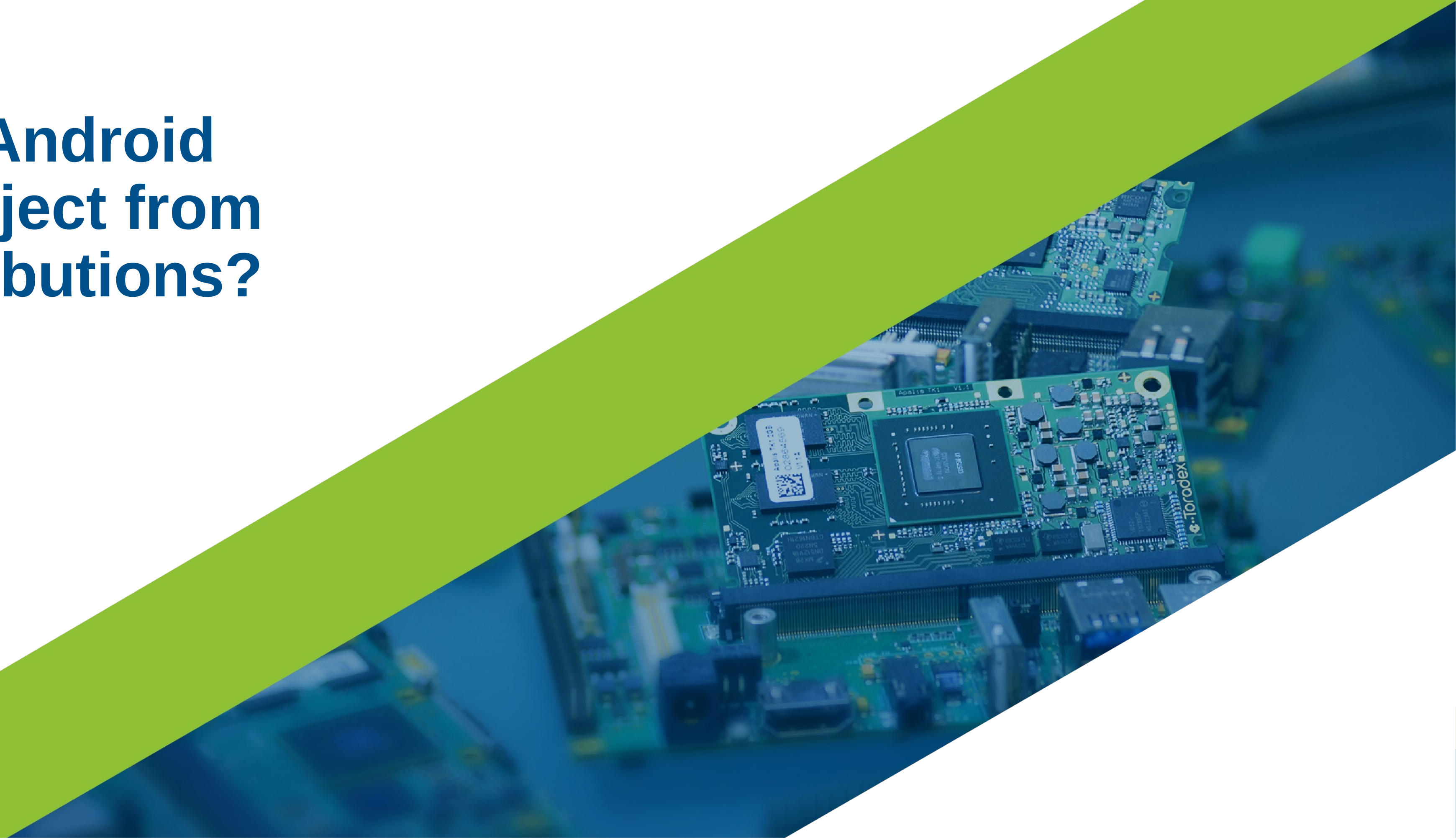
Embedded Linux Conference Europe 2020

What differs the Android Open Source Project from other Linux distributions?



Sergio Prado

Toradex

$ WHOAMI

- Embedded software developer for more than 20 years.
- Team Lead at Toradex (https://www.toradex.com/).
- Consultant and trainer at Embedded Labworks (e-labworks.com/en).
- Contributor of some open source projects, including Buildroot, Yocto Project and the Linux kernel.
- Sometimes write technical stuff at embeddedbits.org.

OBJECTIVES

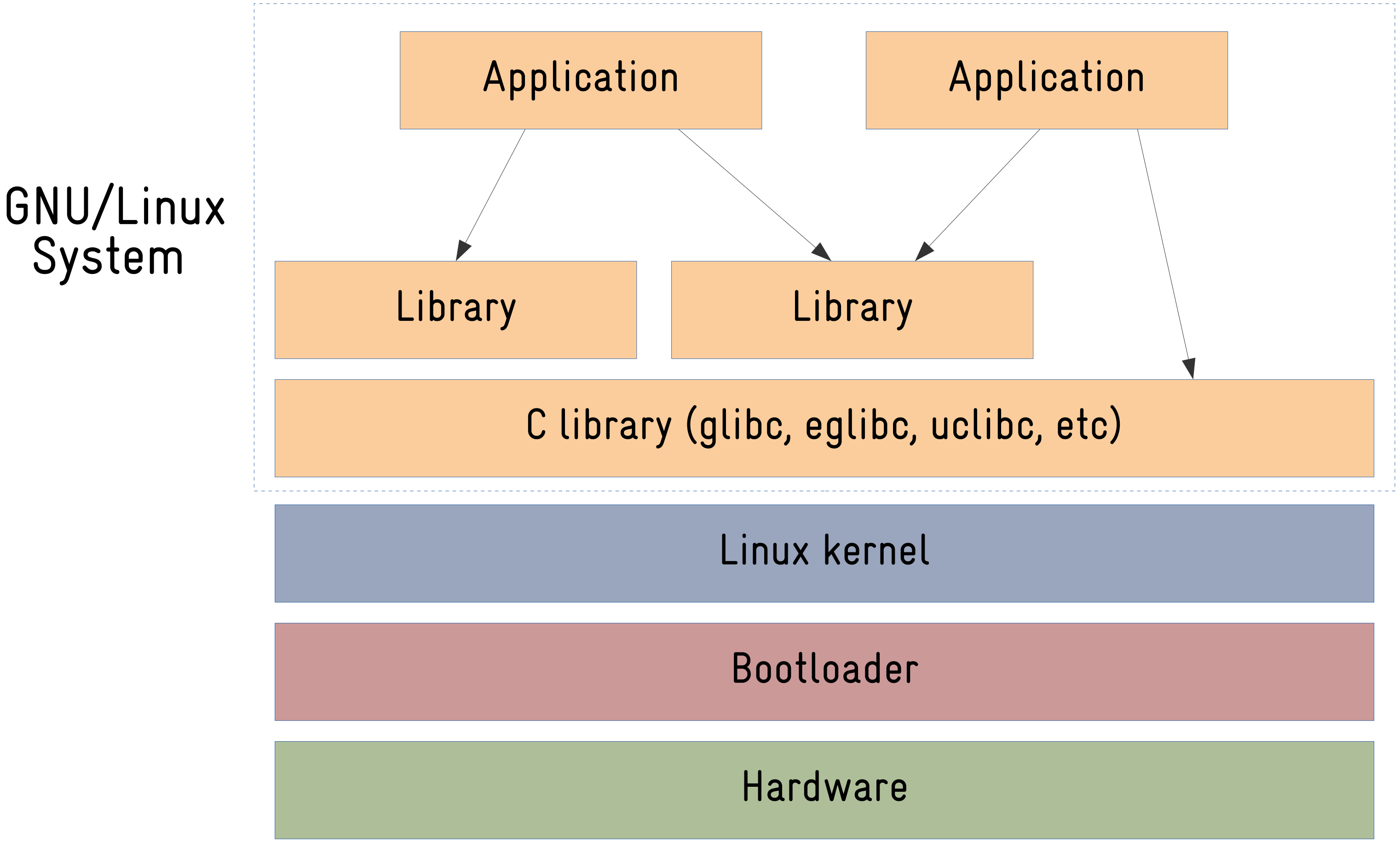
1. Android vs Linux distributions (user perspective).

2. Android vs Linux distributions (application developer perspective).

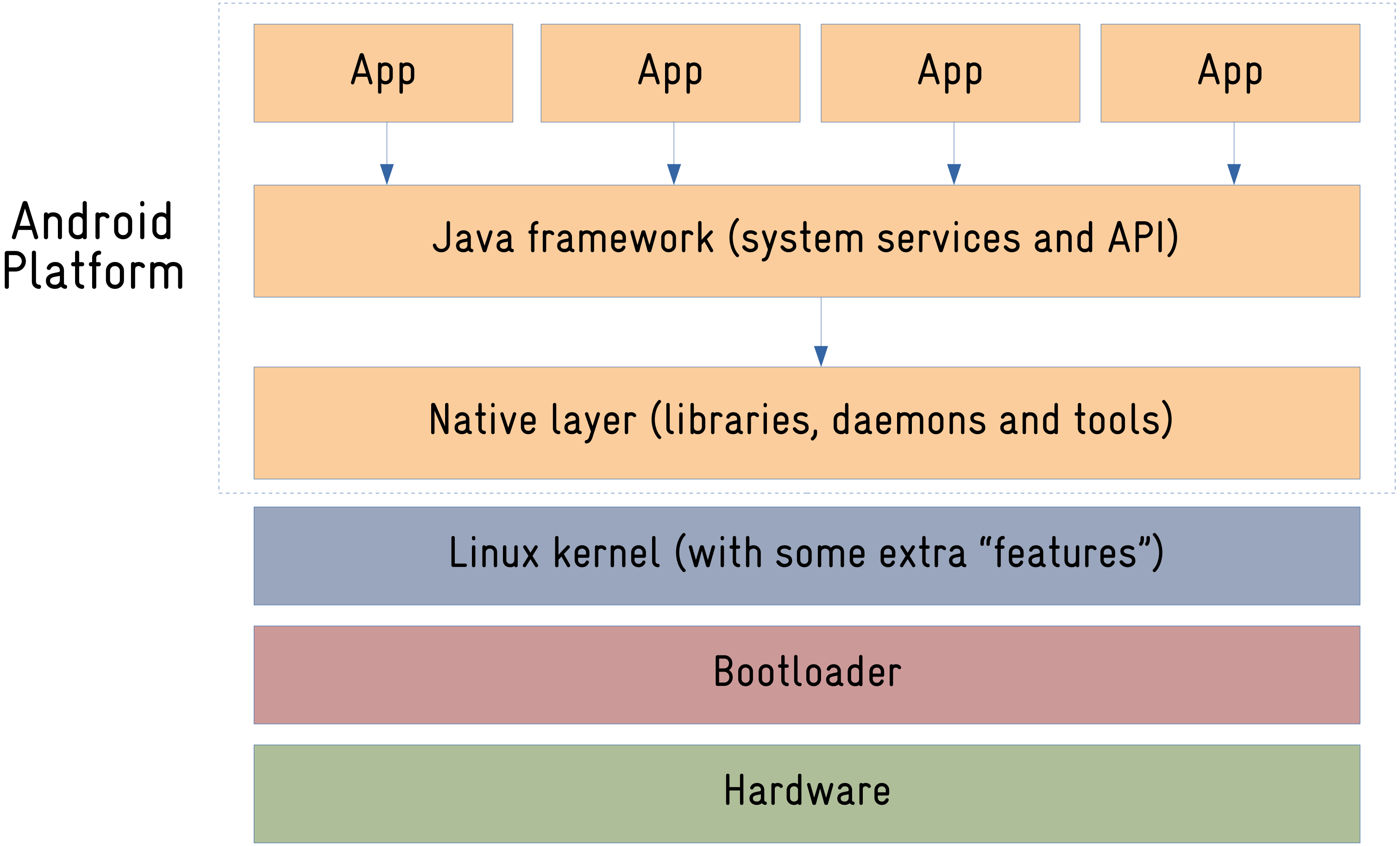
3. Android vs Linux distributions (distribution maintainer perspective).

4. Understand the architecture of the Android operating system.

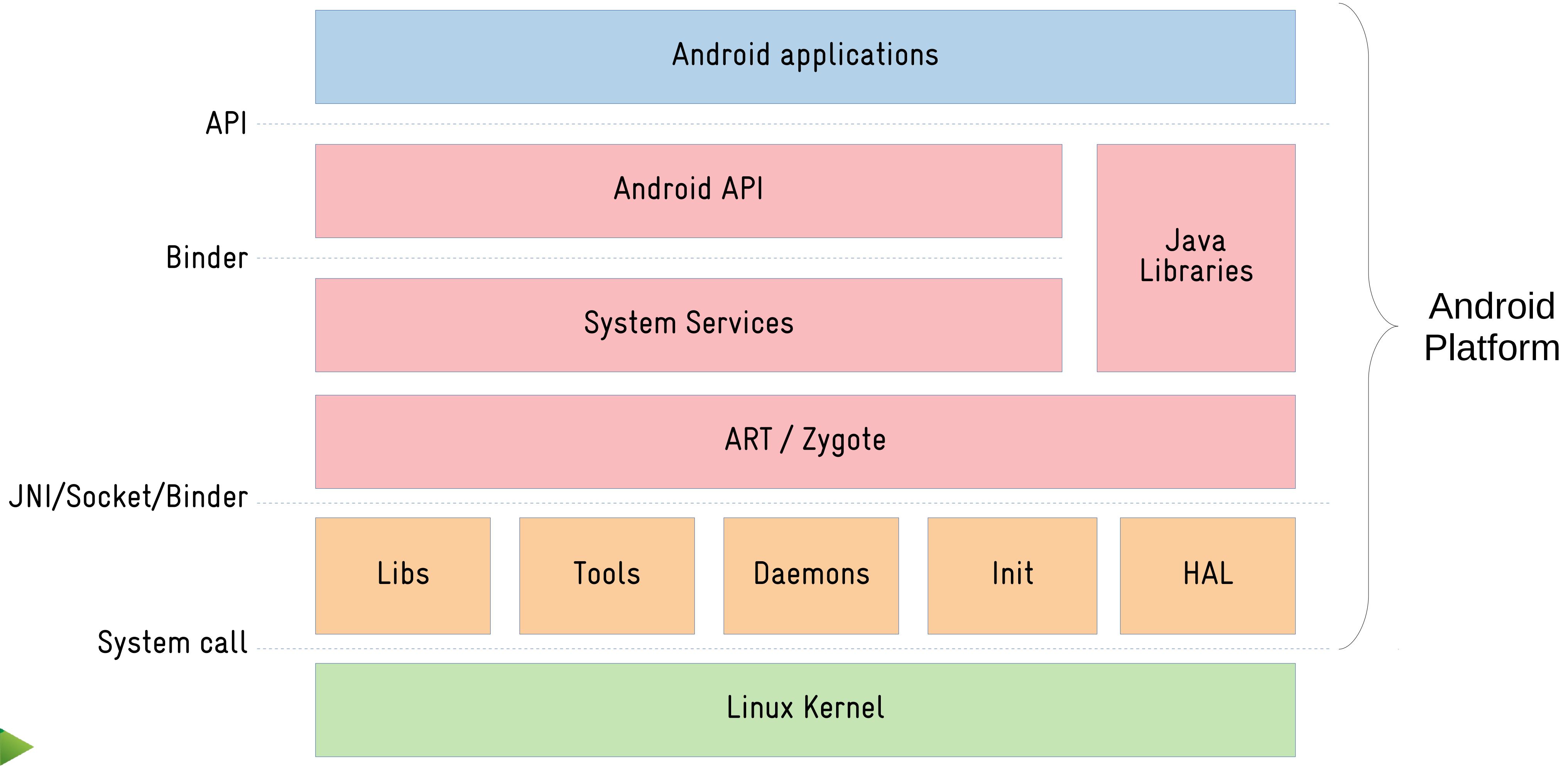
LINUX SYSTEM ARCHITECTURE



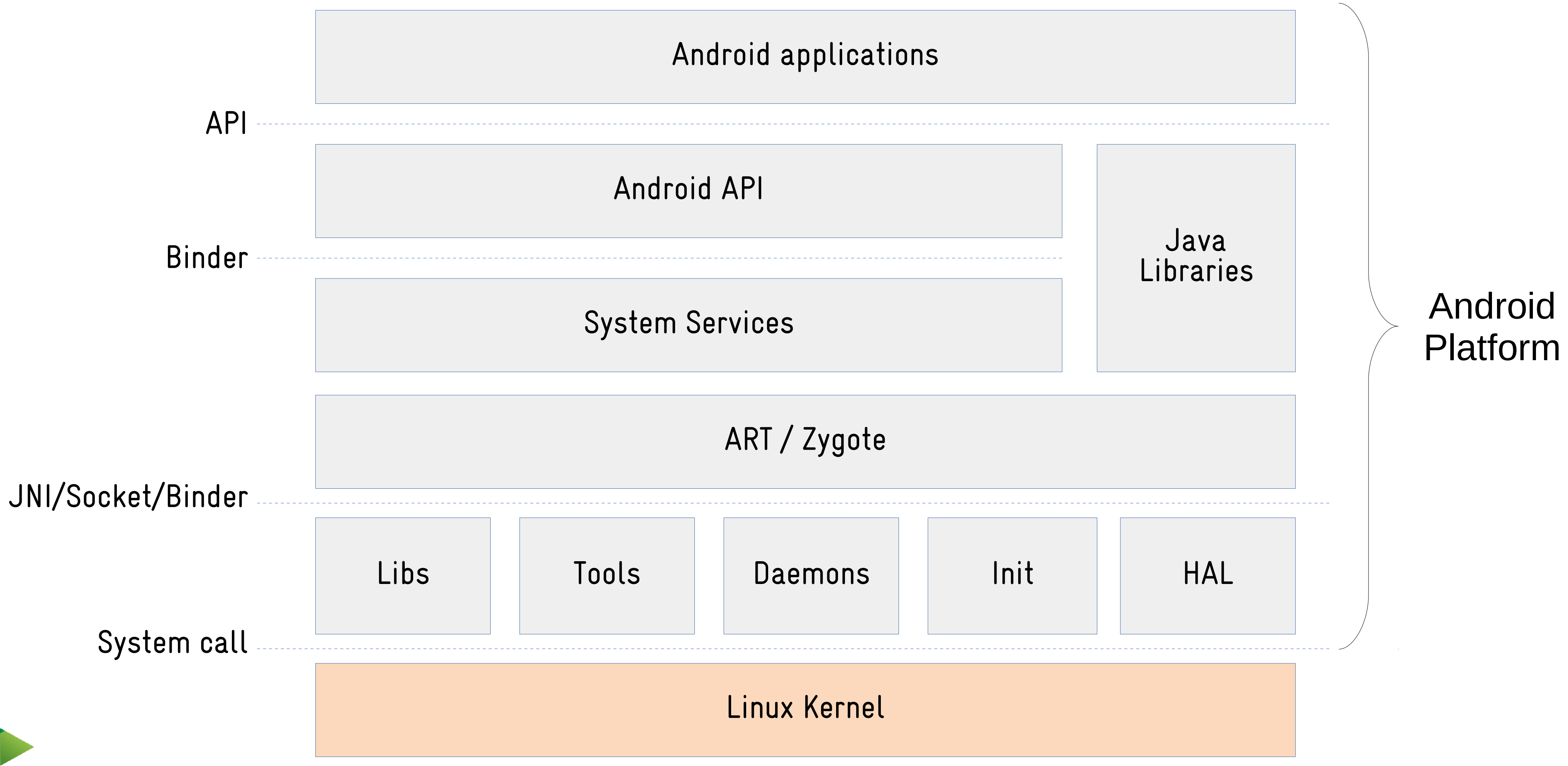
ANDROID ARCHITECTURE


Android Platform
App
App
App
App
Java framework (system services and API)
Native layer (libraries, daemons and tools)
Linux kernel (with some extra “features”)
Bootloader
Hardware

ANDROID ARCHITECTURE



ANDROID ARCHITECTURE



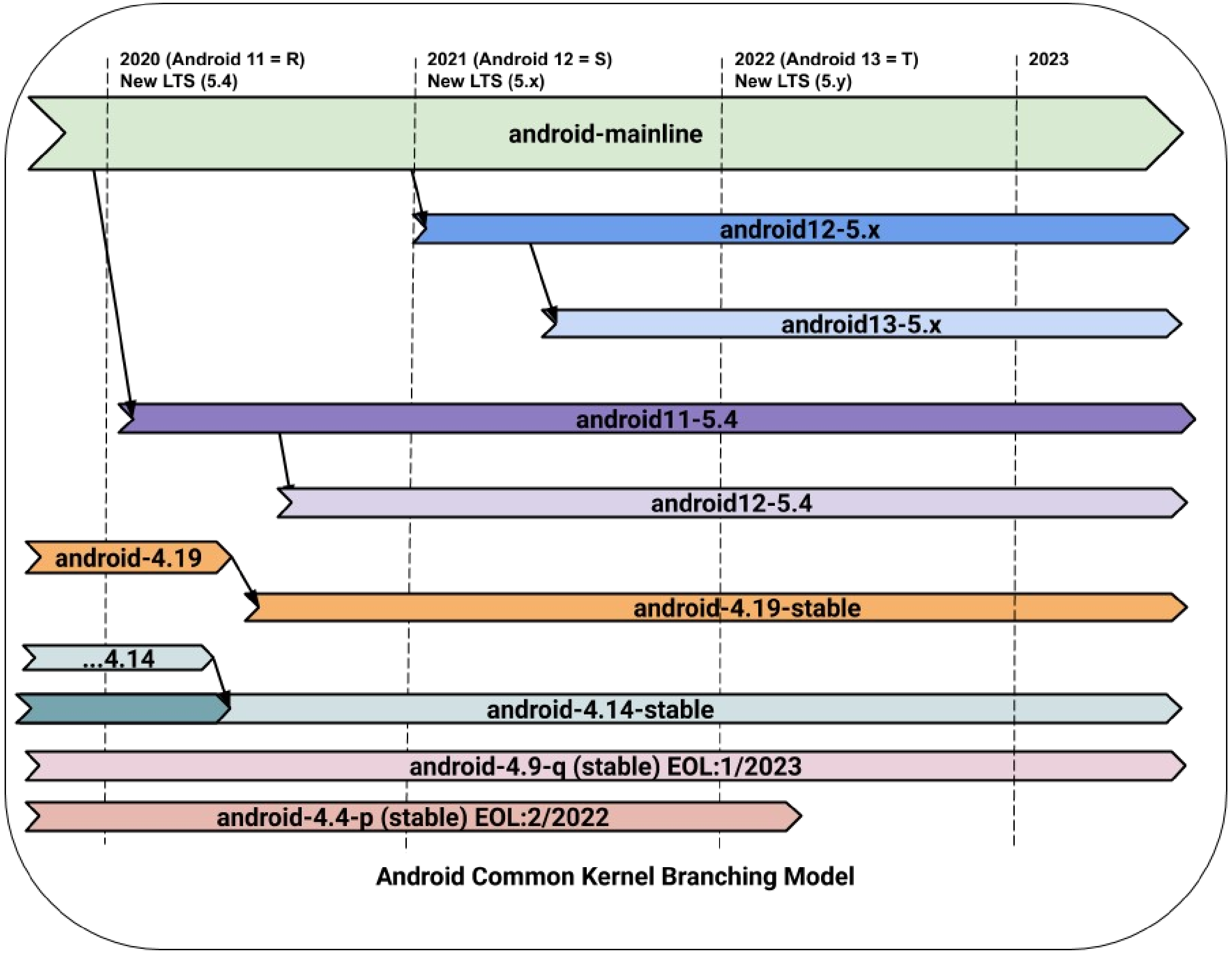
LINUX KERNEL FOR ANDROID

- The Linux kernel needs some extra features to run Android:
  - **binder**: IPC/RPC kernel-based mechanism.
  - **ashmem**: shared memory allocator.
  - **low memory killer**: manage low memory situations.

- Patches available in the kernel common repository:
- https://android.googlesource.com/kernel/common/

- Currently, a mainline kernel has the minimal features required to boot an Android system.

BRANCHING MODEL

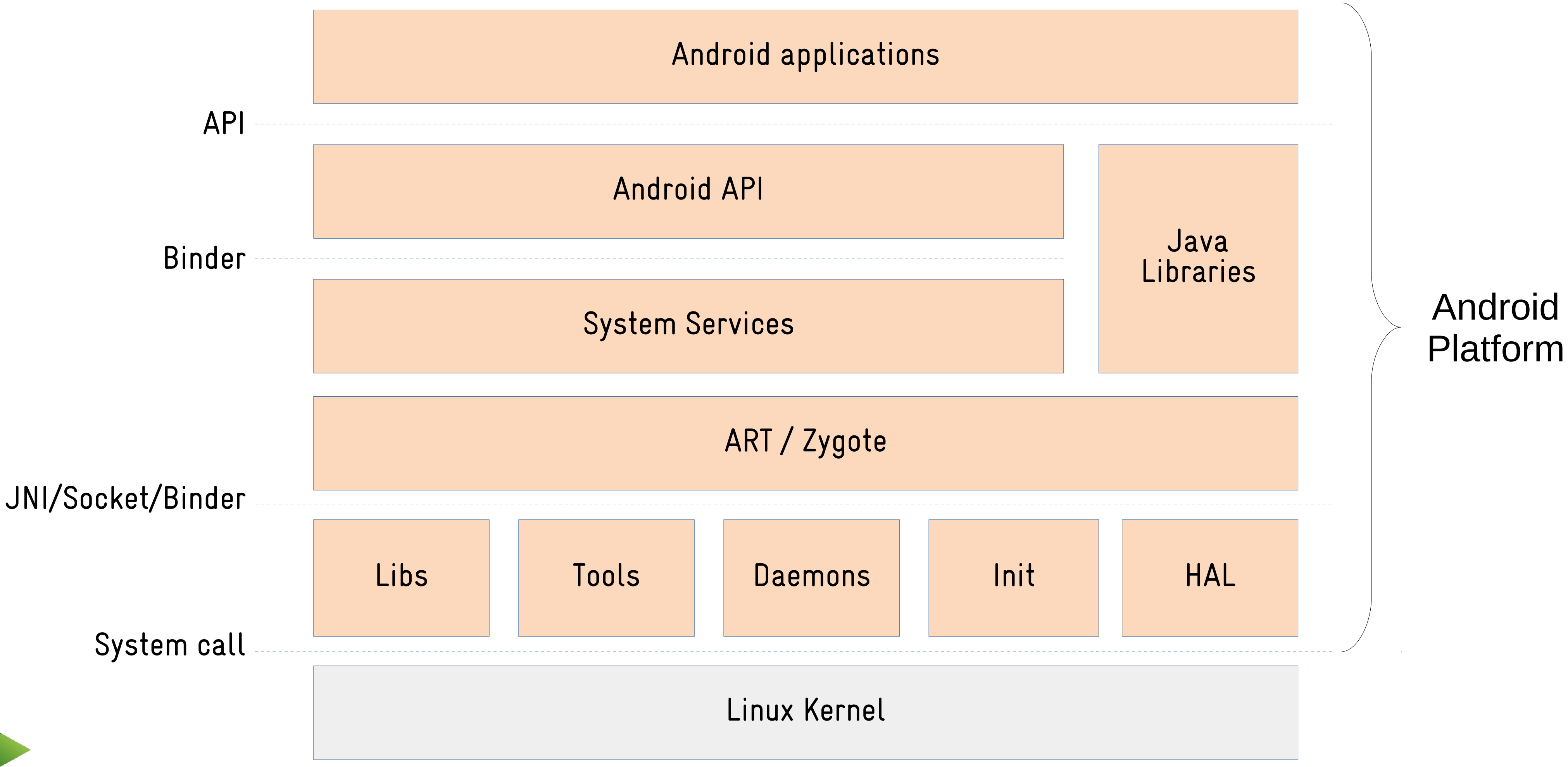


Android Common Kernel Branching Model

KERNEL PATCHES

```
$ git clone https://android.googlesource.com/kernel/common kernel-common

$ git checkout remotes/origin/android11-5.4

$ git log --oneline | grep "ANDROID:" | less
5427f8b72fc0 ANDROID: GKI: update xiaomi symbol list
ecb88922f521 ANDROID: GKI: update Vivo symbol list
32b242337266 ANDROID: sysrq: add vendor hook for sysrq crash information
42e516f6b23b ANDROID: ABI: update allowed list for galaxy
de198b0f2d39 ANDROID: GKI: update Vivo symbol list

$ git log --oneline | grep "ANDROID:" | wc -l
1157
```

ANDROID ARCHITECTURE



AOSP

- The Android platform is the user space part of an Android operating system, and it is implemented in the Android Open Source Project (AOSP).

- The AOSP is made of hundreds of repositories (780 in Android 11).

  https://android.googlesource.com/

- The source code is managed with common tools like `repo` and `git`.

  ```
  $ repo init -u https://android.googlesource.com/platform/manifest
  $ repo sync
  ```

- Large! (Android 11 is 100GB of source code plus 115GB after one build).

SOURCE CODE LISTING

```
$ ls
Android.bp      dalvik       libcore           read-snapshot.txt
art             developers   libnativehelper   sdk
bionic          development  Makefile          system
bootable        device       out               test
bootstrap.bash  external     packages          toolchain
build           frameworks   pdk               tools
compatibility   hardware     platform_testing
cts             kernel       prebuilts
```

COMMUNITY AND COLLABORATION

- Several discussion groups are available to communicate with the community and the developers:

  https://groups.google.com/d/forum/android-platform

- Anyone can contribute to the project via the Gerrit code review tool.

  https://android-review.googlesource.com

- The evolution of the project and the features that will be available in a future version of Android are controlled exclusively by Google.

LICENSING

- The vast majority of software components are under the permissive Apache and BSD licenses.

- Some software components are under GPL/LGPL licenses.

- Some Google applications' source code are closed (Google Play, Gmail, Google Maps, YouTube, etc).
  - These applications are available in a package called Google Mobile Services (GMS), and to obtain them it is necessary to certify the device (ACP).

BUILD SYSTEM

- In the past, the Android build system was purely based on makefiles.
  - Instructions for compiling each software component were defined in `Android.mk` files.

- This build system had several shortcomings, including low performance in incremental builds.

- It was replaced in the latest versions of Android with the Soong build system.

  https://android.googlesource.com/platform/build/soong

SOONG

- The rules for compiling the software components are defined in Blueprint files (`Android.bp`), which have a syntax similar to JSON.

- Blueprint files are processed by the Blueprint tool, which produces `.ninja` files with all the rules for processing Android software components.

  https://opensource.google.com/projects/blueprint

- The `.ninja` files are then processed by the Ninja tool, which will compile all the software components to generate the Android images.

  https://ninja-build.org/

SOONG

- Not all make files (`Android.mk`) were converted to Blueprint files (`Android.bp`) during the migration to this new build system.

- For this reason, there is a tool called `kati` is responsible for converting `Android.mk` files to `.ninja` files.

  https://github.com/google/kati

- All `Android.mk` files should gradually be converted to `Android.bp` in the next Android releases, eliminating the need to use the kati tool in the Android build system.

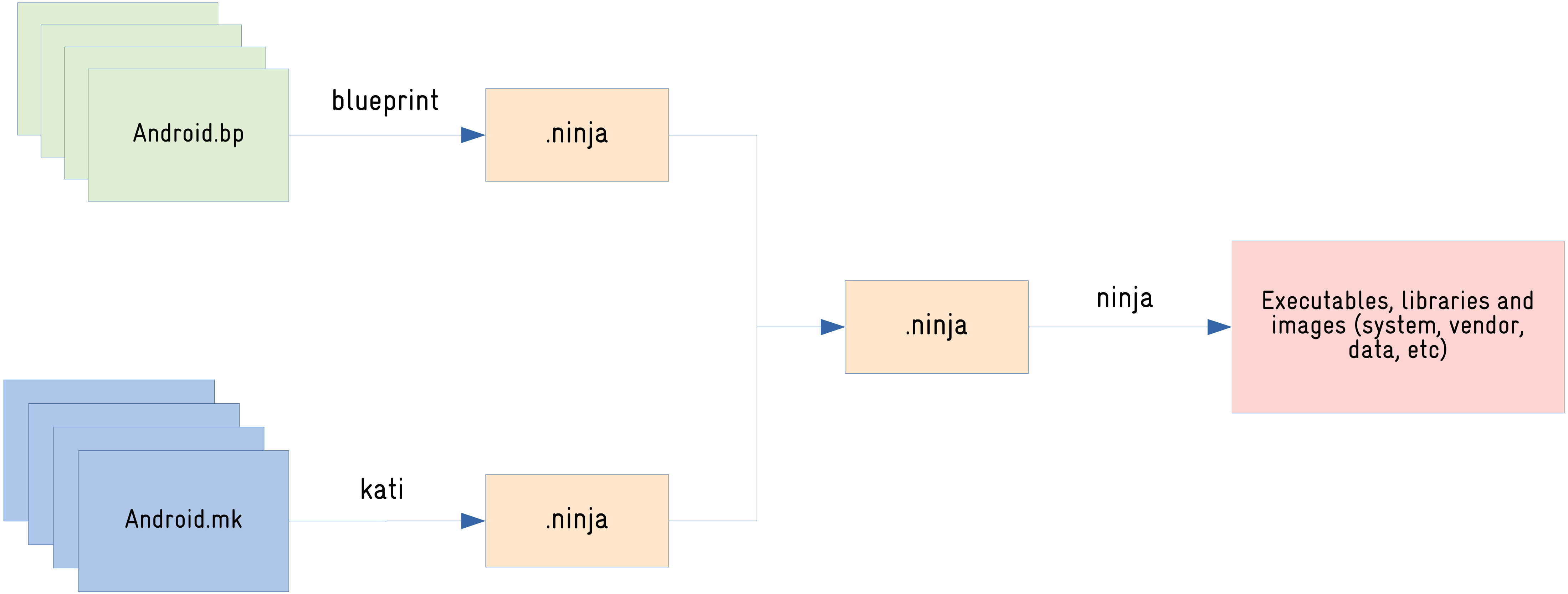
ANDROID.MK

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)

LOCAL_SRC_FILES = helloworld.c
LOCAL_MODULE = helloworld
LOCAL_MODULE_TAGS = optional

include $(BUILD_EXECUTABLE)
```

ANDROID.BP

```
cc_binary {
    name: "helloworld",
    srcs: ["helloworld.c"],
    tags: ["optional"],
}
```

SOONG


Android.bp
blueprint
.ninja
Android.mk
kati
.ninja
.ninja
ninja
Executables, libraries and images (system, vendor, data, etc)

BUILDING ANDROID

```
$ source build/envsetup.sh

$ lunch aosp_x86_64-eng

$ make

$ cd out/target/product/generic_x86_64/ && ls *.img
cache.img          super_empty.img    vbmeta.img
dtb.img            super.img          vendor_boot-debug.img
encryptionkey.img  system.img         vendor_boot.img
ramdisk-debug.img  system-qemu.img    vendor.img
ramdisk.img        userdata.img       vendor-qemu.img
ramdisk-qemu.img   userdata-qemu.img
```

ROOTFS ORGANIZATION

- The rootfs organization on Linux systems is (mostly) standardized (e.g. Filesystem Hierarcy Standard).

  http://www.pathname.com/fhs/

- And Linux distributions try to conform to this standard:
  - Applications expect this format.
  - Make it easier the life of users and developers when they need to work with different Linux systems.

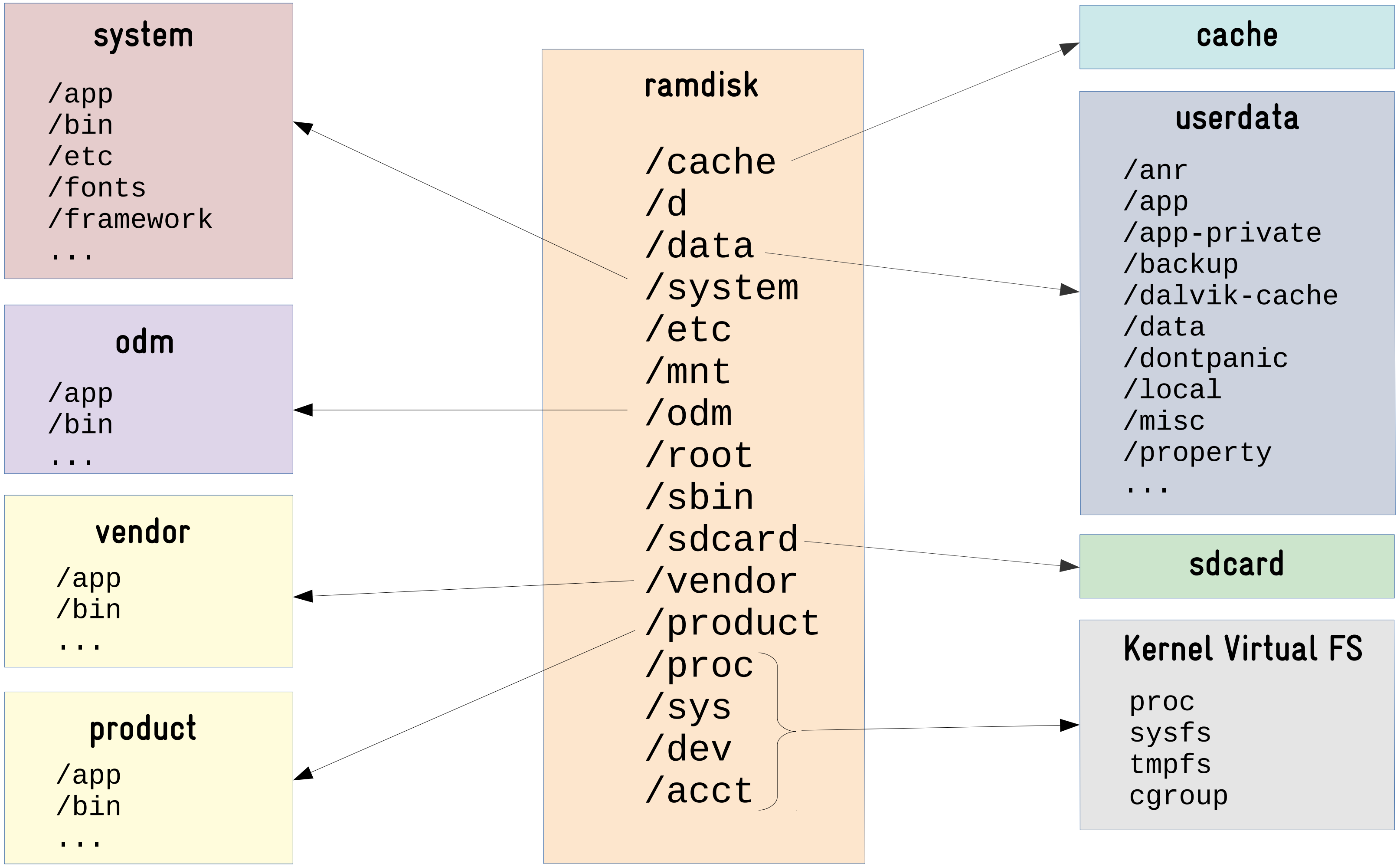
- But Android is an exception!

ANDROID ROOTFS

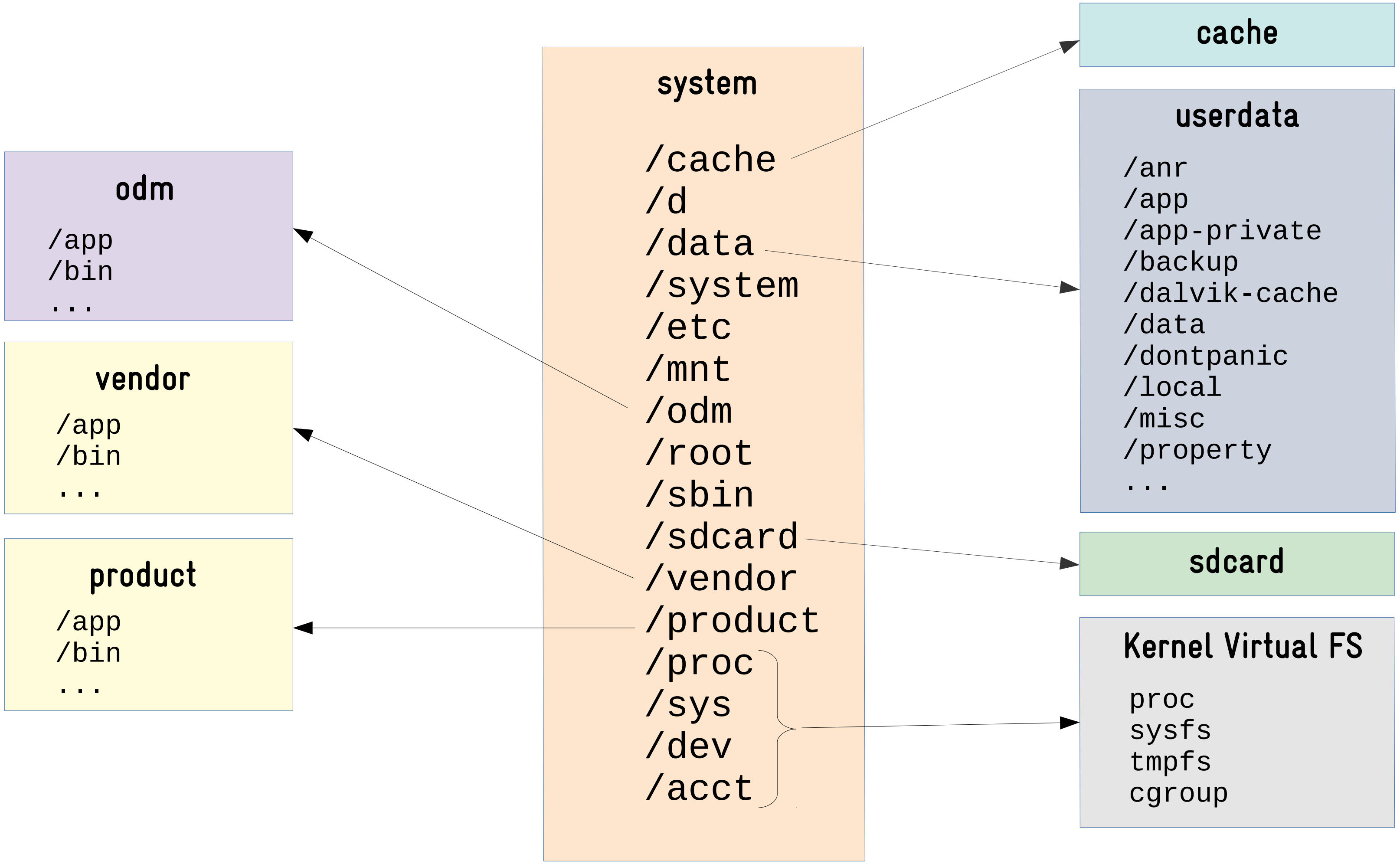
```
# ls /
acct        d              etc              mnt      sdcard
apex        data           init             odm      storage
bin         data_mirror    init.environ.rc  oem      sys
bugreports  debug_ramdisk  linkerconfig     proc     system
cache       default.prop   lost+found       product  system_ext
config      dev            metadata         res      vendor
```

Where is `/sbin`, `/usr`, `/lib`, etc?

PARTITION LAYOUT (BEFORE ANDROID 10)



PARTITION LAYOUT (ANDROID 10+)

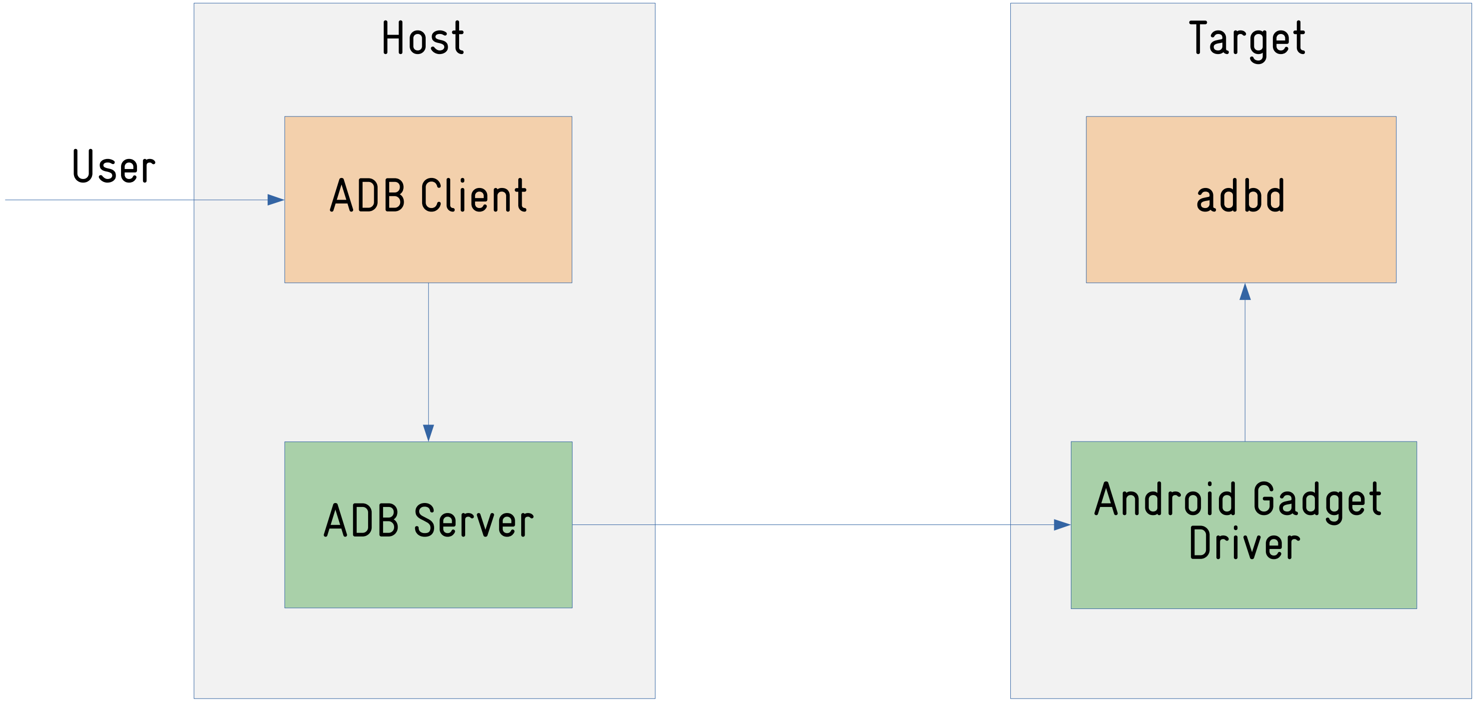


REMOTE CONNECTION

- Usually the debugging process in embedded Linux systems takes place via the a serial port or JTAG interface (for low level debugging).
- However, mobile and consumer devices such as cell phones and tablets do not normally have these interfaces.
- That is why Google has developed ADB (Android Debug Bridge).

  https://developer.android.com/studio/command-line/adb

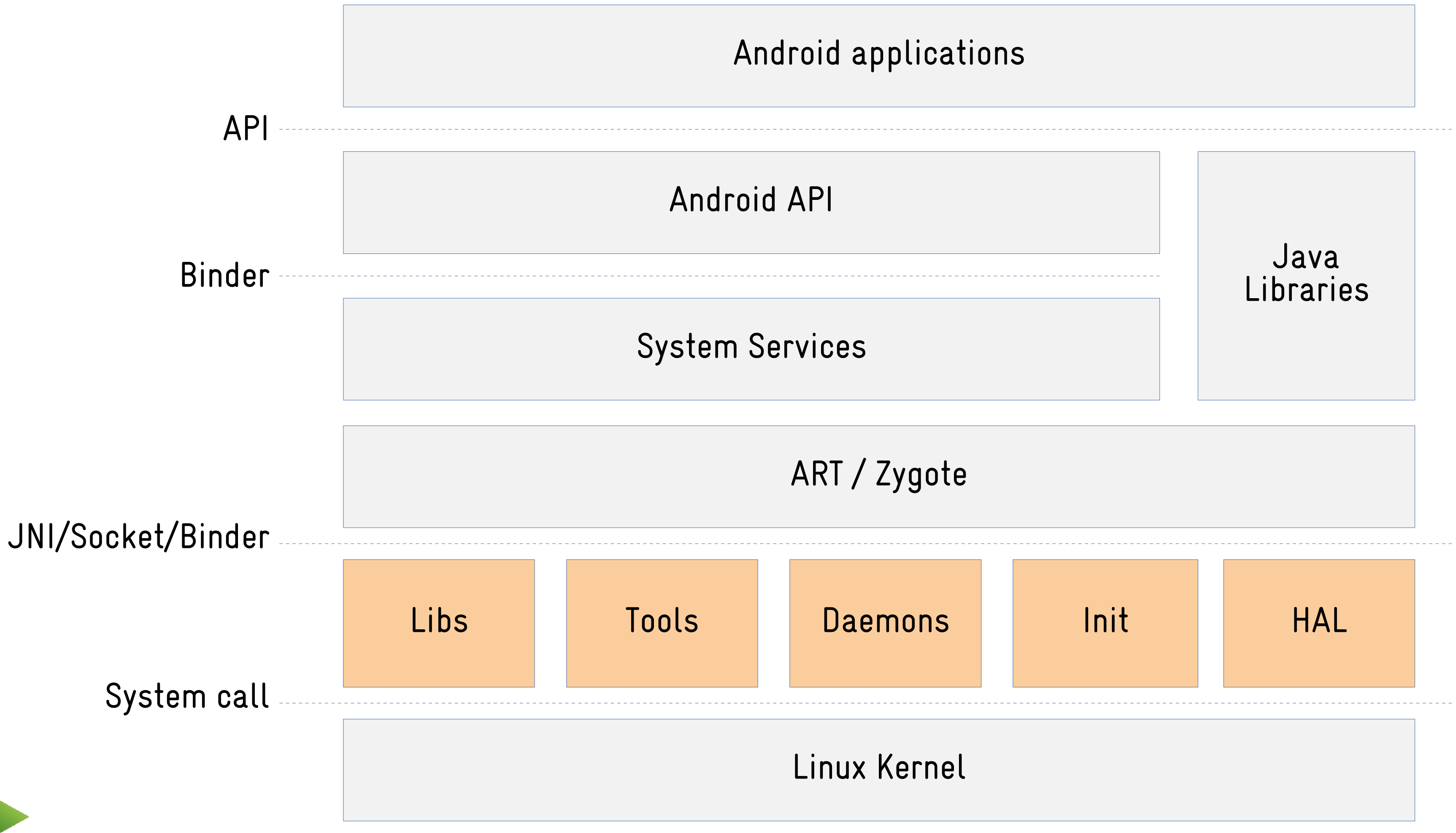
ADB


Host
User
ADB Client
ADB Server
Target
adbd
Android Gadget Driver

ADB EXAMPLES

```
$ adb devices
List of devices attached
emulator-5554 device

$ adb pull /bin/cat
/bin/cat: 1 file pulled, 0 skipped. 8.2 MB/s (384688 bytes in 0.045s)

$ adb shell
generic_x86_64:/ #
```

NATIVE LAYER



C LIBRARY

- One of the main components of an operating system based on the Linux kernel is the C library.

- The C library implements the operating system’s API, providing an interface for applications to access kernel services through system calls.

- Several C libraries are available for Linux systems, including glibc, uclibc-ng and musl.

- Android has its own C library, Bionic!

BIONIC

- At least three reasons motivated Google to implement its own C library: license, speed and size.
- The implementation of Bionic is simple, lightweight and released under the BSD license (source code in `bionic/`).
- It does not have full POSIX support, which can make it difficult to build native Linux applications for Android.

BUSYBOX 1.31.0 (libbb/missing_syscalls.c)

```
#if defined(ANDROID) || defined(__ANDROID__)
/*# include <linux/timex.h> - for struct timex, but may collide with <time.h> */
# include <sys/syscall.h>
pid_t getsid(pid_t pid)
{
     return syscall(__NR_getsid, pid);
}

int sethostname(const char *name, size_t len)
{
     return syscall(__NR_sethostname, name, len);
}

struct timex;
int adjtimex(struct timex *buf)
{
     return syscall(__NR_adjtimex, buf);
}

int pivot_root(const char *new_root, const char *put_old)
{
     return syscall(__NR_pivot_root, new_root, put_old);
}

...
```

BUSYBOX

- It is common to use BusyBox on embedded Linux devices.
- Busybox provides the (re)implementation of common tools and applications such as an init program, a shell and several utilities to manipulate and configure the system.
- But Android does not ship with BusyBox!

TOOLBOX AND TOYBOX

- Android uses Toolbox and Toybox, both released under a BSD license.

- Toolbox is a tool implemented by Google and its source code is available at `system/core/toolbox/`.

- Toybox is a tool implemented by the community (started by Rob Landley, BusyBox ex-maintainer) and its source code is available at `external/toybox/`.

- Because these tools have some limitations, it is common to install BusyBox on an Android device, especially during development.

BUSYBOX

addgroup, adduser, adjtimex, ar, arp, arping, ash, awk, basename, bbconfig, bbsh, brctl, bunzip2, busybox, bzcat, bzip2, cal, cat, catv, chat, chattr, chcon, chgrp, chmod, chown, chpasswd, chpst, chroot, chrt, chvt, cksum, clear, cmp, comm, cp, cpio, crond, crontab, cryptpw, cttyhack, cut, date, dc, dd, deallocvt, delgroup, deluser, depmod, devfsd, df, dhcprelay, diff, dirname, dmesg, dnsd, dos2unix, dpkg, dpkg_deb, du, dumpkmap, dumpleases, e2fsck, echo, ed, egrep, eject, env, envdir, envuidgid, ether_wake, expand, expr, fakeidentd, false, fbset, fbsplash, fdflush, fdformat, fdisk, fetchmail, fgrep, find, findfs, fold, free, freeramdisk, fsck, fsck_minix, ftpget, ftpput, fuser, getenforce, getopt, getsebool, getty, grep, gunzip, gzip, halt, hd, hdparm, head, hexdump, hostid, hostname, httpd, hush, hwclock, id, ifconfig, ifdown, ifenslave, ifup, inetd, init, inotifyd, insmod, install, ip, ipaddr, ipcalc, ipcrm, ipcs, iplink, iproute, iprule, iptunnel, kbd_mode, kill, killall, killall5, klogd, lash, last, length, less, linux32, linux64, linuxrc, ln, load_policy, loadfont, loadkmap, logger, login, logname, logread, losetup, lpd, lpq, lpr, ls, lsattr, lsmod, lzmacat, makedevs, man, matchpathcon, md5sum, mdev, mesg, microcom, mkdir, mke2fs, mkfifo, mkfs_minix, mknod, mkswap, mktemp, modprobe, more, mount, mountpoint, msh, mt, mv, nameif, nc, netstat, nice, nmeter, nohup, nslookup, od, openvt, parse, passwd, patch, pgrep, pidof, ping, ping6, pipe_progress, pivot_root, pkill, poweroff, printenv, printf, ps, pscan, pwd, raidautorun, rdate, rdev, readahead, readlink, readprofile, realpath, reboot, renice, reset, resize, restorecon, rm, rmdir, rmmod, route, rpm, rpm2cpio, rtcwake, run_parts, runcon, runlevel, runsv, runsvdir, rx, script, sed, selinuxenabled, sendmail, seq, sestatus, setarch, setconsole, setenforce, setfiles, setfont, setkeycodes, setlogcons, setsebool, setsid, setuidgid, sh, sha1sum, showkey, slattach, sleep, softlimit, sort, split, start_stop_daemon, stat, strings, stty, su, sulogin, sum, sv, svlogd, swapoff, swapon, switch_root, sync, sysctl, syslogd, tac, tail, tar, taskset, tcpsvd, tee, telnet, telnetd, test, tftp, tftpd, time, top, touch, tr, traceroute, true, tty, ttysize, tune2fs, udhcpc, udhcpd, udpsvd, umount, uname, uncompress, unexpand, uniq, unix2dos, unlzma, unzip, uptime, usleep, uudecode, uuencode, vconfig, **vi**, vlock, watch, watchdog, wc, wget, which, who, whoami, xargs, yes, zcat, zcip

TOOLBOX

```
getprop modprobe setprop start stop toolbox
```

TOYBOX

```
acpi base64 basename blkid blockdev cal cat chattr chcon chgrp chmod chown chroot chrt cksum
clear cmp comm cp cpio cut date dd devmem df diff dirname dmesg dos2unix du echo egrep env expand
expr fallocate false fgrep file find flock fmt free freeramdisk fsfreeze fsync getconf getenforce
getfattr getopt grep groups gunzip gzip head help hostname hwclock i2cdetect i2cdump i2cget
i2cset iconv id ifconfig inotifyd insmod install ionice iorenice iotop kill killall ln
load_policy log logname losetup ls lsattr lsmod lsof lspci lsusb makedevs md5sum microcom mkdir
mkfifo mknod mkswap mktemp modinfo modprobe more mount mountpoint mv nbd-client nc netcat netstat
nice nl nohup nproc nsenter od partprobe paste patch pgrep pidof ping ping6 pivot_root pkill pmap
printenv printf prlimit ps pwd pwdx readelf readlink realpath renice restorecon rev rfkill rm
rmdir rmmod runcon sed sendevent seq setenforce setfattr setsid sha1sum sha224sum sha256sum
sha384sum sha512sum sleep sort split stat strings stty swapoff swapon sync sysctl tac tail tar
taskset tee test time timeout top touch tr traceroute traceroute6 true truncate tty tunctl ulimit
umount uname uniq unix2dos unlink unshare uptime usleep uudecode uuencode uuidgen vconfig vi
vmstat watch wc which whoami xargs xxd yes zcat
```

INIT SYSTEM

- The init application is run by the kernel right after mounting the rootfs, and it is responsible for system initialization and management.
- There are several implementations of the init process for Linux systems, including sysvinit, systemd and upstart.
- As you may already expect, Android has its own init system!

ANDROID INIT

- The Android init process has 3 main responsibilities:
  - Boot the operating system (export environment variables, create and set permissions on files and directories, create links, mount file systems, setup selinux, etc).
  - Start and monitor daemons.
  - Manage system properties.
- The behavior of the init process is defined in a configuration file (by default `/etc/init/hw/init.rc`).

INIT SOURCE CODE (init.cpp)

```
static void LoadBootScripts(ActionManager& action_manager, ServiceList& service_list) {
    Parser parser = CreateParser(action_manager, service_list);

    std::string bootscript = GetProperty("ro.boot.init_rc", "");
    if (bootscript.empty()) {
        parser.ParseConfig("/system/etc/init/hw/init.rc");
        if (!parser.ParseConfig("/system/etc/init")) {
            late_import_paths.emplace_back("/system/etc/init");
        }
        // late_import is available only in Q and earlier release. As we don't
        // have system_ext in those versions, skip late_import for system_ext.
        parser.ParseConfig("/system_ext/etc/init");
        if (!parser.ParseConfig("/product/etc/init")) {
            late_import_paths.emplace_back("/product/etc/init");
        }
        if (!parser.ParseConfig("/odm/etc/init")) {
            late_import_paths.emplace_back("/odm/etc/init");
        }
        if (!parser.ParseConfig("/vendor/etc/init")) {
            late_import_paths.emplace_back("/vendor/etc/init");
        }
    } else {
        parser.ParseConfig(bootscript);
    }
}
```

INIT.RC

```
import /init.environ.rc
import /system/etc/init/hw/init.usb.rc
import /init.${ro.hardware}.rc
import /vendor/etc/init/hw/init.${ro.hardware}.rc
import /system/etc/init/hw/init.usb.configfs.rc
import /system/etc/init/hw/init.${ro.zygote}.rc

# Cgroups are mounted right before early-init using list from /etc/cgroups.json
on early-init
    # Disable sysrq from keyboard
    write /proc/sys/kernel/sysrq 0

    # Android doesn't need kernel module autoloading, and it causes SELinux
    # denials.  So disable it by setting modprobe to the empty string.  Note: to
    # explicitly set a sysctl to an empty string, a trailing newline is needed.
    write /proc/sys/kernel/modprobe \n

    ...
```

INIT.RC

```
on init
    sysclktz 0

    # Mix device-specific information into the entropy pool
    copy /proc/cmdline /dev/urandom
    copy /system/etc/prop.default /dev/urandom

    symlink /proc/self/fd/0 /dev/stdin
    symlink /proc/self/fd/1 /dev/stdout
    symlink /proc/self/fd/2 /dev/stderr

    ...

# Mount filesystems and start core system services.
on late-init
    trigger early-fs

    # Mount fstab in init.{$device}.rc by mount_all command. Optional parameter
    # '--early' can be specified to skip entries with 'latemount'.
    # /system and /vendor must be mounted by the end of the fs stage,
    # while /data is optional.
    trigger fs
```

INIT.RC

```
on property:ro.debuggable=1
    # Give writes to anyone for the trace folder on debug builds.
    # The folder is used to store method traces.
    chmod 0773 /data/misc/trace
    # Give reads to anyone for the window trace folder on debug builds.
    chmod 0775 /data/misc/wmtrace

service ueventd /system/bin/ueventd
    class core
    critical
    seclabel u:r:ueventd:s0
    shutdown critical

service console /system/bin/sh
    class core
    console
    disabled
    user shell
    group shell log readproc
    seclabel u:r:shell:s0
    setenv HOSTNAME console
```

SHELL

- Android currently uses MirBSD Korn Shell.
  https://www.mirbsd.org/mksh.htm

- Probably much more limited than the default shell available in your Linux desktop.

- That means some scripts that run in your desktop may not run on Android!

DAEMONS

- Daemons are processes that run in the background and are responsible for managing some system functionality:
  - Most of them are executed at startup by the `init` process.
  - Usually they run in the background for as long as the system is functional.
  - They are normally used to control and centralize access to a system resource.
- On Android, many daemons are an interface between the Android framework and system resources (network, storage, energy, etc).

ANDROID DAEMONS

- `ueventd`: responsible for managing the connection of hardware devices (device hotplugging). It is the equivalent of udev or mdev on Linux systems.
- `vold`: (volume daemon) is responsible for monitoring events from storage devices.
- `rild`: (radio interface layer daemon) manages communication with the modem chip (voice and data).

ANDROID DAEMONS

- `netd`: (network management service daemon) is responsible for managing network connections (Bluetooth, Wi-Fi, USB, etc).
- `installd`: (install daemon) is responsible for managing the installation of Android applications (* .apk) and their associated resources.
- `lmkd`: (low memory killer daemon) is responsible to manage the kernel low memory killer interface.

ANDROID DAEMONS

```
# ps -A
USER            PID   PPID     VSZ    RSS WCHAN            ADDR S NAME
root              1      0 10782796  9696 do_epoll_+          0 S init
root            122      1 10761204  7376 do_sys_po+          0 S ueventd
logd            145      1 10764228  7932 __x64_sys+          0 S logd
lmkd            146      1 10756496  2456 do_epoll_+          0 S lmkd
system          147      1 10759476  5016 do_epoll_+          0 S servicemanager
system          148      1 10761244  6488 do_epoll_+          0 S hwservicemanager
system          149      1 10759572  4028 do_epoll_+          0 S vndservicemanager
root            153      1 10770096  8732 binder_th+          0 S vold
tombstoned      250      1 10755388  2128 do_epoll_+          0 S tombstoned
statsd          266      1 10766140  4572 do_epoll_+          0 S statsd
root            267      1 10781776  9532 binder_th+          0 S netd
credstore       306      1 10764440  7296 binder_th+          0 S credstore
gpu_service     307      1 10762672  6804 binder_th+          0 S gpuservice
system          308      1 10873496 31972 do_epoll_+          0 S surfaceflinger
root            316      1 10756876  2656 do_sys_po+          0 S netmgr
root            318      1 10758880  3072 do_sys_po+          0 S wifi_forwarder
wifi            320      1 10759960  5464 do_select           0 S hostapd_nohidl
logd            326      1 10756544  3160 __skb_wai+          0 S logcat
root            352      1 10773084  6376 0                   0 S adbd
nobody          354      1 10757496  3164 do_sys_po+          0 S traced_probes
nobody          355      1 10757632  3464 do_sys_po+          0 S traced
cameraserver    356      1   58984  17240 binder_th+          0 S cameraserver
drm             357      1   25952   6512 binder_th+          0 S drmserver
incidentd       359      1 10761968  4992 do_epoll_+          0 S incidentd
root            360      1 10765704  6452 binder_th+          0 S installd
iorapd          361      1 10775424  9536 futex_wai+          0 S iorapd
keystore        362      1 10764916  7404 binder_th+          0 S keystore
root            366      1 10765596  5648 binder_th+          0 S storaged
...
```

LOGGING

- The log daemon (`logd`) is responsible for managing logs in Android.

- Access to the logs is done through sockets exported in `/dev/socket/`.

```
# ls /dev/socket/logd*
/dev/socket/logd  /dev/socket/logdr  /dev/socket/logdw
```

- To read or write to the logs, it is not necessary to directly access these sockets. For this, applications can use the `liblog` library.

- In the terminal, the user can write to the log with the `log` command and read/control the logs through the `logcat` tool.

LOGCAT

```
# logcat
...
10-14 13:36:51.722   771   934 D SmsNumberUtils: enter filterDestAddr. destAddr="[BajqU4K5_YhSYbs-7QUn0dOwcmI]"
10-14 13:36:51.723   771   934 D SmsNumberUtils: destAddr is not formatted.
10-14 13:36:51.723   771   934 D SmsNumberUtils: leave filterDestAddr, new destAddr="[BajqU4K5_YhSYbs-7QUn0dOwcmI]"
10-14 13:36:57.054   316   316 E netmgr  : qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:network' service:
10-14 13:36:57.054   316   316 E netmgr  : Failed to open QEMU pipe 'qemud:network': Invalid argument
10-14 13:36:57.324   318   318 E wifi_forwarder: qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:wififorward' service:
10-14 13:36:57.325   318   318 E wifi_forwarder: RemoteConnection failed to initialize: RemoteConnection failed to open pipe
...
10-14 14:37:45.408   494  1324 D WifiNl80211Manager: Scan result ready event
10-14 14:37:45.408   494  1324 D WifiNative: Scan result ready event
10-14 14:37:59.109   316   316 E netmgr  : qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:network' service:
10-14 14:37:59.109   316   316 E netmgr  : Failed to open QEMU pipe 'qemud:network': Invalid argument
10-14 14:37:59.574   318   318 E wifi_forwarder: qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:wififorward' service:
10-14 14:37:59.575   318   318 E wifi_forwarder: RemoteConnection failed to initialize: RemoteConnection failed to open pipe
10-14 14:38:00.003   642   642 D KeyguardClockSwitch: Updating clock: 2□38
10-14 14:38:59.127   316   316 E netmgr  : qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:network' service:
10-14 14:38:59.127   316   316 E netmgr  : Failed to open QEMU pipe 'qemud:network': Invalid argument
10-14 14:38:59.585   318   318 E wifi_forwarder: qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:wififorward' service:
10-14 14:38:59.585   318   318 E wifi_forwarder: RemoteConnection failed to initialize: RemoteConnection failed to open pipe
10-14 14:39:00.003   642   642 D KeyguardClockSwitch: Updating clock: 2□39
10-14 14:39:59.142   316   316 E netmgr  : qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:network' service:
10-14 14:39:59.142   316   316 E netmgr  : Failed to open QEMU pipe 'qemud:network': Invalid argument
10-14 14:39:59.634   318   318 E wifi_forwarder: qemu_pipe_open_ns:62: Could not connect to the 'pipe:qemud:wififorward' service:
10-14 14:39:59.634   318   318 E wifi_forwarder: RemoteConnection failed to initialize: RemoteConnection failed to open pipe
10-14 14:40:00.006   642   642 D KeyguardClockSwitch: Updating clock: 2□40
...
```

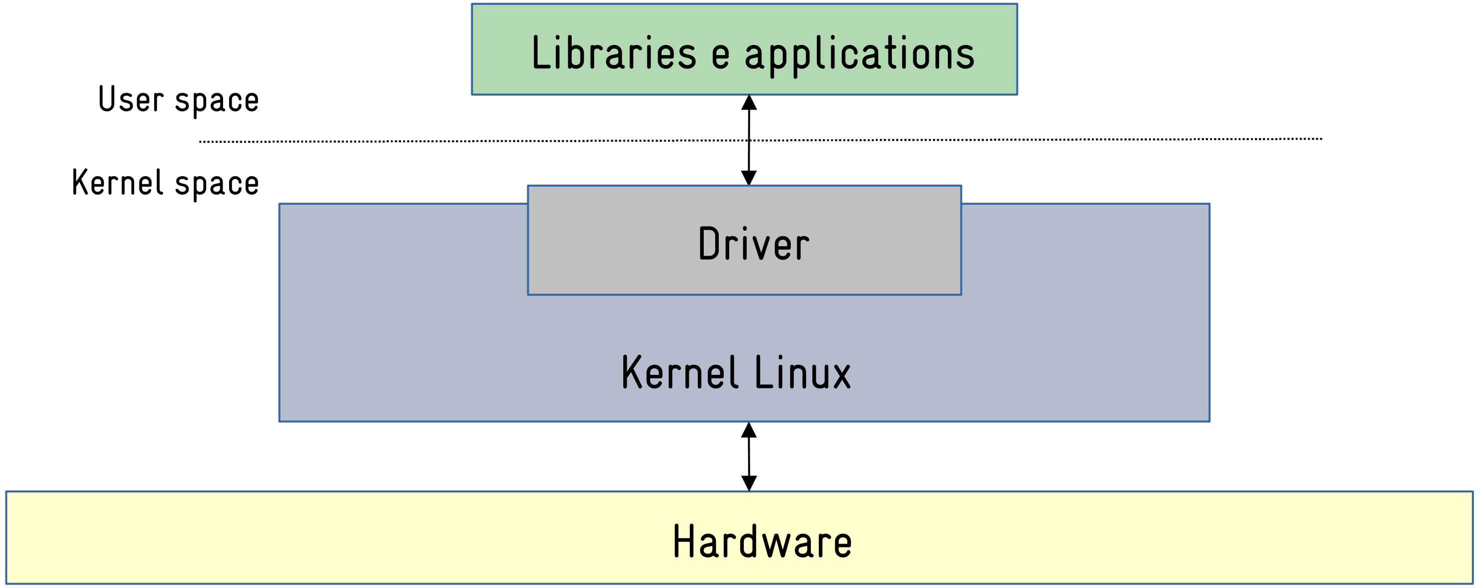
HARDWARE ABSTRACTION LAYER

- On an embedded Linux system, access to hardware devices is exposed to applications via entries in `/dev` or `/sys`.

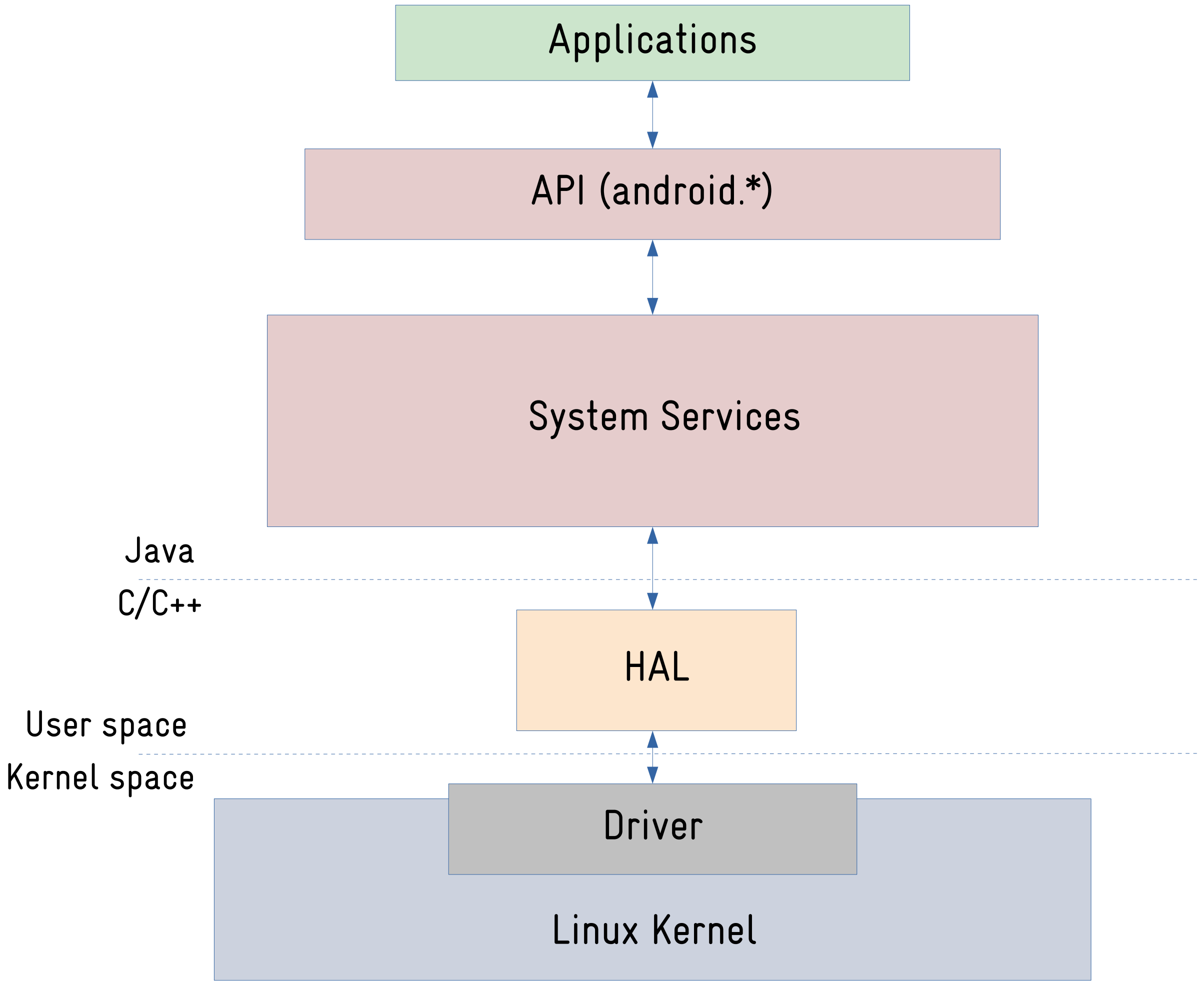
- Android relies on an additional layer (Hardware Abstraction Layer) to abstract access to hardware devices.

- Some motivations for this abstraction layer:
  - Decouple the hardware access from the Android framework.
  - Freedom for the manufacturer to implement the hardware access logic in the HAL code and release under any software license.

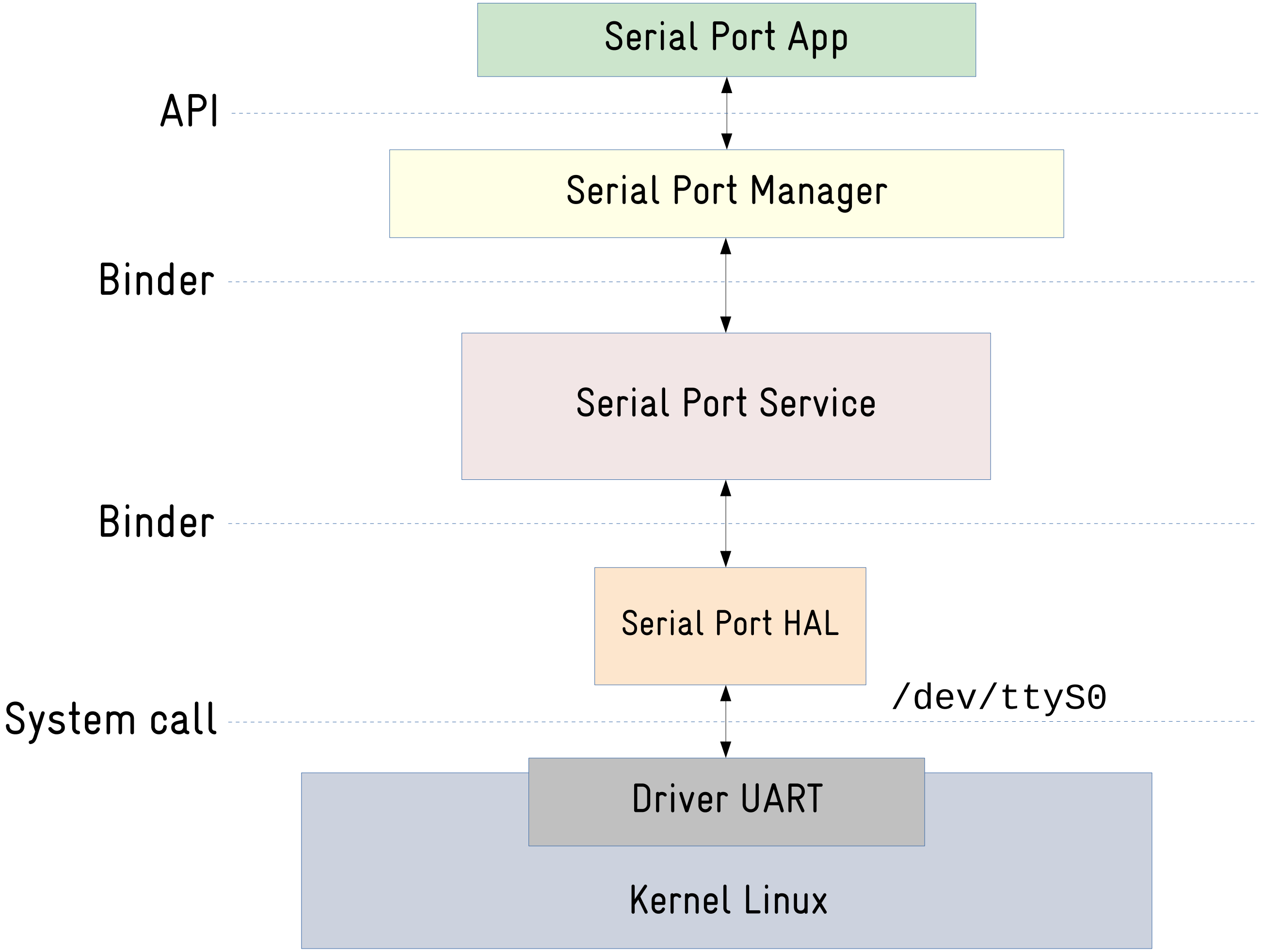
HAL ON EMBEDDED LINUX



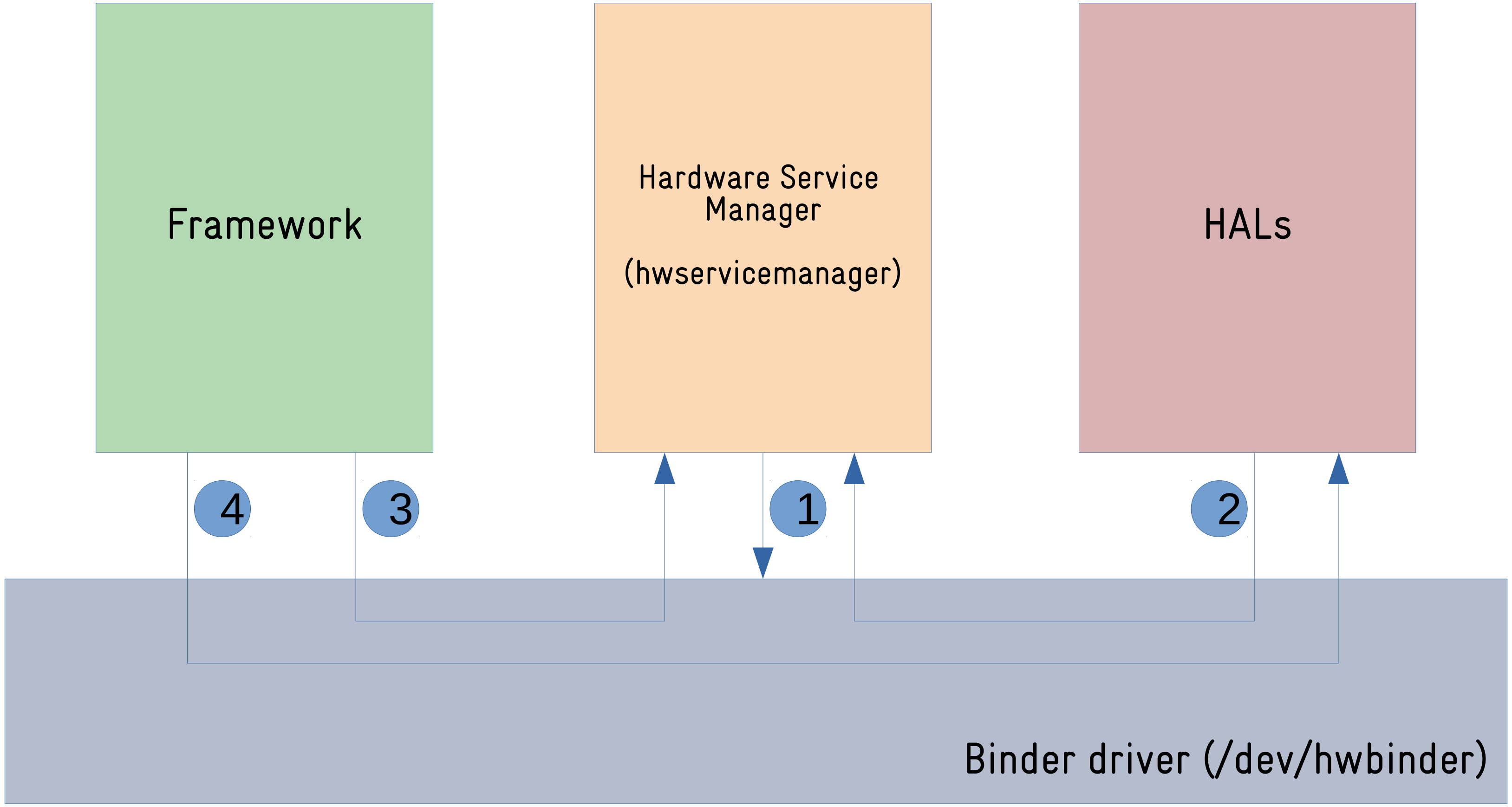
HAL ON ANDROID



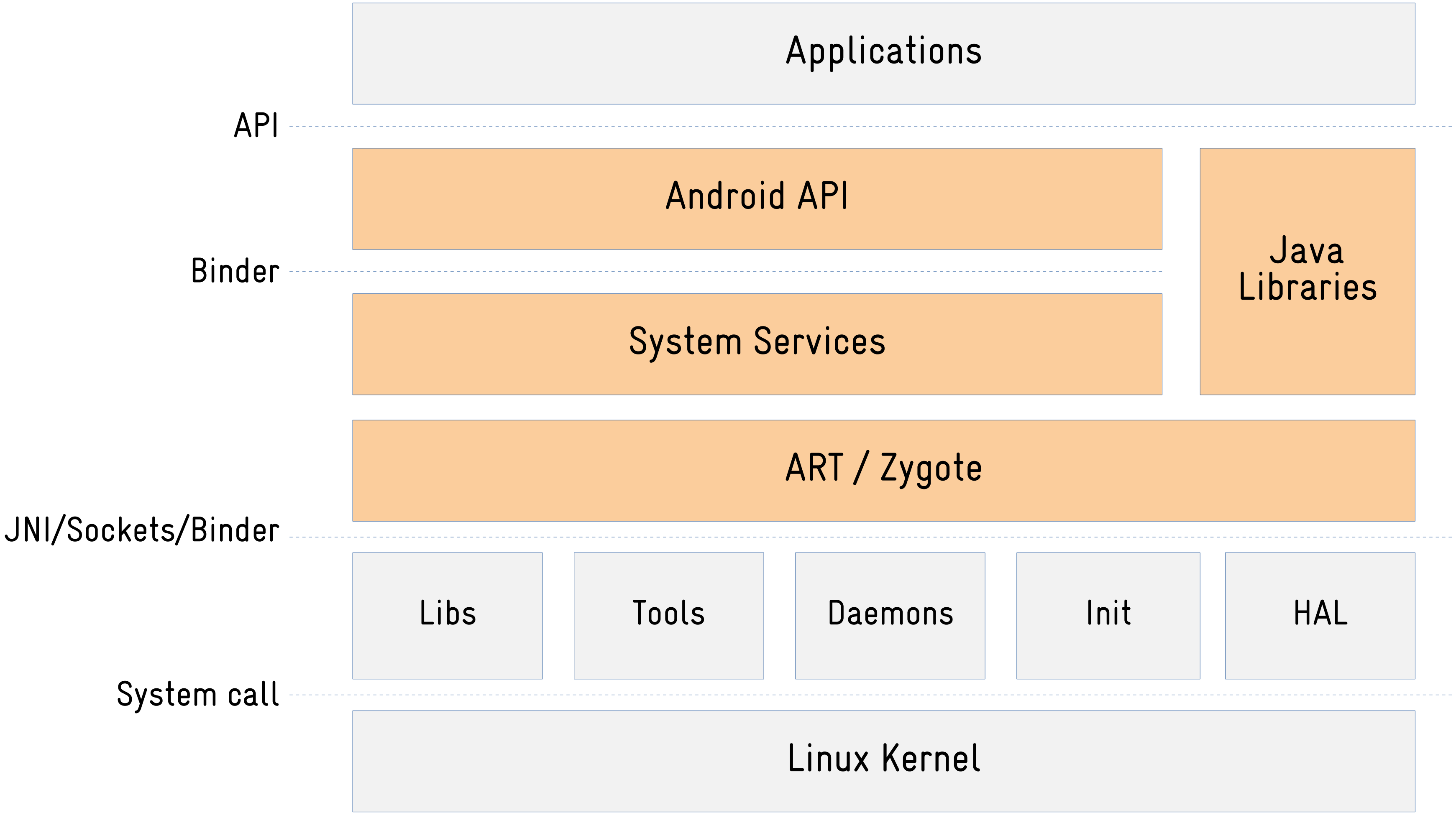
EXAMPLE: SERIAL PORT



BINDER


Framework
Hardware Service Manager
(hwservicemanager)
HALs
4
3
1
2
Binder driver (/dev/hwbinder)

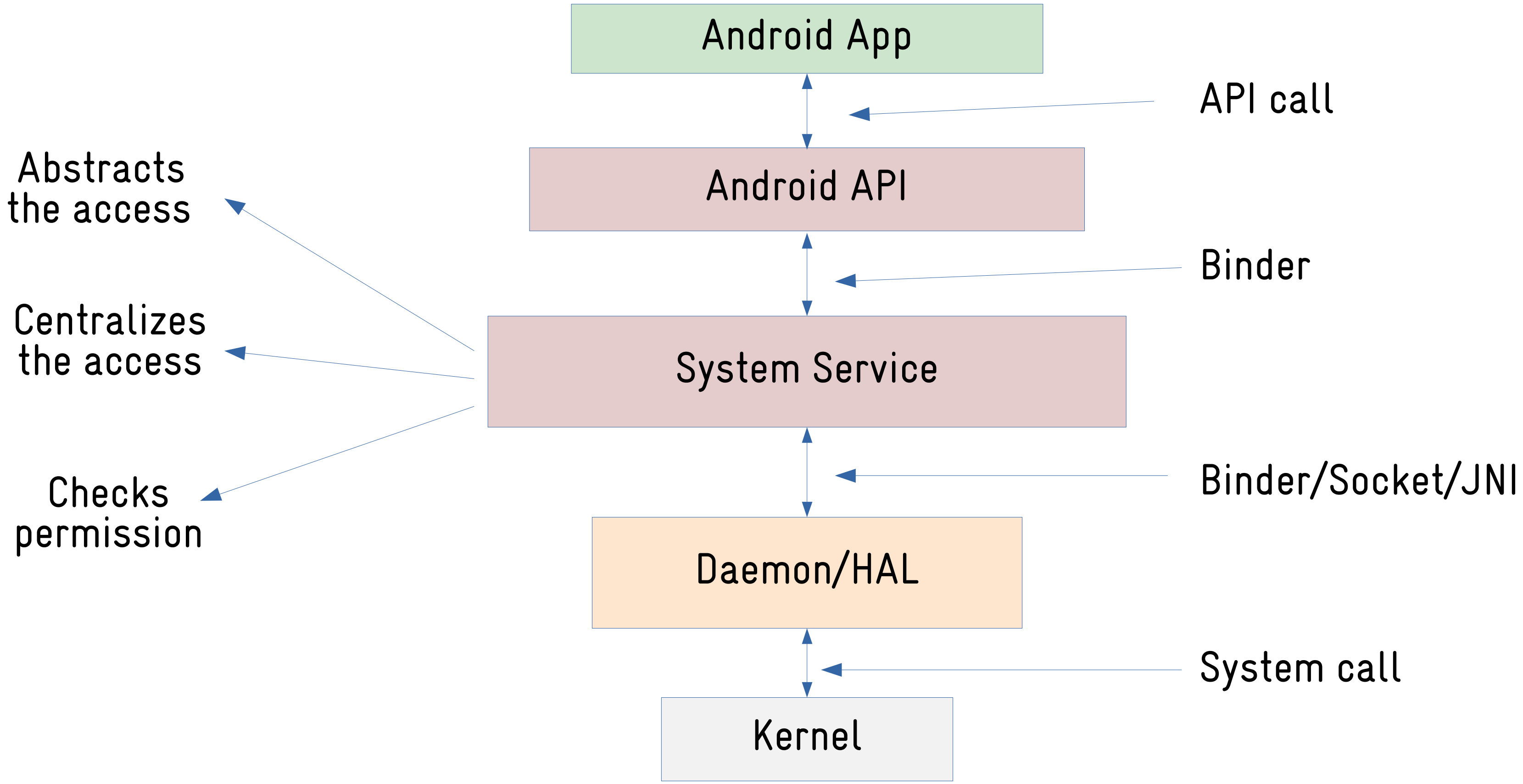
FRAMEWORK LAYER



SYSTEM SERVICES

```
# service list
Found 184 services:
0    DockObserver: []
1    SurfaceFlinger: [android.ui.ISurfaceComposer]
2    accessibility: [android.view.accessibility.IAccessibilityManager]
3    account: [android.accounts.IAccountManager]
4    activity: [android.app.IActivityManager]
5    activity_task: [android.app.IActivityTaskManager]
6    adb: [android.debug.IAdbManager]
7    alarm: [android.app.IAlarmManager]
8    android.hardware.identity.IIdentityCredentialStore/default: [android.hardware.identity.IIdentityCredentialStore]
9    android.hardware.light.ILights/default: [android.hardware.light.ILights]
10   android.hardware.power.IPower/default: [android.hardware.power.IPower]
11   android.hardware.rebootescrow.IRebootEscrow/default: [android.hardware.rebootescrow.IRebootEscrow]
12   android.hardware.vibrator.IVibrator/default: [android.hardware.vibrator.IVibrator]
13   android.security.identity: [android.security.identity.ICredentialStoreFactory]
14   android.security.keystore: [android.security.keystore.IKeystoreService]
15   android.service.gatekeeper.IGateKeeperService: [android.service.gatekeeper.IGateKeeperService]
16   app_binding: []
17   app_integrity: [android.content.integrity.IAppIntegrityManager]
18   appops: [com.android.internal.app.IAppOpsService]
19   appwidget: [com.android.internal.appwidget.IAppWidgetService]
20   audio: [android.media.IAudioService]
21   auth: [android.hardware.biometrics.IAuthService]
...
```

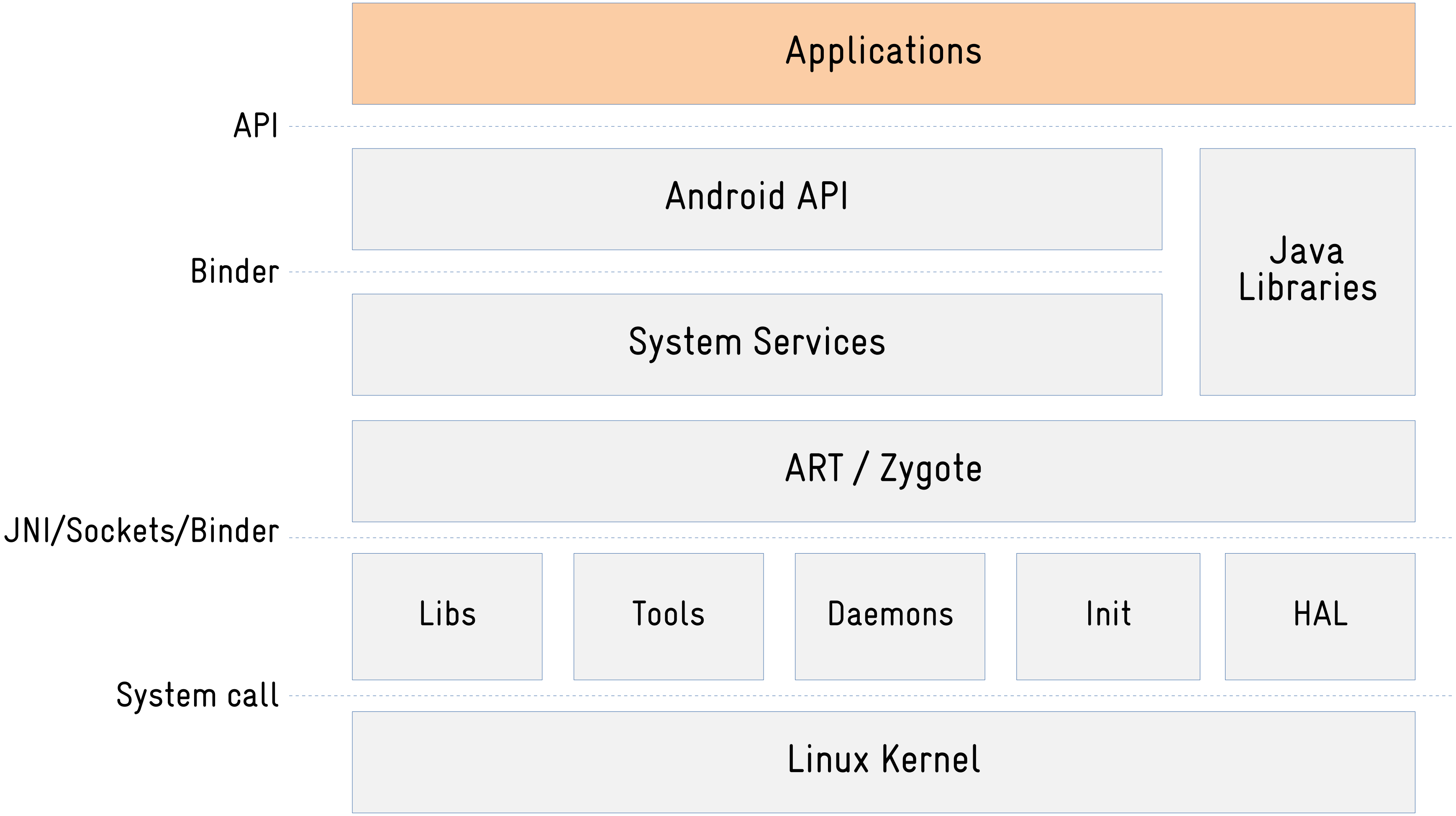
SERVICES ARCHITECTURE



CALLING SERVICES FROM COMMAND LINE!

```
# service call
service: No code specified for call
Usage: service [-h|-?]
       service list
       service check SERVICE
       service call SERVICE CODE [i32 N | i64 N | f N | d N | s16 STR | null | fd f | nfd n | afd f ] ...
Options:
   i32: Write the 32-bit integer N into the send parcel.
   i64: Write the 64-bit integer N into the send parcel.
   f:   Write the 32-bit single-precision number N into the send parcel.
   d:   Write the 64-bit double-precision number N into the send parcel.
   s16: Write the UTF-16 string STR into the send parcel.
  null: Write a null binder into the send parcel.
    fd: Write a file descriptor for the file f to the send parcel.
   nfd: Write file descriptor n to the send parcel.
   afd: Write an ashmem file descriptor for a region containing the data from file f to the send parcel.

# service call phone 2 s16 com.android.launcher3 s16 12345678
Result: Parcel(00000000    '....')
```

APPLICATION LAYER



ANDROID APPLICATIONS

- Well defined set of APIs. https://developer.android.com/reference/packages.html

- Android applications are written Java or Kotlin using the Google SDK.

- They are packaged in files with the `.apk` extension, that contains the compiled code, data and resources used by the application.

- They can be installed via Google Play or manually via ADB or any file manager.

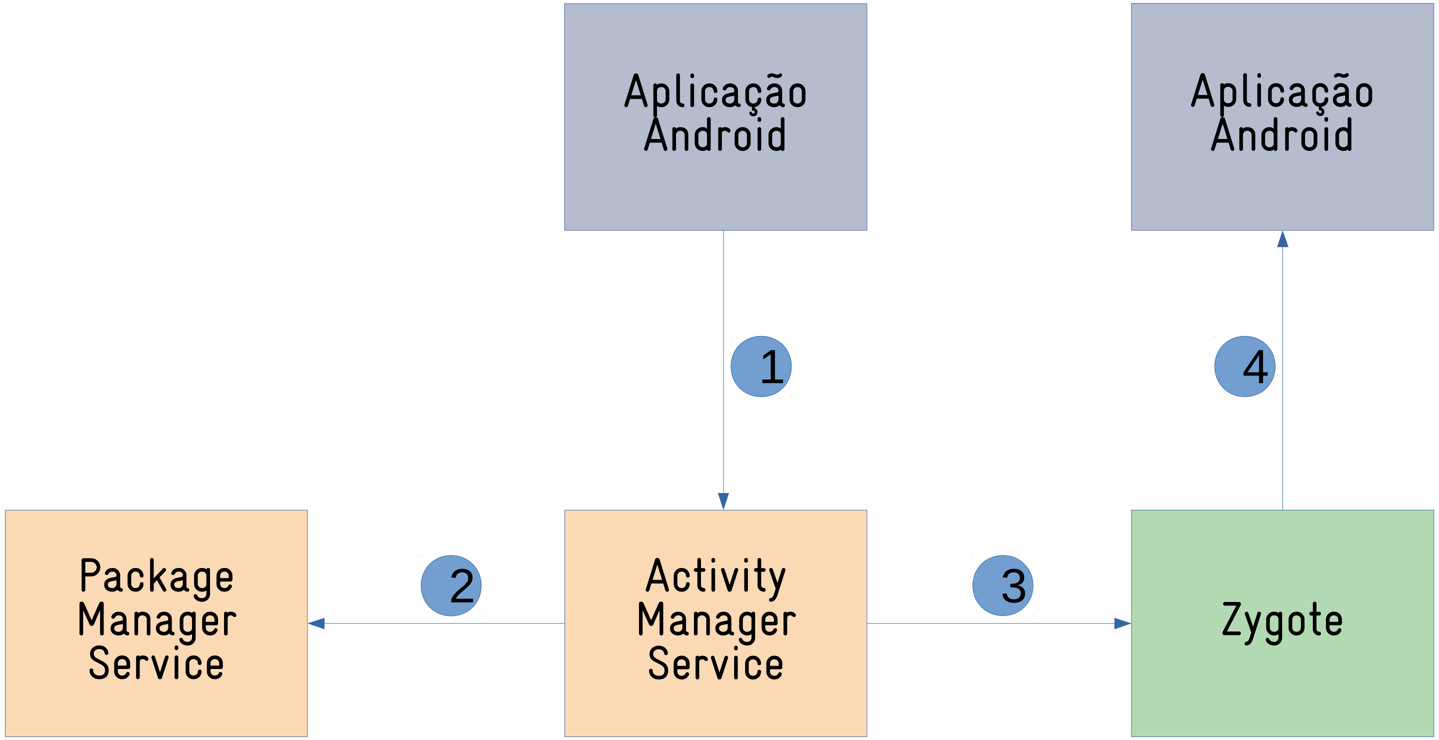
APPLICATION COMPONENTS

- Android applications are basically composed of 4 types of components:
  - Activities.
  - Services.
  - Broadcast receivers.
  - Content providers.

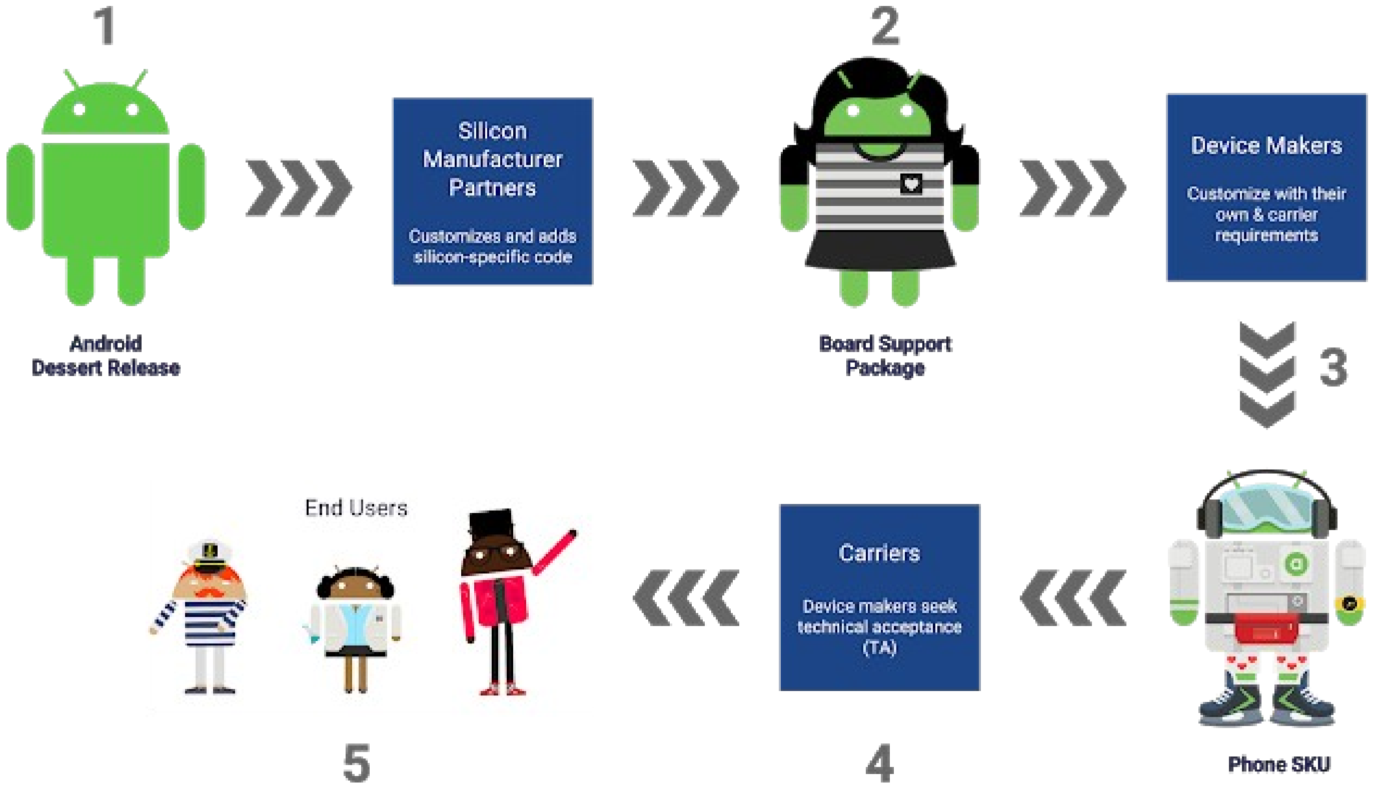
APPLICATION COMMUNICATION

- An application can contain one or more components.
- An application can start any component, including components from other applications.
- The components communicate with each other through a message exchange mechanism called **intent**.

INTENT


Aplicação Android
1
Aplicação Android
4
Package Manager Service
2
Activity Manager Service
3
Zygote

WHAT ABOUT FRAGMENTATION?



CONCLUSION

- Similarities: Based on the Linux kernel.
- Differences: (almost) everything else!
- So is Android a Linux distribution or not?

REFERENCES

- Android official platform documentation: https://source.android.com/

- Android source code!

  https://android.googlesource.com/

- Karim Yaghmour (Opersys) talks: https://www.youtube.com/channel/UCWIZcsPiXb9fQWJcijUtFXg

Q&A

Sergio Prado
sergio@embeddedbits.org

https://twitter.com/sergioprado
https://www.linkedin.com/in/sprado

Thank you!