Introduction to Android Security

Introduction to Android

Android Architecture, Android Run-time

Android Application Framework

Android Application Components, Sandboxing

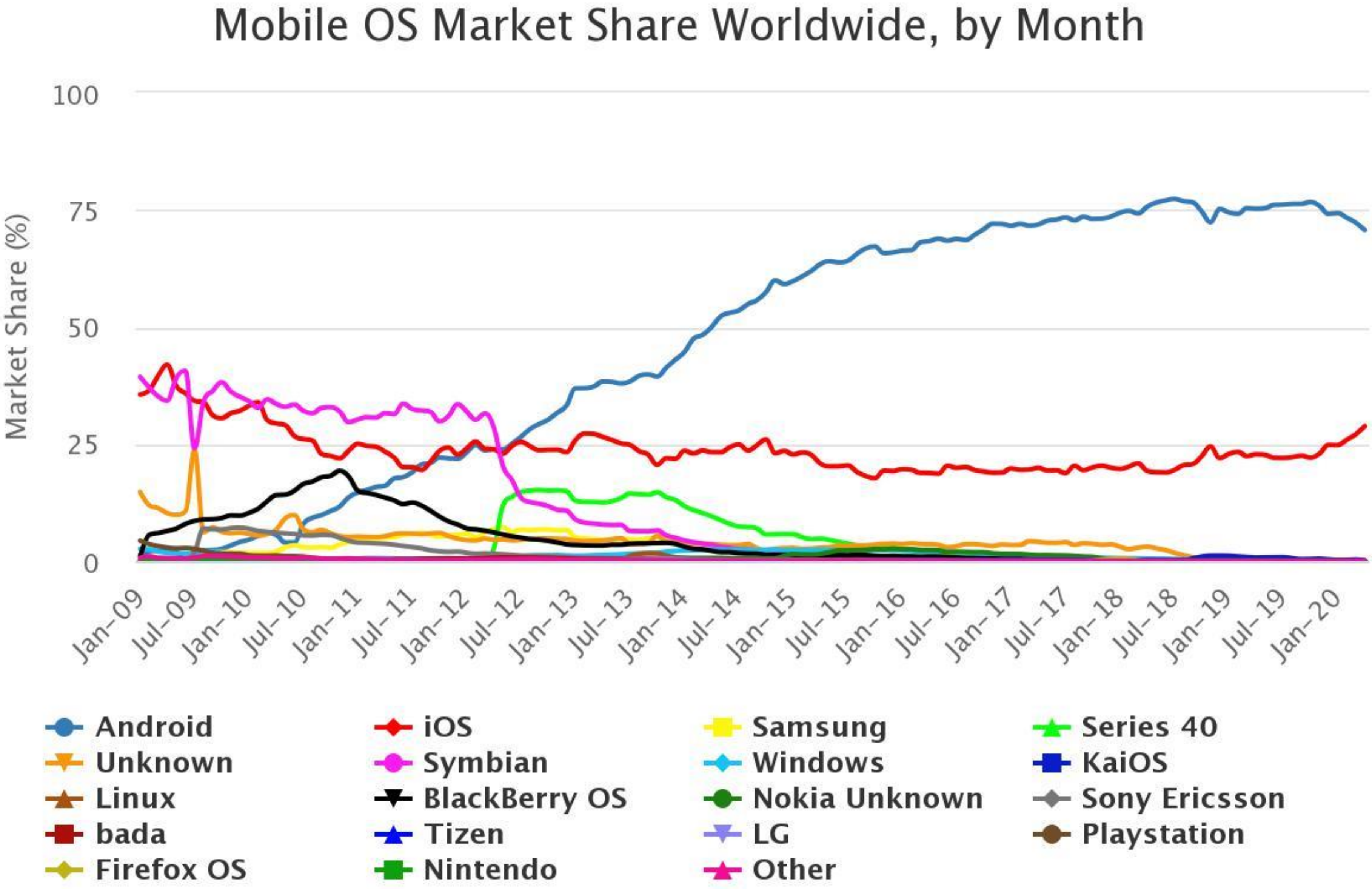
Application Inter-Process Communication

App Permission, Android Boot Process, Partition, File Systems

Mobile OS

android
BlackBerry
webOS
bada
symbian OS
Windows Phone

Mobile OS Market Share World-Wide



https://trends.google.com/trends/explore?date=2010-03-03%202022-04-03&q=%2Fm%2F02wxtgw,%2Fm%2F03wbl14,%2Fm%2F0bbv_rf,%2Fm%2F0jgf9,Windows%20Mobile

Introduction to Android

- Android is an **open-source operating system** based on **Linux** with a **Java and kotlin** programming interface for mobile devices such as Smartphone (Touch Screen Devices who supports Android OS) as well for Tablets too.
- Android was developed by the Open Handset Alliance **(OHA)**, which is led by **Google**.
- The Open Handset Alliance (OHA) is a consortium of multiple companies like Samsung, Sony, Intel and many more to provide services and deploy handsets using the android platform.

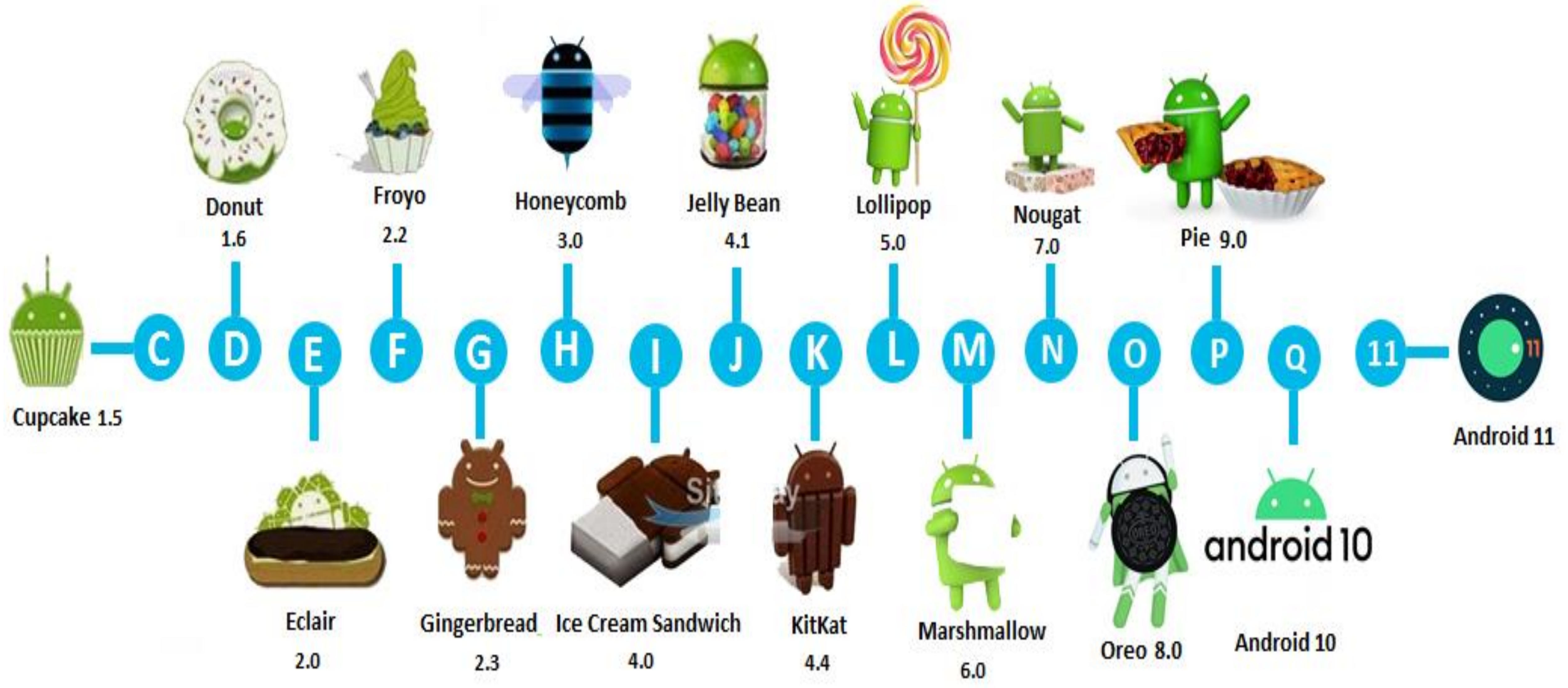
Introduction to Android

- In 2007, Google released a first beta version of the Android Software Development Kit (SDK) and the first commercial version of Android 1.0 (with name Alpha), was released in September 2008.
- In 2012, Google released another version of android, 4.1 Jelly Bean.
- In 2014, Google announced another Version, 5.0 Lollipop.
- Latest release 12, Released in Oct, 2021 and on the way to release Android 13 by June or July

Introduction to Android

- Initially, Andy Rubin founded Android Incorporation in Palo Alto, California, United States in October, 2003.
- In 17th August 2005, Google acquired android Incorporation. Since then, it is in the subsidiary of Google Incorporation.
- The key employees of Android Incorporation are Andy Rubin, Rich Miner, Chris White and Nick Sears.
- Originally intended for camera but shifted to smart phones later because of low market for camera only.
- Android is the nick name of Andy Rubin given by coworkers because of his love to robots.
- In 2007, Google announces the development of android OS. 7) In 2008, HTC launched the first android mobile.

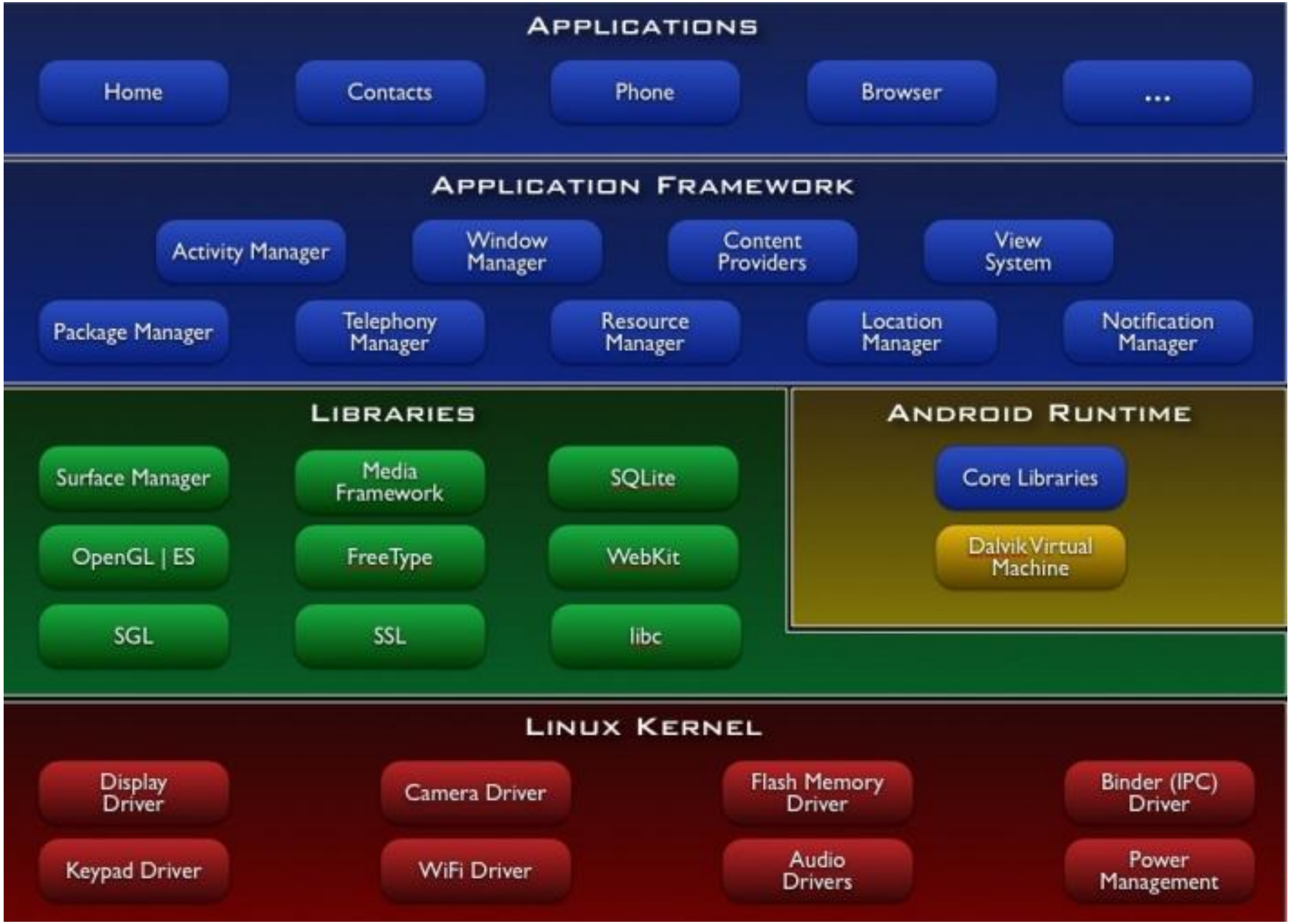
Android Versions



Android Architecture

- Any operating system (desktop or mobile) takes responsibility for **managing the resources** of the system and provides a way for **applications to talk to hardware or physical components** in order to accomplish certain tasks.
- OS manage mobile phones, manages **memory** and **processes, enforces security**, takes care of networking issues
- The Android operating system consists of a stack of layers running on top of each other.

Android Architecture



Android Architecture

✓The Linux kernel:

- Provides a level of **abstraction** between the device hardware and the upper layers.
- Kernel contains **drivers to understand the hardware instruction.**
- The drivers in the kernel control the underlying hardware.
- As shown in the preceding figure, the kernel contains drivers related to Wi-Fi, Bluetooth, USB, audio, display, and so on.
- Such as **process management, memory management, security, and networking, are managed** by Linux kernel

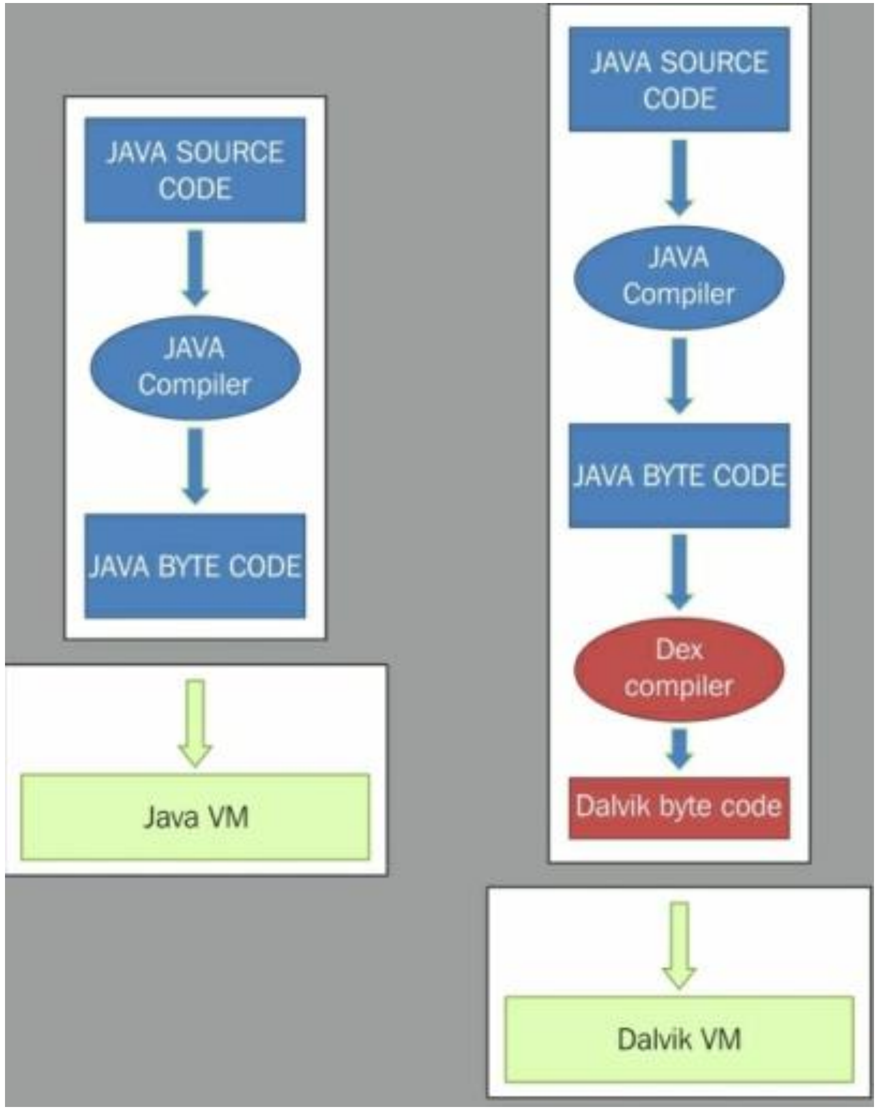
Android Architecture

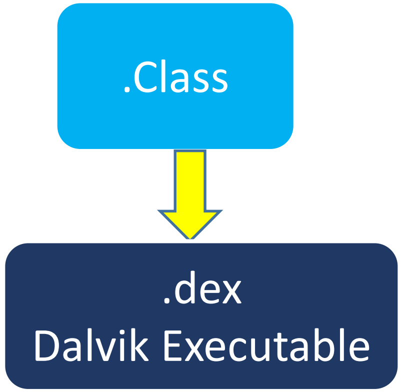
Libraries:

- On top of Linux kernel are Android's native libraries.
- It is with the help of these **libraries that the device handles different types of data**.
- These libraries are written in the **C or C++ programming languages** and are specific to a particular hardware.
- For example, the media framework library supports the recording and playback of audio, video and picture formats.

Android Architecture

- Dalvik Virtual Machine

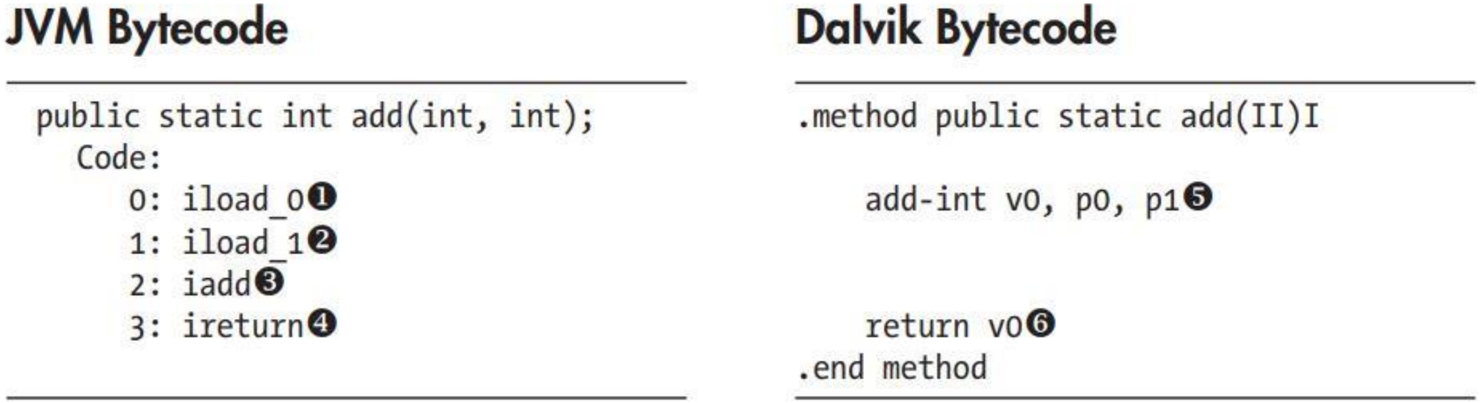



.Class

.dex
Dalvik Executable

Android Architecture

Dalvik Virtual Machine



JVM Bytecode

```
public static int add(int, int);
  Code:
     0: iload_0❶
     1: iload_1❷
     2: iadd❸
     3: ireturn❹
```

Dalvik Bytecode

```
.method public static add(II)I

    add-int v0, p0, p1❺


    return v0❻
.end method
```

- Here, the JVM uses two instructions to load the parameters onto the stack **(1** and **2)**, then executes the addition **3**, and finally returns the result **4**.

- In contrast, Dalvik uses a single instruction to add parameters (in registers p0 and p1) and puts the result in the v0 register **5**. Finally, it returns the contents of the v0 register **6**.

- As you can see, Dalvik uses fewer instructions to achieve the same result.

- Generally speaking, register-based VMs use fewer instructions, but the resulting code is larger than the corresponding code in a stack-based VM.

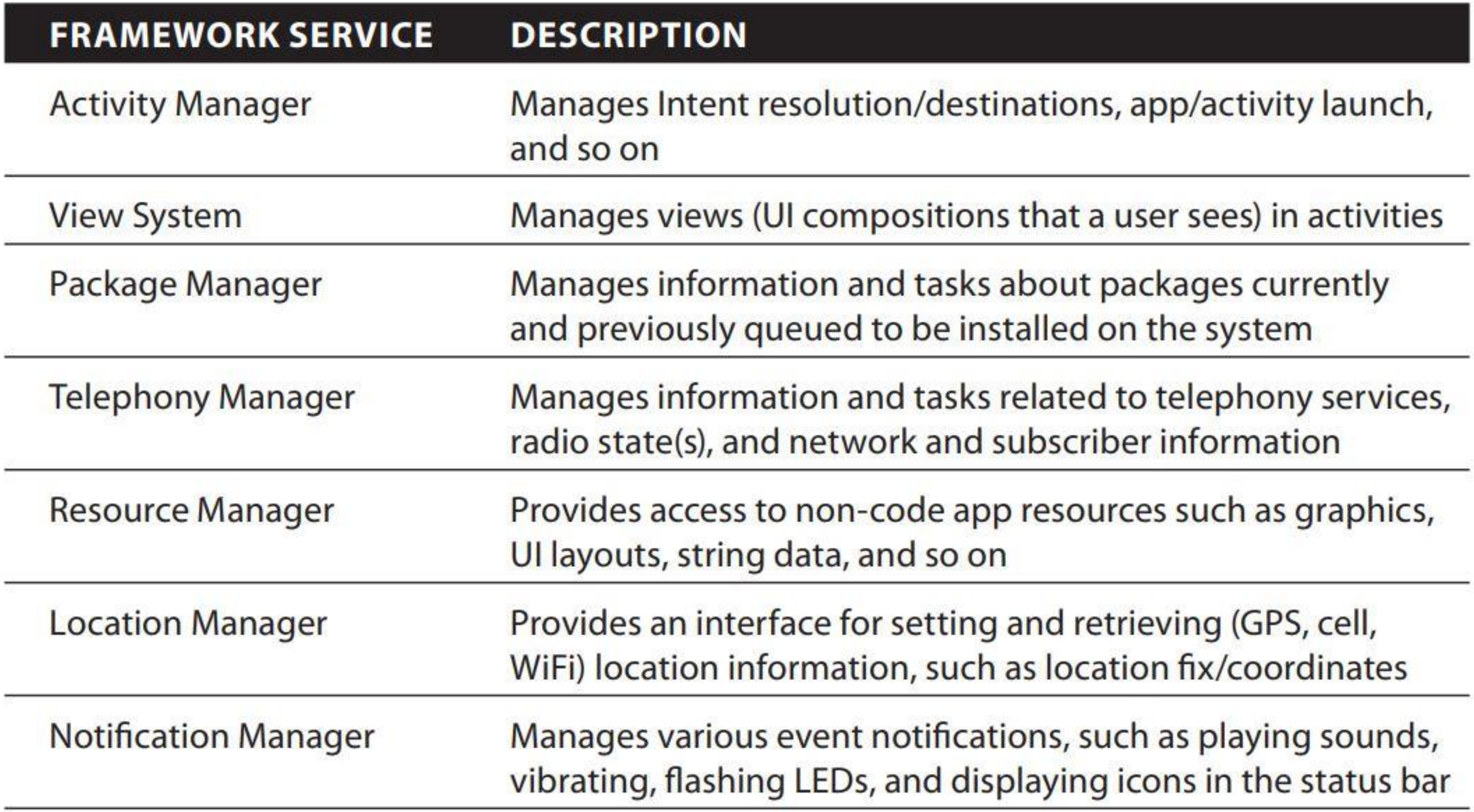
Android Architecture

✓**Dalvik byte code :**

- Dalvik byte code is an **optimized byte code** suitable for low-memory and low-processing environments.
- Also, note that JVM's byte code consists of **one or more .class files**, depending on the number of Java files that are present in an application, but Dalvik byte code is composed of **only one .dex file.**

Android Application Framework

Framework Managers



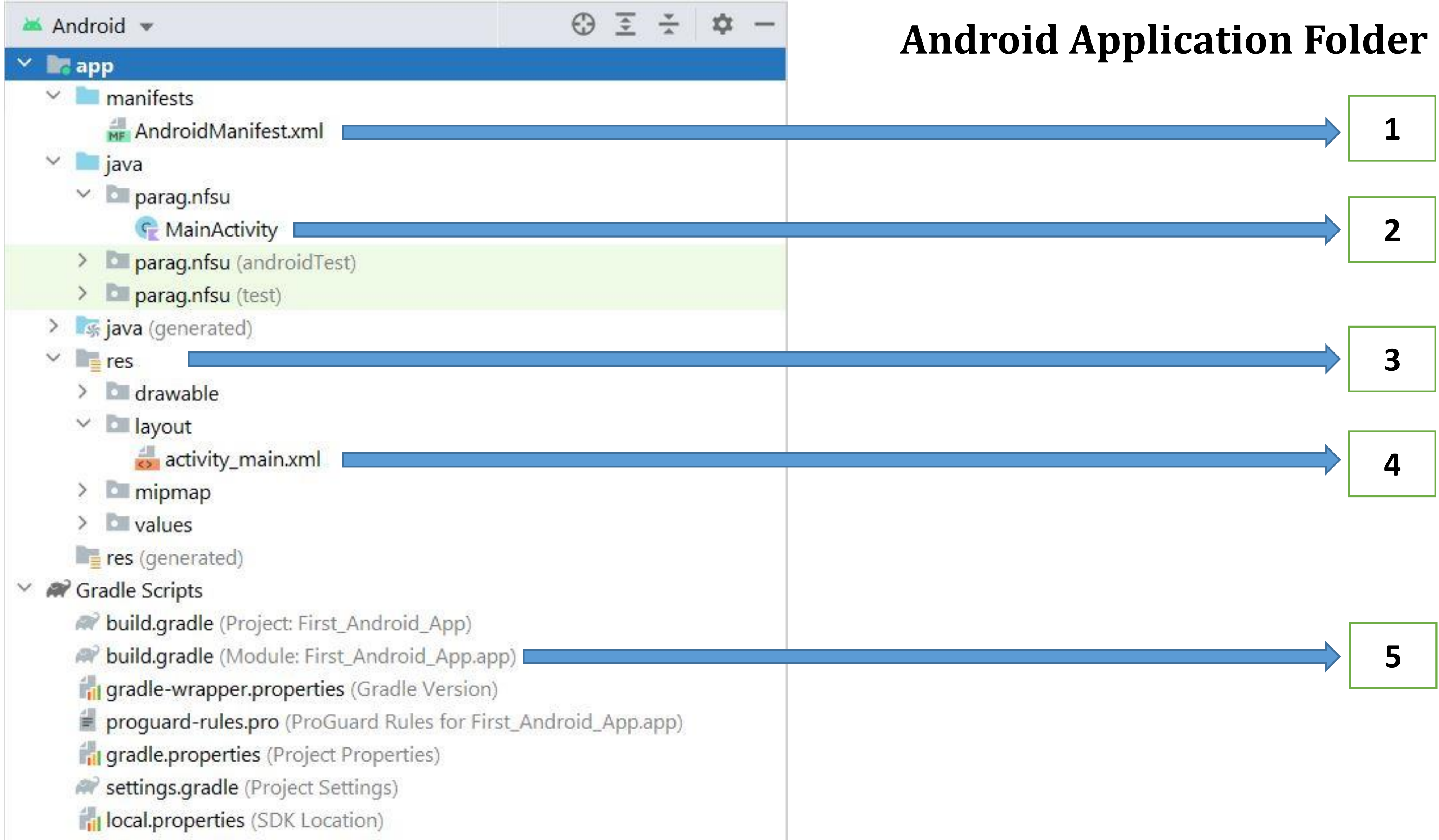
FRAMEWORK SERVICE	DESCRIPTION
Activity Manager	Manages Intent resolution/destinations, app/activity launch, and so on
View System	Manages views (UI compositions that a user sees) in activities
Package Manager	Manages information and tasks about packages currently and previously queued to be installed on the system
Telephony Manager	Manages information and tasks related to telephony services, radio state(s), and network and subscriber information
Resource Manager	Provides access to non-code app resources such as graphics, UI layouts, string data, and so on
Location Manager	Provides an interface for setting and retrieving (GPS, cell, WiFi) location information, such as location fix/coordinates
Notification Manager	Manages various event notifications, such as playing sounds, vibrating, flashing LEDs, and displaying icons in the status bar

Android Application Framework

- Framework Managers
- Android Application Folder Structure
- AndroidManifest.xml
- Resources
- Android Application Components
  - Activity
  - Service
  - Broadcast Receiver
  - Content Providers

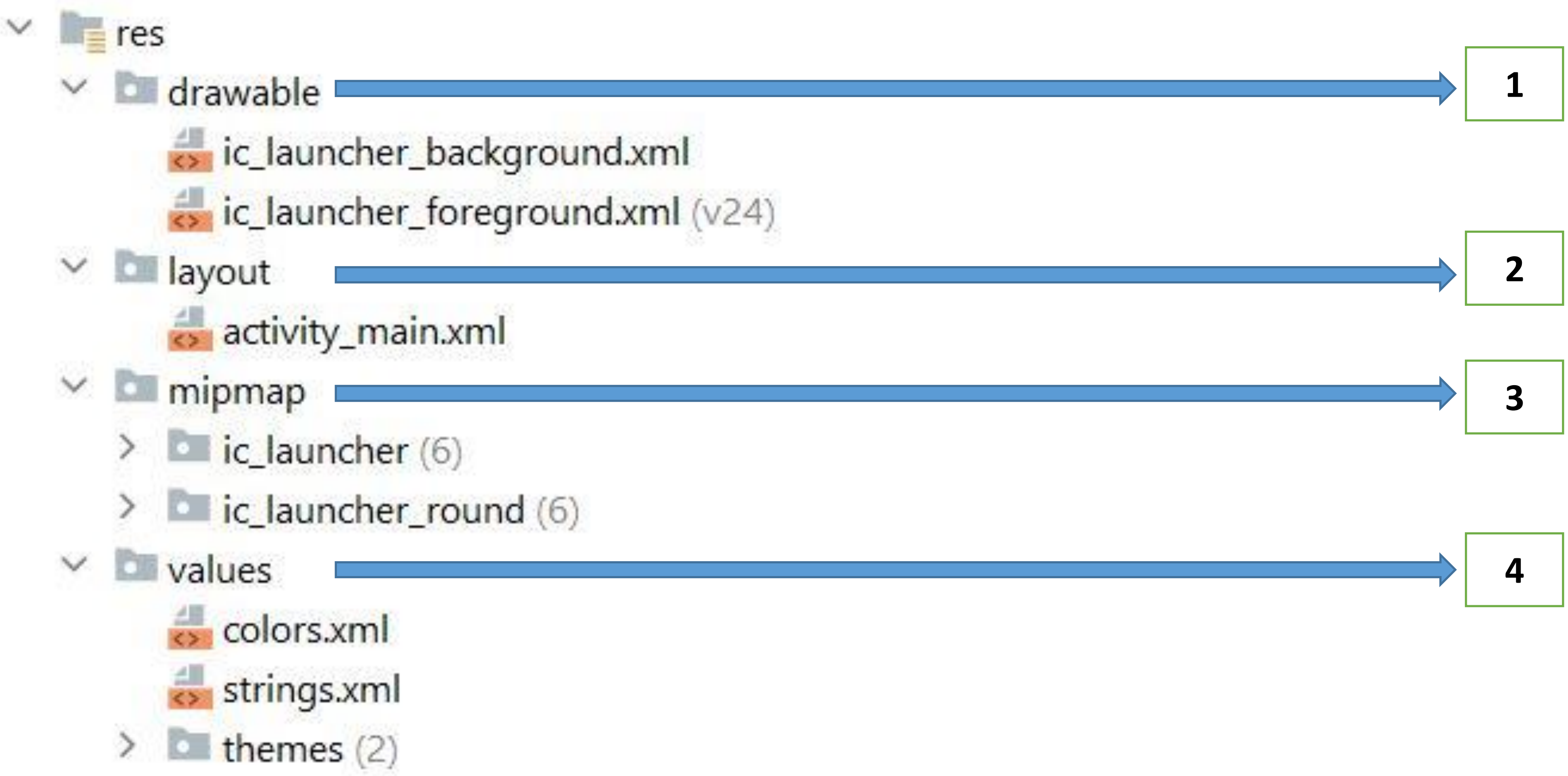
Android Application Framework

Android Application Folder Structure



```
Android ▾
∨ app
    ∨ manifests
          AndroidManifest.xml
    ∨ java
        ∨ parag.nfsu
              MainActivity
        > parag.nfsu (androidTest)
        > parag.nfsu (test)
    > java (generated)
    ∨ res
        > drawable
        ∨ layout
              activity_main.xml
        > mipmap
        > values
      res (generated)
∨ Gradle Scripts
      build.gradle (Project: First_Android_App)
      build.gradle (Module: First_Android_App.app)
      gradle-wrapper.properties (Gradle Version)
      proguard-rules.pro (ProGuard Rules for First_Android_App.app)
      gradle.properties (Project Properties)
      settings.gradle (Project Settings)
      local.properties (SDK Location)
```

Application Resources Overview



```
res
  drawable
    ic_launcher_background.xml
    ic_launcher_foreground.xml (v24)
  layout
    activity_main.xml
  mipmap
    ic_launcher (6)
    ic_launcher_round (6)
  values
    colors.xml
    strings.xml
    themes (2)
```

Android Application Framework

AndroidManifest.xml

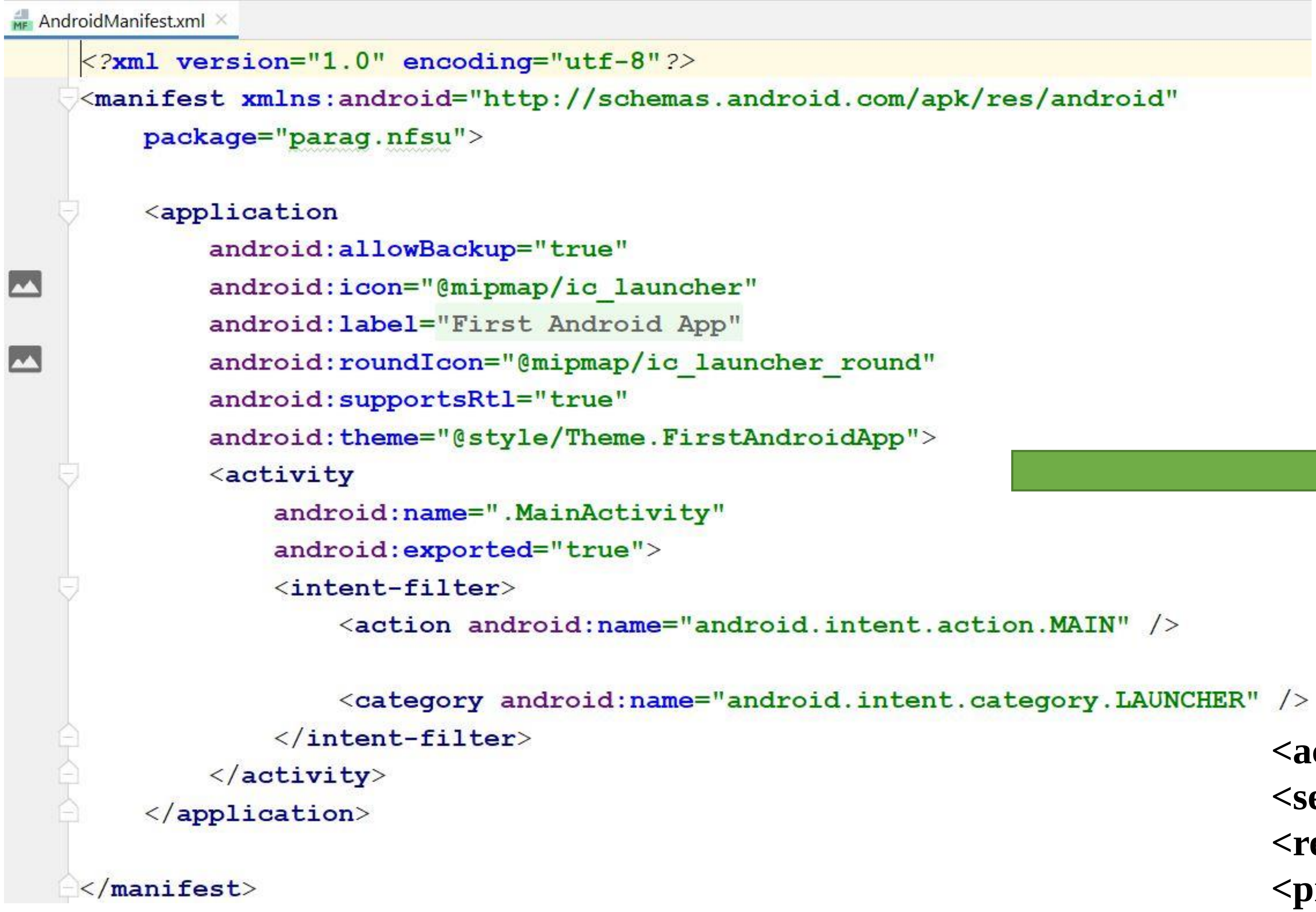
- Every app project must have an AndroidManifest.xml file (with precisely that name) at the **root of the project** source set.
- The manifest file describes essential information about your app to the **Android build tools, the Android operating system, and Google Play.**
- **Manifest file is required to declare the following:**
  - The components of the app, which include all **activities, services, broadcast receivers, and content providers.**

Android Application Framework

AndroidManifest.xml

- **Manifest file is required to declare the following:**
  - The app's package name, which usually matches your **code's namespace**. The **Android build** tools use this to determine the location of code entities when building your project.
  - The **permissions** that the app needs in order to access protected parts of the system or other apps.
  - The manifest file is also where you can declare what **types of hardware or software features your app requires**, and thus, which types of devices your app is compatible with.

Android Application Framework



```xml
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="parag.nfsu">

    <application
        android:allowBackup="true"
        android:icon="@mipmap/ic_launcher"
        android:label="First Android App"
        android:roundIcon="@mipmap/ic_launcher_round"
        android:supportsRtl="true"
        android:theme="@style/Theme.FirstAndroidApp">
        <activity
            android:name=".MainActivity"
            android:exported="true">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />

                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
    </application>

</manifest>
```

AndroidManifest.xml

1 - Which other tag we can use here?

<activity>elements for activities
<service> elements for services
<receiver> elements for broadcast receivers
<provider> elements for content providers

Android Application Framework

Android Application Components

- Four main component that can be used within an Android Application
  - **Activity** – UI and handle user integration with mobile phone.
  - **Service** – Background processing associated with android application.
  - **Broadcast Receivers** – Handle communication between Android OS and Application.
  - **Content Providers** - handle data and database managements operations.

Android Application Framework
Android Components

Activities

- Your application's presentation layer.
- The UI of your application is built around one or more extensions of the Activity class.
- Activities use Fragments and Views to layout and display information, and to respond to user actions. Compared to desktop development, Activities are equivalent to Forms.

Services

- The invisible workers of your application.
- Service components run without a UI, updating your data sources and Activities, triggering Notifications, and broadcasting Intents.
- They're used to perform long running tasks, or those that require no user interaction (such as download file, music player, alarm etc.)

Content Providers

- Shareable persistent data storage.
- Content Providers manage and persist application data and typically interact with SQL databases.
- They're also the preferred means to share data across application boundaries.
- You can configure your application's Content Providers to allow access from other applications, and you can access the Content Providers exposed by others.
- Android devices include several native Content Providers that expose useful databases such as the media files, contact, call logs, calendar etc

Android Application Framework
Android Components

Intents

- A powerful inter application message passing framework.
- Intents are used extensively throughout Android.
- You can use Intents to start and stop Activities and Services, to broadcast messages system-wide or to an explicit Activity, Service, or Broadcast Receiver, or to request an action be performed on a particular piece of data.
- **Two types**
- Implicit Intent
- Explicit Intent

Broadcast Receiver

- Intent listeners
- Broadcast Receivers enable your application to listen for Intents that match the criteria you specify.
- Broadcast Receivers start your application to react to any received Intent, making them perfect for creating event-driven applications.

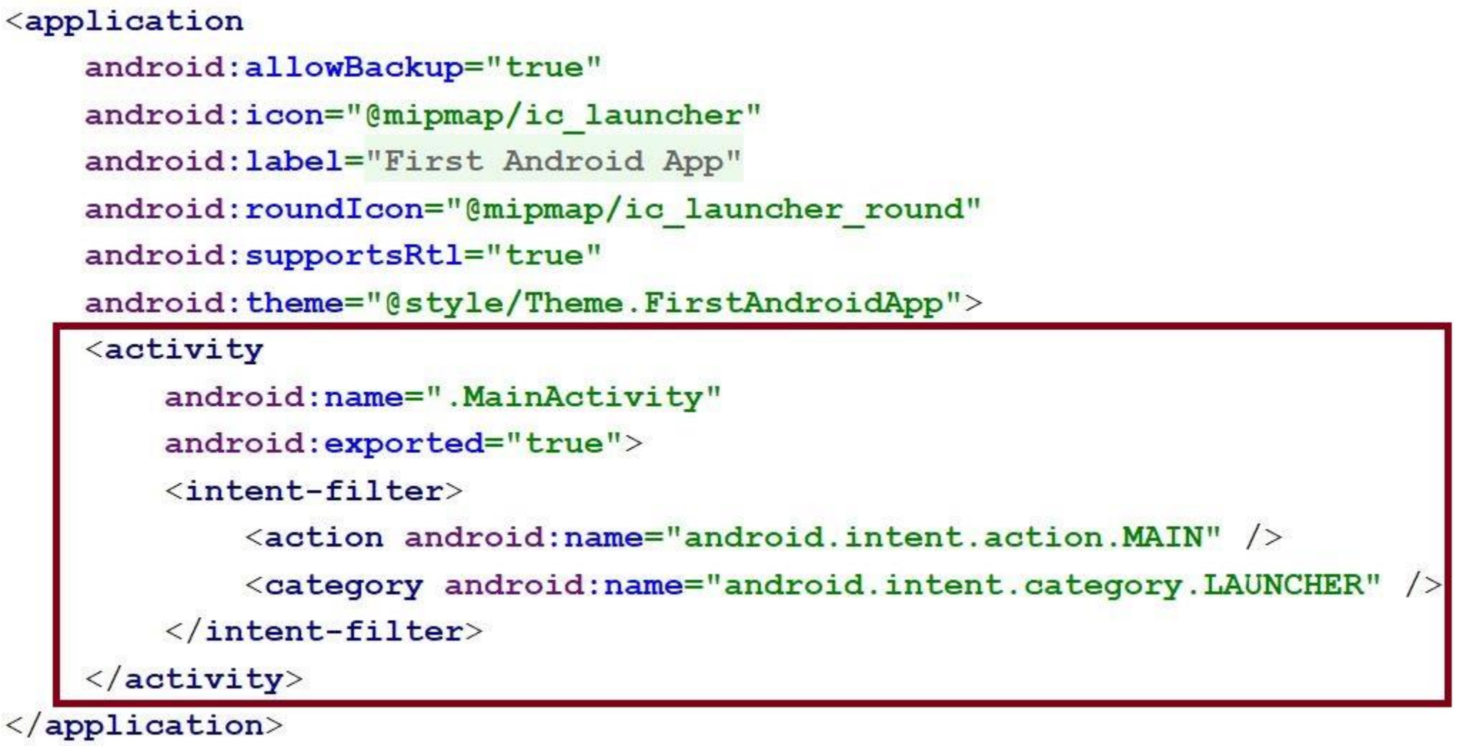
Android Application Framework

Application Resources Overview

- Resources are the **additional files and static content** that your code uses, such as **bitmaps, layout definitions, user interface strings,** animation instructions, and more.
- drawable/Bitmap files (.png, .jpg, .gif etc)
- layout/XML files that define a user interface layout.
- menu/XML files that define app menus, such as an Options Menu, Context Menu, or Sub Menu.
- values/XML files that contain simple values, such as strings, integers, and colors.

Android Application Framework

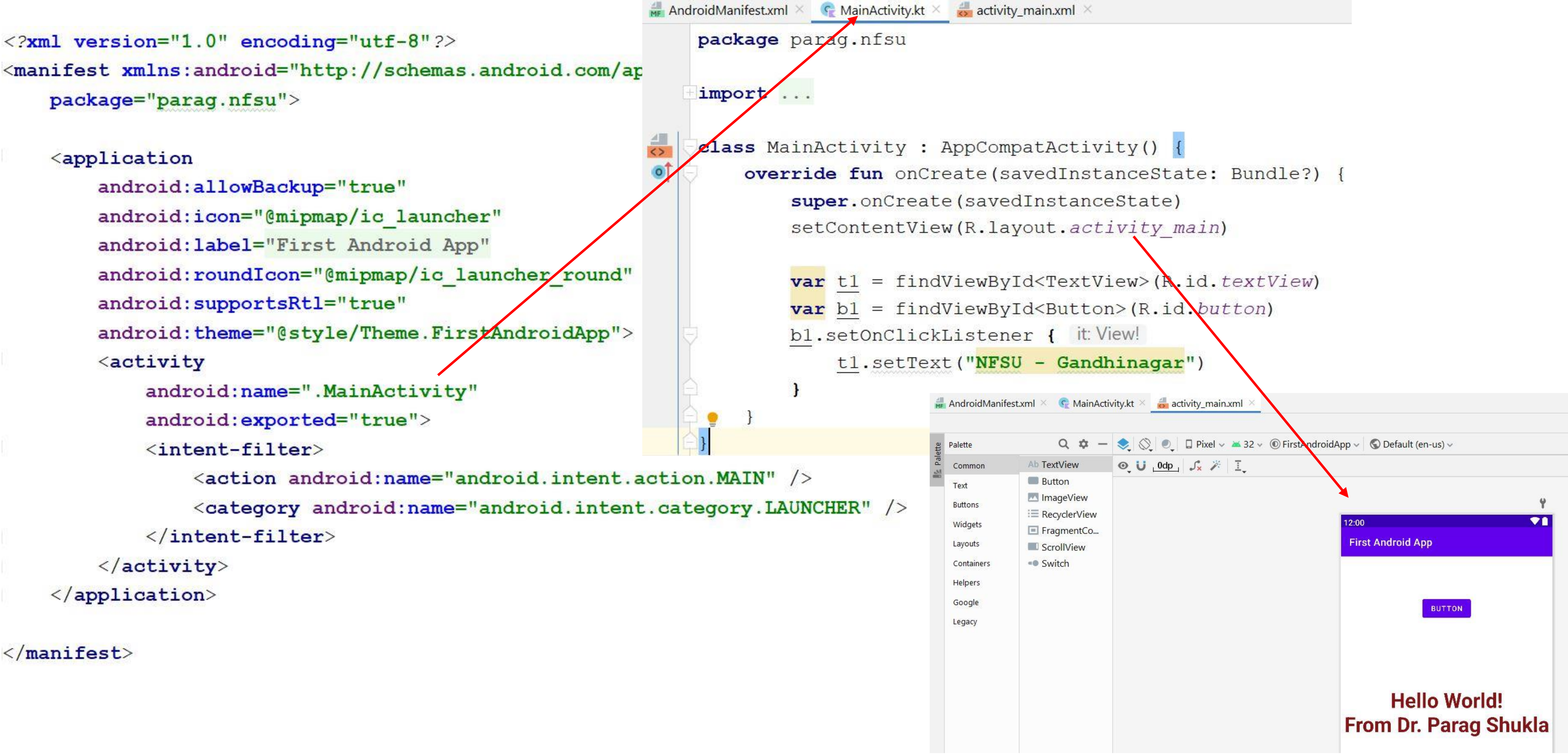
Activity



```
<application
    android:allowBackup="true"
    android:icon="@mipmap/ic_launcher"
    android:label="First Android App"
    android:roundIcon="@mipmap/ic_launcher_round"
    android:supportsRtl="true"
    android:theme="@style/Theme.FirstAndroidApp">
    <activity
        android:name=".MainActivity"
        android:exported="true">
        <intent-filter>
            <action android:name="android.intent.action.MAIN" />
            <category android:name="android.intent.category.LAUNCHER" />
        </intent-filter>
    </activity>
</application>
```

- An activity represents a single screen with a user interface just like window, frame or form.
- An activity represents a **single screen** with a **user interface** just like window or frame.
- An application can have **one or more activities** without any restrictions.
- Every activity you **define** for your application must be declared in your **AndroidManifest.xml file** and
- the main activity for your app must be declared in the manifest with an **<intent-filter>** that includes the **MAIN action and LAUNCHER** category.

Android Application Framework
Activity



```xml
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/ap
    package="parag.nfsu">

    <application
        android:allowBackup="true"
        android:icon="@mipmap/ic_launcher"
        android:label="First Android App"
        android:roundIcon="@mipmap/ic_launcher_round"
        android:supportsRtl="true"
        android:theme="@style/Theme.FirstAndroidApp">
        <activity
            android:name=".MainActivity"
            android:exported="true">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
    </application>

</manifest>
```

```kotlin
package parag.nfsu

import ...

class MainActivity : AppCompatActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)

        var t1 = findViewById<TextView>(R.id.textView)
        var b1 = findViewById<Button>(R.id.button)
        b1.setOnClickListener {  it: View!
            t1.setText("NFSU - Gandhinagar")
        }
    }
}
```

Android Application Framework
Intent

- An Intent is a **messaging object** you can use to request an action from another app component.
- Although intents facilitate **communication** between components in several ways, there are three fundamental use cases:
- It can be used with
  - **startActivity to launch an Activity,**
  - **broadcastIntent** to send it to any interested **BroadcastReceiver** components, and
  - **startService(Intent)** or **bindService(Intent, ServiceConnection, int)** to communicate with a background Service.

Android Application Framework
Intent

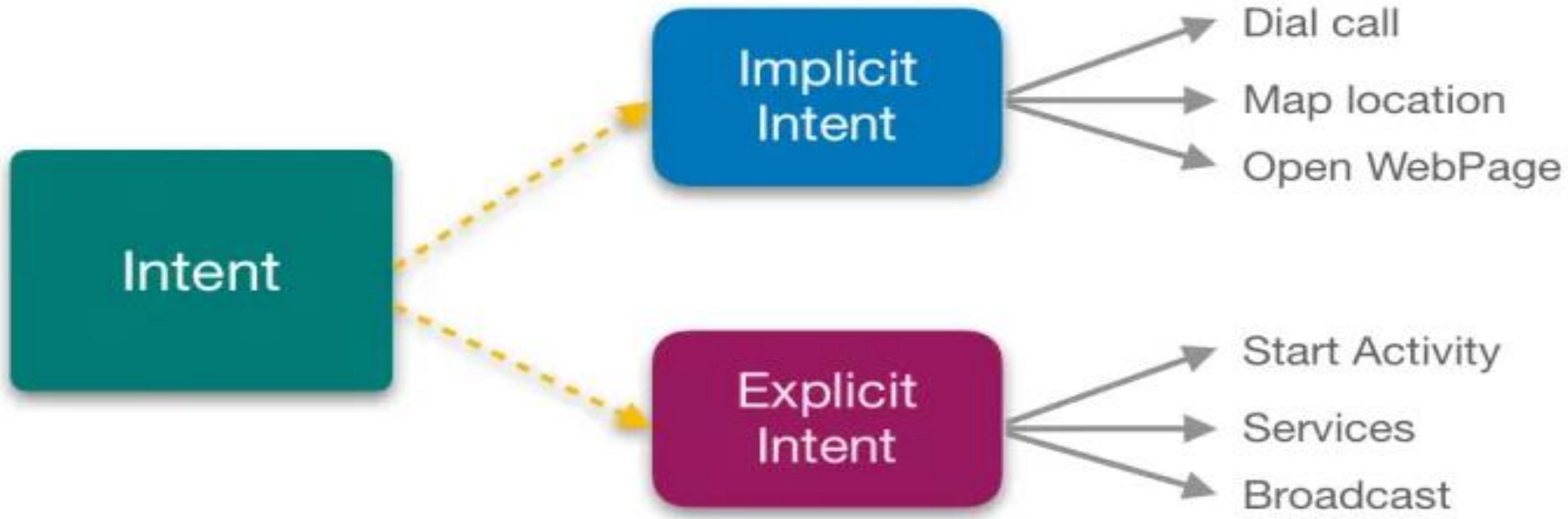
- An Intent object can contain the following components

1. **Action:** This is mandatory part of the Intent object and is a string naming the action to be performed.
2. **Category :** The category is an optional part of Intent object and it's a string containing additional information about the kind of component that should handle the intent.

Android Application Framework
Intent

- There are two types of intents:

1. **Explicit** This intent satisfies the request within the application component. It takes the fully qualified class name of activities or services that we want to start.
2. **Implicit Intent:** This intent does not specify the component name. It invokes the component of another app to handle it.



Android Application Framework
Intent

- There are two types of intents:

1. **Explicit** This intent satisfies the request within the application component. It takes the fully qualified class name of activities or services that we want to start.

   Syntax : Starting the Activity

   Java

   ```
   Intent intent = new Intent(getApplicationContext(), ActivityTwo.class);
   startActivity(intent);
   ```

   Kotlin

   ```
   var intent = Intent(applicationContext, MainActivity::class.java)
   startActivity(intent)
   ```

Android Application Framework
Intent

Syntax:

Starting the Service

```
Intent intent = new Intent(this, HelloService.class);

startService(intent);
```

Delivering Broadcast Receive

```
Intent intent = new Intent (“unique name”);

context.sendBroadcast(intent);
```

Android Application Framework
Intent

2. Implicit Intent: This intent does not specify the component name. It invokes the component of another native app to handle it.

Syntax

Starting the Activity

```
Intent intent = new Intent();
intent.setAction=(Intent.ACTION_DIAL);
intent.setAction=(Intent.ACTION_VIEW);
intent.setAction=(Intent.ACTION_CALL);
```

Android Application Framework
Intent

```
fun openMap(view: View) {
    var ed = findViewById<EditText>(R.id.edLocation)
    var uri = Uri.parse("geo:0,0?q="+ed.text.toString())
    startActivity(Intent(Intent.ACTION_VIEW,uri))
}
```

To Open Google Map

```
fun shareText(view: View) {
    var ed = findViewById<EditText>(R.id.edText)
    ShareCompat.IntentBuilder.from(this)
        .setText(ed.text.toString())
        .setChooserTitle("Share Text")
        .setType("text/plain")
        .startChooser()
}
```

To Share Text

```
fun openWebsite(view: View) {
    var ed = findViewById<EditText>(R.id.edWebsite)
    var uri = Uri.parse(ed.text.toString())
    startActivity(Intent(Intent.ACTION_VIEW,uri))
}
```

To Open Browser

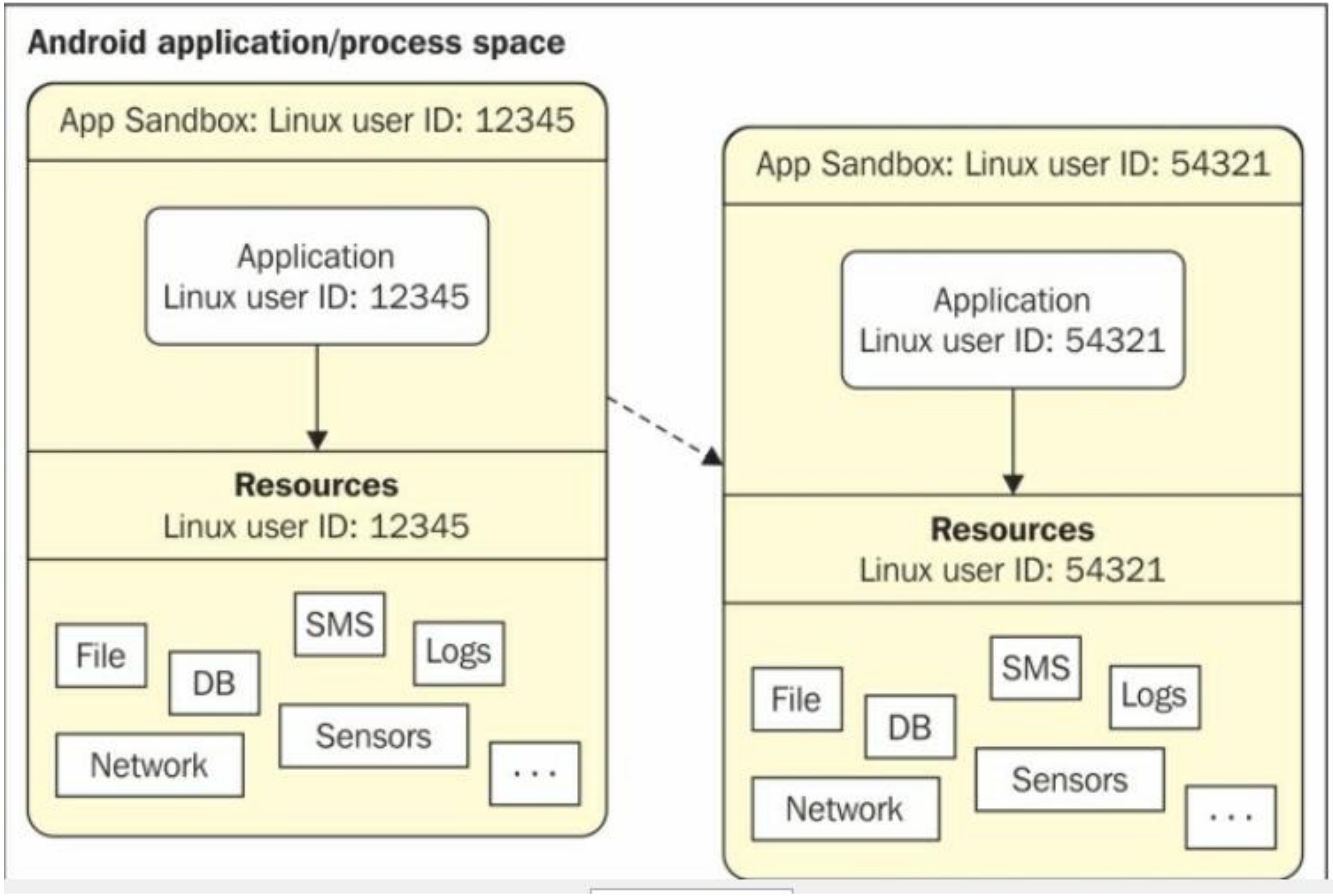
```
fun openDialPad(view: View) {
    var ed = findViewById<EditText>(R.id.edPhone)
    var uri = Uri.parse("tel:"+ed.text.toString())
    startActivity(Intent(Intent.ACTION_DIAL,uri))
}
```

To Open Dial Pad

Application Sandboxing

- In order to isolate applications from each other
- Android takes advantage of the **Linux user-based** protection model.
- In Linux systems, each user is assigned a **unique user ID (UID)** and users are segregated so that one user does not access the data of another user.
- All resources under a particular user are run with the same privileges.
- Android application is assigned a **UID and is run** as a separate process.
- What this means is that even if an installed application tries to do something **malicious**, it can do it only within its **context and with the permissions it has.**
- By default, applications cannot **read or access the data** of other applications and have limited access to the operating system.

Application Sandboxing



Two applications on different processes on with different UID's

Application Sandboxing

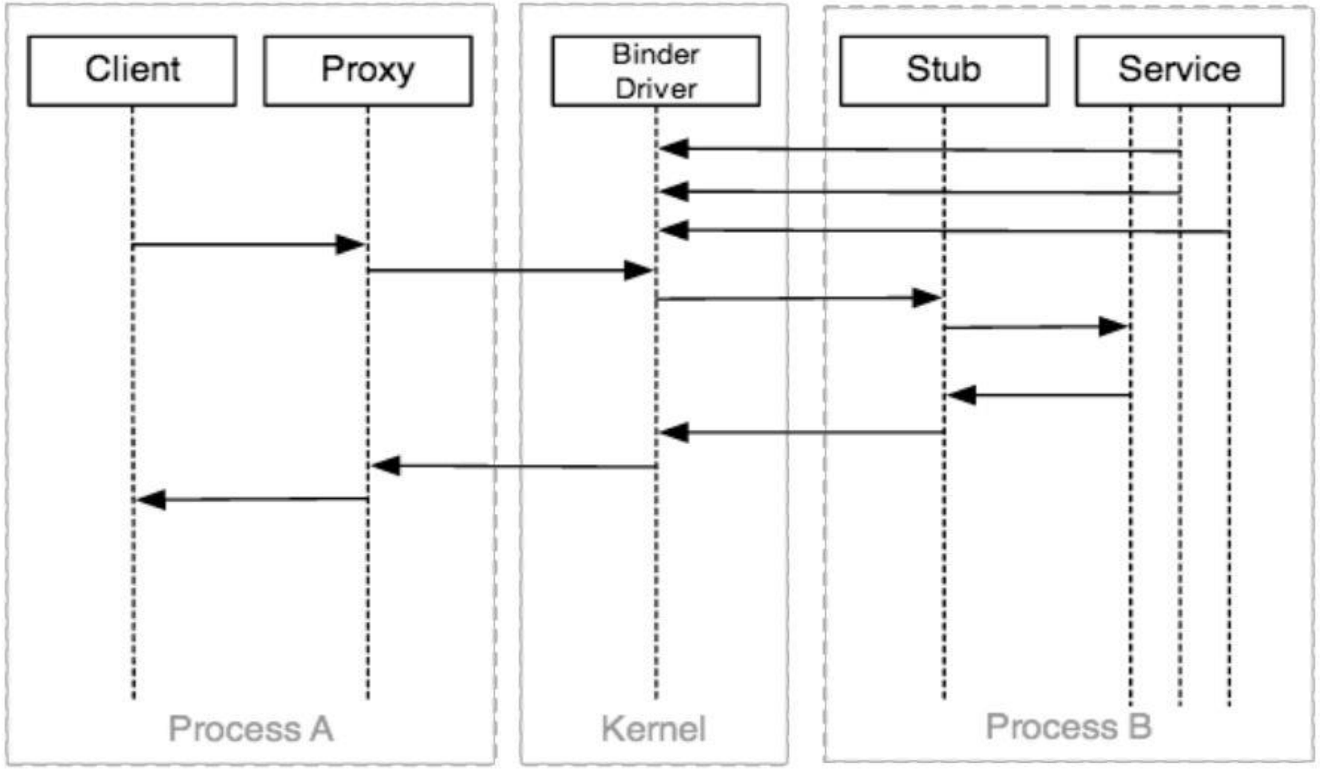
- Since the application sandbox mechanism is implemented at the **kernel level,** it applies to both **native applications and OS applications.**

Secure Inter Process Communication

- As discussed, sandboxing of the apps is achieved by running apps in different processes with different Linux identities.
- System services run in separate processes and have more privileges.
- Thus, in order to organize data and signals between these processes, an inter-process communication (IPC) framework is needed.
- In Android, this is achieved with the use of the Binder
- The **Binder framework** in Android provides the capabilities required to organize **all types of communication between various processes**.
- Android application components, such as **intents** and **content providers**, are also built on top of this Binder framework.
- Using this framework, it is possible to perform a variety of actions such as invoking methods on remote objects.

Secure Inter Process Communication

- Let us suppose the application in Process 'A' wants to use certain behavior exposed by a service which runs in Process 'B’.
- In this case, Process 'A' is the client and Process 'B' is the service.
- The communication model using Binder is shown in the following diagram:



Binder Communication Model

Secure Inter Process Communication

- All communication between the processes using the Binder framework occurs through the **/dev/binder Linux kernel driver**.
- The permissions to this **device driver are set to word readable** and writable.
- Hence, any application may write to and read from this device driver.
- All communications between the client and server happen through proxies on the client side and **stubs** on the **server side**.

Secure Inter Process Communication

- To get this process working, **each service** must be registered with the context manager.
- the **context manager** acts as a **name service**, providing the handle of a service using the name of this service.
- Thus, a client needs to know only the **name of a service** to communicate.
- Each service (also called a Binder service) exposed using the **Binder mechanism** is assigned with a token.

Secure Inter Process Communication

- This token is a 32-bit value and is unique across all processes in the system.
- A client can start interacting with the service after discovering this value.
- This is possible with the help of Binder’s context manager.
- The context manager acts as a name service, providing the handle of a service using the name of this service
- The name is resolved by the context manager and the client receives the token that is later used for communicating with the service

Application Permission

- The purpose of a **permission is to protect the privacy of an Android user.**
- Android apps must **request permission to access sensitive user data** (such as **contacts and SMS**), as well as certain system features (such as **camera and internet**).
- Depending on the feature, the system might grant the permission **automatically** or might **prompt** the user to approve the request.
- A central design point of the Android security architecture is that **no app, by default, has permission to perform any operations** that would adversely impact other apps, the operating system, or the user.
- This includes **reading or writing the user's private data** (such as contacts or emails), reading or writing another app's files, performing network access, keeping the device awake, and so on.

Application Permission

- An app must publicize the permissions it requires by including **<uses-permission>** tags in the app manifest.
- For example, an app that needs to **send SMS messages** would have this line in the manifest:

```
<manifest        xmlns:android=http://schemas.android.com/apk/res/android
 package="parag.nfsu.telephonyApp">
<uses-permission android:name="android.permission.SEND_SMS"/>
<application...>
        ...
    </application>
</manifest>
```

Application Permission Approval

- If your app lists **normal permissions** in its manifest (that is, permissions that **don't pose much risk** to the user's privacy or the device's operation), the system automatically grants those permissions to your app.
- If your app lists **dangerous permissions** in its manifest (that is, permissions that could potentially affect the user's privacy or the device's normal operation), such as the **SEND_SMS permission above**, the user must explicitly agree to grant those permissions.
- **Protection Level**
  - Permissions are divided into several **protection levels.**
  - The protection level affects whether runtime permission requests are required.
  - There are three protection levels that affect **third-party apps: normal, signature, and dangerous permissions.**

Application Permission Protection Level

1. **Normal permissions:**

- Normal permissions cover areas where **your app needs to access data or resources outside the app's sandbox**, but where there's very **little risk** to the user's privacy or the operation of other apps.
- For example, permission to **set the time zone** is a normal permission.
- If an app declares in its manifest that it needs a **normal permission**, the **system automatically** grants the app that permission at install time.
- The system doesn't prompt the user to grant normal permissions, and users cannot revoke these permissions.

Application Permission Protection Level

2. **Signature permissions:**

- The system grants these app permissions at install time, but only when the app that attempts to use a permission is **signed by the same certificate** as the app that defines the permission.
- It’s granted automatically by the system if both applications are signed with the same certificate
- Both applications have been developed by the same company, this means that they most certainly will share the same application signature (**are signed with the same .keystore)**;
- So, we can take this into advantage and define a custom permission with this increased level of security — signature.

Application Permission Protection Level

2. **Signature permissions (Continue..):**

- Advantages of this:
  - There’s no need to prompt the user asking for a different type of permission in order to communicate with another application.
  - Since they share the same signature, the OS automatically grants this access; it’s expected that since the company behind them is the same they’re trustworthy.
  - Since this is addressed by the OS, there’s no need to implement a validation mechanism.

Application Permission Protection Level

3. Dangerous Permissions (Continue…):

- Dangerous permissions cover areas where the app wants **data or resources that involve the user's private information**, or could potentially affect the user's stored data or the operation of other apps.
- For example, the ability to read the **user's contacts** is a dangerous permission.
- android.permission_group.CALENDAR
  - android.permission.READ_CALENDAR
  - android.permission.WRITE_CALENDAR
- android.permission_group.CAMERA
  - android.permission.CAMERA
- android.permission_group.LOCATION
  - android.permission.ACCESS_FINE_LOCATION
  - android.permission.ACCESS_COARSE_LOCATION

Application Permission Protection Level

3. Dangerous Permissions (Continue…):

- android.permission_group.CONTACTS
  - android.permission.READ_CONTACTS
  - android.permission.WRITE_CONTACTS
  - android.permission.GET_ACCOUNTS
- android.permission_group.MICROPHONE
  - android.permission.RECORD_AUDIO
- android.permission_group.SENSORS
  - android.permission.BODY_SENSORS
- android.permission_group.PHONE
  - android.permission.READ_PHONE_STATE
  - android.permission.READ_CALL_LOG
  - android.permission.WRITE_CALL_LOG
  - android.permission.ADD_VOICEMAIL

Application Permission Protection Level

3. Dangerous Permissions (Continue…):

- android.permission_group.SMS
  - android.permission.SEND_SMS
  - android.permission.RECEIVE_SMS
  - android.permission.READ_SMS
  - android.permission.RECEIVE_WAP_PUSH
  - android.permission.RECEIVE_MMS
- android.permission_group.STORAGE
  - android.permission.READ_EXTERNAL_STORAGE
  - android.permission.WRITE_EXTERNAL_STORAGE

Application Permission Protection Level

3. Dangerous Permissions (Continue…):

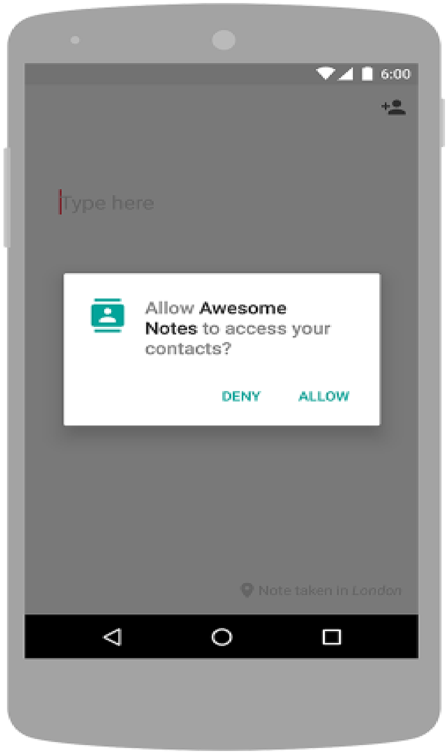
- If an app declares that it needs a dangerous permission, the user has to **explicitly grant the permission** to the app.
- Until the user approves the permission, your app cannot provide functionality that depends on that permission.
- To use a dangerous permission, your app must **prompt the user to grant permission at runtime**.

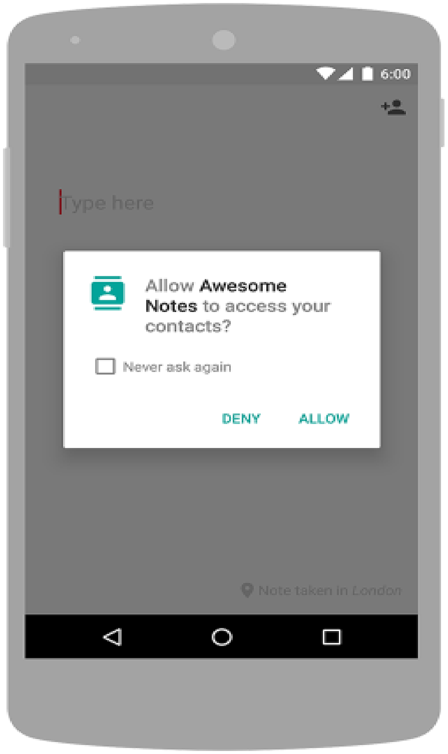
Application Permission – Runtime Request

- If the device is **running Android 6.0 (API level 23)** or higher, and the app's **targetSdkVersion is 23** or higher, the user isn't notified of any app permissions at install time.
- Your app must ask the user to g**rant the dangerous permissions at runtime.**
- When your app requests permission, the user sees a system dialog (as shown in figure 1, left) telling the user which permission group your app is trying to access. The dialog includes a Deny and Allow button.

Application Permission – Runtime Request

- ✓ The dialog includes a **Deny and Allow button.**
- ✓ If the user denies the permission request, the next time your app requests the permission, the dialog contains a checkbox that, when checked, indicates the user doesn't want to be prompted for the permission again

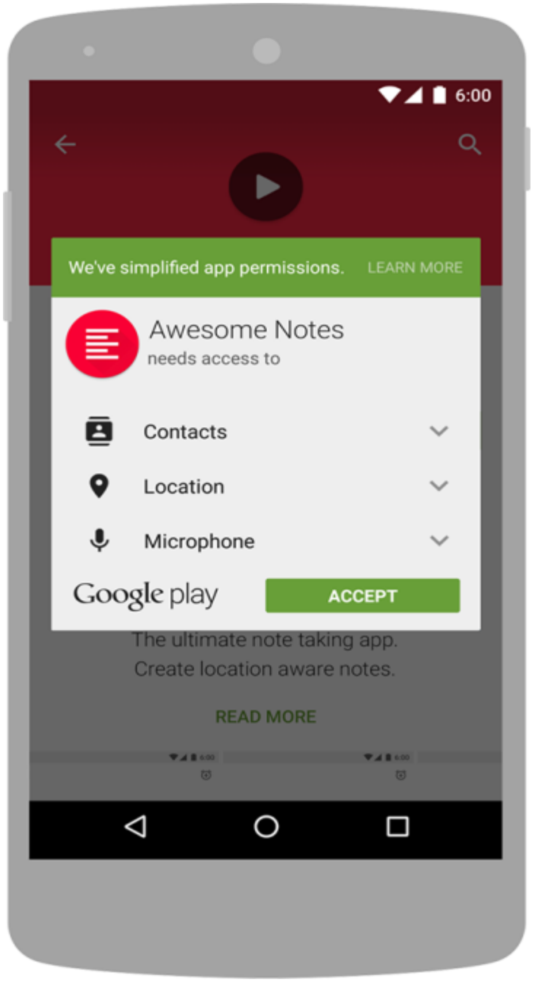

Allow **Awesome Notes** to access your contacts?


Allow **Awesome Notes** to access your contacts?

□ Never ask again

Application Permission – Install time Request

- If the device is running **Android 5.1.1 (API level 22)** or lower, or the app's **targetSdkVersion is 22 or lower** while running on any version of Android, the system automatically asks the user to **grant all dangerous permissions for your app at install-time**.
- If the user clicks **Accept**, all permissions the app requests are granted. If the user denies the permissions request, the system cancels the installation of the app.
- If an app **update includes** the need for additional permissions the user is prompted to accept those new permissions before updating the app.

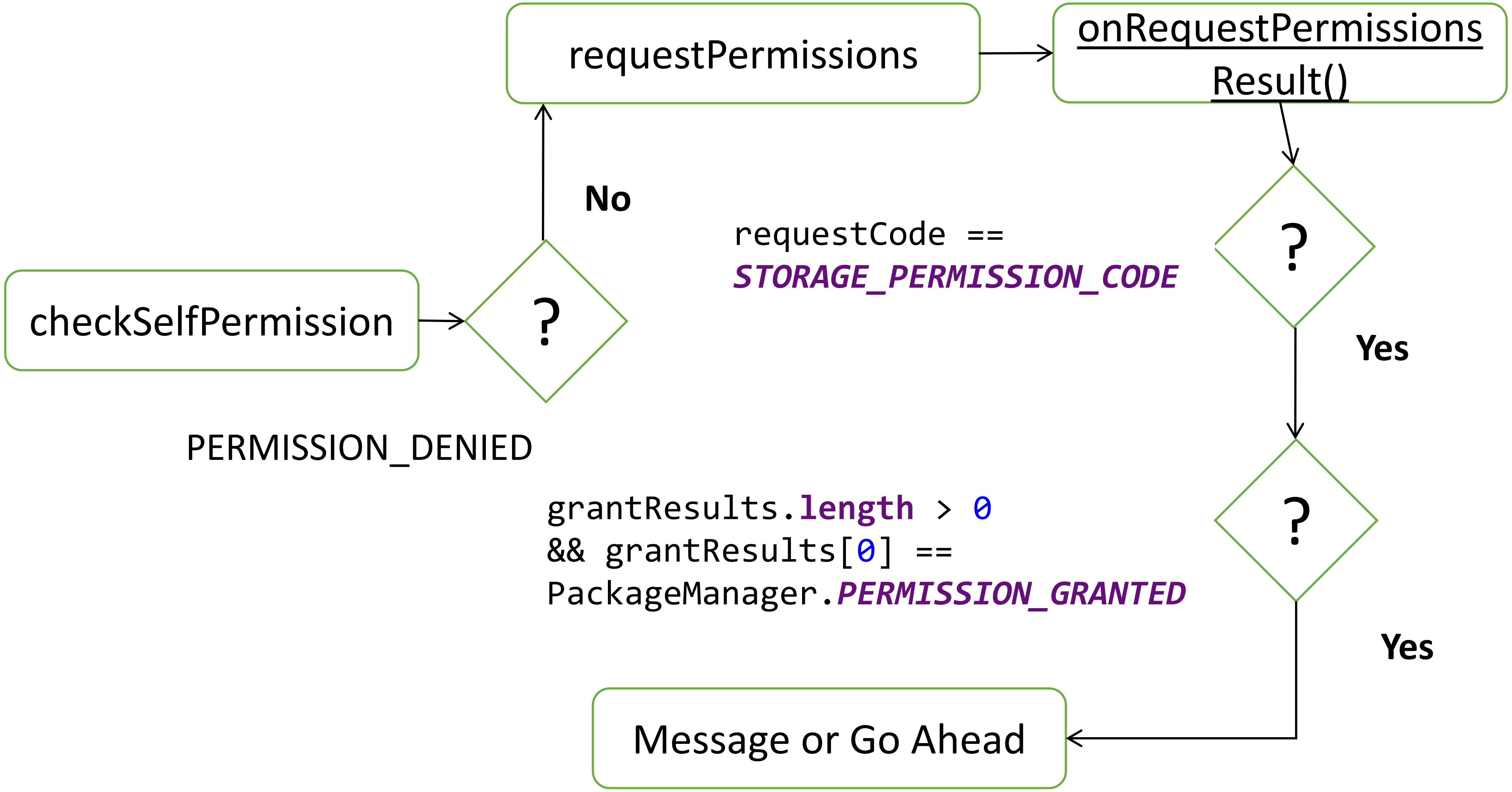


We've simplified app permissions.

Awesome Notes
needs access to

The ultimate note taking app.
Create location aware notes.

Application Permission – Steps



checkSelfPermission

?

PERMISSION_DENIED

No

requestPermissions

onRequestPermissionsResult()

```
requestCode ==
STORAGE_PERMISSION_CODE
```

?

Yes

```
grantResults.length > 0
&& grantResults[0] ==
PackageManager.PERMISSION_GRANTED
```

?

Yes

Message or Go Ahead

Application Permission – Steps

Step-1

- Declare the permission in Android Manifest file: In Android permissions are declared in AndroidManifest.xml file using the uses-permission tag.
- **<uses-permission android:name="android.permission.READ_CONTACTS" />**
- Here we are declaring contacts permission.

Step – 2 Check whether permission is already granted or not.

- If permission isn’t already granted, request user for the permission:
- In order to use any service or feature, the permissions are required.
- Hence we have to ensure that the permissions are given for that. If not, then the permissions are requested.

Application Permission – Steps

```
if(ContextCompat.checkSelfPermission(thisActivity,
Manifest.permission.READ_CONTACTS)
    != PackageManager.PERMISSION_GRANTED)
    { // Permission is not granted }
```

Step-3 Request Permissions:

- When PERMISSION_DENIED is returned from the checkSelfPermission() method in the above syntax, we need to prompt the user for that permission.
- Android provides several methods that can be used to request permission, such **as requestPermissions().**

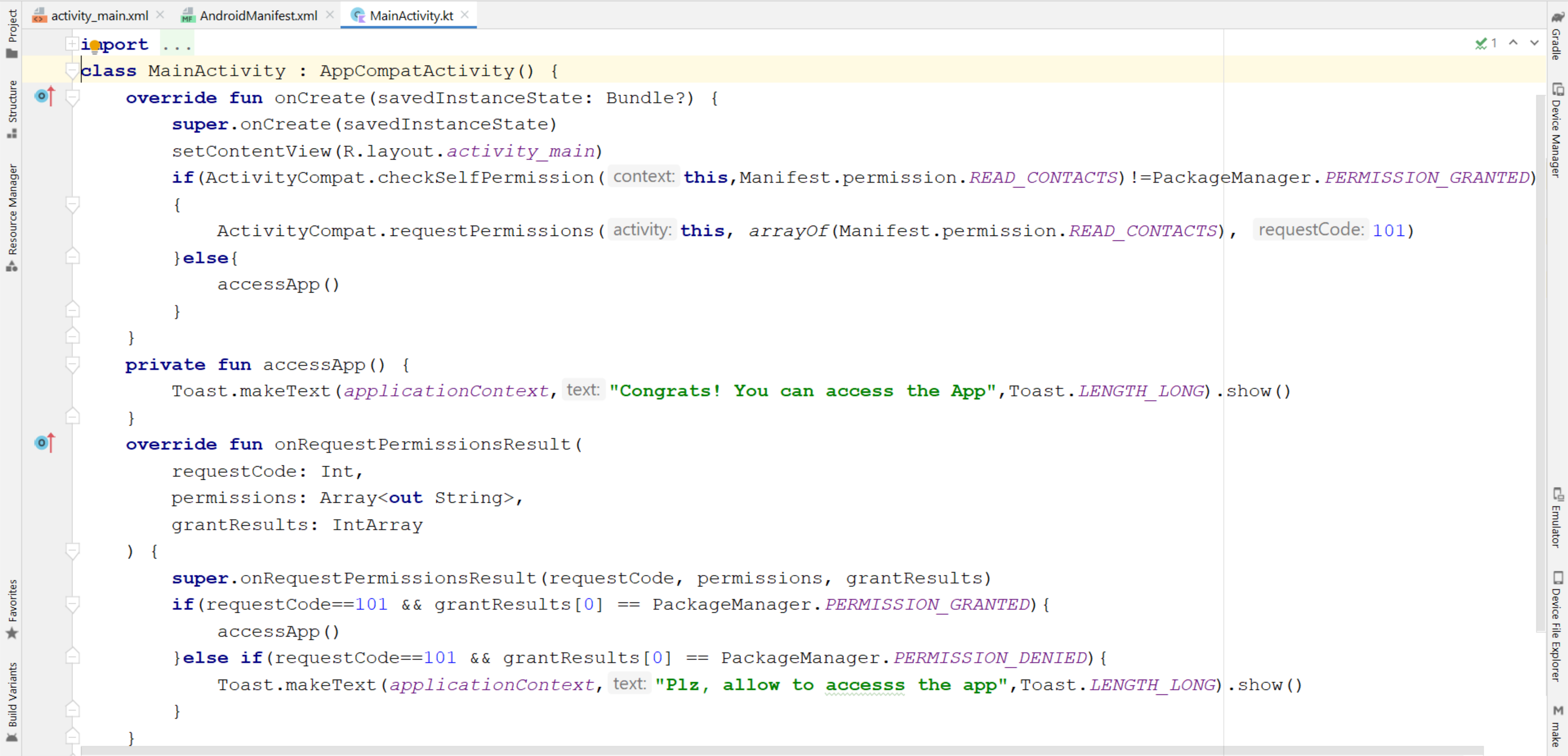
```
ActivityCompat.requestPermissions(MainActivity.this,
permissionArray, requestCode);
```

Application Permission – Steps

- **Step – 4 Override onRequestPermissionsResult() method:**
  - onRequestPermissionsResult() is called when user grant or decline the permission.
  - RequestCode is one of the parameteres of this function which is used to check user action for corresponding request.
  - Here a toast message is shown indicating the permission and user action.

```
onRequestPermissionsResult(int requestCode, String[]
permissions,  int[] grantResults)
```

Application Permission



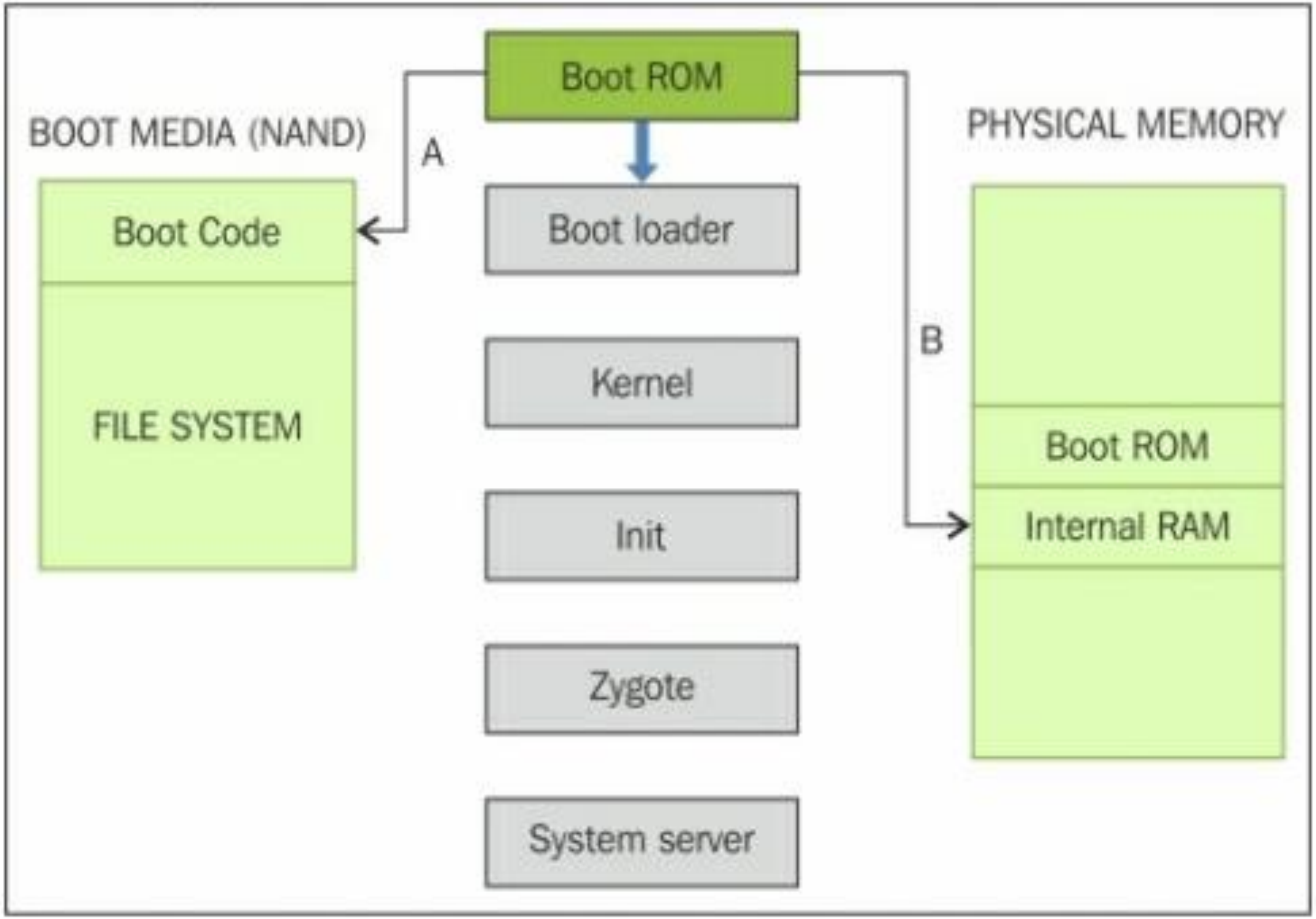
```
import ...
class MainActivity : AppCompatActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)
        if(ActivityCompat.checkSelfPermission( context: this,Manifest.permission.READ_CONTACTS) !=PackageManager.PERMISSION_GRANTED)
        {
            ActivityCompat.requestPermissions( activity: this, arrayOf(Manifest.permission.READ_CONTACTS),  requestCode: 101)
        }else{
            accessApp()
        }
    }
    private fun accessApp() {
        Toast.makeText(applicationContext, text: "Congrats! You can access the App",Toast.LENGTH_LONG).show()
    }
    override fun onRequestPermissionsResult(
        requestCode: Int,
        permissions: Array<out String>,
        grantResults: IntArray
    ) {
        super.onRequestPermissionsResult(requestCode, permissions, grantResults)
        if(requestCode==101 && grantResults[0] == PackageManager.PERMISSION_GRANTED){
            accessApp()
        }else if(requestCode==101 && grantResults[0] == PackageManager.PERMISSION_DENIED){
            Toast.makeText(applicationContext, text: "Plz, allow to accesss the app",Toast.LENGTH_LONG).show()
        }
    }
```

Android Boot Process

- When an Android device is first powered on, there is a sequence of steps that are executed, helping the device to load necessary firmware, OS, application data, and so on into memory.
- The sequence of steps involved in Android boot process is as follows:

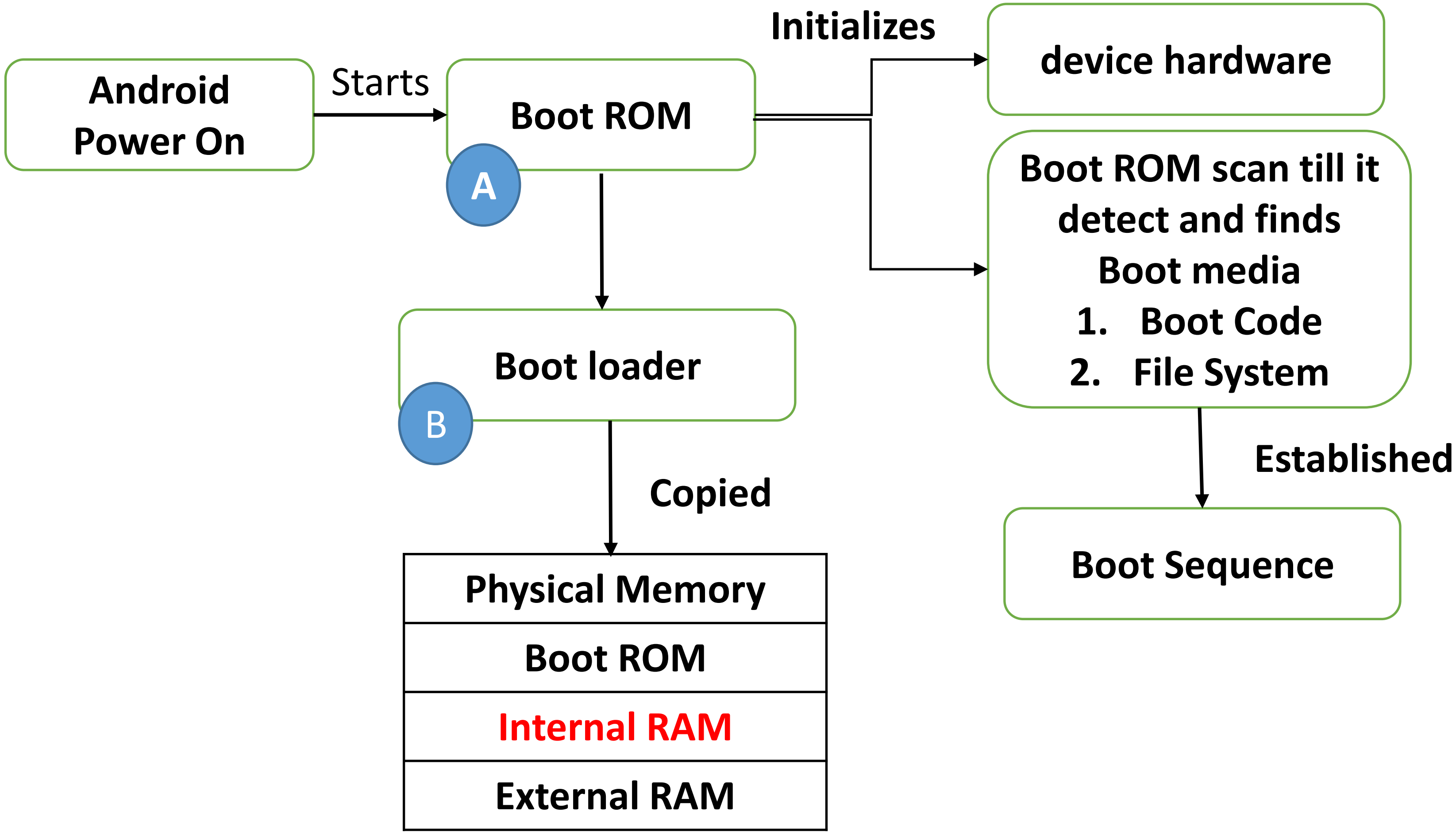
1. Boot ROM code execution
2. The Boot loader
3. The Linux kernel
4. The init process
5. Zygote and Dalvik
6. The system server

Android Boot Process



Back

Android Boot Process – Boot Rom



Android Power On

Starts

Boot ROM

A

Initializes

device hardware

Boot ROM scan till it detect and finds Boot media

1. Boot Code
2. File System

Established

Boot Sequence

Boot loader

B

Copied

Physical Memory
Boot ROM
Internal RAM
External RAM

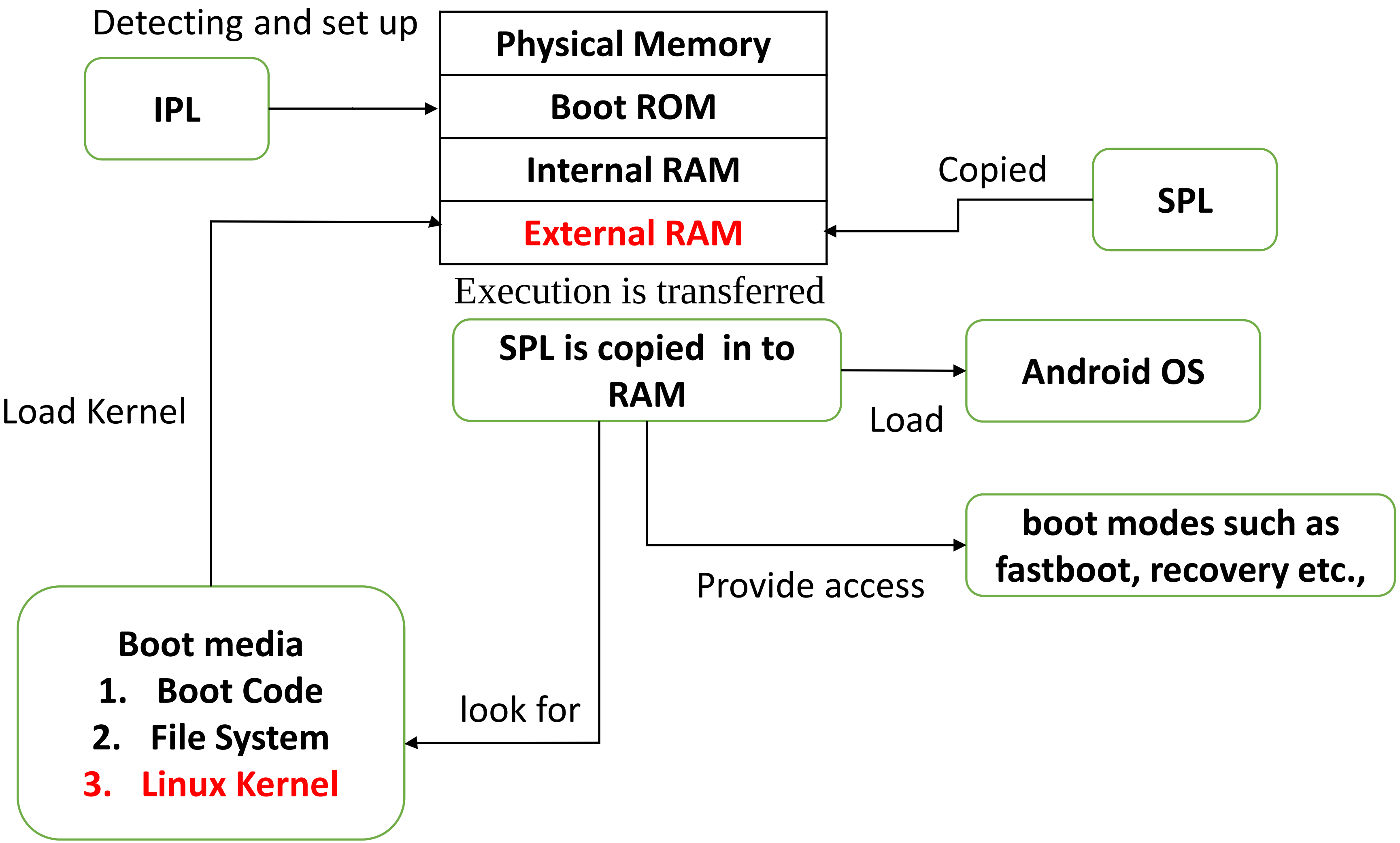
execution shifts to the code loaded into the RAM.

Back

Android Boot Process – Boot Loader

- The boot loader is a piece of program that is executed before the operating system starts to function.
- There are two stages
  - Initial Program Load (IPL)
  - Second Program Load (SPL)
- In the first stage, it detects external RAM and loads a program which helps in the second stage.
- In the second stage, the bootloader setups the network, memory etc which requires to run Kernel.

Android Boot Process – Boot Loader



Back

Android Boot Process – Linux Kernel

- The Linux kernel is the heart of the Android operating system and is responsible for **process management, memory management,** and enforcing security on the device.
- After the kernel is loaded,
- It mounts the root file system (rootfs) and provides access to system and user data.
- When the memory management units and **caches have been initialized**, the system can use virtual memory and launch user space processes.
- The kernel will look in the **rootfs for the init process** and launch it as the **initial user space process.**

Back

Android Boot Process – The init process

- The **init** is the very **first process** that starts and is the root process of all other processes - (**init.rc**).
- The init process will **parse** the **init.rc** script and launch the system service processes.
- At this stage, you will see the **Android logo** on the device screen.

Back

Android Boot Process – Zygote and Dalvik

- Zygote is one of the first init processes created after the device boots.
- It initializes the Dalvik virtual machine and tries to create multiple instances to support each android process.
- Zygote facilitates using a shared code across the VM, thus helping to save the memory and reduce the burden on the system.

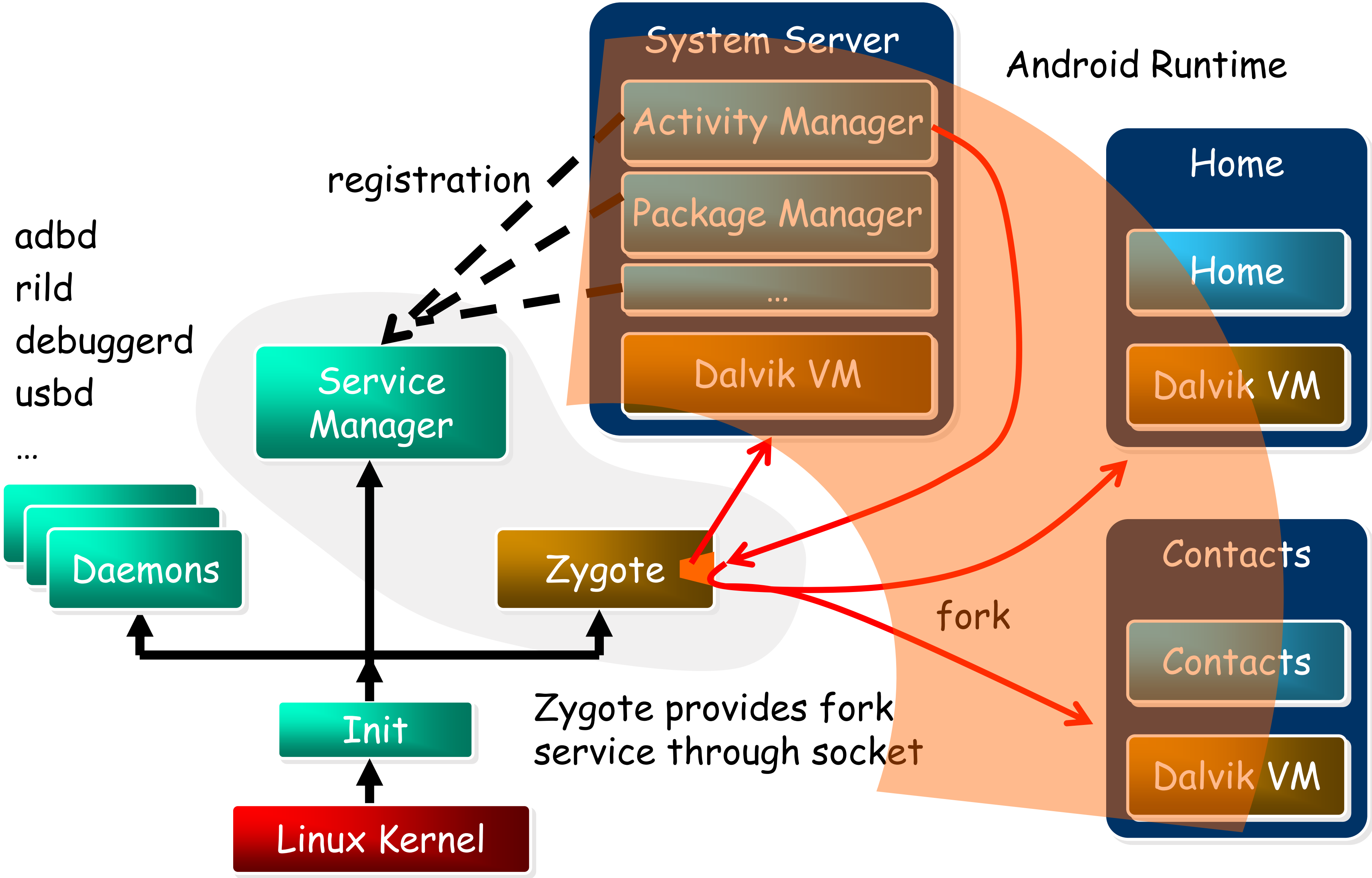
Back

Android Boot Process – System Server

- All the core features of the device such as telephony, network, and other important functions, are started by the system server
- The following core services are started in this process:
  - Start Power Manager
  - Create Activity Manager
  - Start Telephony Registry
  - Start Package Manager
  - Set Activity Manager Service as System Process
  - Start Context Manager etc.,

Back

Android Boot Sequence



Zygote provides fork service through socket

Android Partitions

- The Android partition layout varies between vendors and versions.
- However, a few partitions are present in all the Android devices.
- Partitions:
  - Boot Loader
  - Boot
  - Recovery
  - UserData
  - System
  - Cache
  - Radio

Android Partitions

- Boot Loader :
  - This partition stores the **phone's boot loader program**.
  - This program takes care of initializing the **low level hardware when the phone boots**.
  - Thus, it is responsible for booting the Android kernel and booting into **other boot modes**, such as the recovery mode, download mode, and so on.

Android Partitions

- Boot
  - As the name suggests, this partition has the information and files required for the **phone to boot**.
  - It contains the **kernel and RAM disk**. So, without this partition, the phone cannot start its processes.
- Recovery
  - Recovery partition allows the device to boot into the **recovery console** through which activities such as phone **updates and other maintenance operations are performed.**
  - For this purpose, a minimal Android boot image is stored.

Android Partitions

- Userdata
  - This partition is usually called the **data partition** and is the **device's internal storage for application** data.
  - A bulk of user data is stored here, and this is where most of **our forensic evidence will reside**.
  - It stores all app data and standard communications as well.
- System
  - All the major components other than **kernel and RAM disk** are present here.
  - The Android system image here contains the Android **framework, libraries, system binaries, and preinstalled** applications.
  - Without this partition, the device cannot boot into normal mode.

Android Partitions

- Cache
  - This partition is used to store **frequently accessed data** and various other files, such as recovery logs
  - and update packages downloaded over the cellular network.
- Radio
  - Devices with **telephony capabilities have a baseband image stored in** this partition that takes care of various telephony activities.

Android Partitions - Practical

- adb shell
- root@android: cat proc/partitions
  - Using **cat /proc/partitions** you will get the actual partition name identifier and the number of blocks in the partition
- root@android: cat /proc/mounts
  - Using **cat /proc/mounts** shows the partition file path, the alias, the filesystem type, the starting inode, the number of blocks, read/write status (and other parameters of the individual partition that I'm not entirely sure of).
- root@android: df
  - Using df lists the filesystem path alias and size info (total size, used, free and block size)

Android File Systems

- Filesystem refers to the way data is stored, organized, and retrieved from a volume.
- A basic installation may be based on one volume split into several partitions; here, each partition can be managed by a different filesystem.
- **Microsoft Windows** users are mostly familiar with the FAT32 or NTFS filesystem, whereas **Linux** users are more familiar with the EXT2 or EXT4 filesystem.
- As is true in Linux, Android also utilizes mount points and not drives (that is C : or E :). Each filesystem defines its own rules to manage the files the volume.
- Depending on these rules, each filesystem offers a different speed for file retrieval, security, size, and so on.

Android File Systems

- Understanding the filesystem is very important in Android forensics, as it helps us gain knowledge of how the data is stored and retrieved.
- This knowledge about properties and the structure of a filesystem will prove to be useful during forensic analysis.
- In Linux, mounting is an act of attaching an additional filesystem to the currently accessible filesystem of a computer.
- Linux is known to support a large number of filesystems.
- These filesystems used by the system are not accessed by drive names, but instead are combined into a single hierarchical tree structure that represents these filesystems as a single entity.

Android File Systems

- The filesystems are mounted on to a directory, and files present in this filesystem are now the contents of that directory.
- This directory is called a mount point.
- It makes no difference whether the filesystem exists on the local device or on a remote device. Everything is integrated into a single file hierarchy that begins with root.
- Each filesystem has a separate kernel module that registers the operations that it supports with something called virtual file system (VFS).
- VFS allows different applications to access different filesystems in a uniform way.

Android File Systems - Practical

- The filesystems supported by the Android kernel can be determined by checking the contents of the filesystems file that are present in the proc folder.
- root@android: cat /proc/filesystems
- The filesystems preceded by the nodev property are not mounted on the device.

Android File Systems

- The filesystems present in Android can be divided into three main categories, which are as follows:
  - Flash memory filesystems
  - Media-based filesystems
  - Pseudo filesystems

Android File Systems – Flash Memory File Systems

- ## Flash Memory File Systems
- Flash memory is a type of non-volatile memory that can be erased and reprogrammed in units of memory called blocks.
- Due to the particular characteristics of flash memories, special filesystems are needed to write over the media and deal with the long erase times of certain blocks.
- While the supported filesystems vary on different Android devices, the common flash memory filesystems are as follows:
    1. Extended File Allocation Table (exFAT)
    2. Flash Friendly File System (F2FS)
    3. Journal Flash File System version 2 (JFFS2)
    4. Yet Another Flash File System version 2 (YAFFS2)
    5. Robust File System (RFS):

Android File Systems – Flash Memory File Systems

1. Extended File Allocation Table (**exFAT**):
   - This type of filesystem is a Microsoft proprietary. filesystem optimized for flash drives.
2. Flash Friendly File System (**F2FS**):
   - This type of filesystem is introduced by Samsung as an open source filesystem.
3. Journal Flash File System version 2 (**JFFS2**):
   - Support for flash devices.
   - Better performance. JFFS treated the disk as a purely circular log. This generated a great deal of unnecessary I/O. The garbage collection algorithm in JFFS2 makes this mostly unnecessary.
4. Yet Another Flash File System version 2 (**YAFFS2**): Currently, YAFFS2 is not supported in newer kernel versions, but certain mobile manufacturers might still continue to support it.
5. Robust File System (**RFS**):
   - RFS is a Samsung file system for user space applications formatted as RFS (Robust File System).
   - RFS is a FAT 16/32 based file system with a sort of journalling system on it.
   - The code to build and use the RFS file system is proprietary and only used in Samsung equipment.

Android File Systems – Media Based File Systems

- Besides the flash memory filesystems discussed earlier, Android devices typically support the following media-based filesystems:
  - EXTended file system (EXT2/EXT3/EXT4)
  - File Allocation Table (FAT)
  - Virtual File Allocation Table (VFAT)

Android File Systems – Media Based File Systems

- EXTended file system (EXT2/EXT3/EXT4)
  - This was one of the first filesystems and used the virtual filesystem.
  - EXT2, EXT3, and EXT4 are the subsequent versions. Journaling is the main advantage of EXT3 over EXT2.
  - With EXT3, in the case of an unexpected shutdown, there is no need to verify the filesystem.
  - The EXT4 filesystem, the fourth extended filesystem, has gained significance with mobile devices that implement dual-core processors.

Android File Systems – Media Based File Systems

- File Allocation Table (FAT)
  - These filesystems, such as FAT12, FAT16, and FAT32, are supported by the MSDOS driver.
- Virtual File Allocation Table (VFAT)
  - This filesystem is an extension of the FAT16 and FAT32 filesystems.
  - Microsoft's FAT32 filesystem is supported by most Android devices.
  - It is supported by almost all the major operating systems, including Windows, Linux, and Mac OS.
  - This enables these systems to easily read, modify, and delete the files present on the FAT32 portion of the Android device.
  - Most of the external SD cards are formatted using the FAT32.

Android File Systems – Pseudo File Systems

- Here are pseudo filesystems that can be thought of as logical groupings of files.
  - control group (cgroup)
  - rootfs
  - procfs
  - Sysfs
  - tmpfs: