Mobile Systems

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History of mobile OSes

➡ Early "smart" devices are PDAs (touchscreen, Internet)

Symbian, first modern mobile OS

- released in 2000
- run in Ericsson R380, the first "smartphone" (mobile phone + PDA)
- only support proprietary programs

History of mobile OSes

Many smartphone and mobile OSes followed up

- Palm OS (2001)
- Windows CE (2002)
- Blackberry (2002)

One more thing …

Introduction of iPhone (2007)

- 4GB flash memory, 128 MB DRAM, multi-touch interface
- runs iOS only proprietary apps at first but App Store opened in 2008, allow third party apps

Android – an unexpected rival of the iPhone

Android Inc. founded by *Andy Rubin et al.* in 2003

- original goal is to develop an OS for digital camera
- shift focus on Android as a mobile OS

The startup had a rough time [story]

- run out of cash, landlord threatens to kick them out
- later bought by Google
- no carrier wants to support it except for T-Mobile
- while preparing public launch of Android, iPhone was released

Android 1.0 released in 2008 (HTC G1)

- In 2019, ~87% of mobile OS market (iOS ~13%)

Why are mobile OSes interesting?

Now an essential device part of people's daily life (sometimes the only computing device)

➡ Mobile OSes and traditional OSes share the same core abstractions ... but also have many unique designs

Design considerations for mobile OS

Resources are very constrained

- Limited memory
- Limited storage
- Limited battery life
- Limited processing power
- Limited network bandwidth
- Limited size

➡ User perception are important: Latency ≫ throughput
Users will be frustrated if an app takes several seconds to launch

➡ Environment are frequently changing
Cellular signals from strong to weak and then back to strong

Process management in mobile OS

In desktop/server - an application = a process

Not true in mobile OSes

- When you see an app present to you
  it does not mean an actual process is running
- Multiple apps might share processes
- An app might make use of multiple processes
- When you "close" an app, the process might be still running

➡ Different user-application interaction patterns

Process management in mobile OS

Multitasking is a luxury in mobile OS

- Early versions of iOS did not allow multi-tasking mainly because of battery life and limited memory
- Only one app runs in the foreground, all other user apps are suspended
- OS's tasks are multi-tasked because they are assumed to be well-behaving

➡ Starting with iOS 4, the OS APIs allow multi-tasking in apps but only available for a limited number of app types

Memory management in mobile OS

Most desktop and server OSes today support swap space

Mobile OSes typically do not support swapping

- iOS asks applications to voluntarily relinquish allocated memory
- Android will terminate an app when free memory is running low

➡ App developers must be very careful about memory usage

Storage in mobile OS

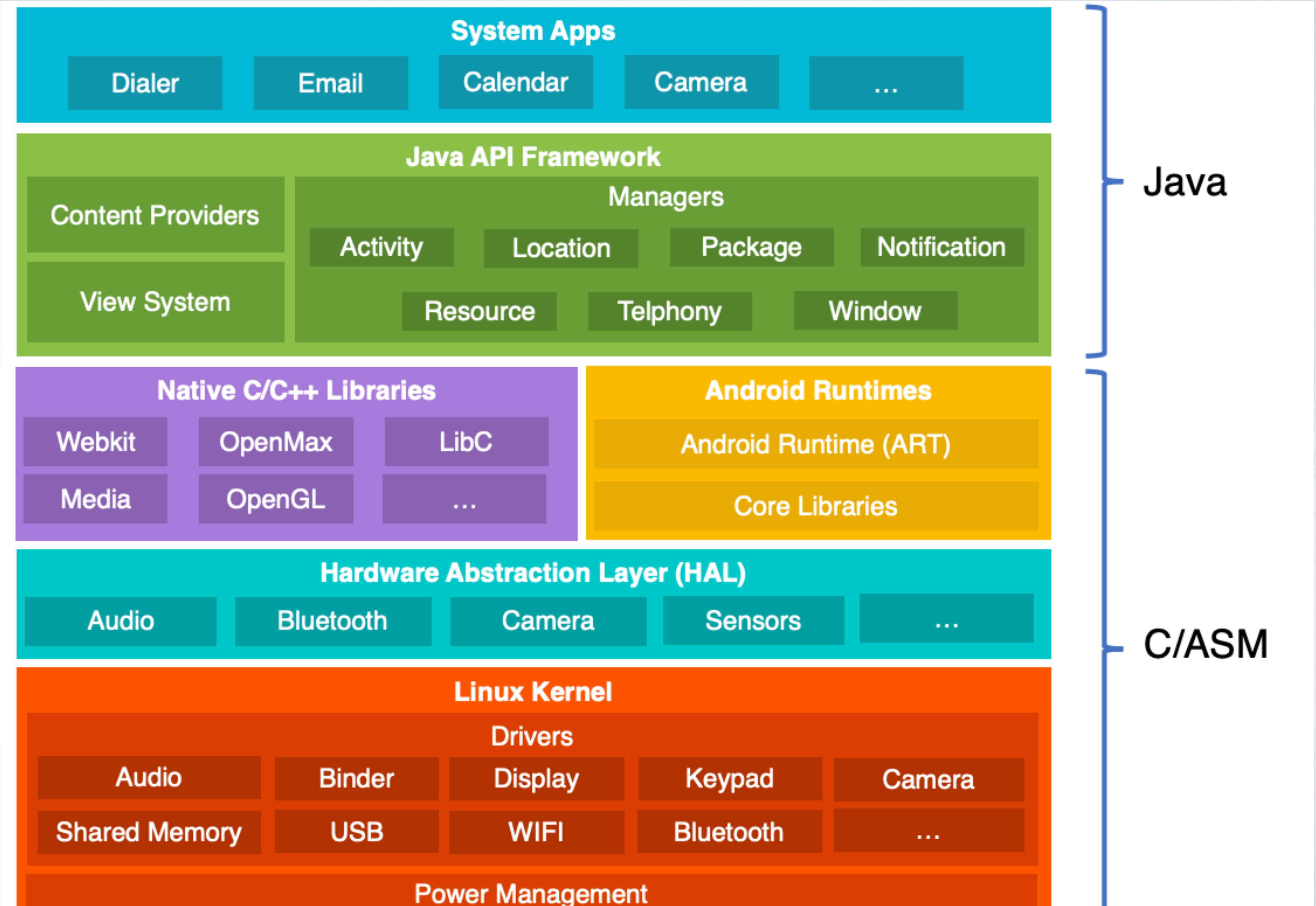
App privacy and security is hugely important in mobile device

- Each app has its own private directory that other apps cannot access
- Only shared storage is external storage

High-level abstractions

- Files
- Database (SQLite)
- Preferences (key-value pairs)

Android OS stack



Linux kernel vs. Android kernel

➡ Linux kernel is the foundation of Android platform

New core code

- binder - interprocess communication mechanism
- shmem - shared memory mechanism
- logger

Performance/power

- wakelock
- low-memory killer
- CPU frequency governor

➡ and much more . . . 361 Android patches for the kernel

Android runtime

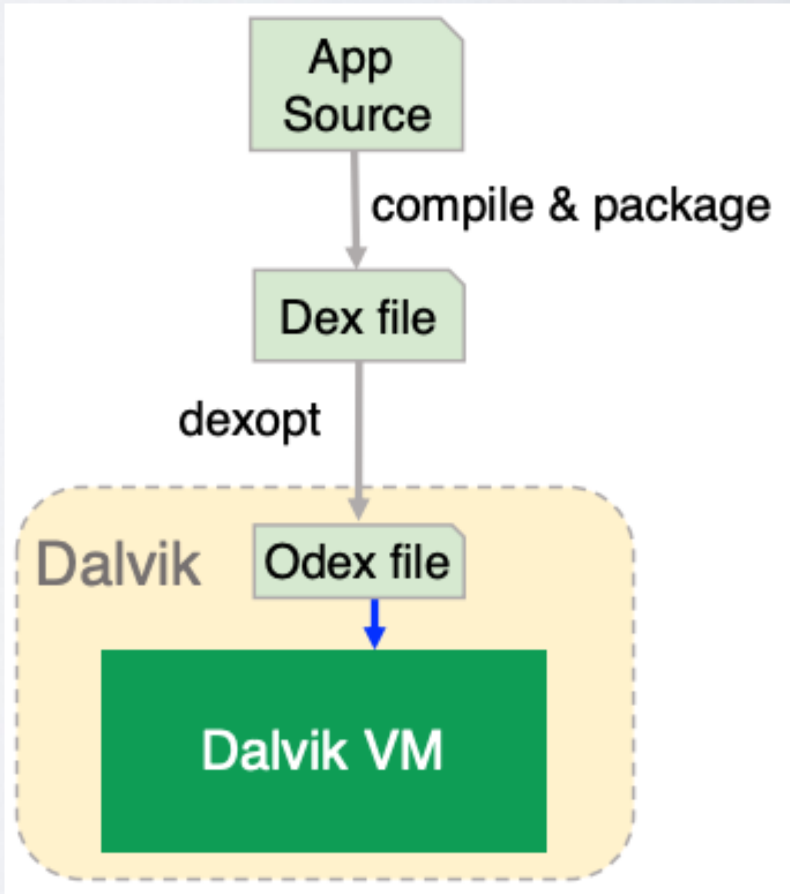
➡ Runtime - a component provides functionality necessary for the execution of a program E.g., scheduling, resource management, stack behavior

Prior to Android 5.0 - Dalvik

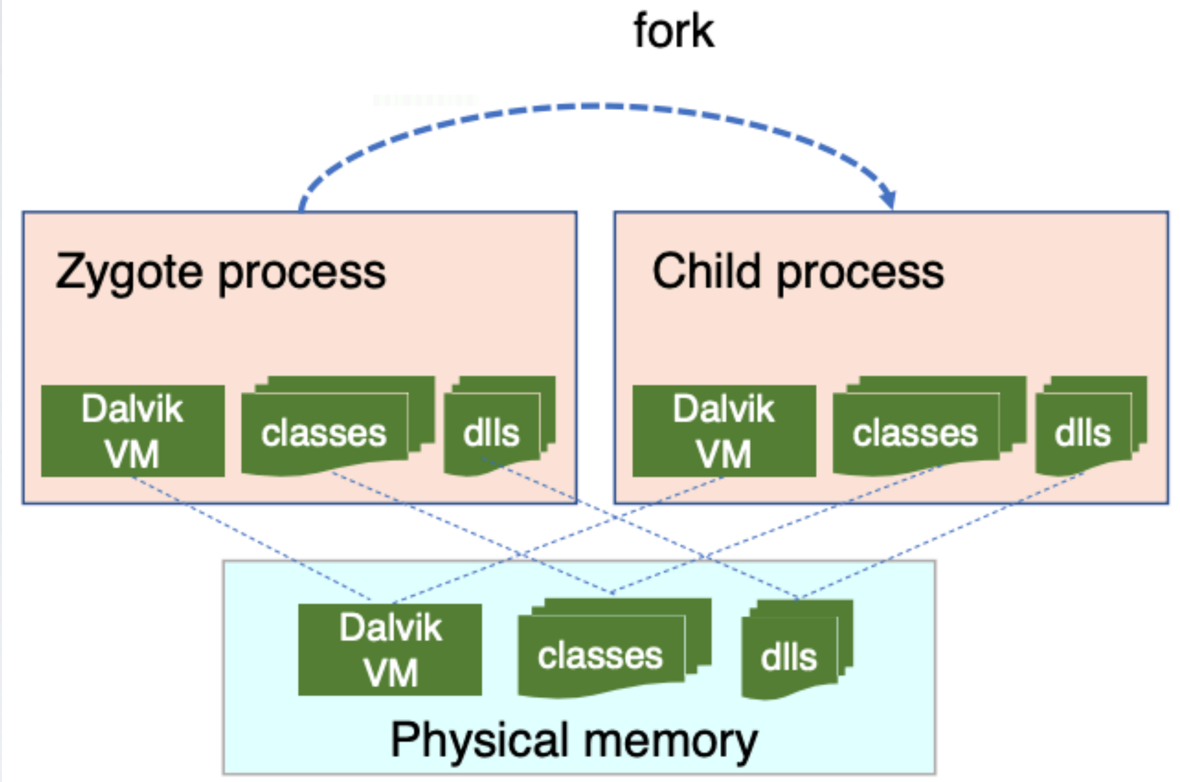
- Each Android app has its own process, runs its own instance of the Dalvik virtual machine (process virtual machine)
- The VM executes the Dalvik executable (.dex) format
- Register-based compared to stack-based of JVM

After Android 5.0 - ART

- Backward compatible for running Dex bytecode
- New feature - Ahead-Of-Time (AOT) compilation
- Improved garbage collection



Android process creation



All Android apps derive from a process called Zygote

- Zygote is started as part of the init process
- Preloads Java classes, resources, starts Dalvik VM
- Registers a Unix domain socket
- Waits for commands on the socket
- Forks off child processes that inherit the initial state of VMs

➡ Uses Copy-on-Write
only when a process writes to a page will a page be allocated

Java API framework

The main Android OS from app point of view

- Provide high-level services and environment to apps
- Interact with low-level libraries and Linux kernel

Some components

- Activity Manager - manages the lifecycle of apps
- Package Manager - keeps track of apps installed
- Power Manager - wakelock APIs to apps

Native C/C++ libraries

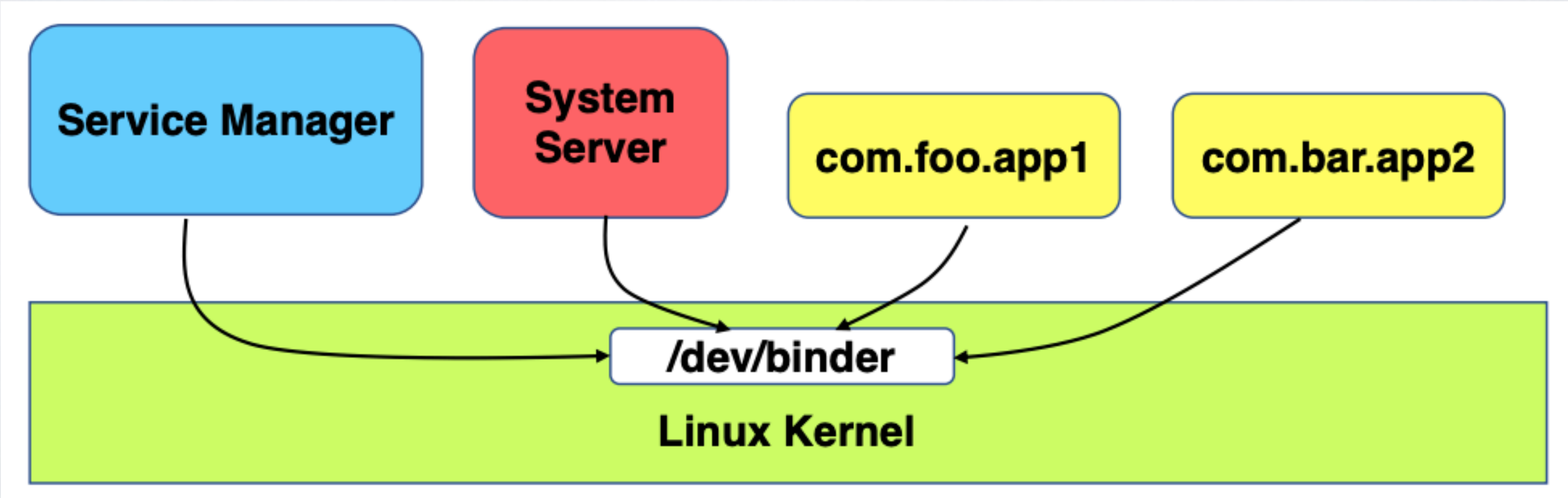
Many core Android services are built from native code

- Require native libraries written in C/C++
- Some of them are exposed through the Java API framework as native APIs e.g. Java OpenGL API

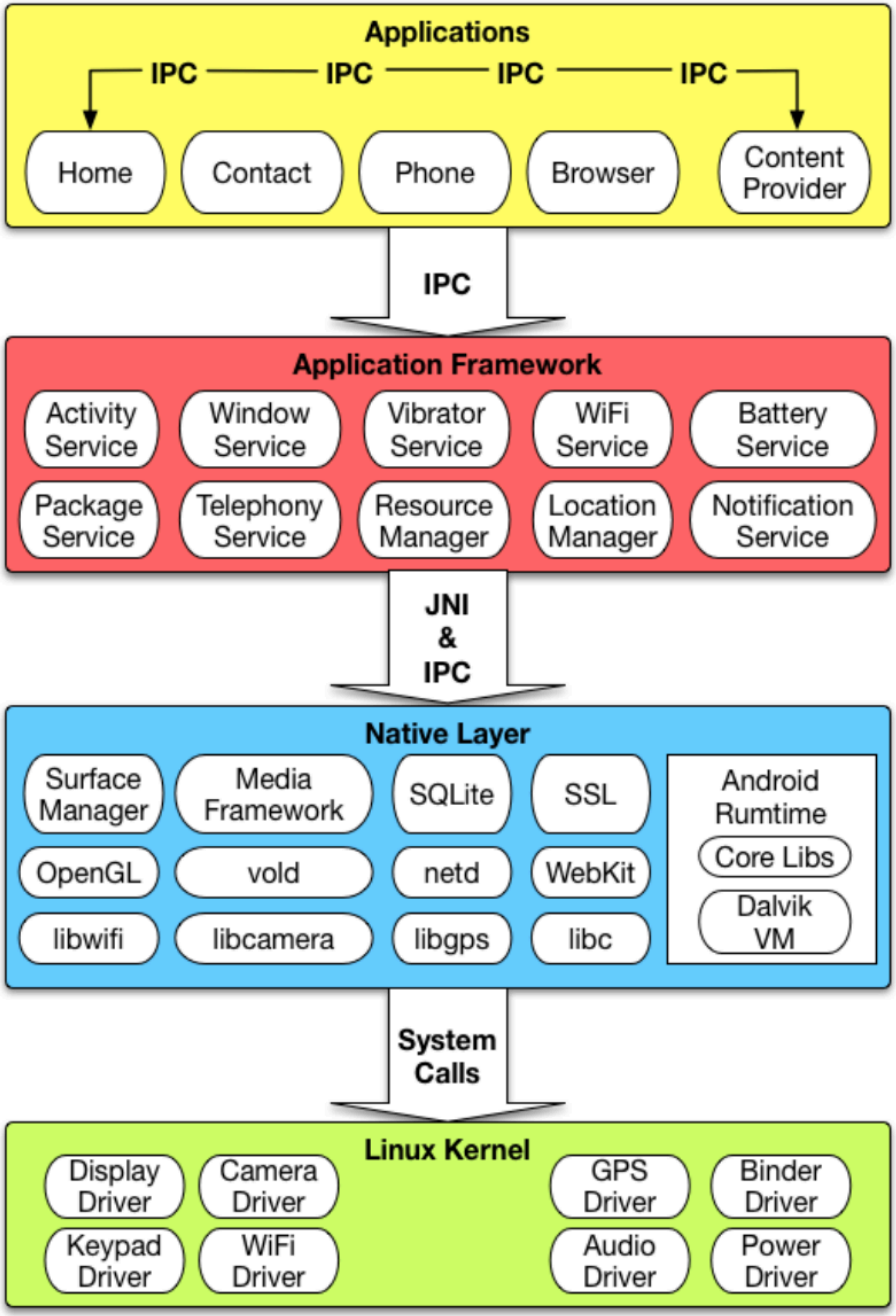
➡ Technique: JNI – Java Native Interface
app developer can use Android NDK to include C/C++ code (common in gaming apps)

Android Binder IPC

Android Binder IPC allows communication among apps, between system services, and between app and system service



IPC is pervasive in Android



Binder is implemented as an RPC

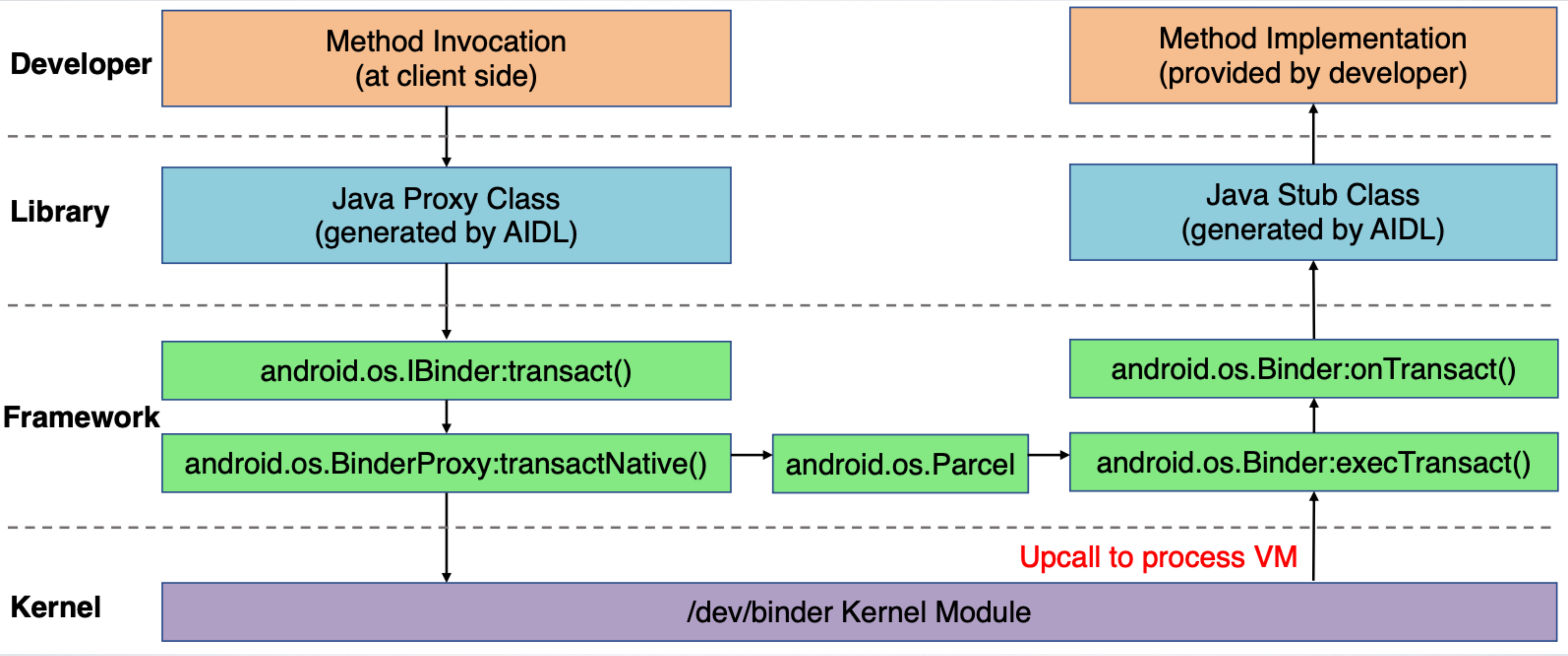
1. Developer defines methods and object interface in an `.aidl` file

```
package com.example.android; // IRemoteService.aidl

/** Example service interface */
interface IRemoteService {
    /** Request the process ID of this service, to do evil things with it. */
    int getPid();
    /** Pause the service for a while */
    void pause(long time);
}
```

2. Android SDK generates a stub Java file for the `.aidl` file and exposes the stub in a Service
3. Developer implements the stub methods
4. Client copies the `.aidl` file to its source
5. Android SDK generates a stub (a.k.a proxy)
6. Client invoke the RPC through the stub

Binder information flow



Some other interesting topics in mobile OSes

- Energy management
- Dealing with misbehaving apps
- Security

Summary

➡ Smartphone has become an ubiquitous computing device

Mobile OS is an interesting and challenging subject

- Constrained resources
- Different user interaction patterns
- Frequently changing environment
- Untrusted, immature third-party apps

Some unique design choices

- Application ≠ process
- Multitasking
- No swap space
- Private storage

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