G53MDP
Mobile Device Programming

Binder and IPC

Bound Services

- If not explicitly started, will be started by the o/s
  - …when something binds to it
  - Then stopped if everything unbinds from it
  - What is it **is** explicitly started?
- Provide an interface for clients (Activities) to interact with a Service
  - Provide a programmatic interface for clients
  - Fast *and* stable?
- **Extending** the Binder class
  - Return an interface via the onBind method
  - Only for a Service used by the same application
    - Local Services only
      - i.e. the same process
    - Make method calls within the same JVM
- Binder object asynchronously provides a reference to the service that we can call methods on
  - Via *ServiceConnection*
  - Why asynchronous?
- *Making objects appear as if they exist in the local process*

Remote Services

- For communicating across process boundaries
  - i.e. using a Service belonging to a different application / process
  - Likely to be used by multiple processes at once
- Starting the service
  - Declare the service as *exported* in the Manifest
    - Explicit rather than implicit
    - More sophisticated permissions system later on
  - Must not use *implicit* Intents (why?)
    - Added in later Android SDK versions
- Communicating
  - Using a Messenger
    - Simplest implementation
    - C.f. using a Handler to talk between Threads
      - Queues Messages into a single Thread, handled sequentially
        - » Bundles of data instead of method calls
    - Messages must be Parcelable
    - Bi-directional communication
  - Defining an interface
    - Registering callbacks
    - System services

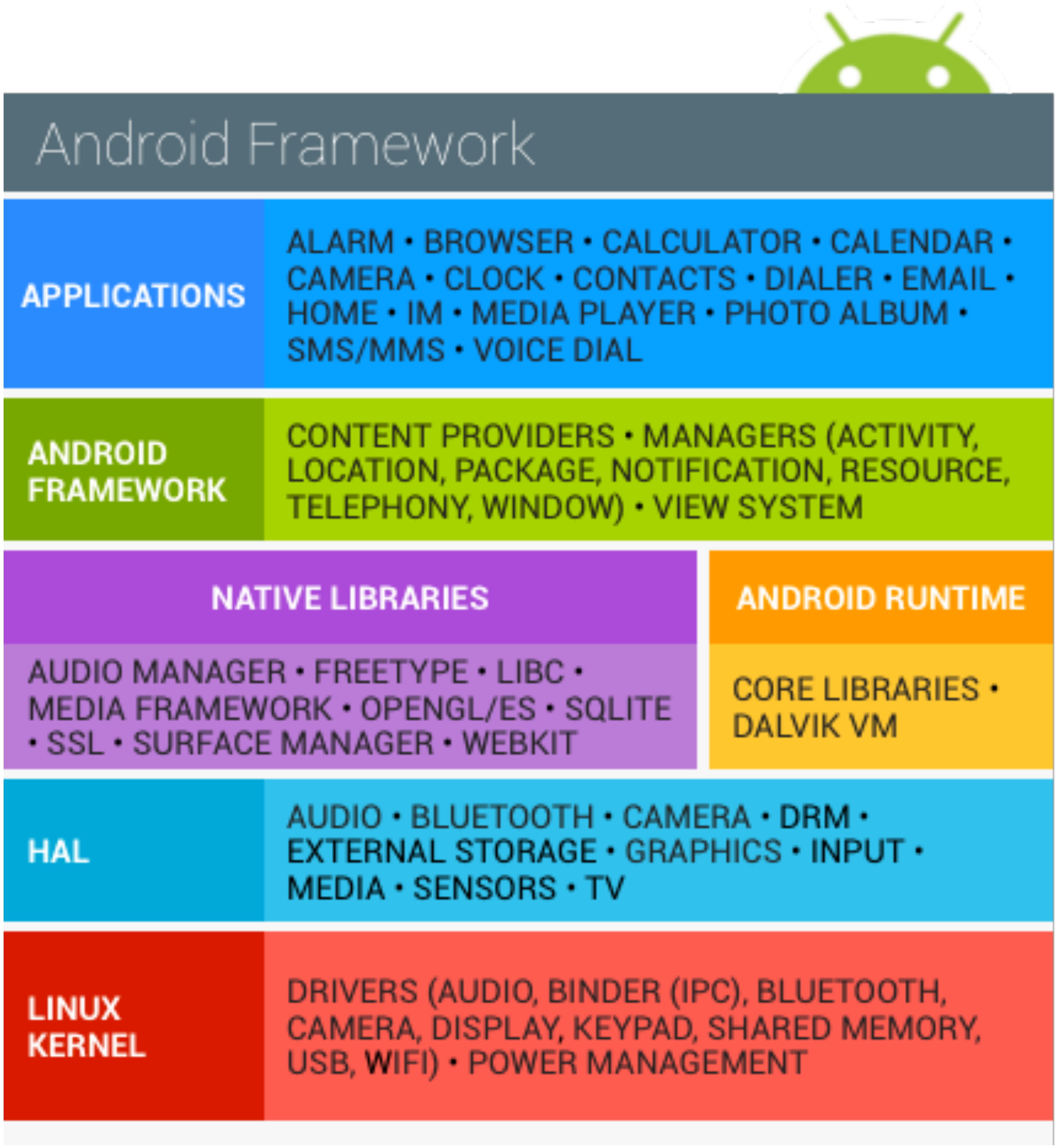
Parcelable

- Locally (same process) bound Services share the same process memory space
  - Easy to call methods, transfer objects / references between classes
- How should different processes talk to each other?
  - java.io.Serializable
    - Short-term persistence
    - Write object ID, field via reflection
    - Change the class / variable name, what happens?
    - Slow
  - Parcelable
    - Define a simple wire-protocol for writing primitives
      - Re-create an object by passing salient data (c.f. deep copy)
    - Immune to minor changes to class definitions
      - Same interface, different class
    - Supported by Android kernel driver
    - Fast!

Let’s have a look…

IPC

- Inter-process communication
- Each process has its own address space
  - Provides data isolation
  - Prevents direct interaction between different processes
    - However, often required for modularisation
- How can we communicate with a Service, or send an Intent?
- Binder
  - Underpins most Android communication
    - i.e. when we use various system capabilities
  - Kernel driver
    - Provides lightweight RPC (remote procedure calls), data passing
      - C.f. Linux/Unix signals / pipes / sockets etc
    - Reading and writing *Parcels* between processes
    - Process, user ID authority / trust
  - Per-process **thread pool** for handling requests
  - **Synchronous** calls between processes



Android Framework

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

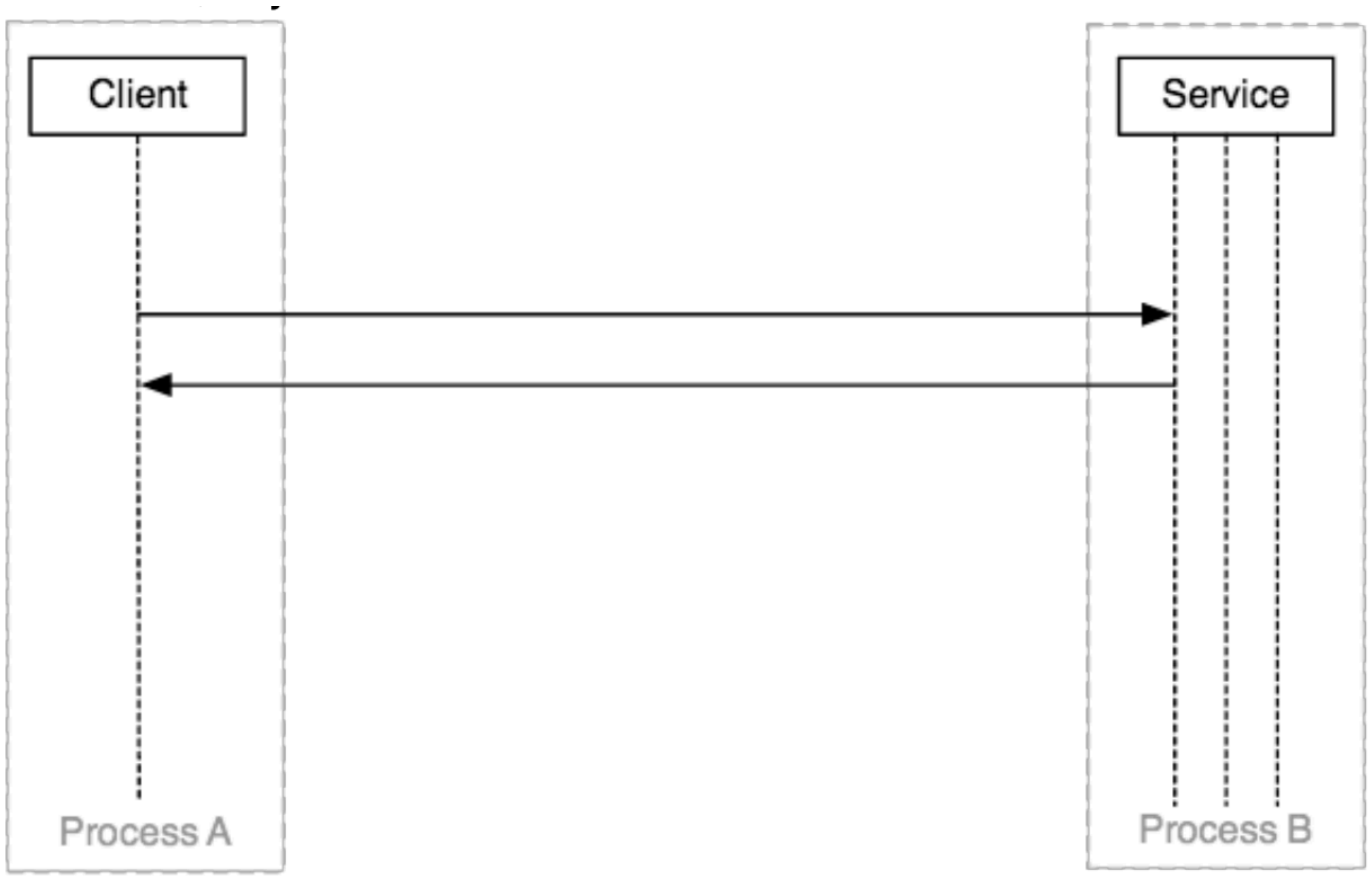
NATIVE LIBRARIES
AUDIO MANAGER • FREETYPE • LIBC • MEDIA FRAMEWORK • OPENGL/ES • SQLITE • SSL • SURFACE MANAGER • WEBKIT

ANDROID RUNTIME
CORE LIBRARIES • DALVIK VM

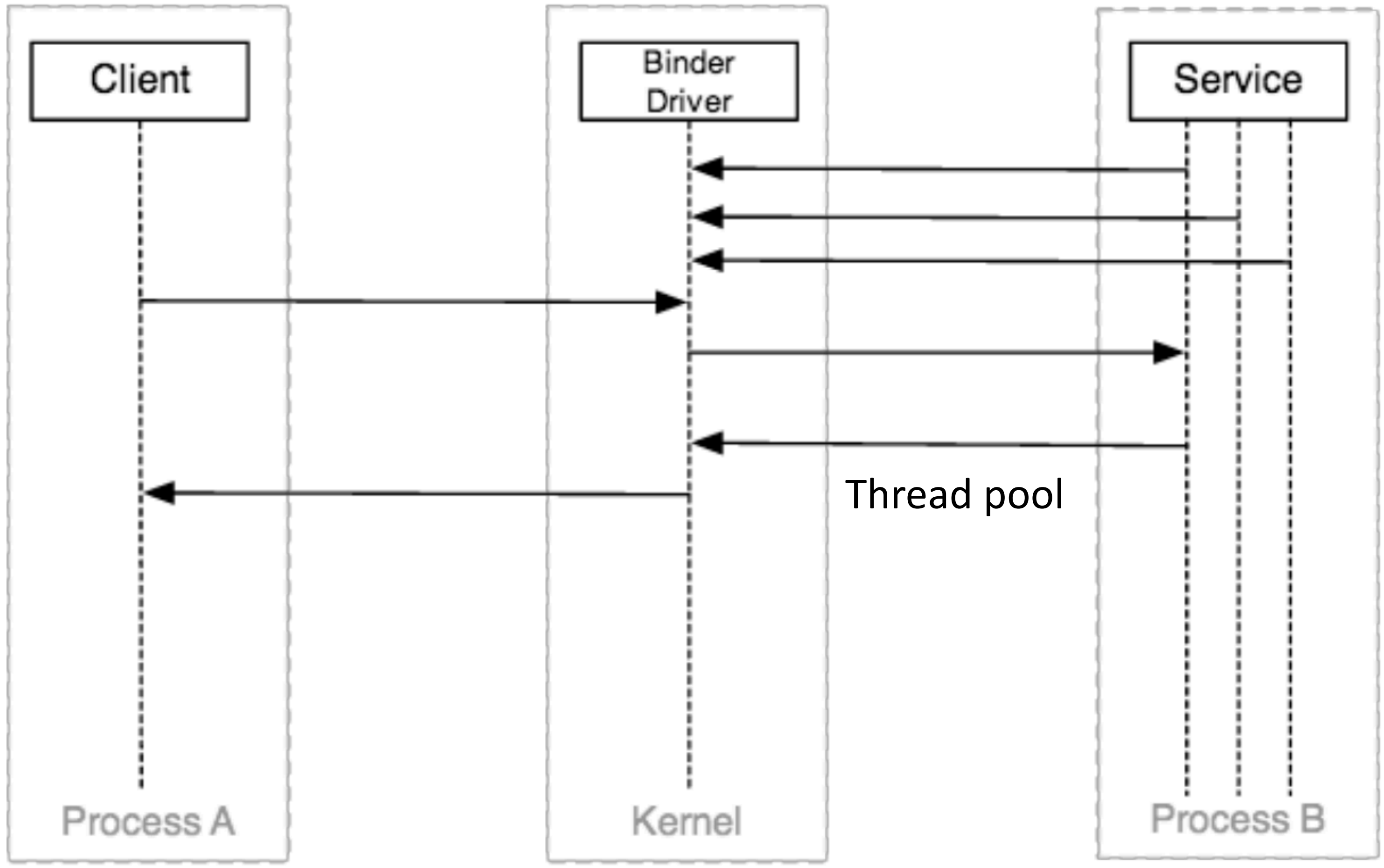
HAL
AUDIO • BLUETOOTH • CAMERA • DRM • EXTERNAL STORAGE • GRAPHICS • INPUT • MEDIA • SENSORS • TV

LINUX KERNEL
DRIVERS (AUDIO, BINDER (IPC), BLUETOOTH, CAMERA, DISPLAY, KEYPAD, SHARED MEMORY, USB, WIFI) • POWER MANAGEMENT

Ideal IPC



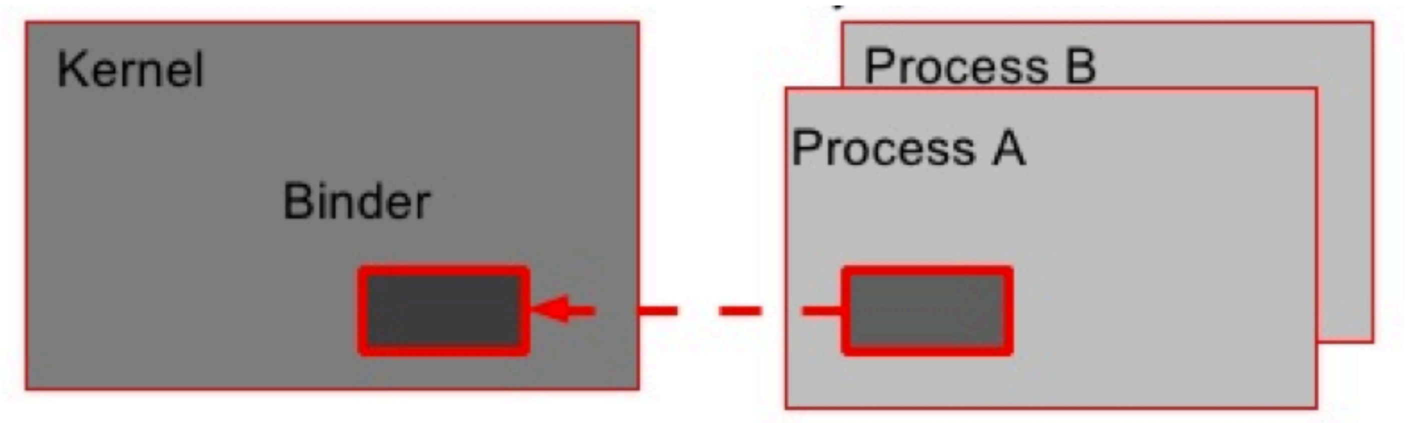
Binder as Intermediary



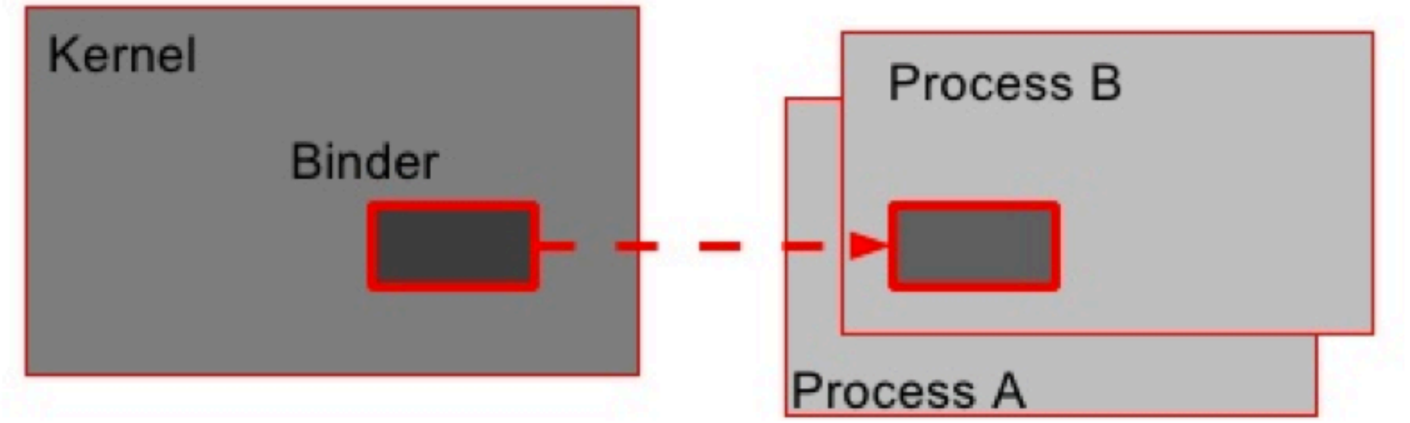
Binder Implementation

- API for apps
  - Written in Java
  - AIDL
  - Java API wrapper
    - Exposes the IBinder interface
    - Wraps the middleware layer
    - Parcelable object marshalling interface
- Middleware
  - Written in C++
  - Implements the user space (i.e. within a process) facilities of the Binder framework
  - Marshalling and unmarshalling of specific data to primitives
  - Provides interaction with the Binder kernel driver
- Kernel drivers
  - Written in C
  - Supports ioctl system calls from the middleware
  - Supports cross-process file operations, memory mapping
  - Thread pool for each service application for IPC
  - Mapping of objects between processes via copy_from_user, copy_to_user

Binder Transactions

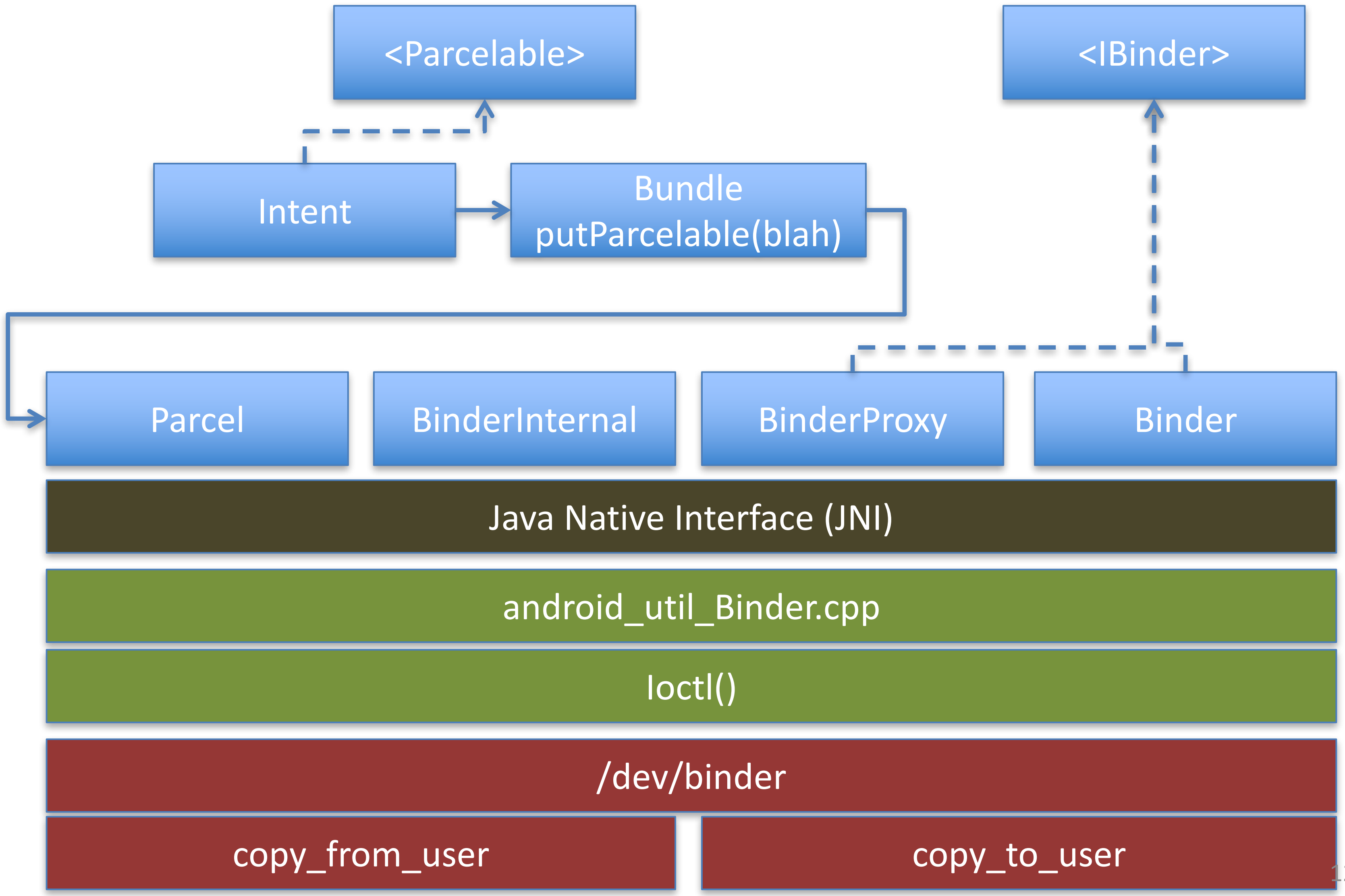


Copy memory by **copy_from _user**
Then, wake up process B

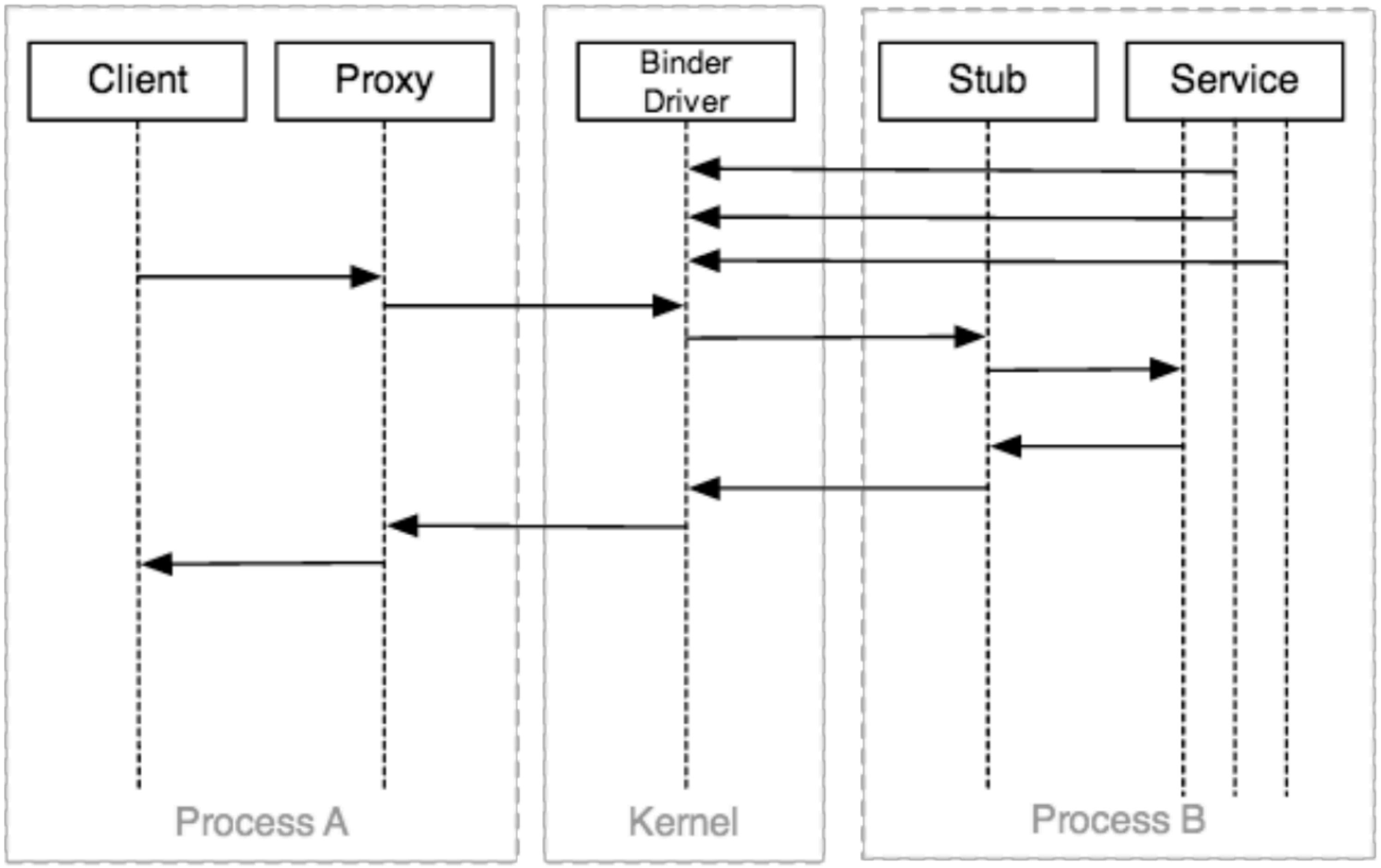


Copy memory by **copy_to_user**

Binder Implementation



Binder Abstraction



Remotely Bound Services

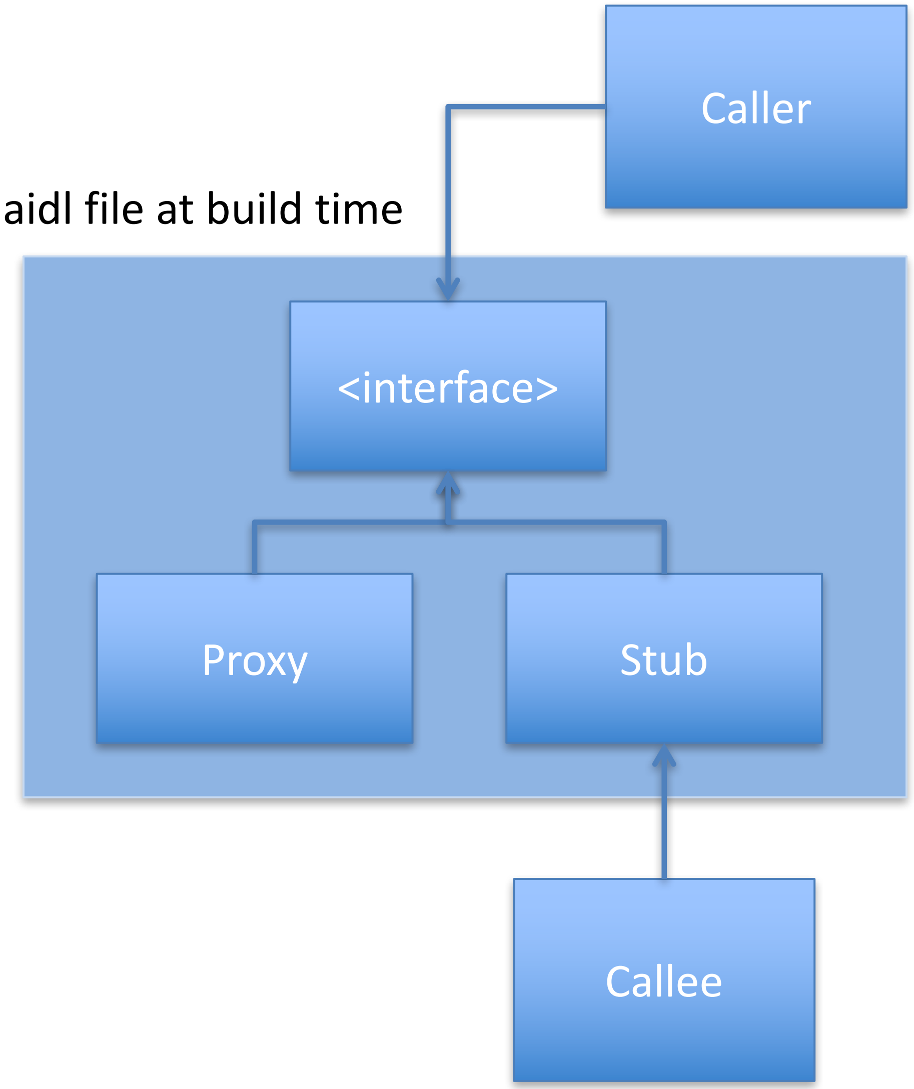
- Using the Android Interface Definition Language (AIDL)
  - Provide a standard interface to access the Service from different applications
    - Specify an interface and **protocol** to cross process boundaries
    - Trigger method calls to a different JVM, return results
- Define remote interface in the Android Interface Definition Language (AIDL)
  - Providing OS wide services for all applications
    - i.e download management
  - Multithreading with complex client / server bi-directional communication
    - A thread pool handles concurrent method calls
- Implement remote interface
  - Stub and application specific methods
- Implement Service methods
- Implement Client methods

AIDL

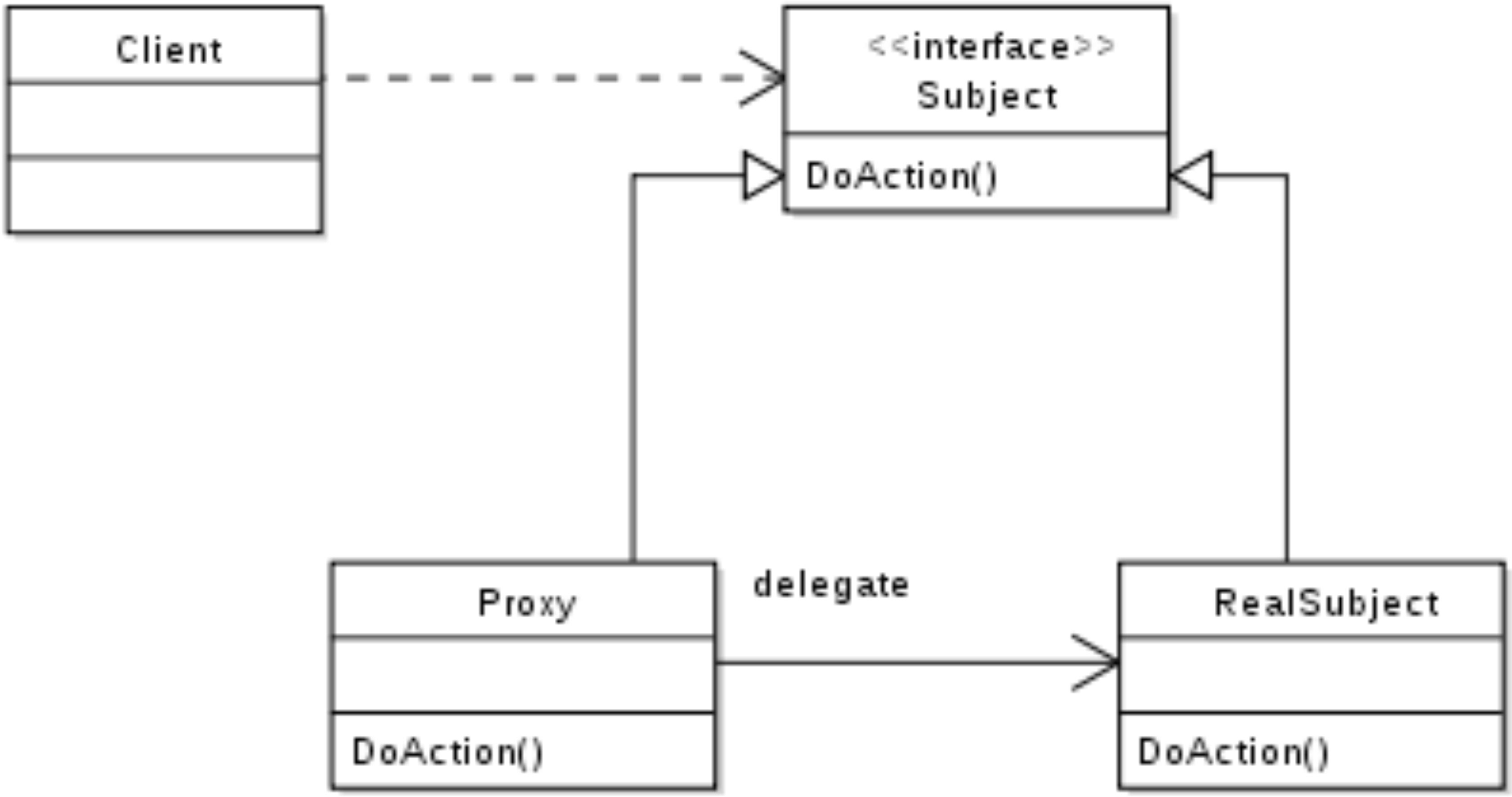
- Similar to Java interface definition syntax
  - Can declare methods
  - Cannot declare static fields
- Label method parameters
  - in: transferred to the remote method
  - out: returned to the caller
  - inout: both in and out
  - oneway: asynchronous
- Types
  - Java **primitive** types
  - StringList
    - List elements must be valid AIDL data types
  - Map
    - Map elements must be valid AIDL data types
  - CharSequence
  - Other AIDL-generated interfaces
  - Classes implementing the Parcelable protocol

AIDL

Auto generated from .aidl file at build time

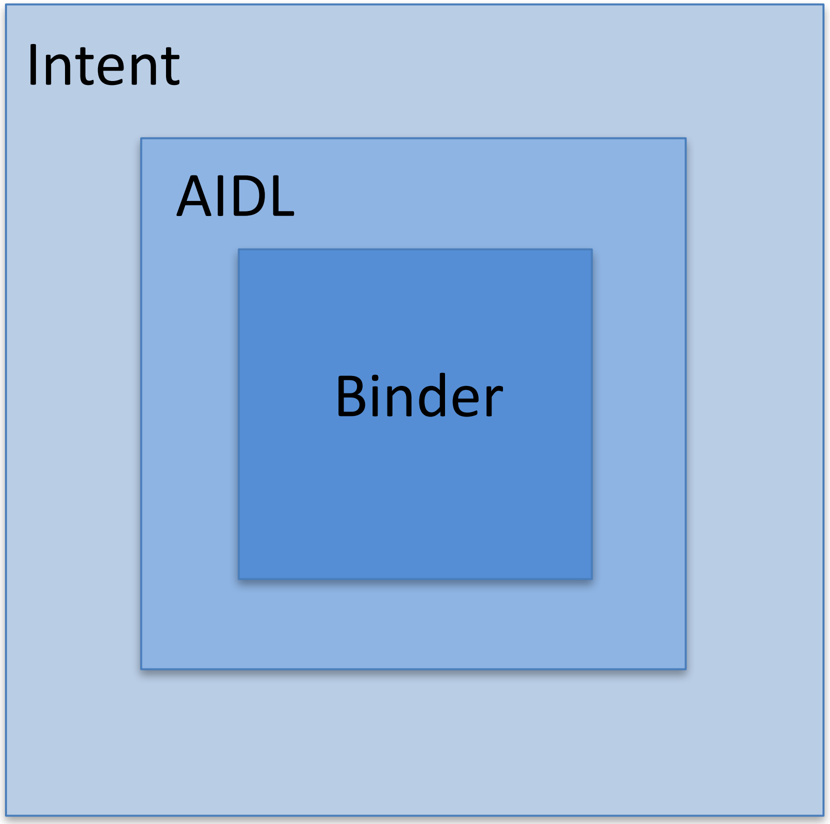


https://en.wikipedia.org/wiki/Proxy_pattern

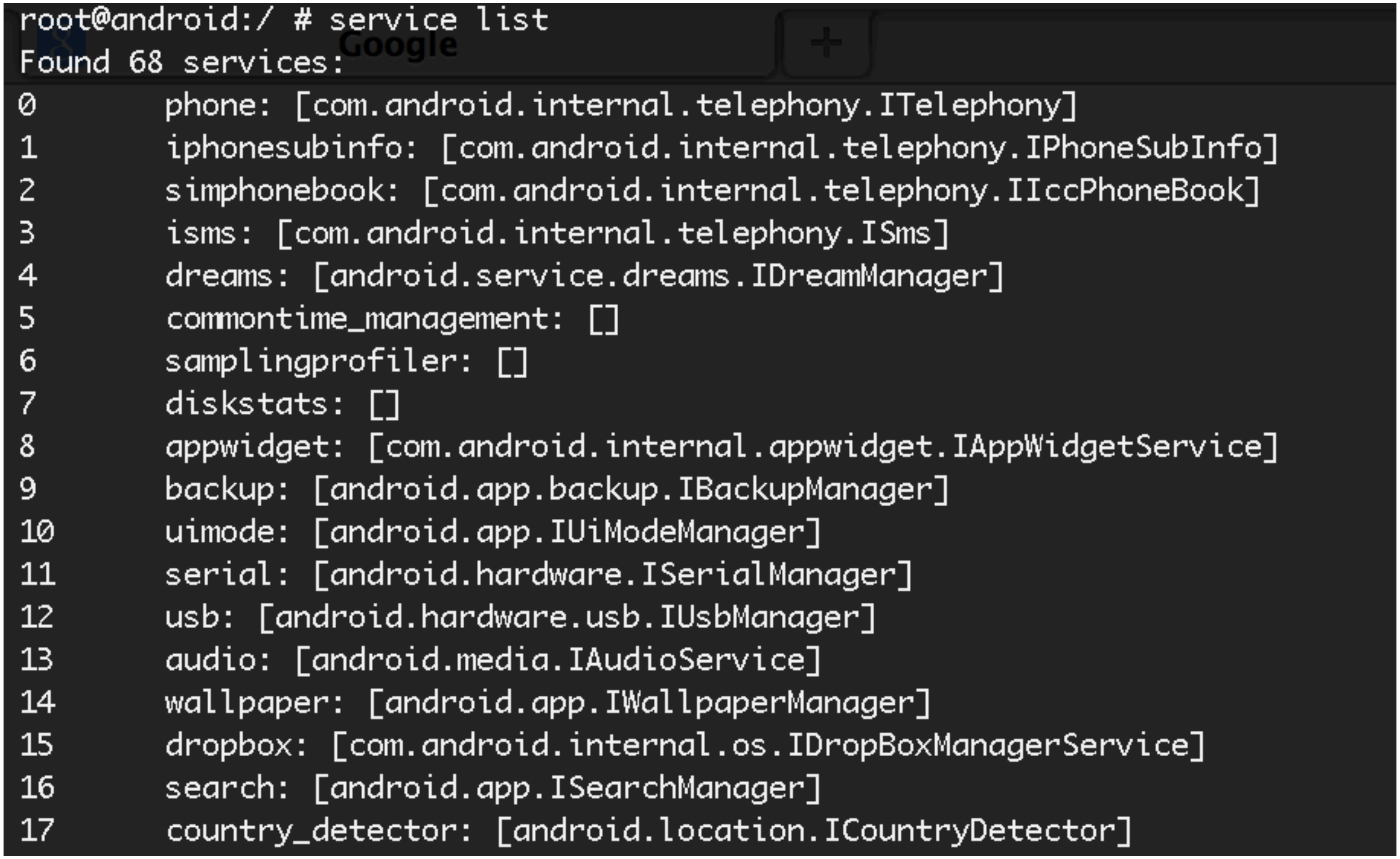


IPC Abstraction

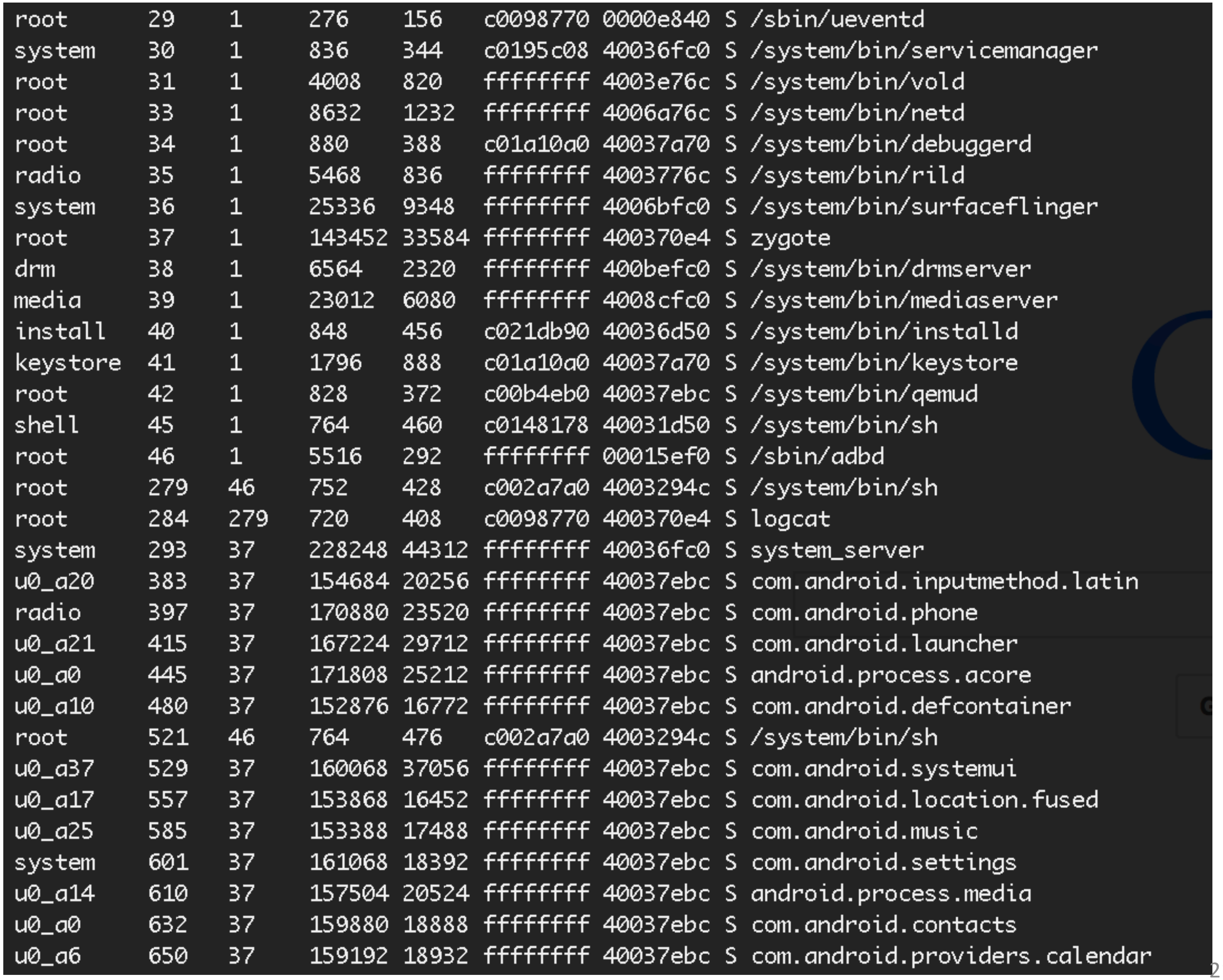
- Intent
  - Highest level abstraction
- Inter process method invocation
  - AIDL
- binder: kernel driver



Let’s have a look…



```
root@android:/ # service list
Found 68 services:
0       phone: [com.android.internal.telephony.ITelephony]
1       iphonesubinfo: [com.android.internal.telephony.IPhoneSubInfo]
2       simphonebook: [com.android.internal.telephony.IIccPhoneBook]
3       isms: [com.android.internal.telephony.ISms]
4       dreams: [android.service.dreams.IDreamManager]
5       commontime_management: []
6       samplingprofiler: []
7       diskstats: []
8       appwidget: [com.android.internal.appwidget.IAppWidgetService]
9       backup: [android.app.backup.IBackupManager]
10      uimode: [android.app.IUiModeManager]
11      serial: [android.hardware.ISerialManager]
12      usb: [android.hardware.usb.IUsbManager]
13      audio: [android.media.IAudioService]
14      wallpaper: [android.app.IWallpaperManager]
15      dropbox: [com.android.internal.os.IDropBoxManagerService]
16      search: [android.app.ISearchManager]
17      country_detector: [android.location.ICountryDetector]
```

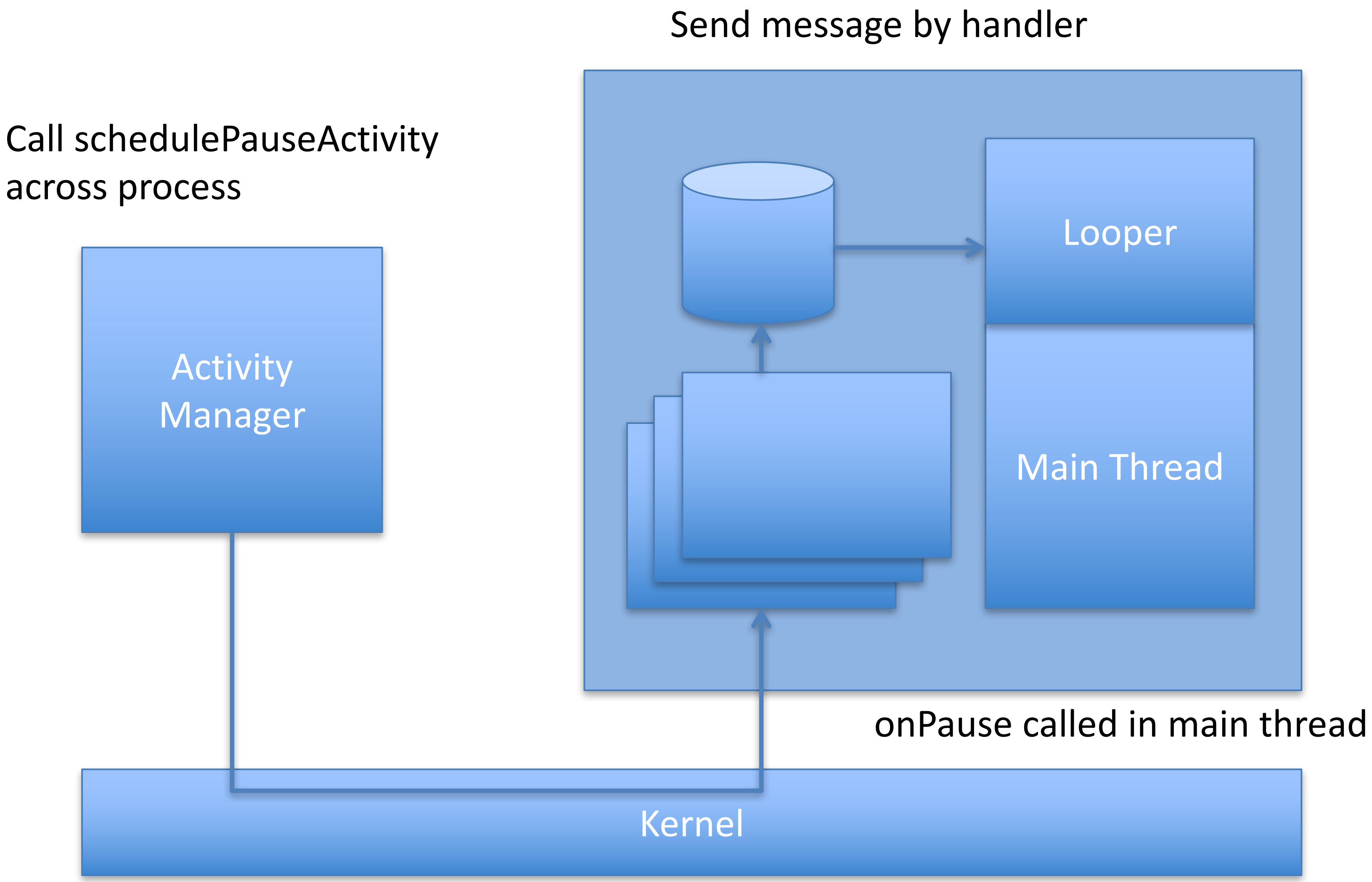


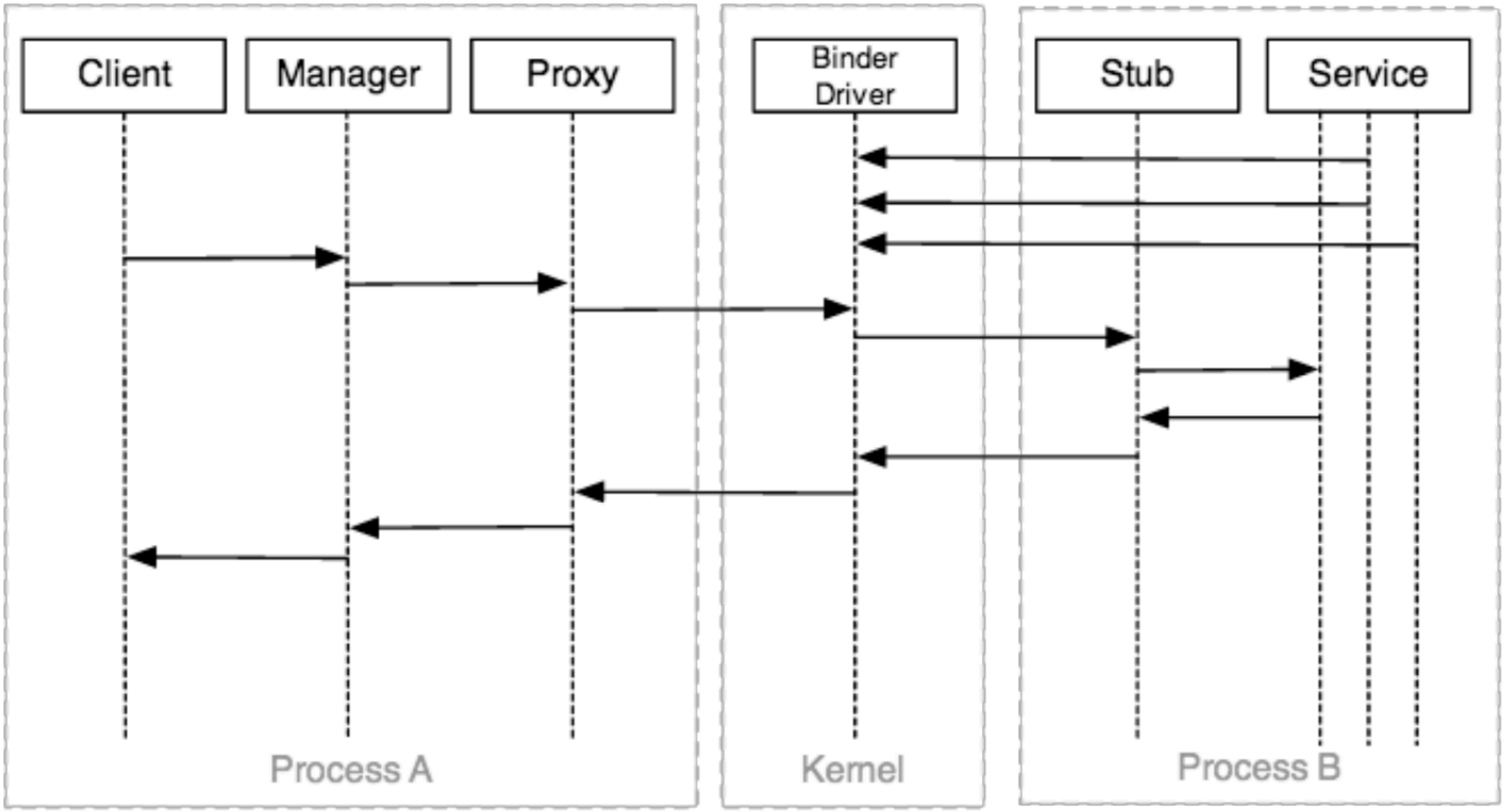
```
root      29    1     276    156   c0098770 0000e840 S /sbin/ueventd
system    30    1     836    344   c0195c08 40036fc0 S /system/bin/servicemanager
root      31    1     4008   820   ffffffff 4003e76c S /system/bin/vold
root      33    1     8632   1232  ffffffff 4006a76c S /system/bin/netd
root      34    1     880    388   c01a10a0 40037a70 S /system/bin/debuggerd
radio     35    1     5468   836   ffffffff 4003776c S /system/bin/rild
system    36    1     25336  9348  ffffffff 4006bfc0 S /system/bin/surfaceflinger
root      37    1     143452 33584 ffffffff 400370e4 S zygote
drm       38    1     6564   2320  ffffffff 400befc0 S /system/bin/drmserver
media     39    1     23012  6080  ffffffff 4008cfc0 S /system/bin/mediaserver
install   40    1     848    456   c021db90 40036d50 S /system/bin/installd
keystore  41    1     1796   888   c01a10a0 40037a70 S /system/bin/keystore
root      42    1     828    372   c00b4eb0 40037ebc S /system/bin/qemud
shell     45    1     764    460   c0148178 40031d50 S /system/bin/sh
root      46    1     5516   292   ffffffff 00015ef0 S /sbin/adbd
root      279   46    752    428   c002a7a0 4003294c S /system/bin/sh
root      284   279   720    408   c0098770 400370e4 S logcat
system    293   37    228248 44312 ffffffff 40036fc0 S system_server
u0_a20    383   37    154684 20256 ffffffff 40037ebc S com.android.inputmethod.latin
radio     397   37    170880 23520 ffffffff 40037ebc S com.android.phone
u0_a21    415   37    167224 29712 ffffffff 40037ebc S com.android.launcher
u0_a0     445   37    171808 25212 ffffffff 40037ebc S android.process.acore
u0_a10    480   37    152876 16772 ffffffff 40037ebc S com.android.defcontainer
root      521   46    764    476   c002a7a0 4003294c S /system/bin/sh
u0_a37    529   37    160068 37056 ffffffff 40037ebc S com.android.systemui
u0_a17    557   37    153868 16452 ffffffff 40037ebc S com.android.location.fused
u0_a25    585   37    153388 17488 ffffffff 40037ebc S com.android.music
system    601   37    161068 18392 ffffffff 40037ebc S com.android.settings
u0_a14    610   37    157504 20524 ffffffff 40037ebc S android.process.media
u0_a0     632   37    159880 18888 ffffffff 40037ebc S com.android.contacts
u0_a6     650   37    159192 18932 ffffffff 40037ebc S com.android.providers.calendar
```

System Services

- Entropy Service
- Power Manager
- Activity Manager
- Telephony Registry
- Package Manager
- Account Manager
- Content Manger
- System Content Providers
- Battery Service
- Lights Service
- Vibrator Service
- Alarm Manager
- Init Watchdog
- Window Manager
- Bluetooth Service
- Device Policy
- Status Bar
- Clipboard Service
- Input Method Service
- NetStat Service
- NetworkManagement Service
- Connectivity Service
- Throttle Service
- Accessibility Manager
- Mount Service
- Notification Manager
- Device Storage Monitor
- Location Manager
- Search Service
- DropBox Service
- Wallpaper Service
- Audio Service
- Headset Observer
- Dock Observer
- USB Observer
- UI Mode Manager Service
- Backup Service
- AppWidget Service
- Recognition Service
- DiskStats Service

onPause()


Send message by handler
Call schedulePauseActivity across process
Activity Manager
Looper
Main Thread
onPause called in main thread
Kernel


Client
Manager
Proxy
Binder Driver
Stub
Service
Process A
Kernel
Process B

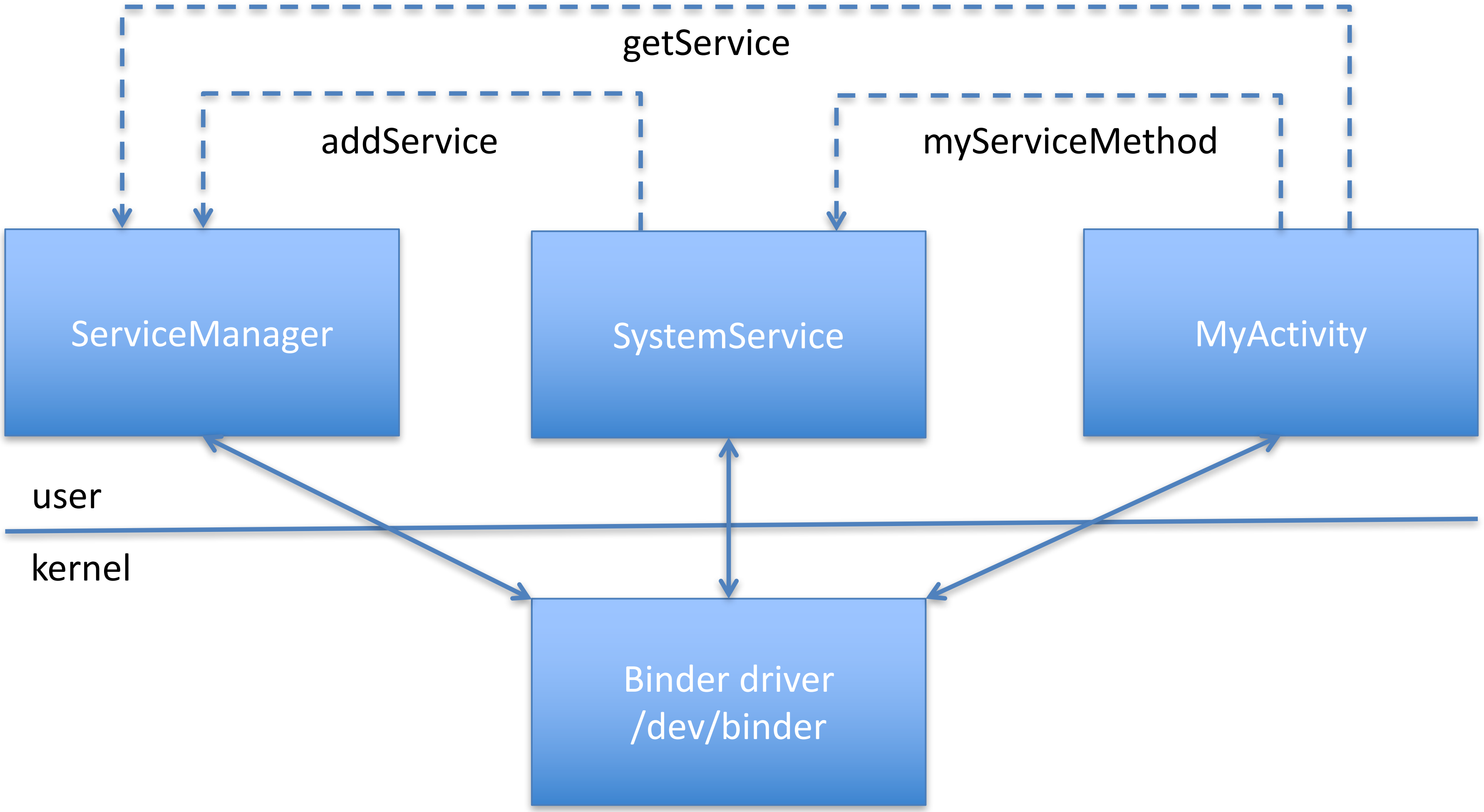
Binder Objects and Tokens

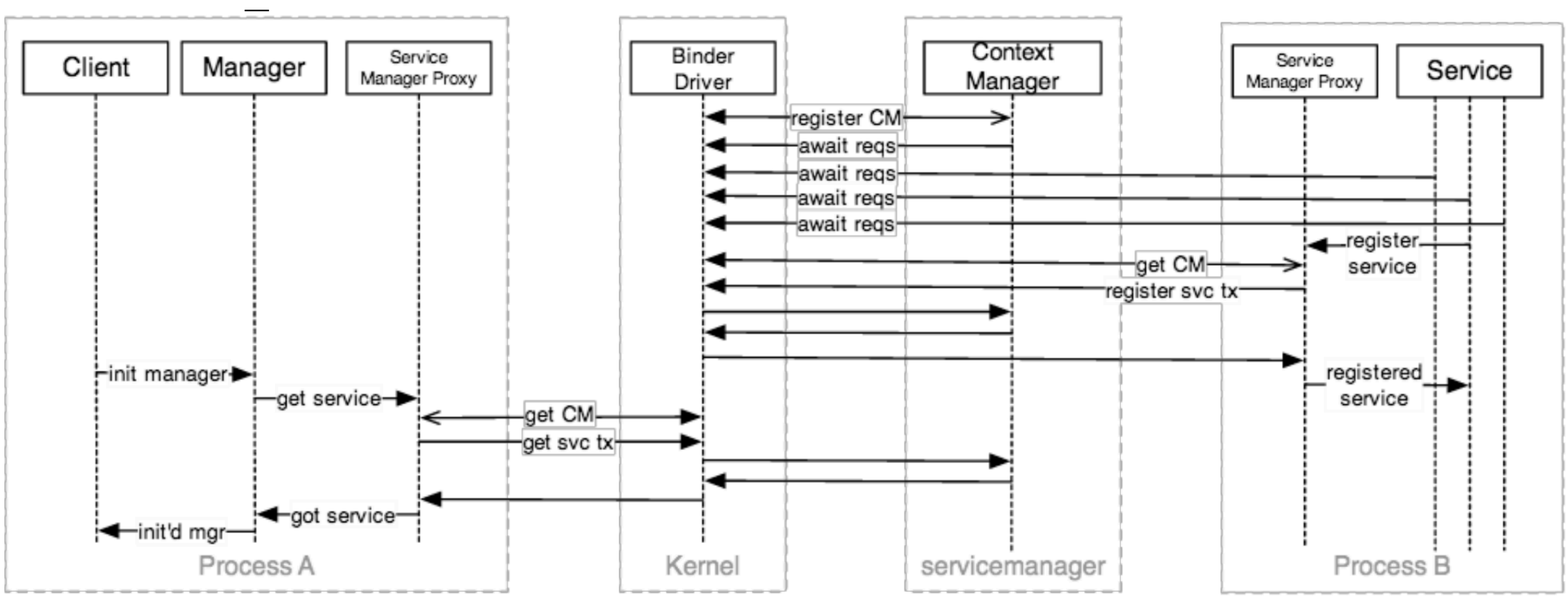
- Binder Object
  - An object that can be accessed through the Binder framework
  - Implements the *IBinder* interface
  - A unique identity maintained across processes
    - Allocated by the Binder driver
      - Cannot be duplicated
    - A 32 bit handle maintained by the kernel
- Process A creates a binder object <- references memory directly
  - Passes it to process B <- referenced by handle
    - Passes it to process C <- referenced by handle
- Capability-based security model
  - Processes are granted access to a particular resource by giving them a *capability* in the form of the binder object
    - Binder object as **token**
  - The possession of a token grants the owning process full access to the Binder object enabling it to perform Binder transactions on the target object
    - The only way to communicate with a Binder object is to be given a reference to it

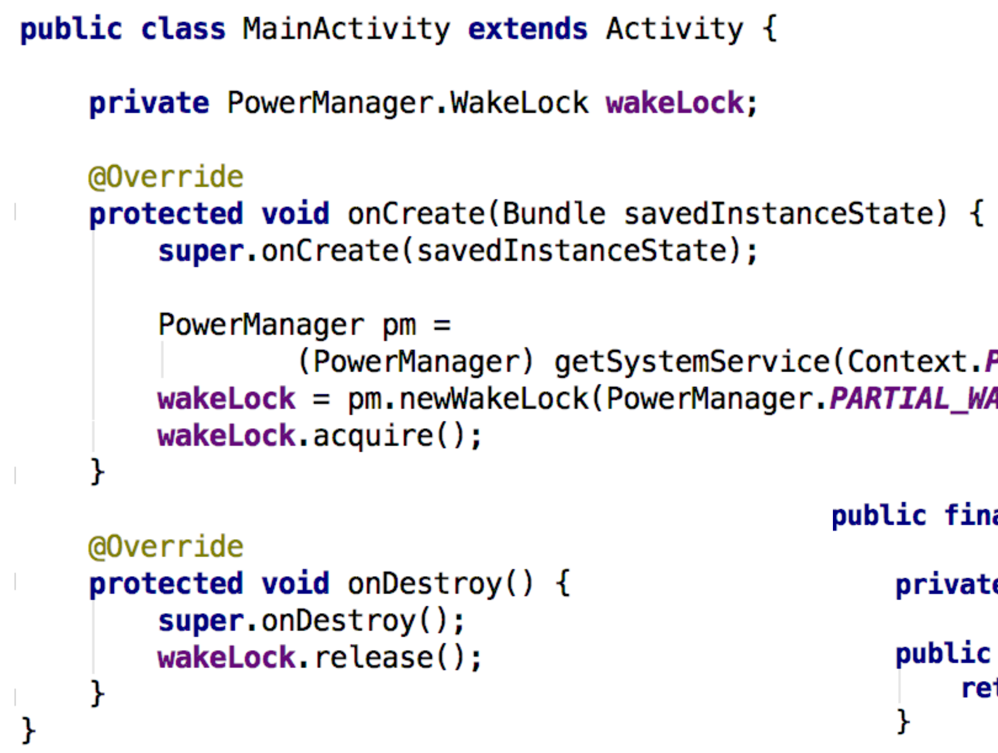
ServiceManager

- So how do we get the token?
- A single *context manager* that maintains references to Binder objects
  - Implemented as ServiceManager
    - Hosts many system services within its process
  - A Binder instance with a known Binder handle (0)
  - Knows about other remote services
    - The first to be registered with Binder
    - Only “trusted” system services allowed to register
      - System, radio, media
- Client does not know the token of remote Binder
  - Only the Binder interface knows its own address
- Binder submits a service name and its Binder token to the ServiceManager via IPC
  - Client retrieves remote service Binder handle with service name
  - Client communicates with remote service

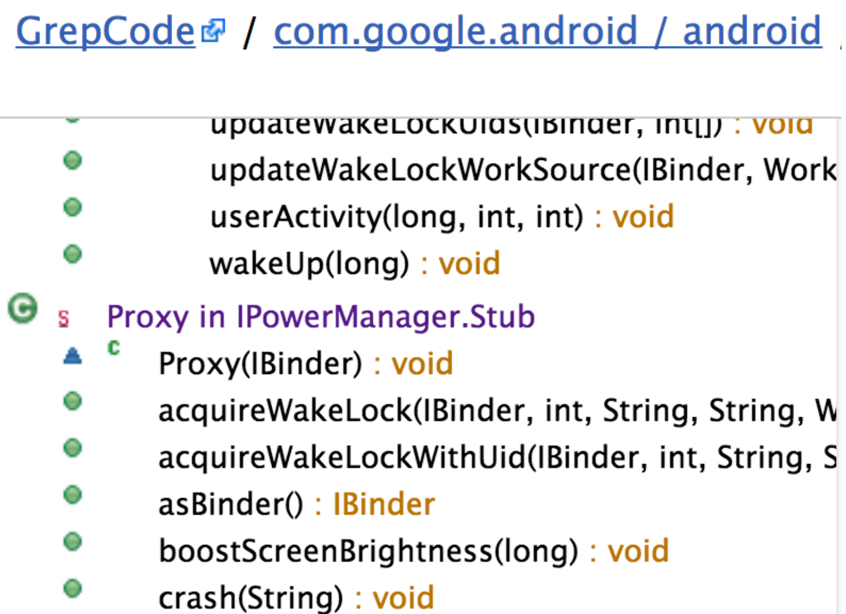
ServiceManager




Client
Manager
Service Manager Proxy
Binder Driver
Context Manager
Service Manager Proxy
Service
register CM
await reqs
await reqs
await reqs
await reqs
register service
get CM
register svc tx
init manager
get service
get CM
get svc tx
registered service
got service
init'd mgr
Process A
Kernel
servicemanager
Process B

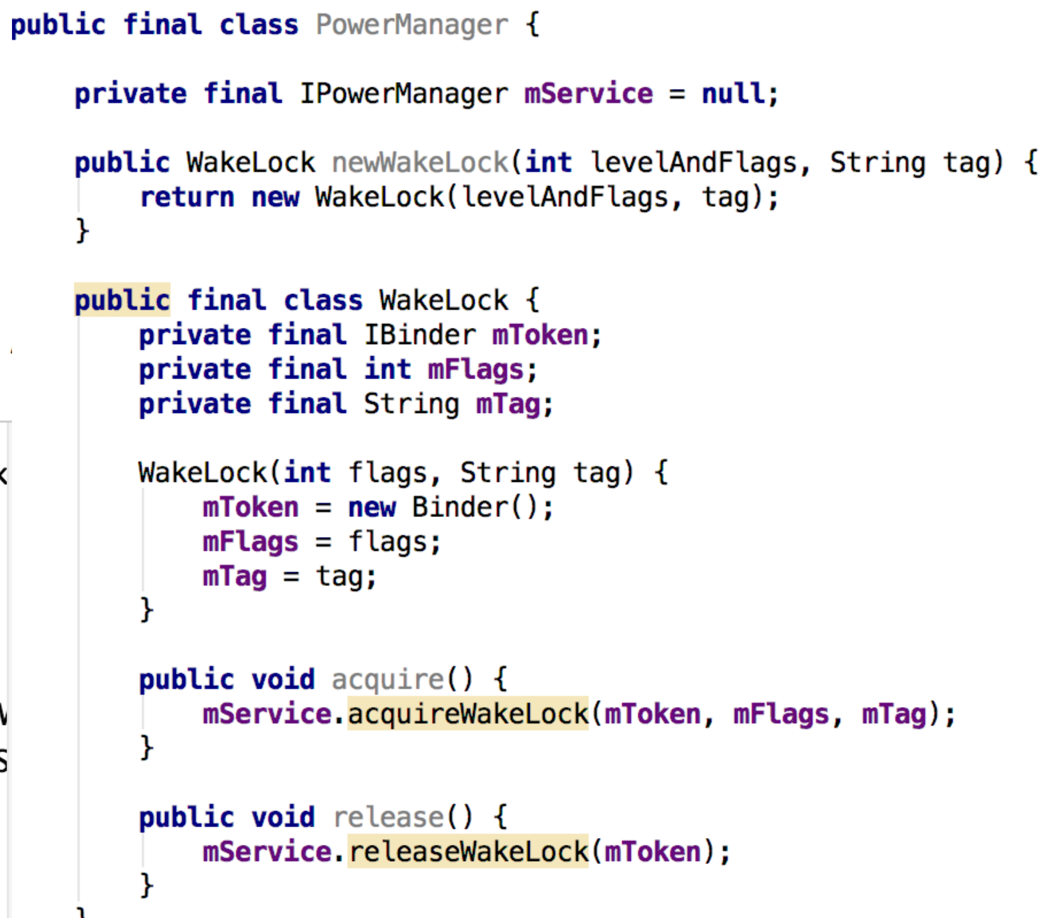


```java
public class MainActivity extends Activity {

    private PowerManager.WakeLock wakeLock;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);

        PowerManager pm =
                (PowerManager) getSystemService(Context.POWER_SERVICE);
        wakeLock = pm.newWakeLock(PowerManager.PARTIAL_WAKE_LOCK, "My Tag");
        wakeLock.acquire();
    }

    @Override
    protected void onDestroy() {
        super.onDestroy();
        wakeLock.release();
    }
}
```



GrepCode / com.google.android / android

```
        updateWakeLockUids(IBinder, int[]) : void
        updateWakeLockWorkSource(IBinder, Work
        userActivity(long, int, int) : void
        wakeUp(long) : void
  Proxy in IPowerManager.Stub
     Proxy(IBinder) : void
     acquireWakeLock(IBinder, int, String, String, W
     acquireWakeLockWithUid(IBinder, int, String, S
     asBinder() : IBinder
     boostScreenBrightness(long) : void
     crash(String) : void
```



```java
public final class PowerManager {

    private final IPowerManager mService = null;

    public WakeLock newWakeLock(int levelAndFlags, String tag) {
        return new WakeLock(levelAndFlags, tag);
    }

    public final class WakeLock {
        private final IBinder mToken;
        private final int mFlags;
        private final String mTag;

        WakeLock(int flags, String tag) {
            mToken = new Binder();
            mFlags = flags;
            mTag = tag;
        }

        public void acquire() {
            mService.acquireWakeLock(mToken, mFlags, mTag);
        }

        public void release() {
            mService.releaseWakeLock(mToken);
        }
```

Binder Security

- Binder doesn't deal with security
  - Enables a **trusted** execution environment
  - Transactions via the kernel
    - Client identity managed by the kernel
      - Binder.getCallingUid(), Binder.getCallingPid()
      - UID / PID included in each transcation
- Access controlled in two ways
  - Limit who can obtain a reference to a Binder object
    - Interface reference security
    - Client cannot guess "address" of a service without going via the Service Manager
  - Check caller identity before performing an action on the Binder objectS
    - Service asks package manager about UID permissions
    - Check whether it holds a permission we want to enforce via PackageManager.getPackageInfo(...)
      - Another system service!

Binder Performance

- Reference counting and Death notifications
  - Binder objects automatically freed when no longer referenced
  - Can be notified when a remote binder host process dies
  - Implemented in the kernel driver
- Explicit limitations
  - Transactional buffer size 1Mb per process for all concurrent transactions
    - Many moderately sized transactions could also exhaust its limit
      - Arguments and return values are too large
    - Keep transaction data small
- Implicit limitations
  - Data is copied
    - Duplication of resources
  - Native binary marshalling
    - Better than reflection based serialization
    - Still has overhead of parcel marshalling
      - Read byte, read byte, read byte
  - Not ideal for large data-streams
    - Good enough for window / activity / surface management
    - Pass file descriptors to shared memory regions (**ashmem -** anonymous shared memory)

References

- http://developer.android.com/guide/components/processes-and-threads.html
- http://developer.android.com/guide/components/services.html
- http://elinux.org/Android_Binder
- http://grepcode.com/file/repository.grepcode.com/java/ext/com.google.android/android/5.1.1_r1/android/os/IPowerManager.java#IPowerManager
- http://grepcode.com/file/repository.grepcode.com/java/ext/com.google.android/android/5.1.1_r1/android/os/PowerManager.java