



Embedded Operating Systems

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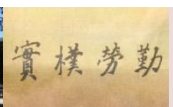
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Linux Environment

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

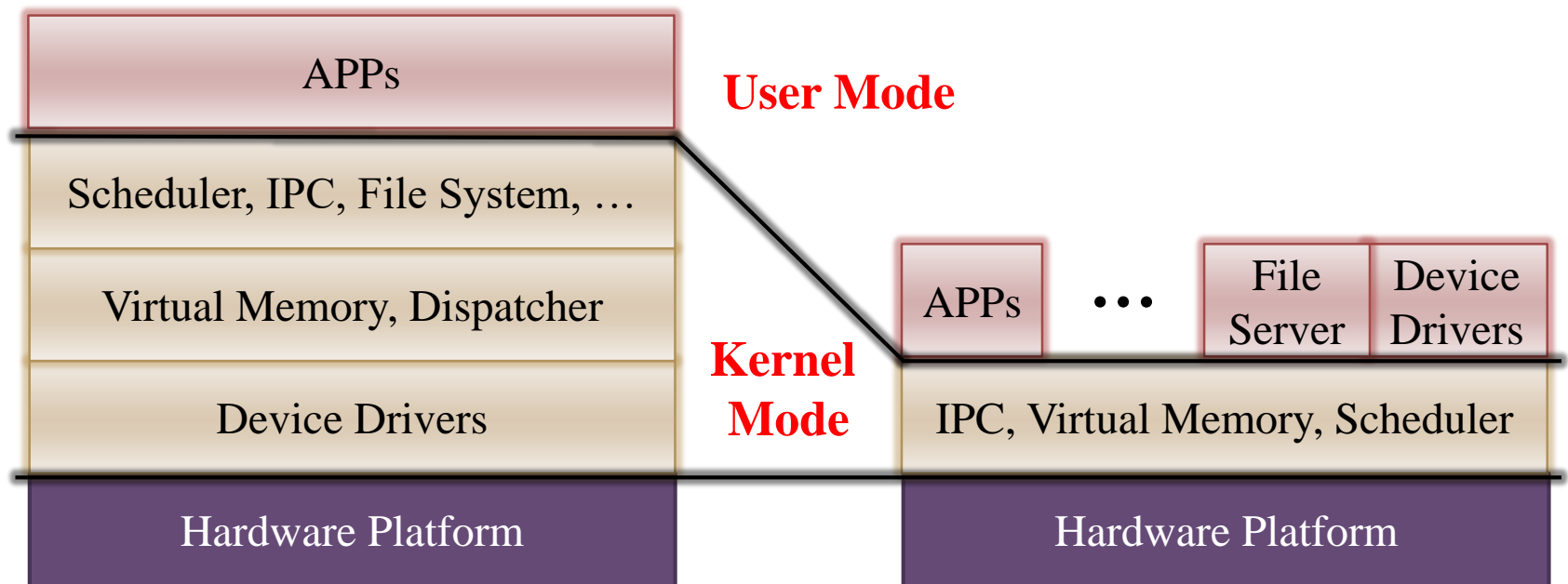
- Kernel functions are partitioned into components
- Communications are via inter process communication (IPC) protocol
- The L4 microkernel is an example



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

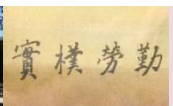
▶ Block Devices

- 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

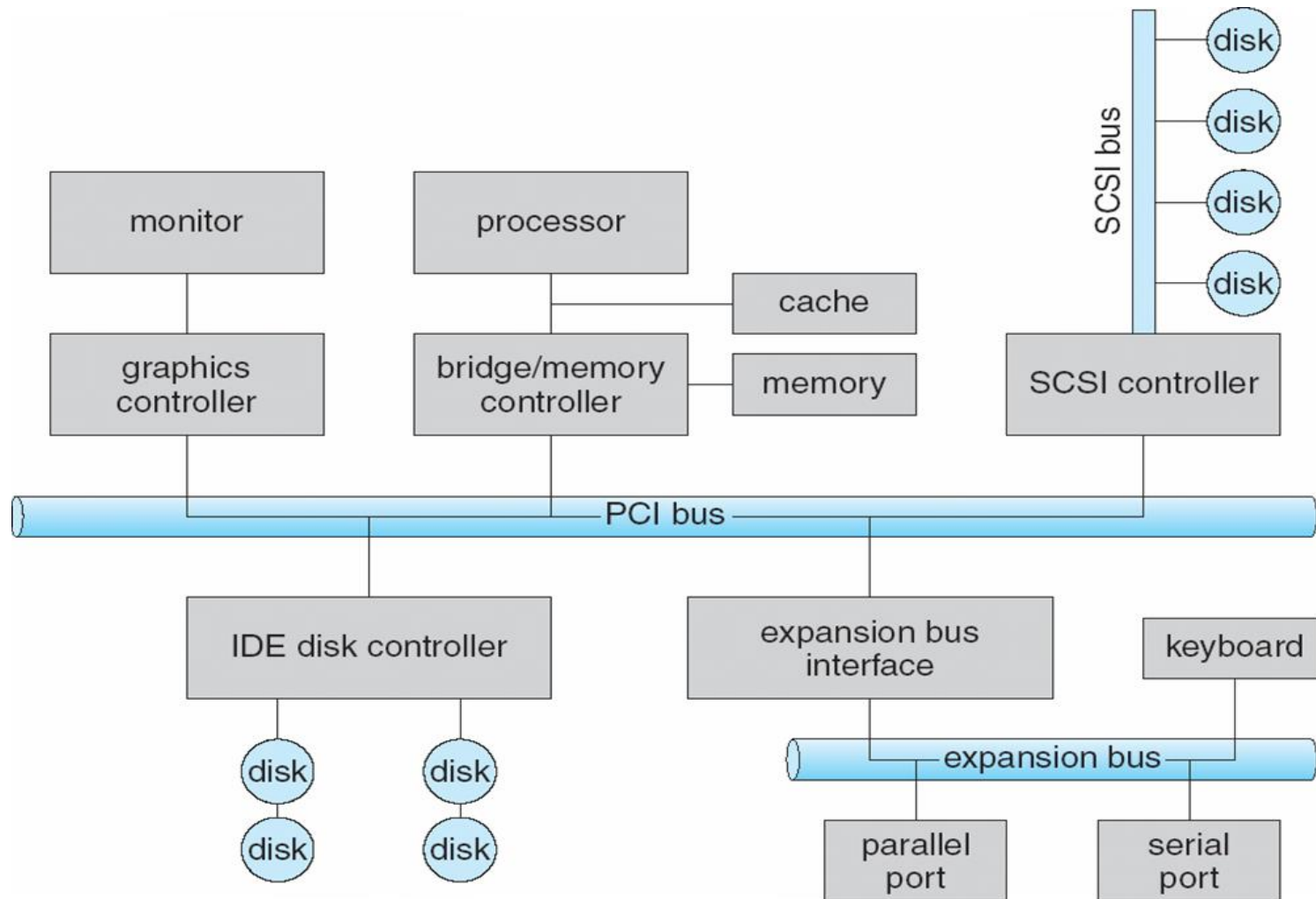


I/O Hardware

- ▶ 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

- ▶ 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

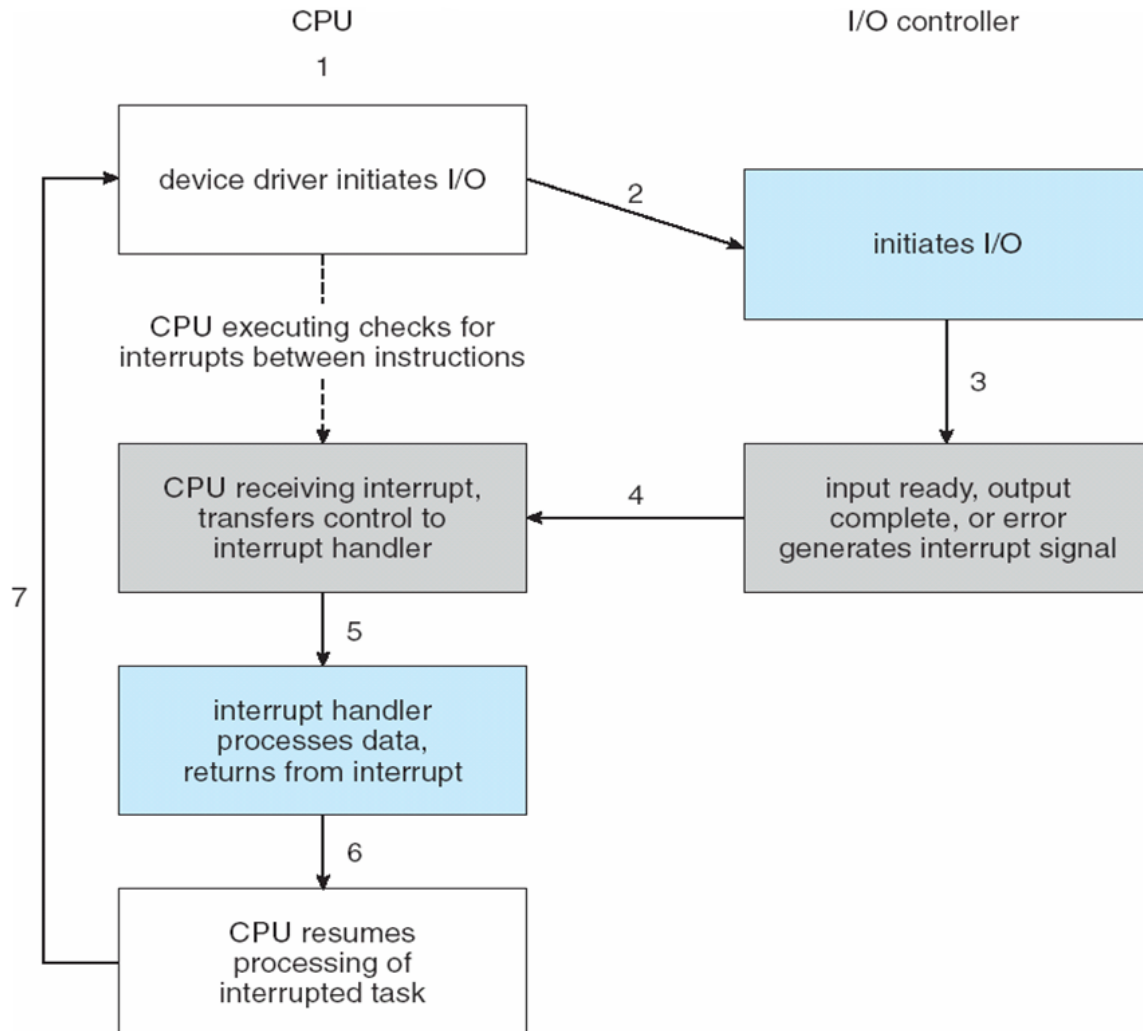


Interrupts

- ▶ 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

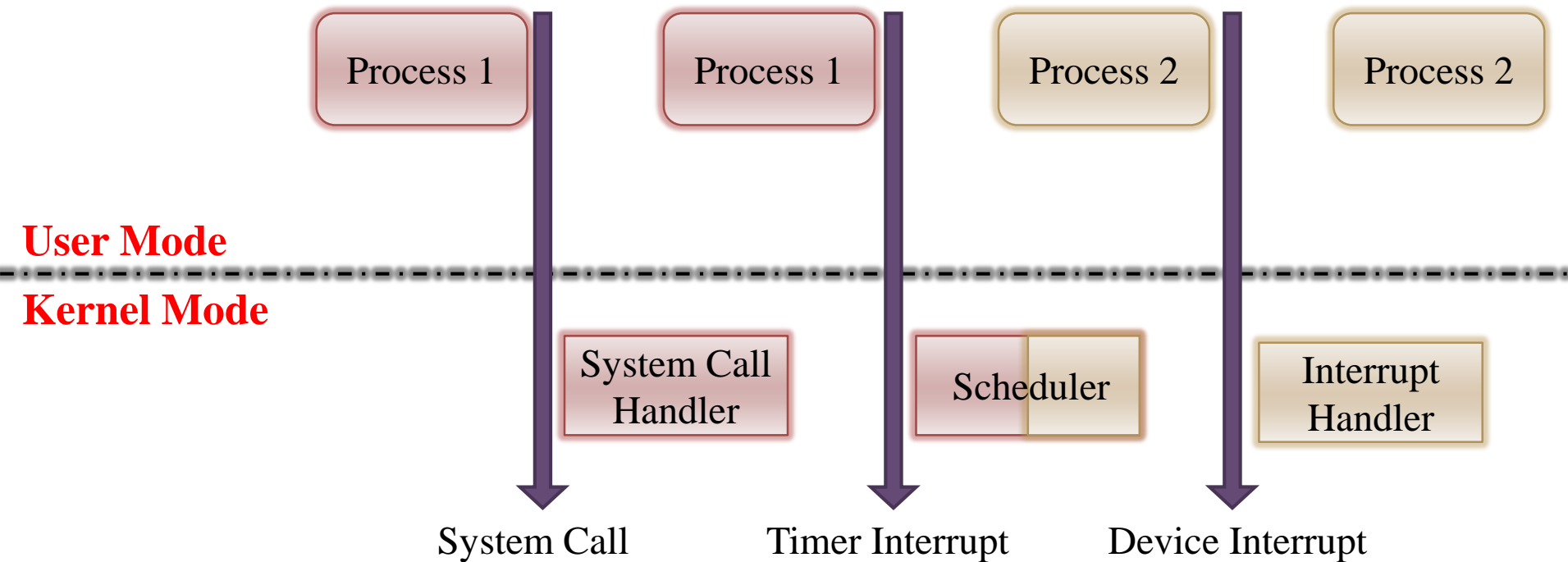


Interrupt Usage

- ▶ 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

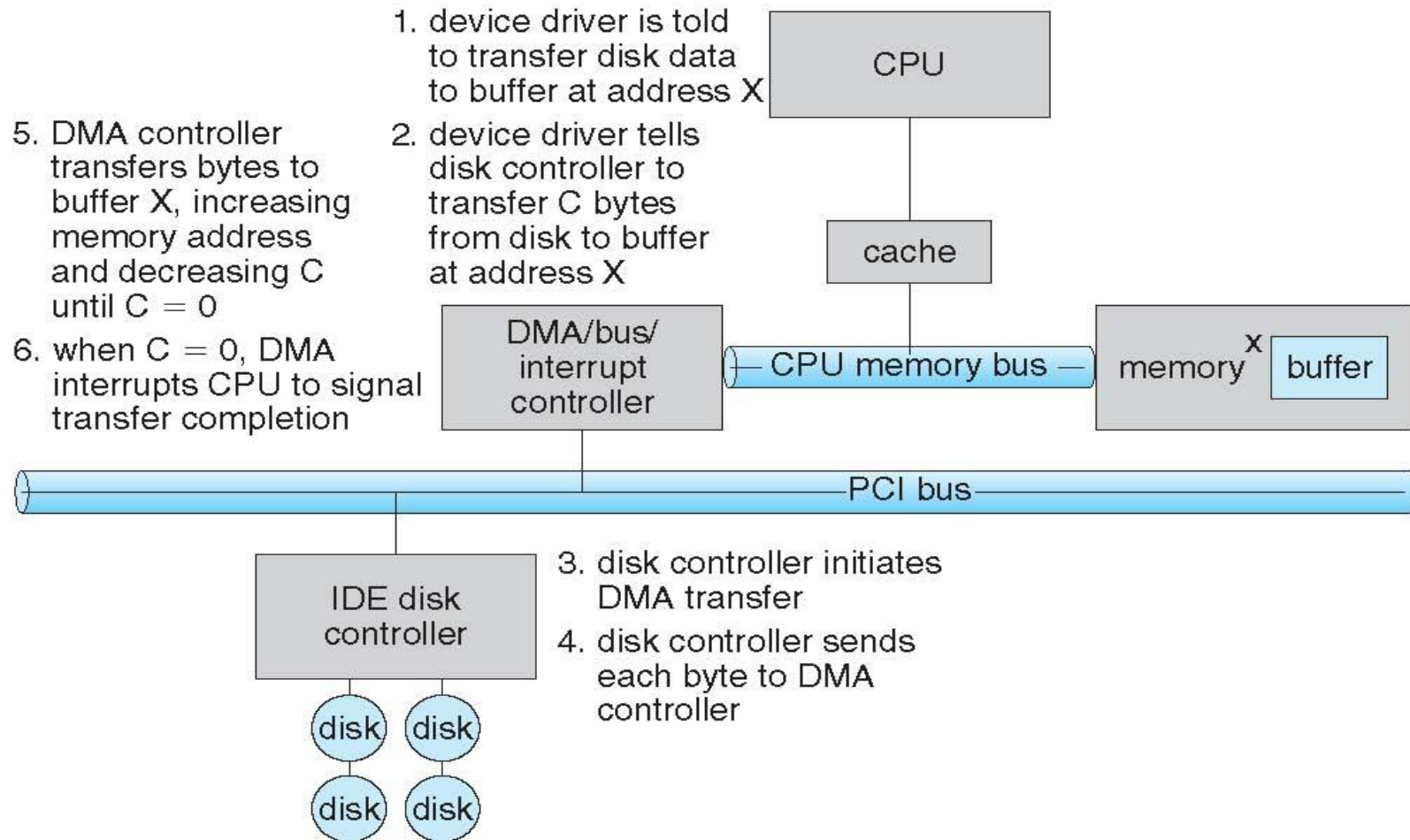


Direct Memory Access

- ▶ 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 11, which was released on September 8, 2020



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

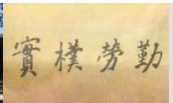
Android 10
Android 10

Android 11
Android 11

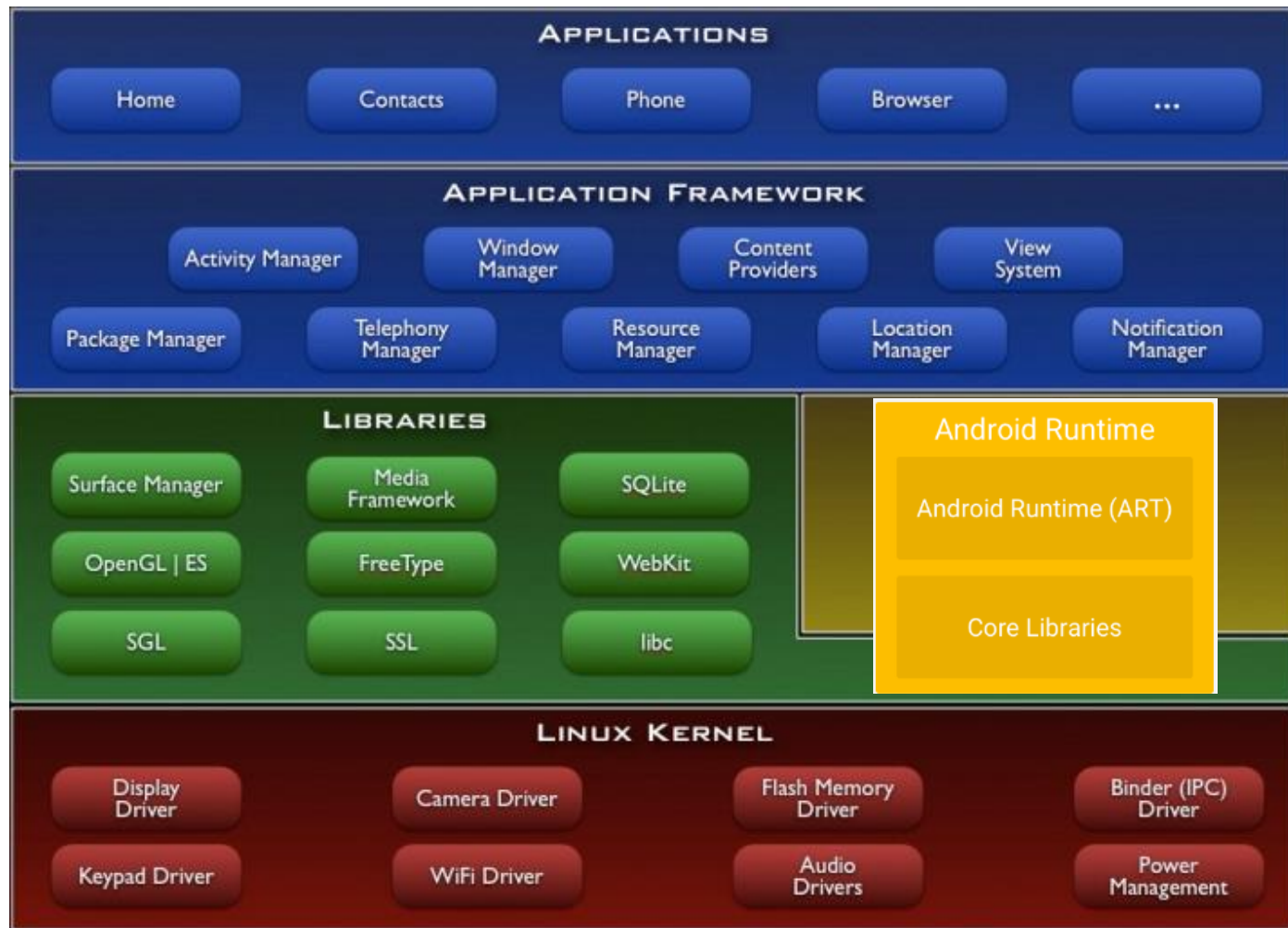


Google Android

- ▶ 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

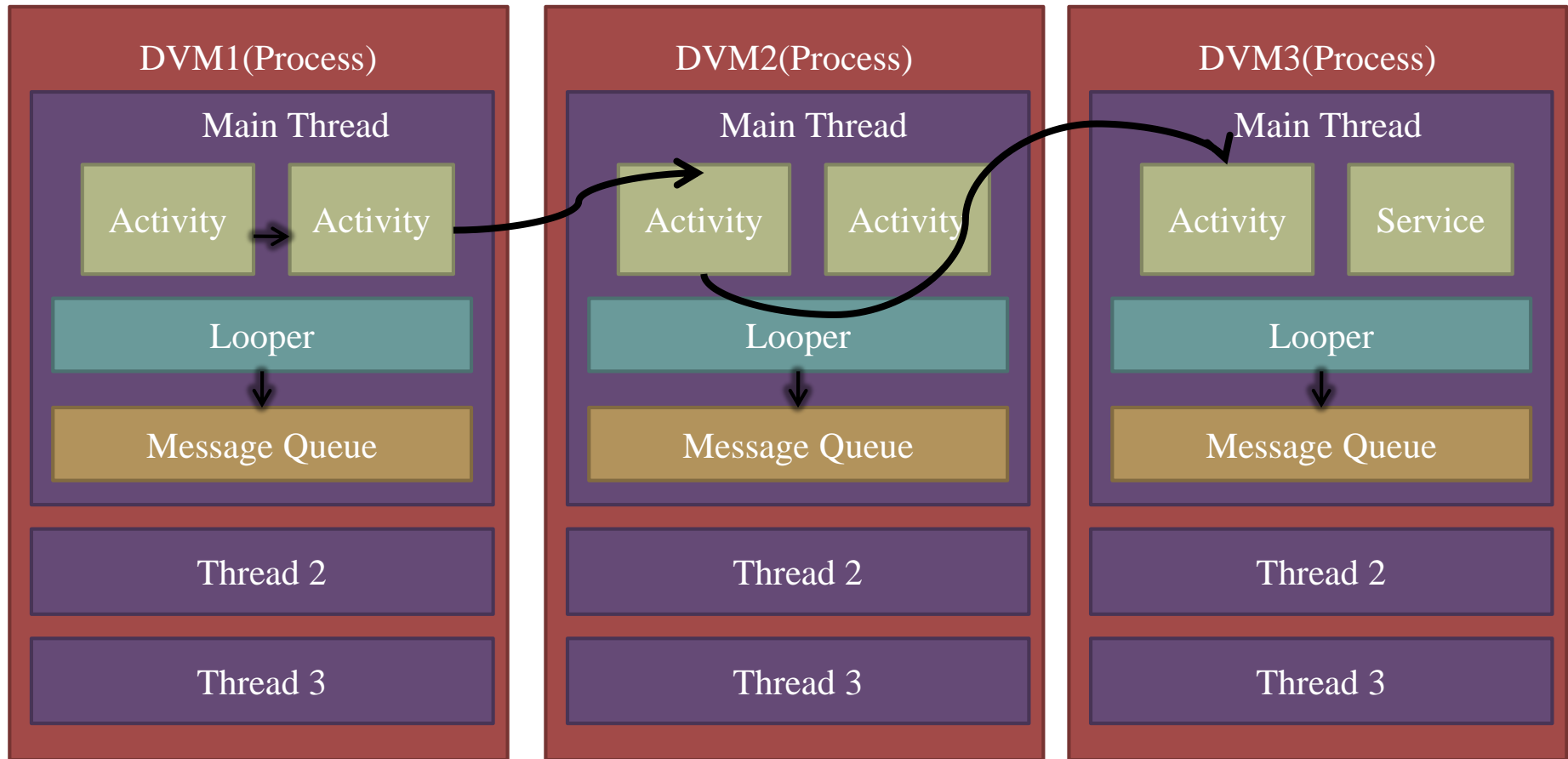
- Always with the user
- Typically have Internet access
- Typically GPS enabled
- Typically have accelerometer & compass
- Most have cameras & microphones

► 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



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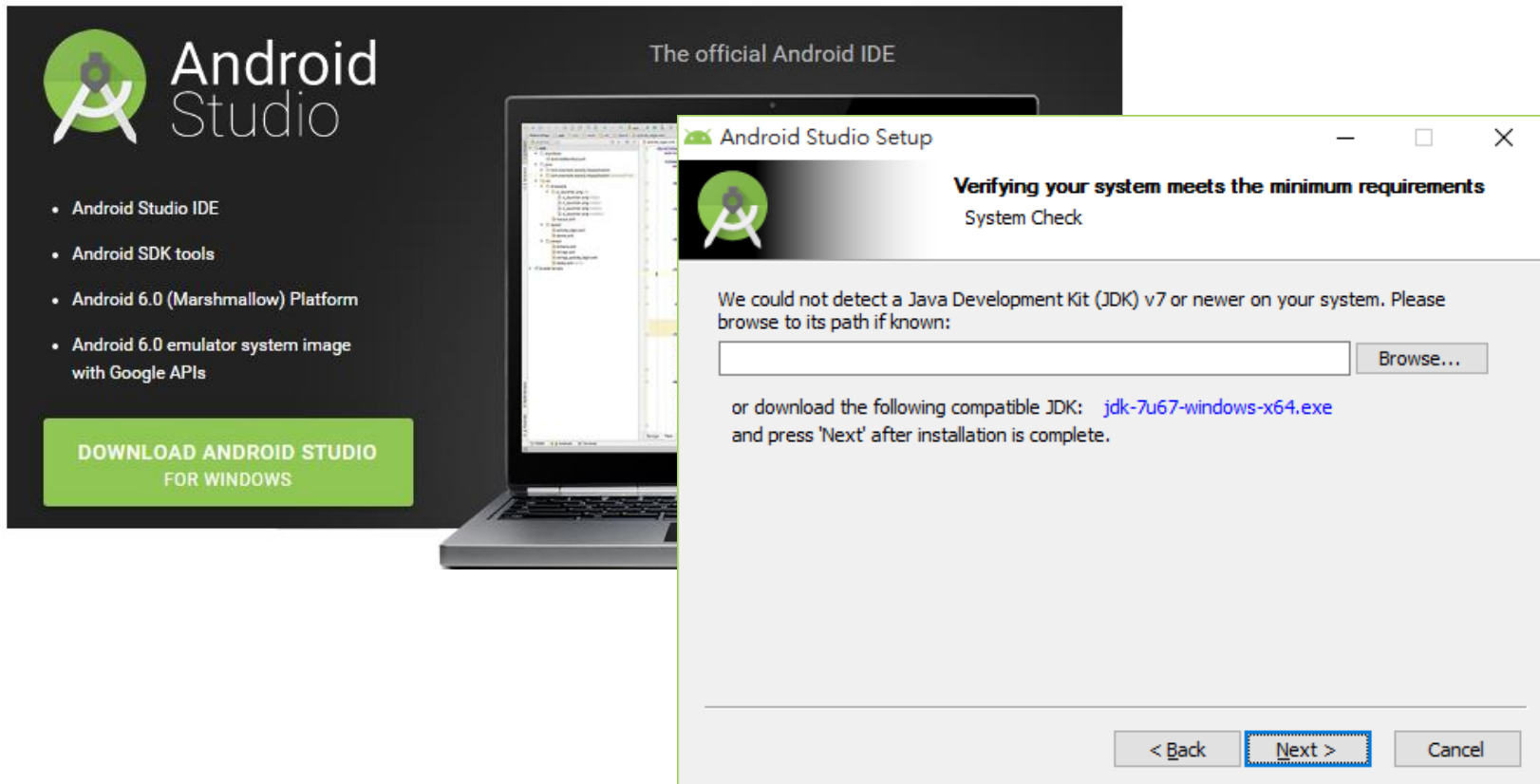


Android Environment


- ▶ 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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Java SE Development Kit 7 Downloads

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.

JDK 7 for Win

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Java SDKs and Tools

Java SE

Java EE and Glassfish

Java ME

Java Card

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Java SE 8u65 / 8u66
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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 - JDK ReadMe
 - JRE ReadMe

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JRE
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Which Java package do I need?

Java SE Development Kit 8u66

You must accept the [Oracle Binary Code License Agreement for Java SE](#) to download this software.

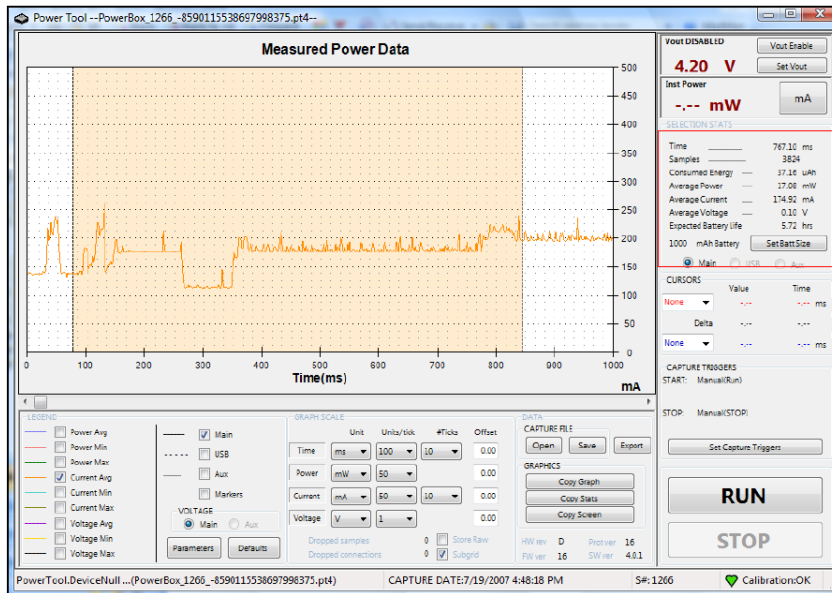
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Linux x64	172.89 MB	jdk-8u66-linux-x64.tar.gz
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Solaris x64 (SVR4 package)	140 MB	jdk-8u66-solaris-x64.tar.Z
Solaris x64	96.2 MB	jdk-8u66-solaris-x64.tar.gz
Windows x86	181.31 MB	jdk-8u66-windows-i586.exe
Windows x64	186.65 MB	jdk-8u66-windows-x64.exe



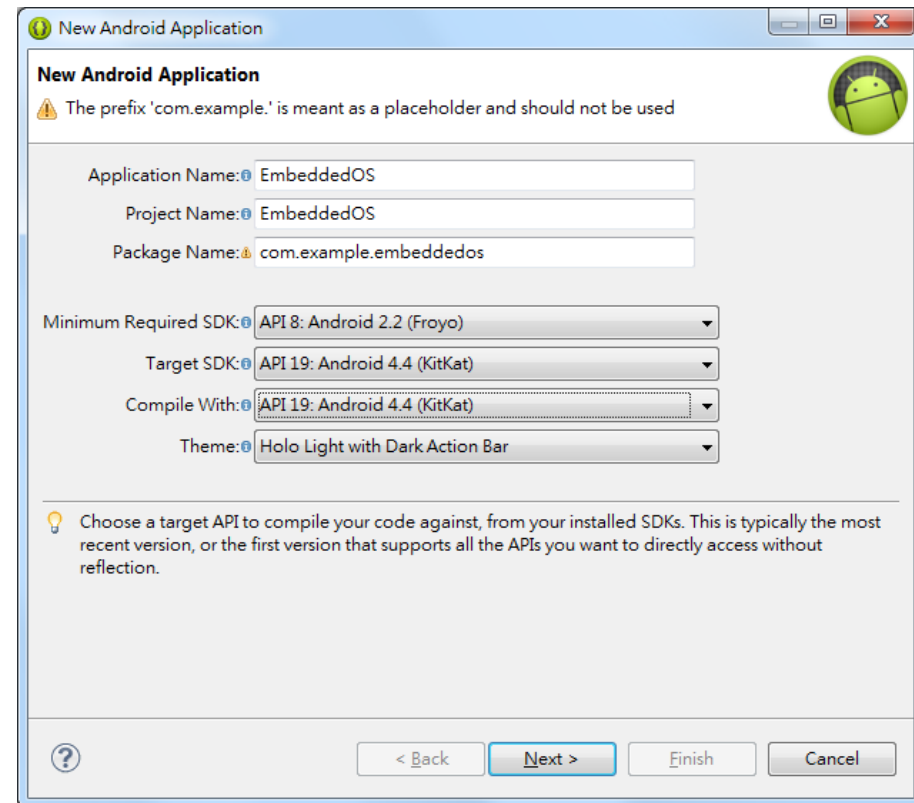
Power Monitor

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



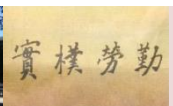
Set Information of the Project

- ▶ **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)



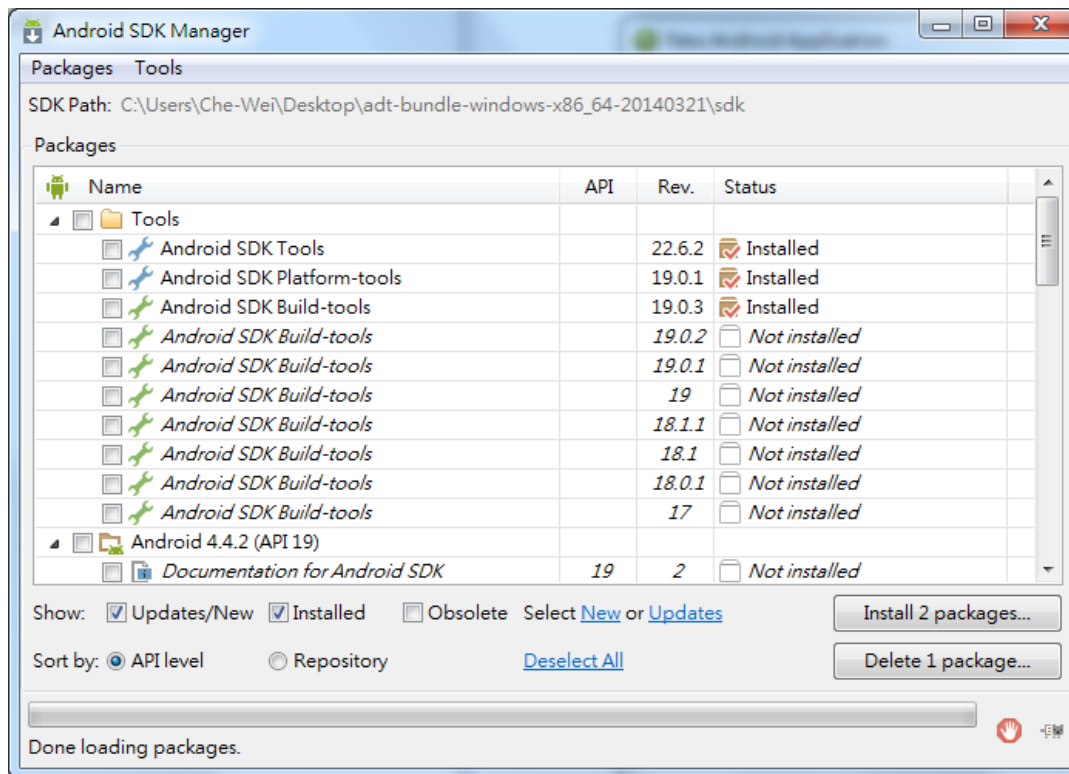
API Support

- ▶ **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



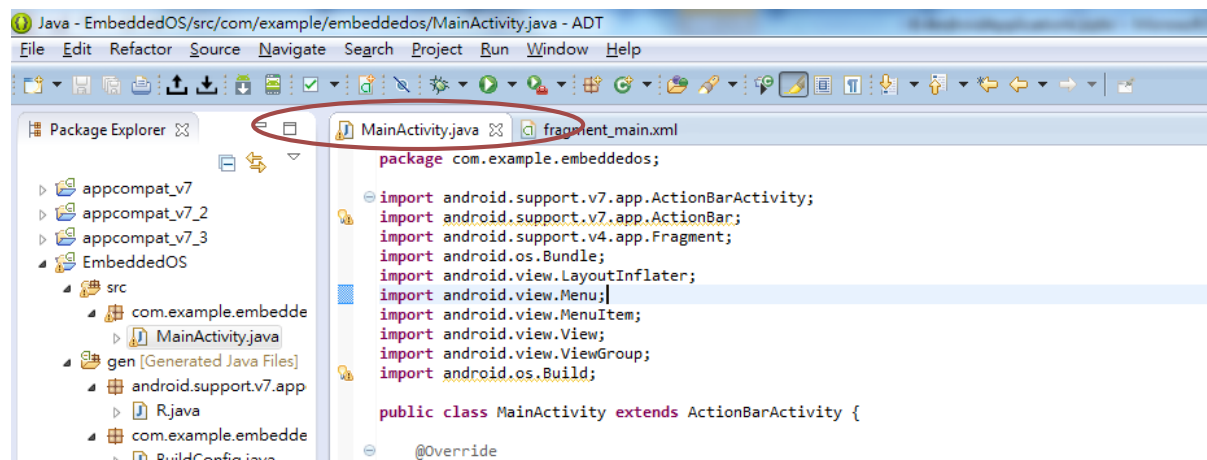
Android Runtime (ART)

- ▶ 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

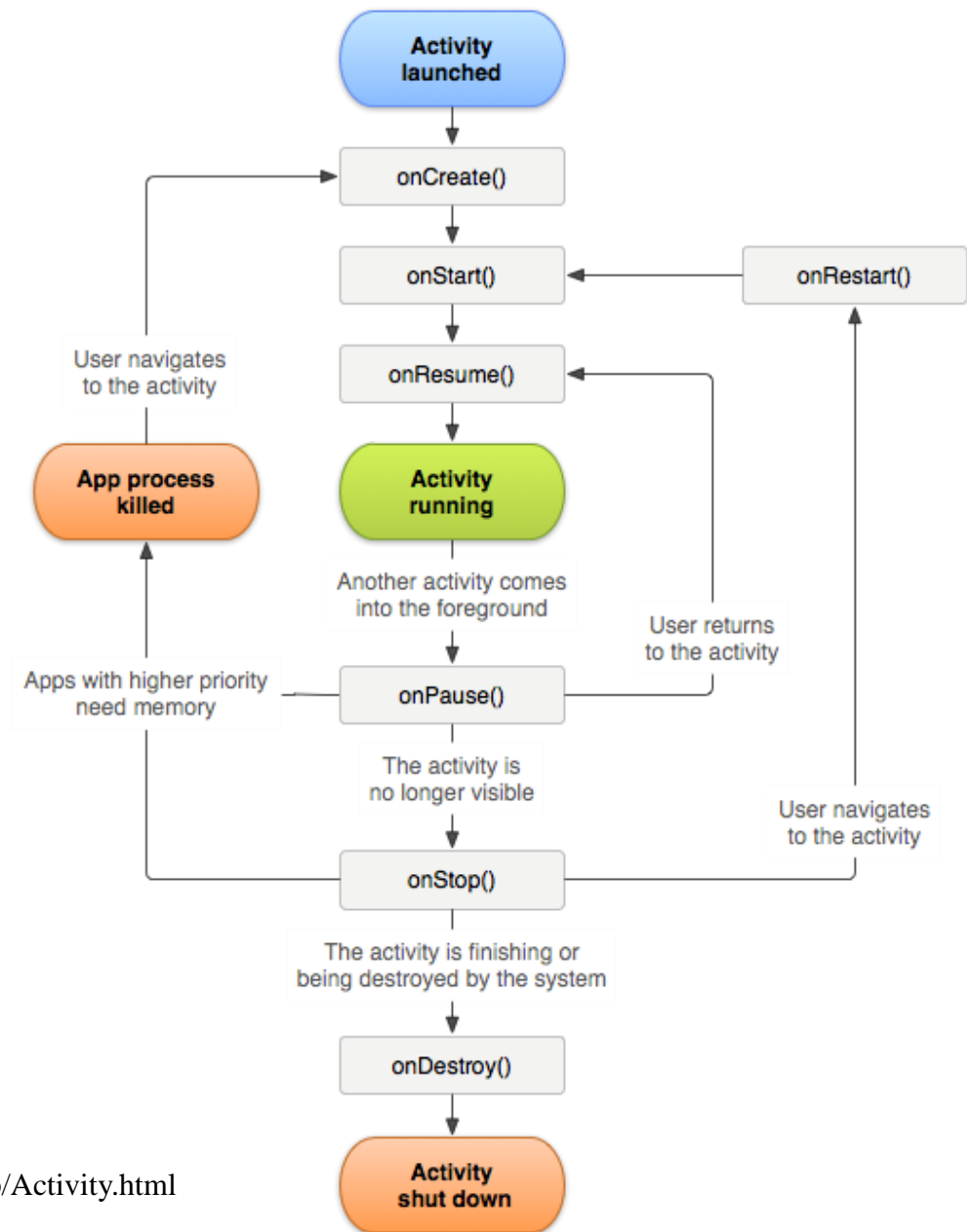


Activities

- ▶ 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>

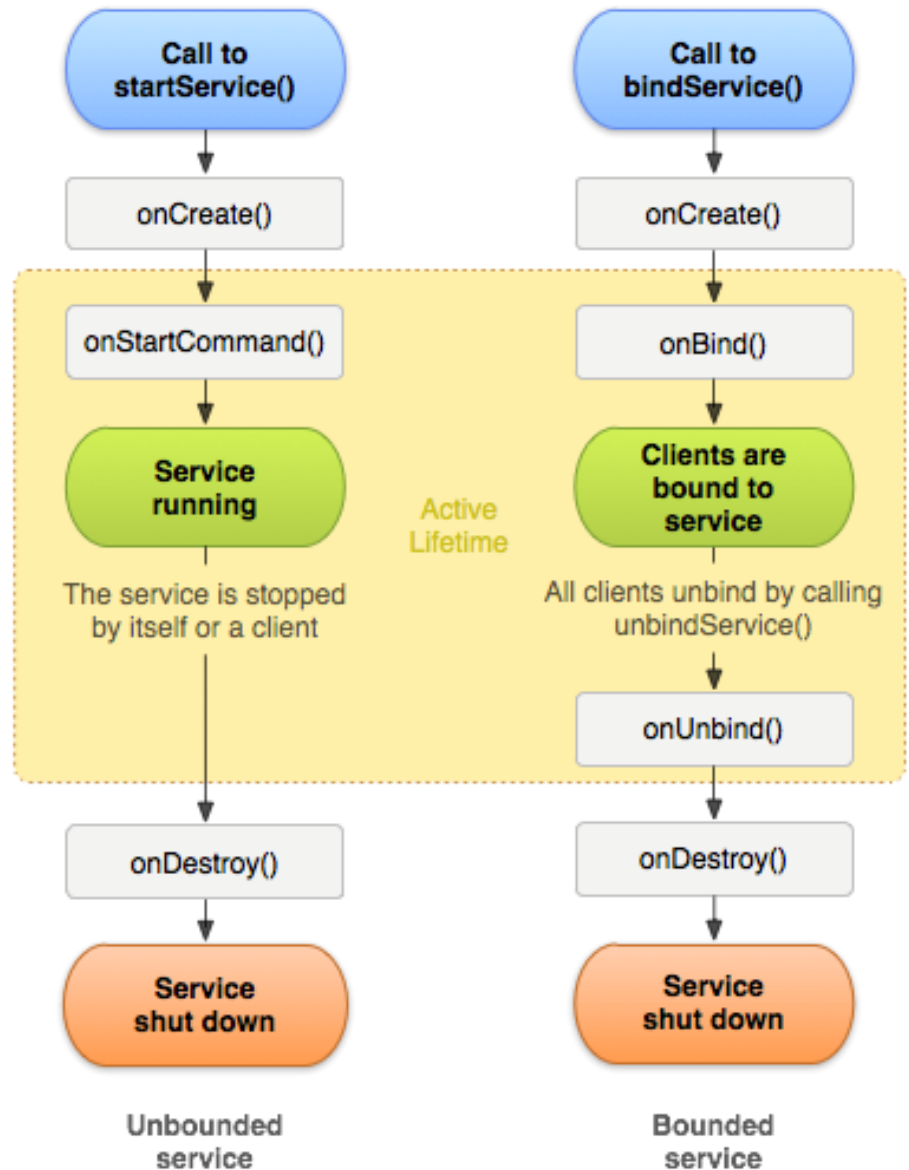


Services

- ▶ 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>

