Operating System Concepts (cont’d)

Course Code: CSC 2209 Course Title: Operating Systems

Dept. of Computer Science
Faculty of Science and Technology

Lecturer No:	**02**	**Week No:**	**02**	**Semester:**	**Fall 2024-25**
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Lecture Outline

1. I/O Structure
2. Storage Structure
3. How a Modern Computer Works
4. Direct Memory Access Structure
5. Computer-System Architecture
6. A Dual-Core Design
7. Clustered Systems
8. Operating-System Operations
9. Multiprogramming and Multitasking
10. Dual-mode and Multimode Operation
11. Process Management
12. Memory Management
13. File-system Management
14. Caching

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 OS 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
  - OS indexes into **I/O device table** to determine device status and to modify table entry to include interrupt

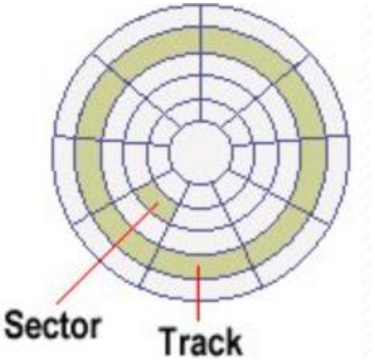
I/O Structure

Device-status table

Device ID	Device Type	Address	State
0	Disk Drive	0x1000	Busy
1	Printer	0x1001	Idle
2	Keyboard	0x1002	Ready
3	Network Card	0x1003	Error

Storage Structure

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

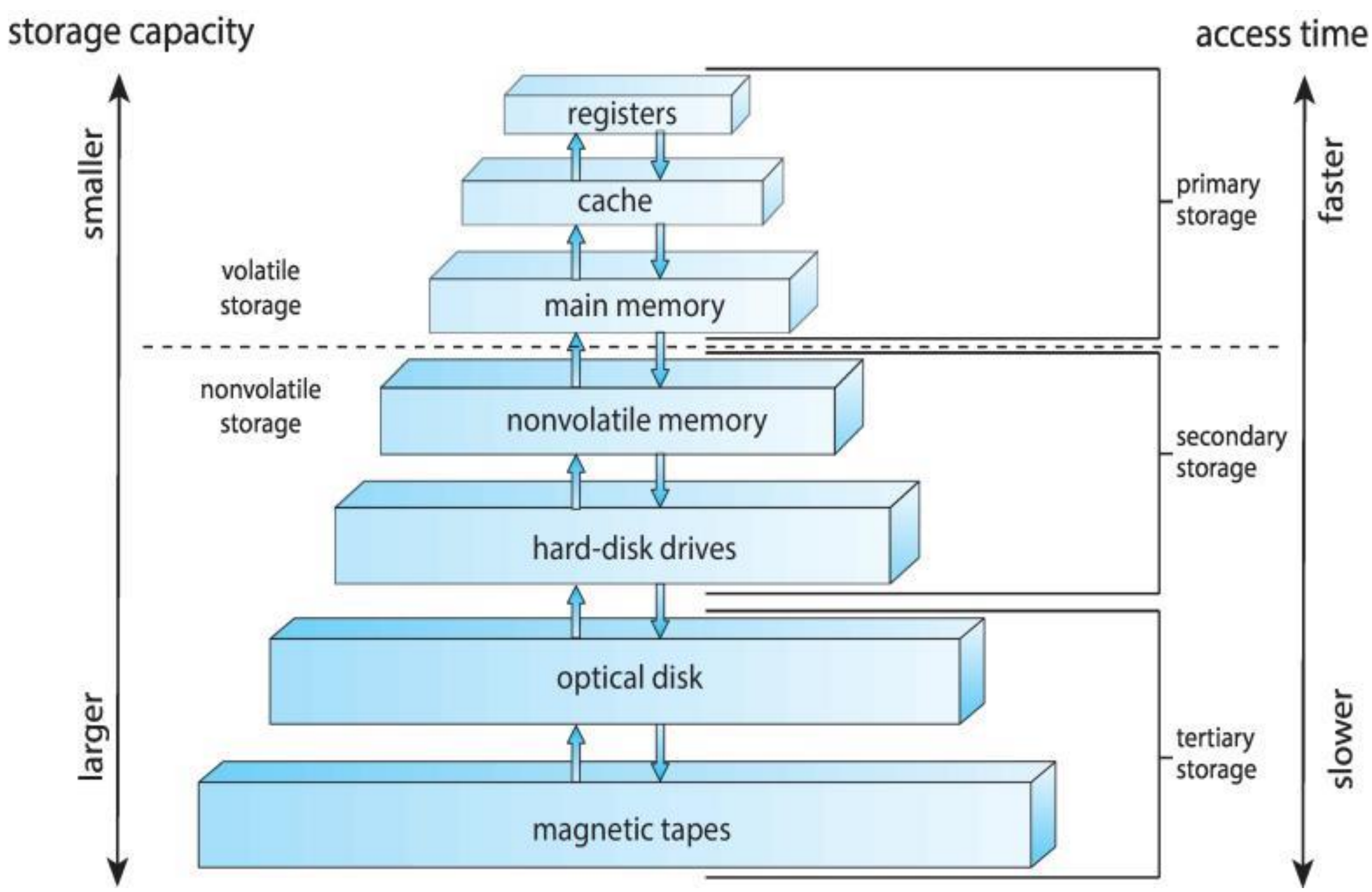


- **Non-volatile memory (NVM)** devices– faster than hard disks,
  - Various technologies
  - Becoming more popular as capacity and performance increases, price drops

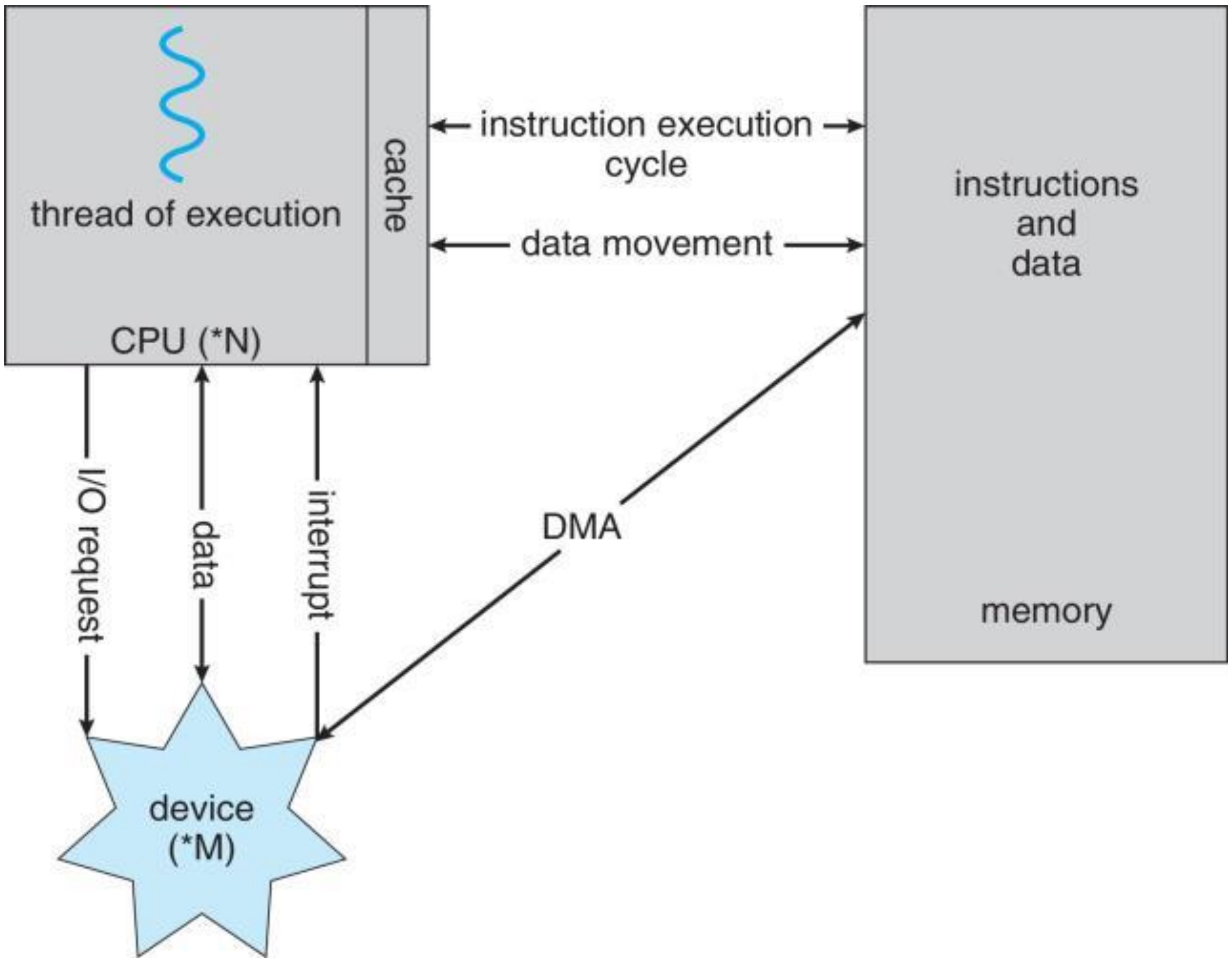
Storage Hierarchy

- Storage systems organized in hierarchy
  - Speed
  - Cost
  - Volatility
- **Caching** – copying information into faster storage system; main memory can be viewed as a cache for secondary storage
- **Device Driver** for each device controller to manage I/O
  - Provides uniform **interface between controller and kernel**

Storage-Device Hierarchy



How a Modern Computer Works



Direct Memory Access (DMA) Structure

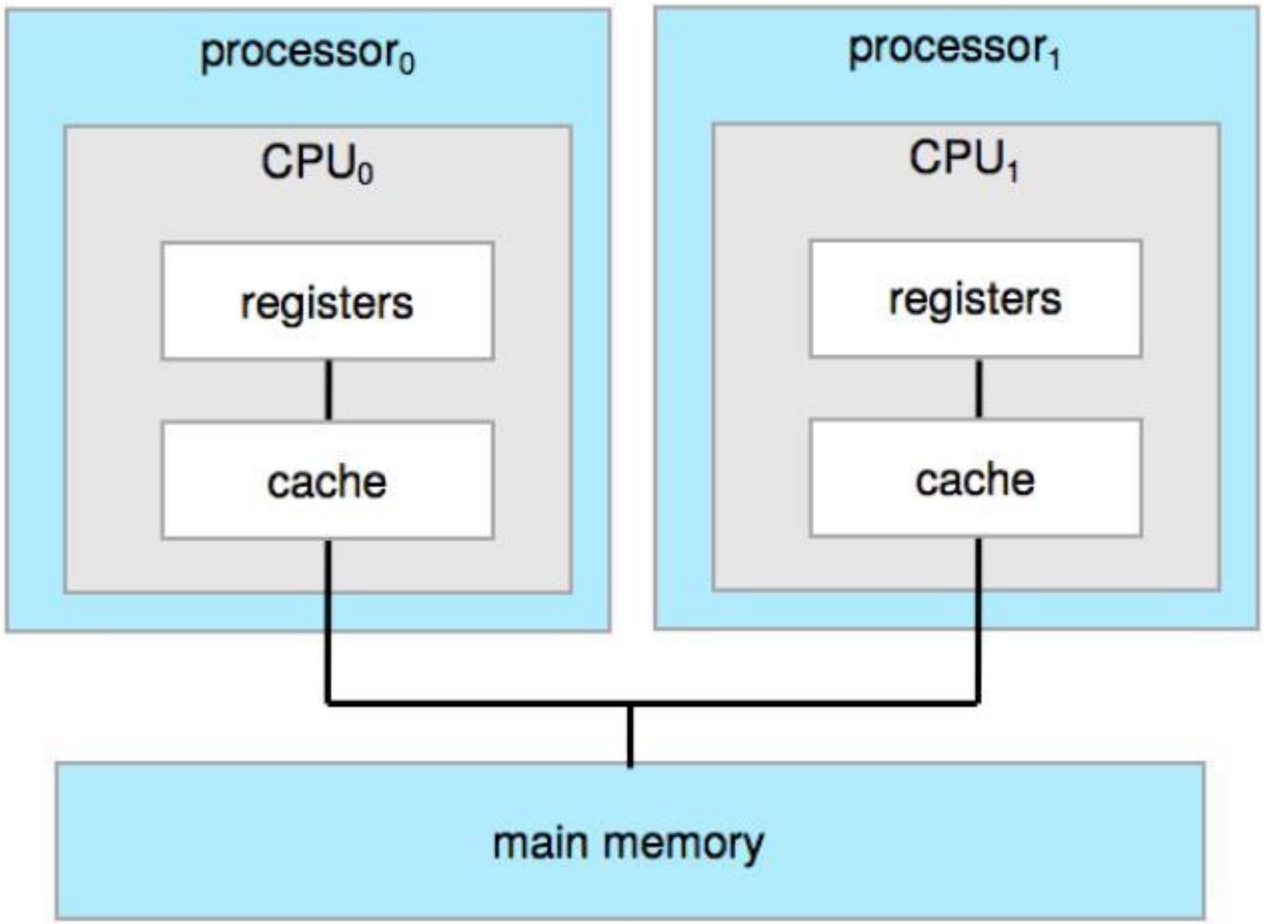
- Used for **high-speed I/O devices** able to **transmit information at close to memory speeds**
- Device controller **transfers blocks of data from buffer storage directly to main memory** without CPU intervention
- Only one interrupt is generated per block, rather than the one interrupt per byte

Computer-System Architecture

- Most systems use a single general-purpose processor
  - Most systems have special-purpose processors as well

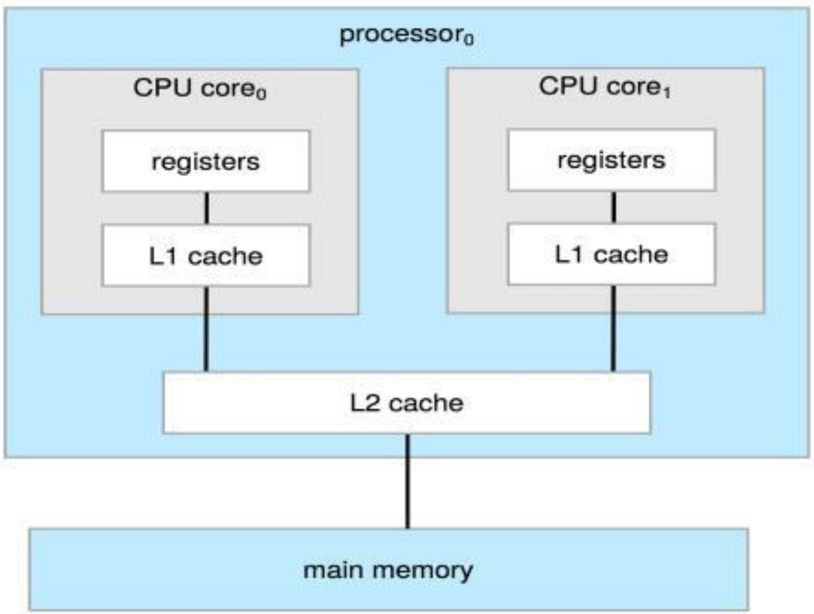
- **Multiprocessors** systems growing in use and importance
  - Also known as **parallel systems**, **tightly-coupled systems**
  - Advantages include:
    1. **Increased throughput**
    2. **Economy of scale**
    3. **Increased reliability** – graceful degradation or fault tolerance
  - Two types:
    1. **Asymmetric Multiprocessing** – each processor is assigned a specie task.
    2. **Symmetric Multiprocessing** – each processor performs all tasks

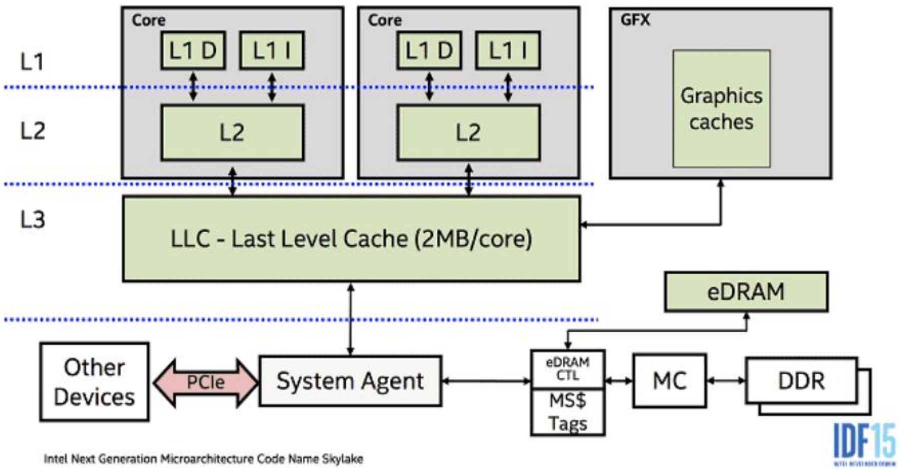
Symmetric Multiprocessing Architecture



A Dual-Core Design

- Multi-chip and **multicore**
- Systems containing all chips
  - Chassis containing multiple separate systems



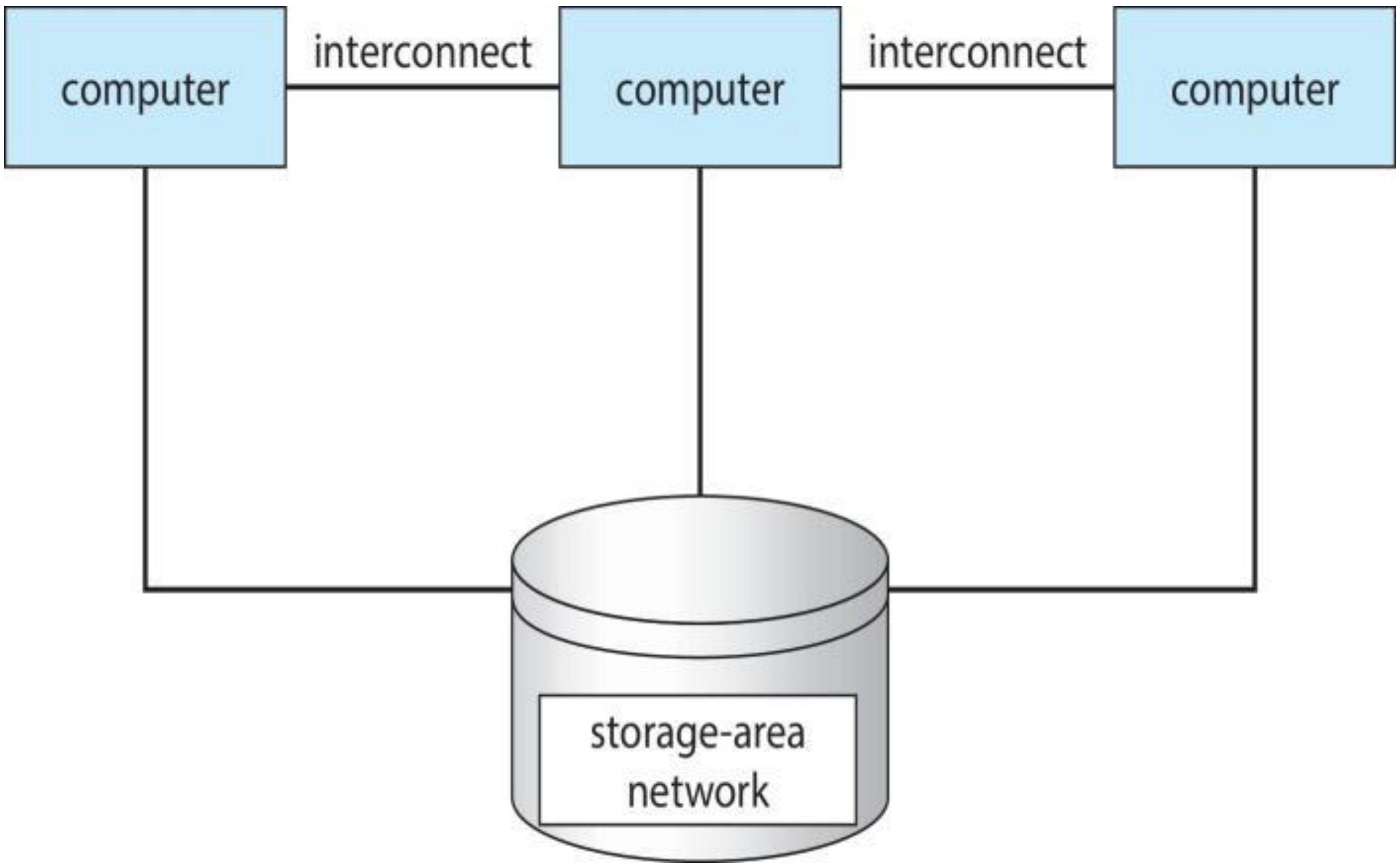


Cache Level	Speed	Size	Volatility	Purpose
L1 Cache	Fastest	16 KB - 128 KB	Volatile	Immediate access to data and instructions
L2 Cache	Fast	256 KB - 2 MB	Volatile	Buffer between L1 and L3/main memory
L3 Cache	Moderate	2 MB - 32 MB+	Volatile	Shared cache for multi-core CPUs

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 clusters are for **high-performance computing (HPC)**
    - Applications must be written to use **parallelization**
  - Some have **distributed lock manager** (**DLM**) to avoid conflicting operations

Clustered Systems



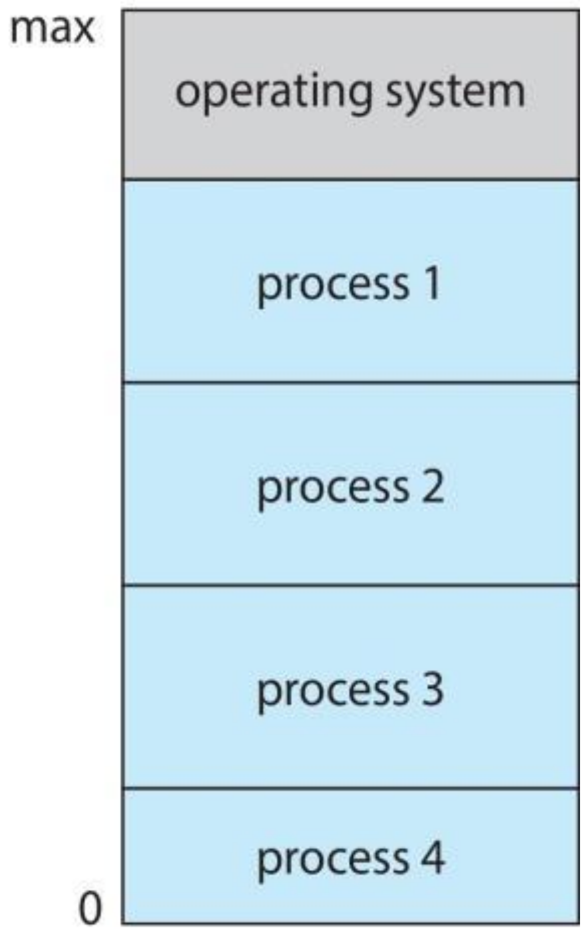
Operating-System Operations

- Bootstrap program – simple code to initialize the system, load the kernel
- Kernel loads
- Starts **system daemons** (services provided outside of the kernel)
- Kernel **interrupt driven** (hardware and software)
  - Hardware interrupt by one of the devices
  - Software interrupt (**exception** or **trap):**
    - Software error (e.g., division by zero)
    - Request for operating system service – **system call**
    - Other process problems include infinite loop, processes modifying each other or the operating system

Multiprogramming and Multitasking

- **Multiprogramming** (**Batch system**) 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 **process**
  - If several jobs ready to run at the same time **CPU scheduling**
  - If processes doesn'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



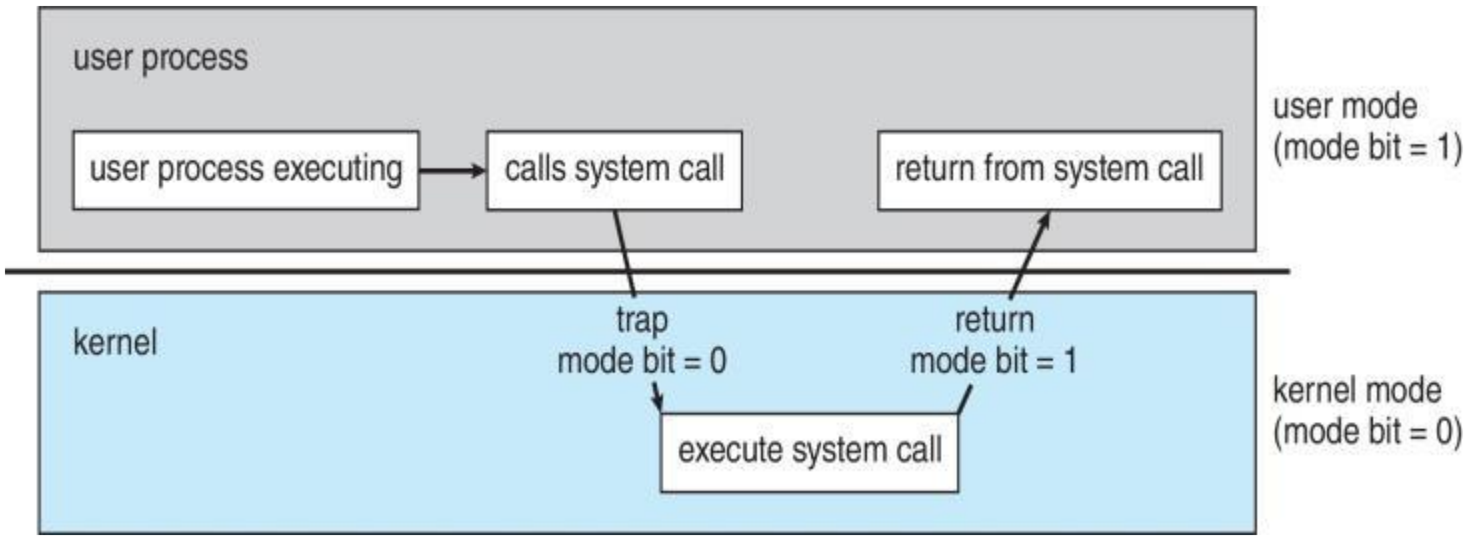
Dual-mode and Multimode Operation

- **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
    - Some instructions designated as **privileged**, only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user
- Increasingly CPUs support multi-mode operations
  - i.e. **virtual machine manager** (**VMM**) mode for guest **VMs**

Transition from User to Kernel Mode

- Timer to prevent infinite loop / process hogging resources
  - Timer is set to interrupt the computer after some time period
  - Keep a counter that is decremented by the physical clock
  - Operating system set the counter (privileged instruction)
  - When counter zero generate an interrupt
  - Set up before scheduling process to regain control or terminate program that exceeds allotted time

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
- **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

- 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

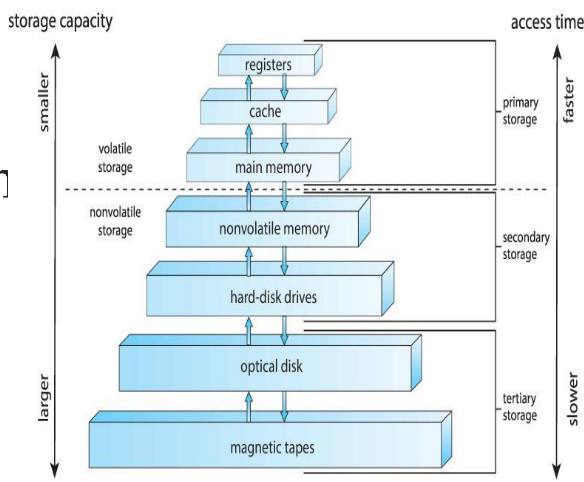
File-system Management

- OS provides uniform, logical view of information storage
  - Abstracts 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 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



Books

- Operating Systems Concept
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  - Edition: 9th

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