II-B.E. IV-SEMESTER

Operating Systems (OS)

Presented By

Dr. D. BASWARAJ

Professor, CSE DEPT.

VCE, HYDERABAD

COURSE OBJECTIVES

- Understand Operating system Structures, Services and threading models.
- Learn operating system services by considering case studies such as Linux, Windows and Android.

COURSE OUTCOMES

1. Explain Operating system structures and internal structure of a process and operations on a process.
2. Compare CPU scheduling algorithms and apply contiguous & non- contiguous techniques for main memory management.
3. Design solutions for classical synchronization problems and describe deadlock handling methods.
4. Explain file system Implementation and device management.
5. Explain I/O operation implementation techniques and apply Access matrix for system protection. Describe the features of Linux, Windows and Android Operating systems.

SYLLABUS

UNIT – I: Introduction to operating systems: Definition, User view and System view of the Operating system, Computer- system organization, Computer-system architecture, Operating system structure, Operating system operations, Operating system services, System calls

Process: Process concept, Process Scheduling, Operations on process, Inter-process communication, Threads, Multithreading Models, Multicore programming.

UNIT – II: CPU Scheduling: Scheduling Criteria, Scheduling Algorithms, Multiprocessor scheduling.

Memory Management: Swapping, Contiguous memory allocation, Paging, Segmentation, Structure of the page table.

Virtual memory: Demand paging, Page replacement Algorithms, Thrashing.

SYLLABUS…

UNIT – III: Process synchronization: The critical Section problem, Peterson's solution, Synchronization Hardware, Semaphores, Classic problems of Synchronization, Monitors.

Deadlocks: System model, deadlock characterization, Methods for handling deadlocks, Deadlock Prevention, Deadlock Avoidance, Deadlock Detection, Recovery from deadlock.

UNIT – IV: File System Interface: File Concept, Access Methods, Directory and Disk Structure

File System Implementation: File-System Structure, File-System Implementation, Directory Implementation, Allocation Methods, Free Space management.

Device Management: Disk Structure, Disk Attachment, Disk Scheduling, Disk Management, Swap Space Management, RAID structure.

SYLLABUS …

UNIT – V:

I/O System: I/O hardware, Application I/O Interface, Kernel I/O Subsystem, Transforming I/O request to hardware operation.

Protection: Goals of protection, Principles of protection, Domain of protection, Access matrix, Implementation of Access matrix

Case Studies: Linux System: Design Principles, Kernel Modules, Process Management, Scheduling Windows - Design Principles, System components ,File system Android: Architecture, Activity and Service life cycle.

SYLLABUS …

Learning Resources:

1. Abraham Silberschatz, Peter B. Galvin, Greg Gagne, *Operating System Concepts*, 9th Edition (2016), Wiley India.
2. Andrew S. Tanenbaum, *Modern Operating Systems*, 2nd Edition (2001), Pearson Education, Asia.
3. Dhananjay, Dhamdhere. M, *Operating System-concept based approach*, 3rd edition (2009), Tata McGraw Hill, Asia
4. Robet Love: *Linux Kernel Development*, (2004)Pearson Education
5. Richard Stevens, Stephen Rago, *Advanced Programming in the UNIX Environment*, 3rd Edition(2013), Pearson Education.

SYLLABUS …

Learning Resources:

1. http://web.stanford.edu/~ouster/cgi-bin/cs140-spring19/index.php
2. https://nptel.ac.in/courses/106106144/
3. https://pages.cs.wisc.edu/~bart/537/lecturenotes/titlepage.html
4. https://www.ics.uci.edu/~ics143/lectures.html
5. http://williamstallings.com/Extras/OS-Notes/notes.html

UNIT-I

PART-1: Introduction to operating systems

1. Definition, User view and System view of the Operating system
2. Computer- system organization and architecture
3. Operating system structure and operations
4. Operating system services, System calls

PART-2: Process:

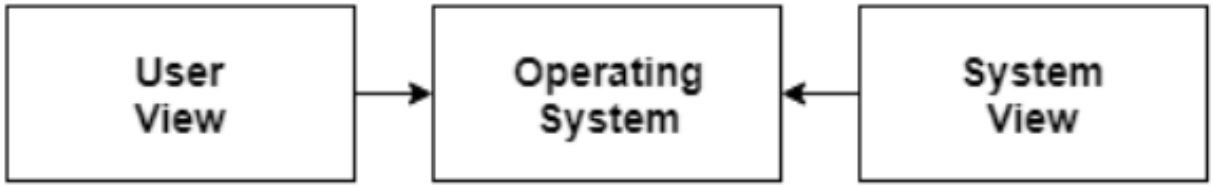
5. Process concept, Process Scheduling
6. Operations on process
7. Inter-process communication
8. Threads, Multithreading Models
9. Multicore programming

1. Definition, User view and System view of the Operating system

- **OS Definition:** OS is a software 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
- An operating system is a construct that allows the user application programs to interact with the system hardware.
- Operating system by itself does not provide any function but it provides an atmosphere in which different

Definition, User view and System view of the Operating system…

- The operating system can be observed from the point of view of the user or the system. This is known as the user view and the system view, respectively.



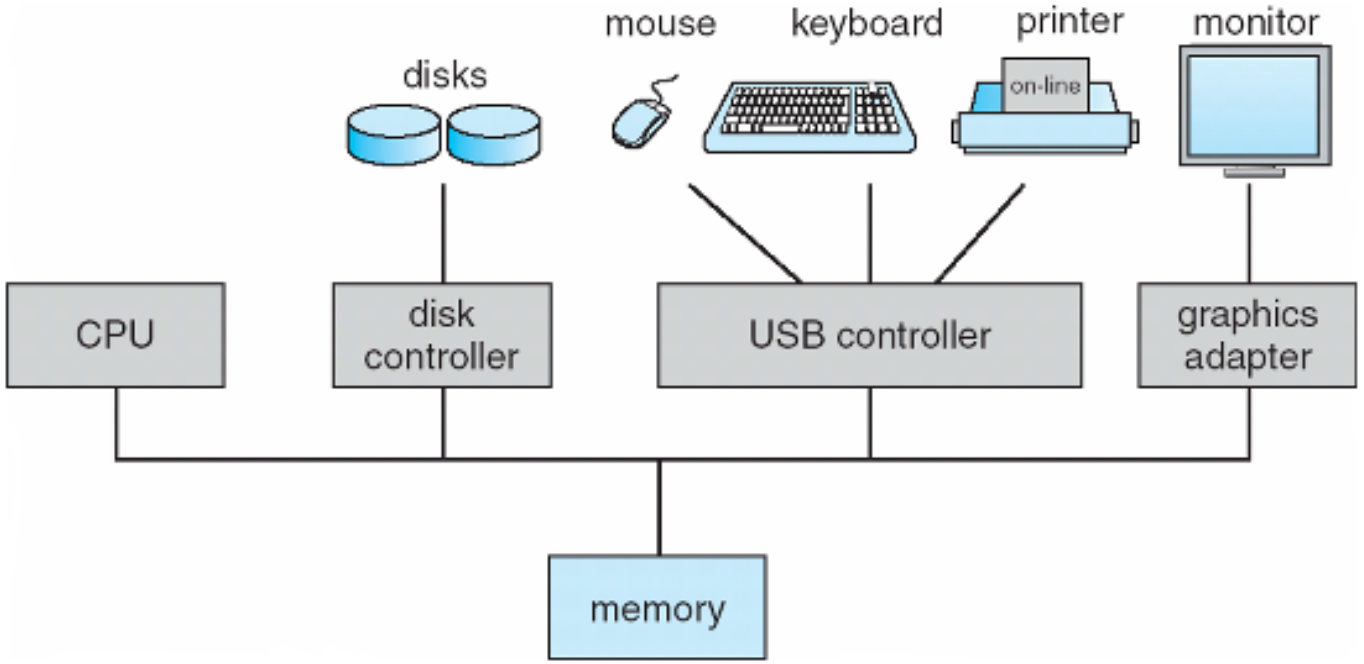
- **User View:** It depends on the system interface that is used by the users. The different types of user views are:
  - If the user using a PC, the OS is largely designed to make the **interaction** easy and efficient to improve the performance of the system.
  - If the user is using a PC, connected to a server, the OS is largely concerned with **resource utilization**.
  - If the user is sitting on a workstation connected to other workstations through networks, then the OS needs to focus on both individual **usage of resources and sharing** though the network.
  - If the user is using a handheld computer such as a mobile, then

Definition, User view and System view of the Operating system…

- **System View:** According to the computer system, the operating system is the bridge between applications and hardware.
- It is most intimate with the hardware and is used to control it as required. The different types of system view for operating system can be explained as follows:
  - The system views the OS as a **resource allocator**. There are many resources such as CPU time, memory space, file storage space, I/O devices etc. that are required by processes for execution.
  - An OS can also work as a **control program**. It manages all the processes and I/O devices so that the system works smoothly and there are no errors.
  - An OS can also be viewed to make using hardware easier.
  - An OS were developed to easily **communicate** with the hardware.
  - An OS can also be considered as a **program** always running in

2. Computer- System Organization and Architecture

- **Computer- System Organization:**
- Computer-system consists of One or more CPUs, device controllers connect through common bus providing access to shared memory.
- Concurrent execution of CPUs and devices competing for memory



Computer- System Organization and Architecture…

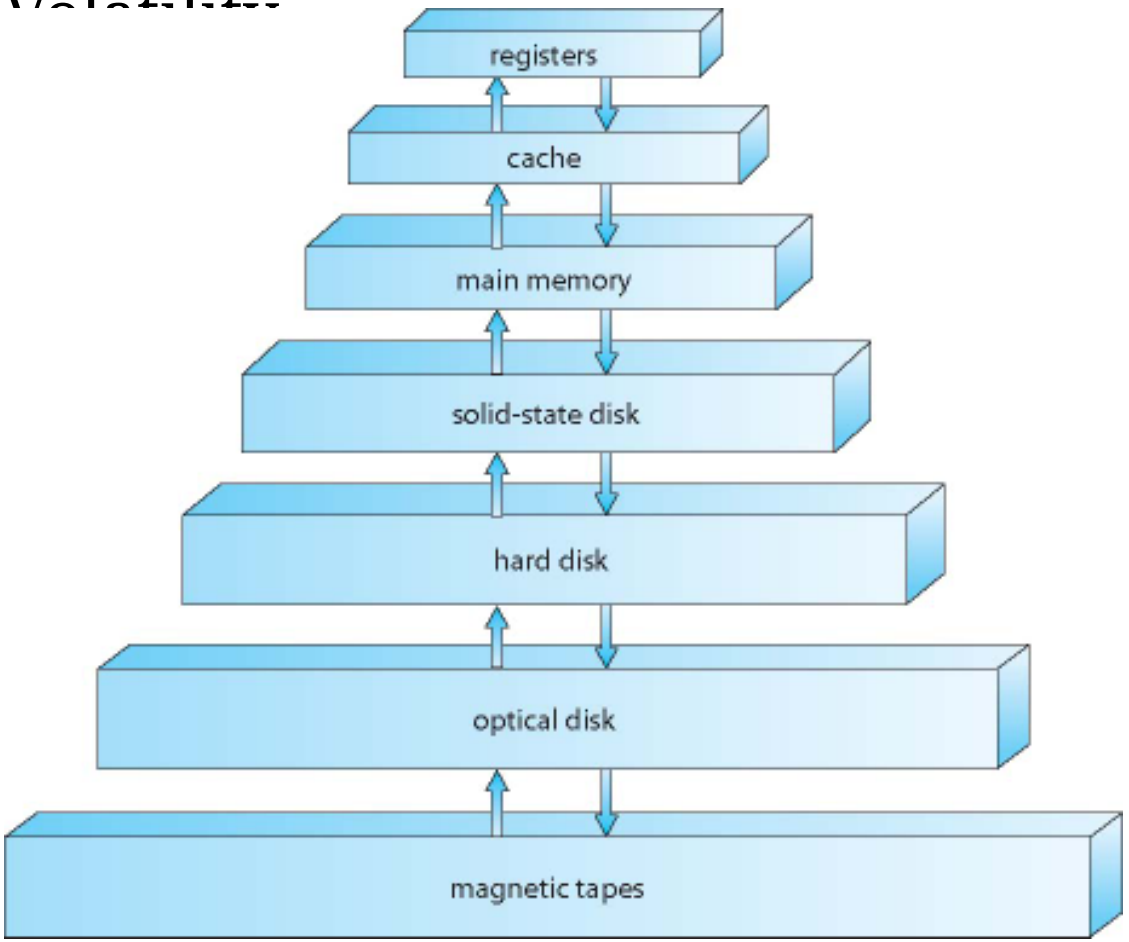
- **I/O Structure:**
- After I/O starts, control returns to user program only upon I/O completion
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access)
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing
  - **System 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

Computer- System Organization and Architecture…

- **Storage Structure:**
- Main memory – only large storage media that the CPU can access directly
  - **Random access,** Typically **volatile**
- Secondary storage – extension of main memory that provides large **nonvolatile** storage capacity
- Hard 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
- **Solid-state disks** – faster than hard disks, nonvolatile
  - Various technologies
  - Becoming more popular

Computer- System Organization and Architecture…

- **Storage Hierarchy:** Storage systems organized in hierarchy
  - Speed, Cost, Volatility

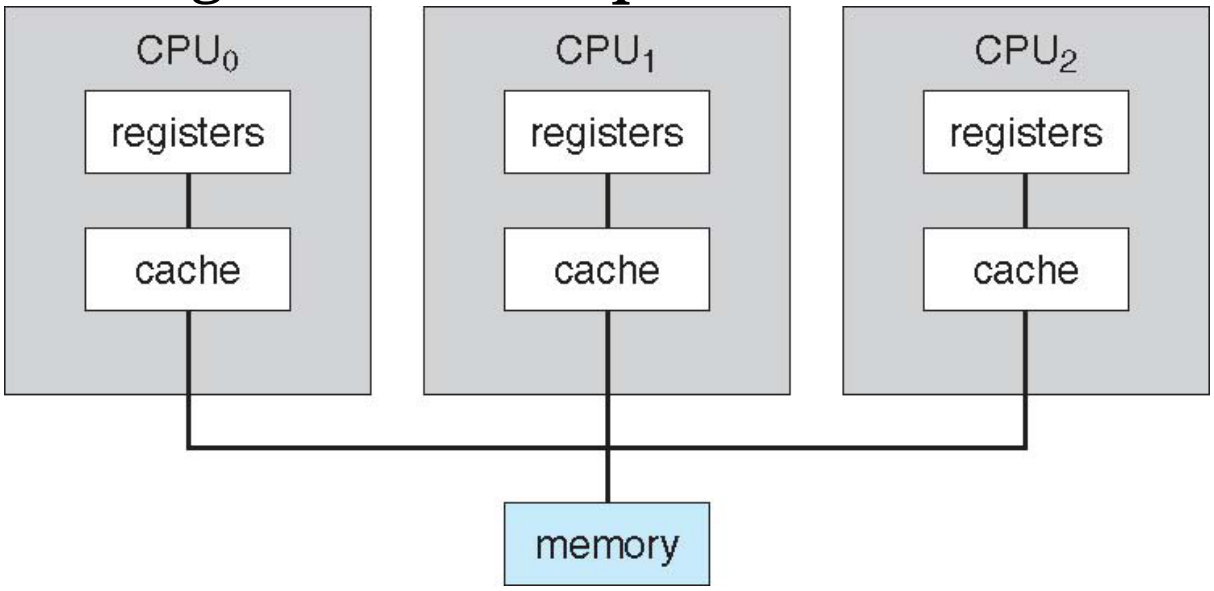


Computer- System Organization and Architecture …

- **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

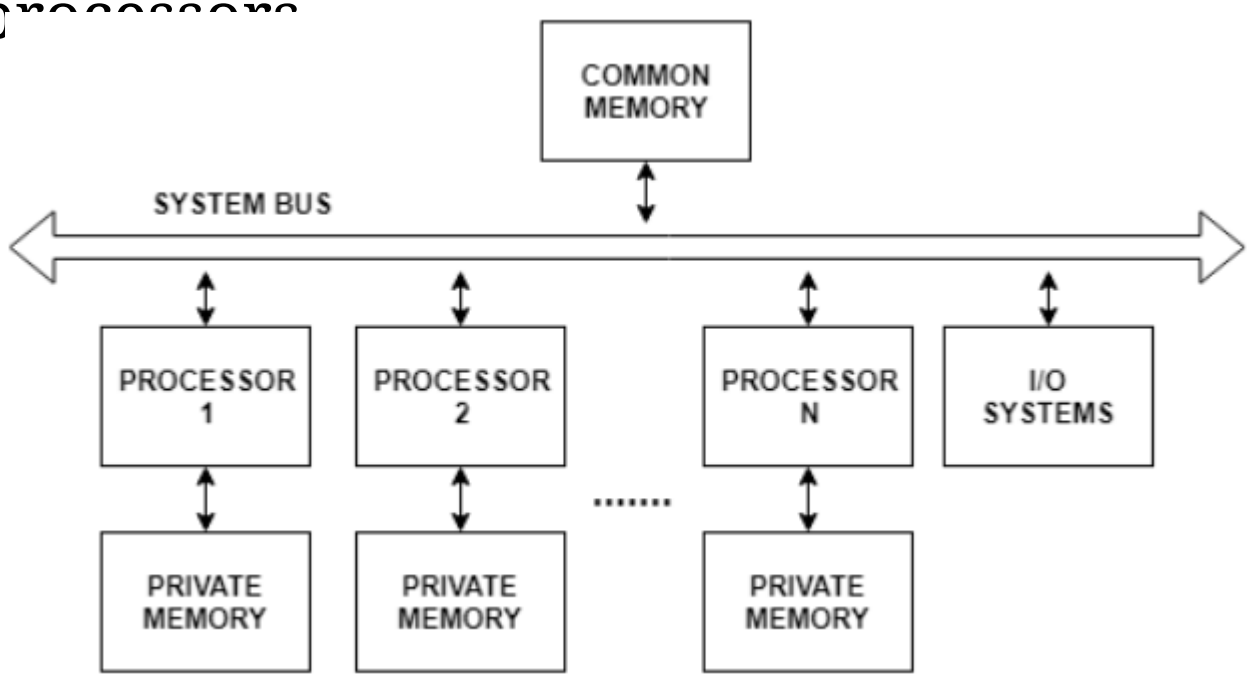
Computer- System Organization and Architecture …

- **Symmetric Multiprocessing Architecture:**
- It involves a multiprocessor computer hardware and software architecture where two or more identical processors are connected to a single, shared main memory, have full access to all I/O devices.
- In other words, Symmetric Multiprocessing is a type of multiprocessing where each processor is self-scheduling.



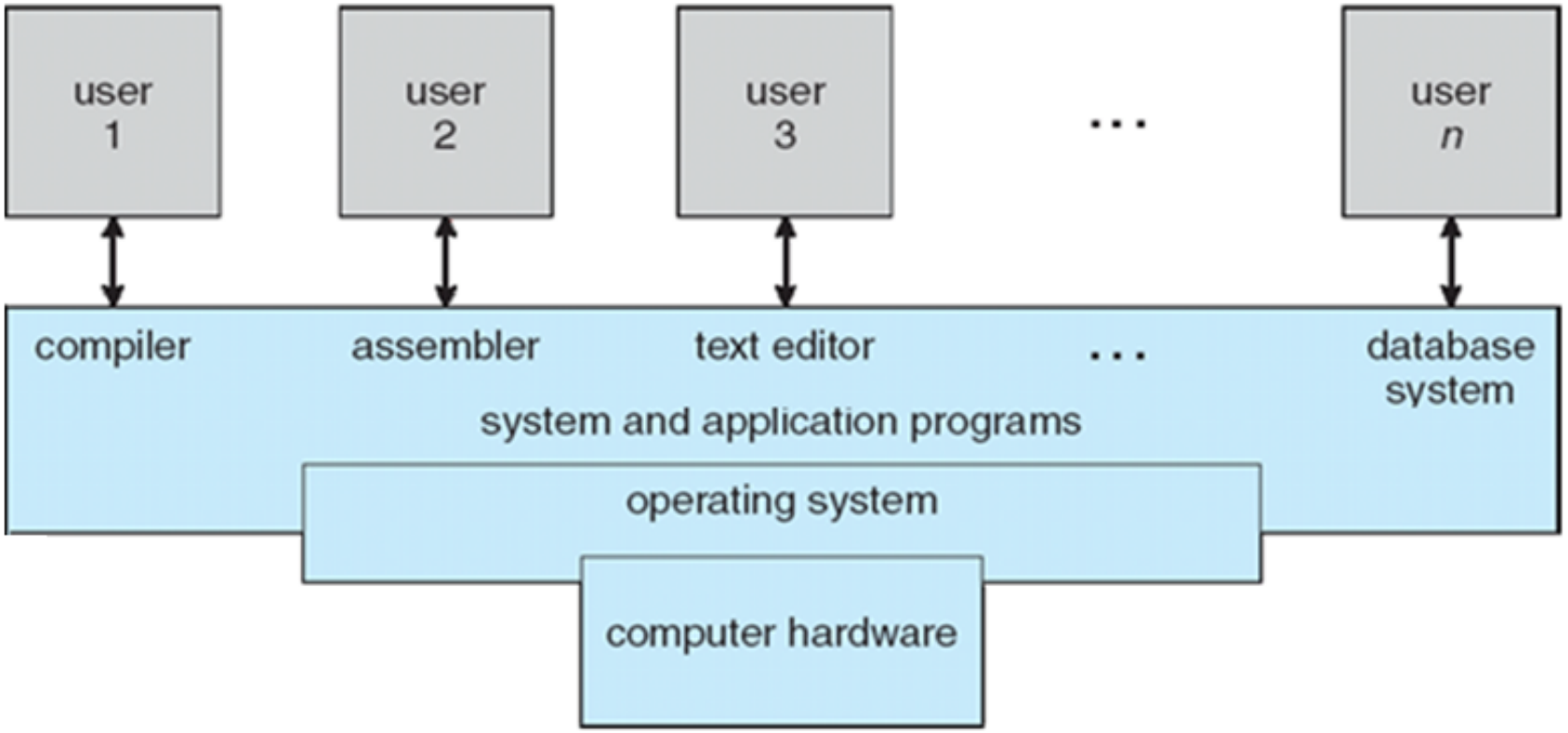
Computer- System Organization and Architecture …

- **Asymmetric Multiprocessing Architecture:**
- In this, all the processors are not treated equally. For example, one processor may handle only I/O related operations, and another may handle only OS code.
- In this, the processors may have a master- slave relationship i.e., a processor may assign processes to other processors



3. Operating system structure and operations

- **Computer System Structure:**
  - Computer system can be divided into four components



Operating system structure and operations …

- **Four Components of a Computer System:**
  - ***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:***
    - 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.

Operating system structure and operations …

- **Other Definitions of OS**:
- No universally accepted definition
- "The one program running at all times on the computer" is the **kernel.** Everything else is either a system program or an application program
- 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 structure and operations …

- **Operating Systems Structure**:
- An operating system provides the environment within which programs are executed.
- Internally, operating systems vary greatly in their makeup, since they are organized along many different lines.
- Operating systems have evolved because of new technologies, new applications, new services and needs.
- There are, however, many commonalities, which we consider in this section.
  - Serial Processing
  - Simple Batch Processing
  - Multi-programmed Batch Systems
  - Time-Sharing Systems
  - Distributed Processing Systems …

Operating system structure and operations …

- **Serial Processing:** It is early version, were
  - Machines run from a console with display lights and toggle switches, input device, and printer
  - Schedule time
  - Setup included loading the compiler, source program, saving compiled program, and loading and linking
- **Simple Batch Processing:** It Monitors
  - Software that controls the running programs
  - Batch jobs together
  - Program branches back to monitor when finished
  - Resident monitor is in main memory and available for execution

Operating system structure and operations …

- **Multiprogramming (Batch system)** needed for efficiency
  - 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 it must 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**

Operating system structure and operations ...

Distributed Processing Systems or Parallel Processing:

Tightly Coupled Systems

- there are multiple processors
- these processors share same main memory and I/O facilities
- All processors can perform the same functions
- Symmetric model – each processor runs on identical copy of OS
- Asymmetric model – unlike symmetric e.g., master/slave system

Loosely Coupled Systems

- There are multiple processors, do not share memory and I/O facilities
- provides the illusion of a single main memory and single secondary memory space
- Distribute computation among several processors.
- Processor communicates with each other through communication lines

Operating system structure and operations ...

Operating Systems Operations:

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
  - Other process problems include infinite loop, processes modifying each other or the operating system

Dual-mode operation allows OS to protect itself and other system components - **User mode** and **kernel mode** (supervisor mode, system mode, or privileged mode)

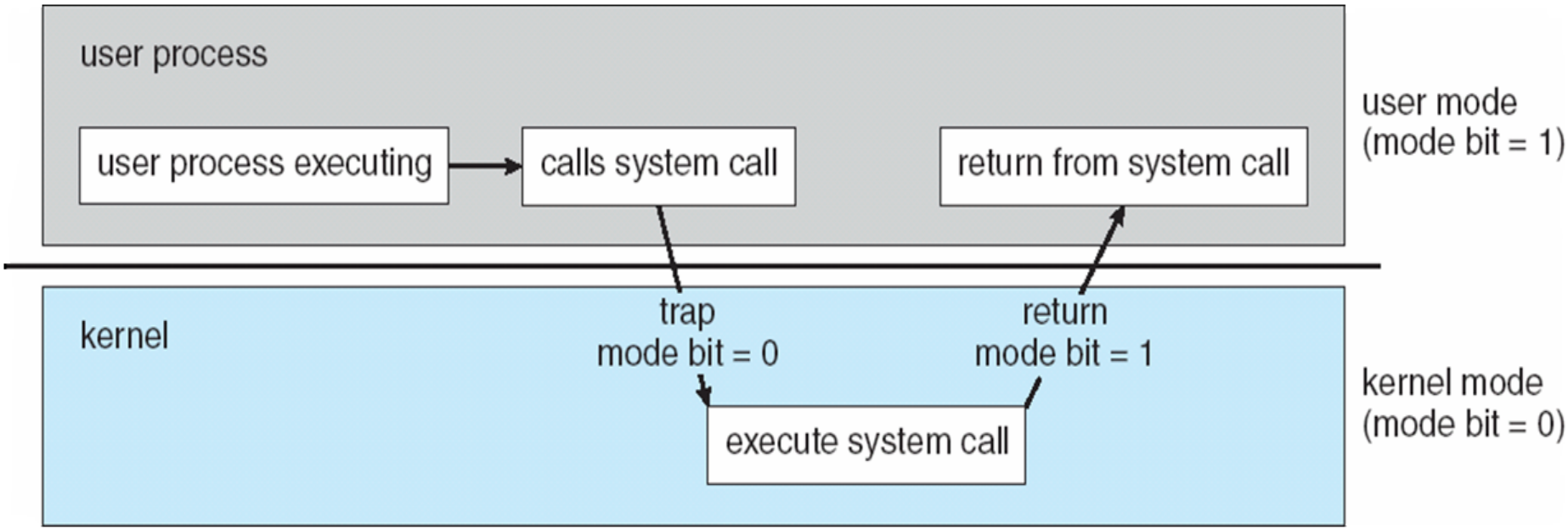
- **Mode bit** provided by hardware, used to distinguish when system is running user code or kernel code. Some instructions designated as **privileged**, only executable in kernel mode.
- System call changes mode from kernel to user mode and vice-versa.

Operating system structure and operations ...

Operating Systems Operations...

Increasingly CPUs support multi-mode operations for example, **virtual machine manager** (**VMM**) mode for guest **VMs**

Following figure depicts transition from one to other Mode:



System Components of OS

- We can create a system as large and complex as an OS only by partitioning it into smaller pieces.
- Each of these pieces should be well-delineated portion of the system, with carefully defined inputs, outputs, and functions.
- However, many modern OS share the goal of supporting the types of system components outlined below:
  - Process Management
  - Main-Memory Management
  - File Management
  - Secondary-Storage or Mass-Storage Management
  - I/O System Management
  - Networking
  - Protection systems
  - Command-Interpreter Systems

System Components of OS…

- **Process Management:**

– A process is the unit of work in a system i.e., a process is a program in execution.

– A system consists of a collection of processes, some of which are OS-processes (those that execute system code) and the rest of which are user- processes (those that execute user code).

– Program is a ***passive entity;*** process is an ***active entity***. Process needs resources to accomplish its task like CPU, memory, I/O etc.

– A thread refers to a single sequential flow of activities being executed in a process. In other words, thread is often referred to as a lightweight process. The process may be split down into so many threads.

– Single-threaded process (or simply 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 and OS running concurrently on one or more CPUs by multiplexing the CPUs among the processes / threads.

System Components of OS…

- **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

System Components of OS…

- **Main-Memory Management:**
  - The main memory is central to the operation of a modern computer system. It is a repository of quickly accessible data shared by the CPU and I/O devices.
  - All data resided in memory before and after processing
  - All instructions resided in memory in order to execute
  - Memory management determines what is in memory and when to be accessed, so as to optimizing CPU utilization and computer response.
- **Main-Memory 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 de-allocating memory space as needed.

System Components of OS…

- **File 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)
  - Files usually organized into directories
  - Access control on most systems to determine who can access what
- **File Management Activities :**
  - Creating and deleting files and/or directories
  - Primitives to manipulate files and/or directories
  - Mapping files onto secondary storage
  - Backup files onto stable (non-volatile) storage media

System Components of OS…

- **Secondary-Storage or 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
  - Entire speed of computer operation hinges on disk subsystem and its algorithms.
- **Secondary-Storage or Mass-Storage Management Activities :**
  - Free-space management
  - Storage allocation
  - Disk scheduling
  - Some storage need not be fast
  - Tertiary storage includes optical storage (CD/DVDs), magnetic tapes.
  - Varies between WORM (write-once, read-many-times)

System Components of OS…

- **I/O System Management:**
- One of the purposes of an operating system is to hide the peculiarities of specific hardware devices from the user.
- The I/O subsystem consists of
  - A memory management component including buffering, caching, and spooling
  - A general device-driver interface
  - Drivers for specific hardware devices.
- **Networking:** The processors in the system are connected through a *communication network*, which can be configured in a number of different ways.
- The network may be fully or partially connected.
- Communication-network design must consider routing and connection strategies, and the problems of contention and security.

System Components of OS…

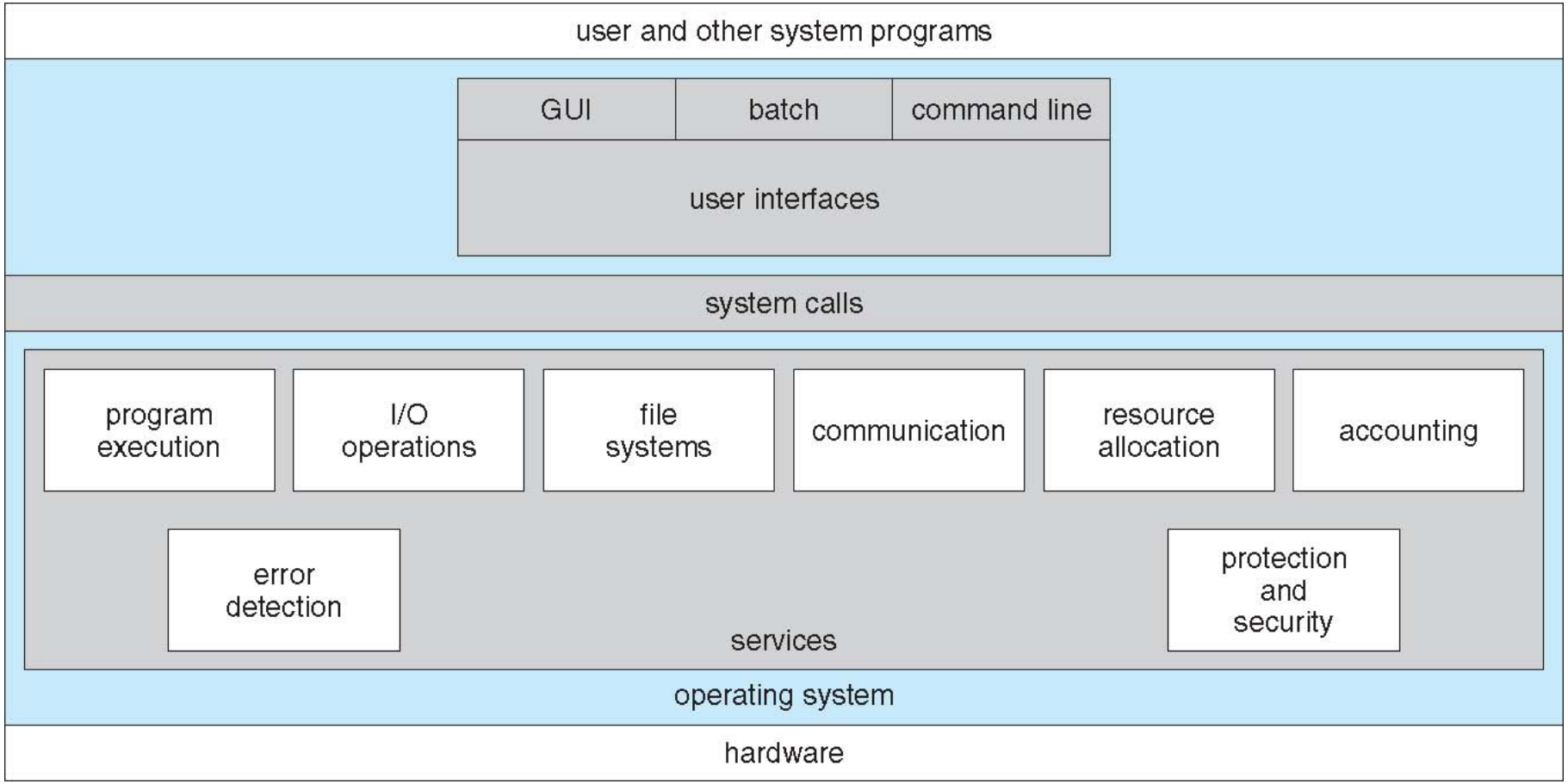
- **Protection systems :**
- If a computer system has multiple users and allows the concurrent execution of multiple processes, then the various processes must be protected from one another's activities.
- For that purpose, mechanisms are provided to ensure that the files, memory segments, CPU, and other resources can be operated on by only those processes that have gained proper authorization from the operating system.
- **Command-Interpreter Systems:** One of the most important systems programs for an operating system is the command interpreter, which is the interface between the user and the operating system.
- Control-card interpreter, or the command-line interpreter, and is often known as the shell, get the next

4. Operating system services, System calls

- **Operating System Services:** An OS provides services to both the users and to the programs.
  - It provides programs an environment to execute.
  - It provides users the services to execute the programs in a convenient manner.
- Following are a few common services provided by an operating system −
  - Program execution
  - I/O operations
  - File System manipulation
  - Communication
  - Error Detection
  - Resource Allocation
  - Protection

Operating system services, System calls…

- **A View of Operating System Services:**



Operating system services, System calls…

- First set of operating-system services provides functions that are helpful to the user:
  - **User interface** - Almost all operating systems have a user interface.
    - Types: **Command-Line Interface (CLI)**, **Graphics User Interface (GUI)**, **Batch Interface**
  - **Program execution** - The system must be able to load a program into memory and to run that program, end execution, either normally or abnormally (indicating error)
  - **I/O operations** - A running program may require I/O, which may involve a file or an I/O device

Operating system services, System calls...

- Second set of operating-system services provides functions that are helpful to the user:
  - **File-system manipulation** - The file system is of particular interest. Programs need to read and write files and directories, create and delete them, search them, list file Information, permission management.
  - **Communications** – Processes may exchange information, on the same computer or between computers over a network
    - Communications may be via shared memory or through message passing (packets moved by the OS)
  - **Error detection** – OS needs to be constantly aware of possible errors
    - May occur in the CPU and memory hardware, in I/O devices, in user program
    - For each type of error, OS should take the appropriate action to ensure correct and consistent computing

Operating system services, System calls…

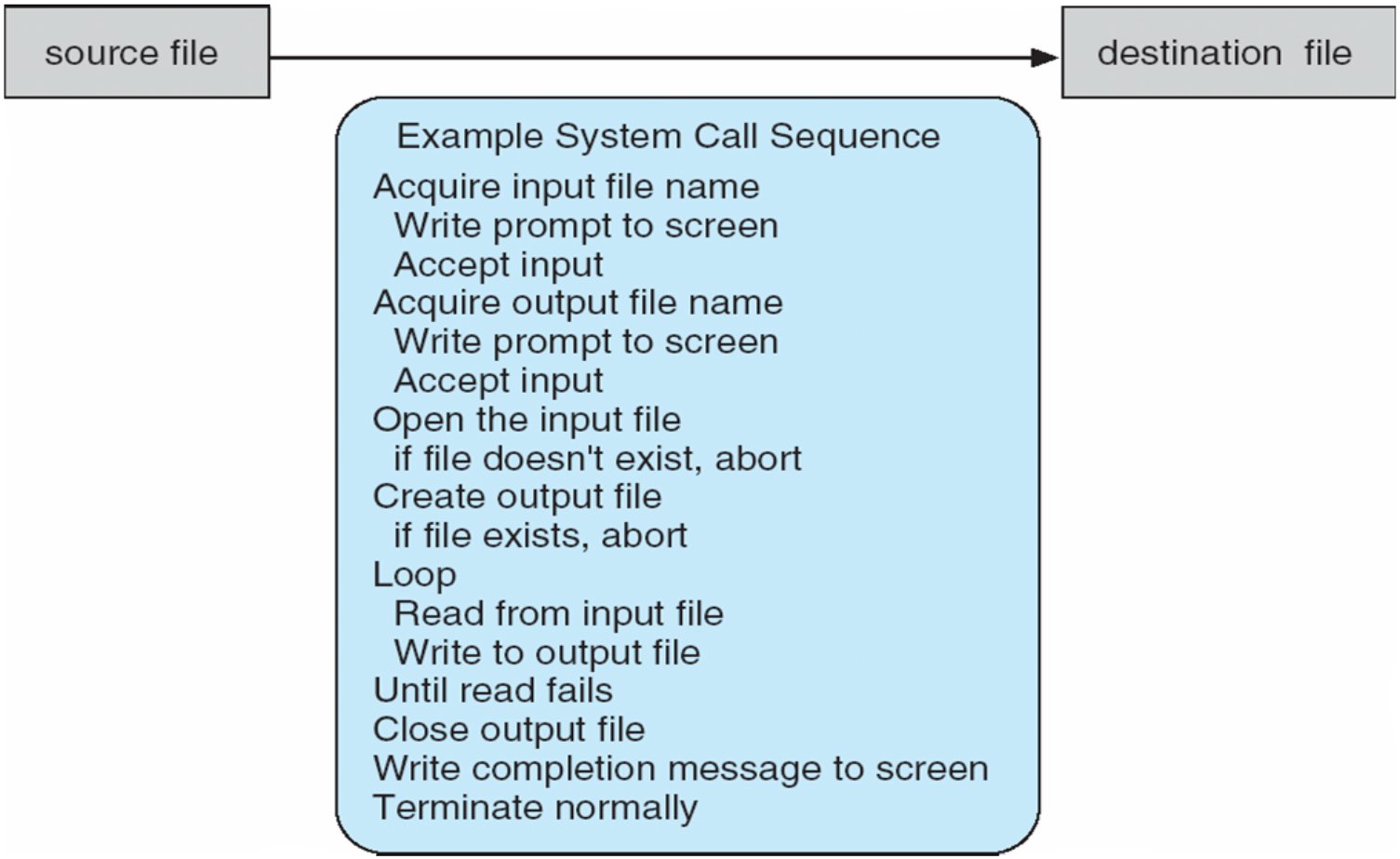
- Third set of OS functions exists for ensuring the efficient operation of the system itself via resource sharing
  - **Resource allocation -** When multiple users or multiple jobs running concurrently, resources must be allocated to each of them
    - Many types of resources - CPU cycles, main memory, file storage, I/O devices.
  - **Accounting -** To keep track of which users use how much and what kinds of computer resources
  - **Protection and security -** The owners of information stored in a multiuser or networked computer system may want to control use of that information, concurrent processes should not interfere with each other
    - **Protection** involves ensuring that all access to system resources is controlled
    - **Security** of the system from outsiders requires user authentication, extends to defending external I/O devices from invalid access attempts

Operating system services, System calls…

- **System Calls:** The interface between a process and an operating system is provided by system calls.
  - Programming interface to the services provided by the OS
  - Typically written in a high-level language (C or C++)
  - Mostly accessed by programs via a high-level **Application Programming Interface (API)** rather than direct system call use
  - Three most common APIs are Win32 API for Windows, POSIX (**Portable Operating System Interface**) API for POSIX-based systems (including virtually all versions of UNIX, Linux, and Mac OS X), and Java API for the Java virtual machine (JVM)
  - **Why use APIs rather than system calls?**
- The functions that are included in the API invoke the actual system calls. By using the API, certain benefits can be gained:
  - **Portability:** as long a system supports API, any program using

Operating system services, System calls...

- **Example of System Calls:** Consider a system call copy, which copy the contents of one file to another file. The System call sequence illustrated using following diagram:



Digital Information Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

END OF

Unit-1: Part-1