Introduction to Operating Systems

Daniel Hagimont (INPT)

hagimont@enseeiht.fr

http://hagimont.perso.enseeiht.fr

Outline

- Introduction
- Processes
- Inter-process communication
- Threads
- Scheduling
- Synchronization
- Memory

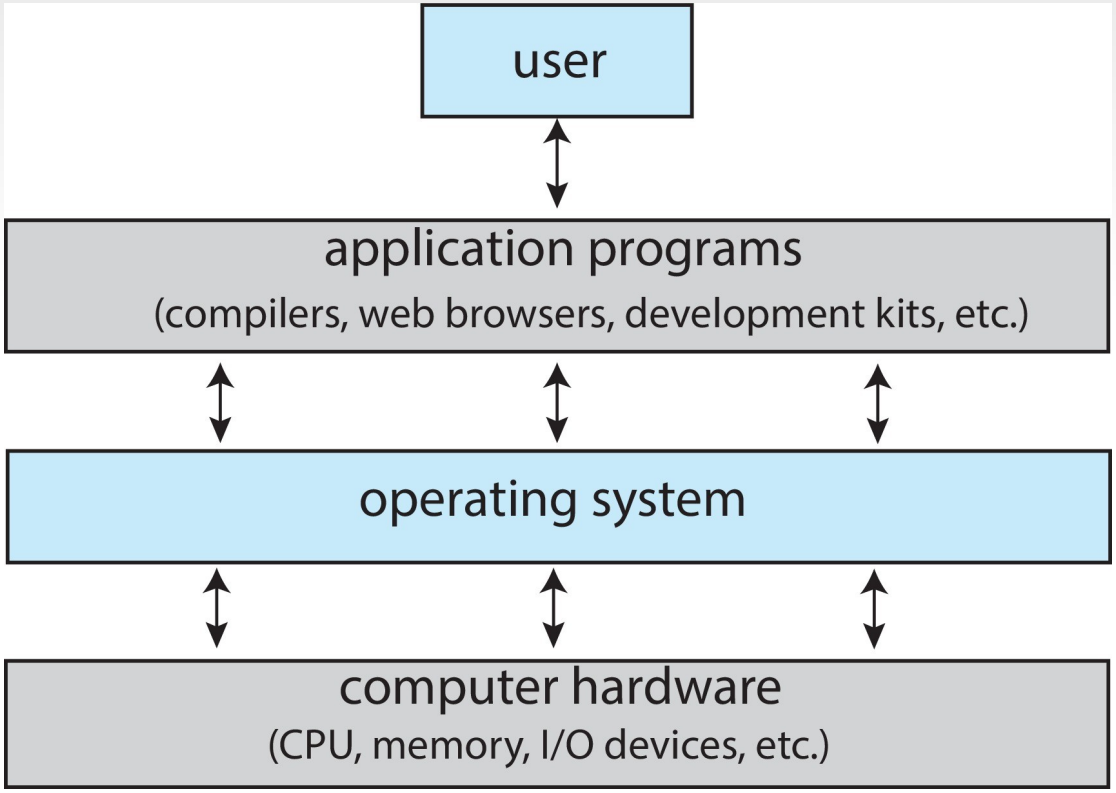
Organization

- To make it manageable, I propose that you constitute groups of 4
- For exercises and/or practicle works
  - We will use discord
    - https://discord.gg/YPdVQ8uysT
  - We will use git/github (see below)
- Git
  - Create a new directory OS2020
  - Fork the course's git repository to your git account
    - https://github.com/hagimont/OS2020
  - Clone your forked repository to your OS2020 directory
    - git clone https://github.com/your-account/OS2020.git
  - Edit «README.md», add your names/emails
  - Commit and push

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

Abstract View of Components of Computer

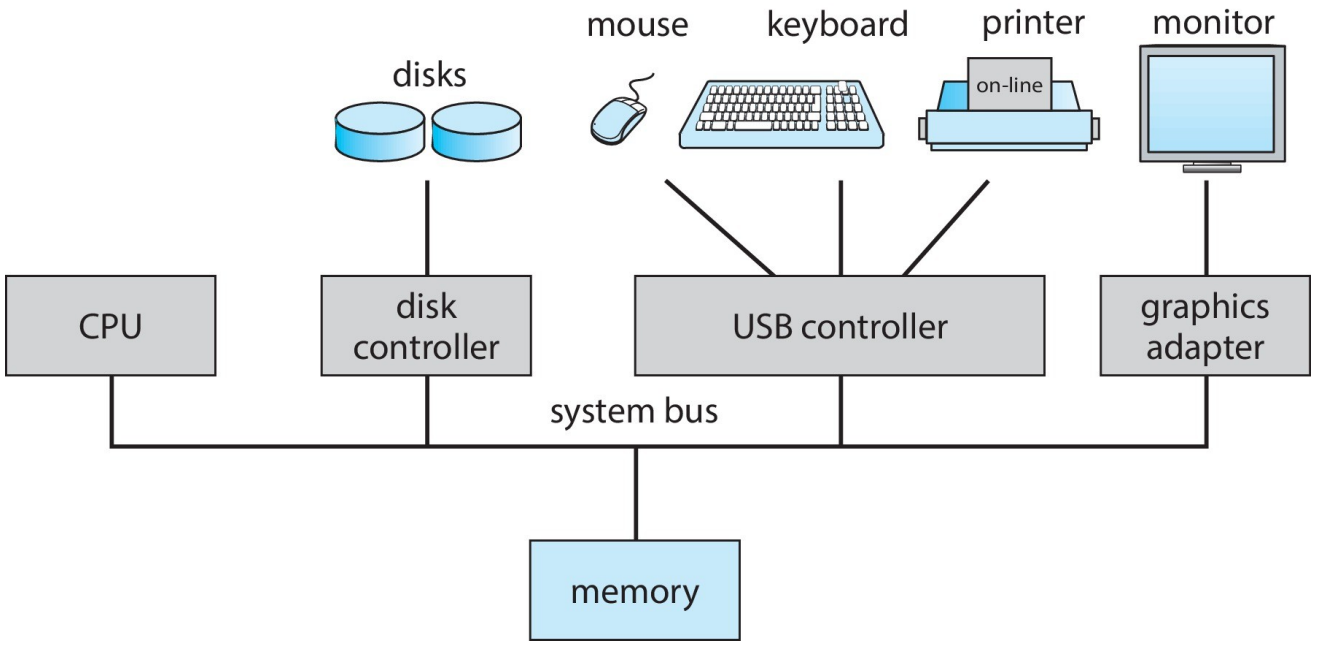


Computer System Structure

- 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
  - Application programs – solve the computing problems of the users
    - Word processors, compilers, web browsers, database systems, video games
  - Users
    - People, machines, other computers

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



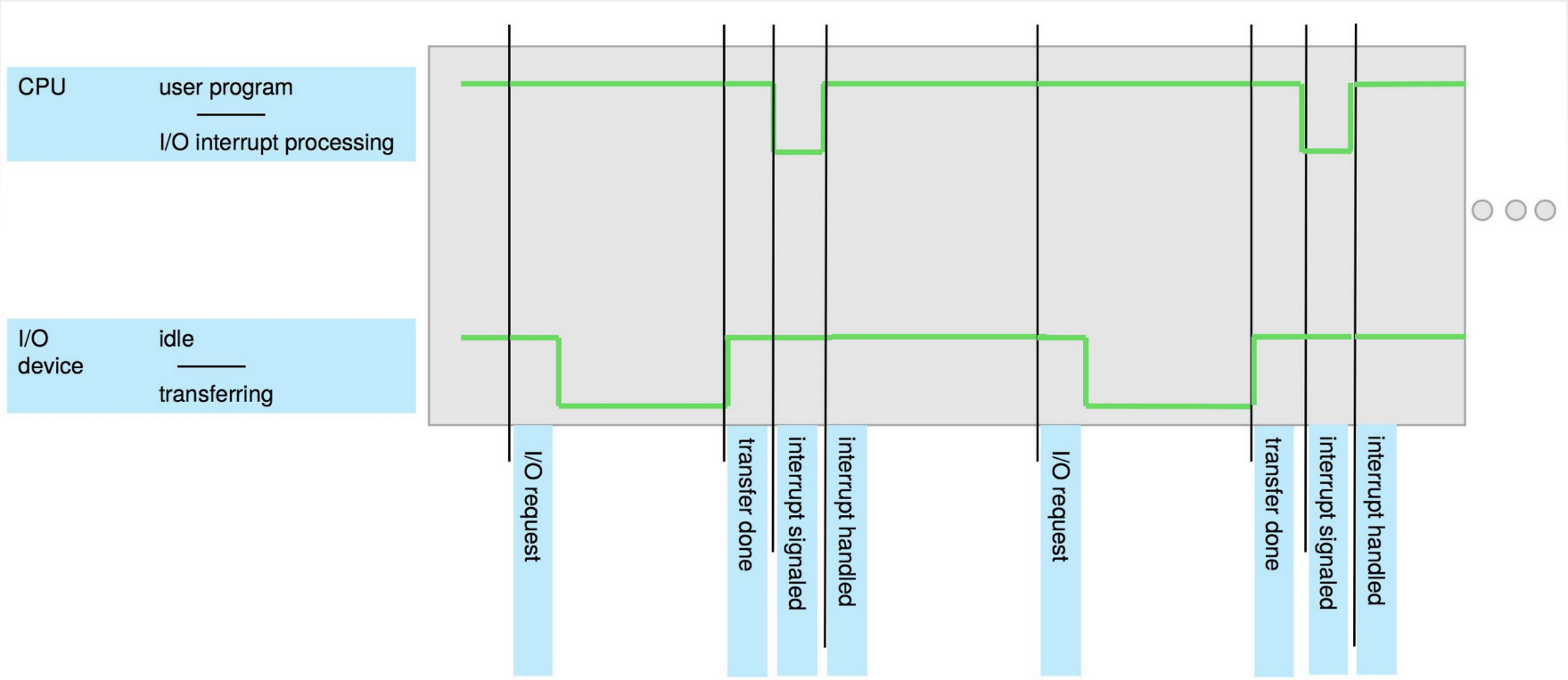
Computer-System Operation

- 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
- Each device controller type has an operating system device driver to manage it
- CPU moves data from/to main memory to/from local buffers (the buffer is generally mapped in memory)
- 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

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 (where it returns after handling)
- A trap or exception is a software-generated interrupt caused either by an error or a user request (system call)
- An operating system is interrupt driven

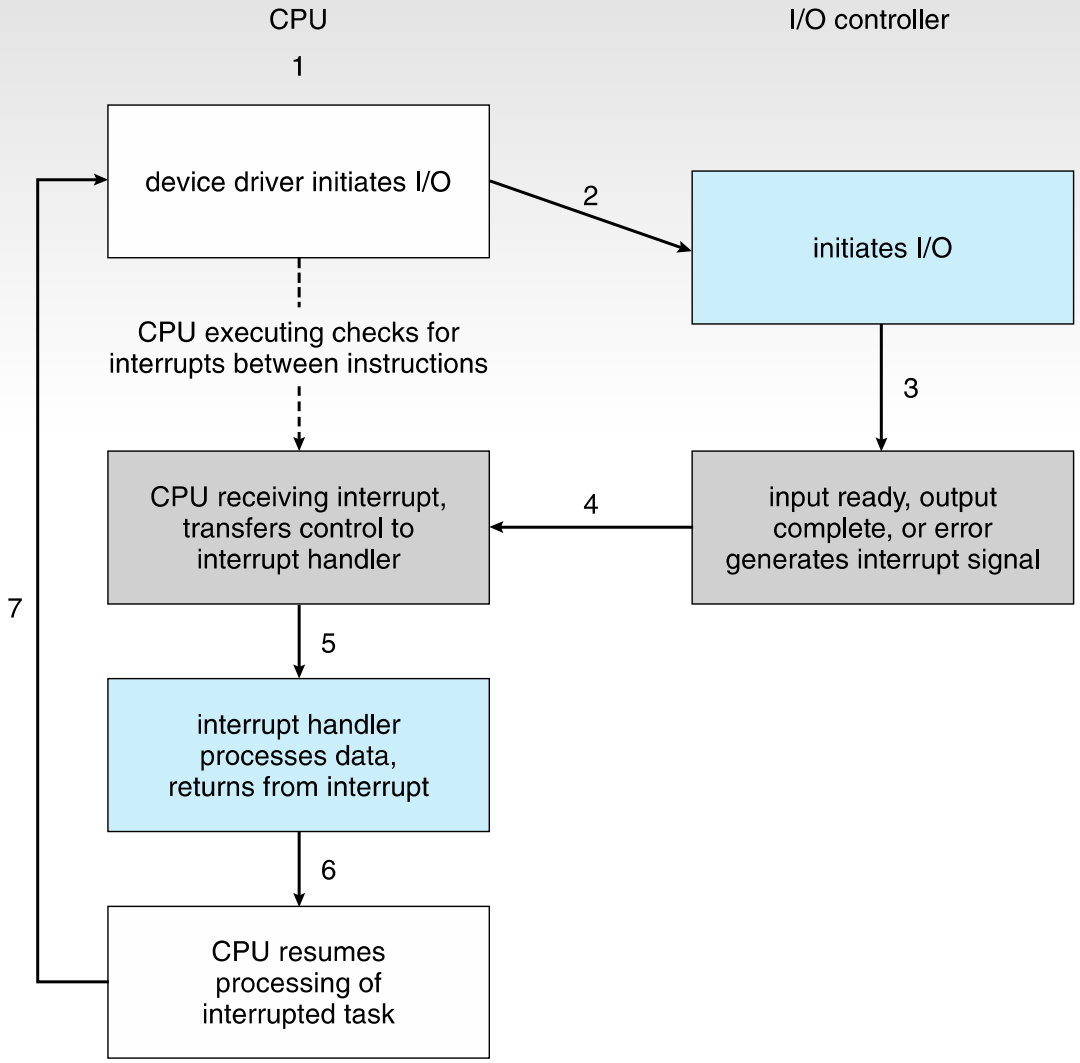
Interrupt: Timeline



Interrupt: Handling

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

Interrupt: I/O Cycle



Two methods for handling I/O

- Non-blocking
  - After I/O starts, control returns to user program without waiting for I/O completion
- Blocking
  - After I/O starts, control returns to user program only upon I/O completion
- Process blocking is implemented by the OS

Memory

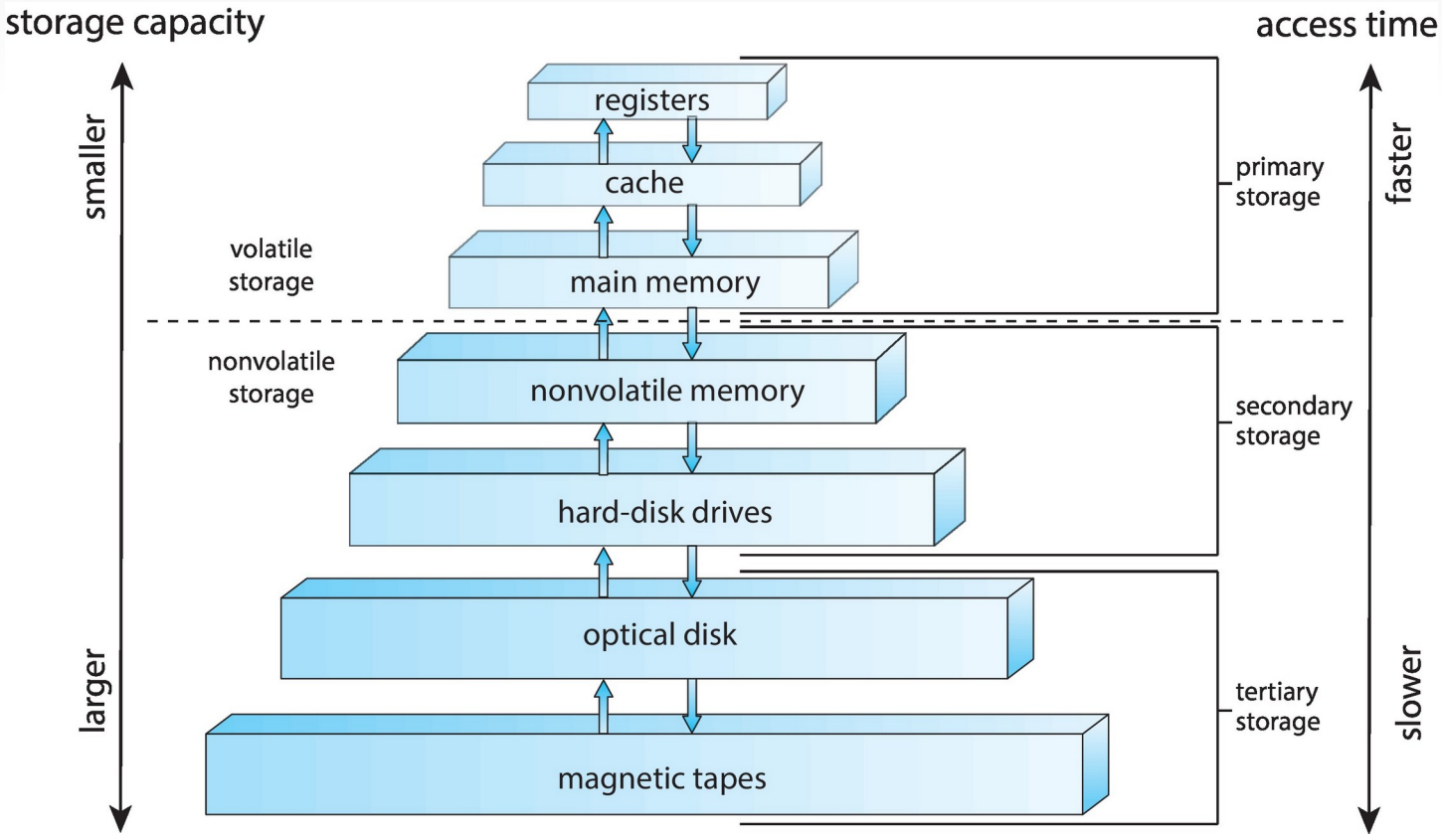
- Main memory – only large storage media that the CPU can access directly
  - Typically volatile
  - Typically random-access memory in the form of Dynamic Random-access Memory (DRAM)
- Secondary storage – extension of main memory that provides large non-volatile storage capacity

Secondary storage

- Hard Disk Drives (HDD) – 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
- Non-volatile memory (NVM) devices – faster than hard disks, nonvolatile
  - Various technologies
  - Becoming more popular as capacity and performance increases, price drops

Memory Hierarchy

- Caching – copying information into faster memory system; main memory can be viewed as a cache for secondary storage



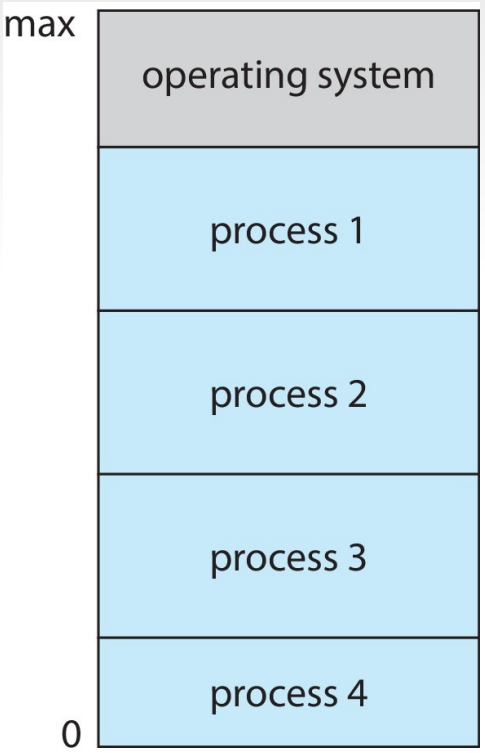
Multiprogramming (Batch system)

- Single user cannot always keep CPU and I/O devices busy
- 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 job has to wait (for I/O for example), OS switches to another job

Multitasking (Timesharing)

- A logical extension of Batch systems– the 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 - process
- If several jobs ready to run at the same time - CPU scheduling
- If processes don’t fit in memory, swapping (on disk) moves them in and out to run
- Virtual memory allows execution of processes not completely in memory

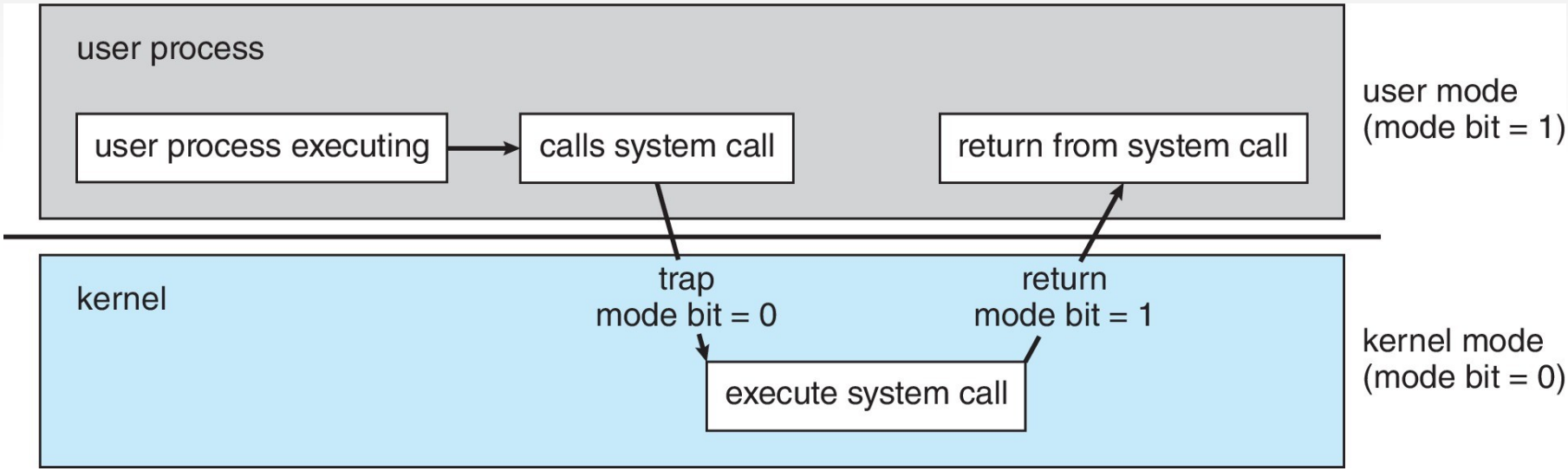
Memory Layout for Multiprogrammed System



OS protection: dual-mode operation

- 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.
  - When a user is running - mode bit is “user”
  - When kernel code is executing - mode bit is “kernel”
- How do we guarantee that user does not explicitly set the mode bit to “kernel”?
  - System call changes mode to kernel, return from call resets it to user
- Some instructions designated as privileged, only executable in kernel mode

Transition from User to Kernel Mode



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
- Each process has one program counter specifying location of next instruction to execute
  - Process executes instructions sequentially, one at a time, until completion
- 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

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

- To execute a program all (or part) of the instructions must be in memory
- All (or part) of the data that is needed by the program must be in memory
- Memory management determines what is in memory and 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

File-system Management

- OS provides uniform, logical view of information storage
  - Abstracts from physical 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 directories
    - Mapping files onto secondary storage
    - Backup files onto stable (non-volatile) storage media

Caching

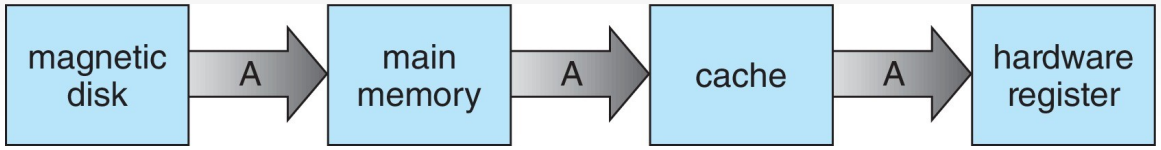
- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily
- Faster storage (cache) checked first to determine if information is there
  - If it is, information used directly from the cache (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

Characteristics of Various Types 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

Migration of data “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

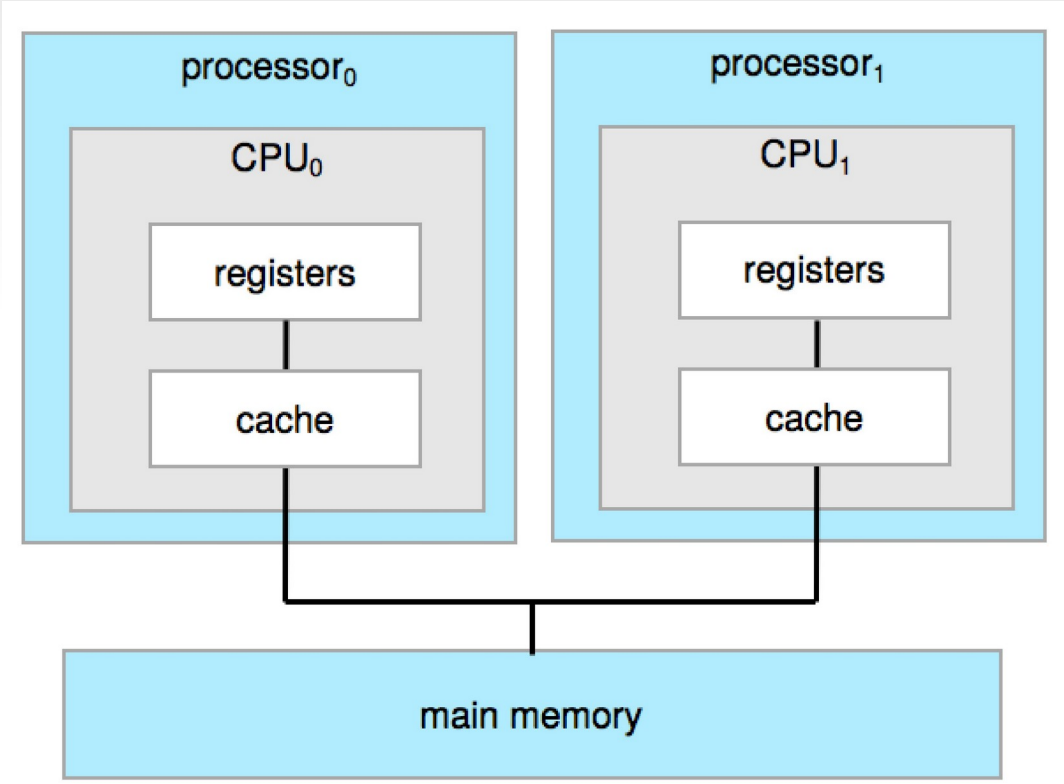
Protection and Security

- 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 (group 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

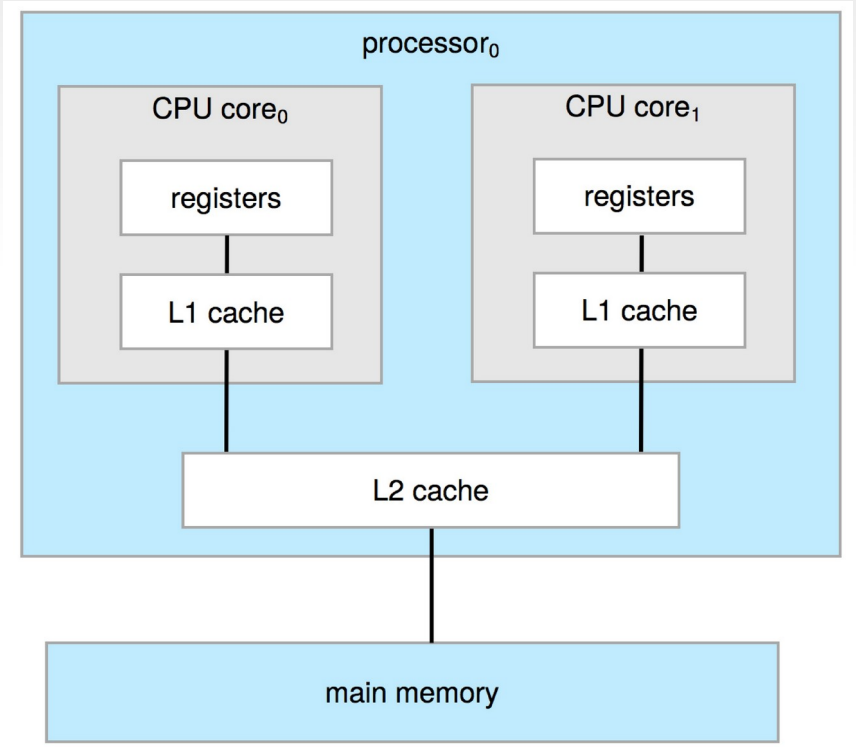
Computer-System Architecture

- Most systems use a single general-purpose processor
  - This processor can be multi-core
  - Most systems have special-purpose processors as well
- Multiprocessors systems growing in use and importance
  - Also known as parallel systems, tightly-coupled systems
  - Advantages include:
    - Increased throughput
    - Economy of scale
    - Increased reliability – graceful degradation or fault tolerance
  - Two types:
    - Asymmetric Multiprocessing – each processor is assigned a specific task
    - Symmetric Multiprocessing – each processor performs all tasks

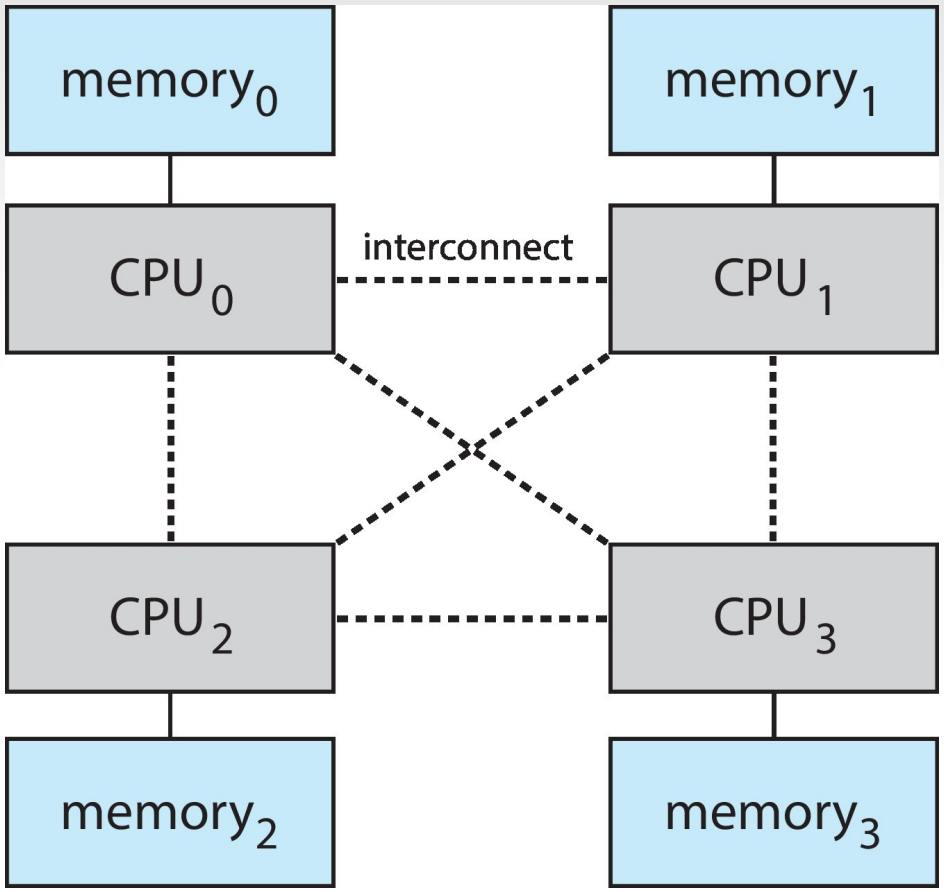
Symmetric Multiprocessing Architecture



Dual-Core Design



Non-Uniform Memory Access System



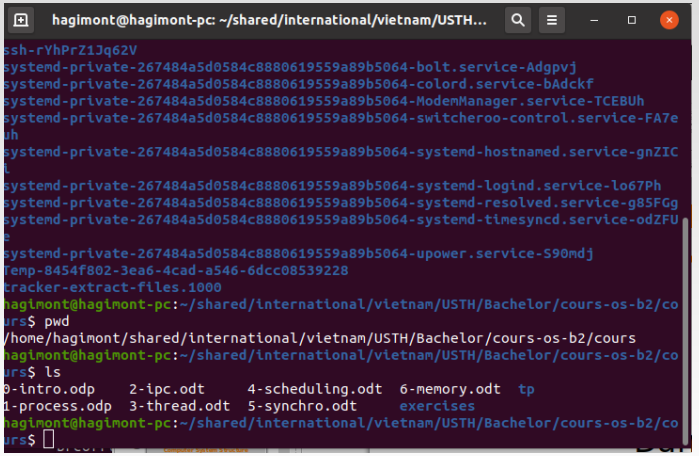
All memories are viewed as a unique memory range

Clustered Systems

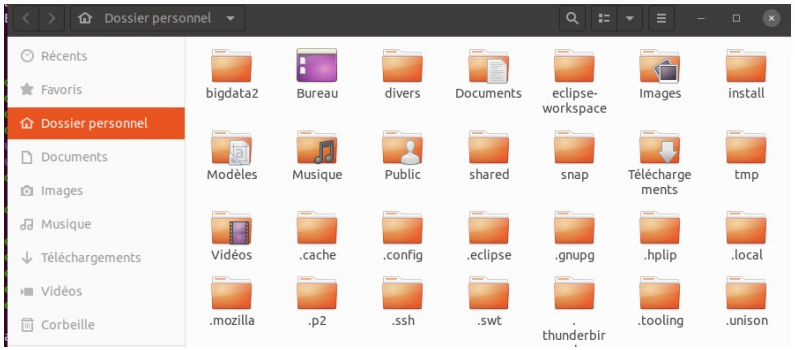
- Like multiprocessor systems, but multiple systems working together
  - Usually sharing storage via a storage-area network (SAN)
  - Provides a high-availability service which survives failures
    - Asymmetric clustering has one machine in hot-standby mode
    - Symmetric clustering has multiple nodes running applications, monitoring each other
  - Some type of clusters
    - High-performance computing (HPC)
    - Big data computing

System interface

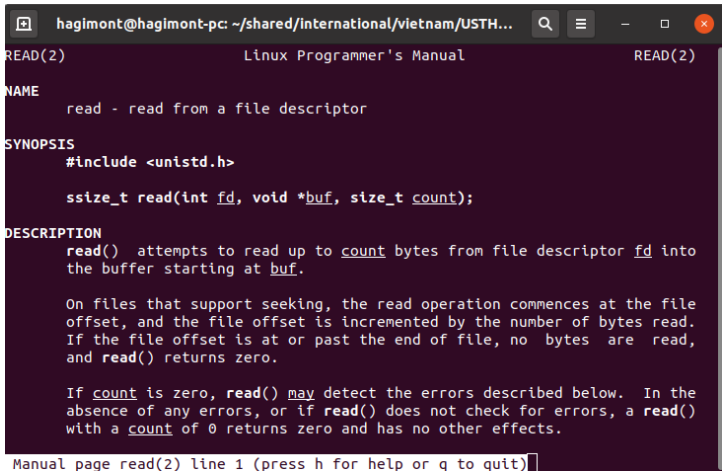
- Command Line Interpreter



- Graphical User Interface



- System APIs



Basic shell commands

Commands	Description
`man [command]`	Display user **man**ual for the specified command.
`cd /directorypath`	**C**hange **d**irectory.
`ls [opts]`	**Ls**t directory contents.
`cat [files]`	Display file's contents after cont**cat**enation.
`mkdir [opts] dir`	**Mk**e a new **dir**ectory.
`cp [opts] src dest`	**Cp**y files and directories.
`mv [opts] src dest`	Rename or **mv**e file(s) or directories.
`rm [opts] dir`	**Rm**ove files and/or directories.
`chmod [opts] mode file`	**Ch**ange a file's **mod**es (permissions).
`chown [opts] file`	**Ch**ange **own**er of a file.
`df [opts]`	Display **d**isk's **f**ree and used space.
`du [opts]`	Show **d**isk **u**sage that each file takes up.
`find [pathname] [expr]`	**Find** for files matching a provided pattern.
`grep [opts] pattern [file]`	Search files or output for a particular pattern.
`nano [file]`	**N**ano's **ano**ther editor

Basic shell commands

Commands	Description
`kill [opts] pid`	**Kill** a process.
`less [opts] [file]`	View the contents of a file one page at a time.
`ln [opts] src [dest]`	Create a shortcut. (**li**n**k**s)
`passwd`	Change your **passwor**d
`ps [opts]`	List **p**rocess **s**tatus.
`pwd`	**P**rint **w**orking **d**irectory
`ssh [opts] user@host [cmd]`	Remotely log in to another machine with **s**ecured **sh**ell
`su [opts] [user]`	**S**witch to another **u**ser account.
`head [opts] [file]`	Display the first n **head**ing lines of a file.
`tail [opts] [file]`	Display the last n **tail**ing lines of a file.
`tar [opts] file`	Store/Extract (and compress/decompress) **t**ape **ar**chives
`top`	Displays resources being used on your system.
`touch file`	Create an empty file with the specified name.
`who [opts]`	Display **who** is logged on.
`wget url`	Non-interactive network downloader

git/github

- To make it manageable, I propose that you constitute groups of 4
- Create a new directory OS2020
- Fork the course's git repository to your git account
  - https://github.com/hagimont/OS2020
- Clone your forked repository to your OS2020 directory
  - git clone https://github.com/your-account/OS2020.git
  - Edit «README.md», add your names/emails
  - Commit and push

Exercise (cmds)

- find
  - Find all the core file in a directory (recursively)
  - Remove them
- chmod
  - Make a binary executable or not
  - Make a directory accessible (with cd) or not
- grep
  - Find the occurences of a word in a file
- ps/kill
  - Create a process and kill it
- ln
  - Create a link to a file

Exercise (cmds)

- apt
  - Install a ssh server
- ssh
  - Connect to the ssh server of another student
- wget
  - Dowload a software from a web site
- tar
  - Uncompress an archive
  - Create an archive
- pipe
  - Count the number of firefox processes running