Operating Systems (CSE531)
Lecture # 02

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Important System Concepts

- Decomposition
- Modularity
- Coupling
- Cohesion

Decomposition

- Divide and Conquer Strategy
- It deals with being able to break down a system into its components.
- Decomposition results in smaller and less complex pieces that are easier to understand than larger, complex pieces.
- Decomposing a system also allows to focus on one particular part of a system, making easier to think of how to modify that part independently of the entire system.

Modularity

- Modularity refers to dividing a system up into chunks or modules of a relatively uniform size.

- You can replace or add any other module (or a component) without effecting the rest of the system.

- It is a design strategy in which system is composed of relatively small and autonomous routines fit together.

Coupling

- Coupling is the extent to which subsystems are dependent on each other.
- Subsystems should be as independent as possible.
- If a subsystem fails and other subsystems are highly dependent on it, the others will either fail themselves or have problems in functioning.

Cohesion

- The extent to which a system or a subsystem performs a single function.

Operating System (OS)

- The operating part of a tool is called as operating system of that tool.
- The purpose of operating system is to facilitate the operation of the underlying machine or tool.
- For a machine, the OS abstracts the machine part in terms of simple services by hiding the details of the machine.
- The OS can provide services to users or other subsystems.
- Examples of typical operating systems:
  - Car operating system, Telephone operating system, TV operating system and so on.

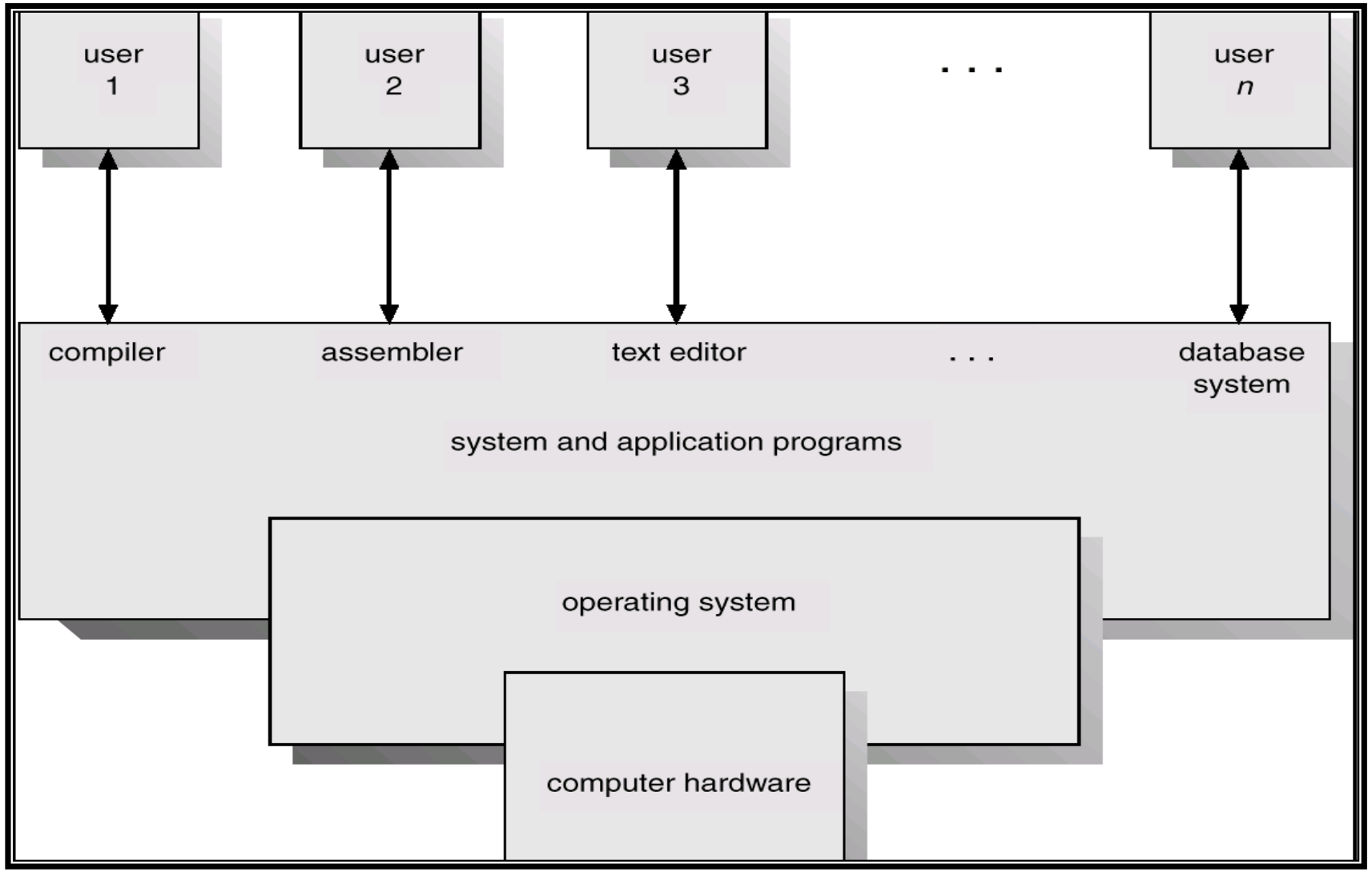
Computer Operating System

- A computer is also a tool that contains machine part and operating part.
- The operating part of a computer is called Computer Operating System.
- For a computer, the operating system abstracts the underlying hardware in terms of simple services by hiding the details of the hardware. The OS can provide services to users or other subsystems.
- Examples of Computer operating systems:
  - WINDOWS, Macintosh, UNIX, SOLARIS, LINUX and so on.
- In the rest of this course, operating system means computer operating system.

Computer OS components

- **Hardware** – provides basic computing resources (CPU, memory, I/O devices).
- **Operating system** – controls and coordinates the use of the hardware among the various application programs for the various users.
- **Applications programs** – define the ways in which the system resources are used to solve the computing problems of the users (compilers, database systems, video games, business programs).
- **Users** (people, machines, other computers).

Computer OS components



Other OS Definitions

- **Resource allocator** – manages and allocates resources.
  - Resources: CPU time, Memory Space, file storage space, I/O devices and son on.
- **Control program** – controls the execution of user programs and operations of I/O devices .
- **Kernel** – the one program running at all times (all else being application programs).
- The two goals, efficiency and convenience are sometimes contradictory.
- Much of OS theory concentrates on optimal use of resources.

Objectives

- The main objective is to understand the operational part of any computer.

- Understanding the general principles of OS design.
  - Focus on general-purpose, multi-user, uni-processor systems.
  - Emphasis on widely applicable concepts rather than any specific features of any specific OS.

- Understanding problems, solutions and design choices.

- Understanding the structure of specific OSs: UNIX, LINUX, WINDOWS

Early Systems (Serial Processing)

- **1940-50:**
  - The programmer interacted directly with the computer hardware.
  - Display light, switches, printer, card reader.
  - No OS. Error is displayed through lights.

- **Problems:**
  - Scheduling → Users spend lots of time at the computer.
    - Signup sheet was used.
  - Job Setup time
    - Loading and compiling
      - Mounting and Un-mounting of tapes
      - Setting up of card desks
  - Libraries of functions, linkers, loaders, debuggers, and I/O driver routines were available for all the users.

Early Systems

- Early computers were (physically) large machines run from a console.
- The programmer would operate the program directly from the console.
  - The program is loaded to the memory from panel of switches, paper tape, and from punched cards.
- As time went on, additional software and hardware were developed.
  - Card readers, line printers, and magnetic tape became common place.
  - Libraries, loaders, and common functions were created.
    - Software reusability.

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Early Systems

- The setup time was a real problem
- CPU is idle while tapes are being mounted or the programmer was operating the console.
- In the early days, few computers were available and they were expensive (millions of dollars).
  - operational costs: power, cooling, programmers.
- Main question:

  How to increase the utilization of CPU ?

Early Systems

- The solution was two fold.
- First, a professional computer operator was hired.
  - Once the program was finished, the operator could start next job.
  - The operator sets up the job, produces the dump, and starts the next job.
  - The set up time was reduced due to operator's experience.
- Second, jobs with similar needs were batched together and run through the computer as a group.
  - For example, if there is a FORTRAN job, COBOL job, and FORTRAN job, two FORTRAN jobs were batched together.
- However, during transition time CPU sat idle.
- Automatic job sequencing to avoid CPU idle time.
  - A first rudimentary OS was created
  - A small program called a **resident monitor** was developed.
  - The resident monitor always resided in memory.

Simple Batch Systems

- In serial systems
  - Machines were very expensive
  - Wasting time was not acceptable.
- To improve usage, the concept of batch OS was developed.
- The main idea is the use of software known as monitor.
  - The user no longer has access to machine.
- The user submits the job (tape) to the operator.
- The operator batches the jobs together sequentially, places entire batch as an input device for use by the computer.

Features of Batch System

- The batch OS is simply a program.
- It relies on the ability of the processor to fetch instructions from various portions of main memory to seize and relinquish control.
- Hardware features:
  - **Memory protection**: While the user program is running, it must not alter the memory area containing the monitor.
  - If such is the case the processor hardware should detect the error and transfer control to monitor.
  - **Timer:** A timer is used to prevent the single job from monopolizing the system

Features of Batch System

- Hardware Features
  - **Privileged instructions**
    - Contains instructions that are only executed by monitor.
    - I/O instructions
    - If a program encounters them the control shifts through monitor.
  - **Interrupts:** It gives OS more flexibility.
    - Relinquishing control and regain control
- With batch OS the machine time alters between execution of user programs and execution of monitor.
- Two overheads
  - Machine time is consumed by the monitor.
  - Memory is consumed by the monitor.
- Still, they improved the performance over serial systems.

Problem with Batch System

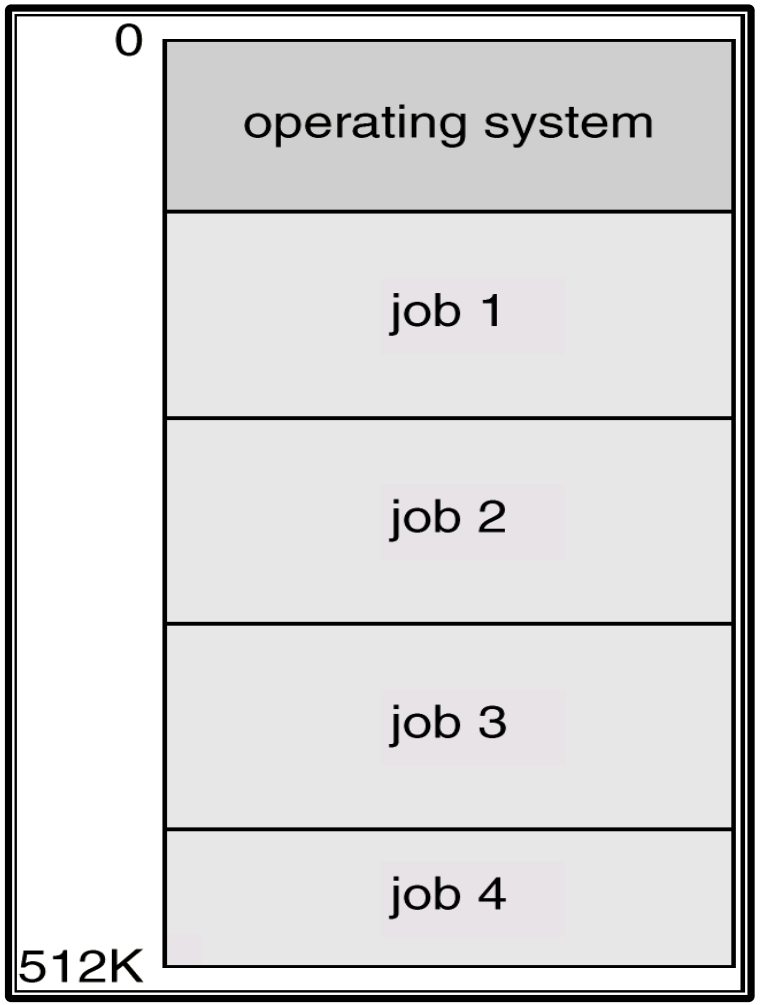
- CPU is idle
- Speed of mechanical devices is very slower than those of electronic devices.
- CPU works in a microsecond range
  - Thousands of instructions/second
- A card reader may read 1200 cards per minute (20 cards per second)
- CPU speed has increased at a faster rate.
- Tape technology improved the performance little-bit.
- Main perceived problem
  - Turn-around time: upto two days
  - CPU often underutilized
    - Most of the time was spent reading and writing from tape.

Multi-programmed Batched Systems (1960s) (or Multi tasking)

- If CPU is executing a job and requires a tape to be mounted
  - In a non multi-programmed system
    - CPU sits idle.
  - In a Multi-programmed system
    - CPU takes up another job.
- **Multiprogramming is the first instance when the OS started taking decisions.**
- Job scheduling is done by OS.
- Having several programs in the memory requires memory management.

Multi-programmed Batched Systems (1960s) (or Multi tasking)

- A single user can not keep either CPU or I/O busy.
- Multiprogramming increases CPU utilization by organizing jobs such that the CPU always has one to execute.
- The OS keeps several jobs in memory at a time and CPU is multiplexed among them



- Introduction & History II

- System Structures I

Simple Batch Systems

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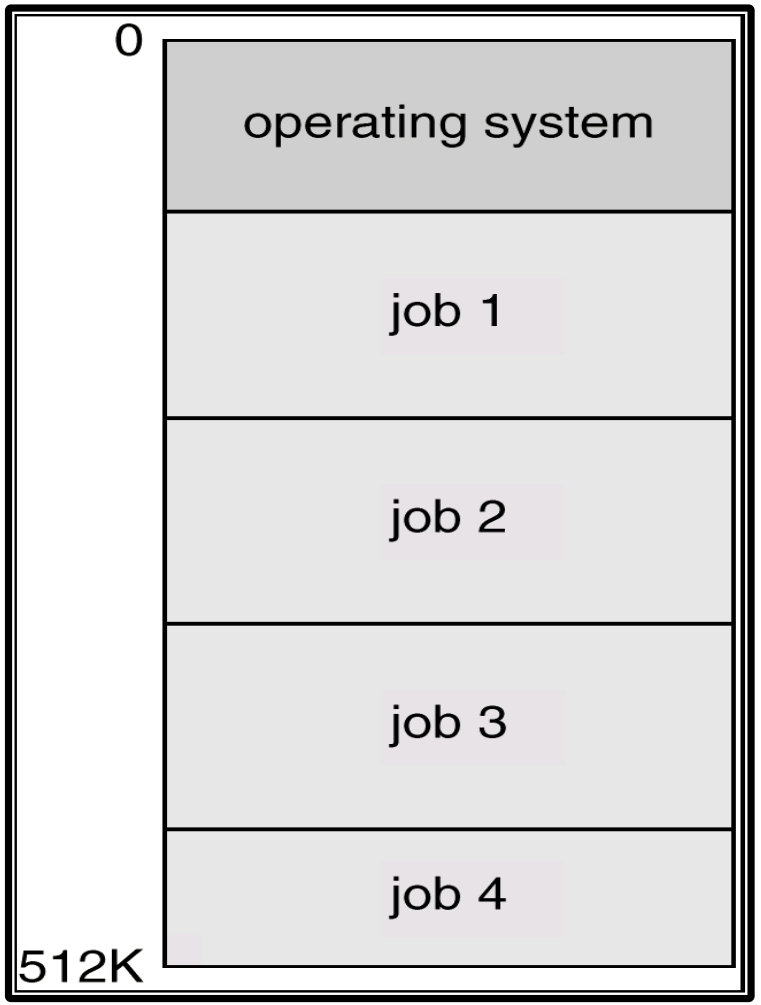


OS Requirements (60s)

- OS Research in 60s
  - MULTICS at MIT
  - Atlas (spooling, demand paging) at Manchester Univ.
  - Multiprogramming
    - Memory allocation and protection
    - I/O operations were responsibility of OS.
  - Interactive systems
    - Scheduling issues
    - Swapping and virtual memory.
  - Users wanted permanent files
    - Hierarchical directory systems.
  - Increased in size and complexity were not well understood
    - IBM: OS/360

UNIX (early 1970s)

- Originally developed at Bell labs for the PDP-7
  - Ken Thomson
  - Dennis Ritchie
- Smaller & Simpler
  - Process spawn and control
    - Each command creates a new process
  - Simple inter-process communication
  - Command interpreter not built in: runs as a user process
  - Files were streams of bytes.
  - Hierarchical file system
- Advantages
  - Written in a high-level language
  - Distributed in source form
  - Powerful OS primitives on an inexpensive platform

Personal Computers (1980s)

- Originally
  - Single user
  - Simplified OSs
    - No memory protection
    - MS-DOS
- Now run sophisticated OSs
  - Windows NT, Linux

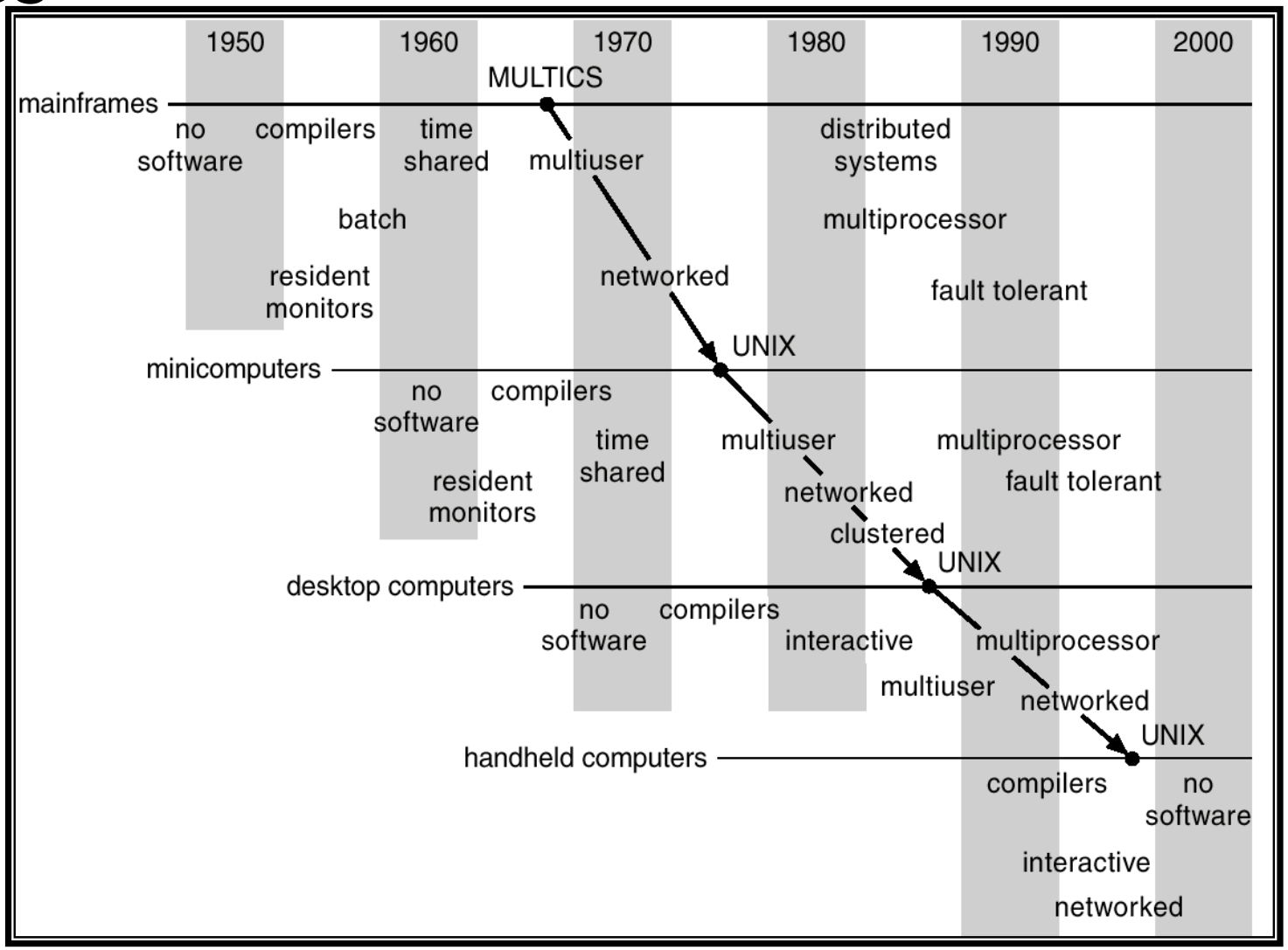
Networks of workstations (1990s)

- High-speed network connections
- Local & world-wide
- Client-server systems
  - File systems
  - Remote windowing systems
- Support a variety of node OSs
  - Unix, Windows XP, OS/2

Future

- Distributed systems
  - Network is invisible
- Micro-kernel and extensible OSs
  - Supports multiple OS flavors
    - E.g., Mach, Amoeba, WINDOWS XP
- Embedded services and network computers
  - Computer runs a very thin OS (Java Virtual machine).

Migration of Operating-System Concepts and Features

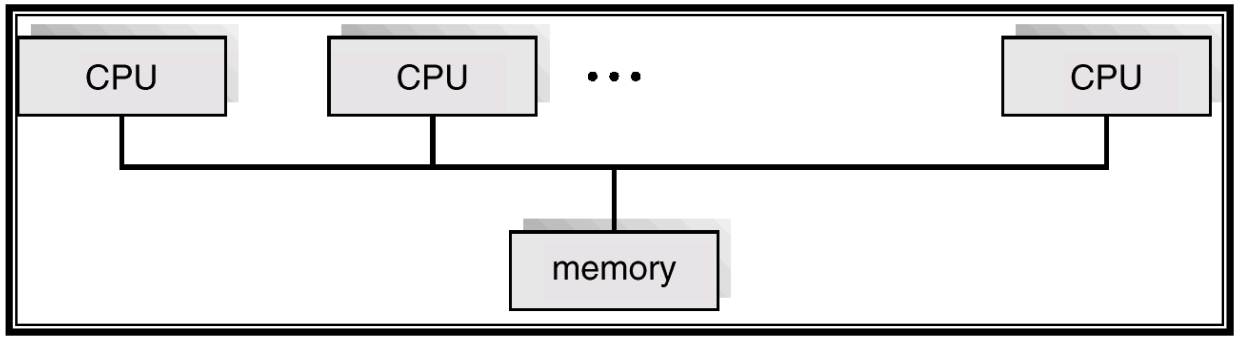


Multiprocessor Systems

- Multiprocessor systems with more than one CPU in close communication.
- *Tightly coupled system* – processors share memory and a clock; communication usually takes place through the shared memory.
- Advantages of multiprocessor system:
  - Increased *throughput:* more processors more work
  - Economical: more computing in same box
  - Increased reliability
    - Graceful degradation & Fault tolerance: failure of one processor will not halt the system. Service is proportional to the level of surviving hardware.

Parallel Systems

- *Symmetric multiprocessing (SMP)*
  - Each processor runs and identical copy of the operating system.
  - Many processes can run at once without performance deterioration.
  - Most modern operating systems support SMP
- *Asymmetric multiprocessing*
  - Each processor is assigned a specific task; master processor schedules and allocated work to slave processors.
  - More common in extremely large systems



SMP Architecture

Distributed Systems

- Distribute the computation among several physical processors.
- *Loosely coupled system*
  - each processor has its own local memory;
  - processors communicate with one another through various communications lines such as high-speed buses or telephone lines.
- Advantages of distributed systems
  - Resources Sharing
  - Computation speed up/load sharing
  - Reliability
  - Communications

Real-Time Systems

- Often used as a control device in a dedicated application such as controlling scientific experiments, medical imaging systems, industrial control systems, and some display systems.

- Well-defined fixed-time constraints.
  - A process must complete within the defined constraints or system will fail.

- Real-Time systems may be either *hard* or *soft* real-time.

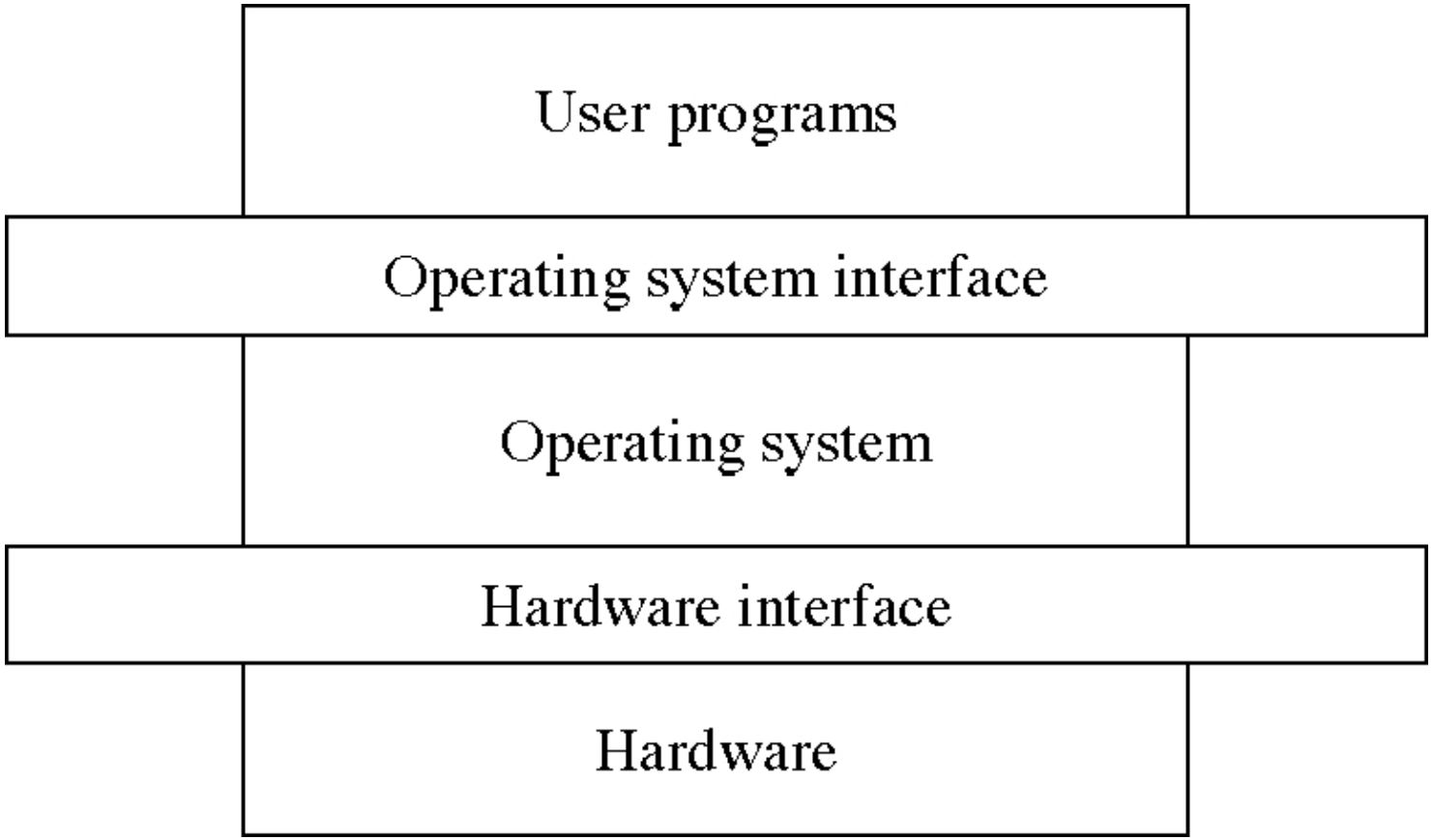
Real-Time Systems

- Hard real-time:
  - Guarantees that critical tasks complete within time.
  - All the delays in the system are bounded.
  - Secondary storage limited or absent, data stored in short term memory, or read-only memory (ROM)
  - Conflicts with time-sharing systems, not supported by general-purpose operating systems.
- Soft real-time
  - Critical time tasks gets priority over other tasks, and retails that priority until it completes.
  - Limited utility in industrial control of robotics
  - Useful in applications (multimedia, virtual reality) requiring advanced operating-system features.

Concept of Virtual Computer

- Multilevel implementation
  - also called layered
- Resources
  - Hardware: provided to the OS
  - Logical (virtual): created by the OS
- Resource management
  - transformation
  - multiplexing
    - time and space

Levels in a computer system



Design: Two-level Implementation

- Two-level implementation
  - Lower level is a problem-specific language
  - Upper level solves the problem at hand
  - Lower level is reusable

- In operating systems
  - *mechanism*: lower level of basic functions, does not change
  - *policy*: upper level policy decisions, easy to change and experiment

Operating System Functions

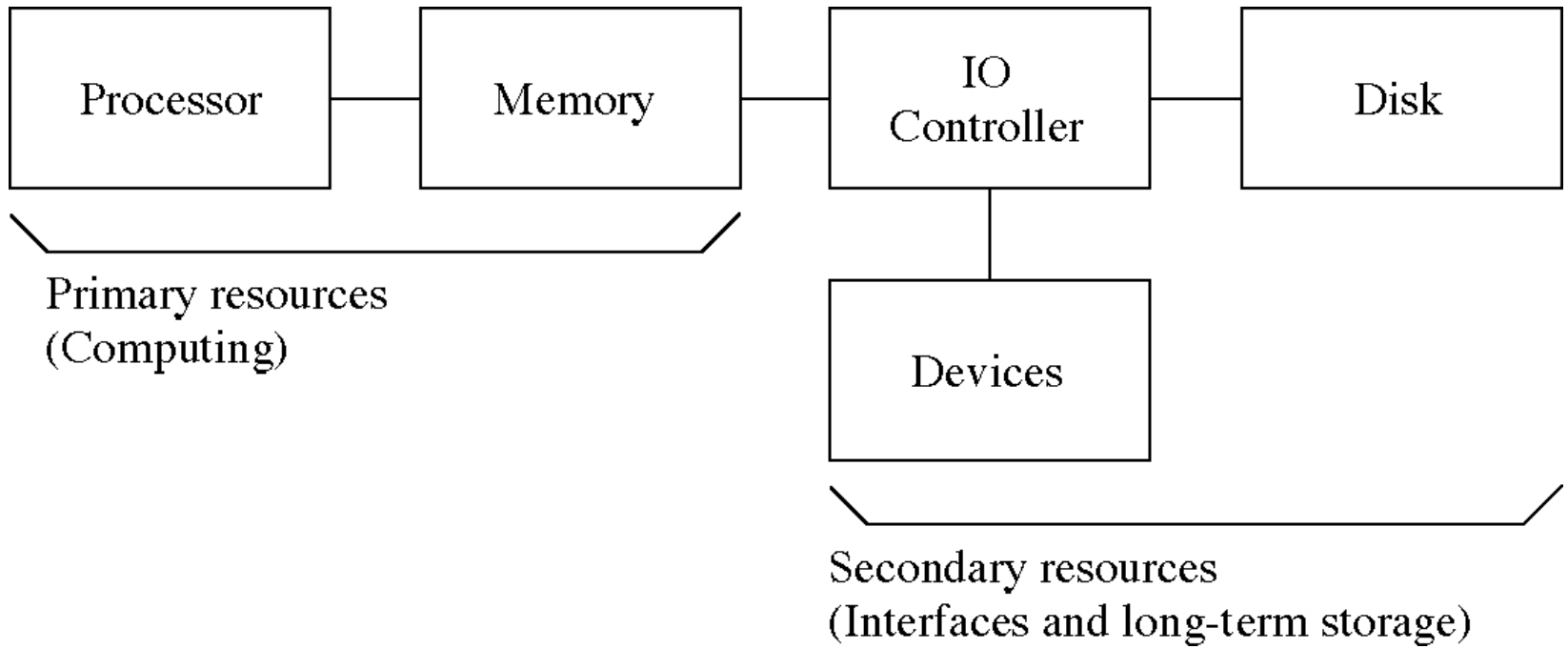
- Resource manager
  - manage hardware and software resources

- Virtual machine manager
  - implement a virtual machine for processes to run in
  - a nicer environment than the bare hardware

Hardware Resources

- *Processor*: execute instructions
- *Memory*: store programs and data
- *Input/output (I/O)controllers*: transfer to and from devices
- *Disk devices*: long-term storage
- *Other devices*: conversion between internal and external data representations

Hardware Resources



Resource Management Functions

- *Transforming* physical resources to logical resources
  - Making the resources easier to use
- *Multiplexing* one physical resource to several logical resources
  - Creating multiple, logical copies of resources
- *Scheduling* physical and logical resources
  - Deciding who gets to use the resources

Types of Multiplexing

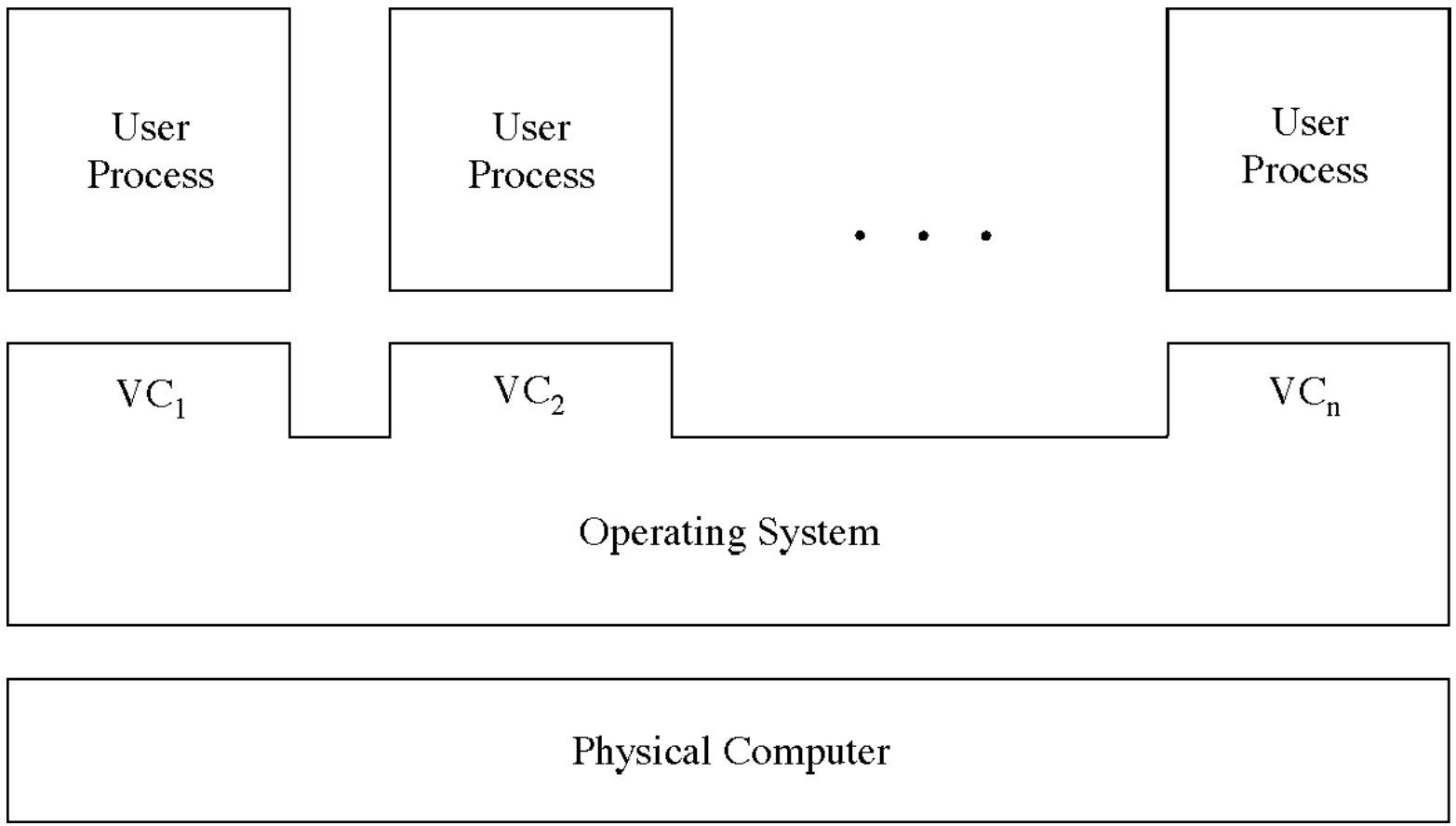
- Time multiplexing
  - time-sharing
  - scheduling a serially-reusable resource among several users

- Space multiplexing
  - space-sharing
  - dividing a multiple-use resource up among several users

Virtual Computers

- Processor virtualized to processes
  - mainly time-multiplexing
- Memory virtualized to address spaces
  - space and time multiplexing
- Disks virtualized to files
  - space-multiplexing
  - transforming

Multiple Virtual Computers



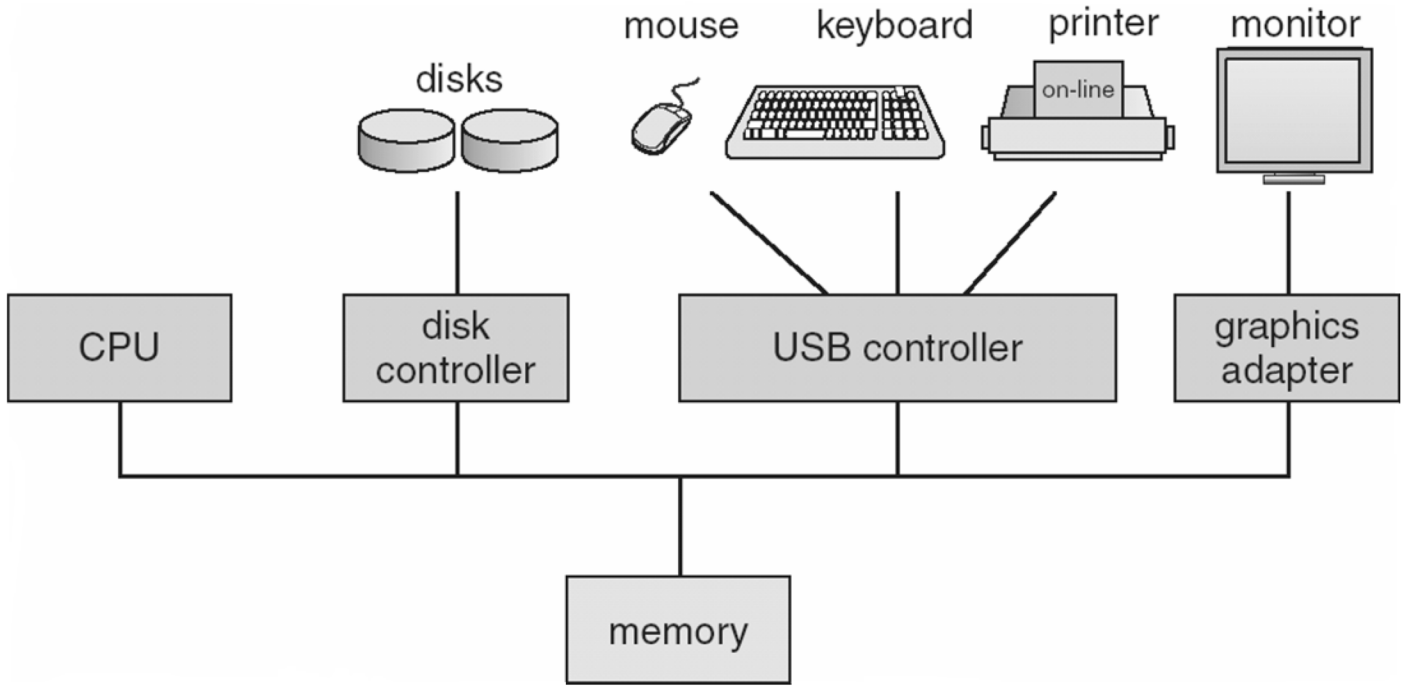
Do we need an OS?

- Not always
  - Some programs run “stand-alone”
- But they are very useful
  - Reusable functions
  - Easier to use than the bare hardware

System Structures I

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



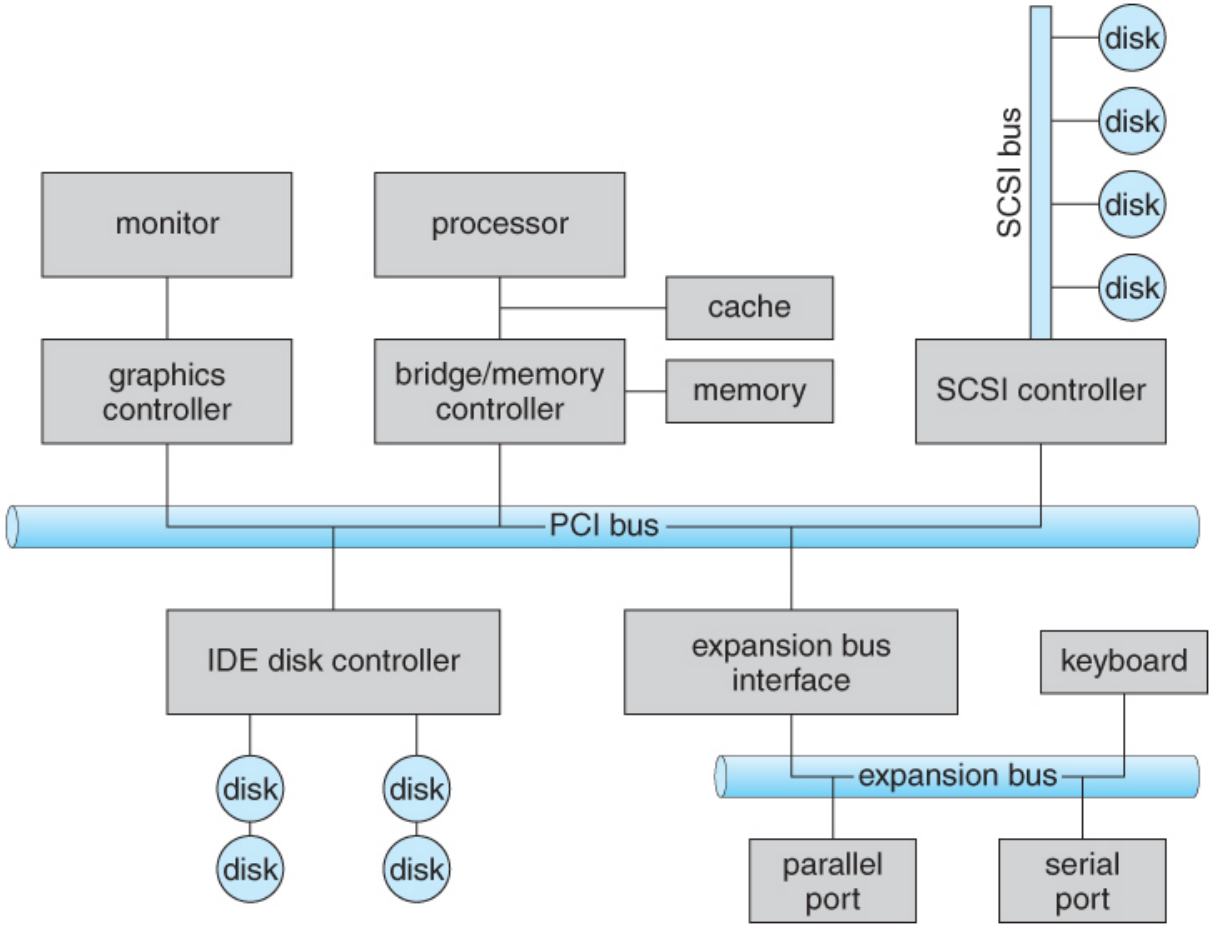
Computer-Components

- Computer consists of processor, memory, and I/O components, with one or more modules of each type. These modules are connected through interconnection network.
- 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*.**

I/O Hardware

- I/O devices can be categorized as storage, communications, user-interface, and others
- Devices connect with the computer via ***ports***, e.g. a serial or parallel port.
- A common set of wires connecting multiple devices is termed a ***bus.***
  - Buses include rigid protocols for the types of messages that can be sent across the bus and the procedures for resolving contention issues.
  - Bus types commonly found in a modern PC:
    - The ***PCI bus*** connects high-speed high-bandwidth devices to the memory subsystem (and the CPU.)
    - The ***expansion bus*** connects slower low-bandwidth devices, which typically deliver data one character at a time (with buffering.)
    - The ***SCSI bus*** connects a number of SCSI devices to a common SCSI controller.
    - A ***daisy-chain bus,*** is when a string of devices is connected to each other like beads on a chain, and only one of the devices is directly connected to the host.

PC Bus Structure



Registers

- One way of communicating with devices is through ***registers*** associated with each port. Registers may be one to four bytes in size, and may typically include (a subset of) the following four:
  - The ***data-in register*** is read by the host to get input from the device.
  - The ***data-out register*** is written by the host to send output.
  - The ***status register*** has bits read by the host to ascertain the status of the device, such as idle, ready for input, busy, error, transaction complete, etc.
  - The ***control register*** has bits written by the host to issue commands or to change settings of the device such as parity checking, word length, or full- versus half-duplex operation.

Memory Mapped I/O

- Another technique for communicating with devices is ***memory-mapped I/O.***
  - In this case a certain portion of the processor's address space is mapped to the device, and communications occur by reading and writing directly to/from those memory areas.
  - Memory-mapped I/O is suitable for devices which must move large quantities of data quickly, such as graphics cards.
  - Memory-mapped I/O can be used either alone or more often in combination with traditional registers. For example, graphics cards still use registers for control information such as setting the video mode.
  - A potential problem exists with memory-mapped I/O, if a process is allowed to write directly to the address space used by a memory-mapped I/O device.

Polling

- One simple means of device ***handshaking*** involves polling:
  - The host repeatedly checks the ***busy bit*** on the device until it becomes clear.
  - The host writes a byte of data into the **data-out register**, and sets the ***write bit*** in the command register (in either order.)
  - The host sets the ***command ready bit*** in the command register to notify the device of the pending command.
  - When the device controller sees the **command-ready bit** set, it first sets the **busy bit**.
  - Then the device controller reads the **command register**, sees **the write bit** set, reads the byte of data from the data-out register, and outputs the byte of data.
  - The device controller then clears the ***error bit*** in the status register, the command-ready bit, and finally clears the busy bit, signaling the completion of the operation.
- Polling can be very fast and efficient, if both the device and the controller are fast and if there is significant data to transfer. It becomes inefficient, however, if the host must wait a long time in the busy loop waiting for the device, or if frequent checks need to be made for data that is infrequently there.

Architecture of a Simple Computer

- **Processor:** Controls the operation of the computer and performs data processing functions. It is called CPU.
- **Main memory:** Stores data and programs; it is volatile
- **I/O modules:** Moves data between the computer and external environment.
- **System bus:** mechanism of communication among processors, main memory, and I/O modules.

Simple Computer

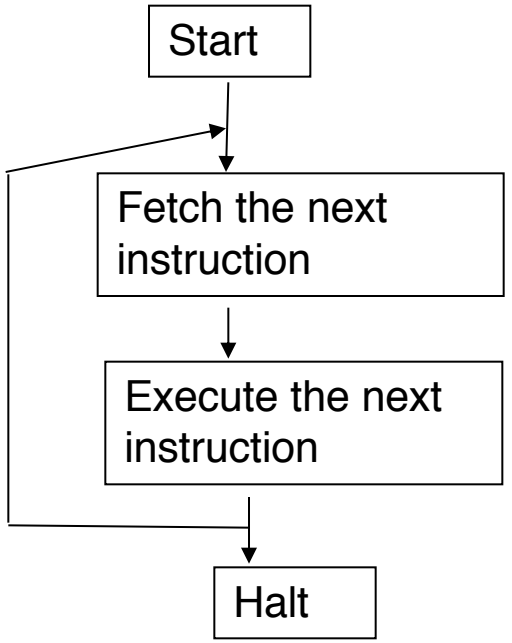
- Operation: Processor controls everything.
  - **MAR**: Memory address register: which specifies the address in memory for the next read or write.
  - **MBR**: Memory buffer register: which contains the data to be written into memory or which receives data read from memory.
  - **I/O AR**: Address of I/O device
  - **I/O BR**: Exchange of data between I/O and computer.

Simple Computer

- **Processor Registers**: Within the processor there is a set of registers that provide a level of memory that is faster and smaller than main memory.
  - User visible registers: Available to programmer
    - **Data registers**: Can be used by the programmer.
    - **Address Registers**: Contains Main memory address of data and instructions.
      - **Index register**: Index to base value
      - **Segment pointer**: It contains a reference to a particular segment.
      - **Stack pointer**: Points top of the stack.
  - **Control and status registers**: These are employed to control the operation of the processor. Differ from machine to machine.
    - MAR, MBR,I/O AR, and I/O BR
    - **Program Counter (PC):** Contains the address of the instruction to be fetched.
    - **Instruction Register (IR)**: Contains the instruction most recently fetched.
    - **Program Status Word (PSW)**: It is a register or a set of registers.

Simple Computer

- **PSW** (Program Status word): It is a register or a set of registers.
    - **Sign:** contains sign bit of last arithmetic operation
    - **Zero**: it is set if the result of arithmetic operation is zero
    - **Carry:** It is set if there is a carry or borrow.
    - **Equal:** If the compare result is equality
    - **Overflow:** It is set if the result is overflow.
    - **Interrupt enable/disable:** Used to disable or enable interrupts.
    - **Supervisor:** Indicates whether the processor is executing in supervisor or user mode.
- **Instruction execution:**
    - Program execution is the main function of the computer.
    - Instruction fetch and execute

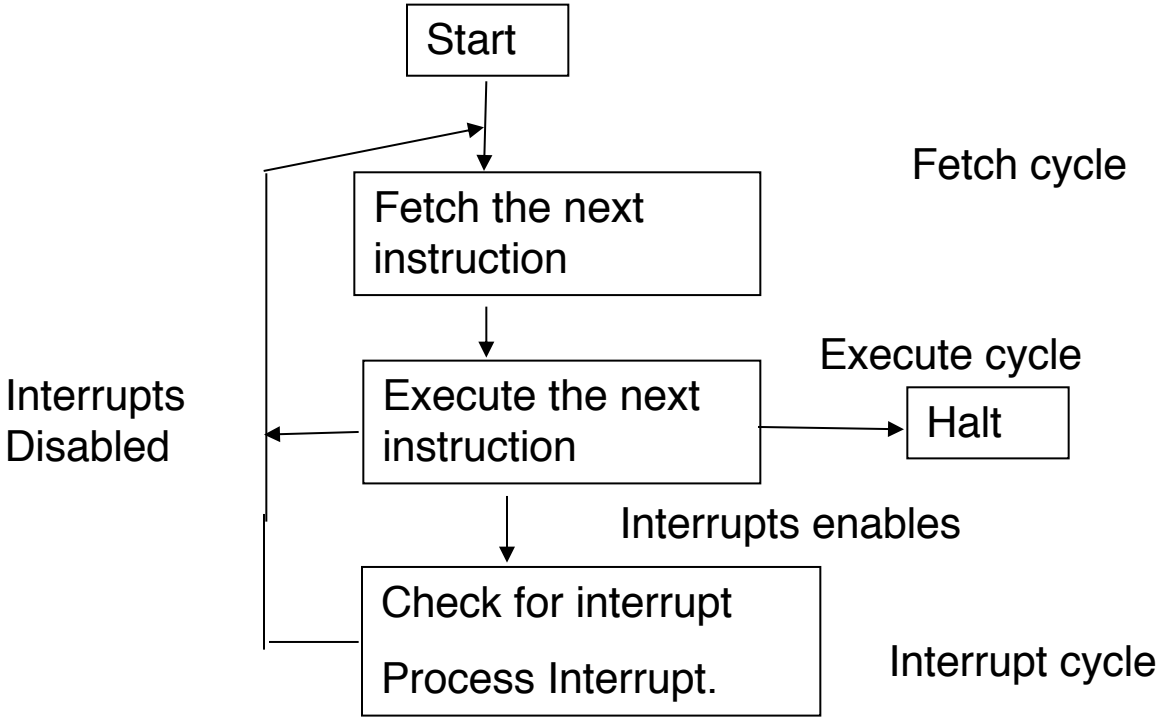


Simple Computer

- **Fetching:** Bringing the instructions from the main memory.
  - **PC**: Contains the address of the next instruction to be fetched.
    - Incremented unless told otherwise
- **Execute:**
  - The processor interprets the instructions and performs the required action.
    - **Processor-memory:** Transfer data from the memory
    - **Processor-I/O-** transfer data from peripheral device from the memory.
    - **Data processing:** Arithmetic and logic operations
    - **Control:** The instructions may specify the sequence of the next instruction to be fetched.

Interrupt Processing

- To improve the performance, interrupts are provided.
- With interrupts, the processor can be engaged in executing other processes while an I/O operation is in progress.
- Interrupt cycle is added to the instruction cycle.



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.
- **An operating system is *interrupt* driven.**

I/O Controller Interrupting

- To start I/O operation, CPU loads the appropriate registers within the device controller
- The device controller examines the contents of these registers to determine what action to take.
- If it s a read operation the controller transfers the data into local buffer.
- Then it informs the CPU through interrupt.
- The operating system preserves the state of the CPU by storing registers and the program counter.

Interrupt Handling

- **Interrupt handler:** The CPU hardware has a wire called interrupt request line; that CPU senses after executing every instruction.
  - When a CPU senses a signal, it saves the PC, and PSW on a stack and jump to the interrupt handler routine at a fixed address in memory.

- **Interrupt vector:** It contains the memory addresses of specialized interrupt handlers.

THANK YOU