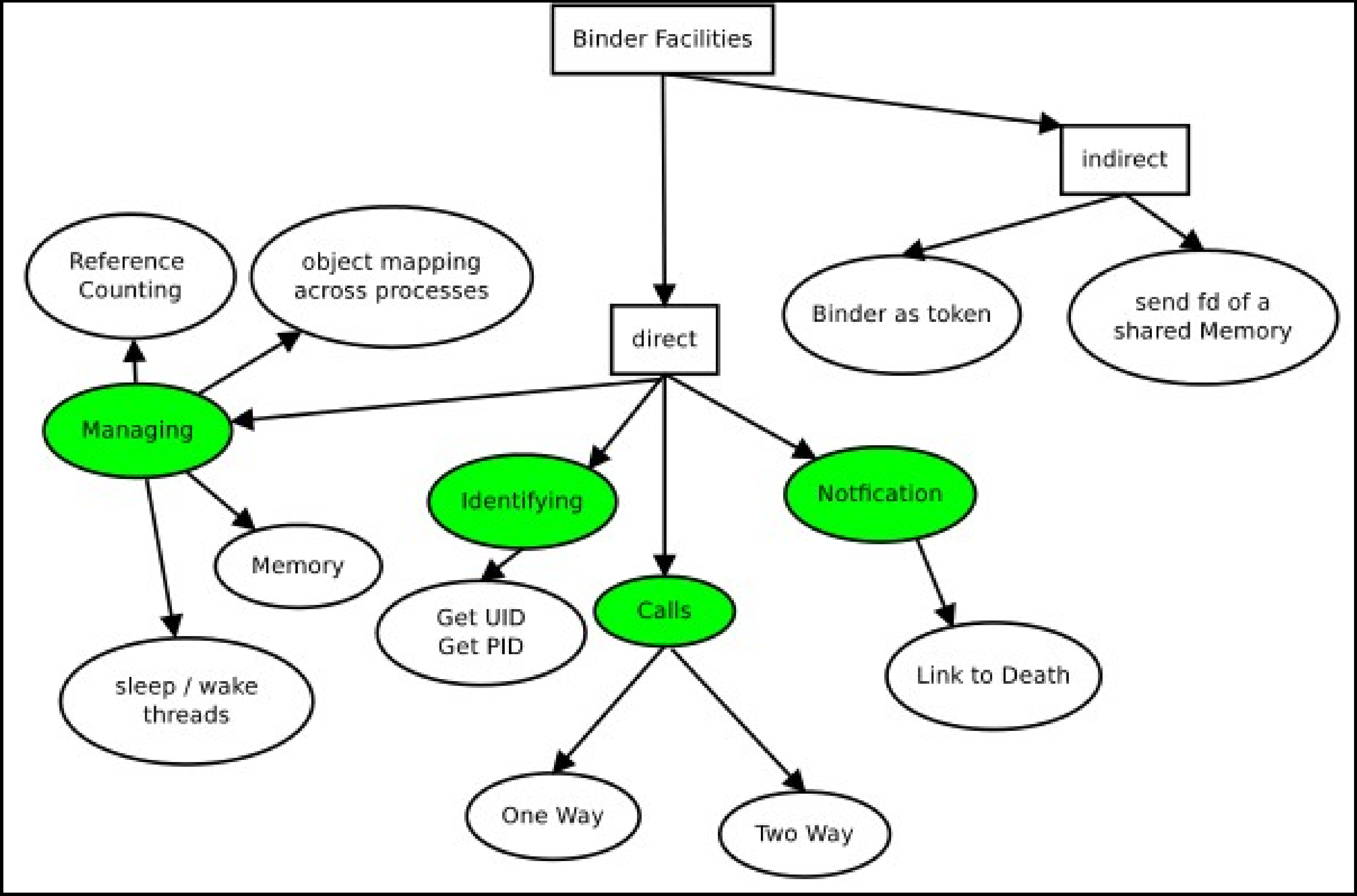
Binder protocol is important. You don't have to take care about the existence of target object.

Facilities

- Simple inter process messaging system
- Managing
- Identifying
- Calls
- Notification
- Binder as a security access token

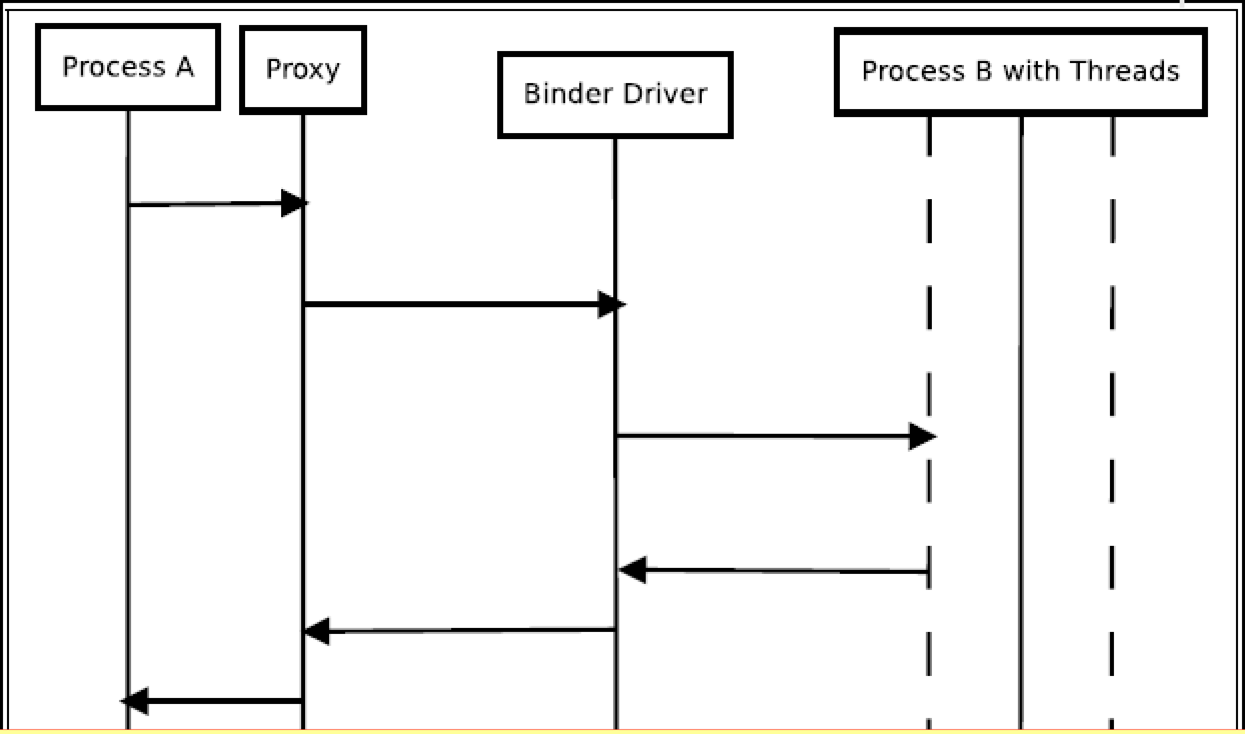
Binder simplifies the traditional RPC by abstracting its behavior.

- Binder framework provides more than a simple interprocess messaging system.
- Methods on remote objects can be called as if they where local object methods.

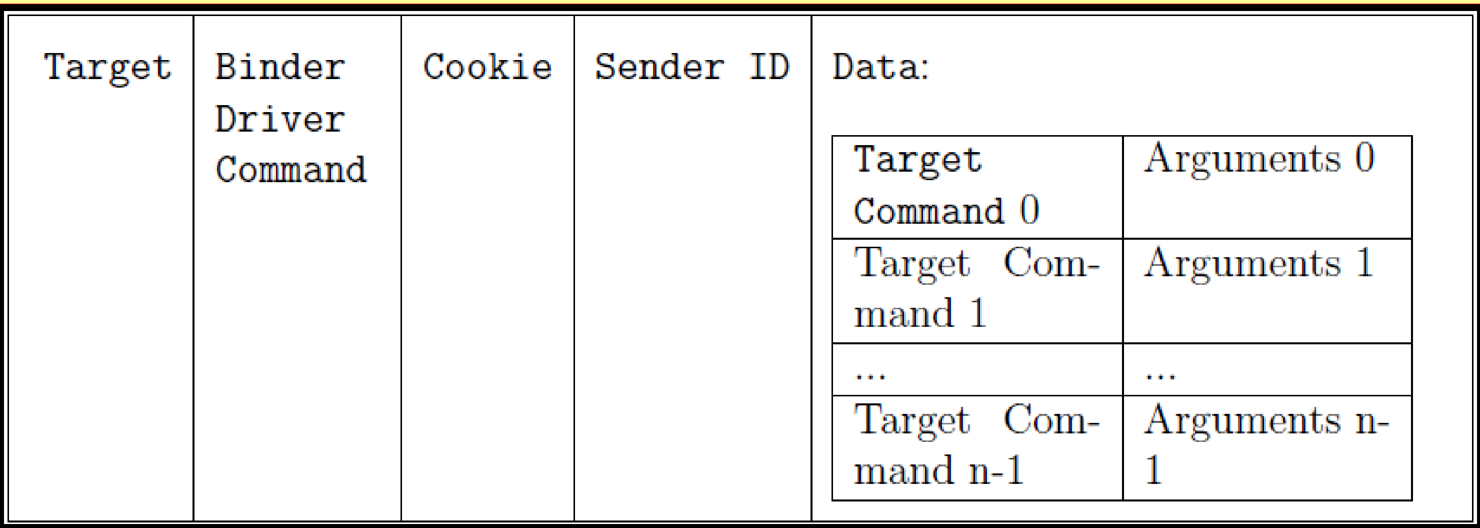


- Binder IPC facilities:
- Direct:
  - Managing
  - Identifying
  - Calls
  - Notification
- Indirect:
  - Binder as token
  - Find fd of shared memory

Communication protocol



If one process sends data to another process, it is called transaction.
The data is called transaction data.

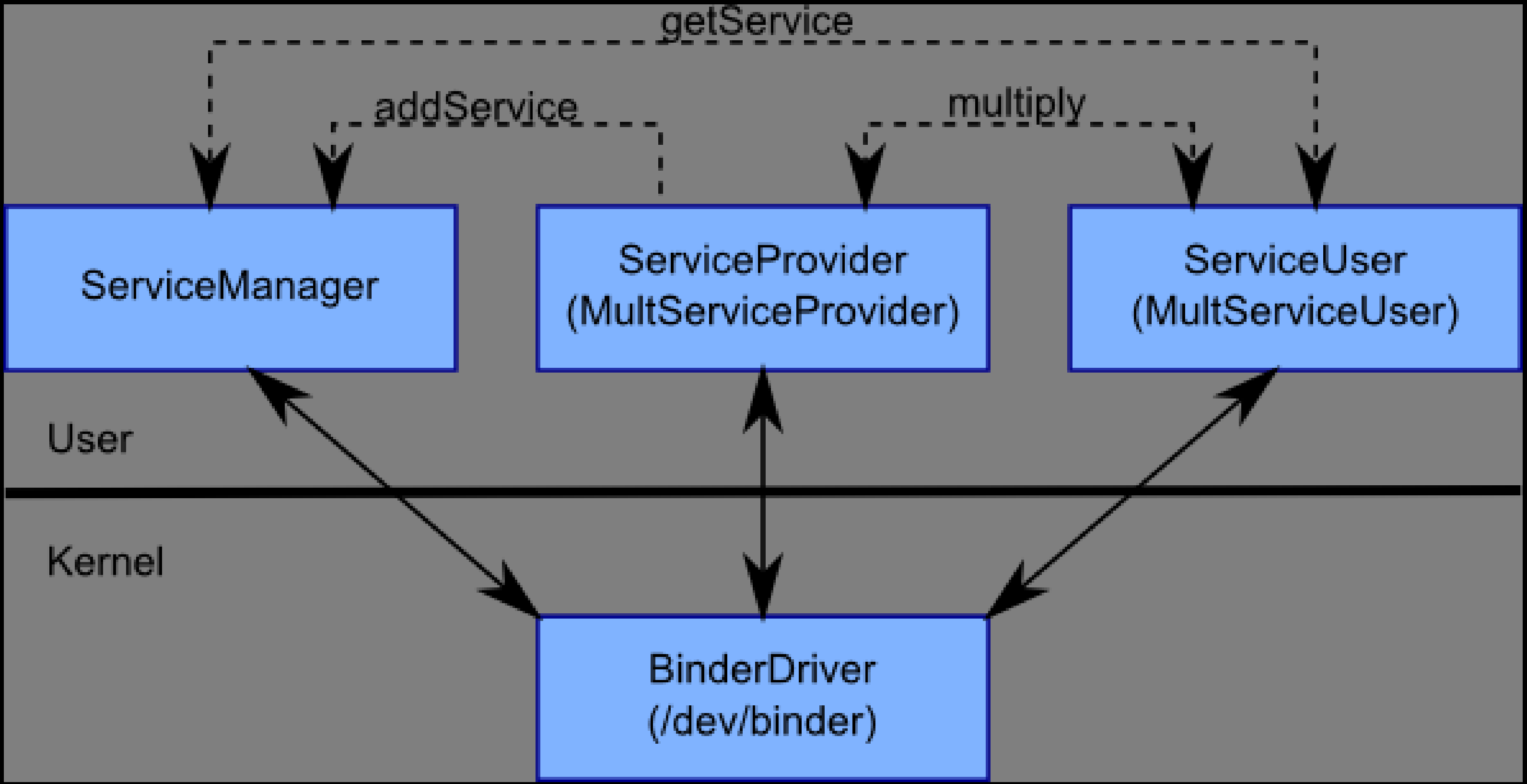


Target	Binder Driver Command	Cookie	Sender ID	Data:

Target Command 0	Arguments 0
Target Command 1	Arguments 1
...	...
Target Command n-1	Arguments n-1

Service Manager (SM)

- Special Binder node with known Binder address
- Client does not know the address of remote Binder
  only Binder interface knows its own address
- Binder submits a name and its Binder token to SM
  Client retrieves Binder address with service name from SM


getService
addService
multiply
ServiceManager
ServiceProvider (MultServiceProvider)
ServiceUser (MultServiceUser)
User
Kernel
BinderDriver (/dev/binder)

Get Service list from SM

```
$ adb shell service list
Found 71 services:
0  stub_isms: [com.android.internal.telephony.ISms]
1  stub_phone: [com.android.internal.telephony.ITelephony]
2  stub_iphonesubinfo:
               [com.android.internal.telephony.IPhoneSubInfo]
..
5  stub_telephony.registry:
           [com.android.internal.telephony.ITelephonyRegistry]
...
7  stub_activity: [android.app.IActivityManager]
...
9  phone: [com.android.internal.telephony.ITelephony]
…
56 activity: [android.app.IActivityManager]
...
64 SurfaceFlinger: [android.ui.ISurfaceComposer]
...
```

Call remote method in ActivityManager

```
$ adb shell service list
...
```

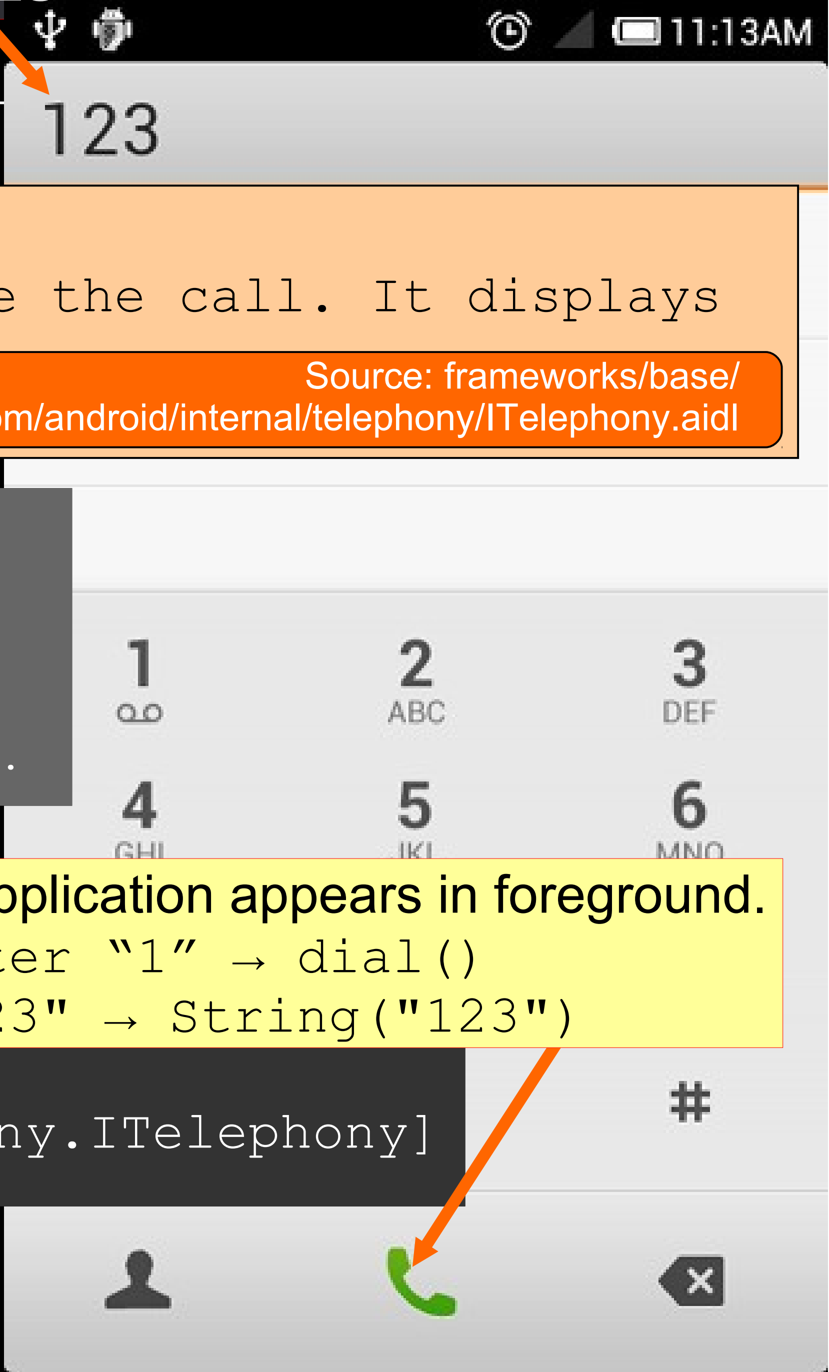
```
56 activity: [android.app.IActivityManager]
...
$ adb shell service call activity 1598968902
Result: Parcel(
  0x00000000: 0000001c 006e0061 00720064 0069006f '....a.n.d.r.o.i.'
  0x00000010: 002e0064 00700061 002e0070 00410049 'd...a.p.p...I.A.'
  0x00000020: 00740063 00760069 00740069 004d0079 'c.t.i.v.i.t.y.M.'
  0x00000030: 006e0061 00670061 00720065 00000000 'a.n.a.g.e.r.....')
```

```
public abstract interface IBinder {
    ...
    field public static final int INTERFACE_TRANSACTION
        = 1598968902; // 0x5f4e5446
    …
}
```

Source: frameworks/base/api/current.txt

Interact with Android Service

```
$ adb shell service call phone 1 s16 "123"
Result: Parcel(00000000 '....')
```



```
interface ITelephony {
    /* Dial a number. This doesn't place the call. It displays
     * the Dialer screen. */
    void dial(String number);
```

Source: frameworks/base/telephony/java/com/android/internal/telephony/ITelephony.aidl

```
service call SERVICE CODE [i32 INT | s16 STR] …

Options:

   i32: Write the integer INT into the send parcel.

   s16: Write the UTF-16 string STR into the send parcel.
```

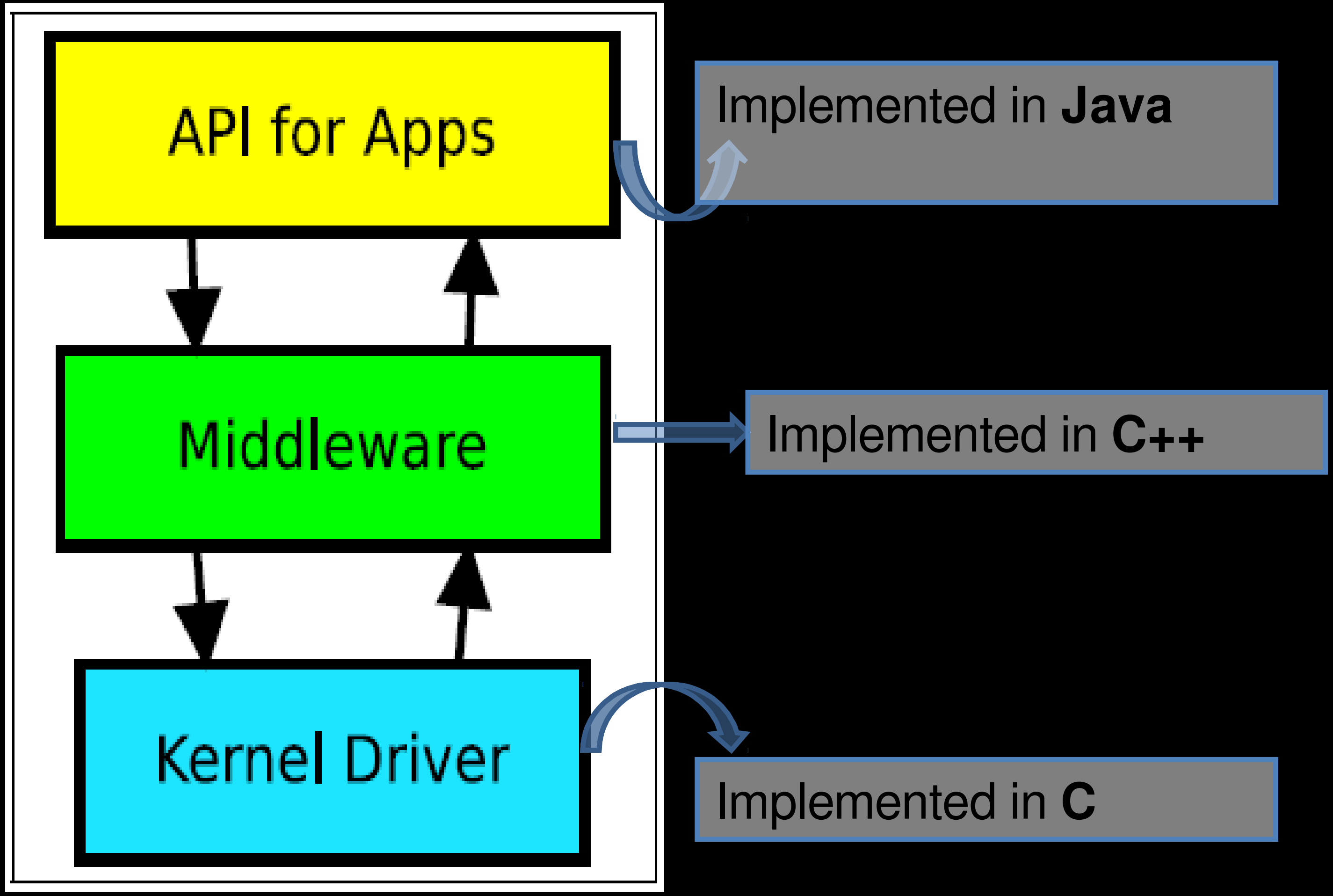
```
$ adb shell service list
Found 71 services:
...
9  phone: [com.android.internal.telephony.ITelephony]
```

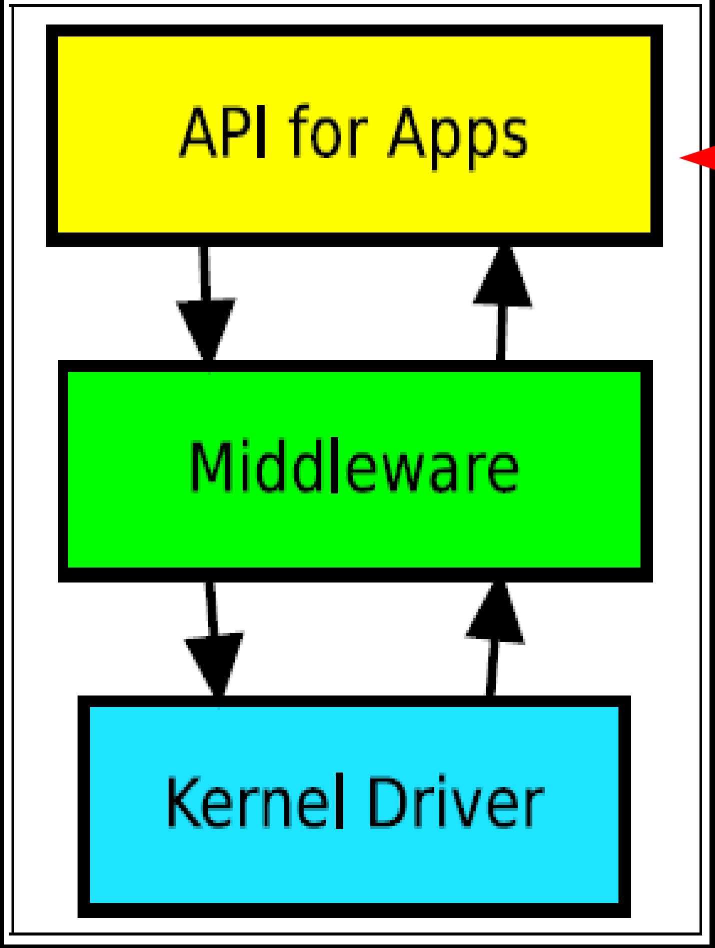
Phone Application appears in foreground.
parameter "1" → dial()
s16 "123" → String("123")

“I can call you after getService() from SystemManager."
Even if you don't know the phone number (= memory address) of that girl, you can still make phone call because SM exists.

Binder and Android Framework

Implementation Layers of Binder





API Layer

- **AIDL** (Android Interface Definition Language)
  - Ease the implementation of Android remote services
  - Defines an interface with method of remote services
  - AIDL parser generates Java class
    - Proxy class for Client
    - Stub class for Service
- **Java API Wrapper**
  - Introduce facilities to the binder
  - Wraps the middleware layer

AIDL

- Data Types
    - Java Primitives
    - Containers
        - String, List, Map, CharSequence
        - List<>
        - Multidimensional Array
    - Parcelable
    - Interface Reference
- Direction: in, out, inout
- oneway
    - android.os.IBinder.FLAG_ONEWAY

AIDL Compiler

- Full-fledged Java(-only) Support
- Stub and Proxy Generator

```
// Interface
interface IRemoteService {
    void ping();
}
```

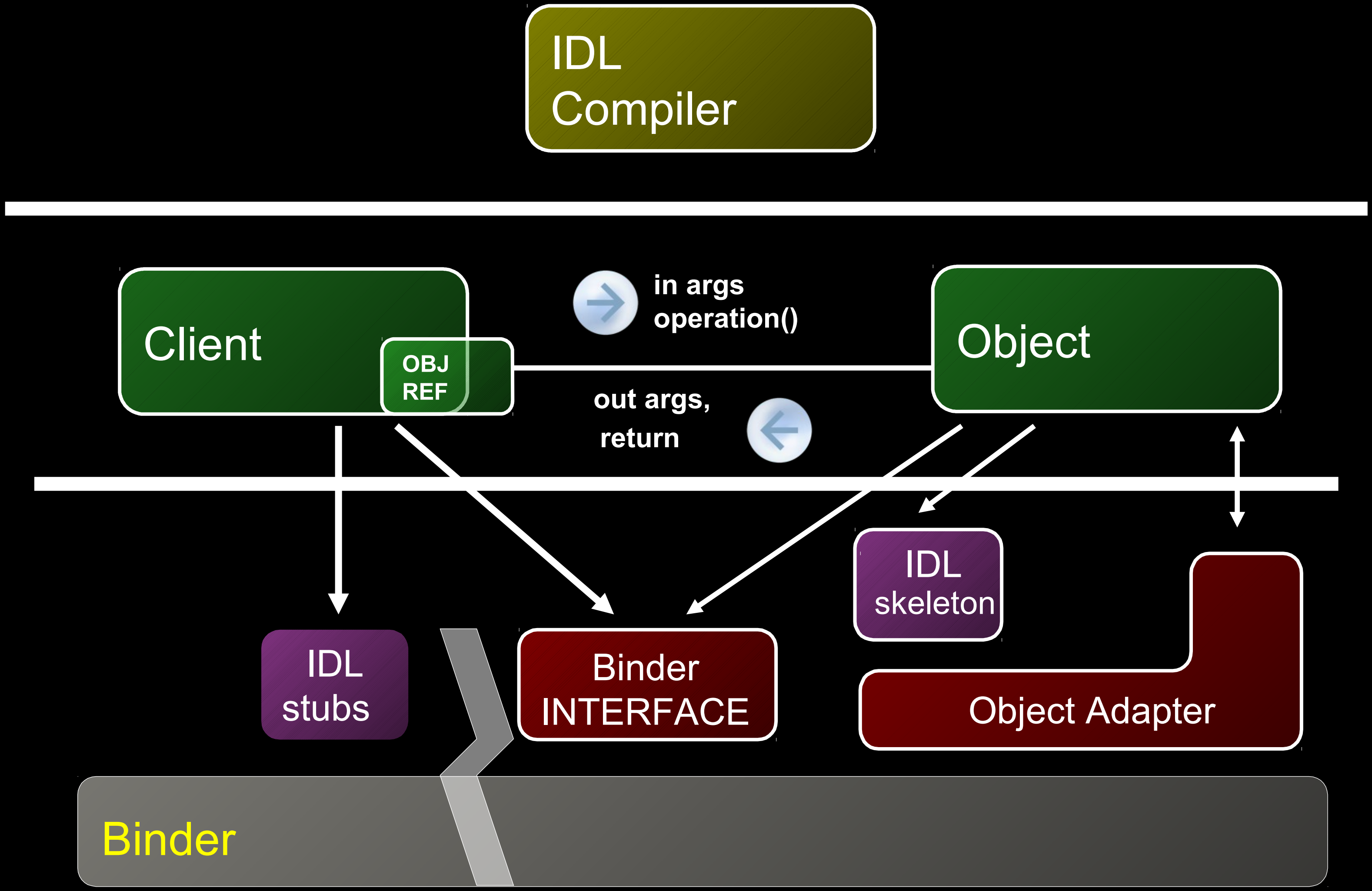
Client

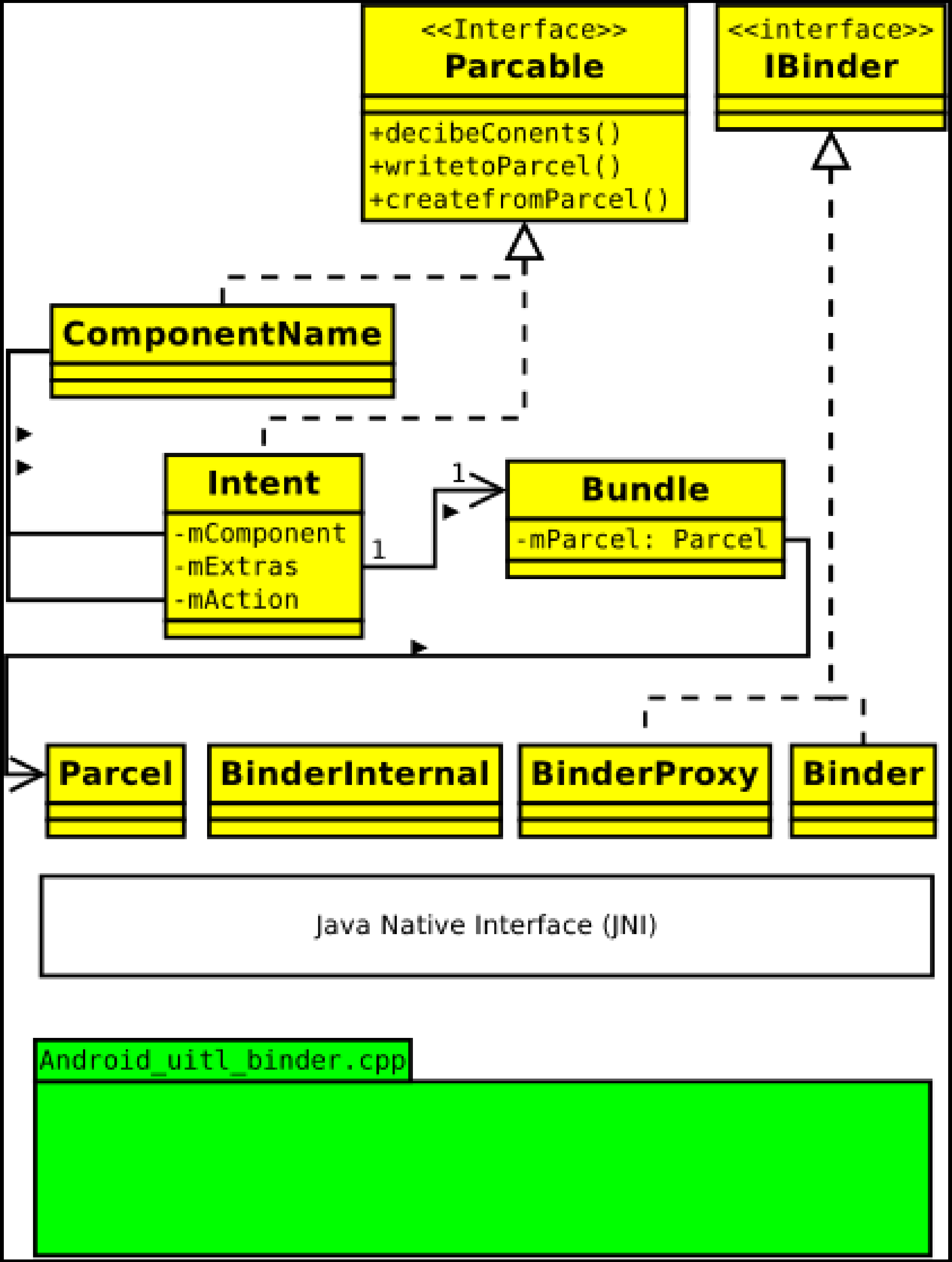
```
IRemoteService mService =
    IRemoteService.Stub.asInterface(service);
```

Server

```
public class RemoteService extends Service {
    public IBinder onBind(Intent intent) { return mBinder; }
    private final IRemoteService.Stub mBinder =
        new IRemoteService.Stub() {
            public void ping() { // Nothing }
    };
}
```

General Architecture





<<Interface>>
Parcable
+decibeConents()
+writetoParcel()
+createfromParcel()
<<interface>>
IBinder
ComponentName
Intent
-mComponent
-mExtras
-mAction
1
1
Bundle
-mParcel: Parcel
Parcel
BinderInternal
BinderProxy
Binder
Java Native Interface (JNI)
Android_uitl_binder.cpp

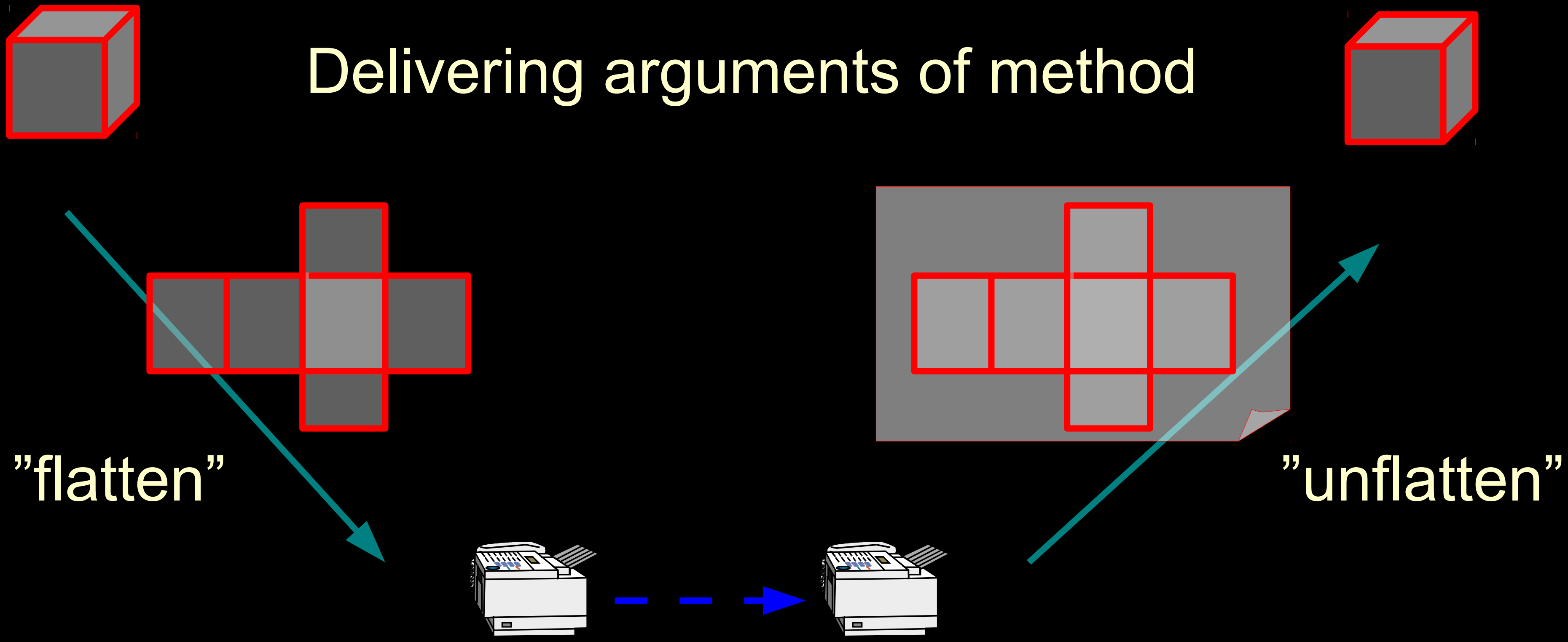
Parcels and Marshalling

- Simple inter process messaging system
- In an object oriented view, the transaction data is called parcel.
- The procedure of building a parcel is called **marshalling** an object.
- The procedure of rebuilding a object from a parcel is called **unmarshalling** an object.

Parcel

- Marshalling – The transferring of data across process boundaries
    - Represented in native binary encoding
- Mostly handled by AIDL-generated code
- Extensible – Parcelable

android.os.Parcel

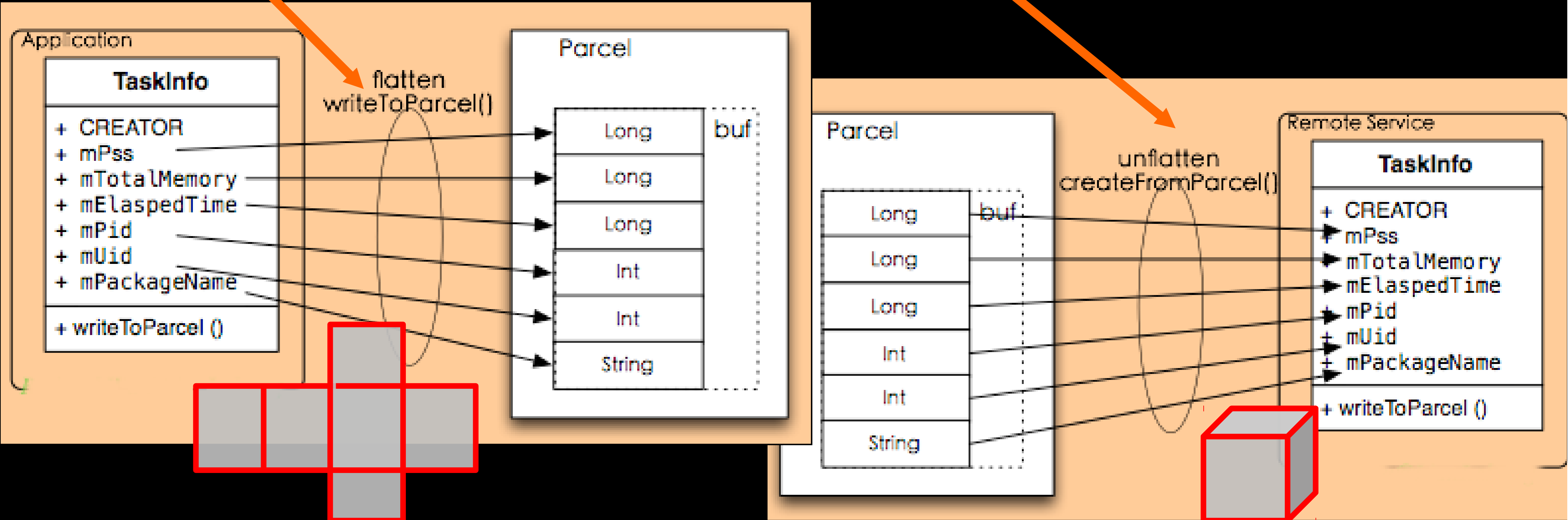


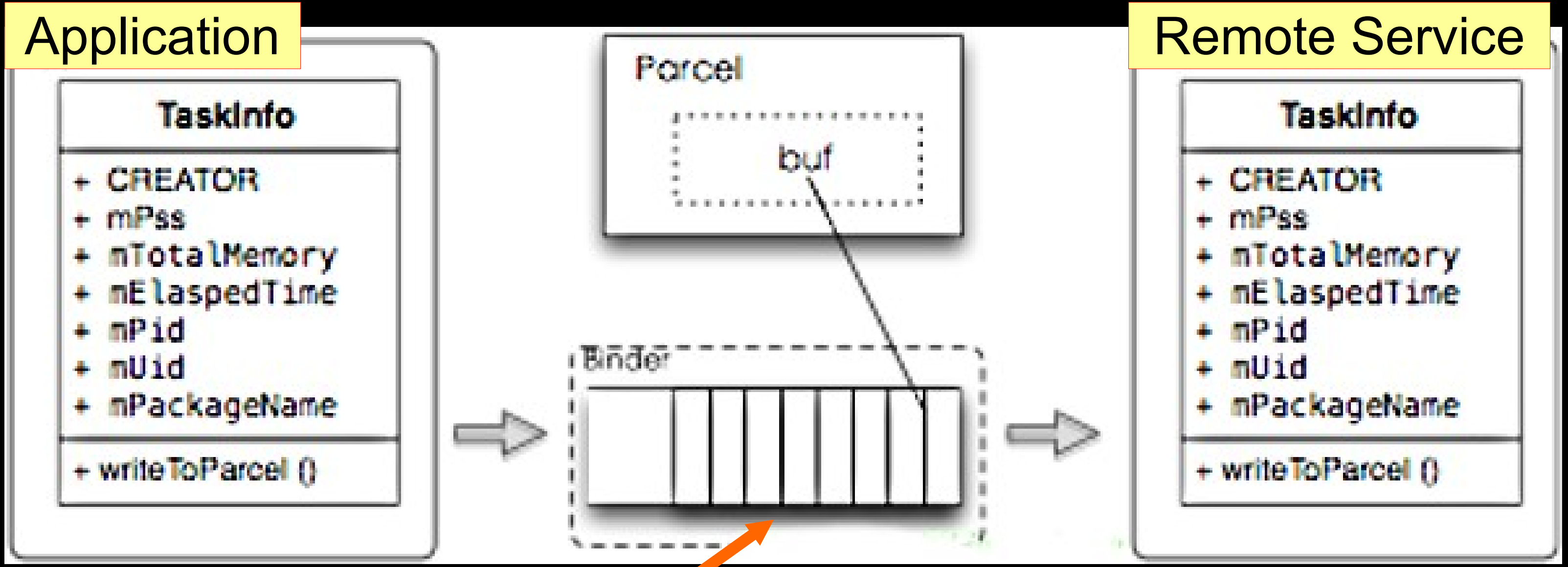
Transmit object as FAX

Source: Inter-process communication of Android, Tetsuyuki Kobayashi

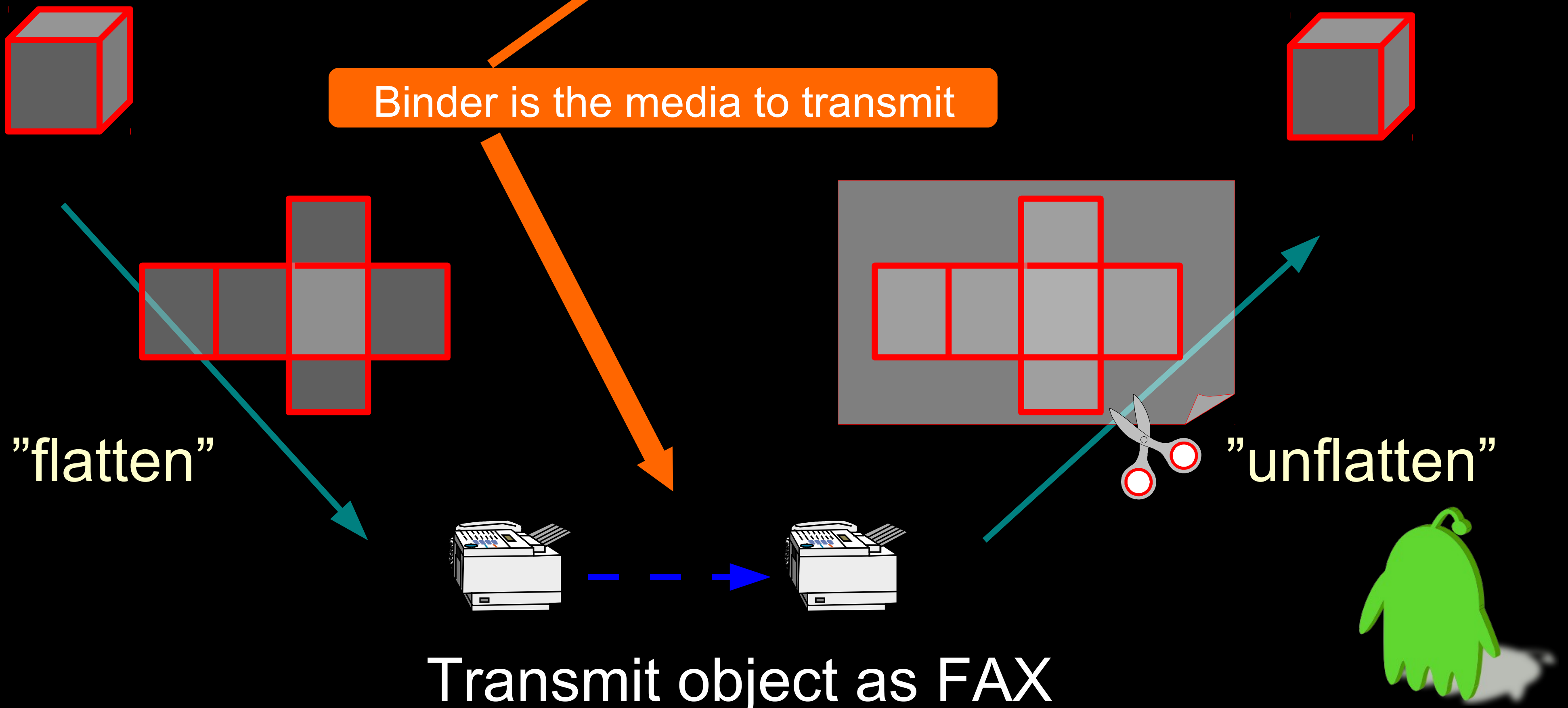
```
public class TaskInfo implements android.os.Parcelable {
    public long mPss, mTotalMemory, mElapsedTime;
    public int mPid, mUid;
    public String mPackageName;
    TaskInfo() { ... }
    public void writeToParcel(Parcel out, int flags) { … }
    public static final Parcelable.Creator<TaskInfo>CREATOR =
        new Parcelable.Creator<TaskInfo>() { … }
    public TaskInfo createFromParcel(Parcel in)  {
        return TaskInfo(in); }
    private TaskInfo(Parcel in) { … }
```

class TypeInfo as example





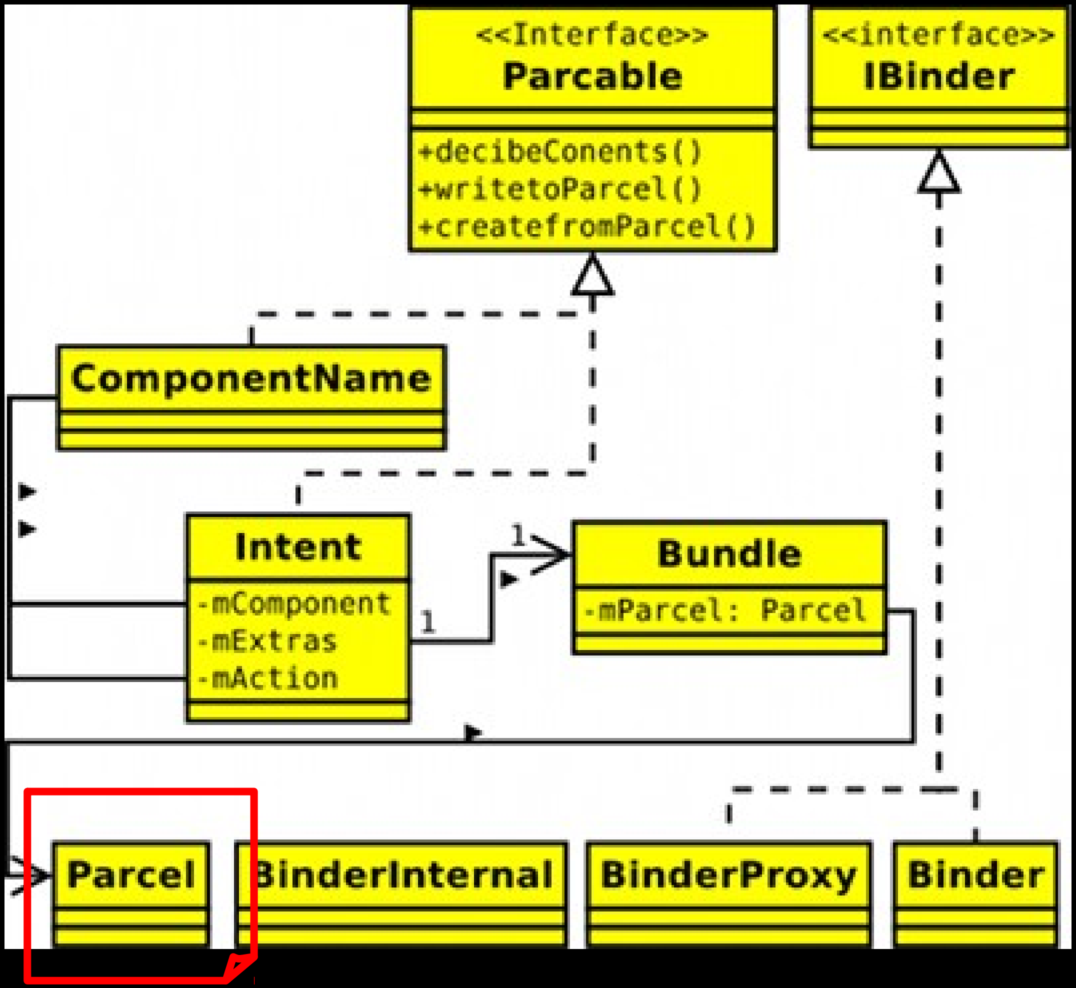
Binder is the media to transmit



Transmit object as FAX

Parcel Definition

- Container for a message (data and object references) that can be sent through an IBinder.



- A Parcel can contain both flattened data that will be unflattened on the other side of the IPC (using the various methods here for writing specific types, or the general Parcelable interface), and references to live IBinder objects that will result in the other side receiving a proxy IBinder connected with the original IBinder in the Parcel.

Representation of Parcel

- Parcel is not for general-purpose serialization

  This class (and the corresponding Parcelable API for placing arbitrary objects into a Parcel) is designed as a high-performance IPC transport.

  Not appropriate to place any Parcel data into persistent storage

- Functions for writing/reading primitive data types:

```
writeByte(byte) / readByte()
writeDouble(double) / readDouble()
writeFloat(float) / readFloat()
writeInt(int) / readInt()
writeLong(long) / readLong()
writeString(String) / readString()
```

Parcelable

- The Parcelable protocol provides an extremely efficient (but low-level) protocol for objects to write and read themselves from Parcels.
- Use the direct methods to write/read

```
    writeParcelable(Parcelable, int)
    readParcelable(ClassLoader)
    writeParcelableArray(T[],int)
    readParcelableArray(ClassLoader)
```

- These methods write both the class type and its data to the Parcel, allowing that class to be reconstructed from the appropriate class loader when later reading.

Parcelable

- Implement the Parcelable interface.
    implement `writeToParcel()` and `readFromParcel()`.

    Note: the order in which you write properties must be the same as the order in which you read them.

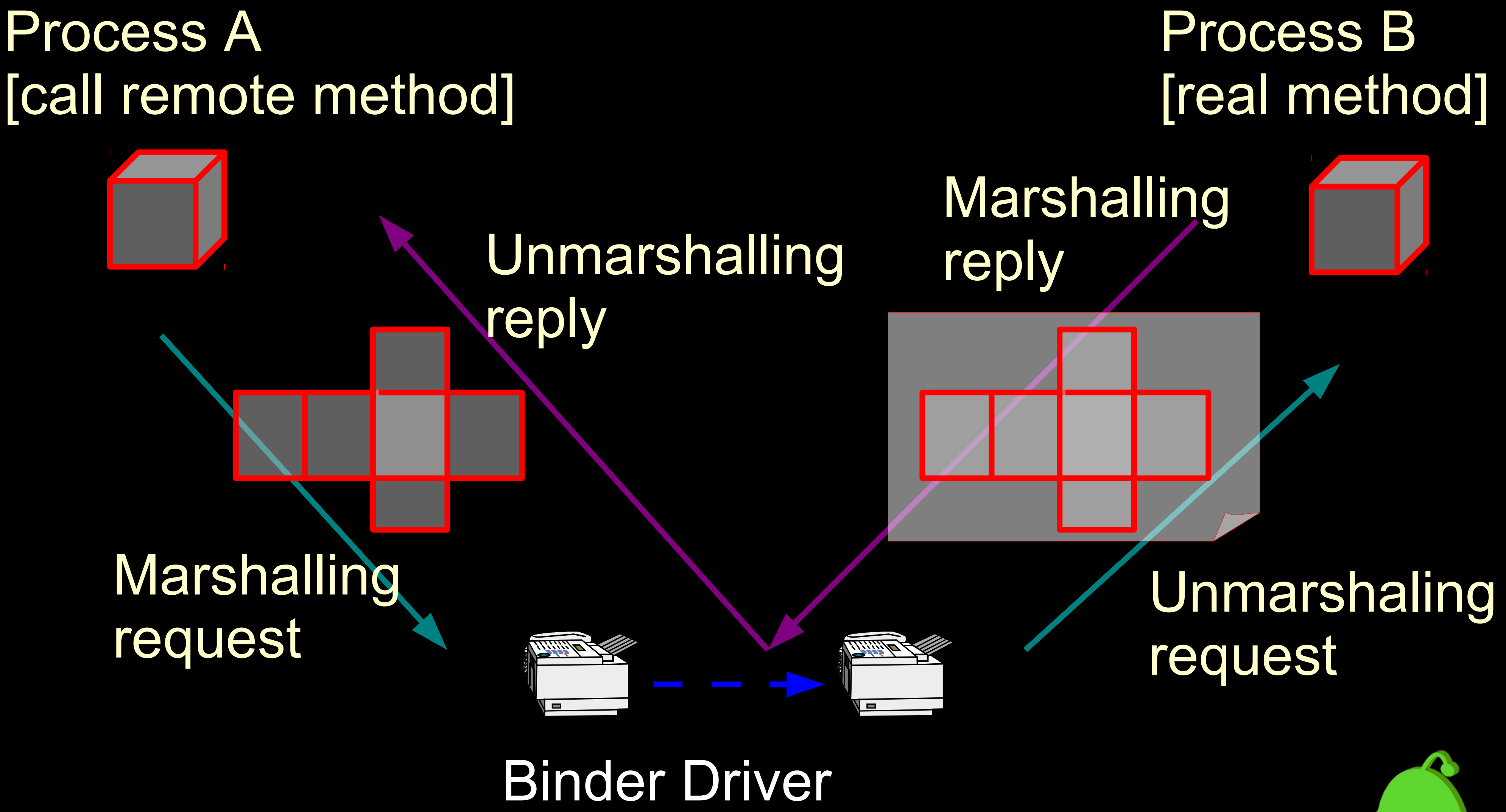
- Add a static final property to the class with the name CREATOR .
    The property needs to implement the **`android.os.Parcelable.Creator<T>`** interface.

- Provide a constructor for the Parcelable that knows how to create the object from the Parcel.
- Define a Parcelable class in an .aidl file that matches the .java file containing the complex type .
    AIDL compiler will look for this file when compiling your AIDL files.

Bundles

- A special type-safe container, called Bundle, is available for key/value maps of heterogeneous values.
- This has many optimizations for improved performance when reading and writing data, and its type-safe API avoids difficult to debug type errors when finally marshalling the data contents into a Parcel.

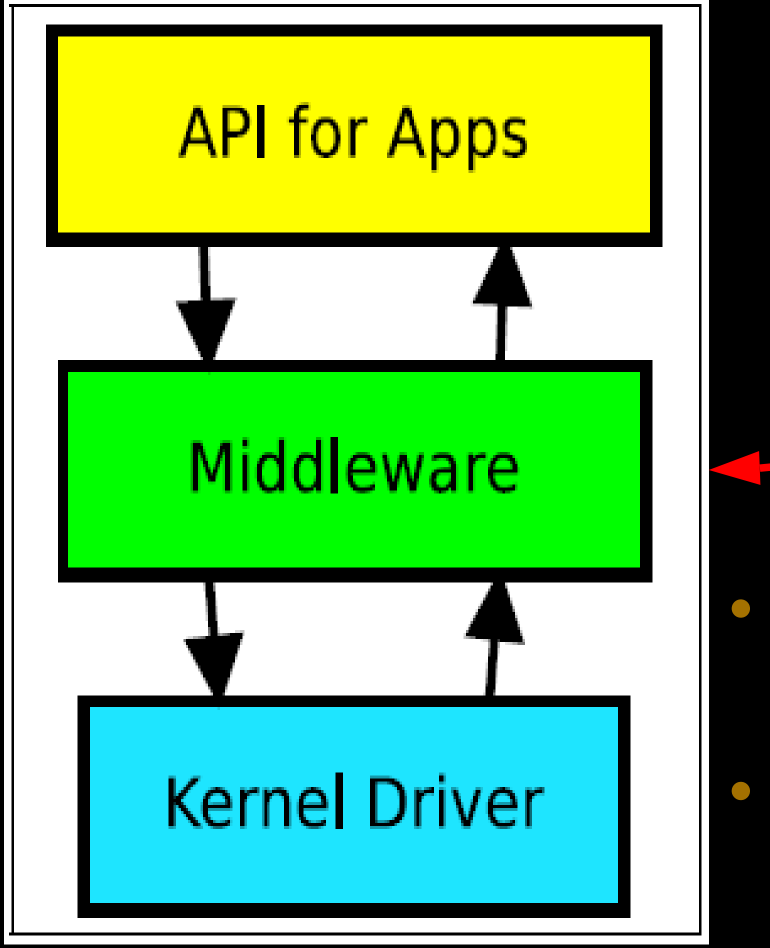
RPC Implementation in Binder



- Parcel
- Parcelable
- Bundle

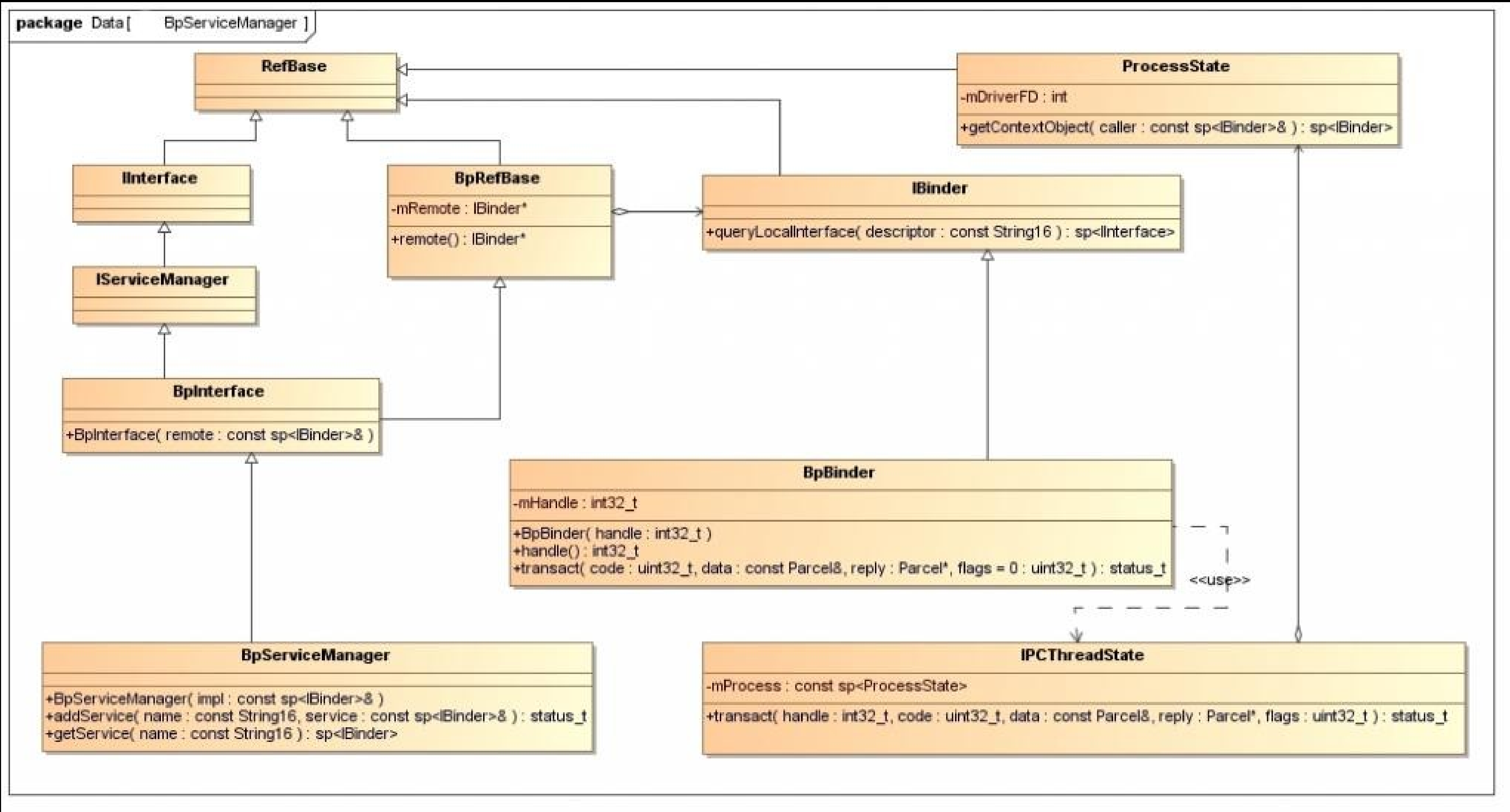
"May I pack you back to my home by Parcel?"

Middleware Layer



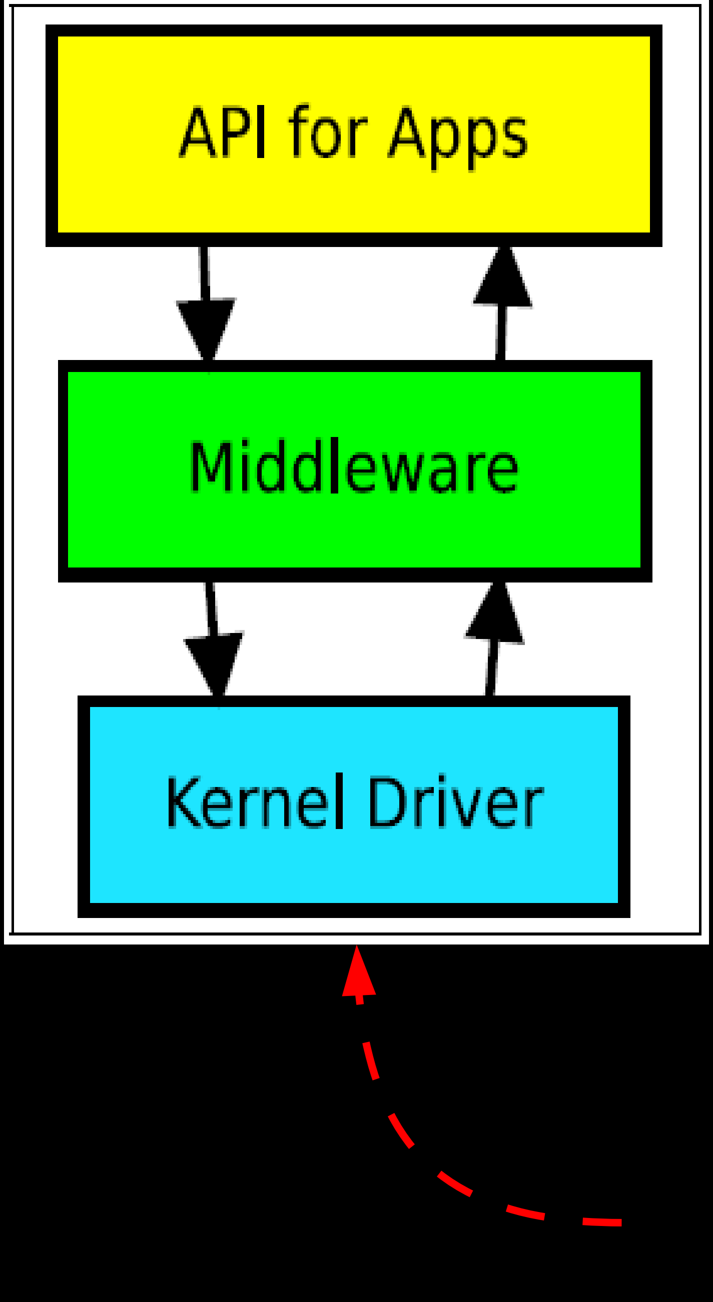
- Implements the user space facilities of the Binder framework in C++
- Implements structures and methods to spawn and manage new threads
- Marshalling and unmarshalling of specific data
- Provides interaction with the Binder kernel driver

- frameworks/base/include/binder/IServiceManager.h
  `sp<IServiceManager> defaultServiceManager()`
- frameworks/base/include/binder/IInterface.h
  `template` **`BpInterface`**



package Data[BpServiceManager]
RefBase
ProcessState
-mDriverFD : int
+getContextObject(caller : const sp<IBinder>&) : sp<IBinder>
IInterface
BpRefBase
-mRemote : IBinder*
+remote() : IBinder*
IBinder
+queryLocalInterface(descriptor : const String16) : sp<IInterface>
IServiceManager
BpInterface
+BpInterface(remote : const sp<IBinder>&)
BpBinder
-mHandle : int32_t
+BpBinder(handle : int32_t)
+handle() : int32_t
+transact(code : uint32_t, data : const Parcel&, reply : Parcel*, flags = 0 : uint32_t) : status_t
<<use>>
BpServiceManager
+BpServiceManager(impl : const sp<IBinder>&)
+addService(name : const String16, service : const sp<IBinder>&) : status_t
+getService(name : const String16) : sp<IBinder>
IPCThreadState
-mProcess : const sp<ProcessState>
+transact(handle : int32_t, code : uint32_t, data : const Parcel&, reply : Parcel*, flags : uint32_t) : status_t

Kernel Driver Layer



- Binder Driver supports the file operations open, mmap, release, poll and the system call ioctl
- ioctl arguments
  - Binder driver command code
  - Data buffer

Command codes

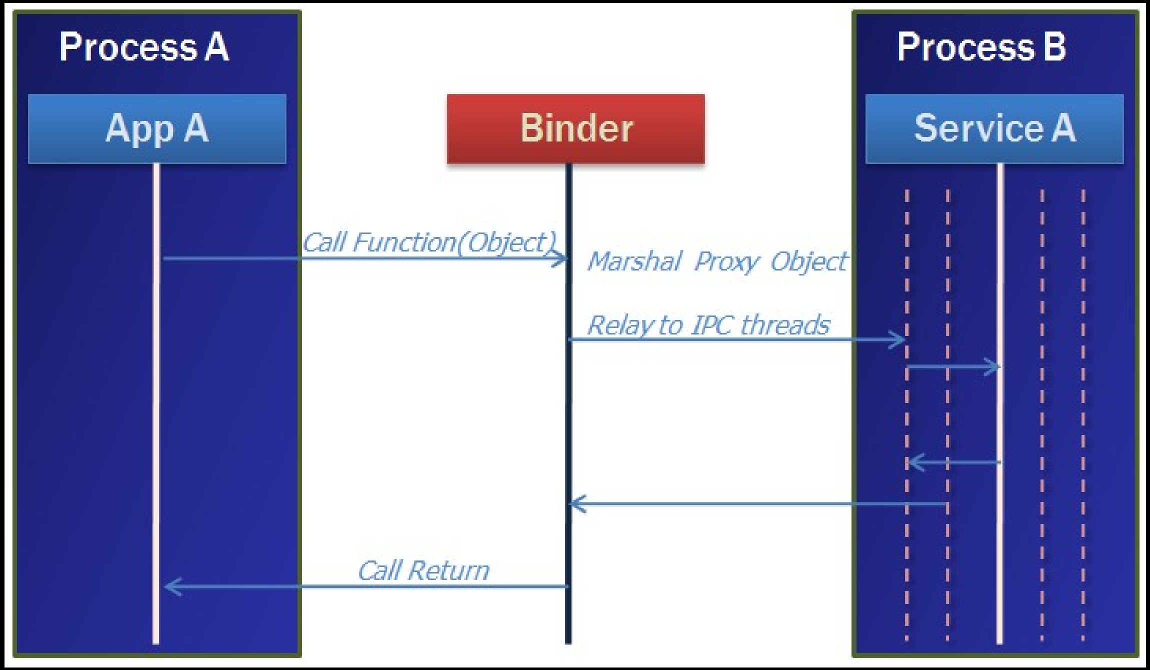
- BINDER_WRITE_READ
- BINDER_SET_MAX_THREADS
- BINDER_SET_CONTEXT_MGR
- BINDER_THREAD_EXIT
- BINDER_VERSION

Binder Driver

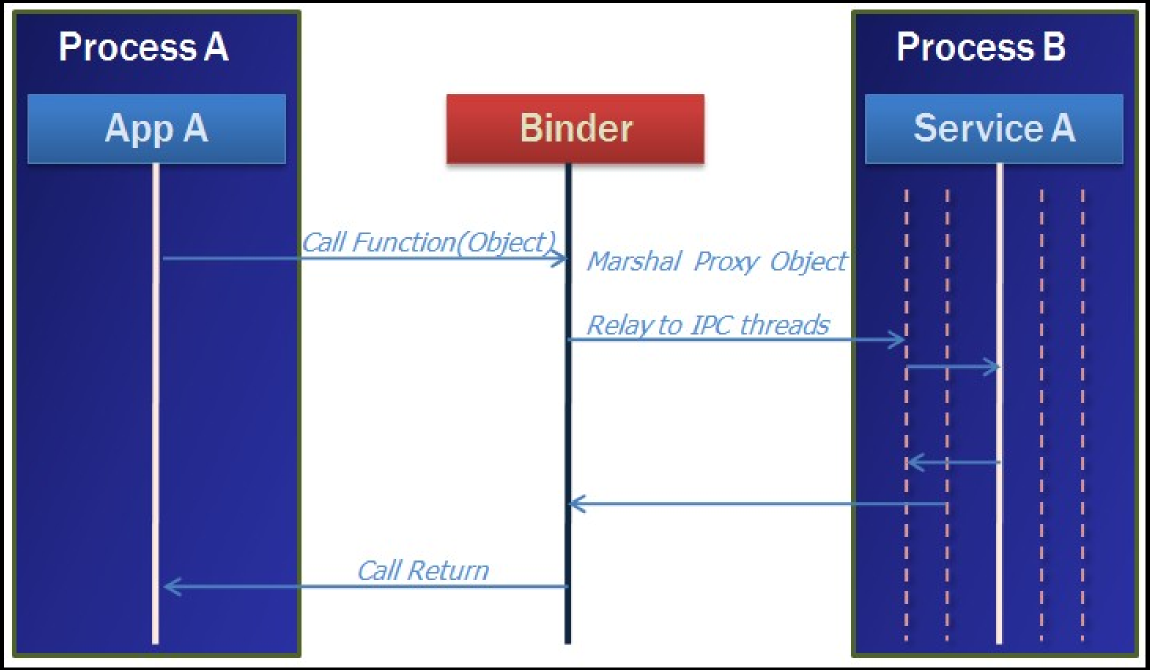
- Multi-thread aware

  Have internal status per thead

  Compare to UNIX socket: sockets have internal status per file descriptor (FD)



Binder Driver

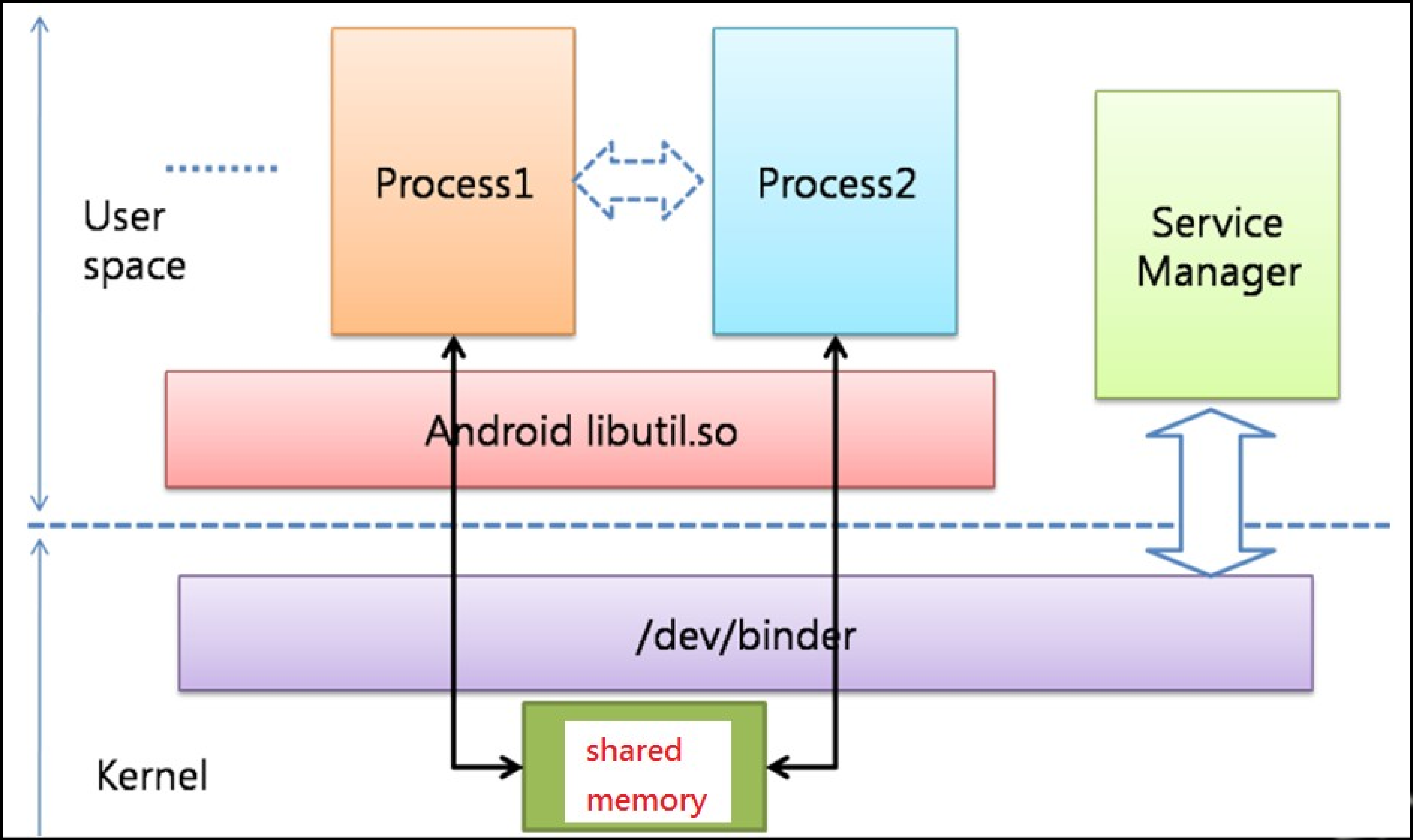


- A pool of threads is associated to each service application to process incoming IPC
- Binder performs mapping of object between two processes.
- Binder uses an object reference as an address in a process's memory space.
- Synchronous call, reference counting

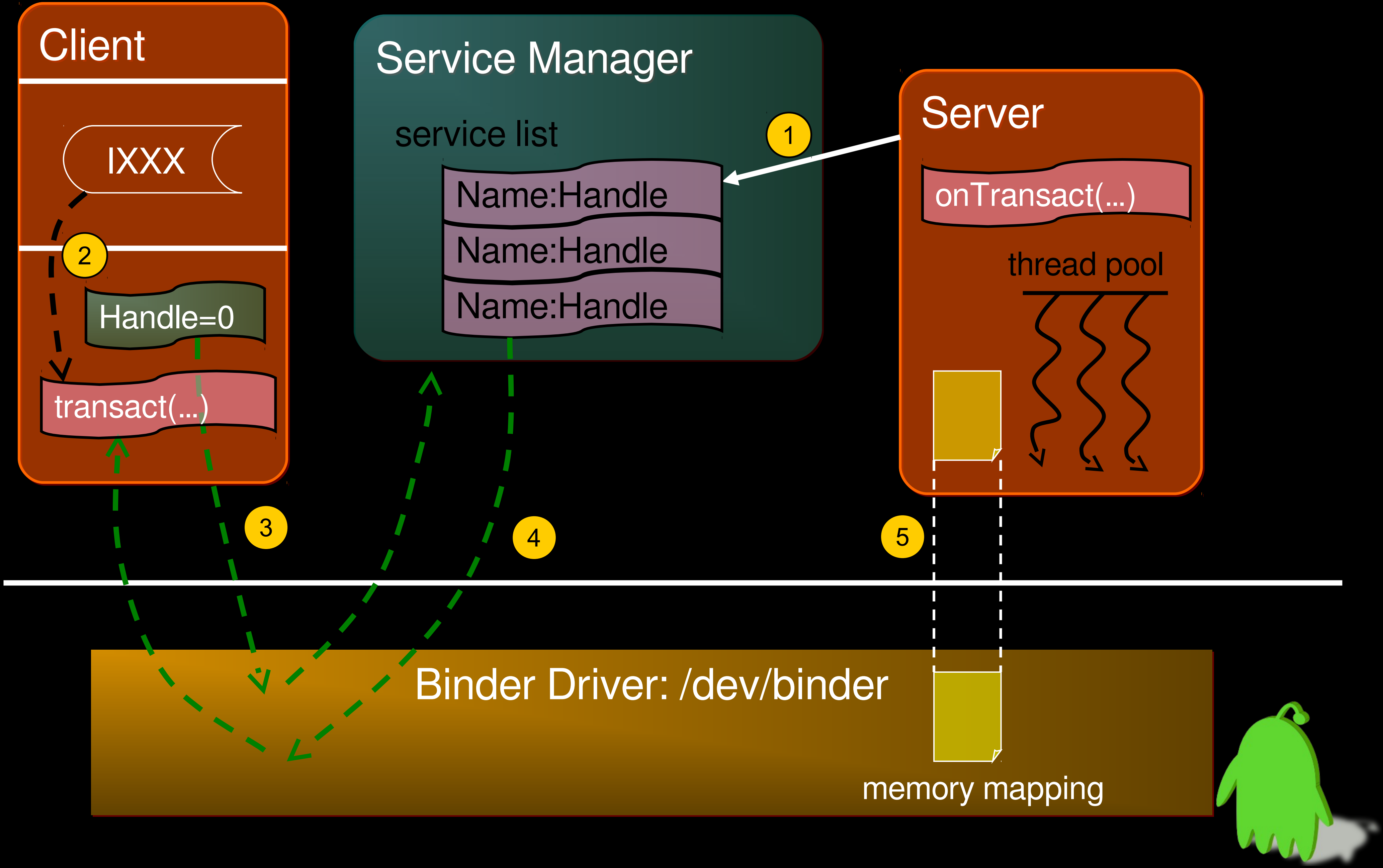
Binder is different from UNIX socket

	socket	binder
internal status	associated to FD	associated to PID (FD can be shared among threads in the same process)
read & write operation	stream I/O	done at once by **ioctl**
network transparency	Yes	No expected local only

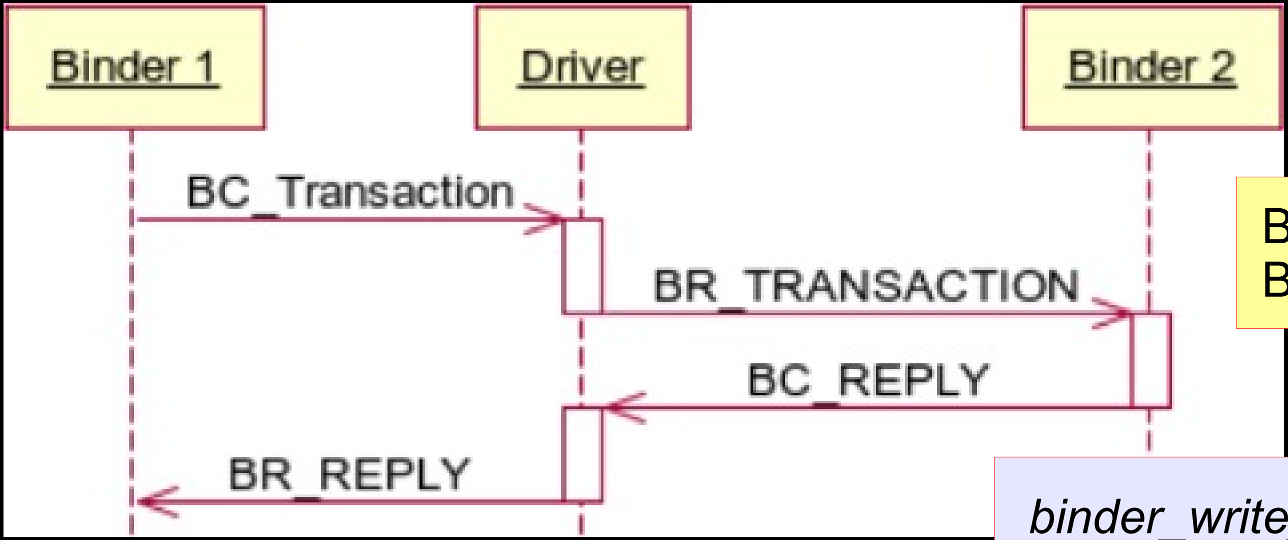
Binder


User space
Process1
Process2
Service Manager
Android libutil.so
/dev/binder
Kernel
shared memory

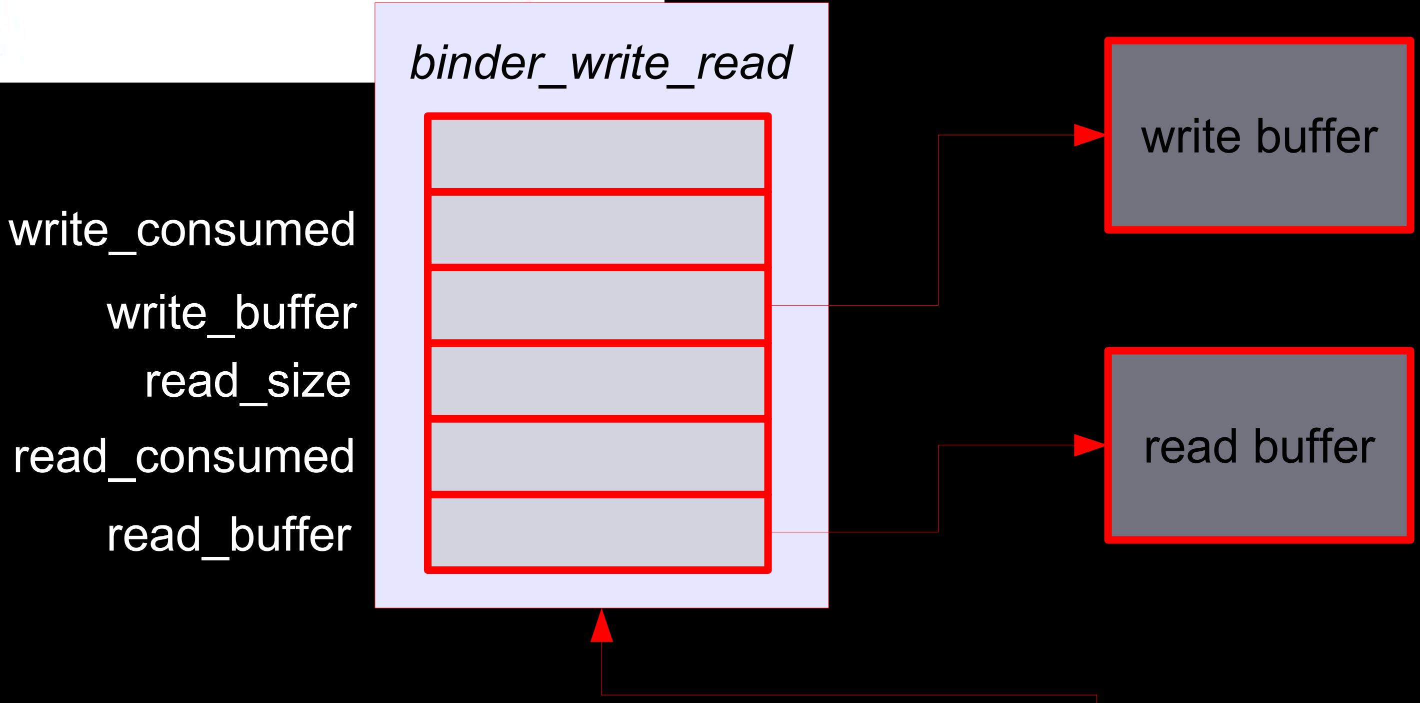
from SM to Binder Driver



Transaction

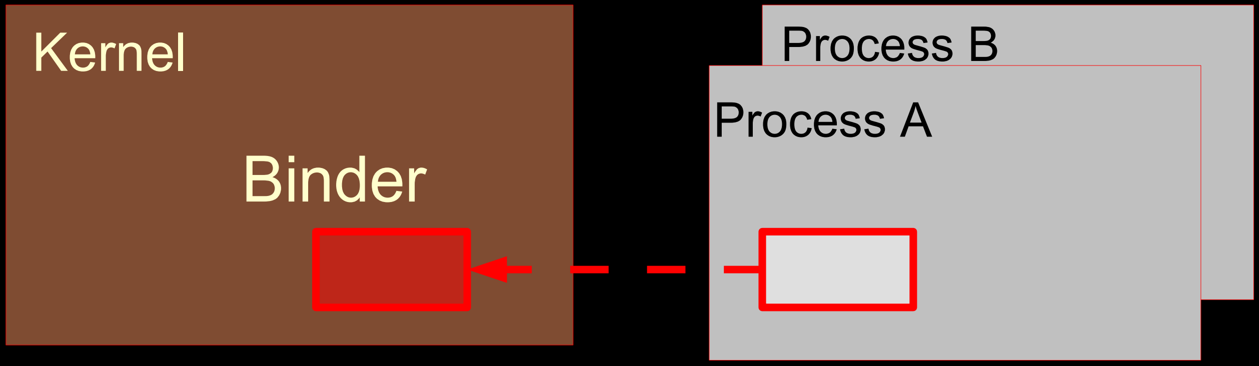


BR → BinderDriverReturnProtocol
BC → BinderDriverCommandProtocol

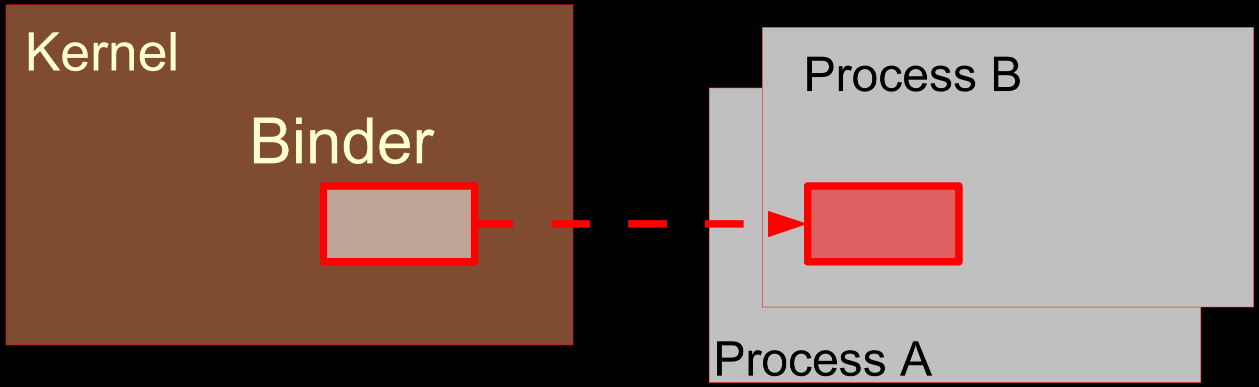


```
if (ioctl(fd, BINDER_WRITE_READ, &bwt ) >= 0)
    err = NO_ERROR;
else
    err = -errno;
```

Transaction of Binder



Copy memory by **copy_from _user**



Copy memory by **copy_to_user**

Internally, Android uses Binder for graphics data transaction across processes.
It is fairly efficient.

Process A
Process B
Transaction
Binder Driver: /dev/binder

Binder driver manipulates memory mapping for userspace transaction.

Limitation of Binder IPC

- Binders are used to to communicate over process boundaries since different processes don't share a common VM context
    - no more direct access to each others Objects (memory).
- Binders are not ideal for transferring large data streams (like audio/video) since every object has to be converted to (and back from) a Parcel.

Binder Performance

- Good
  - Compact method index
  - Native binary marshalling
  - Support of ashmem shortcut
  - No GUID
- Bad
  - Dalvik Parcel overhead
  - ioctl() path is not optimal
  - Interface name overhead
  - Global lock

Binder Security

- Binder's Security Features
  - Securely Determined Client Identity
    - Binder.getCallingUid(), Binder.getCallingPid()
    - Similar to Unix Domain Socket
    - `getsockopt(..., SO_PEERCRED, ...)`
  - Interface Reference Security
    - Client cannot guess Interface Reference
- Service Manager
  - Directory Service for System Services
- Server should check client permission

```
Context.checkPermission(permission, pid, uid)
```

Binder is not ideally perfect, but it makes busy world work.

Binder sample program

- Build binder benchmark program

```
cd system/extras/tests/binder/benchmarks
```

```
mm
```

```
adb push \
  ../../../../out/target/product/crespo/data/nativebenchmark/binderAddInts \
   /data/local/
```

- Execute

```
adb shell
```

```
su
```

```
/data/local/binderAddInts -d 5 -n 5 &
```

```
ps
```

```
...
root      17133 16754 4568   860   ffffffff 400e6284 S
/data/local/binderAddInts
root      17135 17133 2520   616   00000000 400e5cb0 R
/data/local/binderAddInts
```

Binder sample program

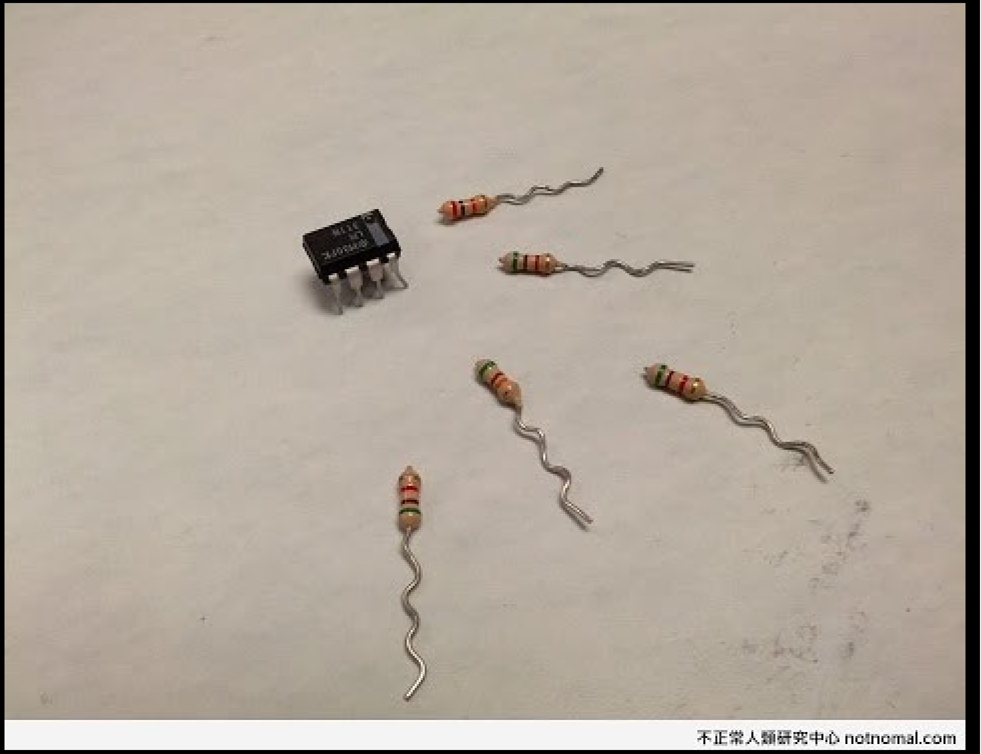
- Execute

```
/data/local/binderAddInts -d 5 -n 5 &
ps
...
root      17133 16754 4568   860   ffffffff 400e6284 S
/data/local/binderAddInts
root      17135 17133 2520   616   00000000 400e5cb0 R
/data/local/binderAddInts
cat /sys/kernel/debug/binder/transaction_log
transaction_log:3439847: call  from 17133:17133 to 72:0 node
1 handle 0 size 124:4
transaction_log:3439850: reply from 72:72 to 17133:17133 node
0 handle 0 size 4:0
transaction_log:3439855: call  from 17135:17135 to 17133:0
node 3439848 handle 1 size 8:0
...
```

Binder sysfs entries

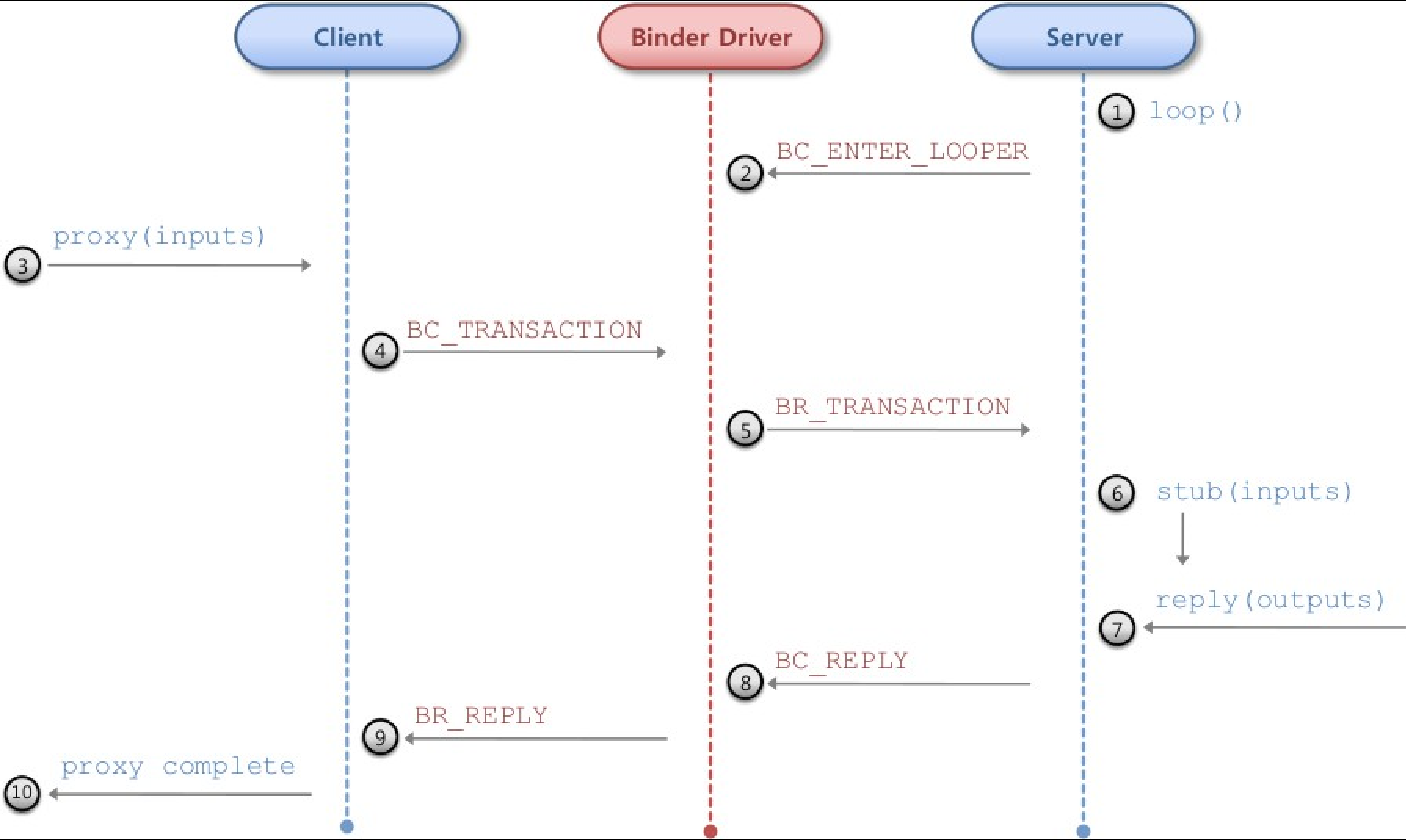
- `adb shell ls /sys/kernel/debug/binder`

```
failed_transaction_log
proc
state
stats
transaction_log
transactions
```

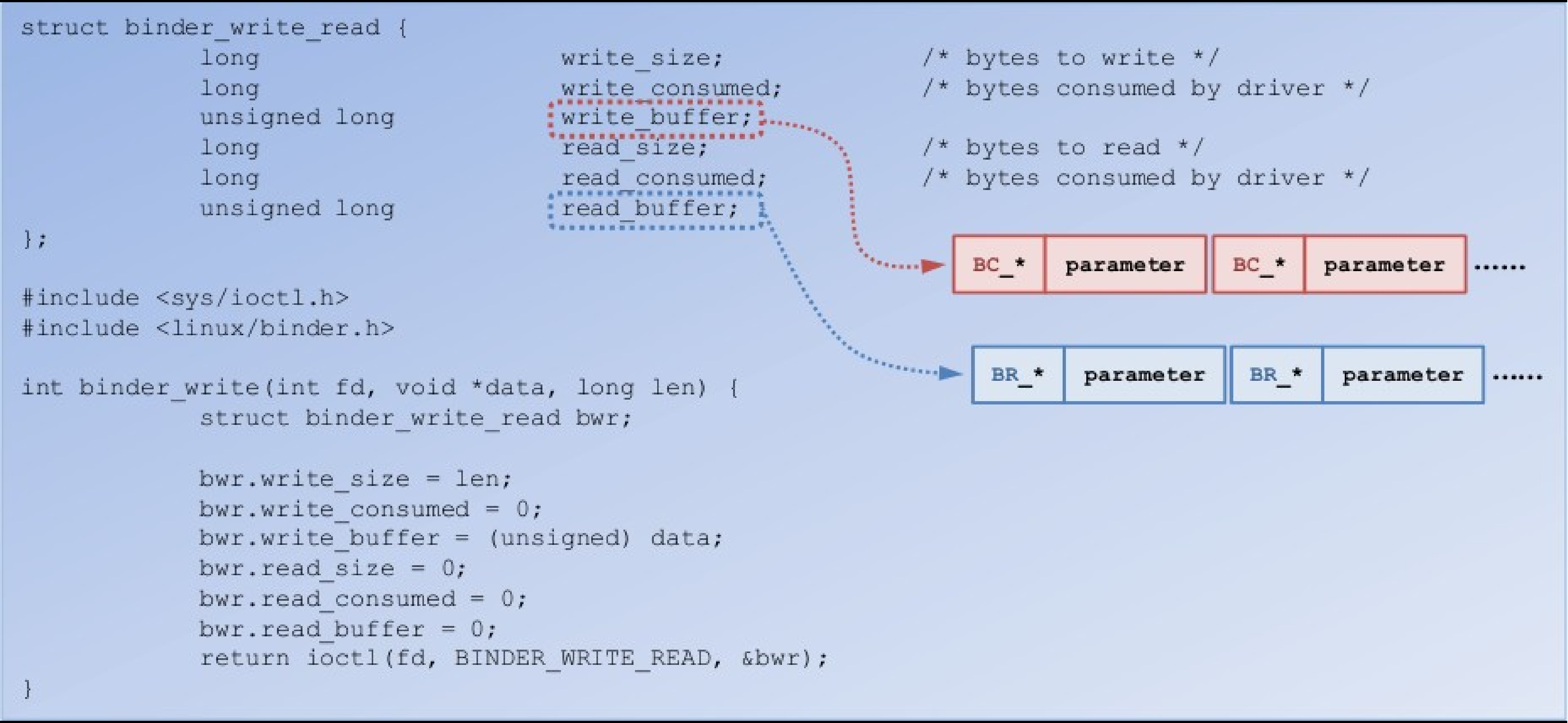


Activities and Services are communicating with each other by Binder!

Remote Procedure Call



BINDER_WRITE_READ

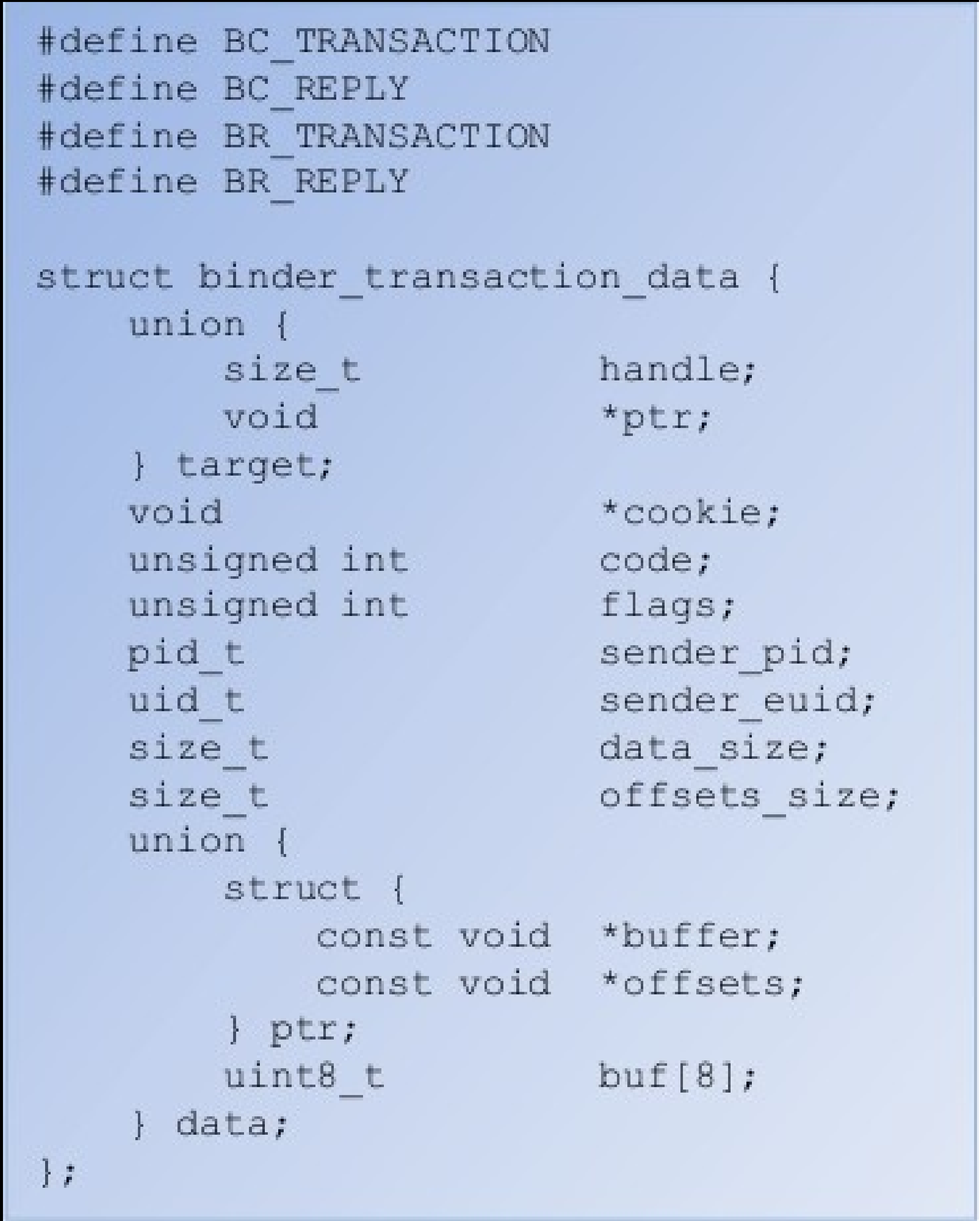


```
struct binder_write_read {
            long                    write_size;          /* bytes to write */
            long                    write_consumed;      /* bytes consumed by driver */
            unsigned long           write_buffer;

            long                    read_size;           /* bytes to read */
            long                    read_consumed;       /* bytes consumed by driver */
            unsigned long           read_buffer;
};

#include <sys/ioctl.h>
#include <linux/binder.h>

int binder_write(int fd, void *data, long len) {
            struct binder_write_read bwr;

            bwr.write_size = len;
            bwr.write_consumed = 0;
            bwr.write_buffer = (unsigned) data;
            bwr.read_size = 0;
            bwr.read_consumed = 0;
            bwr.read_buffer = 0;
            return ioctl(fd, BINDER_WRITE_READ, &bwr);
}
```

BC_* parameter BC_* parameter ......
BR_* parameter BR_* parameter ......

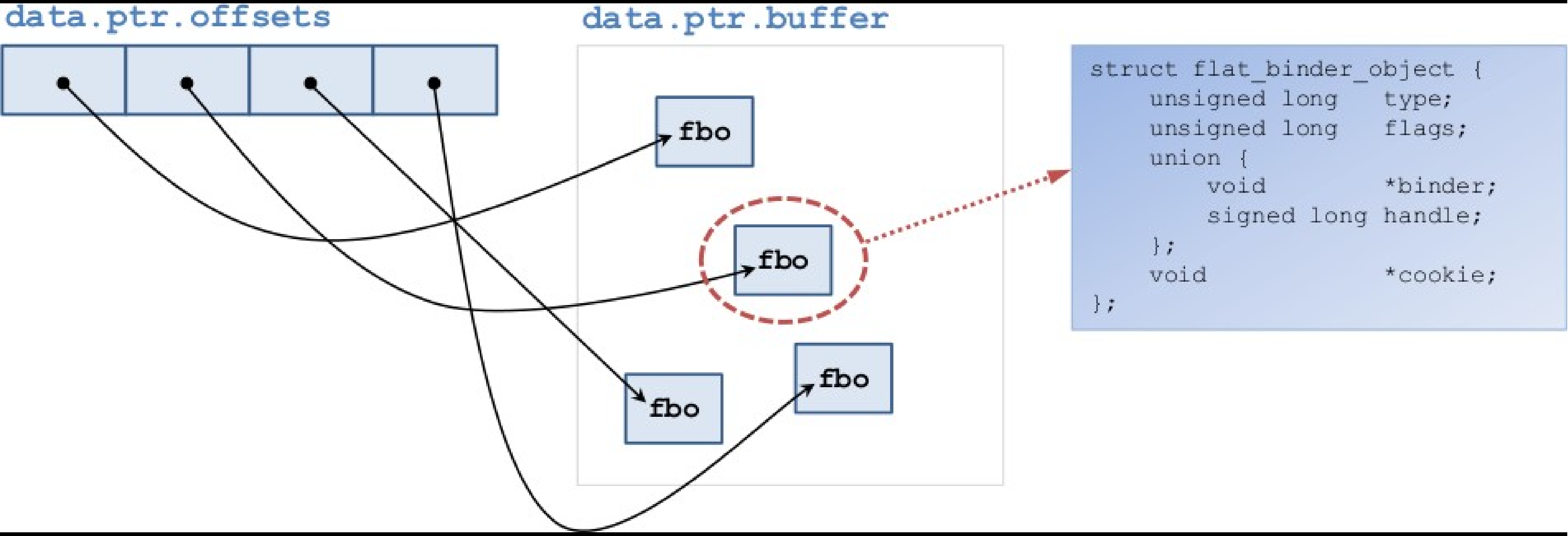
Binder Transaction

- Target Method
  - handle : Remote Interface
  - ptr & cookie : Local Interface
  - code : Method ID
- Parcel - Input/Output Parameters
  - data.ptr.buffer
  - data_size
- Object Reference Management
  - data.ptr.offsets
  - offsets_size
- Security
  - sender_pid
  - sender_euid
- No Transaction GUID
  - Transparent Recursion



```
#define BC_TRANSACTION
#define BC_REPLY
#define BR_TRANSACTION
#define BR_REPLY

struct binder_transaction_data {
    union {
        size_t              handle;
        void                *ptr;
    } target;
    void                    *cookie;
    unsigned int            code;
    unsigned int            flags;
    pid_t                   sender_pid;
    uid_t                   sender_euid;
    size_t                  data_size;
    size_t                  offsets_size;
    union {
        struct {
            const void      *buffer;
            const void      *offsets;
        } ptr;
        uint8_t             buf[8];
    } data;
};
```

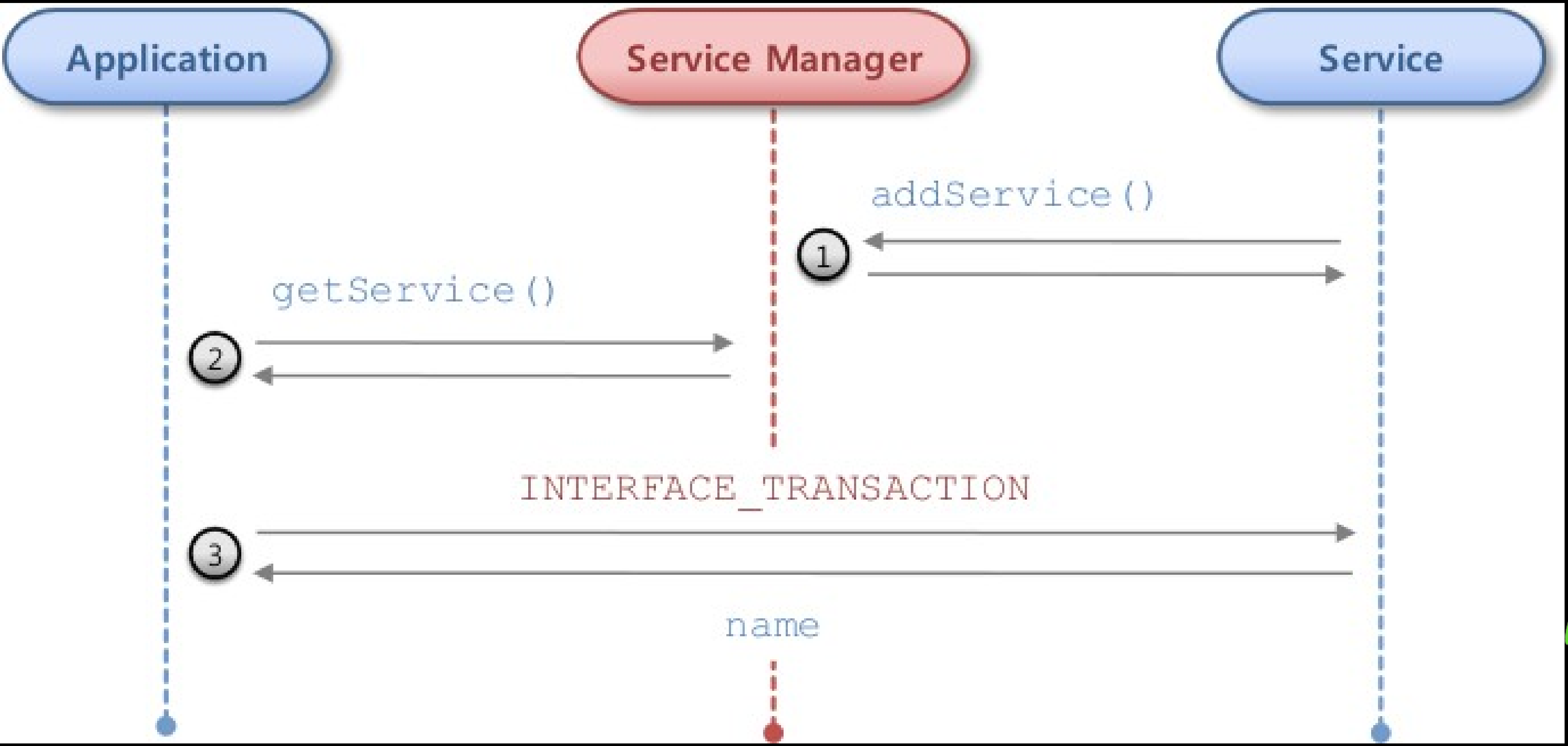
Object Reference Management



```
struct flat_binder_object {
    unsigned long   type;
    unsigned long   flags;
    union {
        void          *binder;
        signed long handle;
    };
    void              *cookie;
};
```

Service Registration and Discovery

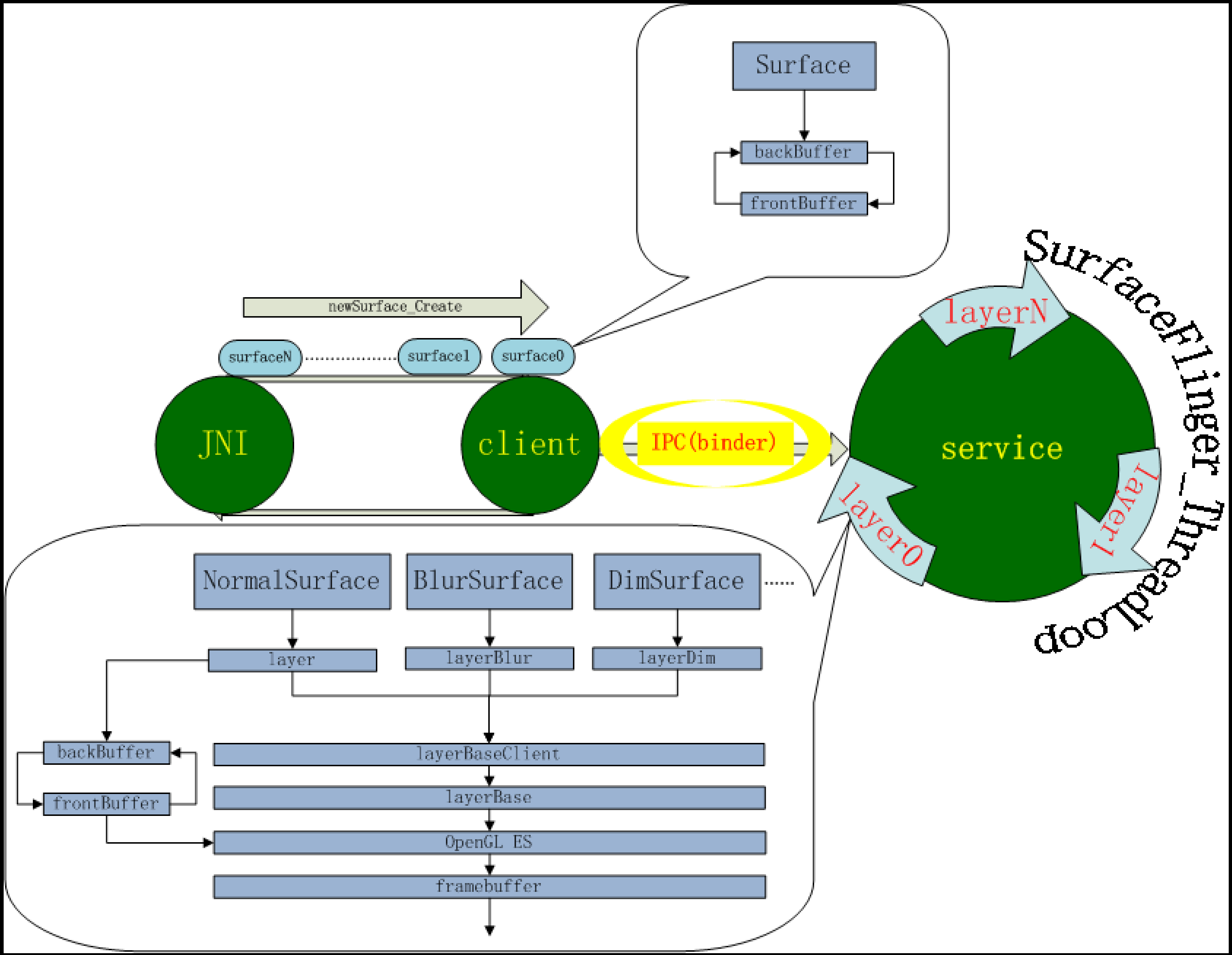
- System service is executed by `IServiceManager::addService()` calls.
  Parameter: handle to Binder Driver
- Look up the name of specific service in Binder Driver Map
  `IServiceManager::getService()` returns the handle of the found registered services
- `android.os.IBinder.INTERFACE_TRANSACTION`: the actual name



Let's take a break!

Binder use case: Android Graphics

Real Case



Binder IPC is used for communicating between Graphics client and server.
Taken from http://www.cnblogs.com/xl19862005/archive/2011/11/17/2215363.html

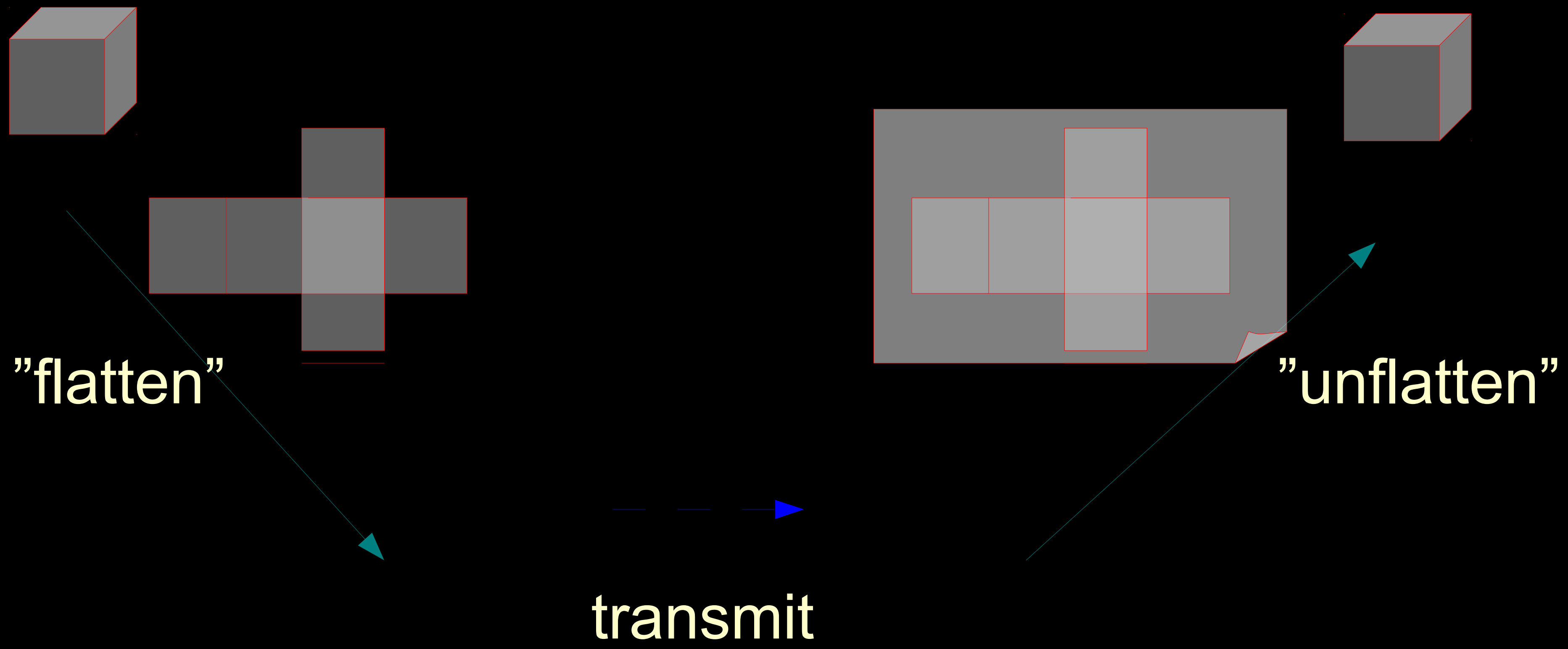
Surface

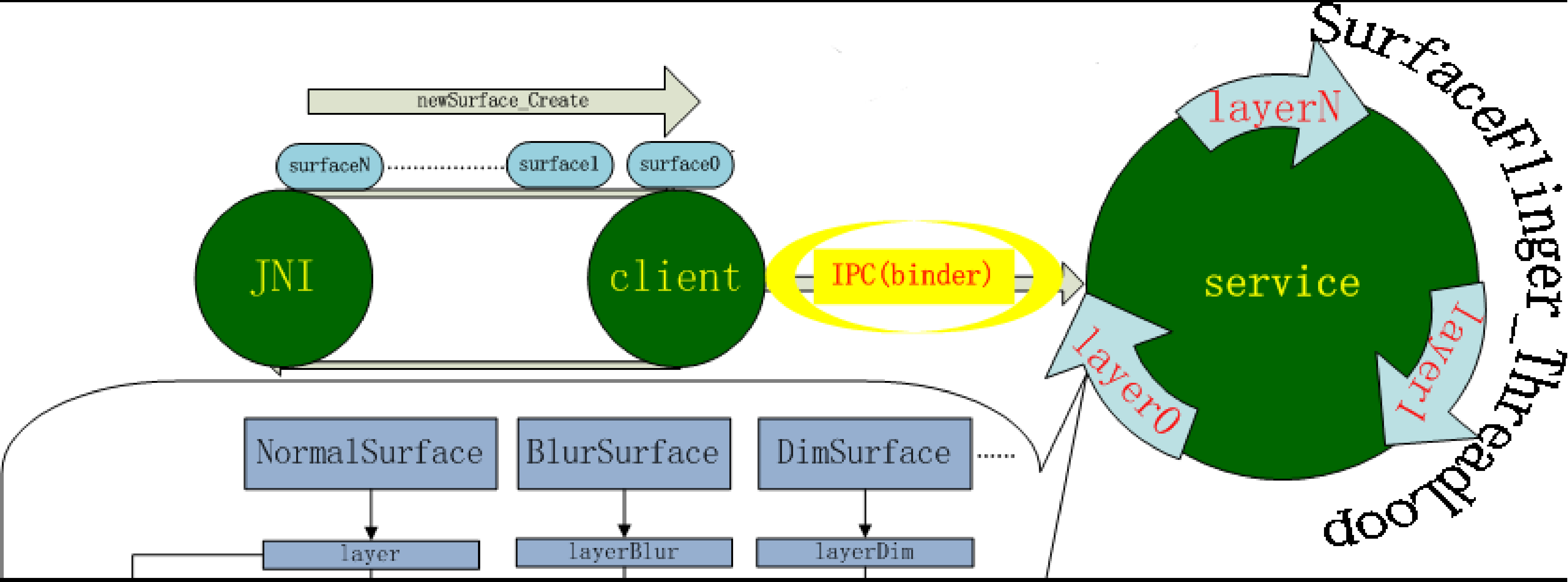
Source: frameworks/base/core/java/android/view/Surface.java

- /* **Handle on to a raw buffer that is being managed by the screen compositor** */

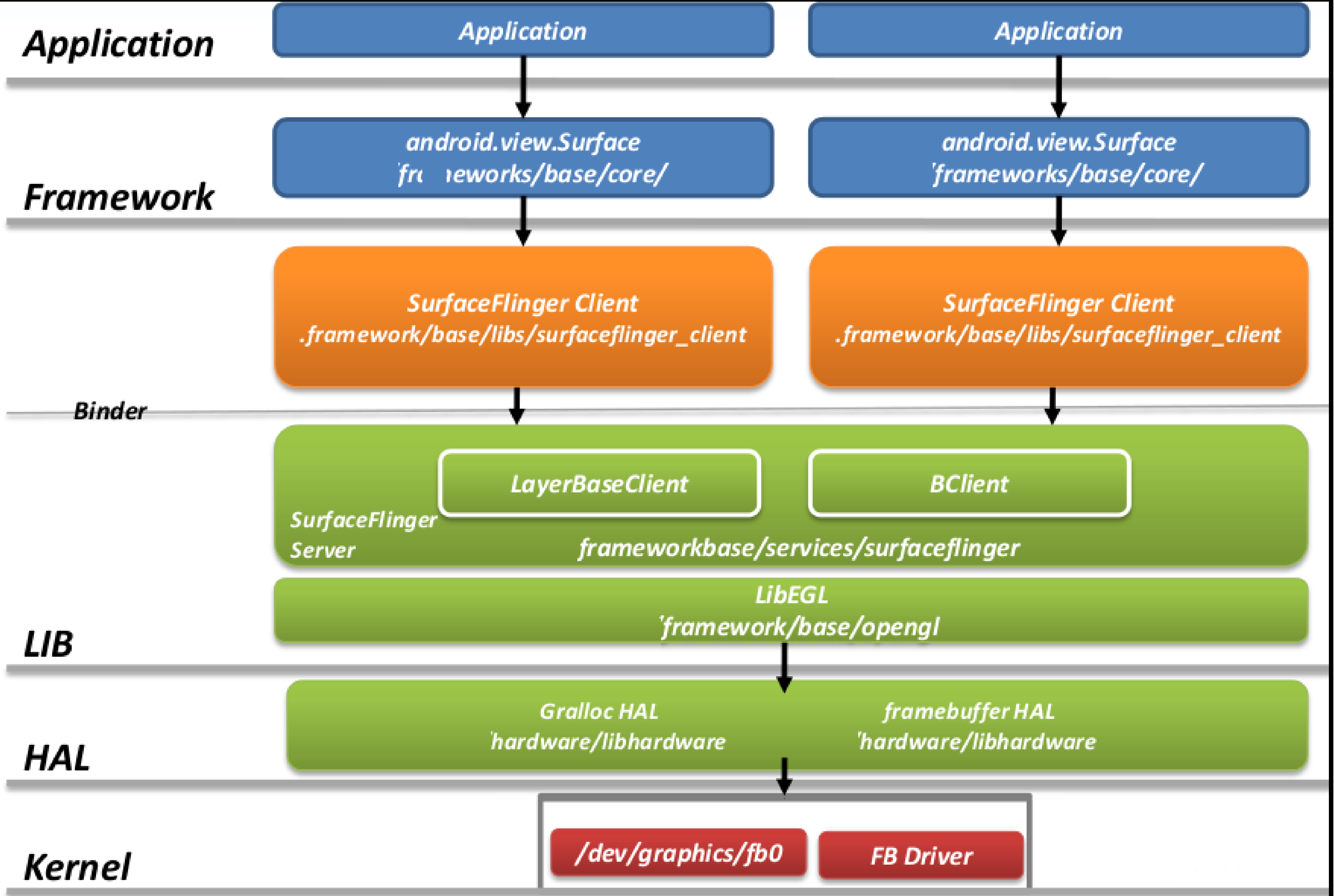
```
public class Surface implements Parcelable {
    public Surface() {
        mCanvas = new CompatibleCanvas();
    }
    private class CompatibleCanvas
                extends Canvas { /* ... */ }
}
```

Surface instances can be written to and restored from a Parcel.

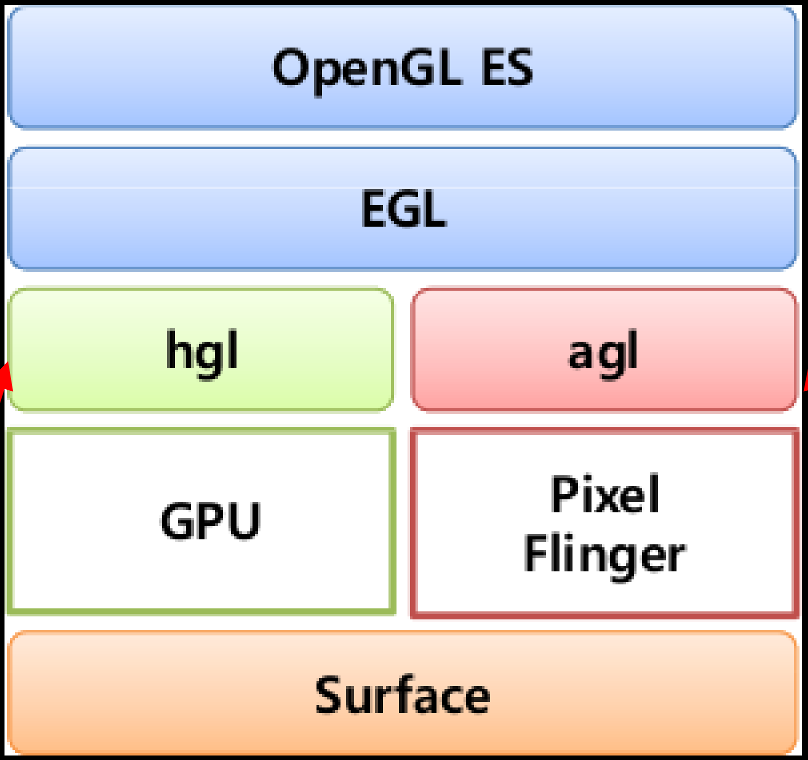

"flatten"
"unflatten"
transmit

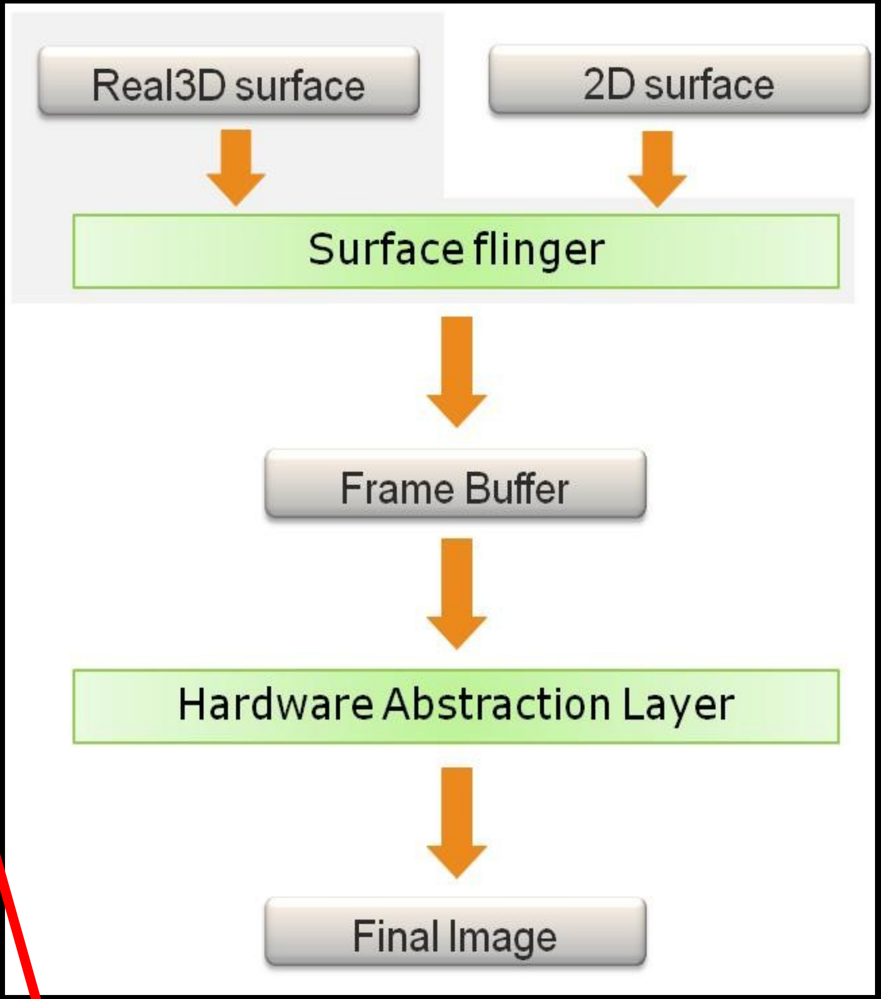

newSurface_Create
surfaceN
surface1
surface0
JNI
client
IPC(binder)
service
layerN
layer0
layer1
SurfaceFlinger_Threadloop
NormalSurface
BlurSurface
DimSurface
layer
layerBlur
layerDim

from SurfaceFlinger to Framebuffer



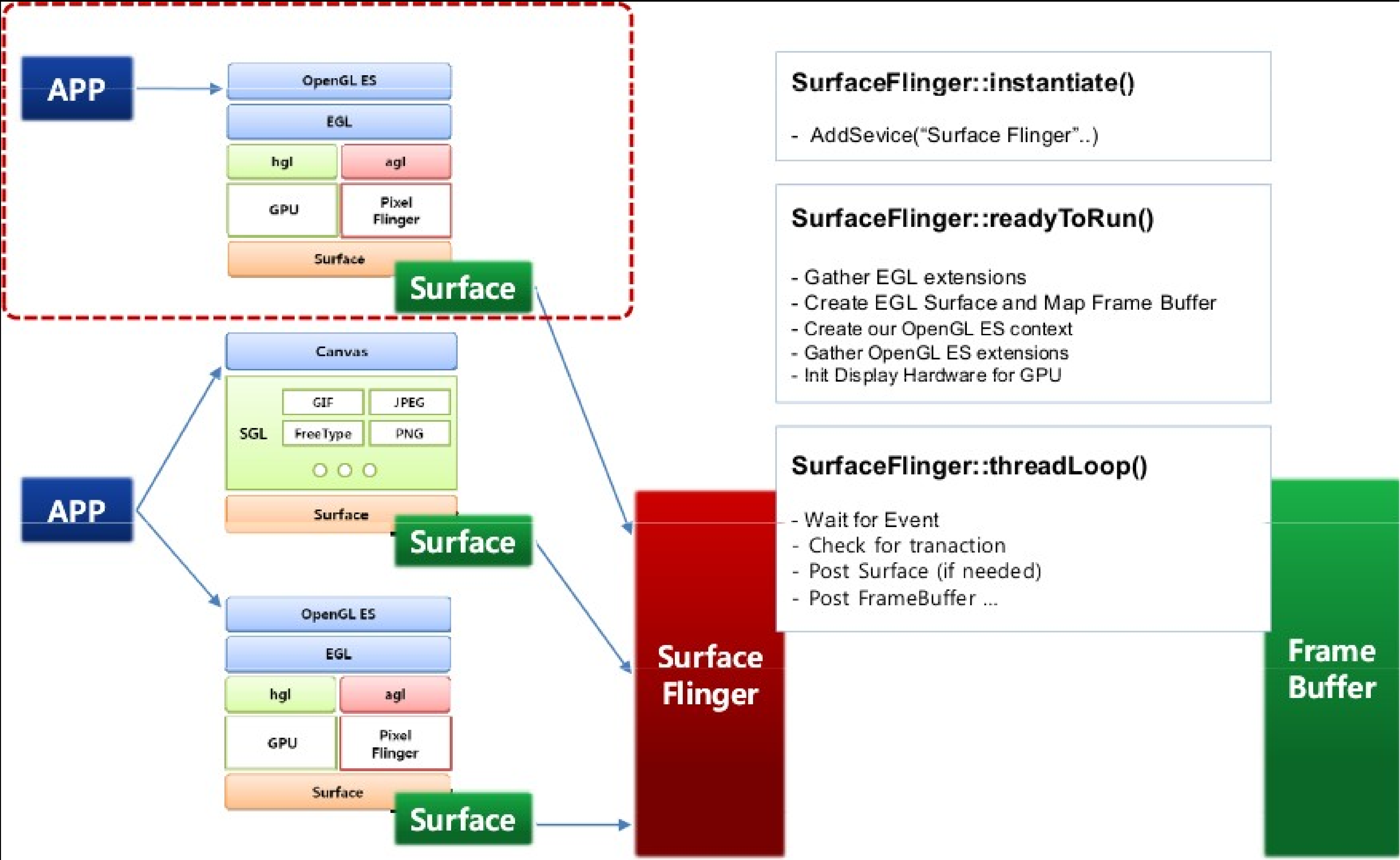
from EGL to SurfaceFlinger





hgl = hardware OpenGL|ES

agl = android software OpenGL|ES renderer



SurfaceFlinger::instantiate()

- AddSevice("Surface Flinger"..)

SurfaceFlinger::readyToRun()

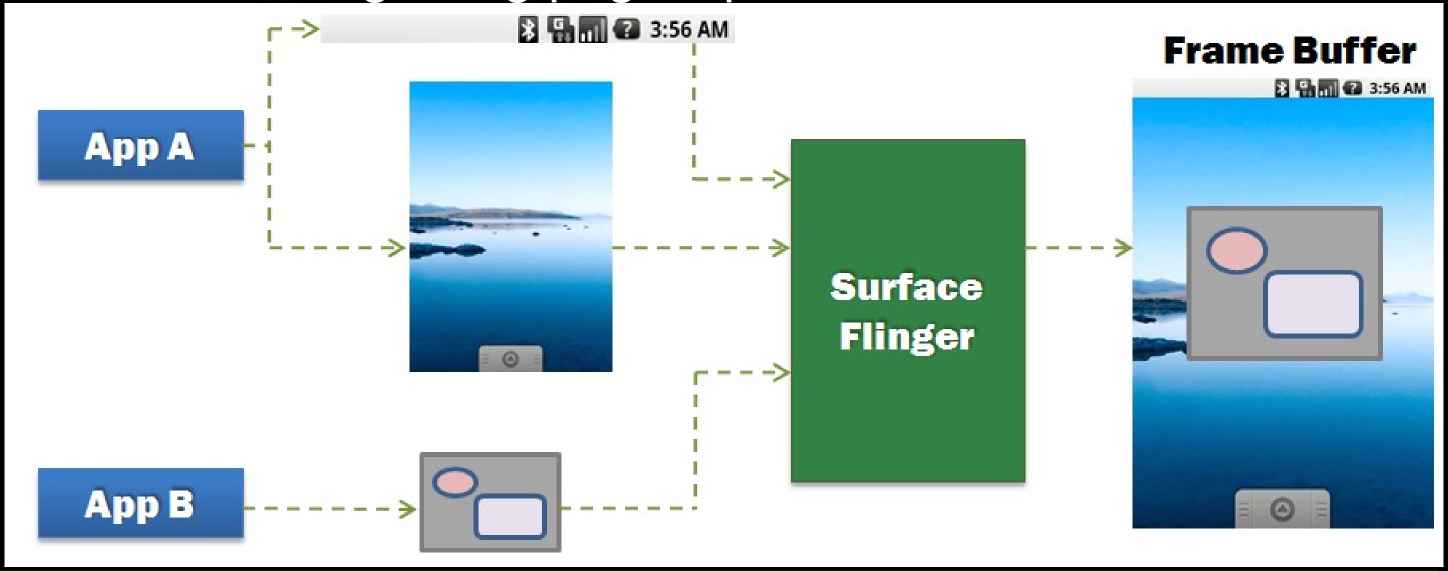
- Gather EGL extensions
- Create EGL Surface and Map Frame Buffer
- Create our OpenGL ES context
- Gather OpenGL ES extensions
- Init Display Hardware for GPU

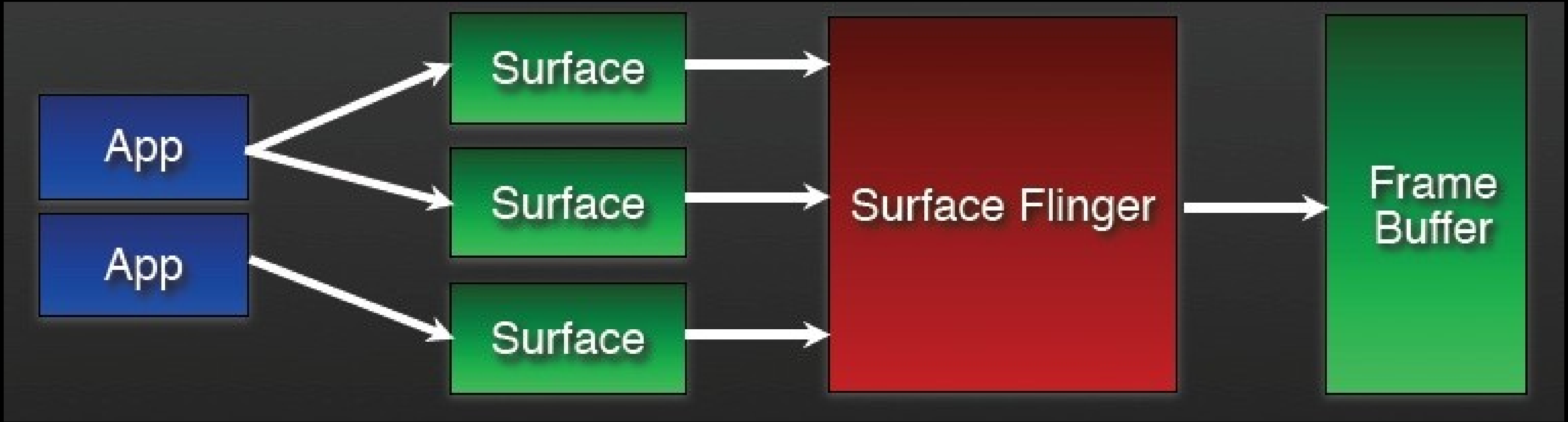
SurfaceFlinger::threadLoop()

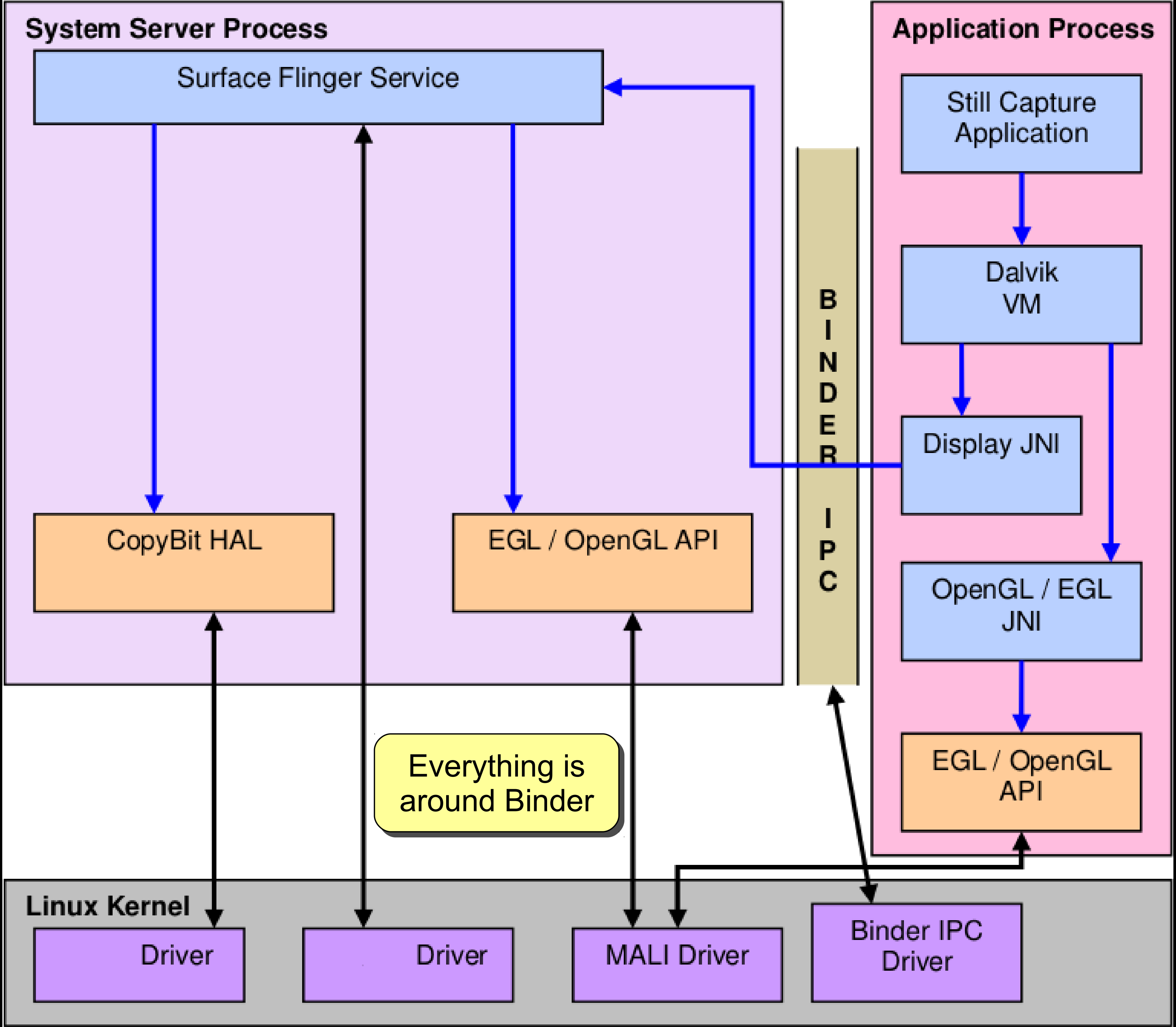
- Wait for Event
- Check for tranaction
- Post Surface (if needed)
- Post FrameBuffer ...

Android SurfaceFlinger

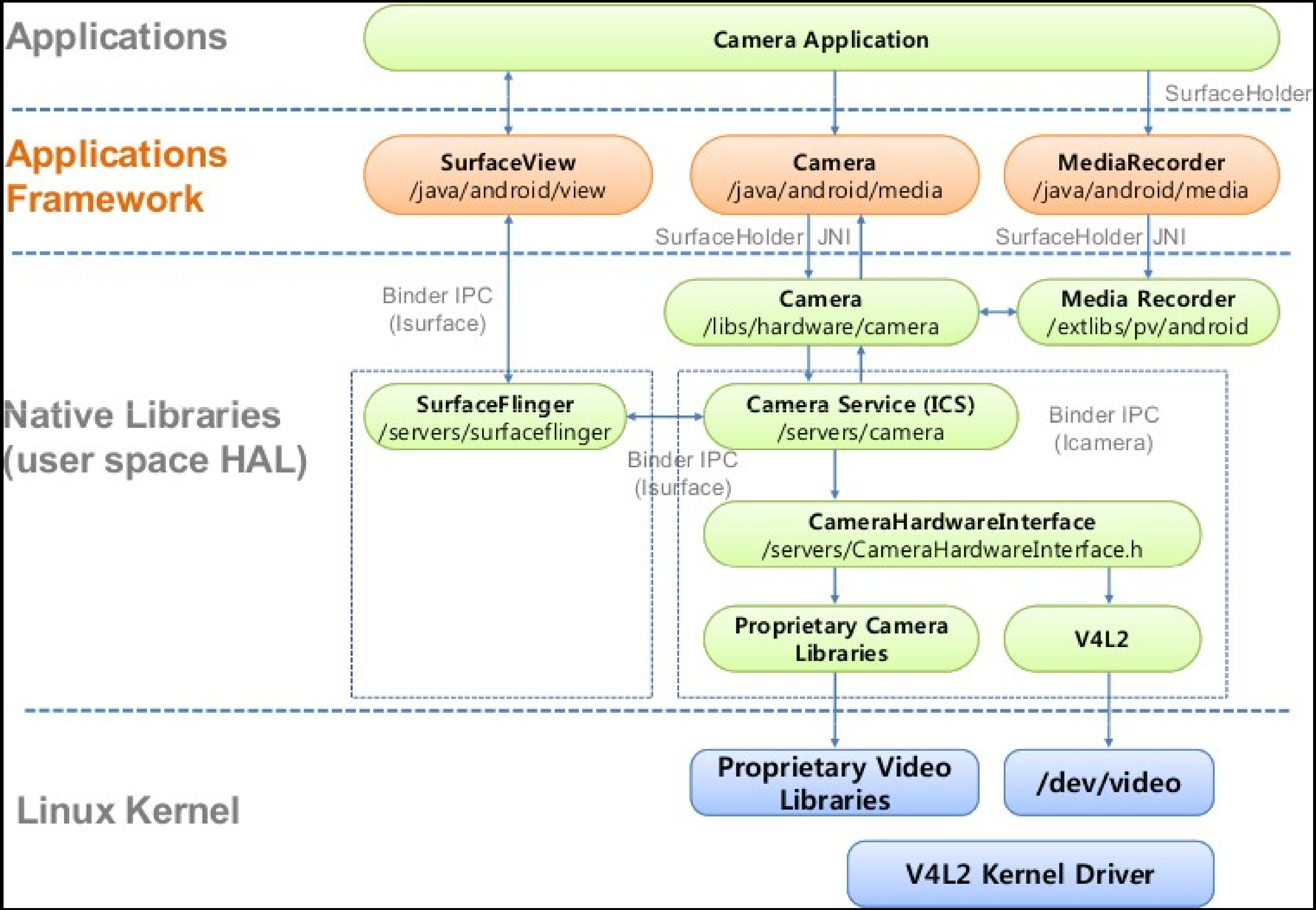
- Properties
  - Can combine 2D/3D surfaces and surfaces from multiple applications
  - Surfaces passed as buffers via Binder IPC calls
  - Can use OpenGL ES and 2D hardware accelerator for its compositions
    - Double-buffering using page-flip





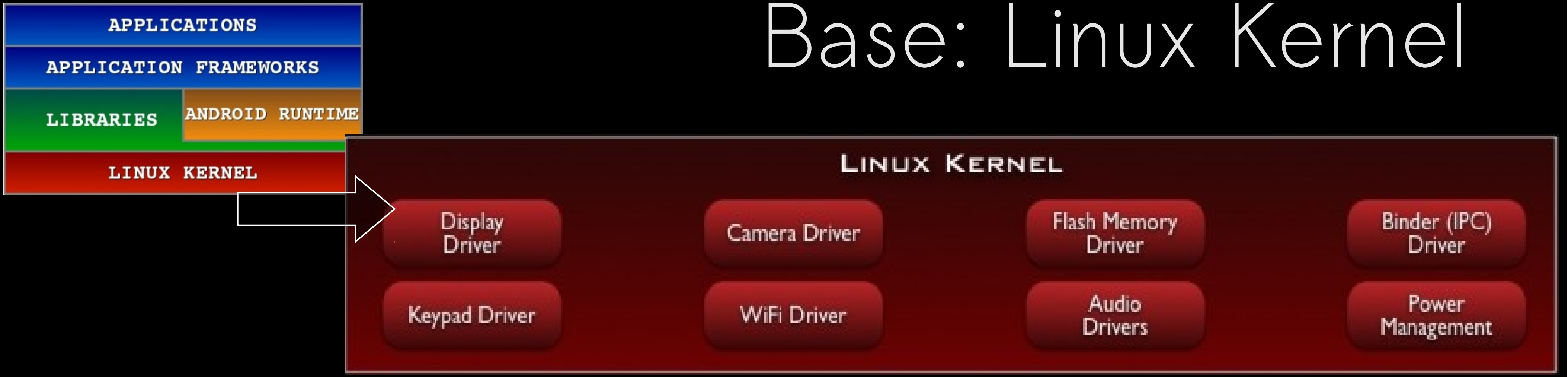

System Server Process
Surface Flinger Service
CopyBit HAL
EGL / OpenGL API
BINDER IPC
Application Process
Still Capture Application
Dalvik VM
Display JNI
OpenGL / EGL JNI
EGL / OpenGL API
Everything is around Binder
Linux Kernel
Driver
Driver
MALI Driver
Binder IPC Driver

Camera + SurfaceFlinger + Binder


Applications
Camera Application
SurfaceHolder
Applications Framework
SurfaceView /java/android/view
Camera /java/android/media
MediaRecorder /java/android/media
SurfaceHolder
JNI
SurfaceHolder
JNI
Binder IPC (Isurface)
Camera /libs/hardware/camera
Media Recorder /extlibs/pv/android
Native Libraries (user space HAL)
SurfaceFlinger /servers/surfaceflinger
Camera Service (ICS) /servers/camera
Binder IPC (Icamera)
Binder IPC (Isurface)
CameraHardwareInterface /servers/CameraHardwareInterface.h
Proprietary Camera Libraries
V4L2
Linux Kernel
Proprietary Video Libraries
/dev/video
V4L2 Kernel Driver

Binder use case: Android Power Management

Base: Linux Kernel

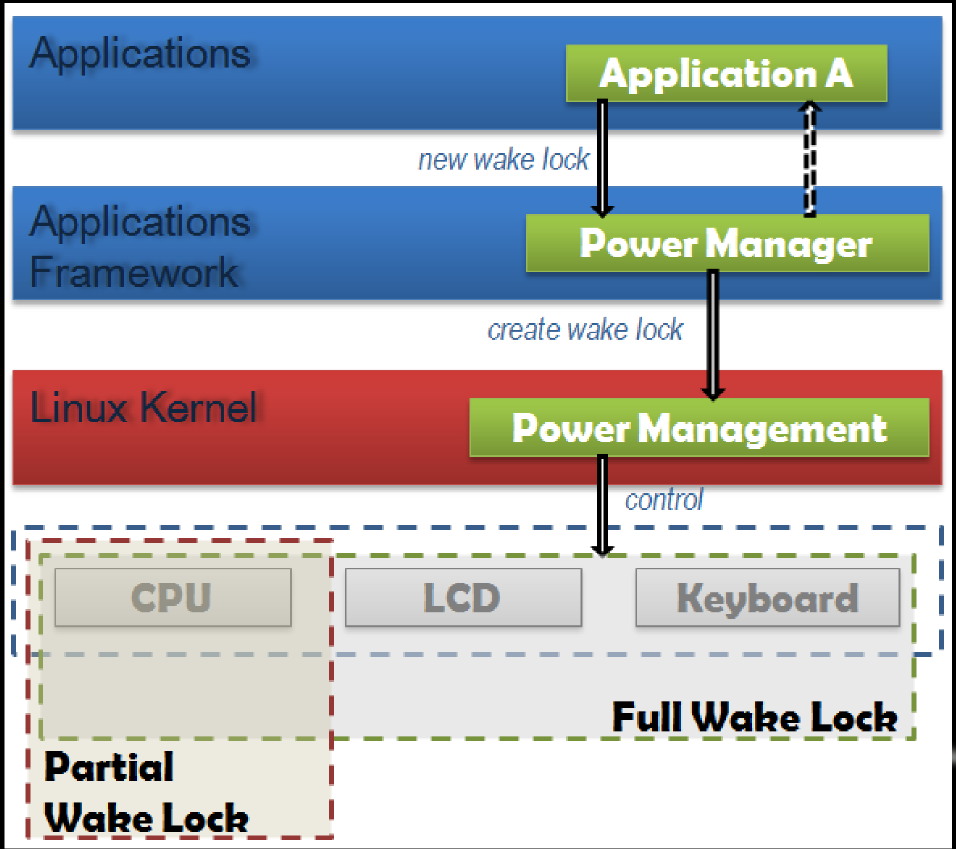


- Android does rely on Linux Kernel for core system services
  - Memory/Process Management
  - Device Driver Model
  - sysfs, kobject/uevent, netlink
- Android Kernel extensions
  - Binder
  - android_power
    - /sys/android_power/, /sys/power/

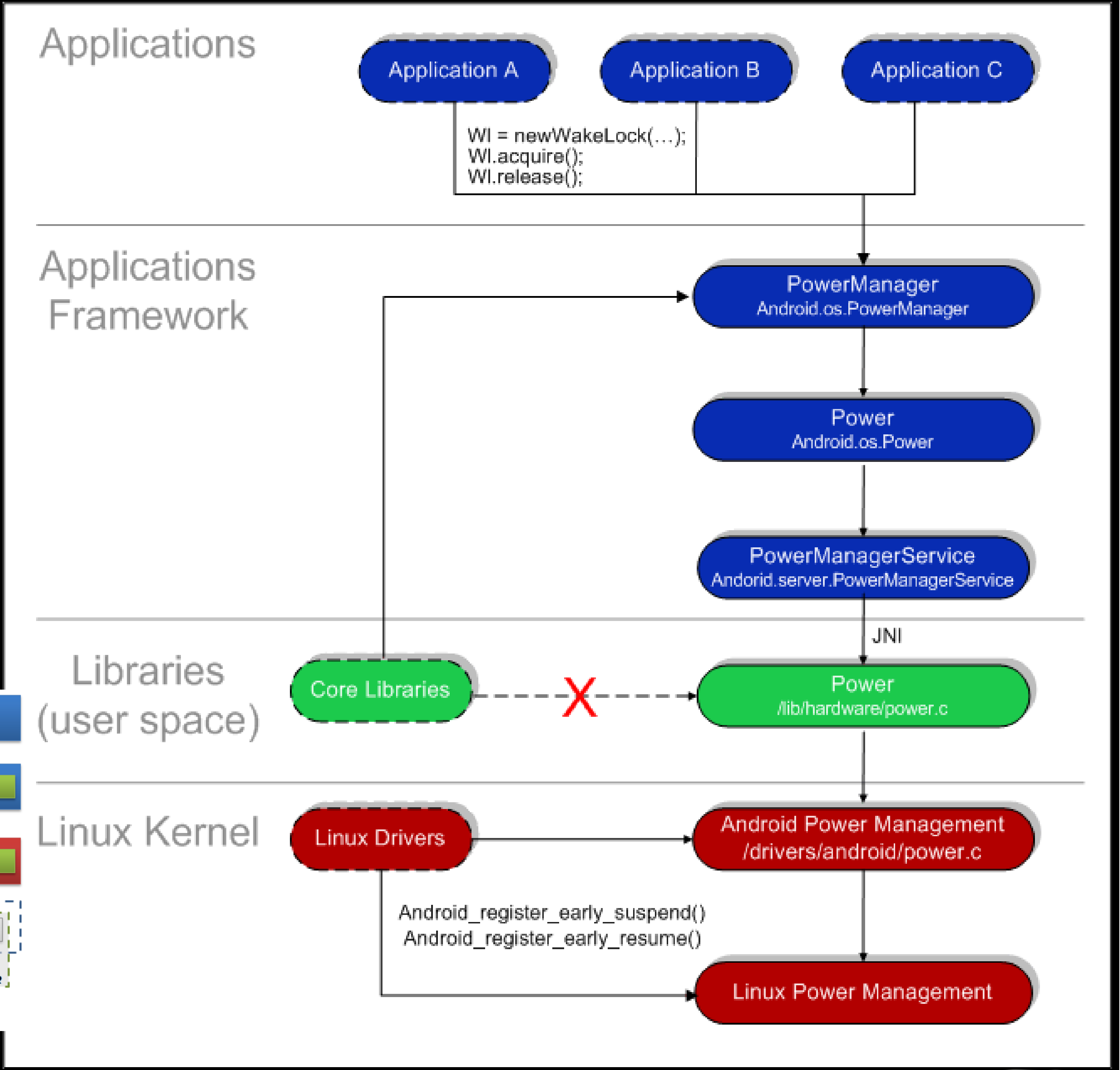
Key Idea: Android attempts to provide an abstraction layer between hardware and the related software stack.

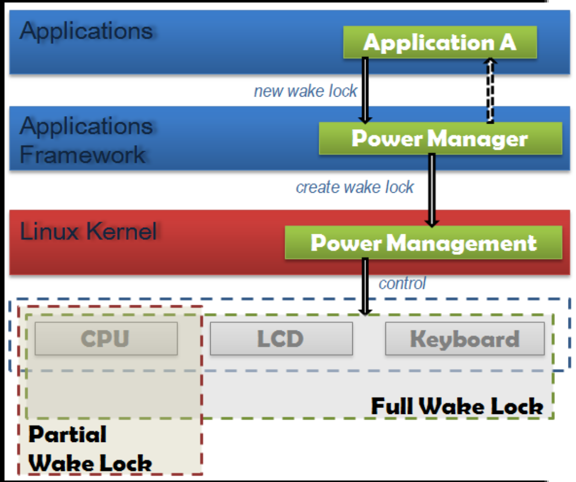
Android's PM Concepts

- Android PM is built on top of standard Linux Power Management.
- It can support more aggressive PM, but looks fairly simple now.
- Components make requests to keep the power on through "**Wake Locks**".
  - PM does support several types of "Wake Locks".

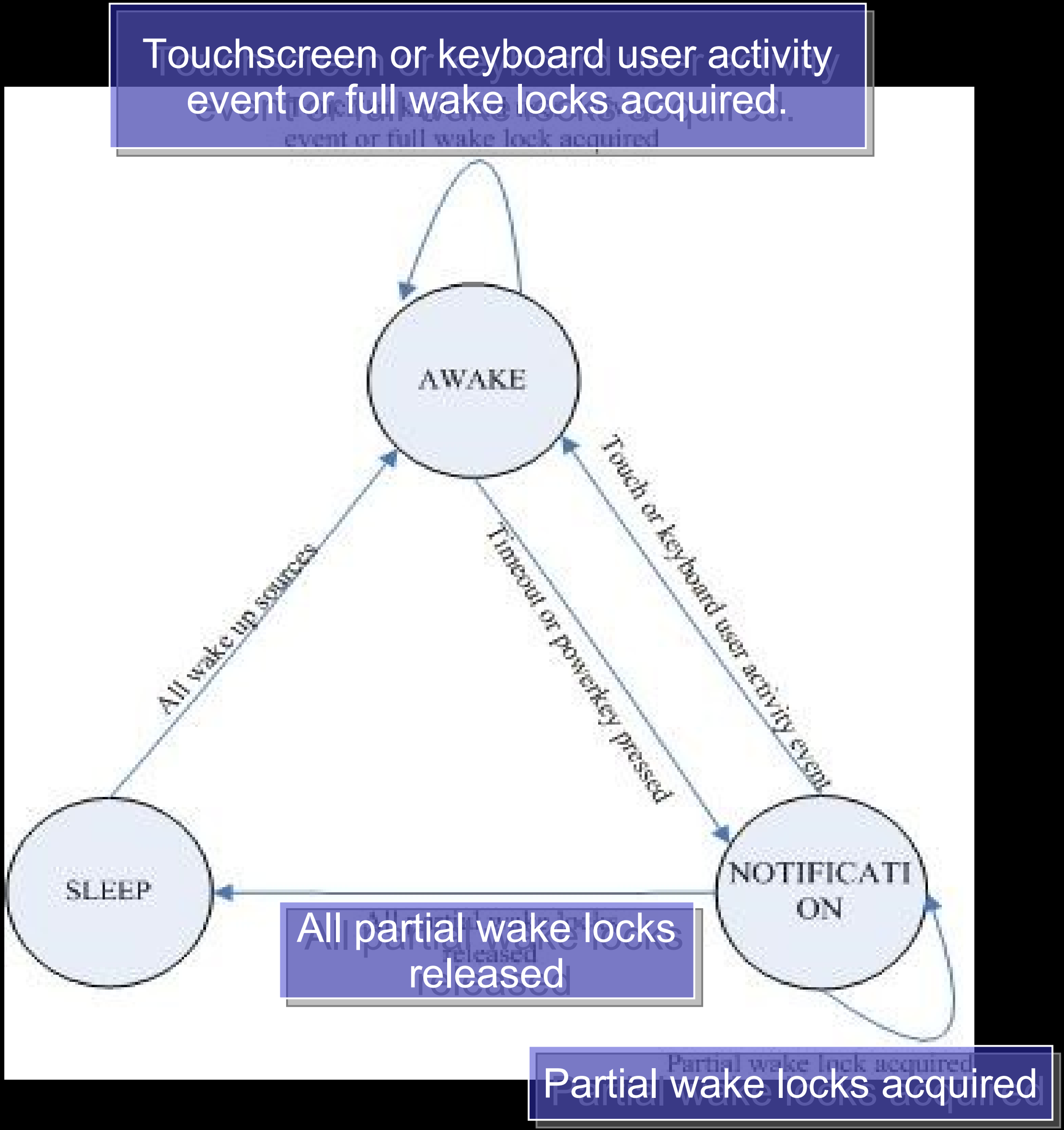


- If there are no active wake locks, CPU will be turned off.
- If there is are partial wake locks, screen and keyboard will be turned off.

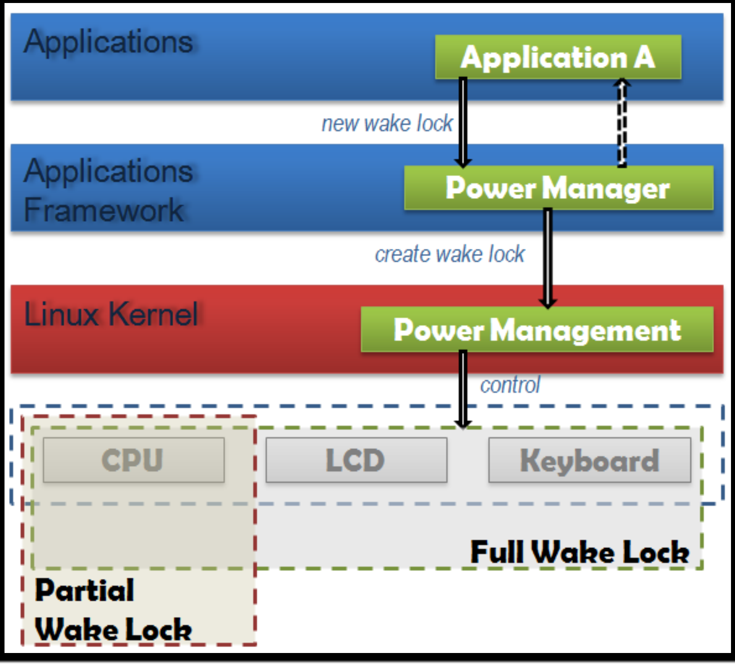

Applications
Application A
Application B
Application C
Wl = newWakeLock(…);
Wl.acquire();
Wl.release();
Applications Framework
PowerManager
Android.os.PowerManager
Power
Android.os.Power
PowerManagerService
Andorid.server.PowerManagerService
JNI
Libraries (user space)
Core Libraries
X
Power
/lib/hardware/power.c
Linux Kernel
Linux Drivers
Android Power Management
/drivers/android/power.c
Android_register_early_suspend()
Android_register_early_resume()
Linux Power Management

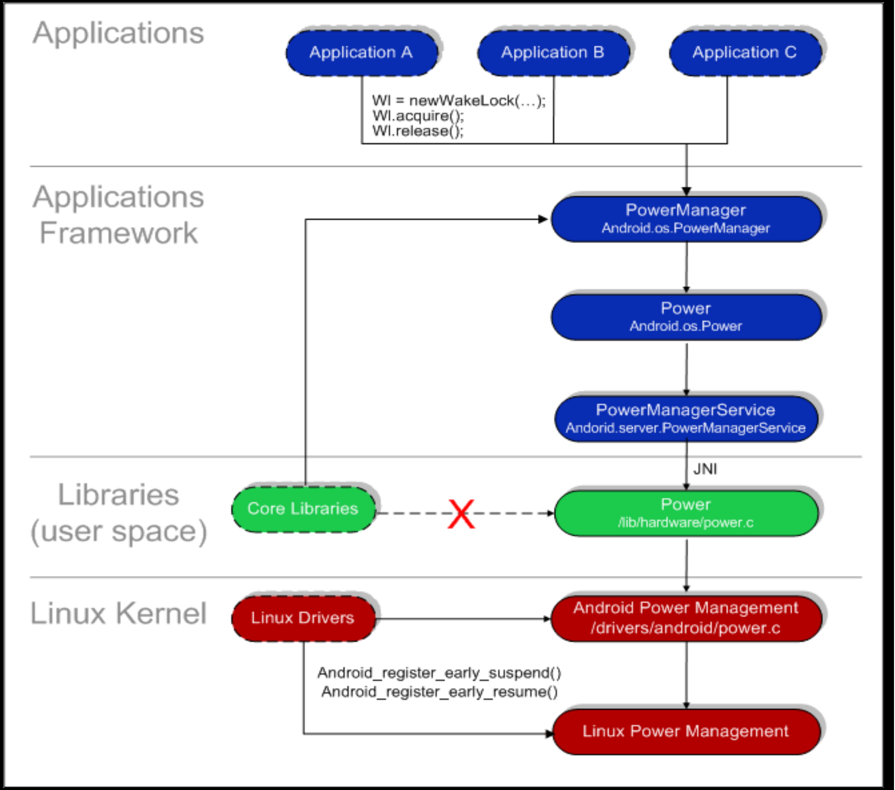

Applications
Application A
new wake lock
Applications Framework
Power Manager
create wake lock
Linux Kernel
Power Management
control
CPU
LCD
Keyboard
Full Wake Lock
Partial Wake Lock

PM State Machine



Touchscreen or keyboard user activity event or full wake locks acquired.
event or full wake lock acquired
AWAKE
All wake up sources
Timeout or powerkey pressed
Touch or keyboard user activity event
SLEEP
NOTIFICATION
All partial wake locks released
Partial wake locks acquired
Partial wake lock acquired

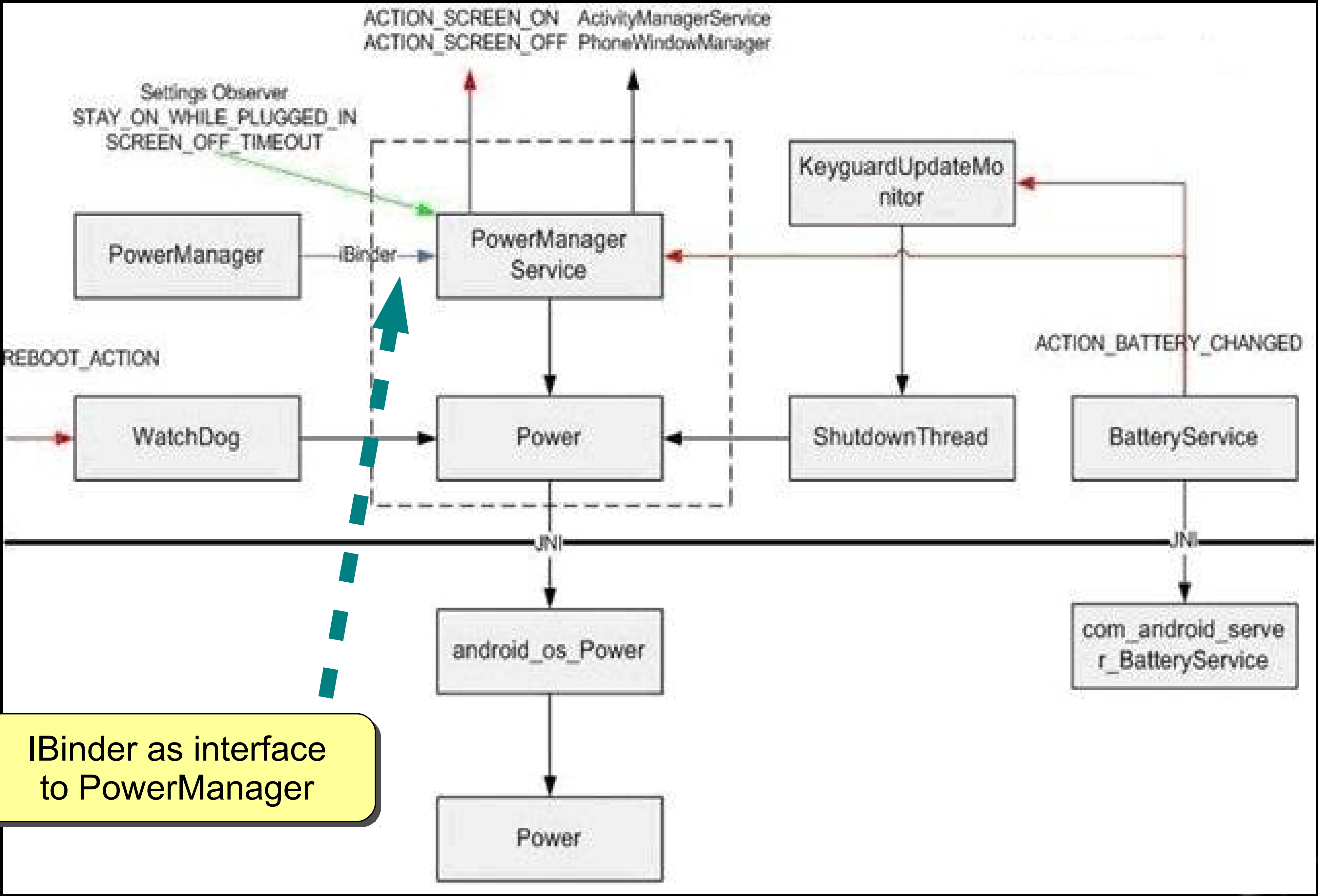




```
Wl = newWakeLock(…);
Wl.acquire();
Wl.release();
```

```
Android_register_early_suspend()
Android_register_early_resume()
```

Design and Implementation



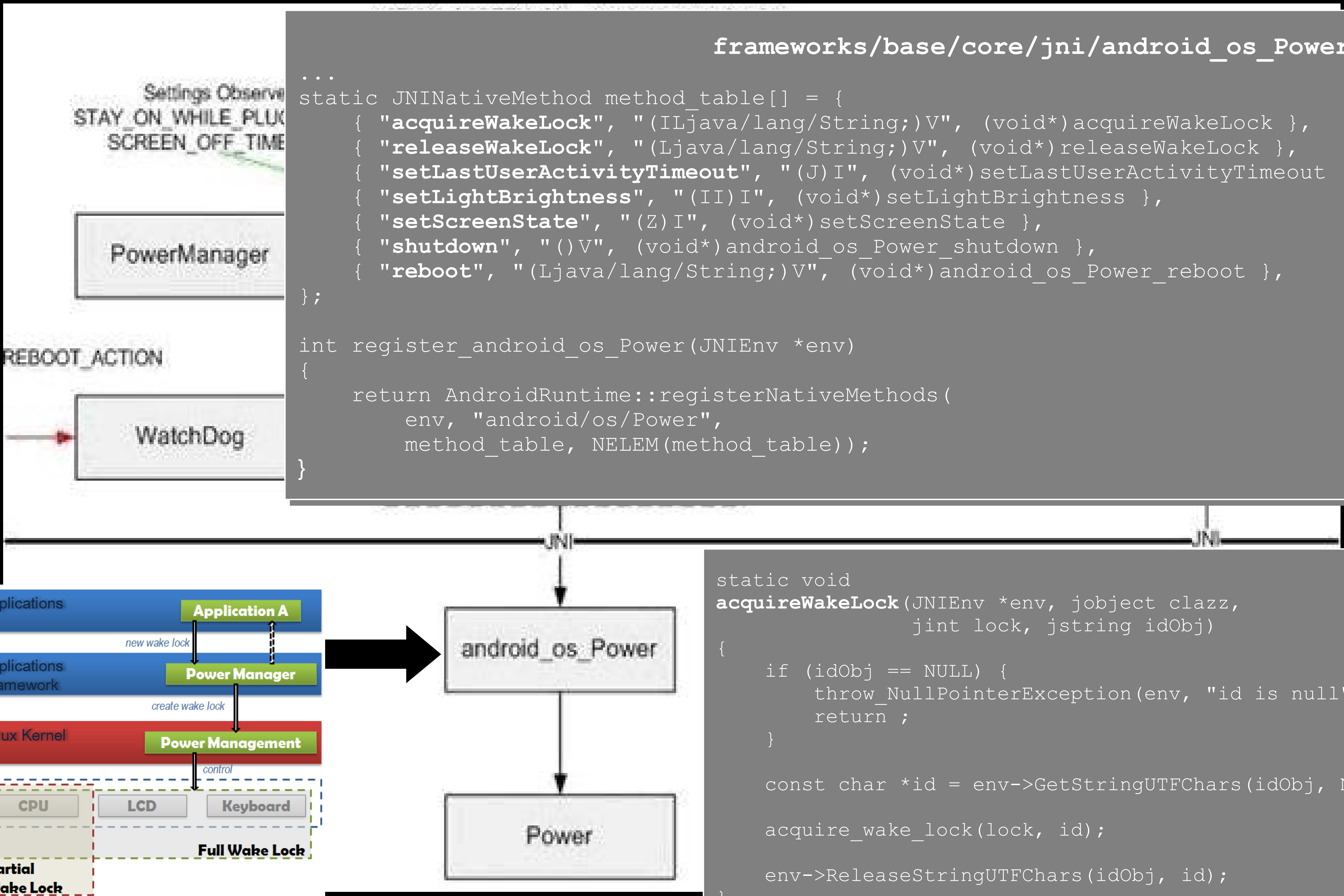
IBinder as interface to PowerManager

Sample WakeLocks usage: AudioFlinger

- File frameworks/base/services/audioflinger/AudioFlinger.cpp

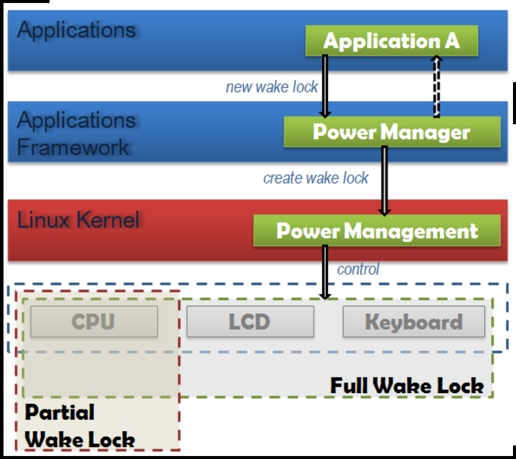
```
void AudioFlinger::ThreadBase::acquireWakeLock_l() {
    if (mPowerManager == 0) {
        sp<IBinder> binder =
            defaultServiceManager()->checkService(String16("power"));
        if (binder == 0) {
            LOGW("Thread %s can't connect to the PM service", mName);
        } else {
            mPowerManager = interface_cast<IPowerManager>(binder);
            binder->linkToDeath(mDeathRecipient);
        }
    }
    if (mPowerManager != 0) {
        sp<IBinder> binder = new BBinder();
        status_t status =
            mPowerManager->acquireWakeLock(POWERMANAGER_PARTIAL_WAKE_LOCK,
                                           binder, String16(mName));
        if (status == NO_ERROR) { mWakeLockToken = binder; }
        LOGV("acquireWakeLock_l() %s status %d", mName, status);
    }
}
```

android_os_Power



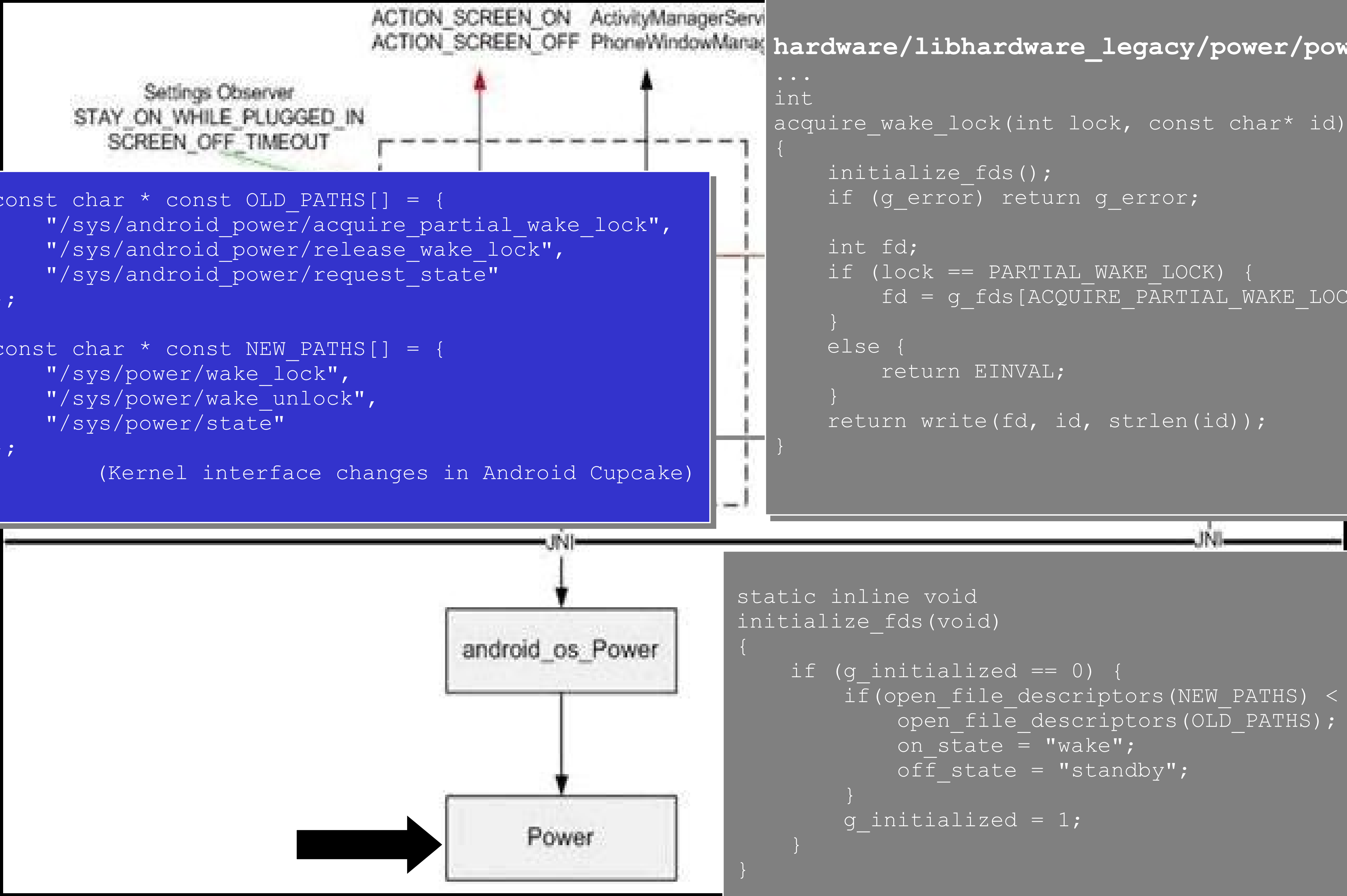
frameworks/base/core/jni/android_os_Power.cpp

```
...
static JNINativeMethod method_table[] = {
    { "acquireWakeLock", "(ILjava/lang/String;)V", (void*)acquireWakeLock },
    { "releaseWakeLock", "(Ljava/lang/String;)V", (void*)releaseWakeLock },
    { "setLastUserActivityTimeout", "(J)I", (void*)setLastUserActivityTimeout },
    { "setLightBrightness", "(II)I", (void*)setLightBrightness },
    { "setScreenState", "(Z)I", (void*)setScreenState },
    { "shutdown", "()V", (void*)android_os_Power_shutdown },
    { "reboot", "(Ljava/lang/String;)V", (void*)android_os_Power_reboot },
};

int register_android_os_Power(JNIEnv *env)
{
    return AndroidRuntime::registerNativeMethods(
        env, "android/os/Power",
        method_table, NELEM(method_table));
}
```



```
static void
acquireWakeLock(JNIEnv *env, jobject clazz,
                jint lock, jstring idObj)
{
    if (idObj == NULL) {
        throw_NullPointerException(env, "id is null");
        return ;
    }

    const char *id = env->GetStringUTFChars(idObj, NULL);

    acquire_wake_lock(lock, id);

    env->ReleaseStringUTFChars(idObj, id);
}
```

Power



```
const char * const OLD_PATHS[] = {
    "/sys/android_power/acquire_partial_wake_lock",
    "/sys/android_power/release_wake_lock",
    "/sys/android_power/request_state"
};

const char * const NEW_PATHS[] = {
    "/sys/power/wake_lock",
    "/sys/power/wake_unlock",
    "/sys/power/state"
};
        (Kernel interface changes in Android Cupcake)
```

hardware/libhardware_legacy/power/power.c

```
...
int
acquire_wake_lock(int lock, const char* id)
{
    initialize_fds();
    if (g_error) return g_error;

    int fd;
    if (lock == PARTIAL_WAKE_LOCK) {
        fd = g_fds[ACQUIRE_PARTIAL_WAKE_LOCK];
    }
    else {
        return EINVAL;
    }
    return write(fd, id, strlen(id));
}
```

```
static inline void
initialize_fds(void)
{
    if (g_initialized == 0) {
        if(open_file_descriptors(NEW_PATHS) < 0) {
            open_file_descriptors(OLD_PATHS);
            on_state = "wake";
            off_state = "standby";
        }
        g_initialized = 1;
    }
}
```

Android PM Kernel APIs

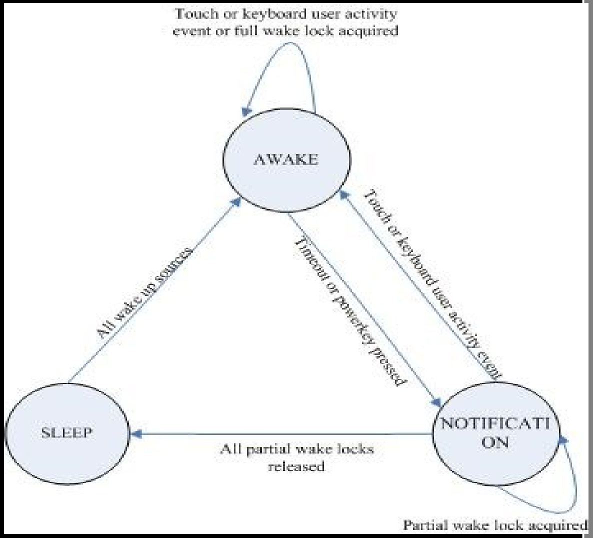
- Source code
  - kernel/power/userwake.c
  - /kernel/power/wakelock.c

```
static int power_suspend_late(
     struct platform_device *pdev,
     pm_message_t state)
{
     int ret =
          has_wake_lock(WAKE_LOCK_SUSPEND) ?
          -EAGAIN : 0;
     return ret;
}

static struct platform_driver power_driver = {
     .driver.name = "power",
     .suspend_late = power_suspend_late,
};
static struct platform_device power_device = {
     .name = "power",
};
```

```
static long has_wake_lock_locked(int type)
{
     struct wake_lock *lock, *n;
     long max_timeout = 0;
     BUG_ON(type >= WAKE_LOCK_TYPE_COUNT);
     list_for_each_entry_safe(lock, n,
               &active_wake_locks[type], link) {
          if (lock->flags & WAKE_LOCK_AUTO_EXPIRE) {
               long timeout = lock->expires - jiffies;
               if (timeout <= 0)
                    expire_wake_lock(lock);
               else if (timeout > max_timeout)
                    max_timeout = timeout;
          } else
               return -1;
     }
     return max_timeout;
}

long has_wake_lock(int type)
{
     long ret;
     unsigned long irqflags;
     spin_lock_irqsave(&list_lock, irqflags);
     ret = has_wake_lock_locked(type);
     spin_unlock_irqrestore(&list_lock, irqflags);
     return ret;
}
```

Android PM Kernel APIs

- kernel/power/wakelock.c


Touch or keyboard user activity event or full wake lock acquired
AWAKE
All wake up sources
Timeout or powerkey pressed
Touch or keyboard user activity event
SLEEP
All partial wake locks released
NOTIFICATION
Partial wake lock acquired

```
static int __init wakelocks_init(void)
{
     int ret;
     int i;

     for (i = 0; i < ARRAY_SIZE(active_wake_locks); i++)
          INIT_LIST_HEAD(&active_wake_locks[i]);


     wake_lock_init(&main_wake_lock, WAKE_LOCK_SUSPEND, "main");
     wake_lock(&main_wake_lock);
     wake_lock_init(&unknown_wakeup, WAKE_LOCK_SUSPEND, "unknown_wakeups");

     ret = platform_device_register(&power_device);
     if (ret) {
          pr_err("wakelocks_init: platform_device_register failed\n");
          goto err_platform_device_register;
     }
     ret = platform_driver_register(&power_driver);
     if (ret) {
          pr_err("wakelocks_init: platform_driver_register failed\n");
          goto err_platform_driver_register;
     }

     suspend_work_queue = create_singlethread_workqueue("suspend");
     if (suspend_work_queue == NULL) {
          ret = -ENOMEM;
          goto err_suspend_work_queue;
     }
```

Review

- Low-level parts
- Process, Thread, system call
- Memory operations
- Binder IPC
- interactions with frameworks

Reference

- Inter-process communication of Android, Tetsuyuki Kobayashi
- 淺談 Android 系統進程間通信（ IPC ）機制 Binder 中的 Server 和 Client 獲得 Service Manager 接口之路

  http://blog.goggb.com/?post=1580
- Service 與 Android 系統設計，宋寶華
- Android Binder – Android Interprocess Communication, Thorsten Schreiber

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