Operating System

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(玉泉教7-206)

周二第7,8节;周四第9,10节/教4-301

实验：周四第7,8节/ 曹西-503

Lecture 1: Overview

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Outlines of the overview

- Also known as “Principles of Operating System”
- Background
  - The main purpose of this course
  - The contents and schedule of the course
  - The pre-requisite knowledge for the course
- Chapter 1 Introduction
- Chapter 2 Operating-System Structures

Main objectives

An introductory course for Operating System

- To learn the basics and internal design of operating systems
- To look at both the history and the state-of-the-art techniques used in operating systems
- To study the design methodologies applied in OS
- To prepare to practice the techniques in your future work

and

- To have fun !?

These are NOT the main objectives

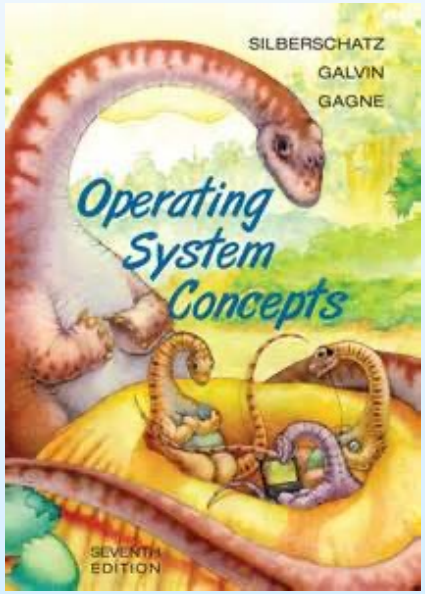
- To learn the cool Linux/RISCV commands (stuff like shell programming, pipes, scripts, …)
- To write a new OS for my PC
- To learn how to design a big system
- To analyze the source code of an OS
  - http://www.chromium.org/chromium-os
  - *https://**source**.android.com*
  - http://www.tinyos.net/

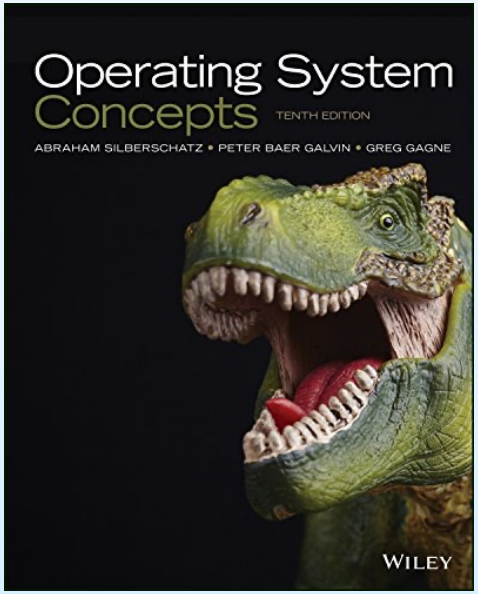
Contents

- Overview - 1 session
  - Intro
  - OS structure
- Process Management - 6 sessions
  - Processes
  - Threads
  - CPU scheduling
  - Process Synchronization
  - Deadlocks
- Memory Management- 4 sessions
  - Main memory
  - Virtual memory
- Storage Management-4 sessions
  - File-system interface
  - File-system implementation
  - Mass-storage structure
  - I/O systems
- Additional Topic – 2 session

Textbook & resources

- **Main Textbook: Operating System Concepts 7th/10th, Abrraham Silberschatz、Peter Galvin，Greg Gagne**
- 高等教育出版社（第7/10版影印版）
- **Course webpage: http://course.zju.edu.cn**





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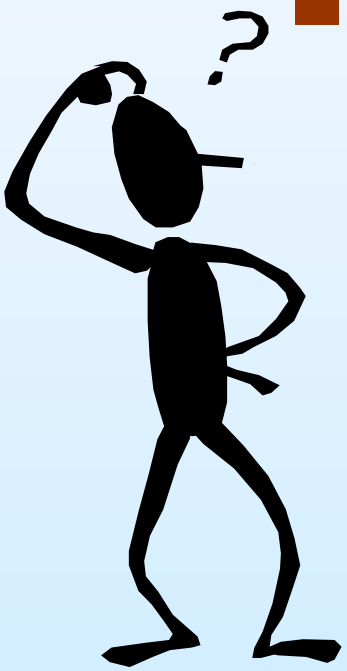
Pre-requisite Knowledge

- Computer system architecture/organization
- Programming language C
- Assembling language
- Data structures

Final Grade

- Final Exam = 50%
- Homework = 5%
- Quiz = 5%
- Project Report = 20%
- Project Face-face check = 20%



Project of OS

- Individual Project
  - Lab0: Riscv64 Kernel Compilation 5%
  - Lab1: Riscv64 Kernel Bootup and Time Interrupt 15%
  - Lab2: Riscv64 Process Scheduling 15%
- Group Project, 2 ppl/group
  - Lab3: Riscv64 Virtual Memory 20%
  - Lab4: Riscv64 User Space and System Call 15%
  - Lab5: Riscv64 Fork and Page Fault 30%
- Selective Project (bonus), group
  - Lab6: File System 10%

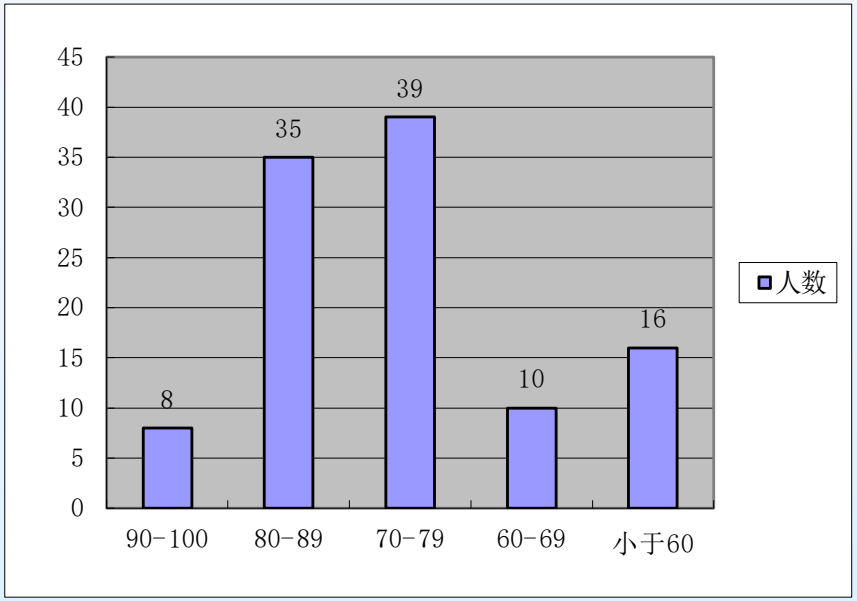
Project Site : https://yuque.zju.edu.cn/qz21wl/ernn3p/xw0d3r

My suggestions on learning OS

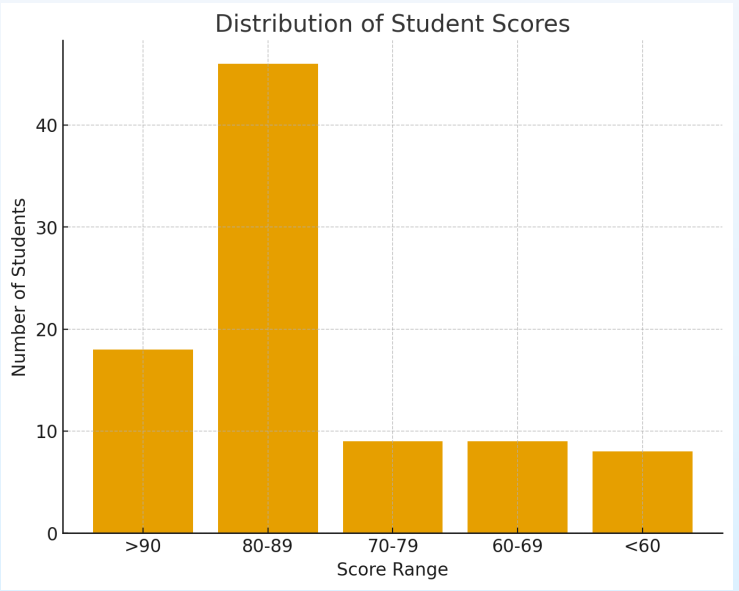
- Do a lot of readings before or after the lecture sessions, especially from the English textbook
- If you have any question, raise your hand!!!
- Do NOT refer to the so-called “standard” answers to the exercises, they contain many mistakes. Once you are caught using the wrong “standard” answers, penalty might be applicable.
- Hopefully more interactions during the lectures

Previous Performance

Only the final exam



Combined with other grades



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Chapter 1 Introduction

Outlines for Chapter ONE

Overview

- What Operating Systems Do
- Computer-System Organization
- Computer-System Architecture

Structure

- Operating-System Structure
- Operating-System Operations

Main parts

- Process Management
- Memory Management
- Storage Management

- Protection and Security
- Distributed Systems
- Special-Purpose Systems
- Computing Environments

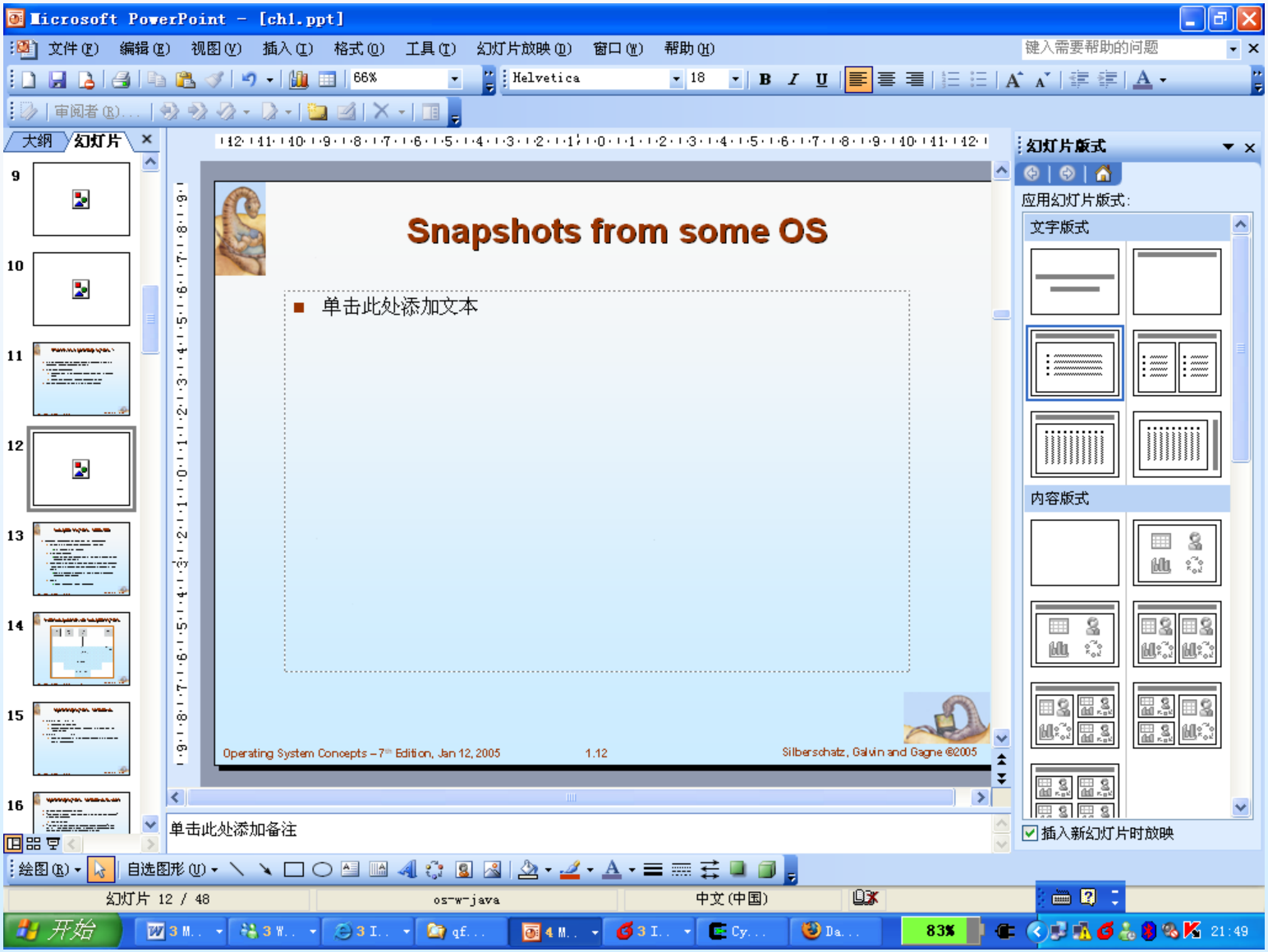
Objectives

- To provide a grand tour of the major operating systems components
- To provide coverage of basic computer system organization

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware.
- Operating system goals:
  - Execute user programs and make solving user problems easier.
  - Make the computer system convenient to use.
- Use the computer hardware in an efficient manner.

Snapshots from some OS




开始
蔡耀明
张婉茹
答复：今晚一起吃饭好吗？好呀！就去那家后面带露台的新餐厅吧？
邮件
8
足球训练
体育场
下午 5：30 – 下午 8：30
8
星期一
Internet Explorer
应用商店
必应 Bing
照片
地图
SkyDrive
游戏
桌面
消息
23°C
北京
多云 17° / 24°
天气
热气球节本周末开幕
音乐

From my linux box

dbgpucluster.d1.comp.nus.edu.sg - dbgpu* - SSH Secure Shell

File Edit View Window Help

Quick Connect Profiles

```
[wusai@dbgpucluster ~]$
[wusai@dbgpucluster ~]$ cd knnsearch/
[wusai@dbgpucluster knnsearch]$ make
make: Nothing to be done for `default'.
[wusai@dbgpucluster knnsearch]$ ls
clib_port.h  db_int.h              dbstl_dbt.h           dbstl_resource_manager.h  HyperplaneLSH.h  IndexDB.o        main.cpp
data.db      dbstl_base_iterator.h dbstl_element_ref.h   dbstl_set.h               HyperplaneLSH.o  knnSearch        main.o
db_config.h  dbstl_common.h        dbstl_exception.h     dbstl_utility.h           index.db         lib              makefile
db_cxx.h     dbstl_container.h     dbstl_inner_utility.h dbstl_vector.h            IndexDB.cpp      libdb-6.1.so     siftgeo.bin
db.h         dbstl_dbc.h           dbstl_map.h           HyperplaneLSH.cpp         IndexDB.h        libdb_cxx-6.1.so sqlite3.h
[wusai@dbgpucluster knnsearch]$ make clean
rm -f knnSearch *.o *~
[wusai@dbgpucluster knnsearch]$ make
g++ -g -Wall  -c main.cpp
main.cpp: In function 銅nt main()?
main.cpp:22:37: warning: deprecated conversion from string constant to 鈉har*?[-Wwrite-strings]
  indexer.importAsLSH("./siftgeo.bin");
                                    ^
main.cpp:42:26: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
  for(int i=0; i<val.size(); i++)
                         ^
g++ -g -Wall  -c IndexDB.cpp
IndexDB.cpp: In member function 鈸td::vector<int> IndexDB::getApproximateKNNByLSH(int*, int)?
IndexDB.cpp:209:28: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
   for(int j=0; j<next.size(); j++)
                           ^
IndexDB.cpp:216:19: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
  while(all.size()<K)
                  ^
IndexDB.cpp:222:29: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
    for(int j=0; j<next.size(); j++)
                             ^
IndexDB.cpp:229:29: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
    for(int j=0; j<next.size(); j++)
                             ^
IndexDB.cpp:260:17: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
   if(knn.size()<K)
                ^
g++ -g -Wall -c HyperplaneLSH.cpp
g++ -g -Wall -L./lib -ldb-6.1 -ldb_cxx-6.1 -lpthread main.o IndexDB.o HyperplaneLSH.o  -o knnSearch
[wusai@dbgpucluster knnsearch]$
```

Connected to dbgpucluster.d1.comp.nus.edu.sg SSH2 - aes128-cbc - hmac-md5 157x41 NUM

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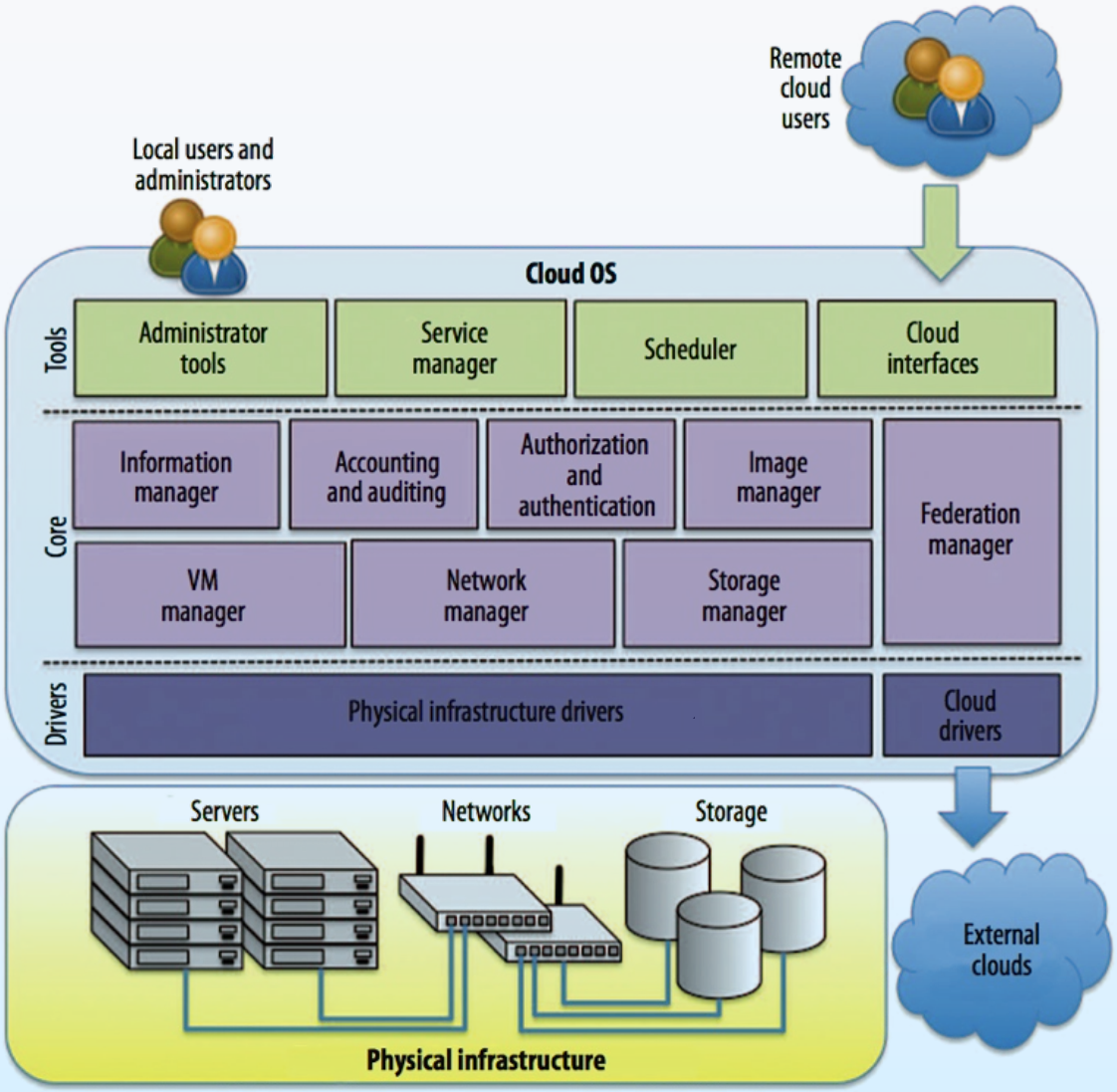
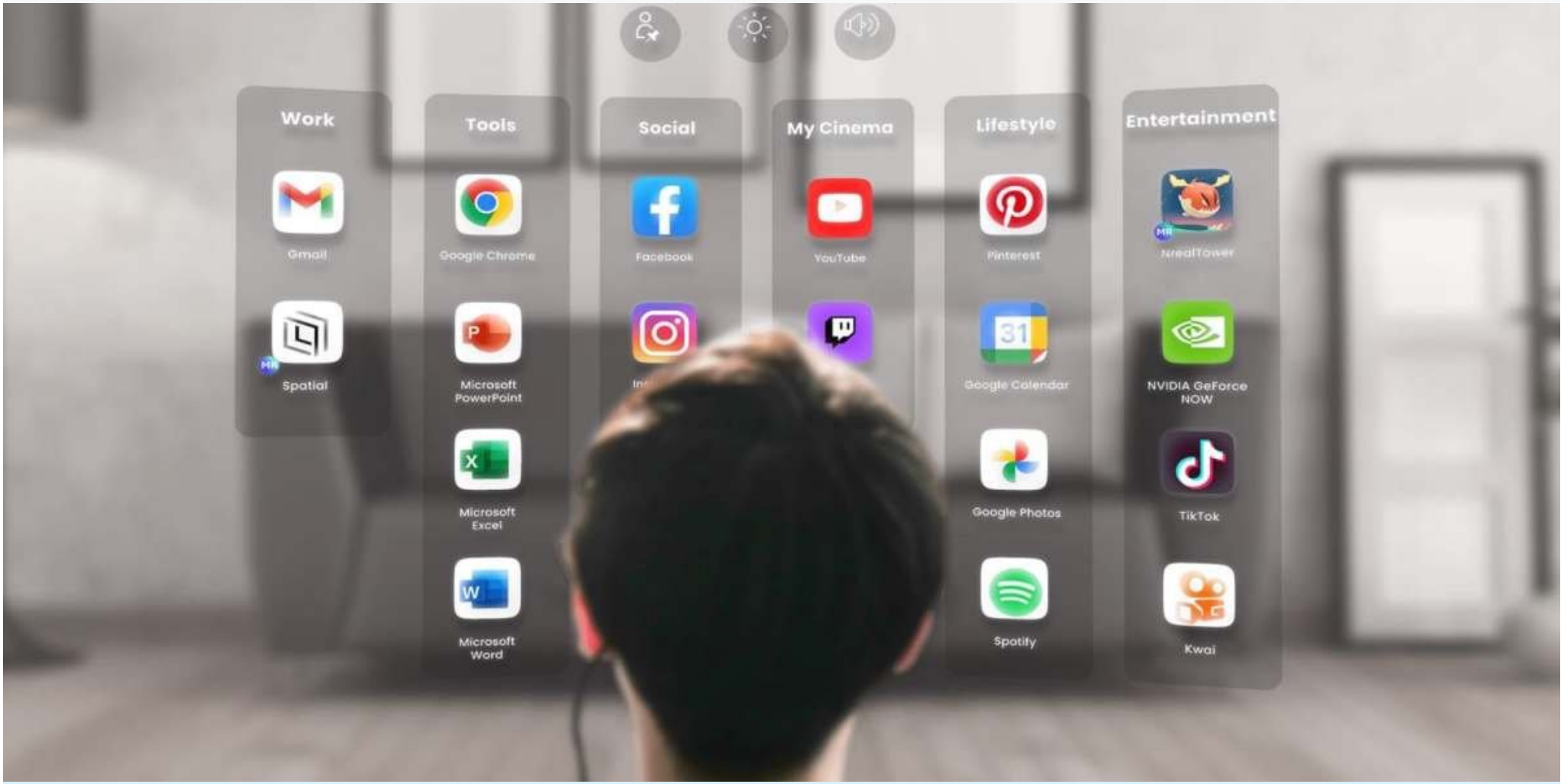
Smartphones & Tablets

Cloud Operating System



Metaverse Operating System



AI Operating System

- Merging LLM with OS turns the operating system into a conversational, adaptive, and self-optimizing platform. Instead of being a passive resource manager, the OS becomes an active collaborator

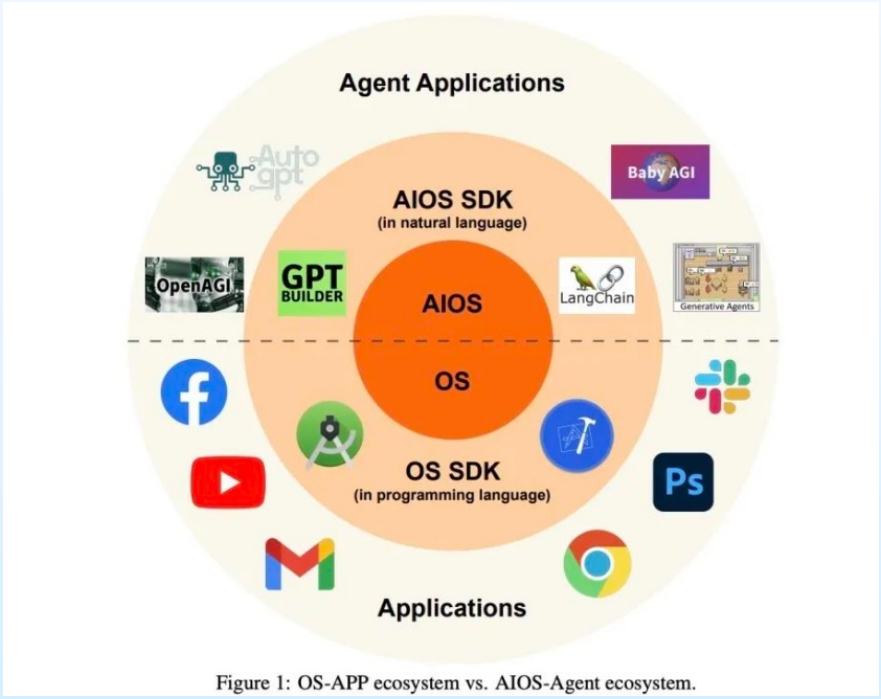


Figure 1: OS-APP ecosystem vs. AIOS-Agent ecosystem.

It used to look like this …

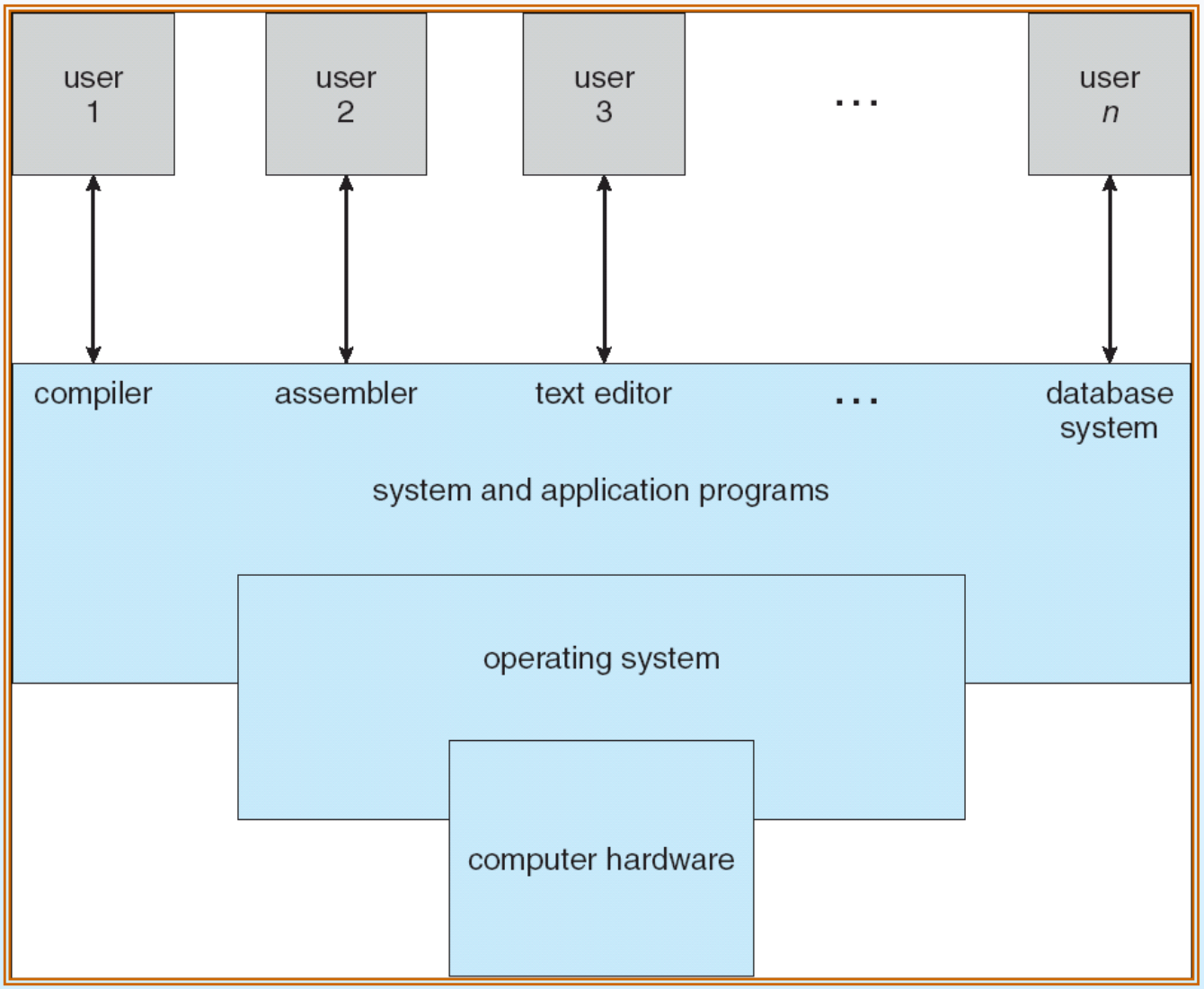
Firmware vs Operating System

- Firmware: low-level code, stored in bios/cd
- OS: a system-level software

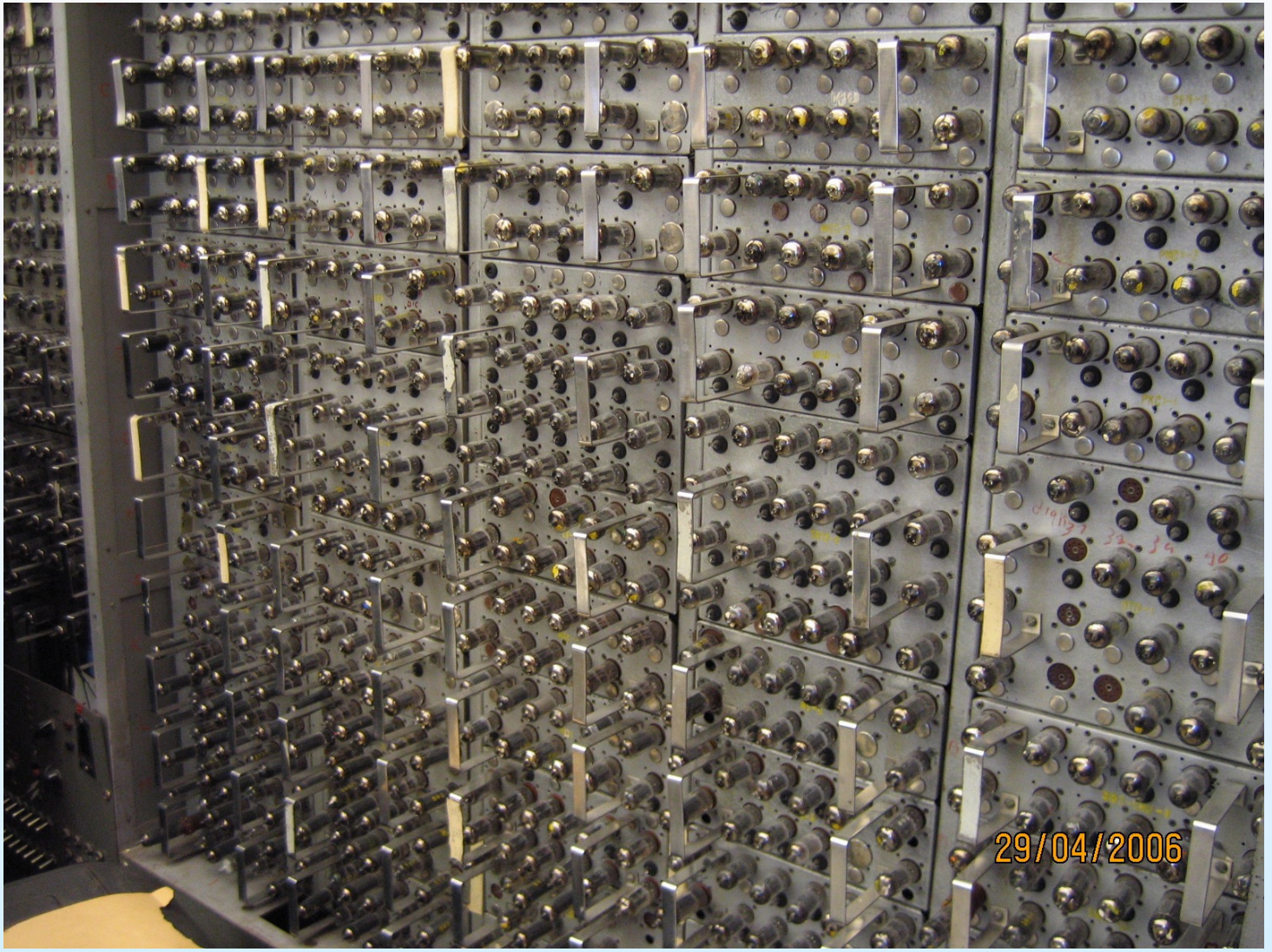
Computer System Structure

- Computer system can be divided into four components
  - Hardware – provides basic computing resources
    - CPU, memory, I/O devices
  - Operating system
    - Controls and coordinates use of hardware among various applications and users
  - System & application programs – define the ways in which the system resources are used to solve the computing problems of the users
    - Word processors, compilers, web browsers, database systems, video games
  - Users
    - People, machines, other computers

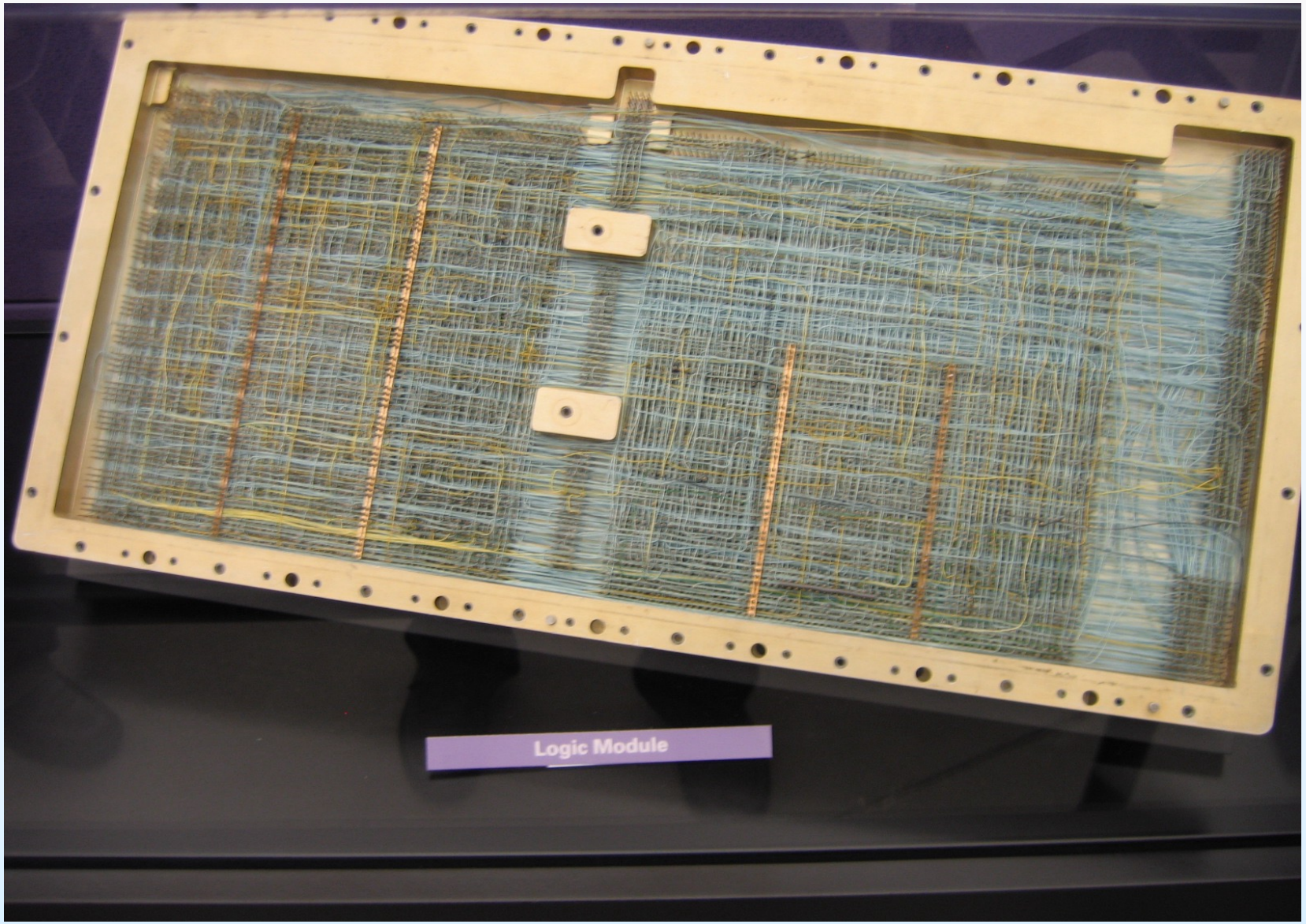
Four Components of a Computer System



How hard each component has evolved!



The WISC computer developed by Univ of Wisconsin.



The Logic Module used by Apollo guidance computer, putting a Man on the moon with a computer that had 36KB of memory

My very first computer: 386

- A 386 running a win 32 system
- Mainly used for typing practice and gaming…

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 (Cont.)

- 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

Operating System Definition (Cont.)

- From deepseek

什么是操作系统

当然！这是一个关于“操作系统”的详细解释，从简单定义到深入功能，希望能让你全面理解。

一句话概括

操作系统（Operating System，简称 OS）是计算机中最基本、最核心的系统软件，它是硬件和应用程序之间的桥梁，负责管理计算机的硬件和软件资源，并为用户提供一个方便、高效、安全的操作环境。

你可以把它想象成一个**公司的总经理或交通系统的指挥中心**：

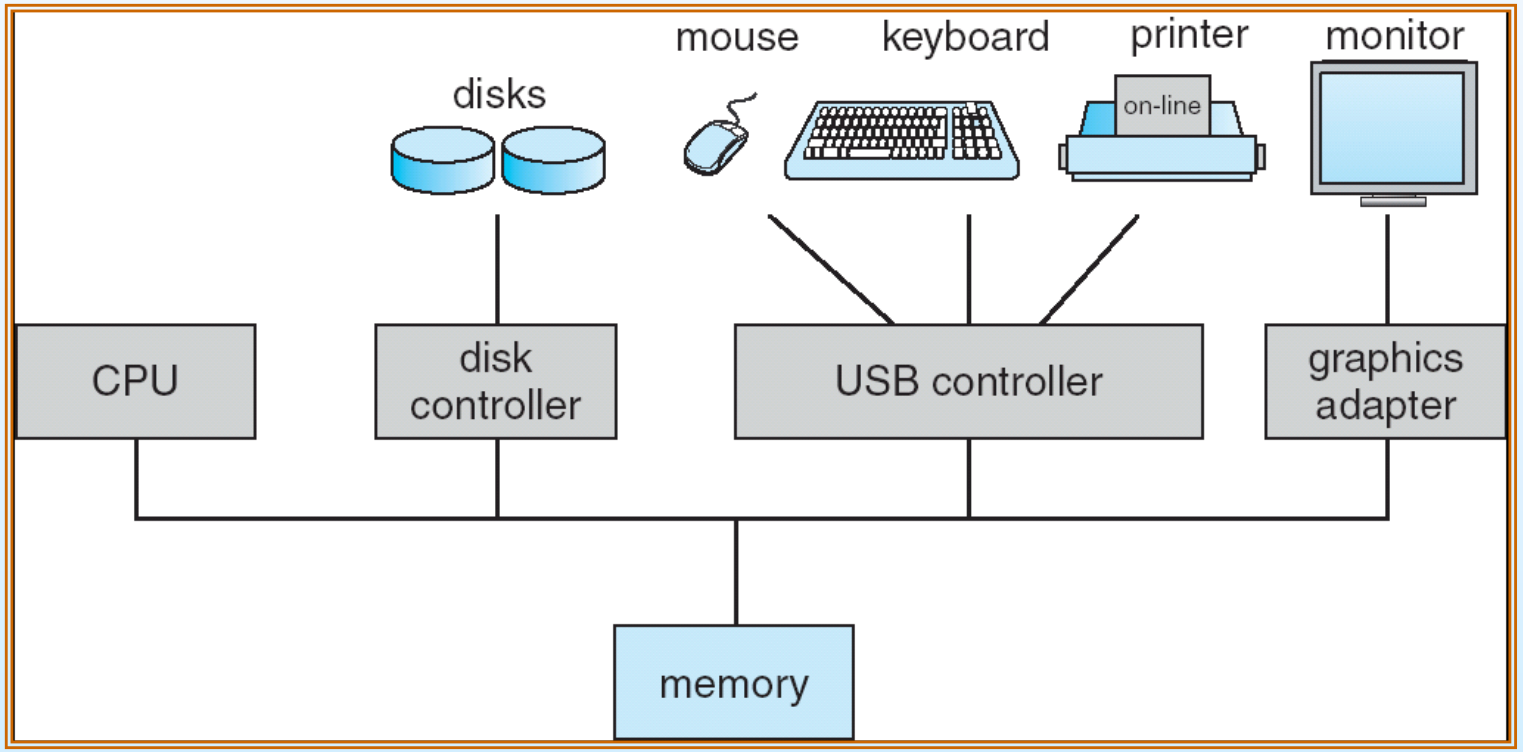
- **硬件（电脑的CPU、内存、硬盘等）** 就像公司的员工和资源（桌椅、打印机）、或者道路上的车辆和信号灯。
- **应用程序（浏览器、游戏、Word等）** 就像公司里各个部门的项目组，或者想要去不同目的地的司机。
- **操作系统（总经理/指挥中心）** 不直接做具体项目（不直接算数学题、画图），但它负责分配谁用什么资源、什么时候用、用多少，确保整个系统有条不紊地高效运行，避免混乱和冲突。

Computer Startup

- **bootstrap program** is loaded at power-up or reboot
  - Typically stored in ROM or EPROM, generally known as **firmware**
  - Initializes all aspects of system
  - Loads operating system kernel and starts execution

Computer System Organization

- Computer-system operation
  - One or more CPUs, device controllers connect through common bus providing access to shared memory
  - Concurrent execution of CPUs and devices competing for memory cycles



Computer-System Operation

- I/O devices and the CPU can execute concurrently.
- Each device controller is in charge of a particular device type.
- Each device controller has a local buffer.
- CPU moves data from/to main memory to/from local buffers
- I/O is from the device to local buffer of controller.
- Device controller informs CPU that it has finished its operation by causing an *interrupt* (via system bus).

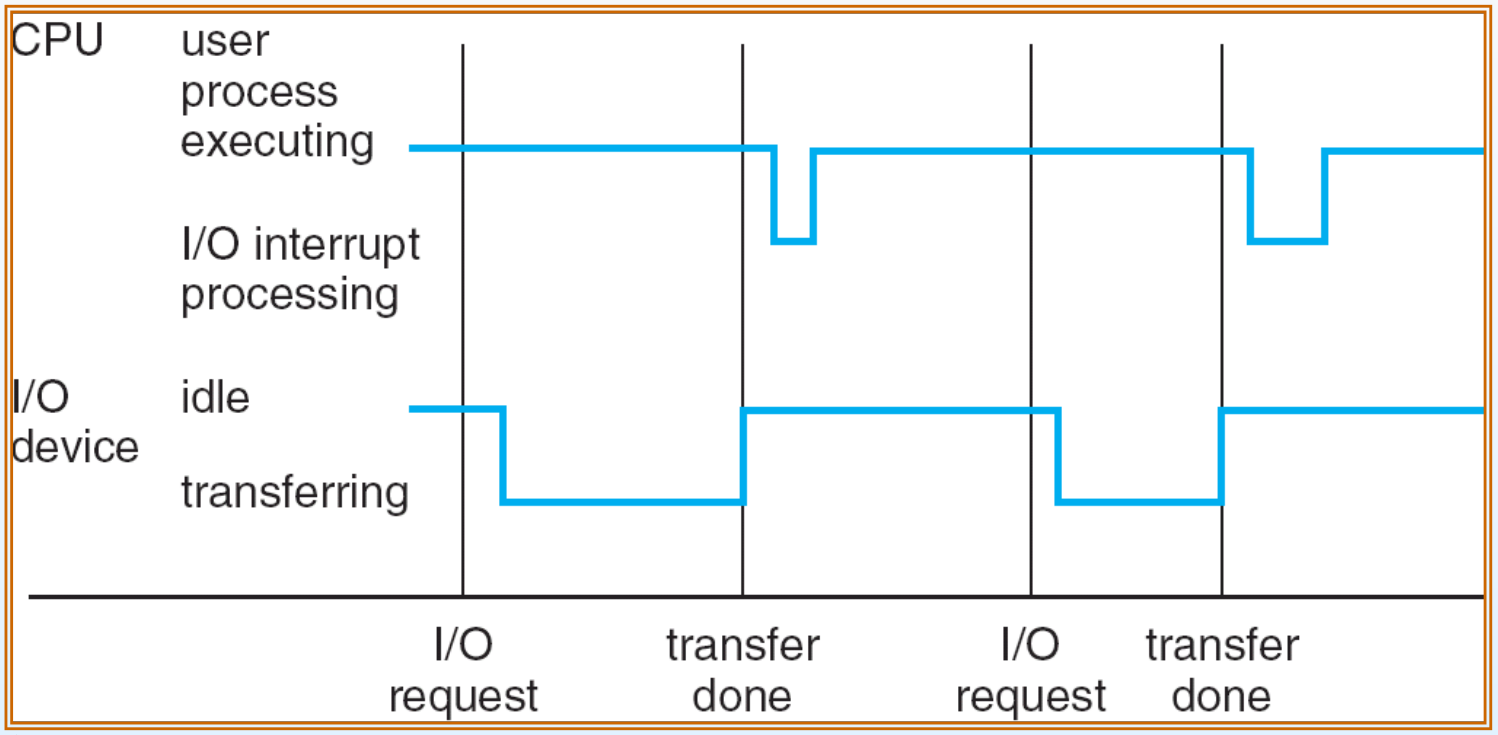
Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the *interrupt vector*, which contains the addresses of all the service routines.
- Interrupt architecture must save the address of the interrupted instruction.
- Incoming interrupts are *disabled* while another interrupt is being processed to prevent a *lost interrupt*.
- A *trap* is a software-generated interrupt caused either by an error or a user request (the latter is often referred to as a *system call*).
- An operating system is *interrupt* driven.

Interrupt Handling

- The operating system preserves the state of the CPU by storing registers and the program counter.
- Determines which type of interrupt has occurred:
  - *polling* by a generic routine
  - *vectored* interrupt system
- Separate segments of code determine what action should be taken for each type of interrupt

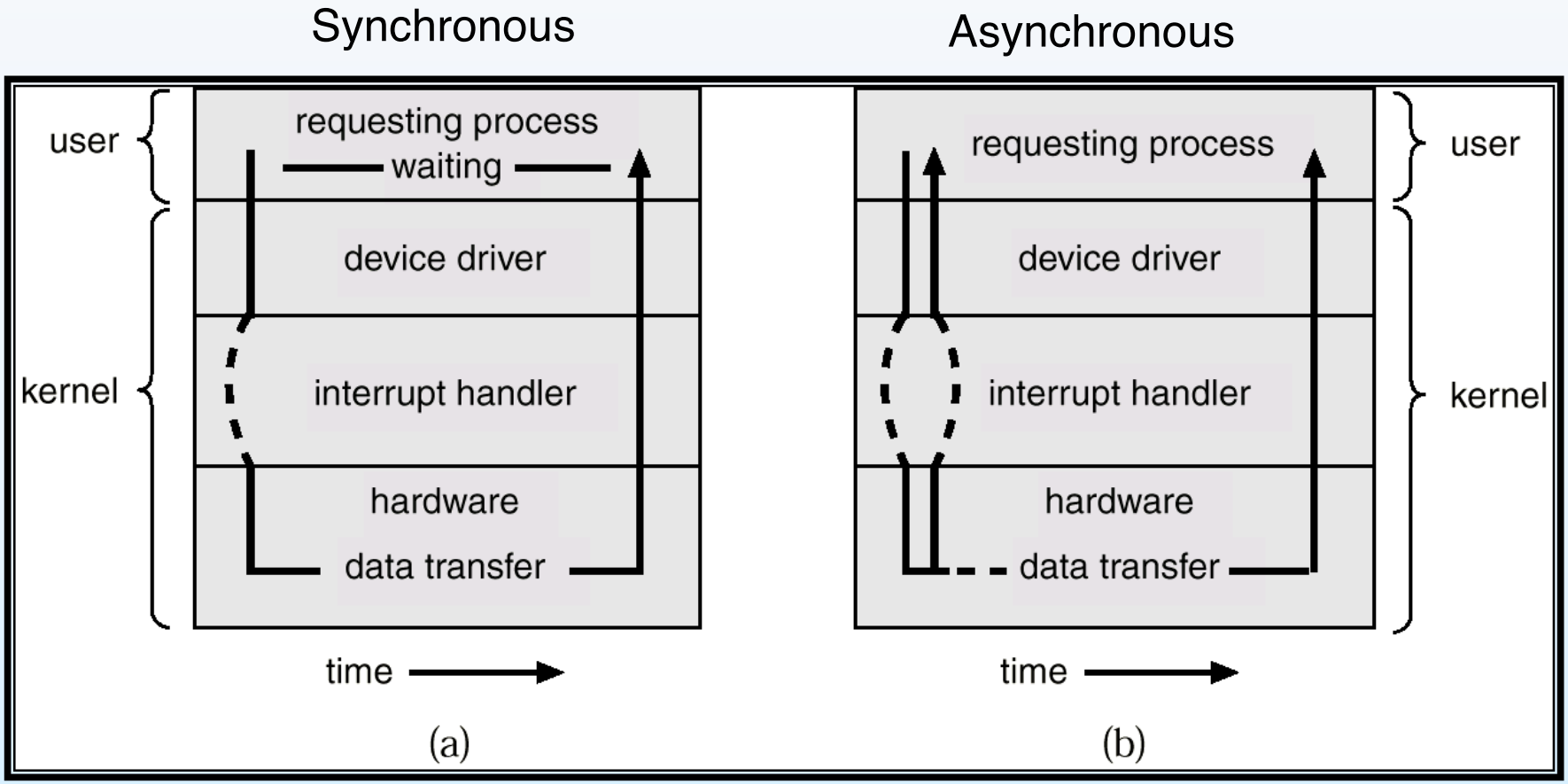
Interrupt Timeline



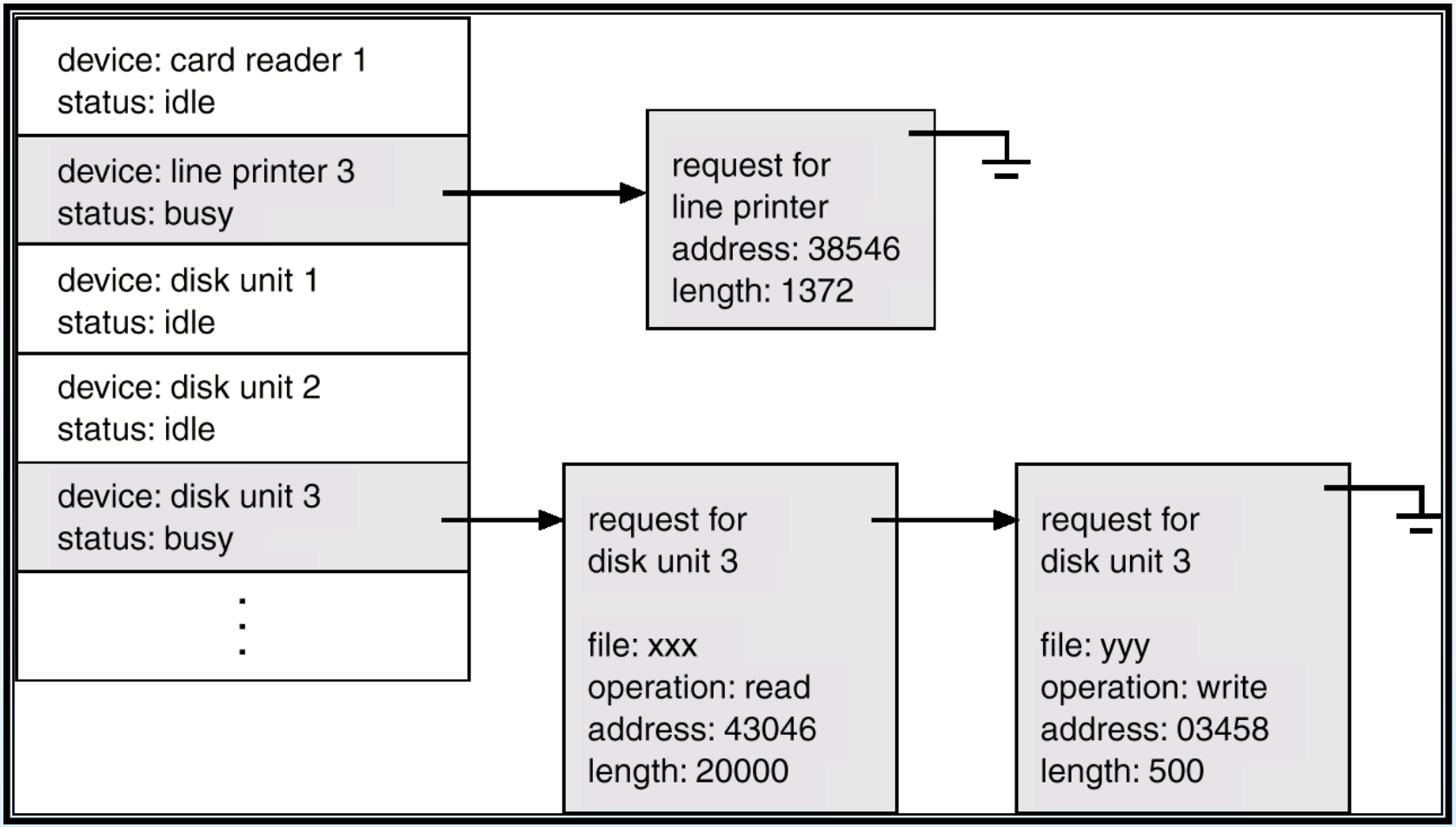
I/O Structure

- After I/O starts, control returns to user program only upon I/O completion.
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access).
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing.
- After I/O starts, control returns to user program without waiting for I/O completion.
  - *System call* – request to the operating system to allow user to wait for I/O completion.
  - *Device-status table* contains entry for each I/O device indicating its type, address, and state.
  - Operating system indexes into I/O device table to determine device status and to modify table entry to include interrupt.

Two I/O Methods



Device-Status Table



Direct Memory Access Structure

- Used for high-speed I/O devices able to transmit information at close to memory speeds.
- Device controller transfers blocks of data from buffer storage directly to main memory without CPU intervention.
- Only one interrupt is generated per block, rather than the one interrupt per byte.

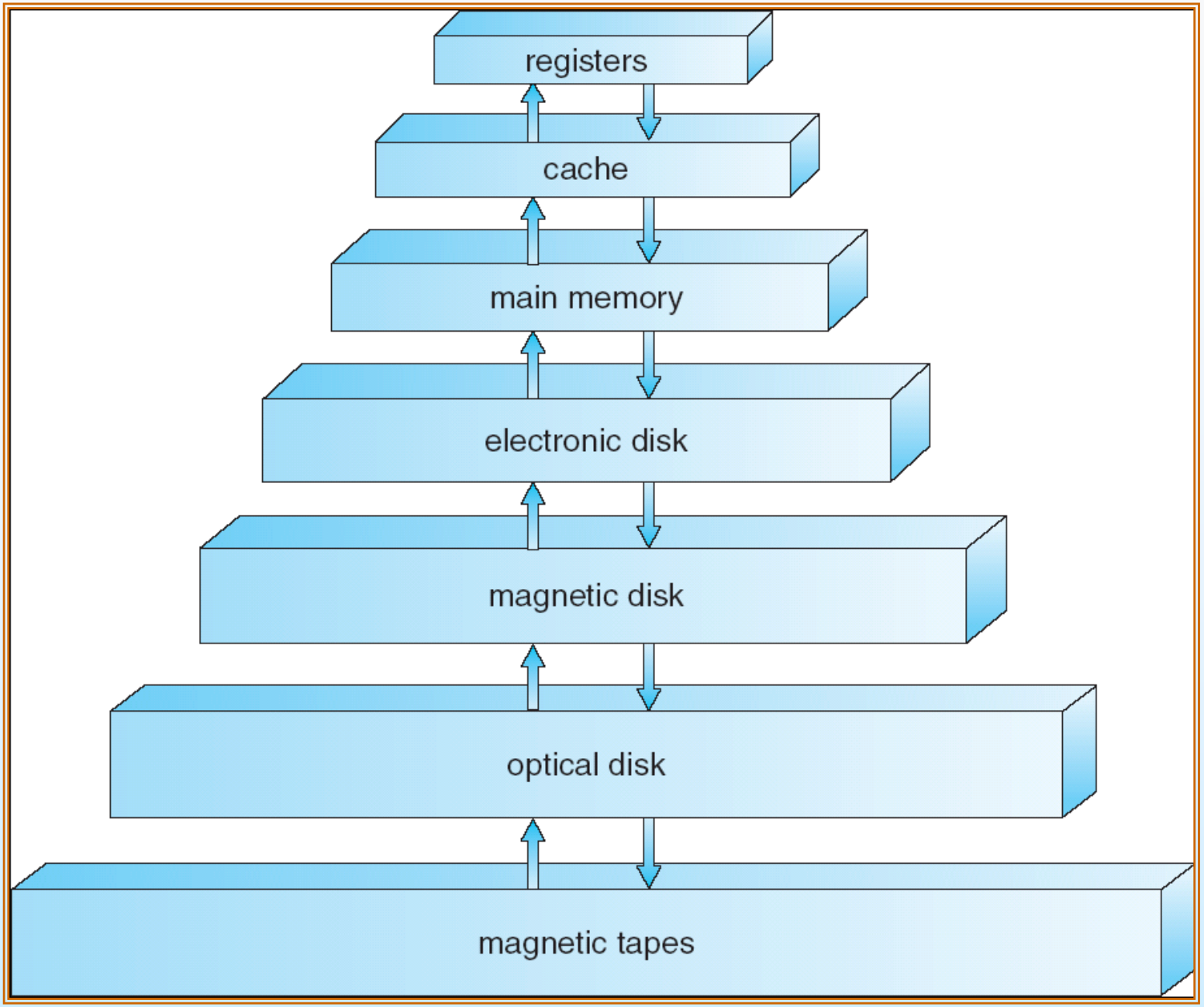
Storage Structure

- Main memory – only large storage media that the CPU can access directly.
- Secondary storage – extension of main memory that provides large nonvolatile storage capacity.
- Magnetic disks – rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into *tracks*, which are subdivided into *sectors*.
  - The *disk controller* determines the logical interaction between the device and the computer.

Storage Hierarchy

- Storage systems organized in hierarchy.
  - Speed
  - Cost
  - Volatility
- *Caching* – copying information into faster storage system; main memory can be viewed as a last *cache* for secondary storage.

Storage-Device Hierarchy



Caching

- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily – Speed mismatch
- Faster storage (cache) checked first to determine if information is there
  - If it is, information used directly from the cache (fast)
  - If not, data copied to cache and used there
- Cache smaller than storage being cached
  - Cache management important design problem
  - Cache size and replacement policy

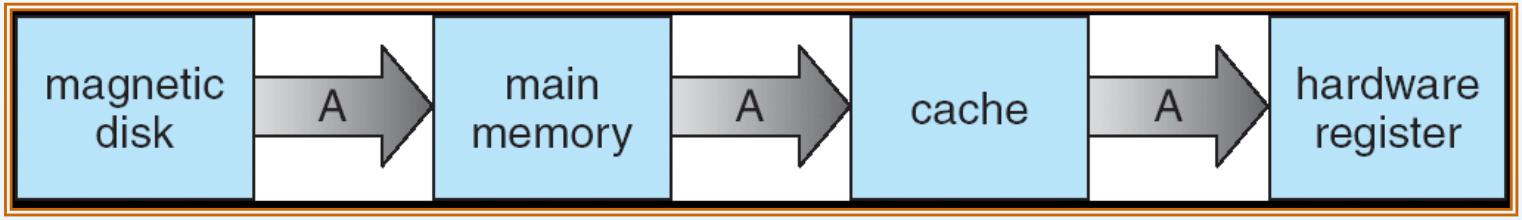
Performance of Various Levels of Storage

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

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Migration of Integer A from Disk to Register

- Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy

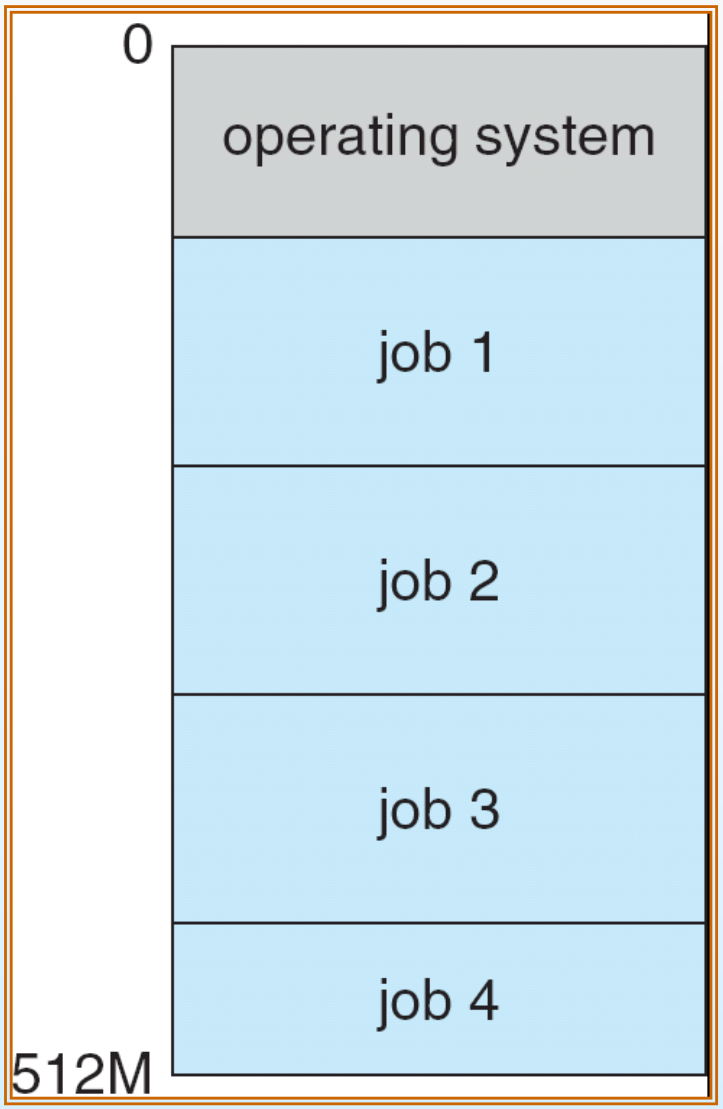


- Multiprocessor environment must provide cache coherency in hardware such that all CPUs have the most recent value in their cache
- Distributed environment situation even more complex
  - Several copies of a datum can exist
  - Various solutions covered in Chapter 17

Operating System Structure

- **Multiprogramming** needed for efficiency **(CPU utilization)**
  - 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 **(interactivity)**
  - **Response time** should be < 1 second
  - Each user has at least one program executing in memory ⇨**process**
  - If several jobs ready to run at the same time ⇨ **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



Operating-System Operations

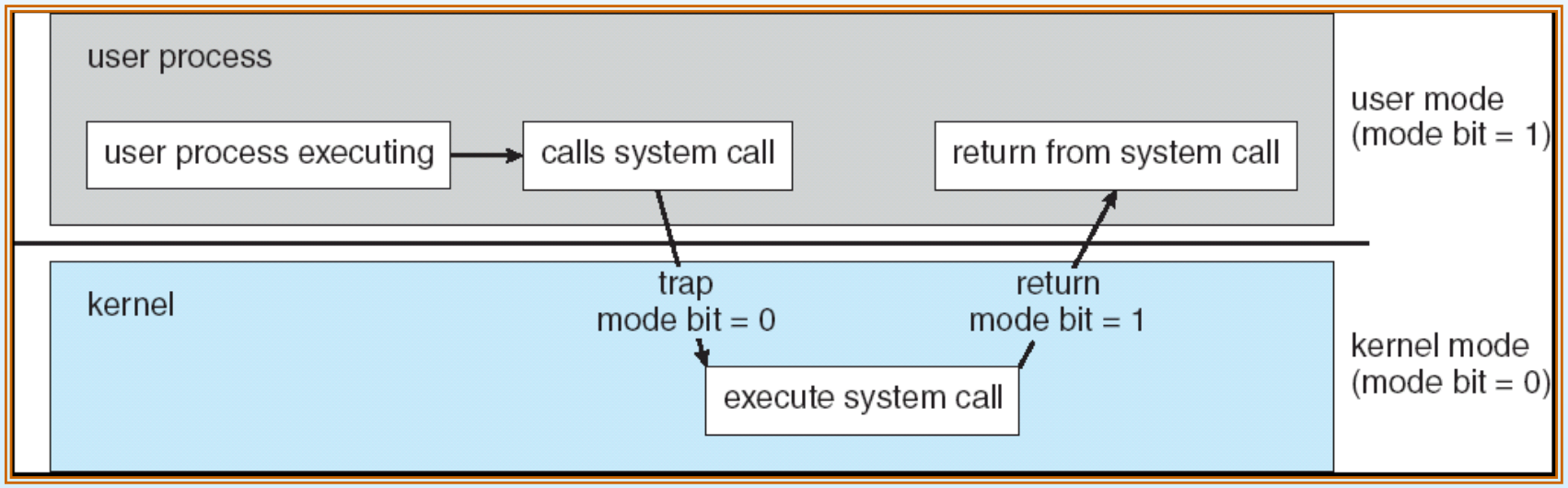
- Interrupt driven by hardware
- Software error or request creates **exception** or **trap**
  - Division by zero, request for operating system service
- Other process problems include infinite loop, processes modifying each other or the operating system

Thus we need protection:

- **Dual-mode** operation allows OS to protect itself and other system components
  - **User mode** and **kernel mode**
  - **Mode bit** provided by hardware
    - Provides ability to distinguish when system is running user code or kernel code
    - Some instructions designated as **privileged**, only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user

Transition from User to Kernel Mode

- Timer to prevent infinite loop / process hogging resources
  - Set interrupt after specific period
  - Operating system decrements counter
  - When counter zero generate an interrupt
  - Set up before scheduling process to regain control or terminate program that exceeds allotted time



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 must be in memory before and after processing
- All instructions must be 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

Mass-Storage Management

- Usually disks used to store data that does not fit in main memory or data that must be kept for a “long” period of time.
- Proper management is of central importance
- Entire speed of computer operation hinges on disk subsystem and its algorithms
- OS activities
  - Free-space management
  - Storage allocation
  - Disk scheduling
- Some storage need not be fast
  - Tertiary storage includes optical storage, magnetic tape
  - Still must be managed
  - Varies between WORM (write-once, read-many-times) and RW (read-write)

I/O Subsystem

- One purpose of OS is to hide peculiarities of hardware devices from the user – *ease of usage & programming*
- I/O subsystem responsible for
  - Memory management of I/O including buffering (storing data temporarily while it is being transferred), caching (storing parts of data in faster storage for performance), spooling (the overlapping of output of one job with input of other jobs)
  - General device-driver interface
  - Drivers for specific hardware devices

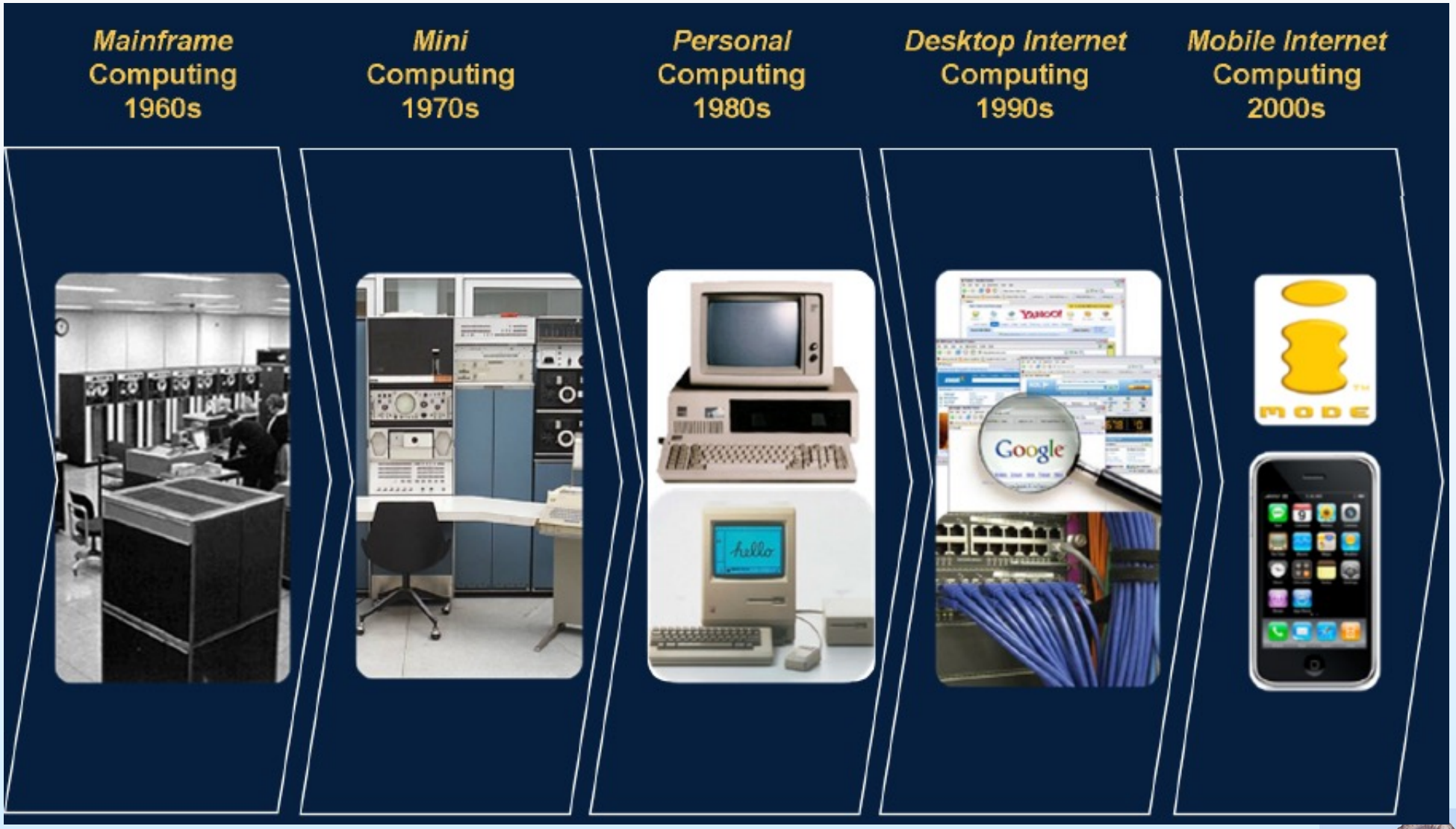
Protection and Security

- **Protection** – any mechanism for controlling access of processes or users to resources defined by the OS
- **Security** – defense of the system against internal and external attacks
  - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Systems generally first distinguish among users, to determine who can do what
  - User identities (**user IDs**, security IDs) include name and associated number, one per user
  - User ID then associated with all files, processes of that user to determine access control
  - Group identifier (g**roup ID**) allows set of users to be defined and controls managed, then also associated with each process, file
  - **Privilege escalation** allows user to change to effective ID with more rights

Computing Environments

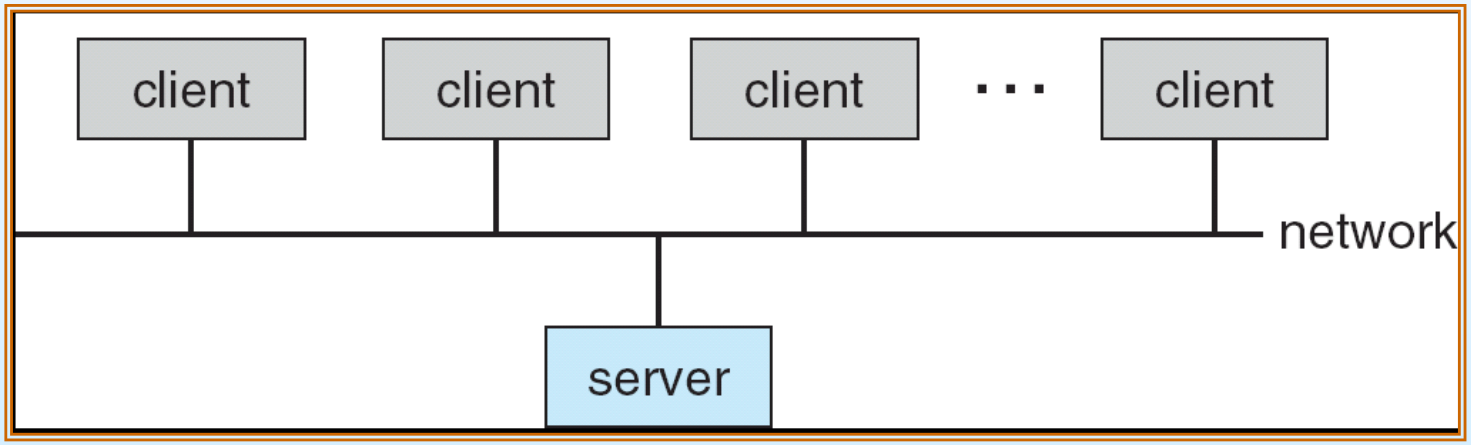
- Traditional computer
  - Blurring over time
  - Office environment
    - PCs connected to a network, terminals attached to mainframe or minicomputers providing batch and timesharing
    - Now portals allowing networked and remote systems access to same resources
  - Home networks
    - Used to be single system, then modems
    - Now firewalled, networked

Computing Environments (Cont.)



Computing Environments (Cont.)

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



Peer-to-Peer Computing

- 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*

Web-Based Computing

- Web has become ubiquitous
- PCs most prevalent devices
- More devices becoming networked to allow web access
- New category of devices to manage web traffic among similar servers: **load balancers**
- Use of operating systems like Windows 95, client-side, have evolved into Linux and Windows XP, which can be clients and servers
- Web based office software! http://Docs.google.com

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End of Chapter 1