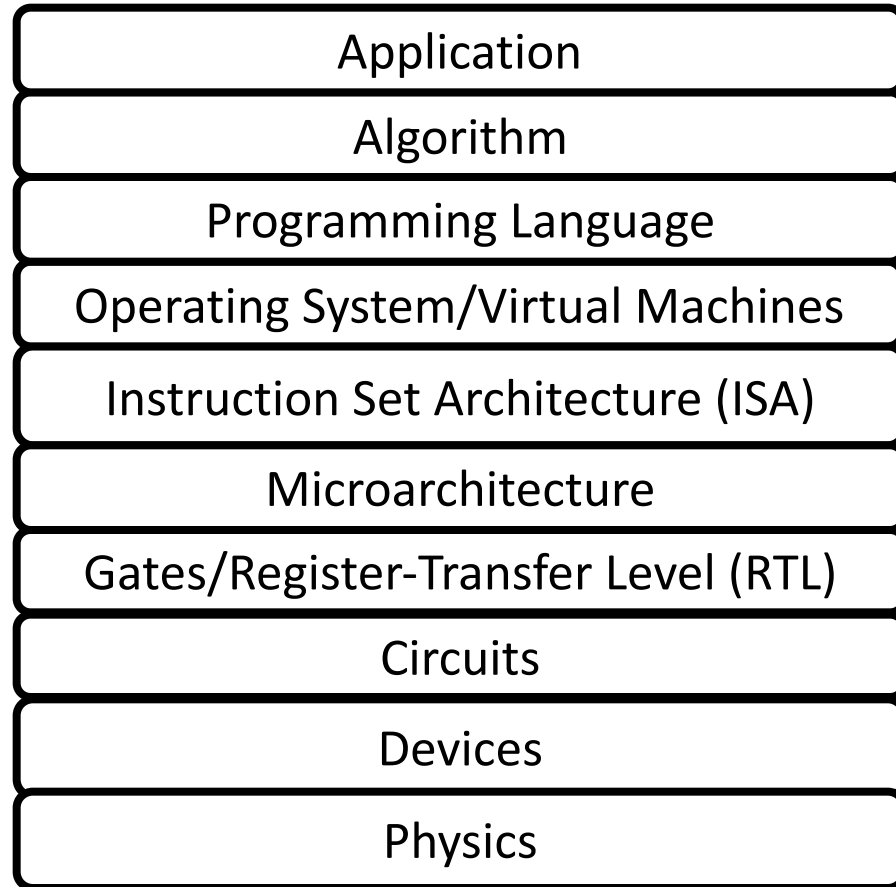


Computer operating system

Ding Pan

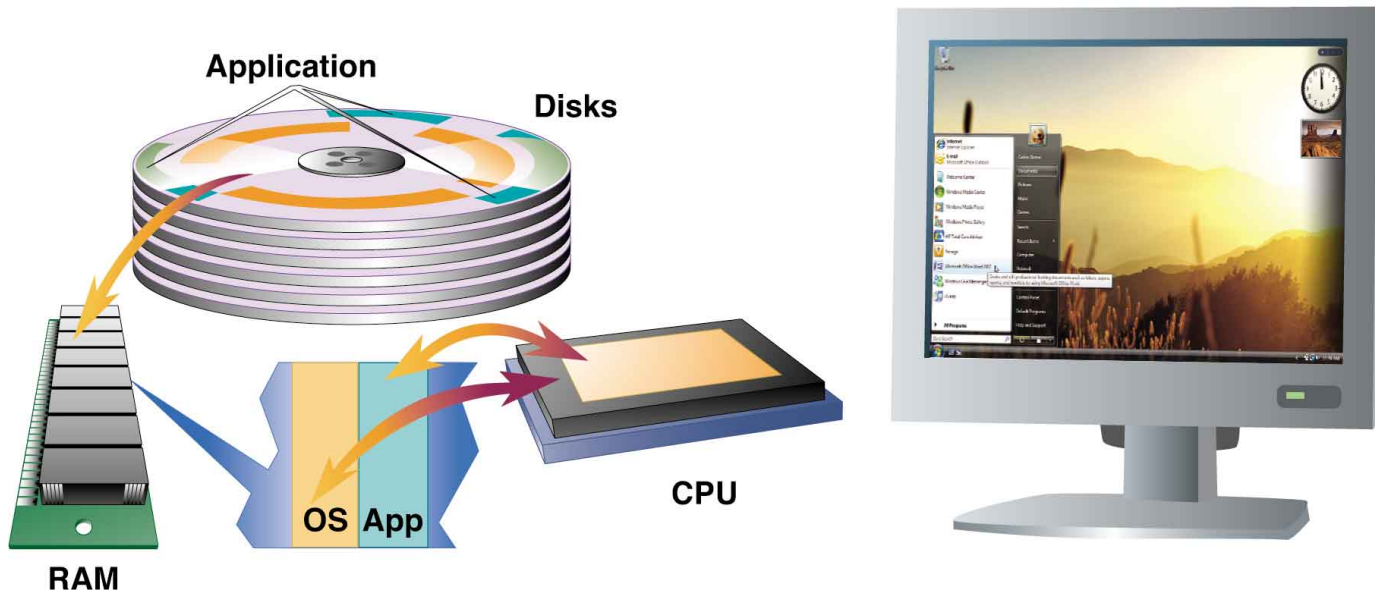
dingpan@ust.hk

Abstraction Layers in Modern Systems



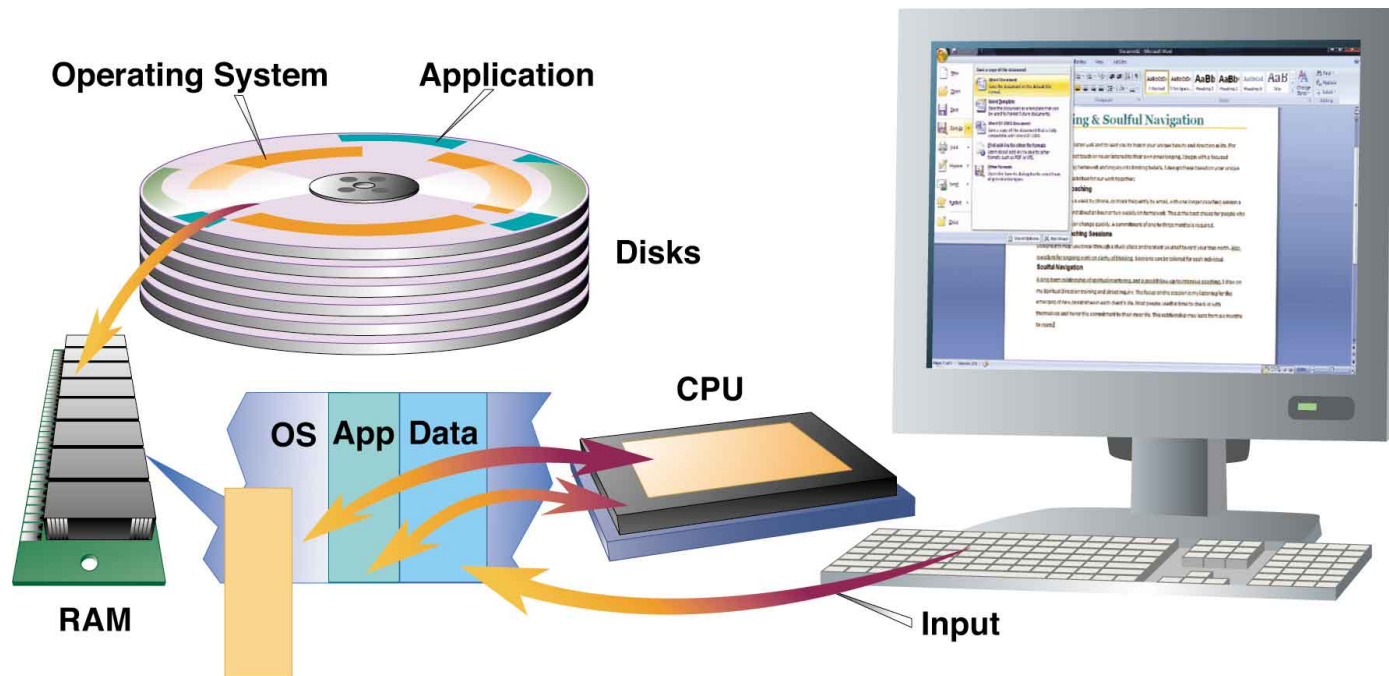
The Operating System

When you turn on the computer, the CPU automatically begins executing instructions stored in ROM. The operating system (OS) loads from the disk into part of the system's memory.

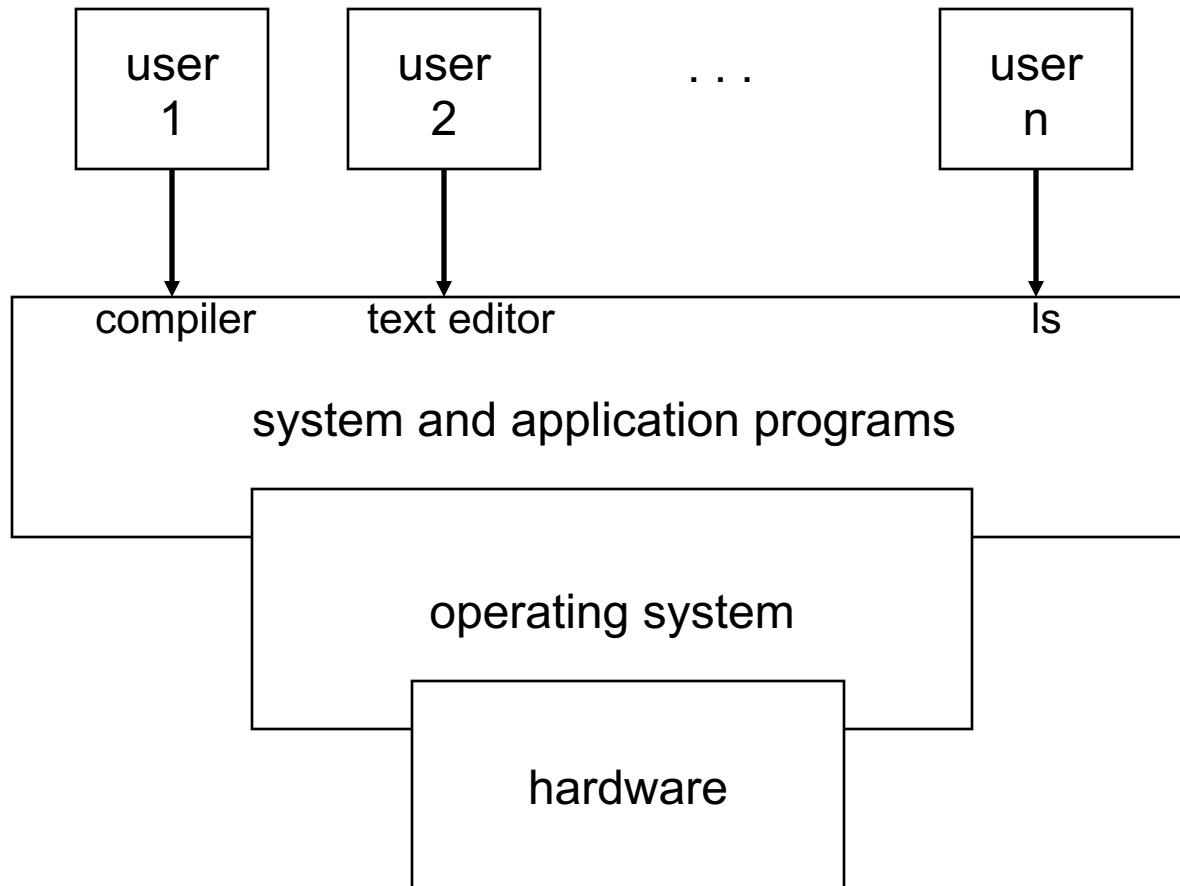


The Operating System (cont.)

The OS loads the application program into memory and remains in memory, so it can provide services to the application program—display on-screen menus, communicate with the printer, and perform other common actions.



System Diagram



What is operating system(OS)

- An operating system is an intermediary between a computer user and the hardware.
- Make the hardware convenient to use.
- Manages system resources.
- Use the hardware in an efficient manner.

What Operating Systems Do

- Depends on the point of view
- Users want convenience, **ease of use**
 - Don't care about **resource utilization**
- But shared computer such as **mainframe** or **minicomputer** must keep all users happy
- Users of dedicated systems such as **workstations** have dedicated resources but frequently use shared resources from **servers**
- Handheld computers are resource poor, optimized for usability and battery life
- Some computers have little or no user interface, such as embedded computers in devices and automobiles

Operating System Definition

- OS is a **resource allocator**
 - Manages all resources
 - Decides between conflicting requests for efficient and fair resource use
- OS is a **control program**
 - Controls execution of programs to prevent errors and improper use of the computer

Operating System Definition

- No universally accepted definition
- “Everything a vendor ships when you order an operating system” is good approximation
 - But varies wildly
- “The one program running at all times on the computer” is the kernel. Everything else is either a system program (ships with the operating system) or an application program.

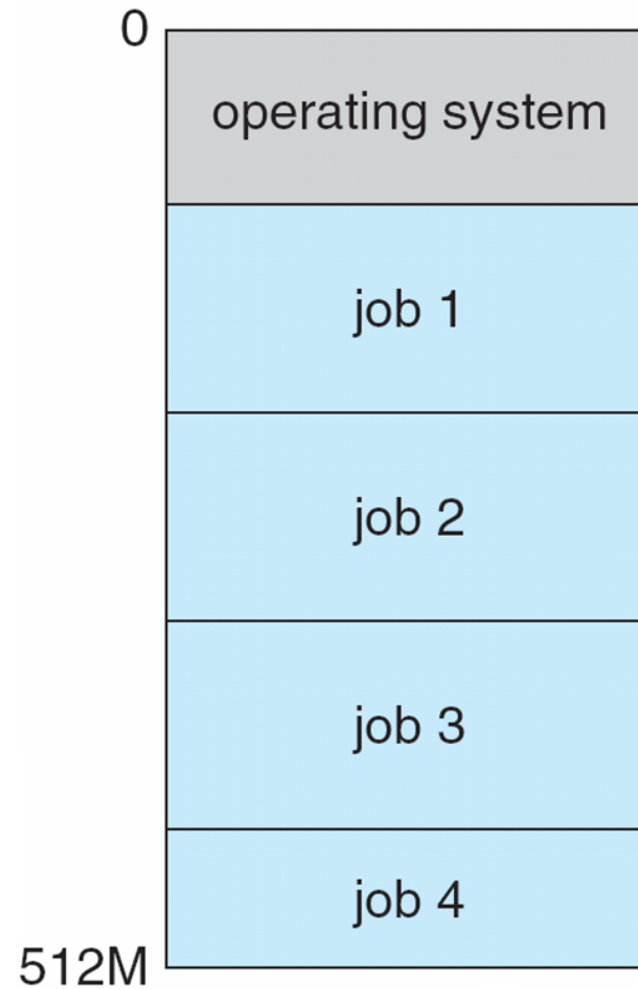
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Operating System Structure

- **Multiprogramming** needed for efficiency
 - Single user cannot keep CPU and I/O devices busy at all times
 - Multiprogramming organizes jobs (code and data) so CPU always has one to execute
 - A subset of total jobs in system is kept in memory
 - One job selected and run via **job scheduling**
 - When it has to wait (for I/O for example), OS switches to another job
- **Timesharing (multitasking)** is logical extension in which CPU switches jobs so frequently that users can interact with each job while it is running, creating **interactive** computing
 - **Response time** should be < 1 second
 - Each user has at least one program executing in memory \Rightarrow **process**
 - If several jobs ready to run at the same time \Rightarrow **CPU scheduling**
 - If processes don't fit in memory, **swapping** moves them in and out to run
 - **Virtual memory** allows execution of processes not completely in memory

Memory Layout for Multiprogrammed System



Process Management

- A process is a program in execution. It is a unit of work within the system. Program is a ***passive entity***, process is an ***active entity***.
- Process needs resources to accomplish its task
 - CPU, memory, I/O, files
 - Initialization data
- Process termination requires reclaim of any reusable resources
- Single-threaded process has one **program counter** specifying location of next instruction to execute
 - Process executes instructions sequentially, one at a time, until completion
- Multi-threaded process has one program counter per thread
- Typically system has many processes, some user, some operating system running concurrently on one or more CPUs
 - Concurrency by multiplexing the CPUs among the processes / threads

Process Management Activities

The operating system is responsible for the following activities in connection with process management:

- Creating and deleting both user and system processes
- Suspending and resuming processes
- Providing mechanisms for process synchronization
- Providing mechanisms for process communication
- Providing mechanisms for deadlock handling

Memory Management

- All data in memory before and after processing
- All instructions in memory in order to execute
- Memory management determines what is in memory when
 - Optimizing CPU utilization and computer response to users
- Memory management activities
 - Keeping track of which parts of memory are currently being used and by whom
 - Deciding which processes (or parts thereof) and data to move into and out of memory
 - Allocating and deallocating memory space as needed

Storage Management

- OS provides uniform, logical view of information storage
 - Abstracts physical properties to logical storage unit - **file**
 - Each medium is controlled by device (i.e., disk drive, tape drive)
 - Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
 - Files usually organized into directories
 - Access control on most systems to determine who can access what
 - OS activities include
 - Creating and deleting files and directories
 - Primitives to manipulate files and dirs
 - Mapping files onto secondary storage
 - Backup files onto stable (non-volatile) storage media

Performance of Various Levels of Storage

Level	1	2	3	4	5
Name	registers	cache	main memory	solid state disk	magnetic disk
Typical size	< 1 KB	< 16MB	< 64GB	< 1 TB	< 10 TB
Implementation technology	custom memory with multiple ports CMOS	on-chip or off-chip CMOS SRAM	CMOS SRAM	flash memory	magnetic disk
Access time (ns)	0.25 - 0.5	0.5 - 25	80 - 250	25,000 - 50,000	5,000,000
Bandwidth (MB/sec)	20,000 - 100,000	5,000 - 10,000	1,000 - 5,000	500	20 - 150
Managed by	compiler	hardware	operating system	operating system	operating system
Backed by	cache	main memory	disk	disk	disk or tape

- Movement between levels of storage hierarchy can be explicit or implicit

Computing Environments - Traditional

- Stand-alone general purpose machines
- But blurred as most systems interconnect with others (i.e. the Internet)
- **Portals** provide web access to internal systems
- **Network computers** (**thin clients**) are like Web terminals
- Mobile computers interconnect via **wireless networks**
- Networking becoming ubiquitous – even home systems use **firewalls** to protect home computers from Internet attacks

Computing Environments - Mobile

- Handheld smartphones, tablets, etc
- What is the functional difference between them and a “traditional” laptop?
- Extra feature – more OS features (GPS, gyroscope)
- Allows new types of apps like ***augmented reality***
- Use IEEE 802.11 wireless, or cellular data networks for connectivity
- Leaders are **Apple iOS** and **Google Android**

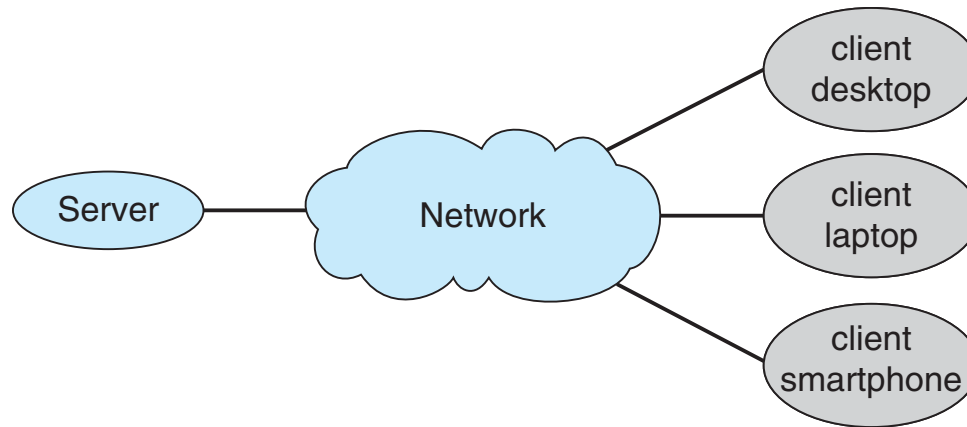
Computing Environments – Distributed

- Distributed
 - Collection of separate, possibly heterogeneous, systems networked together
 - **Network** is a communications path, **TCP/IP** most common
 - **Local Area Network (LAN)**
 - **Wide Area Network (WAN)**
 - **Metropolitan Area Network (MAN)**
 - **Personal Area Network (PAN)**
 - **Network Operating System** provides features between systems across network
 - Communication scheme allows systems to exchange messages
 - Illusion of a single system

Computing Environments – Client-Server

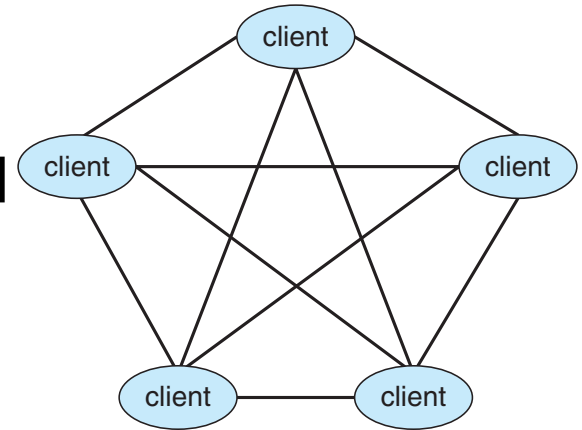
■ Client-Server Computing

- Dumb terminals supplanted by smart PCs
- Many systems now **servers**, responding to requests generated by **clients**
 - ▶ **Compute-server system** provides an interface to client to request services (i.e., database)
 - ▶ **File-server system** provides interface for clients to store and retrieve files



Computing Environments - Peer-to-Peer

- Another model of distributed system
- P2P does not distinguish clients and servers
 - Instead all nodes are considered peers
 - May each act as client, server or both
 - Node must join P2P network
 - Registers its service with central lookup service on network, or
 - Broadcast request for service and respond to requests for service via **discovery protocol**
 - Examples include Napster and Gnutella, **Voice over IP (VoIP)** such as Skype



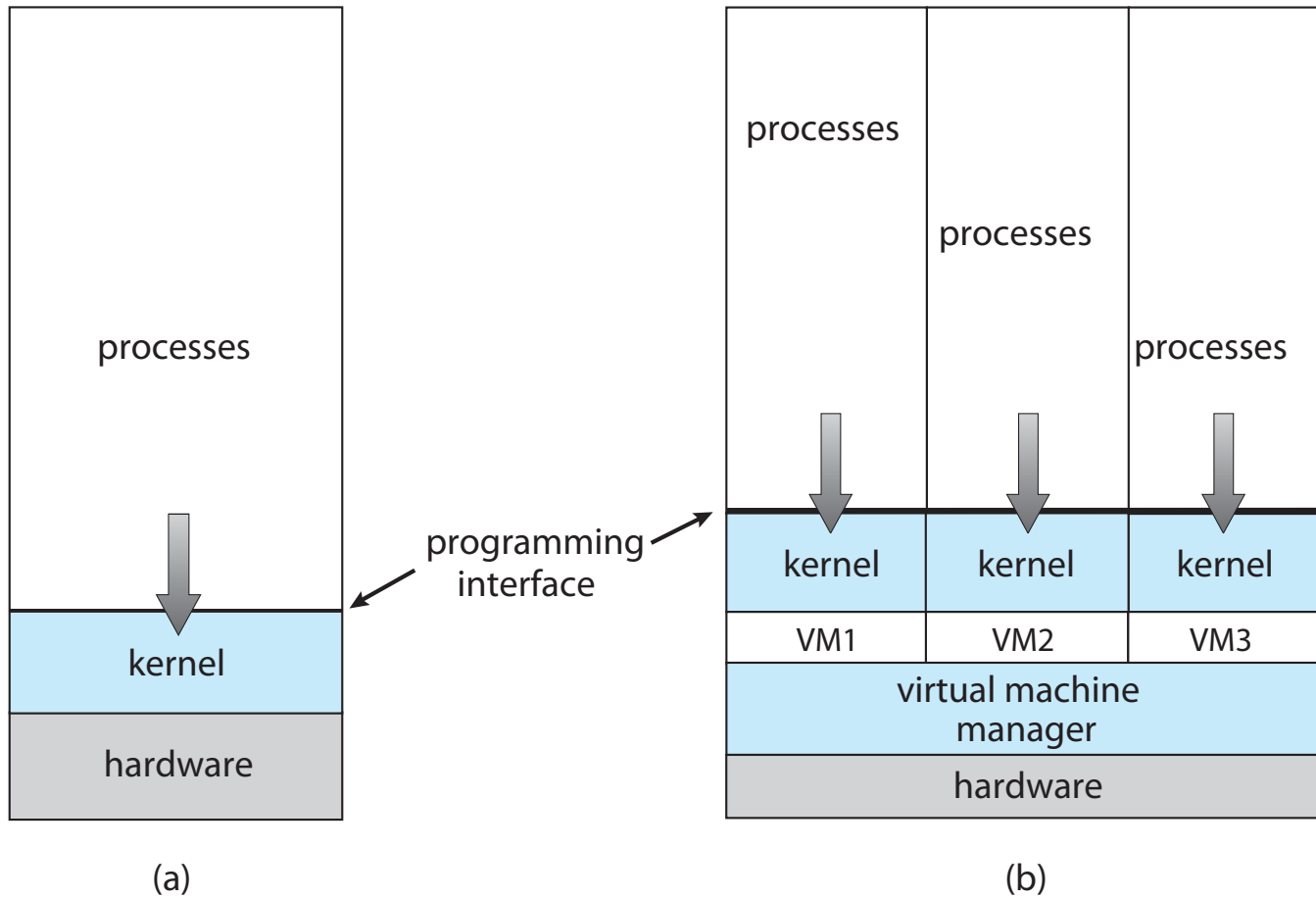
Computing Environments - Virtualization

- Allows operating systems to run applications within other OSes
 - Vast and growing industry
- **Emulation** used when source CPU type different from target type (i.e. Loongson or IBM PowerPC to Intel x86)
 - Generally slowest method
 - When computer language not compiled to native code – **Interpretation**
- **Virtualization** – OS natively compiled for CPU, running **guest** OSes also natively compiled
 - Consider Vmware or virtualbox running WinXP guests, each running applications, all on native WinX **host** OS
 - **VMM** provides virtualization services

Computing Environments - Virtualization

- Use cases involve laptops and desktops running multiple OSeS for exploration or compatibility
 - Apple laptop running Mac OS X host, Windows or Linux as a guest
 - Developing apps for multiple OSeS without having multiple systems
 - QA testing applications without having multiple systems
 - Executing and managing compute environments within data centers
- VMM can run natively, in which case they are also the host
 - There is no general purpose host then (VMware ESX and Citrix XenServer)

Computing Environments - Virtualization

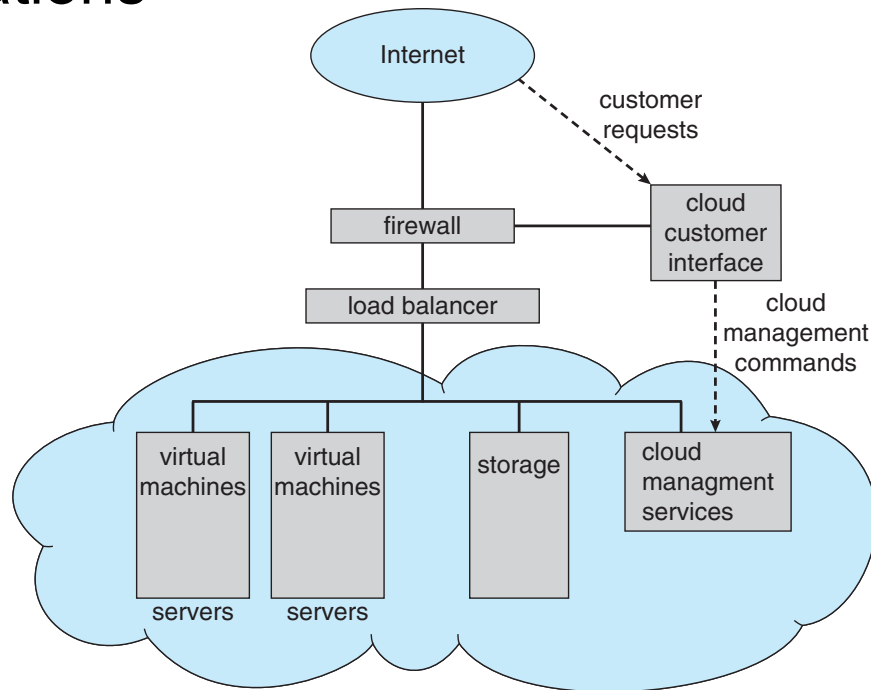


Computing Environments – Cloud Computing

- Delivers computing, storage, even apps as a service across a network
- Logical extension of virtualization as based on virtualization
 - Amazon **EC2** has thousands of servers, millions of VMs, PBs of storage available across the Internet, pay based on usage
- Many types
 - **Public cloud** – available via Internet to anyone willing to pay
 - **Private cloud** – run by a company for the company's own use
 - **Hybrid cloud** – includes both public and private cloud components
 - Software as a Service (**SaaS**) – one or more applications available via the Internet (i.e. word processor)
 - Platform as a Service (**PaaS**) – software stack ready for application use via the Internet (i.e. a database server)
 - Infrastructure as a Service (**IaaS**) – servers or storage available over Internet (i.e. storage available for backup use)

Computing Environments – Cloud Computing

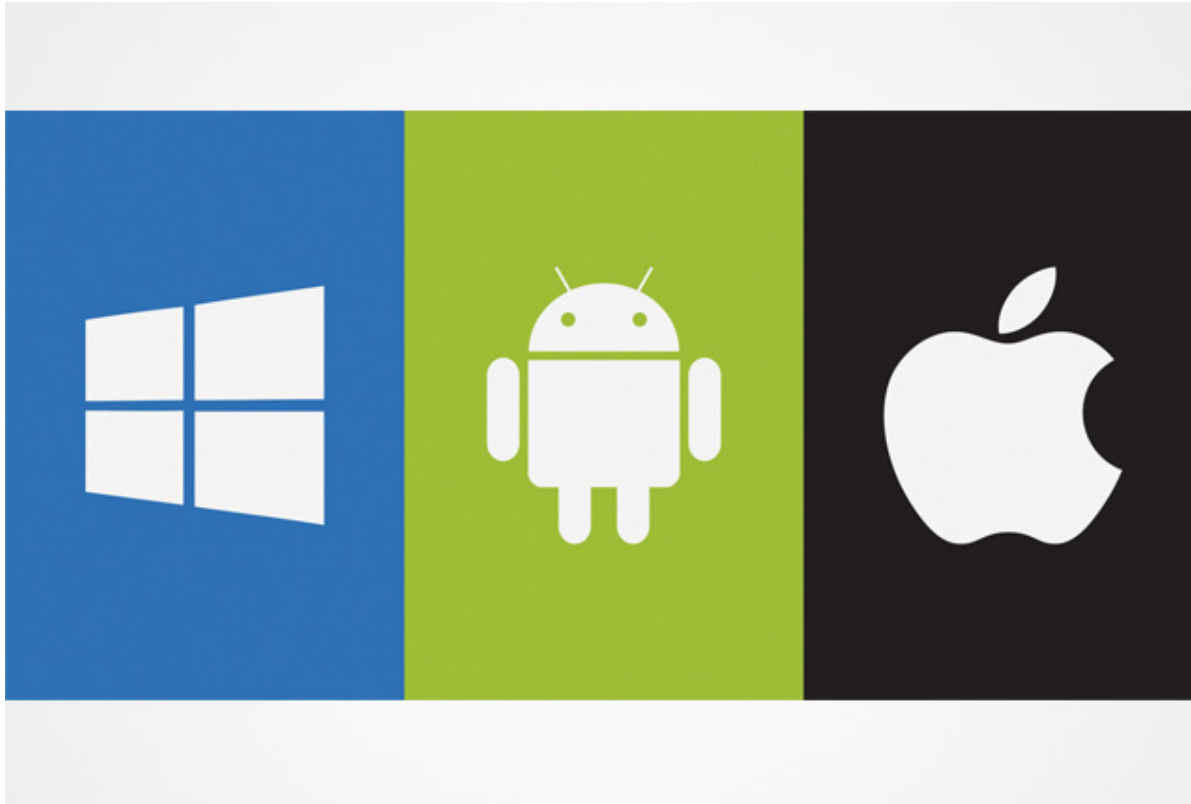
- Cloud compute environments composed of traditional OSes, plus VMMs, plus cloud management tools
 - Internet connectivity requires security like firewalls
 - Load balancers spread traffic across multiple applications



Computing Environments – Real-Time Embedded Systems

- Real-time embedded systems most prevalent form of computers
 - Vary considerable, special purpose, limited purpose OS, **real-time OS**
 - Use expanding
- Many other special computing environments as well
 - Some have OSes, some perform tasks without an OS
- Real-time OS has well-defined fixed time constraints
 - Processing ***must*** be done within constraint
 - Correct operation only if constraints met

Popular operating systems



What is Linux?

- Linux is a family of open source Unix-like operating systems based on the Linux kernel.
- Linux is a Unix clone written from scratch by Linus Torvalds with assistance from a loosely-knit team of hackers across the Net.
- Unix is a multitasking, multi-user computer operating system originally developed in 1969 by a group of AT&T employees at Bell Labs.
- Linux and Unix strive to be POSIX compliant.



Linux is popular

- Linux runs ~90% of the public cloud workload.
- 70.5% of web servers run Linux/Unix, and 29.5% run Microsoft Windows (W3Techs, Jan 2019).
- Android, which is based on the Linux kernel, has become the dominant operating system for smartphones.
- According to the Linux Movies Group, more than 95% of the servers and desktops at large animation and visual effects companies use Linux.

Linux Has Many Distributions



What is Linux?

Linux + GNU Utilities = Free Unix



- Linux is an O/S core written by Linus Torvalds and others AND



- a set of small programs written by Richard Stallman and others. They are the GNU utilities.

<http://www.gnu.org/>

GNU/Linux is “free” and open-source

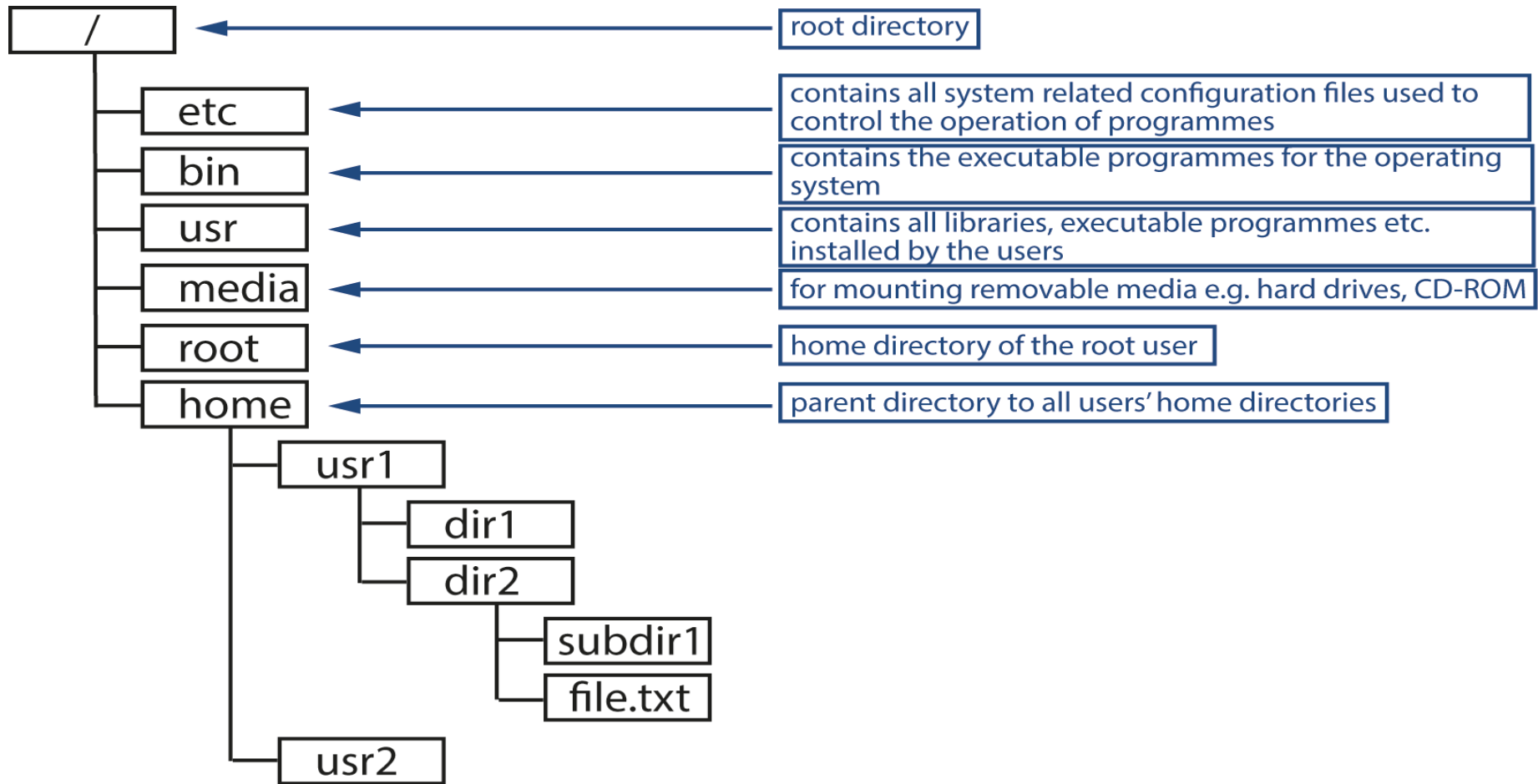
- “Free software” means software that respects users' freedom and community. Roughly, it means that **the users have the freedom to run, copy, distribute, study, change and improve the software**. Thus, “free software” is a matter of liberty, not price.
- Copyright: Linux kernel is licensed under the GNU General Public License (GPL).
- **Copyleft**: Everyone will be permitted to modify and redistribute GNU, but no distributor will be allowed to restrict its further redistribution.

Unix philosophy

- Write programs that do one thing and do it well.
- Write programs to work together.
- Write programs to handle text streams, because that is a universal interface.

Peter H. Salus in A Quarter-Century of Unix (1994)

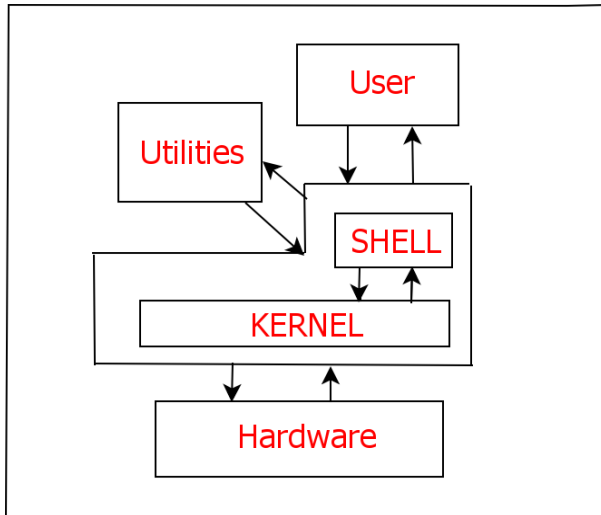
Everything is a file



Frequently used Linux commands

- ls
- cd
- cp
- mkdir
- rm
- more
- less
- cat
- tail
- grep
- sudo
- apt
- top
- tail
- ps
- env
- chmod
- vi/vim
- man
- ...

GNU Bash shell



- *Shell* is a user interface for access to an operating system's services
- Bash has been used widely as the default login shell for most Linux distributions and Apple's macOS Mojave and earlier versions.

```
#!/bin/bash
```

```
for i in `seq 1 4`;do
```

```
    cd ../$i
```

```
    pwd
```

```
    if [ ! -f result.out ]; then
```

```
        echo "Warning: File 'result.out' is NOT found in $i"
```

```
    fi
```

```
    cat result.out >> total-result.out
```

```
done
```

Setup your bash: .bashrc

```
#Alias:
```

```
alias rm='rm -i'
```

```
alias cp='cp -i'
```

```
alias mv='mv -i'
```

```
###local software
```

```
export PATH=${PATH}:/home/dingpan/local/bin
```

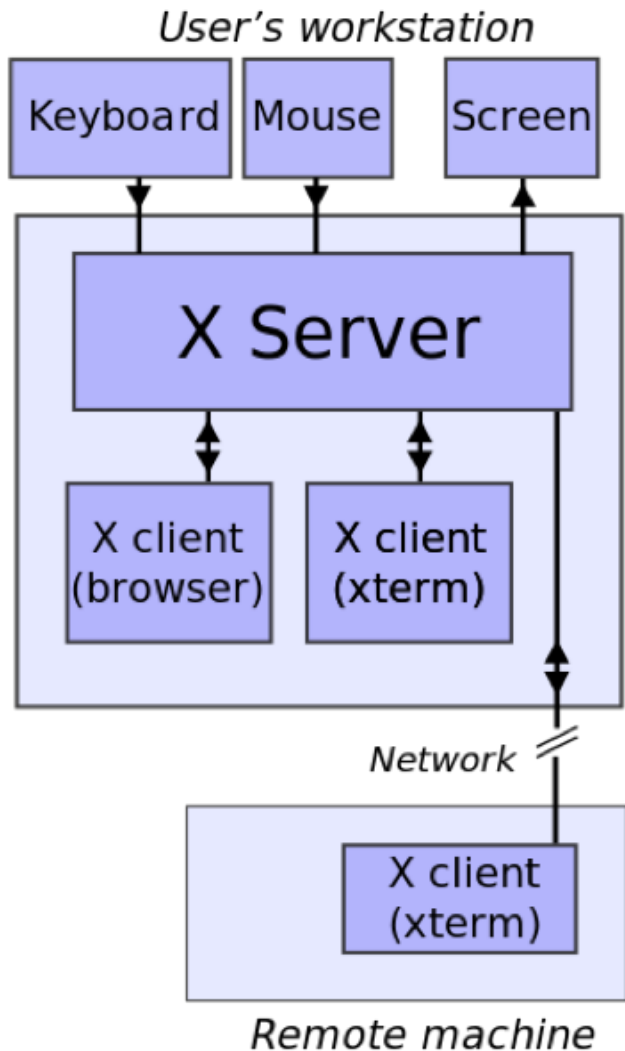
How to compile a code

- GNU toolchain: GCC, make, GDB(debugger), glibc...
- GCC: contains front ends for C (gcc), C++ (g++), Objective C, Fortran, Ada (GNAT), Go, and D.
- gcc XXX.c

Ubuntu OS

- an open-source[7][8] Linux distribution based on Debian.
- Powerful package manager:
 `sudo apt install <XXX package>`
- Huge number of apps (free or private)
- detailed documentation
- A big and active community

Graphic user interface (GUI)



eg., ssh

- The X Window System (X11, or simply X) is a windowing system for bitmap displays
- Desktop environment: GNOME, KDE...

Google cloud computing

- <https://cloud.google.com/>

AWS educate

- <https://aws.amazon.com/education/awseducate/>

Regular expressions

- a sequence of characters that define a search pattern
- used by string-searching algorithms for "find" or "find and replace" operations on strings, or for input validation.

E.g.

```
grep "blockID" blocklist.xml
```

```
grep "g[0-9]" blocklist.xml
```

```
egrep "g[0-9]{4}" blocklist.xml
```

Git

- git status
- git add
- git commit
- git branch
- git switch