Embedded Operating Systems

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Linux Environment

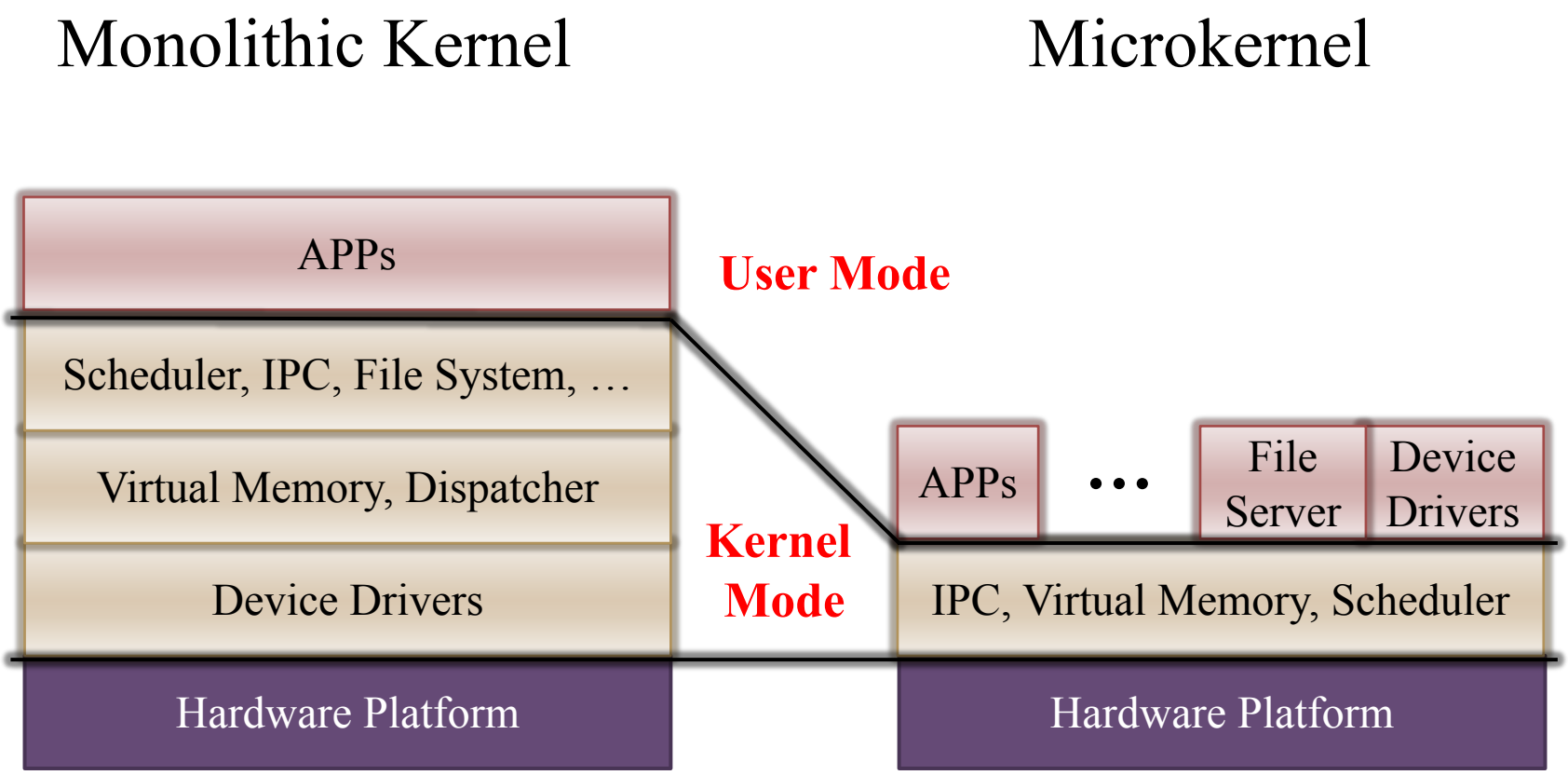
Advantages of Linux

- Linux is free— both in source code and cost, due to the GPL
- Linux is fully customizable in all its components
- Linux can runs on low-end, inexpensive hardware (HW) platforms, e.g., one with 4 MB RAM
- Most Linux systems are stable
- The Linux kernel can be very small and compact
- Linux is highly compatible with many common applications and functions
- Linux is well-supported

Different Type of Operating System Kernels

- Monolithic kernel
  - The entire operating system is working in kernel space
  - All parts of the kernel share the same kernel-level memory
  - Kernel components might affect other components
  - The Linux kernel is an example
- Microkernel
  - Kernel functions are partitioned into components
  - Communications are via inter process communication (IPC) protocol
  - The L4 microkernel is an example

Monolithic Kernel and Microkernel



Device Driver

- Character Devices
  - Sequential access
  - Examples might include printers, scanners, sound boards
  - The same device may have both block and character oriented interfaces
- Block Devices
  - Block devices can support filesystem
  - The block size is from 512B to 4KB and is going to increase in advanced devices
  - For example, disks are commonly implemented as block devices

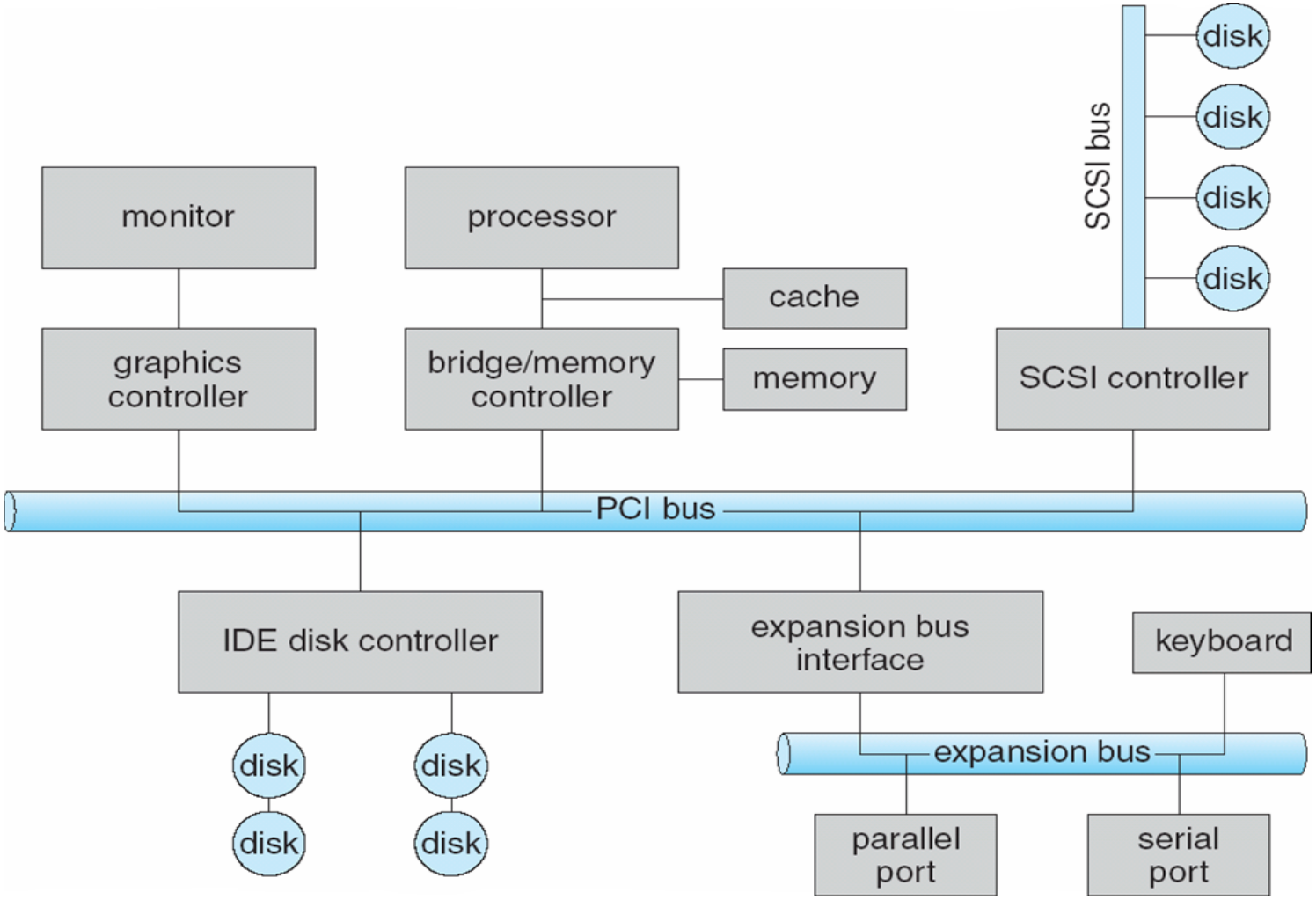
Major and Minor Numbers

- Major number
  - Each device driver is identified by a unique major number
  - This number is assigned by the Linux Device Registrar
- Minor number
  - The number uniquely identifies a particular instance of a device of the same device type
  - If there are three devices with the same device driver, they should have the same major number but different minor numbers
- Command: mknod [device name][bcp] [Major] [Minor]
  - b: block devices
  - c: character devices
  - p: a FIFO file

I/O Hardware

- Incredible Variety of I/O Devices
  - Storage
  - Transmission
  - Human-interface
  - …
- Common Concepts
  - Port: a connection point for a device
  - Bus: can be daisy chain or shared direct access
  - Controller (host adapter): electronics that operate ports, buses, devices

Typical PC Bus Structure



Access to I/O Hardware

- Devices registers which can be accessed by the host
  - The data-in register is read by the host to get the input
  - The data-out register is written by the host to send the output
  - The status register contains bits which indicate device states
  - The control register is written by the host to send commands
- Methods to access devices with their addresses
  - Direct I/O instructions
  - Memory-mapped I/O
    - Device data and command registers mapped to processor address space
    - Especially for large address spaces (graphics)

Device I/O Port Locations on PCs (Partial)

I/O address range (hexadecimal)	device
000–00F	DMA controller
020–021	interrupt controller
040–043	timer
200–20F	game controller
2F8–2FF	serial port (secondary)
320–32F	hard-disk controller
378–37F	parallel port
3D0–3DF	graphics controller
3F0–3F7	diskette-drive controller
3F8–3FF	serial port (primary)

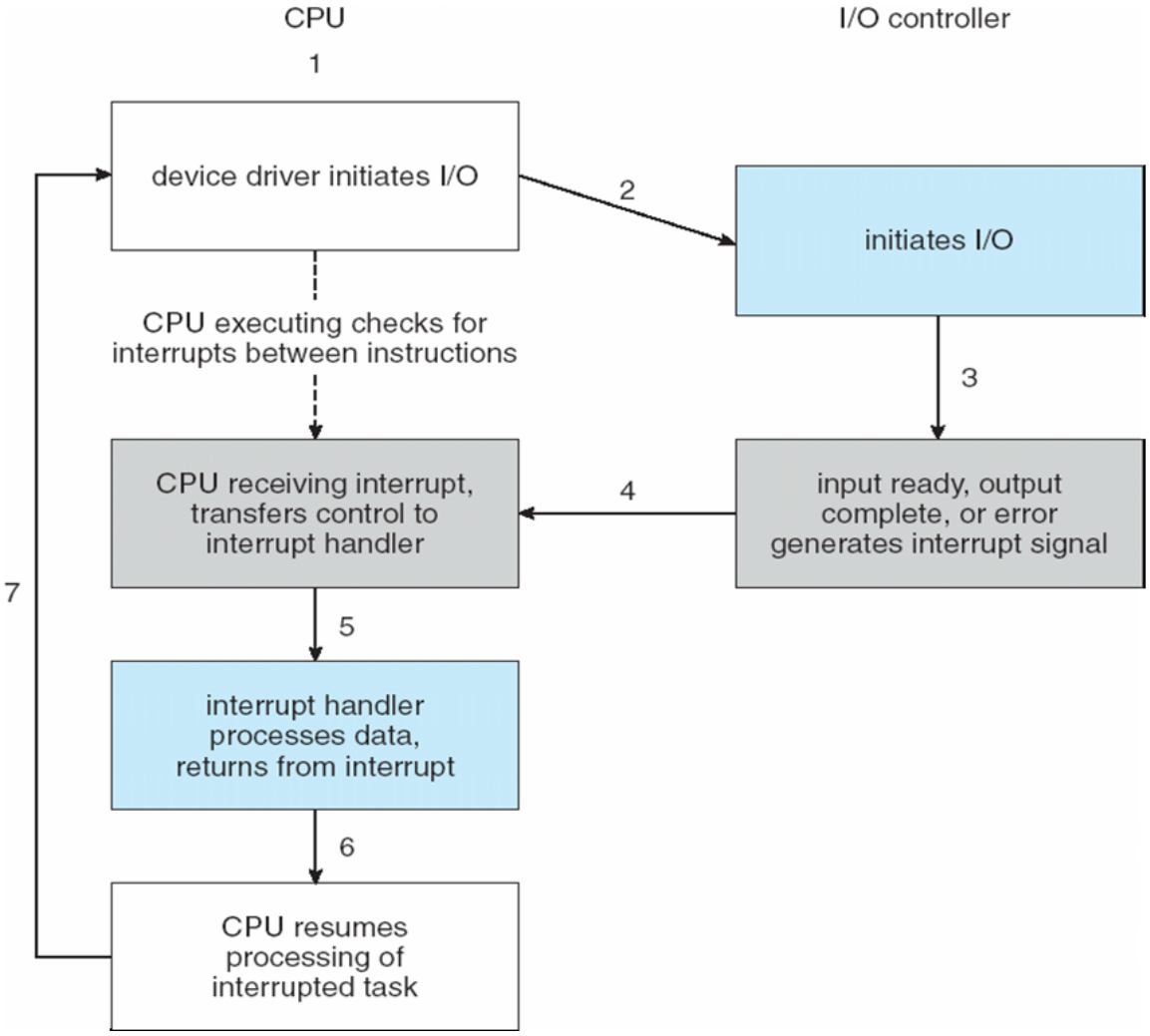
Polling

- An example of polling I/O
  1. Host reads the busy bit from the status register until 0
  2. Host sets read or write bit and copies data into data-out register if it is going to write data
  3. Host sets command-ready bit
  4. Controller sets busy bit, executes the transmission
  5. Controller clears busy bit, error bit, and command-ready bit when the transmission is done
- Step 1 is busy-waiting to wait for I/O from devices
  - Reasonable if device is fast
  - But inefficient if device is slow
    - CPU switches to other tasks?
      - Might miss some data

Interrupts

- CPU interrupt-request line triggered by I/O device
  - Checked by processors (hardware) after each instruction
- Interrupt handler receives interrupts
  - Masked to ignore or delay some interrupts
- Interrupt vector table is used to dispatch interrupt to correct handler
  - Context switches at start and end
  - Based on priority
  - Some nonmaskable
  - Interrupt chaining if more than one device at the same interrupt number

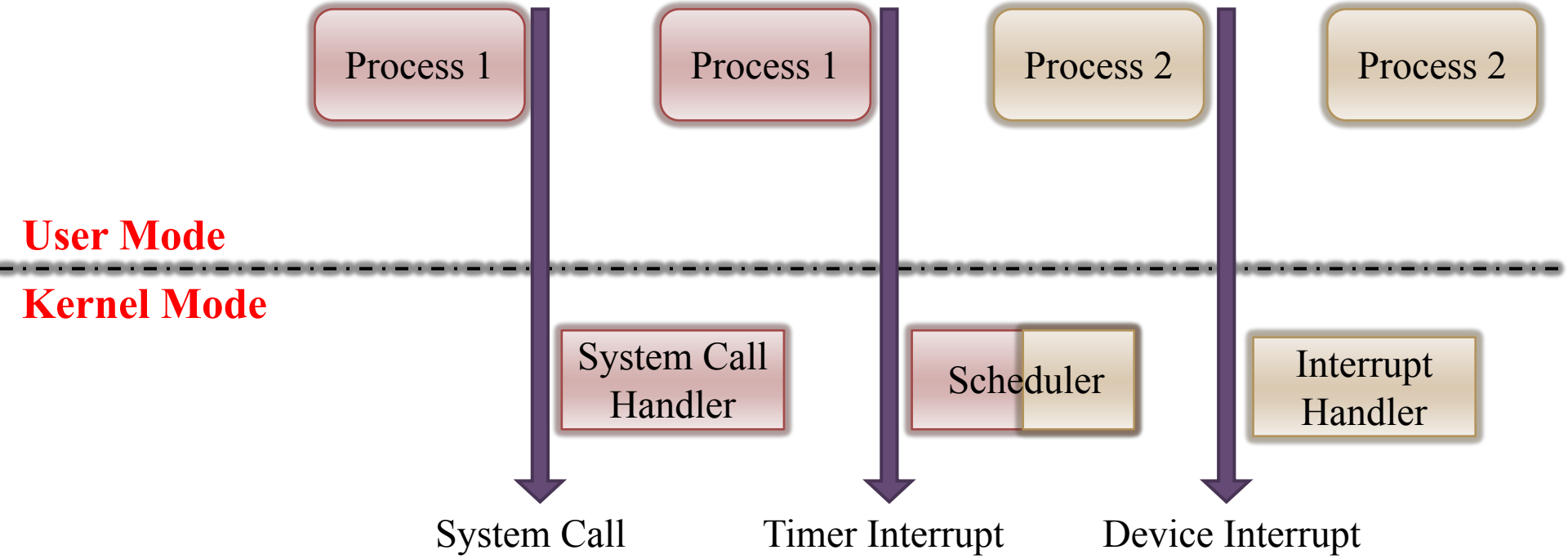
Interrupt-Driven I/O Cycle



Interrupt Usage

- Interrupt vector table is used to identify which device sent out the interrupt
  - When multiple devices share an interrupt number, the handlers are checked one by one
- Interrupt mechanism is also used for exceptions
  - Terminate process or crashed subsystem due to hardware error
  - Page fault executes when there is some memory access error
  - System call executes via a trap to trigger the kernel to execute some request
- Multi-CPU systems can process interrupts concurrently
  - If operating system designed to handle it

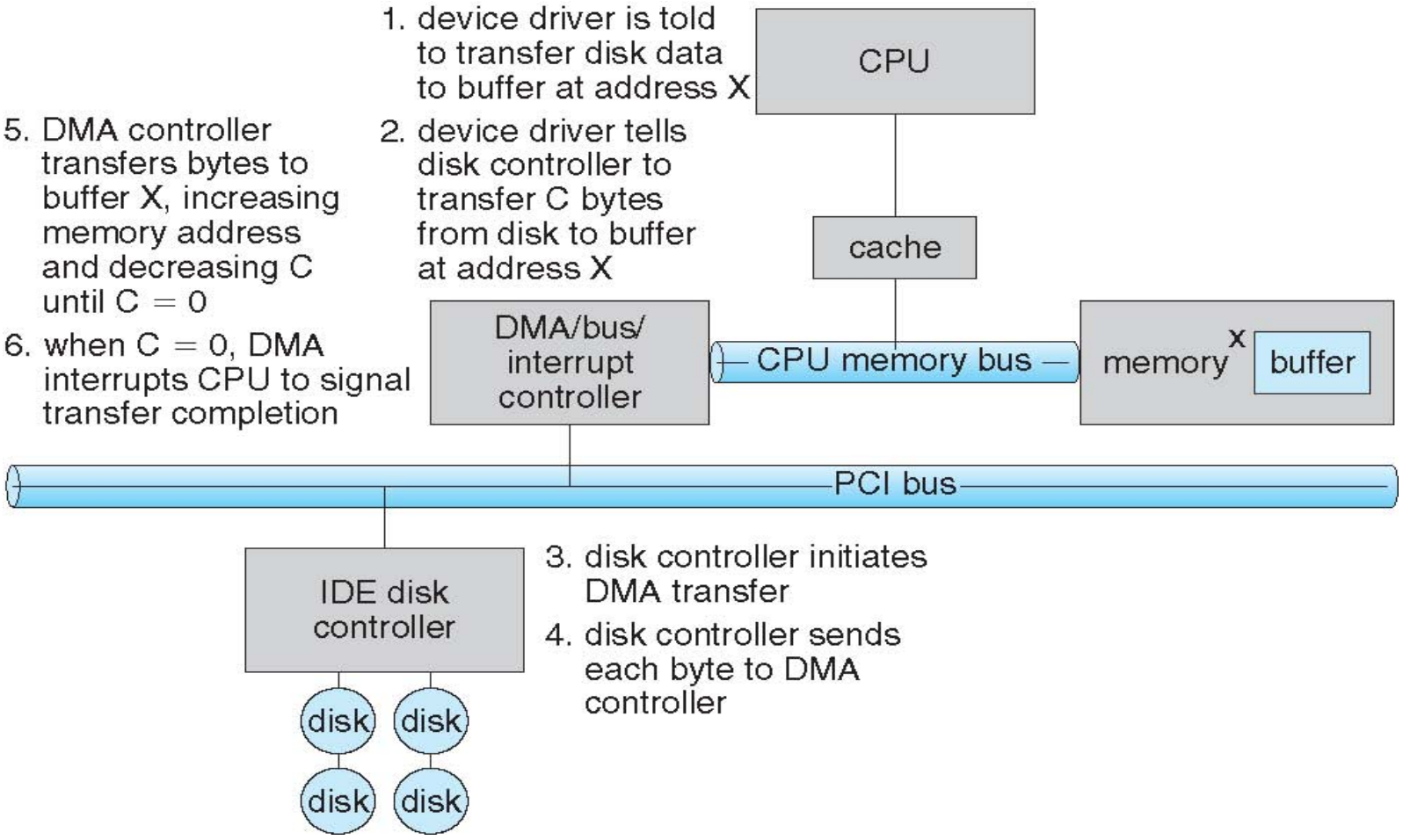
Transitions between User and Kernel Modes in Linux



Direct Memory Access

- Used to avoid programmed I/O (one byte at a time) for large data movement
- Requires a DMA controller
- Bypasses the CPU to transfer data directly between I/O devices and memory
- OS writes a DMA command block into memory
  - Source and destination addresses
  - Read or write mode
  - Number of bytes
- OS writes the location of the command block to the corresponding DMA controller
  - Bus mastered by the DMA controller – grabs bus from CPU
  - When transmission is done, the DMA controller sends an interrupt

DMA Transfer



Getting Started

- Installing Linux is now easier than installing MS Windows
- Doing it on a virtual machine can be harmless
- Many distributions are there for you

- Which Linux distribution is better?
  - If you ask this question, it means “it doesn't matter for you”
  - Just use the distribution with the most supports you can find

Android Environment

History of Android

- Android was founded in Palo Alto, California in October 2003
- Google acquired Android in August 2005
- The Open Handset Alliance started in November 2007
- The first commercially available smartphone running Android was the HTC Dream, released on October 22, 2008
- The latest released version is Android Oreo 8.0.0, which was released on August 21, 2017

Android Versions

Cupcake
Android 1.5

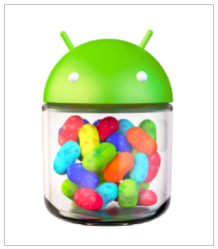
Donut
Android 1.6

Eclair
Android 2.0/2.1

Froyo
Android 2.2

Honeycomb
Android 3.0-3.2

Ice cream Sandwich
Android 4.0+



Jelly Bean
Android 4.1-4.3

KitKat
Android 4.4

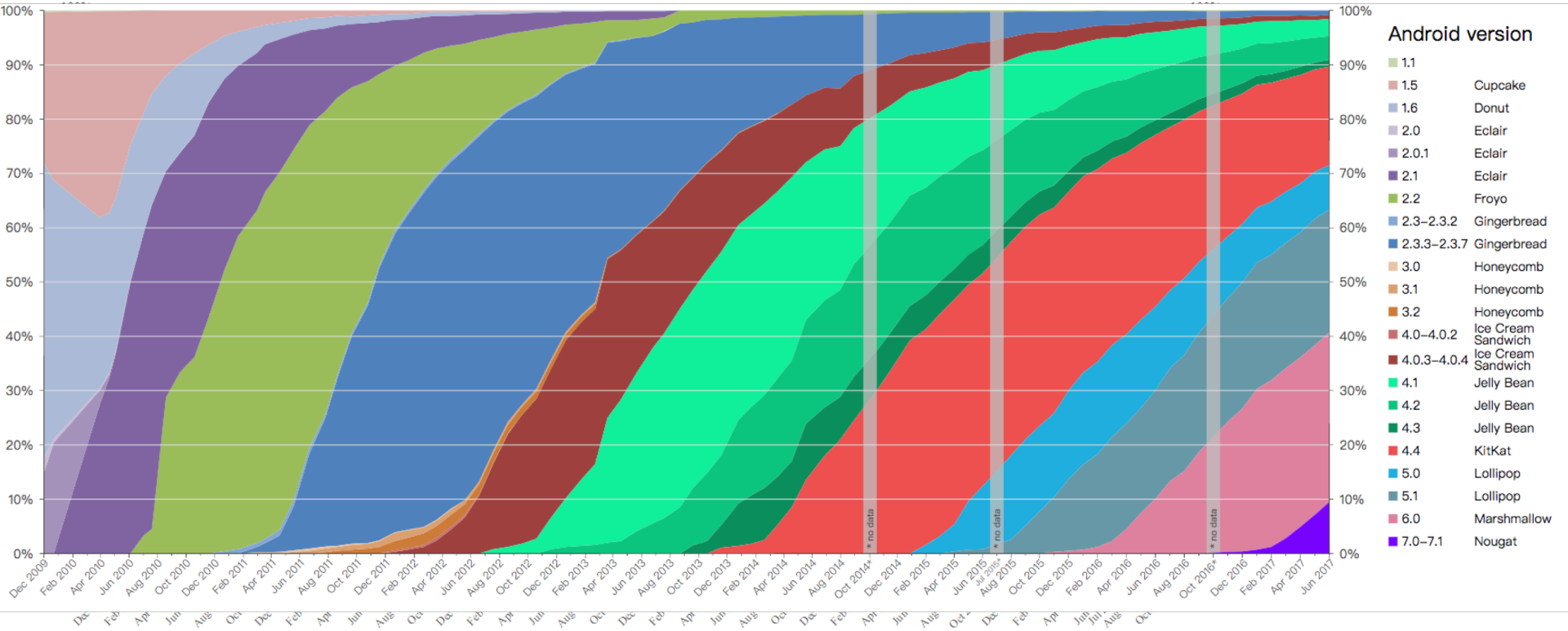
Lollipop
Android 5.0-5.1

Marshmallow
Android 6.0-6.0.1

Nougat
Android 7.0 – 7.1.2

Oreo
Android 8.0-

Android Distribution

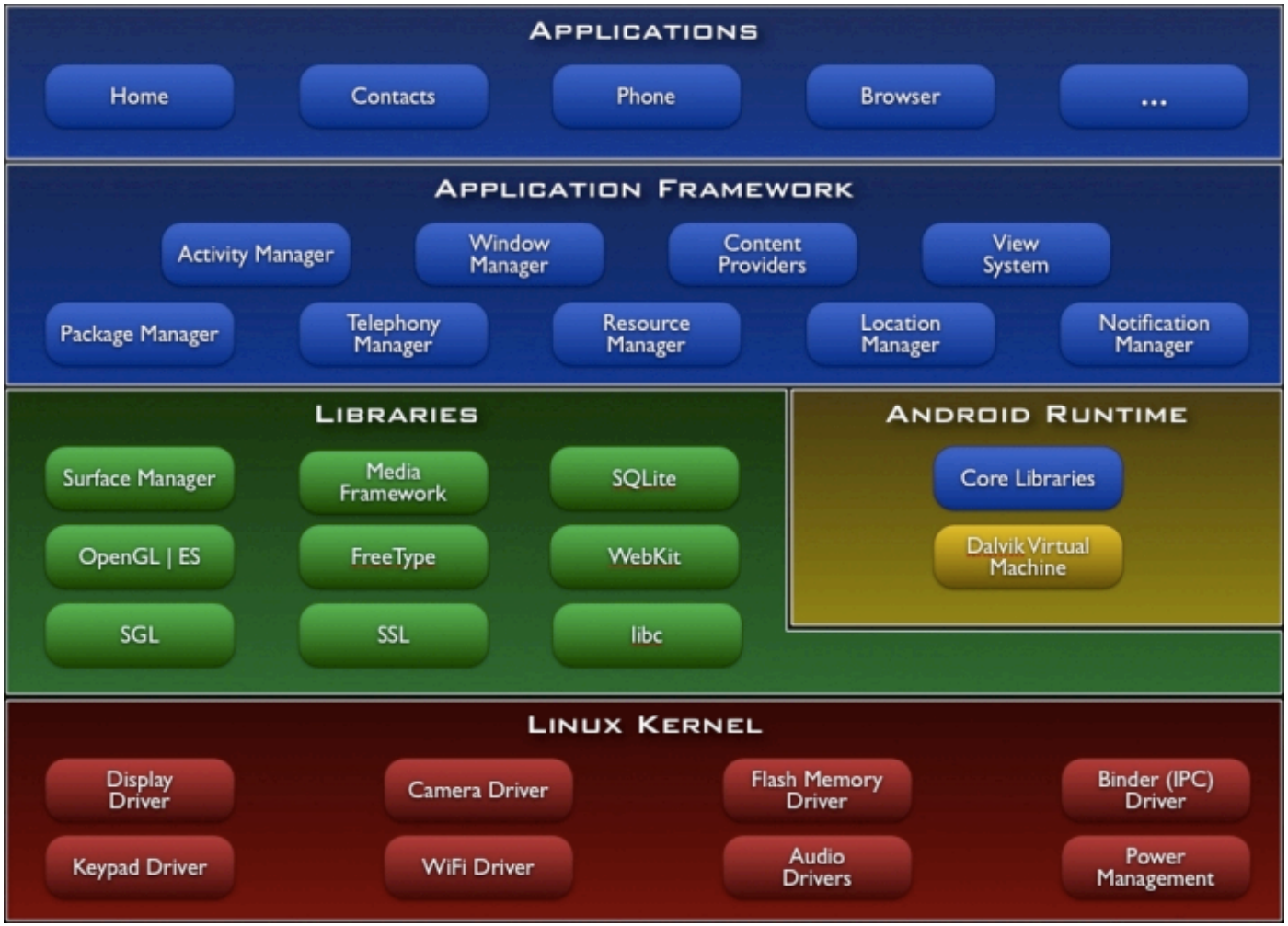


Source: http://en.wikipedia.org/wiki/File:Android_historical_version_distribution_-_vector.svg

Google Android

- A software stack for mobile devices
  - An operating system
  - Middleware
  - Key Applications
- Linux for core system services
  - Security
  - Memory management
  - Process management
  - Power management
  - Hardware drivers

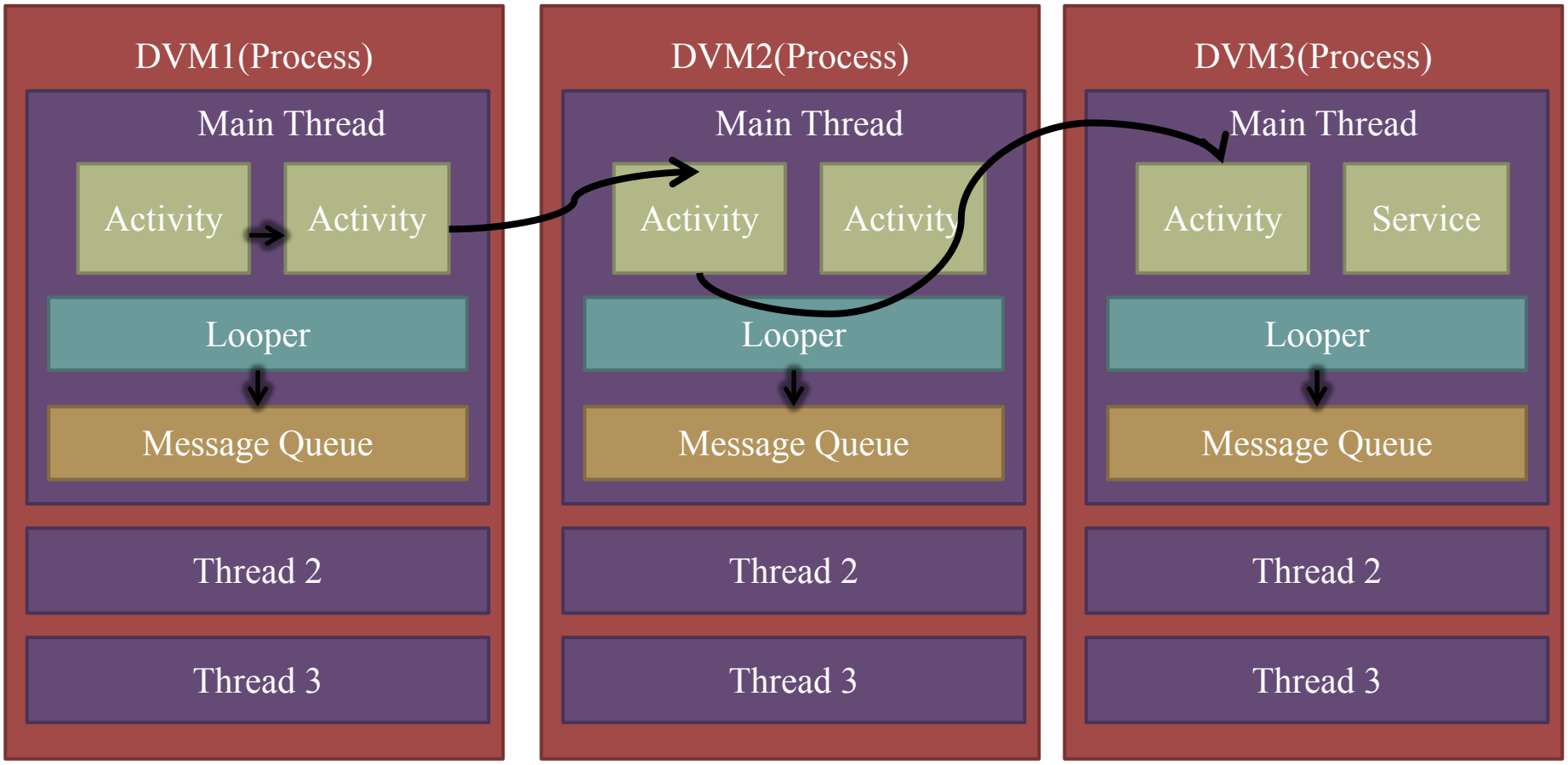
Android Architecture



Mobile Devices

- Advantages
  - Always with the user
  - Typically have Internet access
  - Typically GPS enabled
  - Typically have accelerometer & compass
  - Most have cameras & microphones
- Disadvantages
  - Limited screen size
  - Limited battery life
  - Limited processor speed
  - Limited web browser functionality

Android Applications



Android Market / Google Play

- Has various categories, allows ratings
- Have both free/paid apps
- Featured apps on web and on phone
- Initial release: October 23, 2008, as Android Market
- Development status:
  - 1+ million apps, as of July, 2013
  - 1.3+ million apps, as of July, 2014
  - 1.5+ million apps, as of Q1, 2015
  - 1.9+ million apps, as of Q1, 2016
  - 2.7+ million apps, as of Q1, 2017

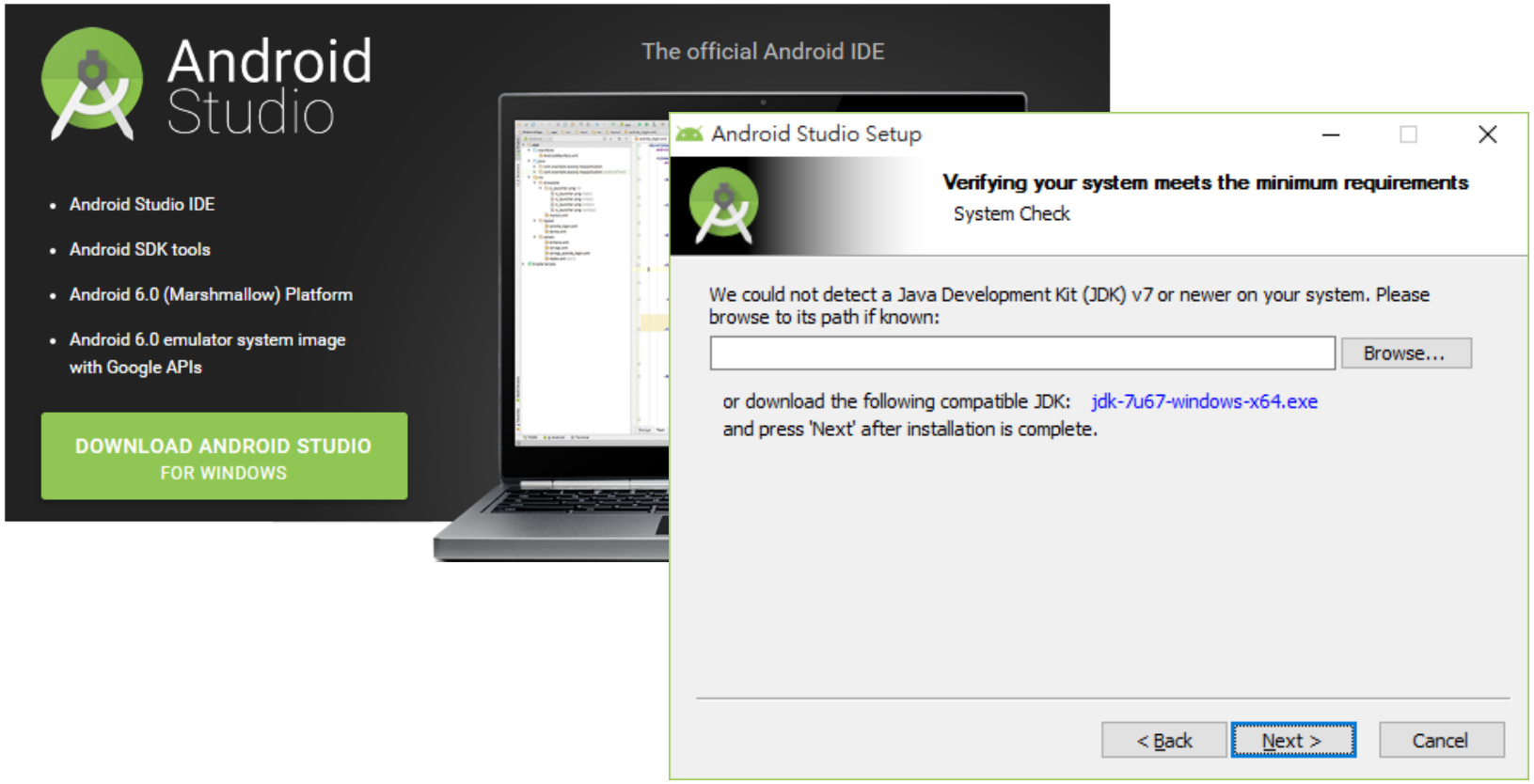
Publish Your APP

- Link to an Account
  - Developer Account: $25 fee
  - Link to your checking account
  - Developer take 70% of app purchase price

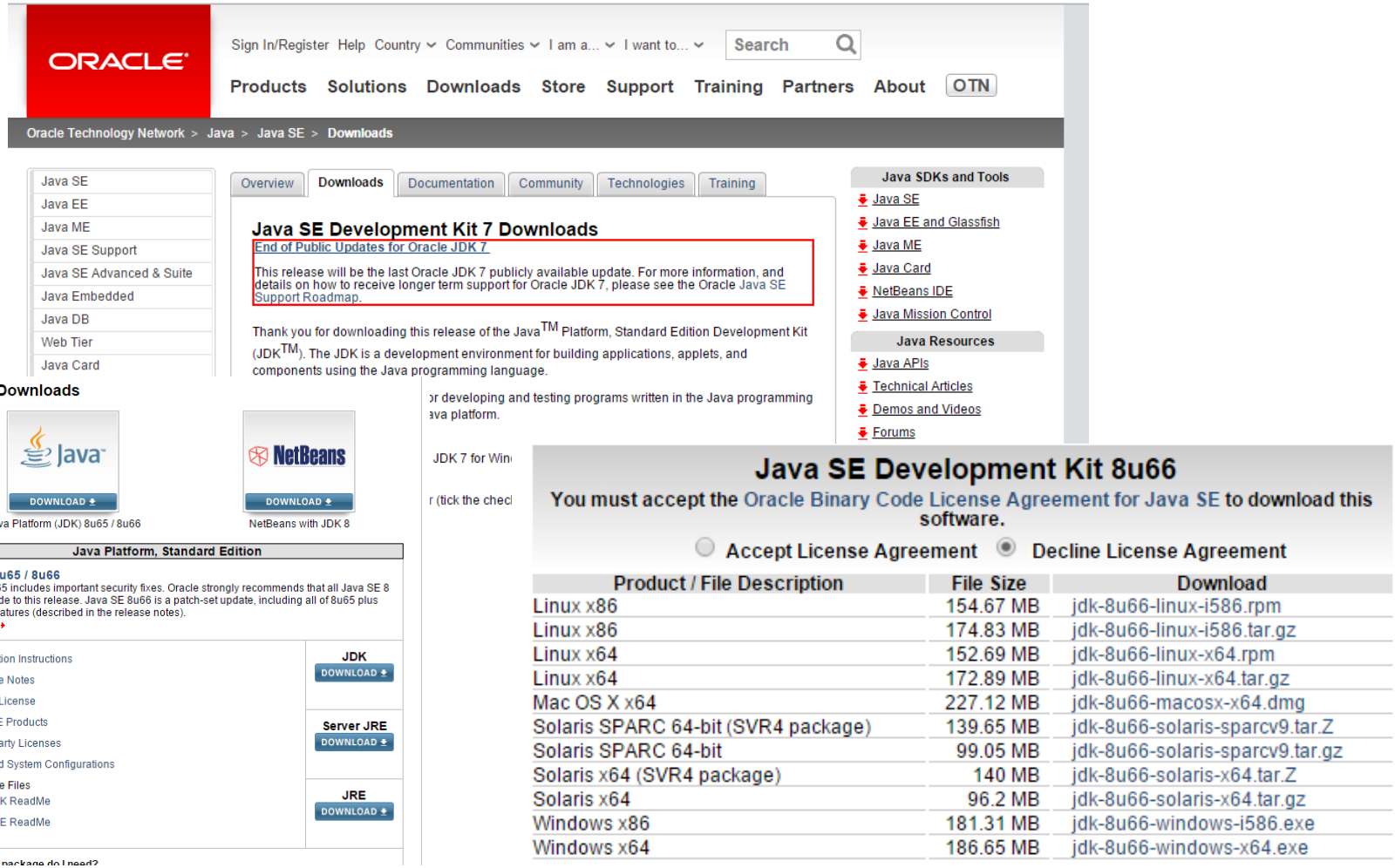
Android Environment

- Eclipse + ADT (Android Developer Tools) Plugin
- Android SDK (System Development Kit) Tools
- Android Platform-Tools
- The Latest Android Platform Configuration
- The Latest Android System Image for the Emulator

Android Studio

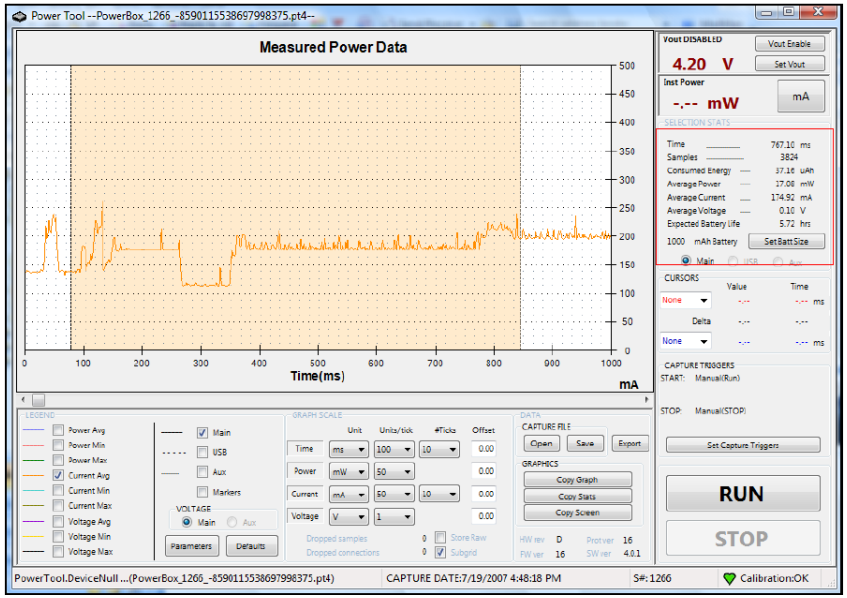


Java Development Kit



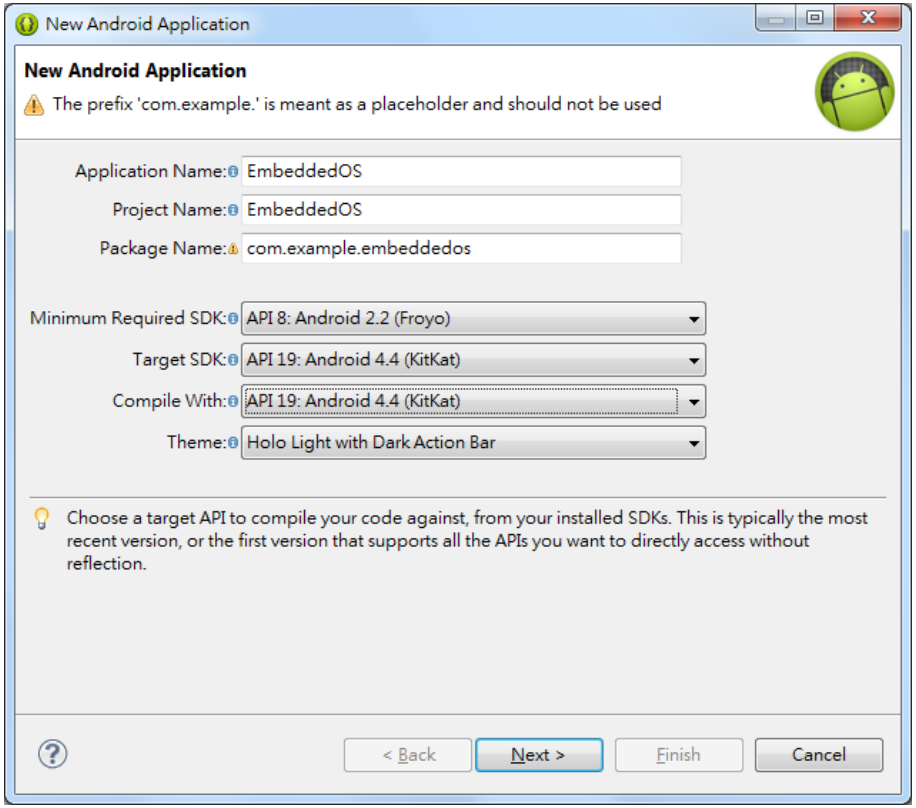
Power Monitor

- Power measurement for any device with a single lithium battery



Set Information of the Project

- Application Name is the app name that appears to users
- Project Name is the name of your project directory and the name visible in Eclipse
- Package Name is the package namespace for your app (following the same rules as packages in the Java programming language)

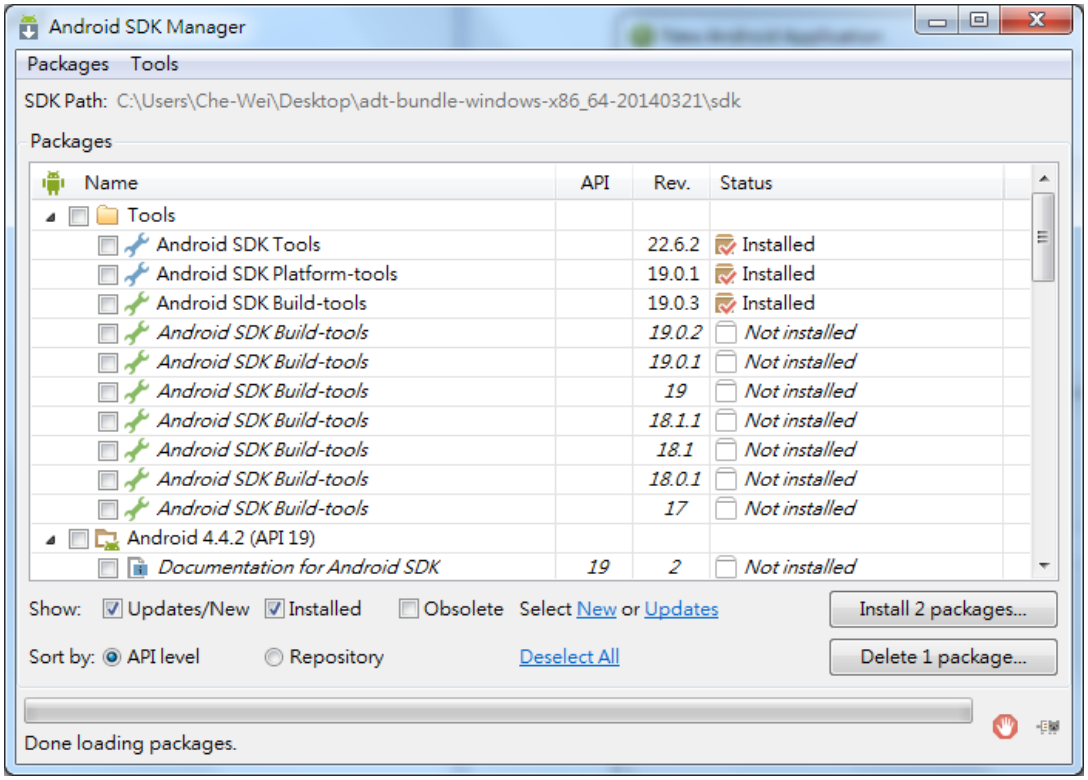


API Support

- Minimum Required SDK is the lowest version of Android that your app supports
- Target SDK indicates the highest version of Android
- Compile With is the platform version against which you will compile your app
  - By default, this is set to the latest version of Android available in your SDK
- Theme specifies the Android UI style to apply for your app

SDK Manager

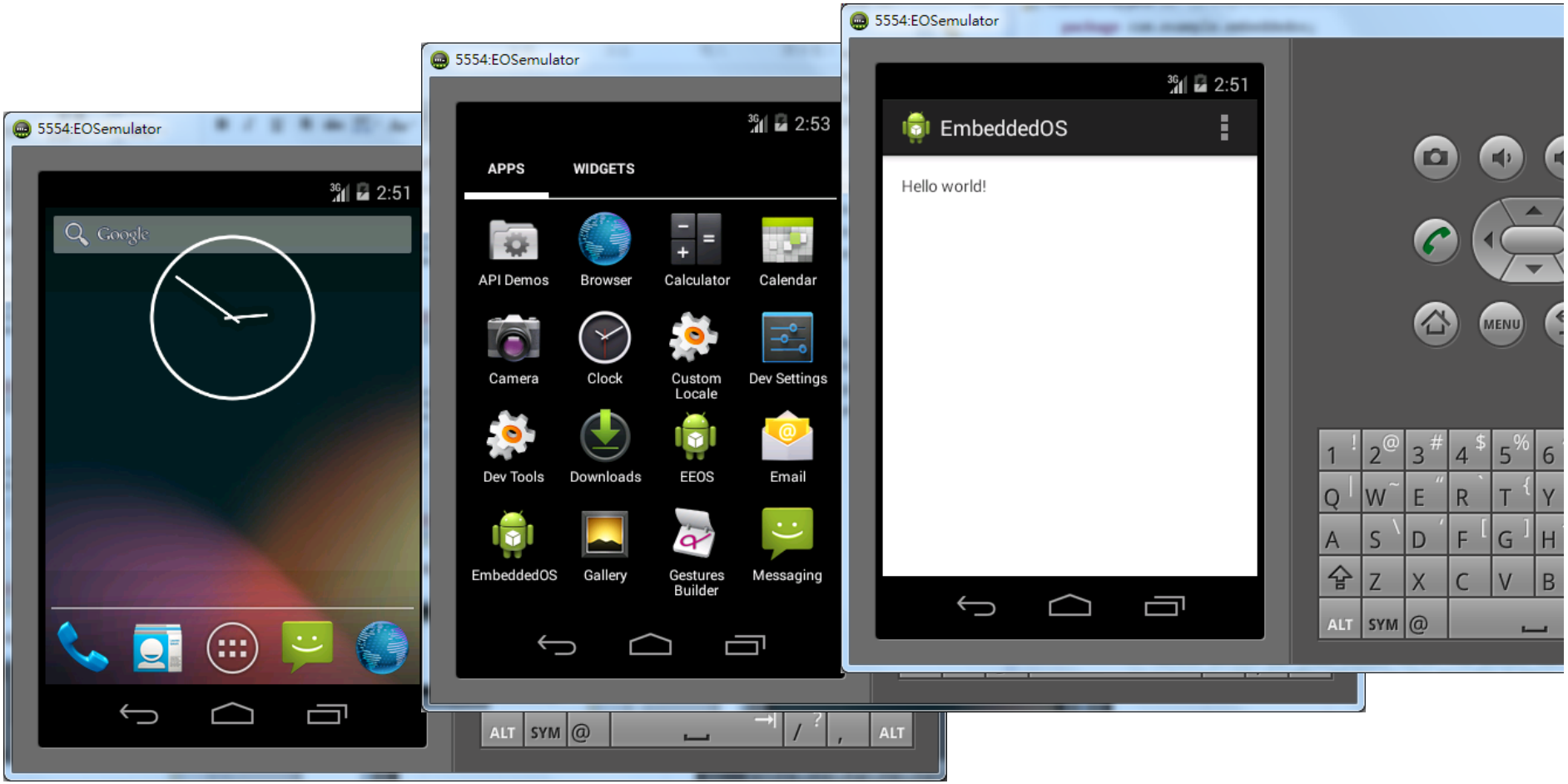
- If you want to install more libraries for different Android versions or different function supports



Execute APP on an Android Device

- Enable USB debugging on your device
  - On most devices running Android 3.2 or older, you can find the option under Settings → Applications → Development
  - On Android 4.0 and newer, it's in Settings →Developer options
  - On Android 4.2 and newer, Developer options is hidden by default
    - To make it available, go to Settings → About phone → tap Build number (版本號碼 or 軟體版本) seven times
      - It might be different for different Android devices
    - Return to the previous screen to find Developer options
- Developer Options → Enable USB debugging
- Down and install the USB driver and install it

Hello World



Dalvik Virtual Machine

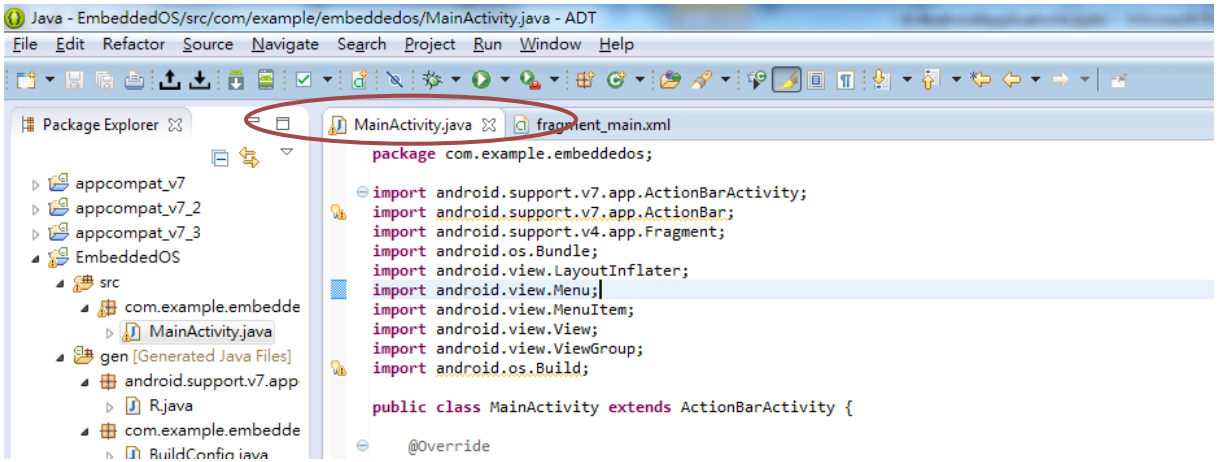
- Providing environment on which every Android application runs
  - Each Android application runs in its own process, with its own instance of the Dalvik Virtual Machine (DVM)
  - Register-based virtual machine
- Executing the Dalvik Executable (.dex) format
  - .dex format is optimized for minimal memory footprint
- Relying on the Linux Kernel
  - Multi-threading
  - Low-level memory management

Android Runtime (ART)

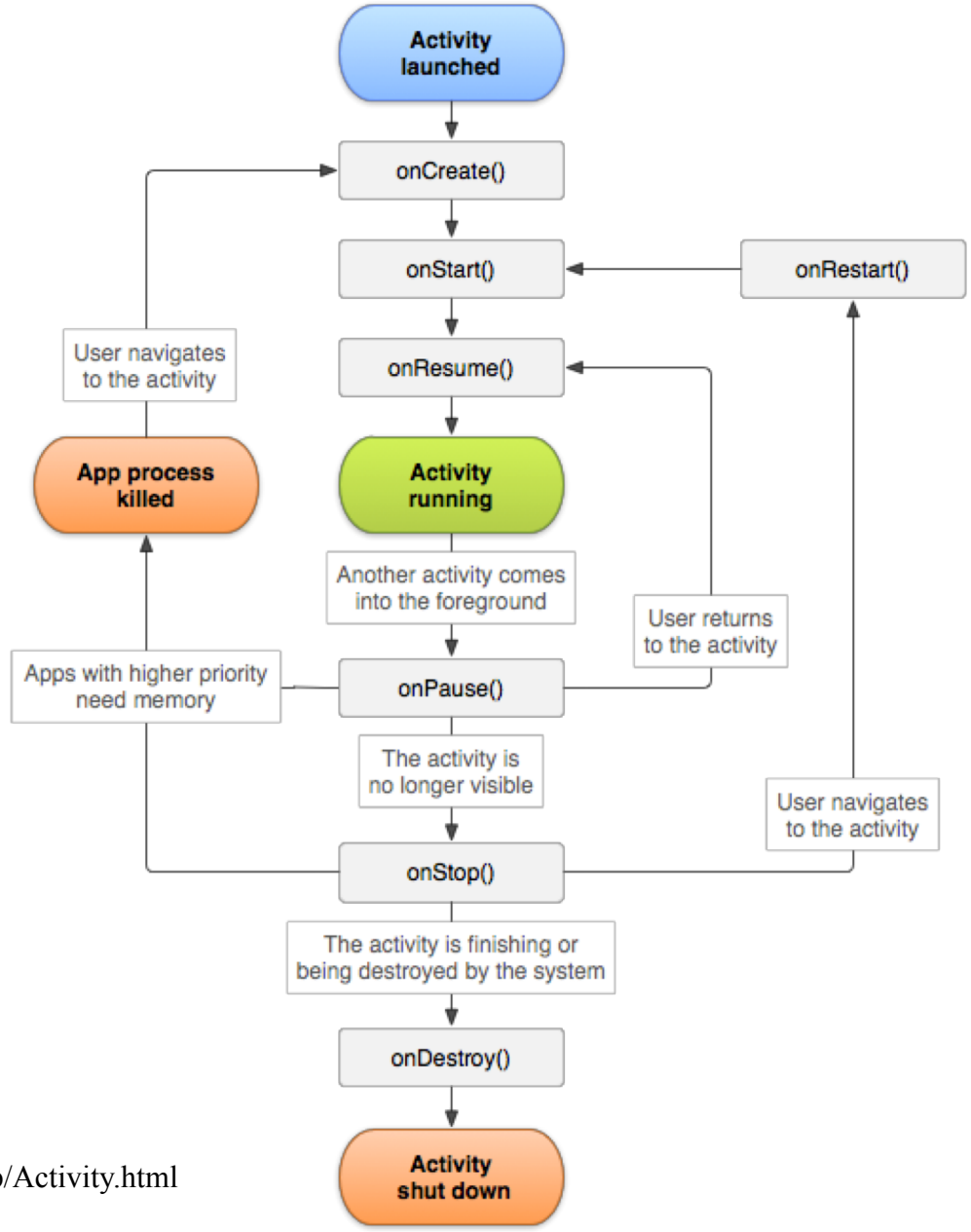
- Android Runtime (ART) is an application runtime environment
- ART is provided to replace Dalvik
- ART introduces the use of ahead-of-time (AOT) compilation
- AOT compiles entire applications into native machine code upon their installation
- Android 4.4 has alternatives to use ART or Dalvik
- After Android 5.0, Dalvik was entirely replaced by ART

Activities

- Activities are the basis of android applications
- An Activity defines a viewable screen
- Multiple Activities for an application are allowed
- Each activity is a separate entity
- They have a life cycle
  - Events happen either via touching buttons or programmatically



Activity Lifecycle

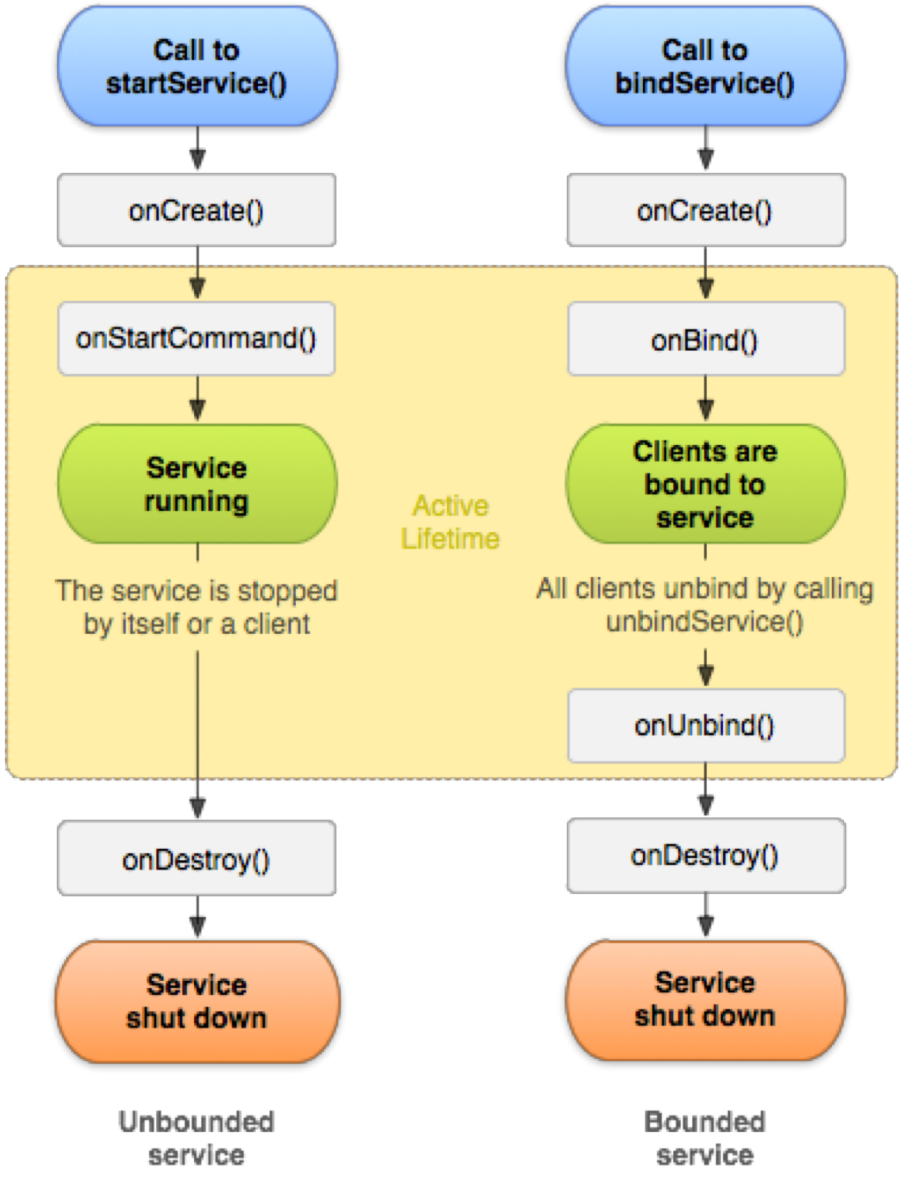


Source: http://developer.android.com/reference/android/app/Activity.html

Services

- Run in the background
  - Should be used if something needs to be done while the user is not interacting with application
  - Should create a new thread in the service to do work in
- Can be bound to an application
  - It will terminate when all applications bound to it have unbound
  - Multiple applications can communicate with each other via a service
- Needs to be declared in manifest file

Service Lifecycle



Source: http://developer.android.com/guide/components/services.html