



# 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

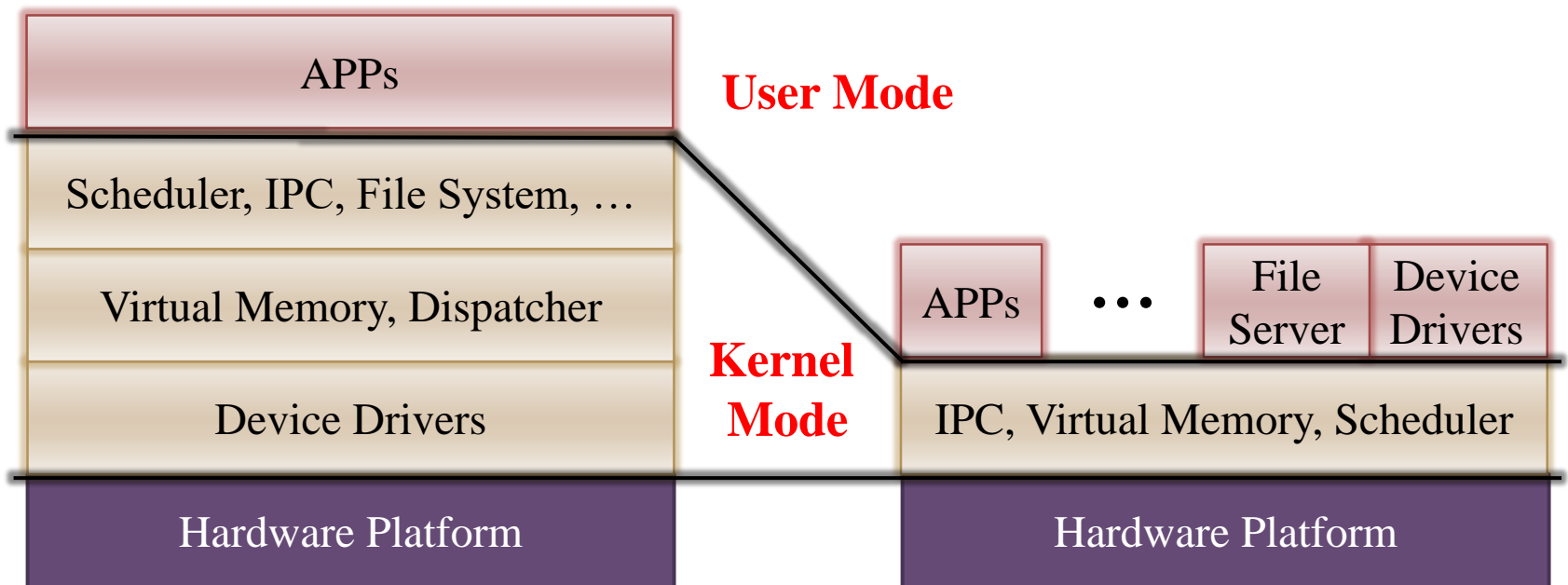
- Kernel functions are partitioned into components
- Communications are via inter process communication (IPC) protocol
- The L4 microkernel is an example



# Monolithic Kernel and Microkernel

## Monolithic Kernel

## 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

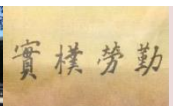
## ▶ Block Devices

- 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



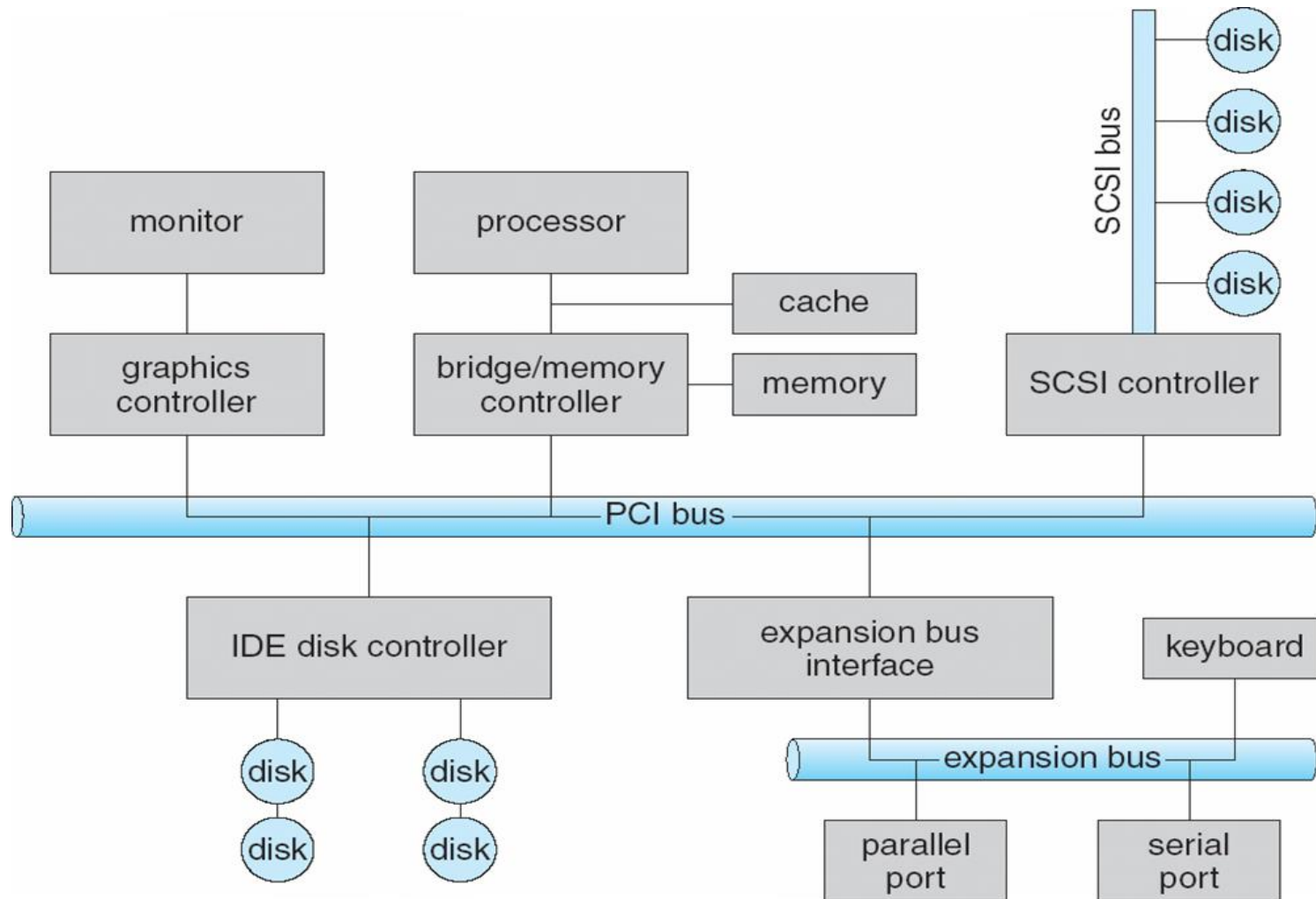
# I/O Hardware

- ▶ 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

- ▶ Device 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

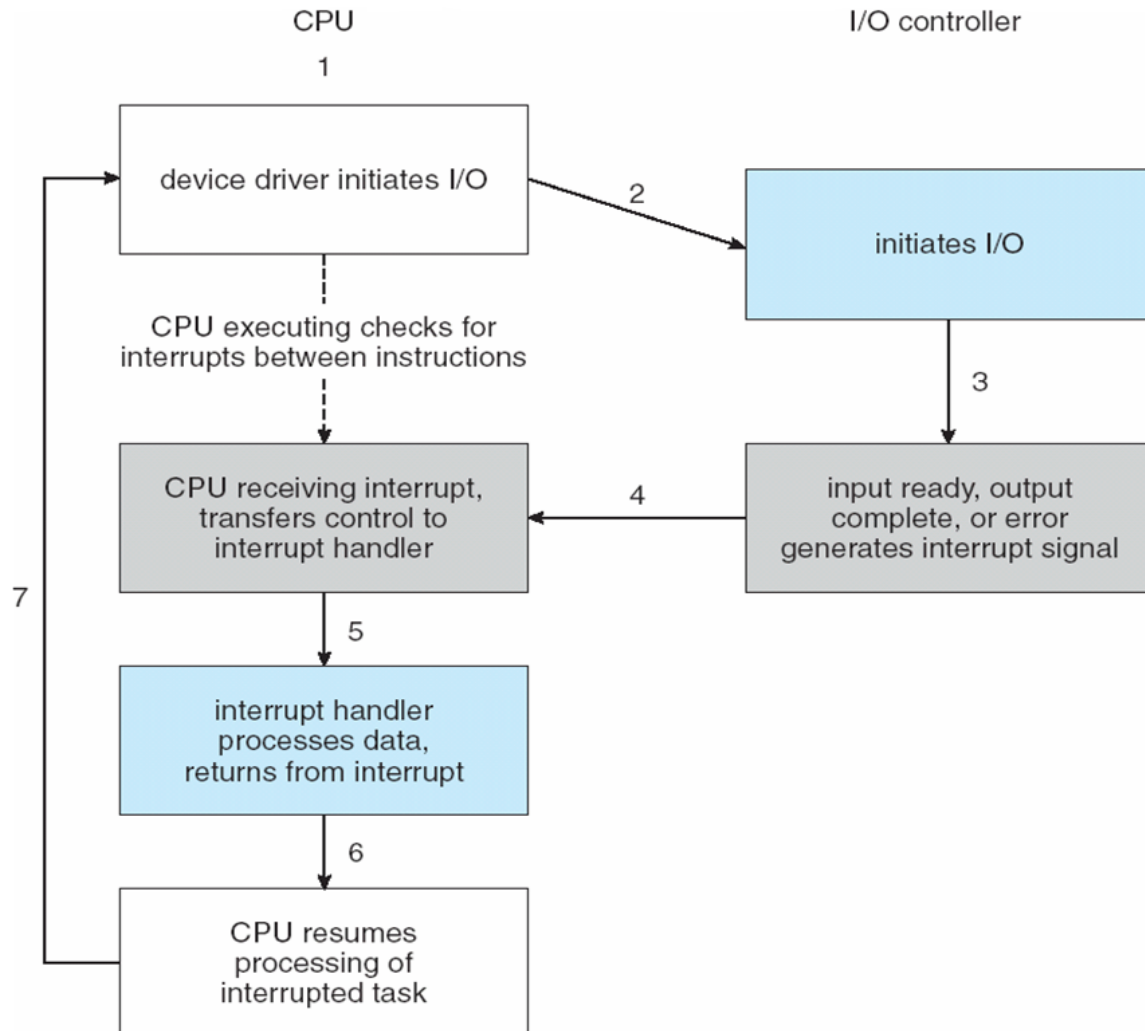


# Interrupts

- ▶ 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

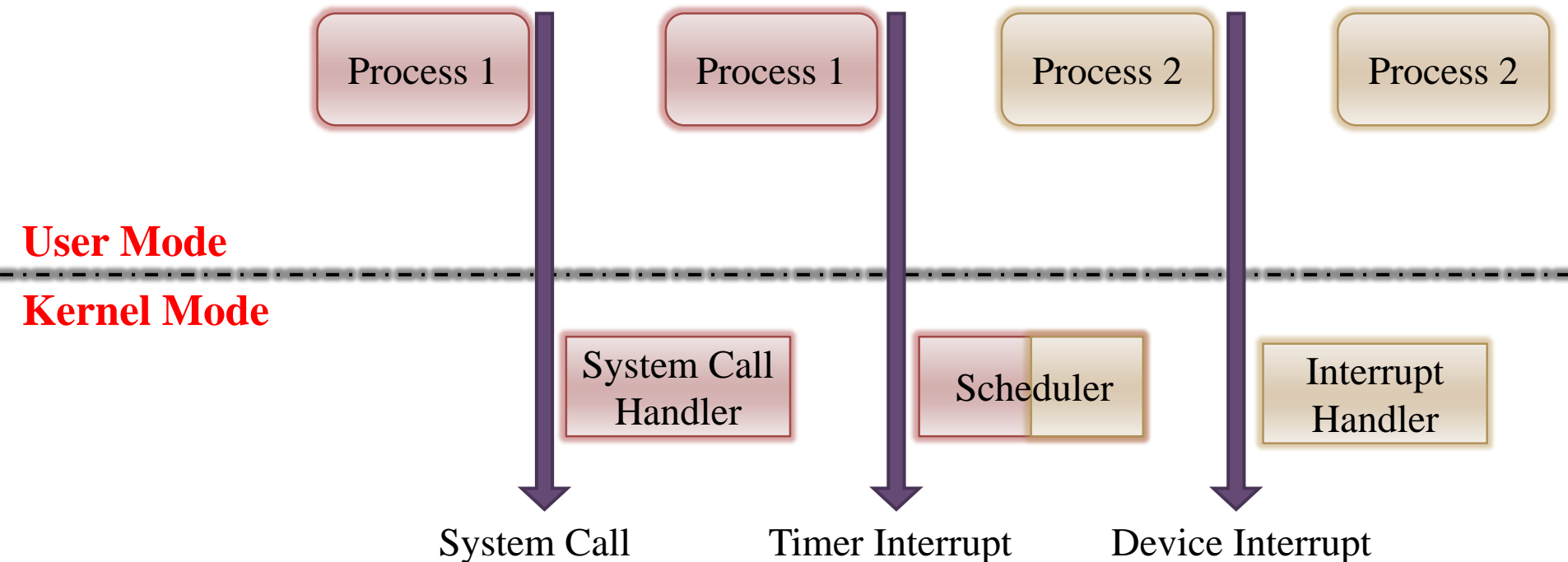


# Interrupt Usage

- ▶ 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



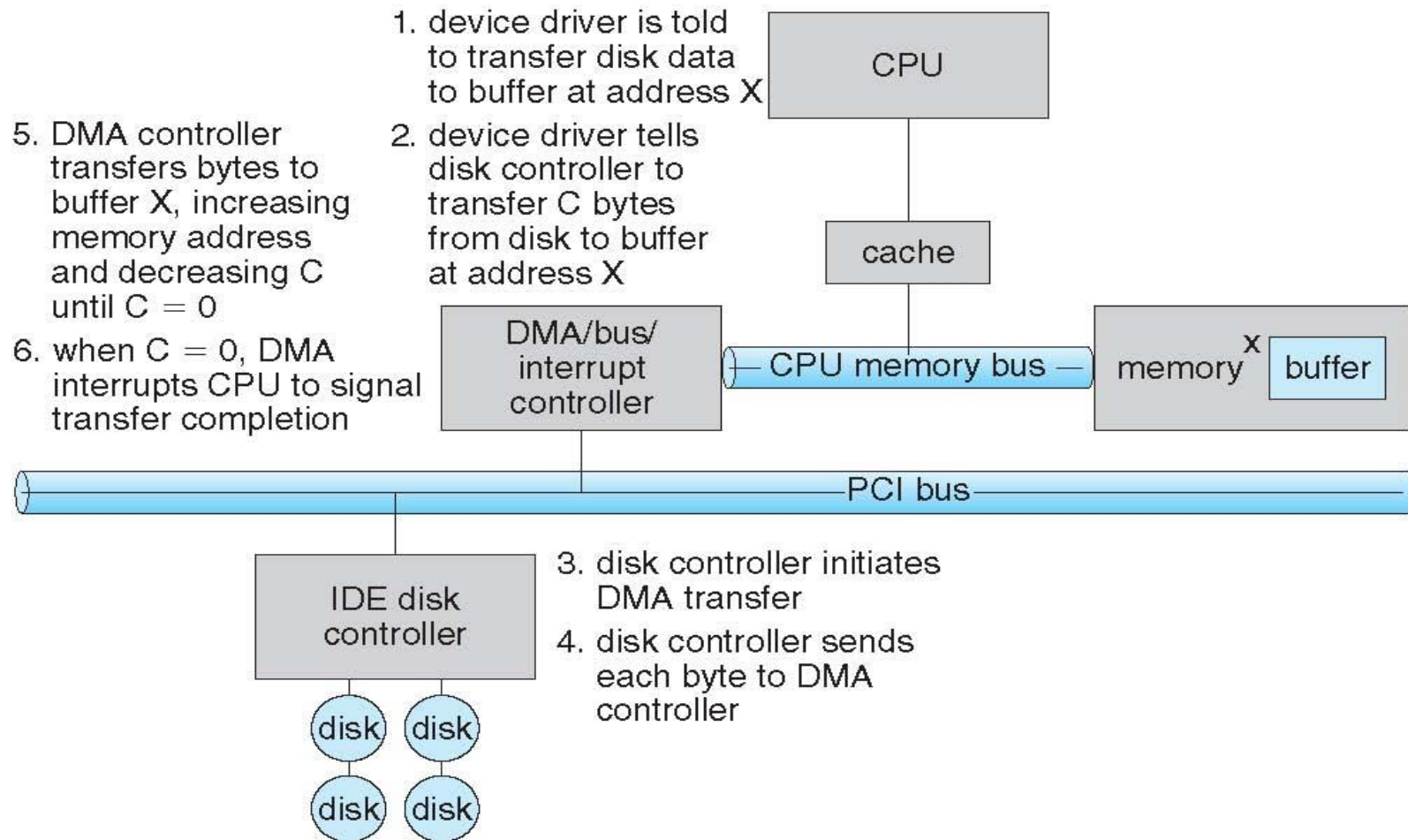


# Direct Memory Access

- ▶ 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 13, which was released on August 8, 2022





# 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 - 8.1



**Pie**  
Android 9.0

Android 10, 11, 12, 13, 14  
Android 10, 11, 12, 13, 14

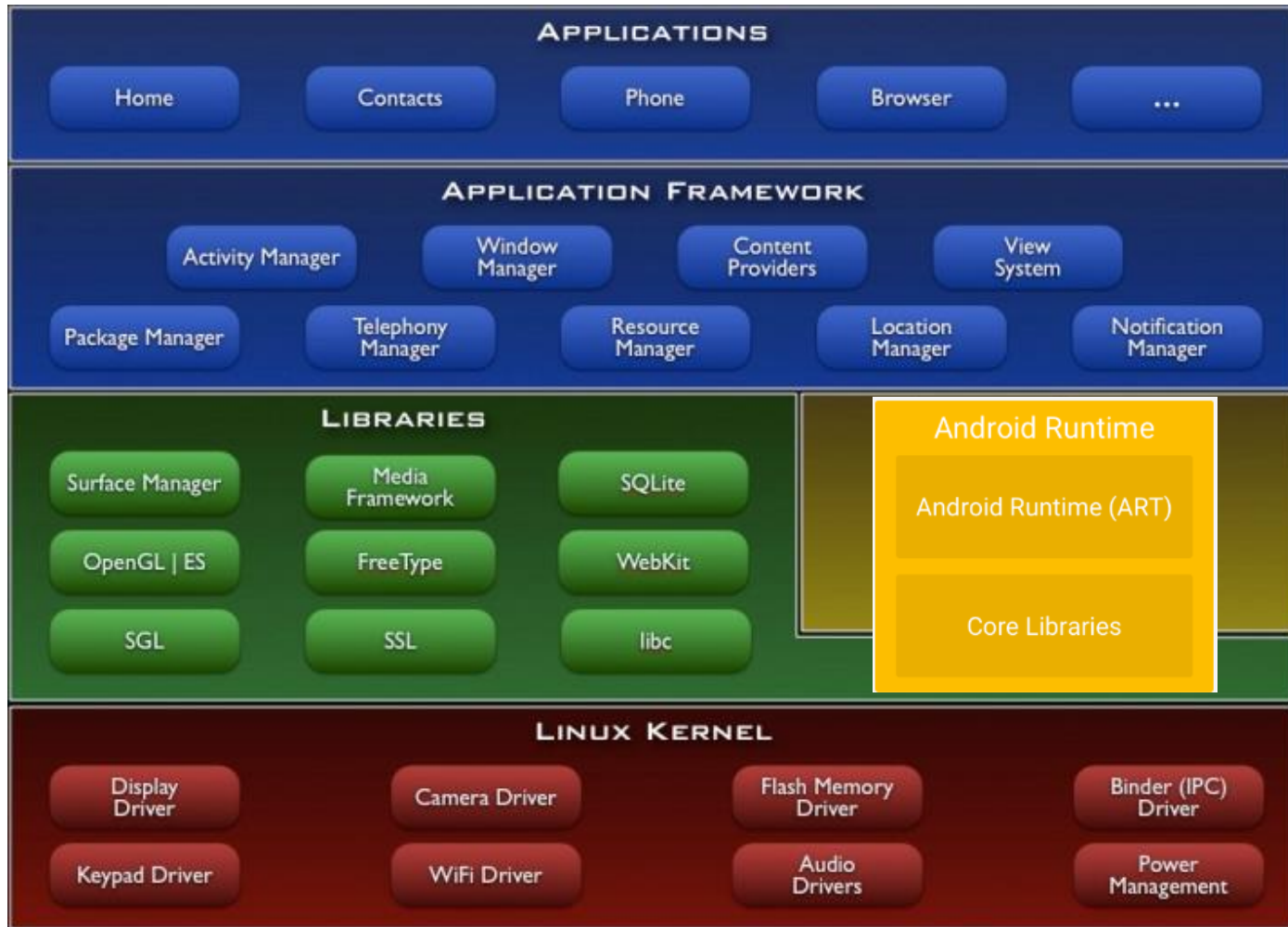


# Google Android

- ▶ 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 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
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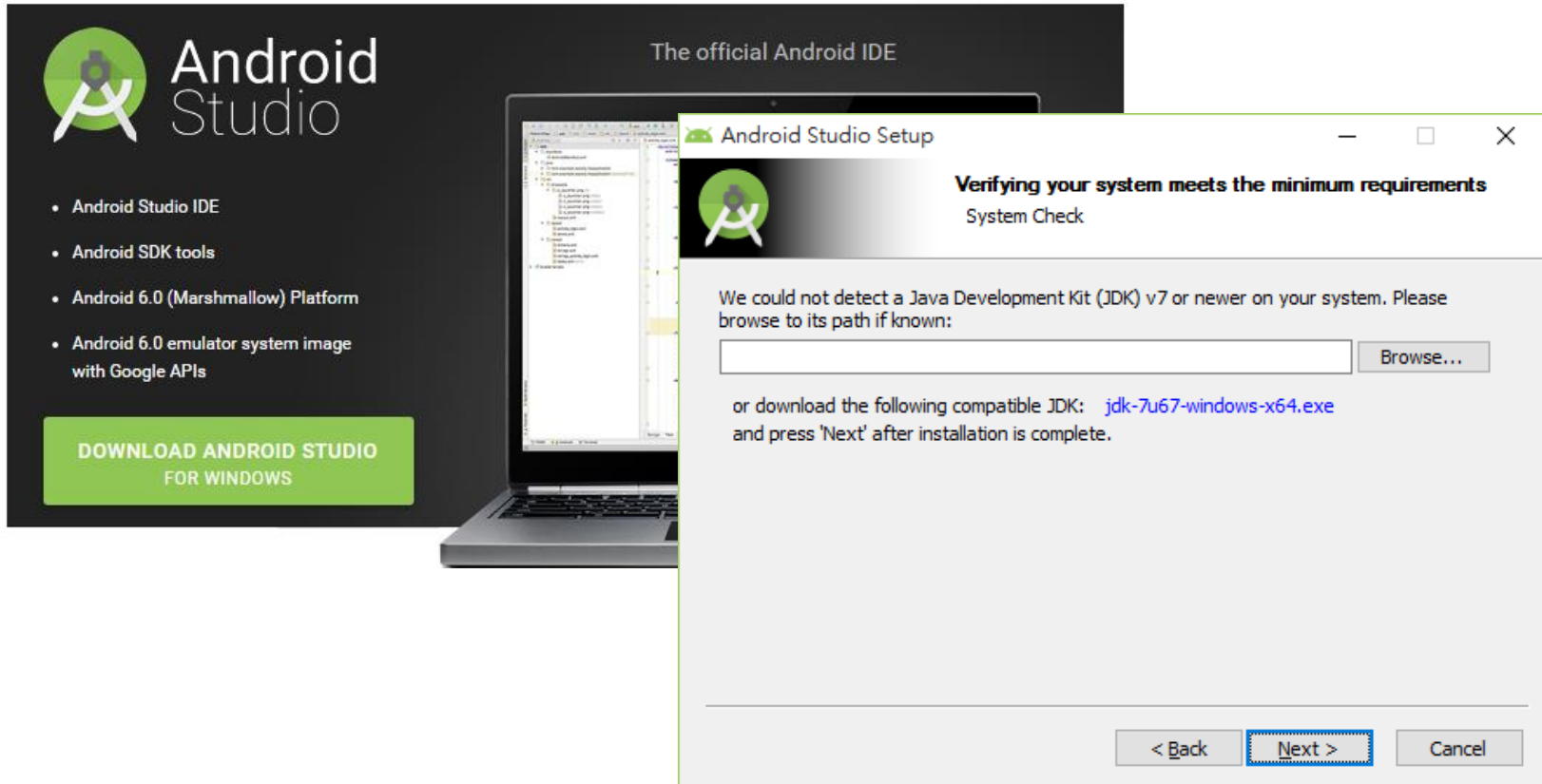


# Android Environment


- ▶ 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



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End of Public Updates for Oracle JDK 7

This release will be the last Oracle JDK 7 publicly available update. For more information, and details on how to receive longer term support for Oracle JDK 7, please see the Oracle Java SE Support Roadmap.

Thank you for downloading this release of the Java™ Platform, Standard Edition Development Kit (JDK™). The JDK is a development environment for building applications, applets, and components using the Java programming language.

or developing and testing programs written in the Java programming language platform.

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Java SE 8u65 includes important security fixes. Oracle strongly recommends that all Java SE 8 users upgrade to this release. Java SE 8u66 is a patch-set update, including all of 8u65 plus additional features (described in the release notes). Learn more

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Release Notes

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Which Java package do I need?

Java SE Development Kit 8u66

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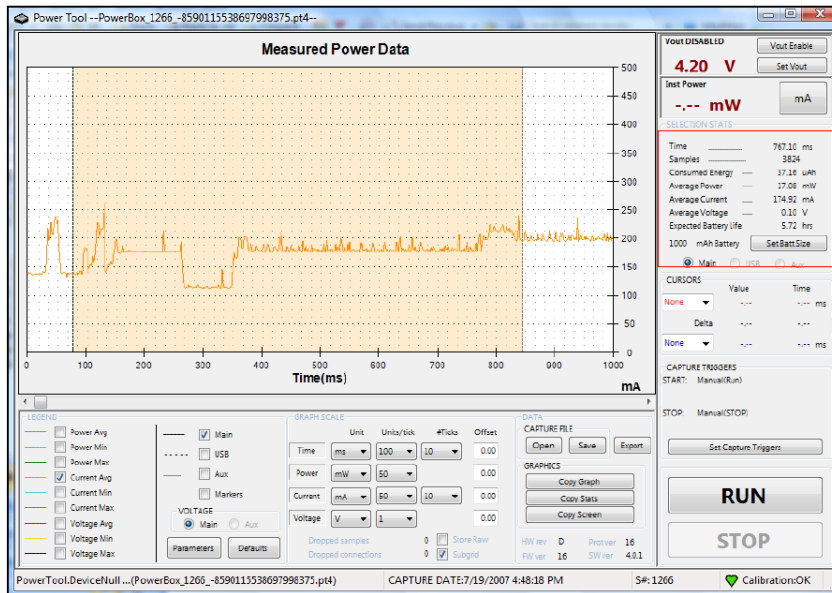
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Windows x86	181.31 MB	jdk-8u66-windows-i586.exe
Windows x64	186.65 MB	jdk-8u66-windows-x64.exe



# Power Monitor

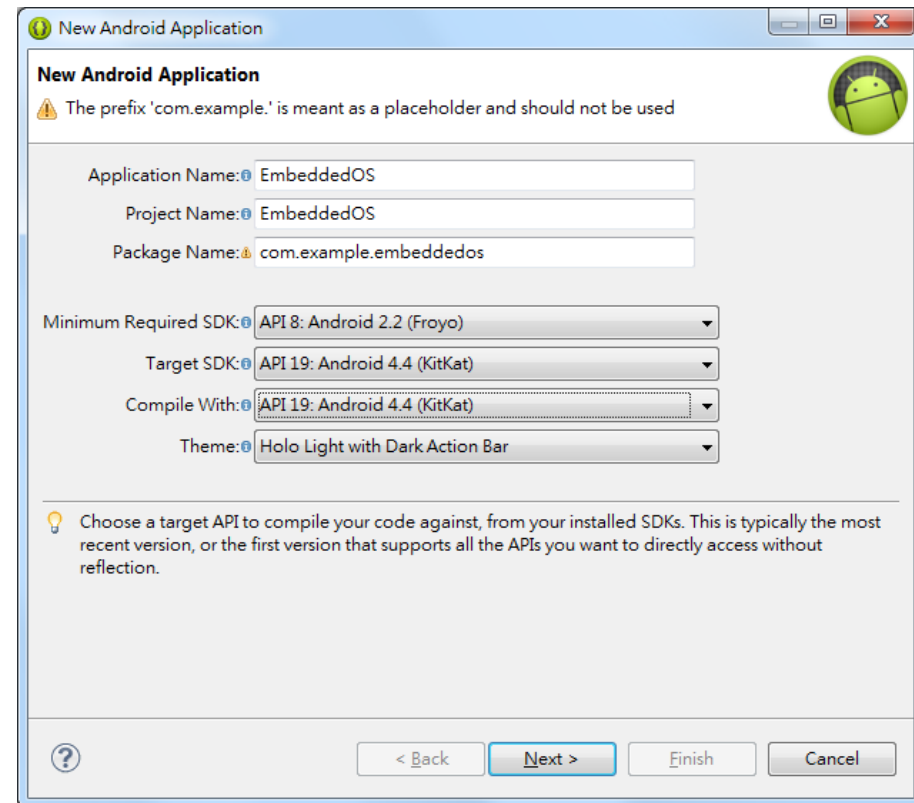
- ▶ Power measurement for any device with a single lithium battery





# Set Information of the Project

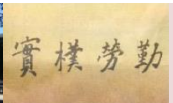
- ▶ **Application Name** is the app name that appears to users
- ▶ **Project Name** is the name of your project directory and the name visible in Eclipse
- ▶ **Package Name** is the package namespace for your app (following the same rules as packages in the Java programming language)





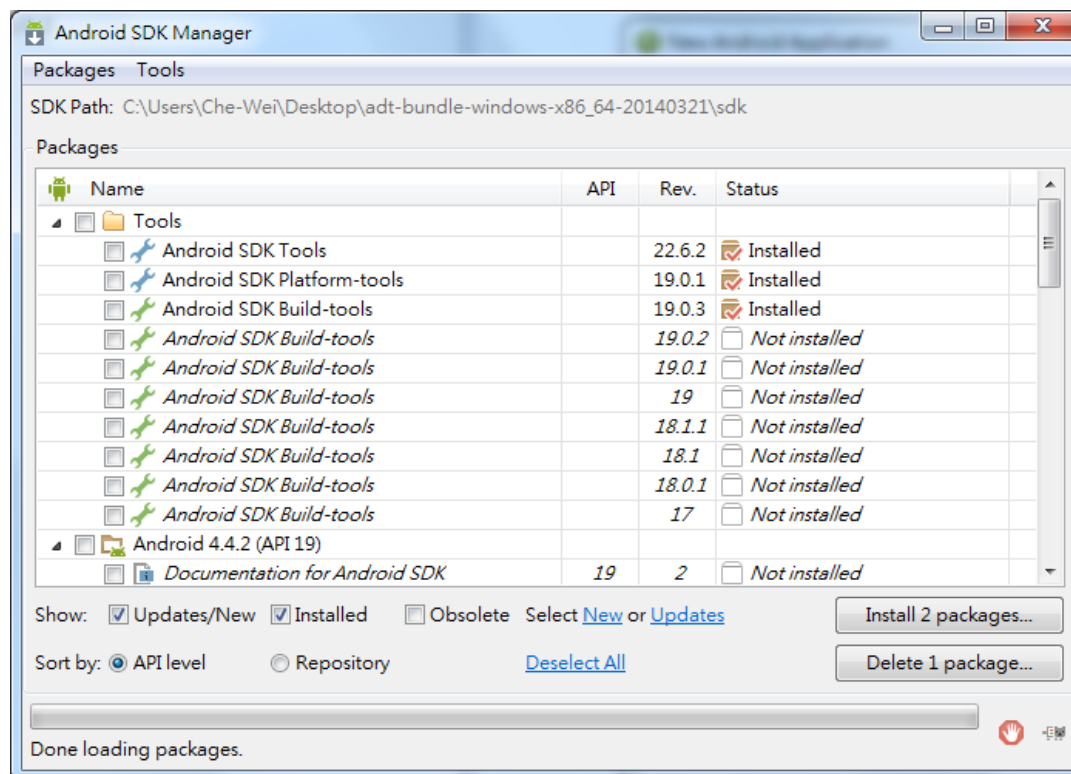
# API Support

- ▶ **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

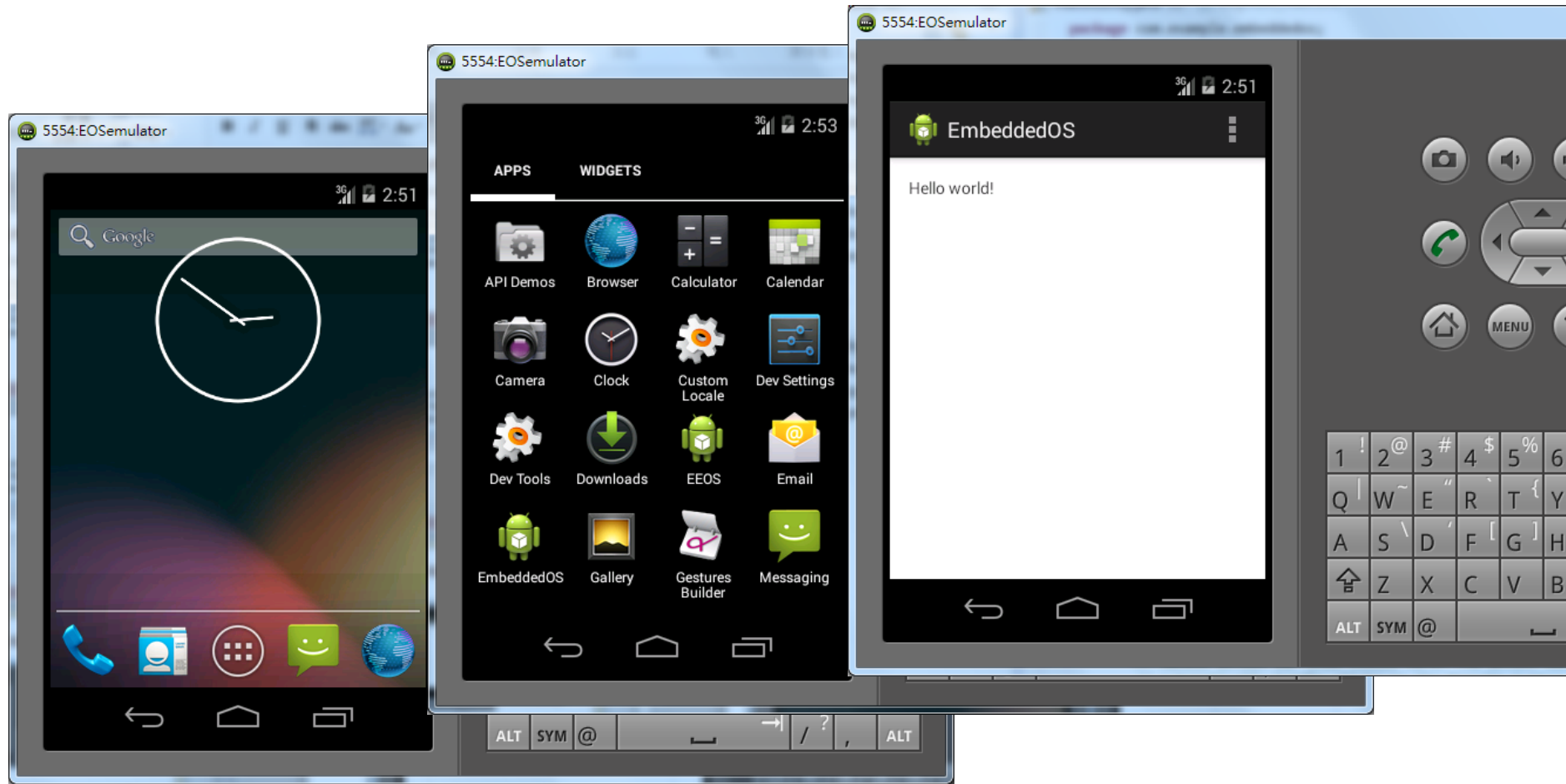


# Execute APP on an Android Device

- ▶ 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



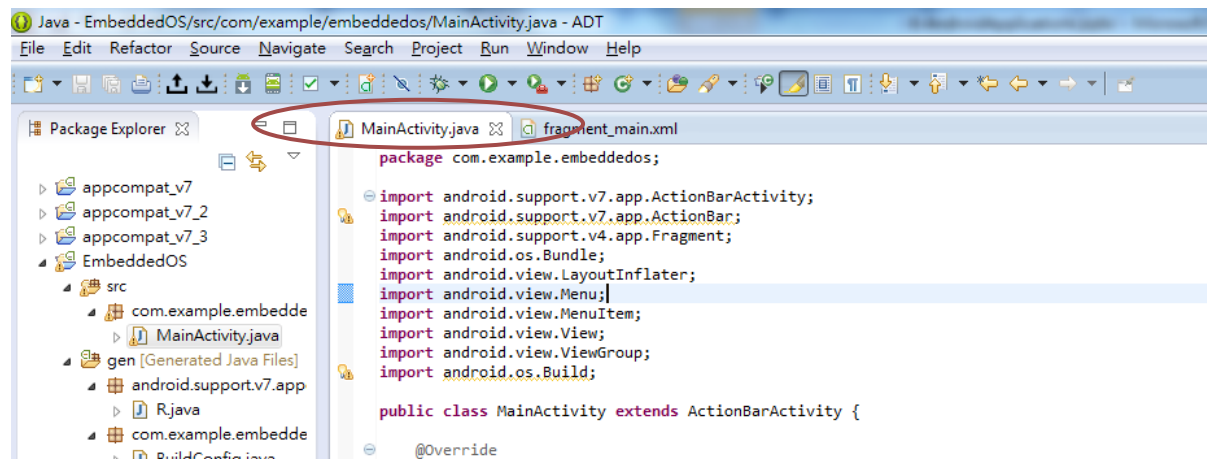
# Android Runtime (ART)

- ▶ 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

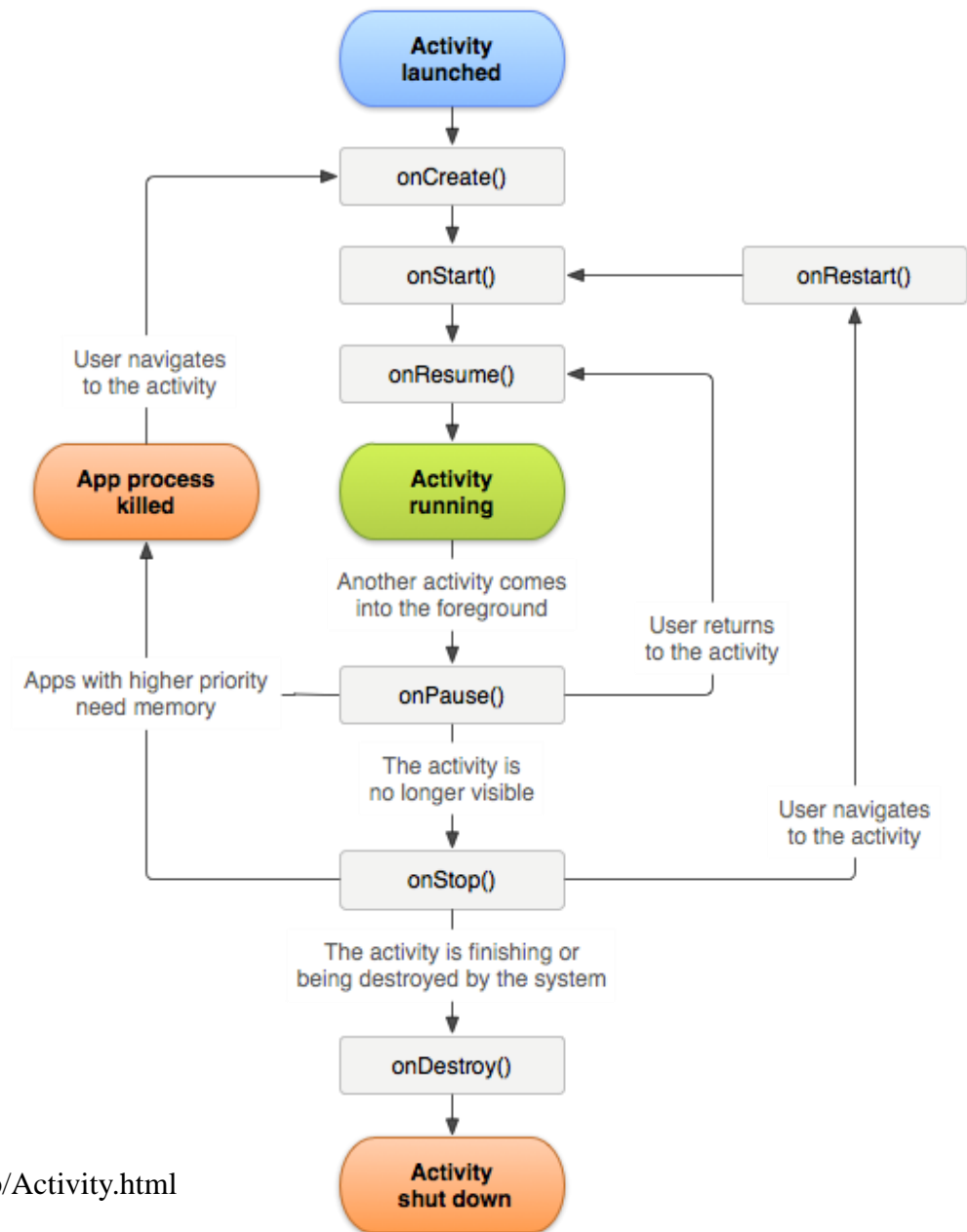


# Activities

- ▶ 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>

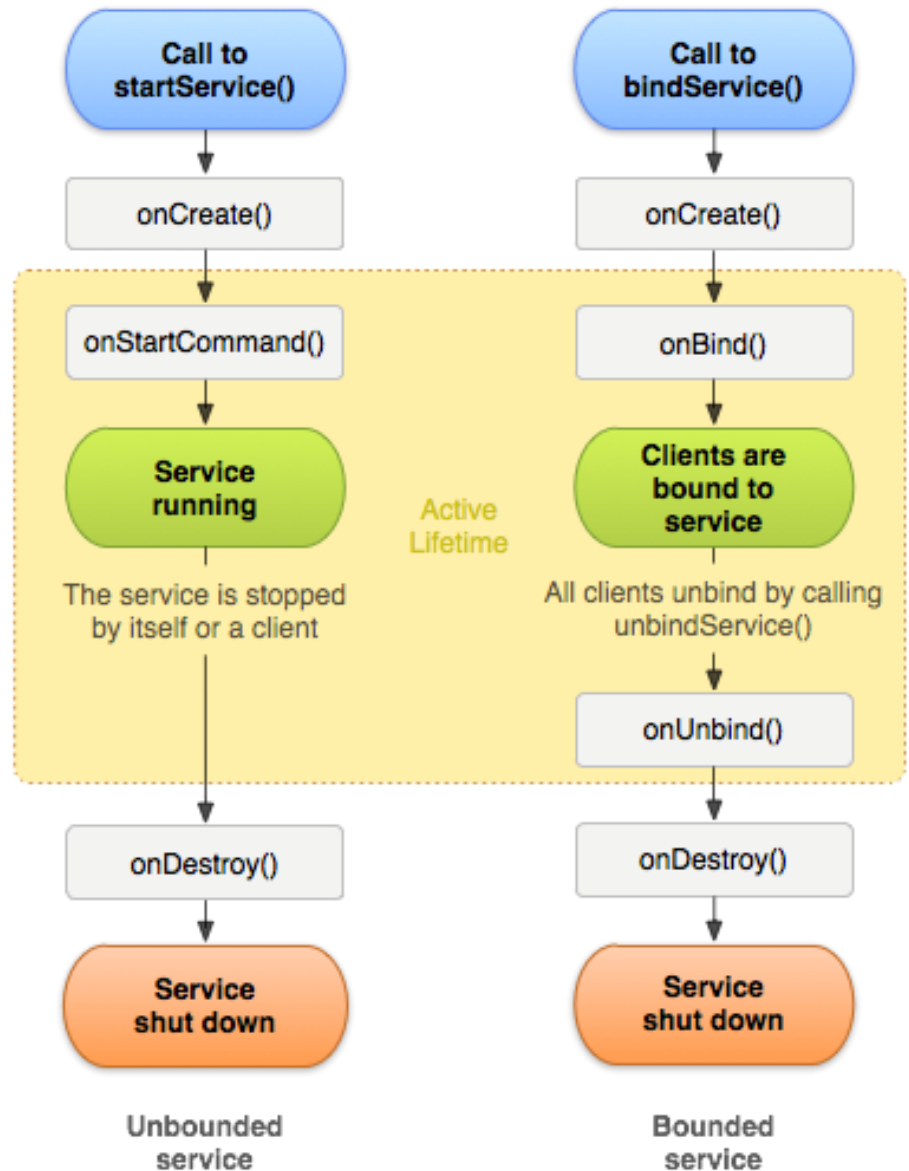


# Services

- ▶ 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>

