A.K.

CONTENTS

RCS 401 : OPERATING SYSTEMS

1 UNIT

Computer System

PART-1

Introduction : Operating System and Function, Classification of Operating System : Batch, Interactive, Time-Sharing, Real Time System, Multi-processor Systems, Multi-user Systems, Multi-process Systems, Multi-threaded System.

CONCEPT OUTLINE : PART-1

- An operating system is a program that acts an intermediary between a user of a computer and the computer hardware.
- **Function of operating system :**
  i. Memory management
  ii. Processor management
  iii. Device management
  iv. File management
- The feature of a batch system is the lack of interaction between the user and the job while that job is executing.
- A multi-processor is a computer system with two or more central processing units, with each one sharing the common main memory as well as peripherals.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. What is operating system ? Write the major functions of an operating system.

Answer

1. An operating system acts as an intermediary between the user of a computer and computer hardware.
2. An operating system is software that manages the computer hardware.
3. The hardware must provide appropriate mechanisms to ensure the correct operation of the computer system and to prevent user programs from interfering with the proper operation of the system.

Functions of an operating system :

The operating systems perform the following functions :

1. **Booting**
   i. Uses diagnostic routines to test system for equipment failure.
   ii. Copies BIOS (Basic Input System) programs from ROM chips to main memory.
   iii. Loads operating system into computer's main memory.
2. **Formatting :**
   Formats (initializes) diskettes so they can store data and programs.
3. **Managing computer resources :**
   i. Keeps track of locations in main memory where programs and data are stored (memory management).
   ii. Moves data and programs back and forth between main memory and secondary storage (swapping) via partitioning, using foreground and background areas, and using buffers and queues.
4. **Managing files :**
   i. Copies files/programs from one disk to another.
   ii. Backup files/programs.
   iii. Erases (deletes) files/programs.
   iv. Renames files.
5. **Managing tasks :**
   May be able to perform multi-tasking, multi-programming, time-sharing or multi-processing.

Que 1.2. **Describe the classification of operating system.**

OR

Write down the different types of operating system.

AKTU 2016-17, Marks 10

Answer

Various types of operating system are as follows :

1. **Batch system :**
   a. This type of operating system was used in the earlier age.
   b. To speedup processing, jobs with similar needs were batched together and were run through the computer as a group.
   c. The definitive feature of a batch system is the lack of interaction between the user and the job while that job is executing.
   d. In this execution environment, the CPU is often idle.
2. **Multi-programming system :**
   a. In this type of operating system, more than one program will reside into main memory.
   b. The operating system picks and begins to execute one of the jobs in the memory.

   c. Eventually, the job may have to wait for some task, the operating system simply switches to another job and executes it.
   d. When the first job finishes, waiting job gets the CPU back.
   e. As long as there is always some job to execute, the CPU will never be idle.
3. **Time-sharing system :**
   a. A time-shared operating system allows the many users to share the computer simultaneously.
   b. A time-shared operating system uses CPU scheduling and multi-programming to provide each user with a small portion of a time-shared computer.
4. **Real time operating system :**
   a. Real time operating system is a special purpose operating system, used when there are rigid time requirements on the operation of a processor or the flow of data.

Que 1.3. **What is real time operating system ? What is the difference between hard real time and soft real time operating system ?**

AKTU 2013-14, Marks 05

Answer

1. Real time operating system is a special purpose operating system, used when there are rigid time requirements on the operation of a processer or the flow of data.
2. Real time operating system has well-defined, fixed time constraints otherwise system will fail.
3. For example, scientific experiments, medical imaging systems, industrial control systems, weapon systems, robots, home-appliances controllers, air traffic control system etc.

Difference between hard real time and soft real time operating system :

S. No.	Characteristic	Hard real time	Soft real time
1.	Response time	Hard required	Soft desired
2.	Peak-load performance	Predictable	Degraded
3.	Control of pace	Environment	Computer
4.	Safety	Often critical	Non-critical
5.	Size of data files	Small/medium	Large
6.	Redundancy type	Active	Checkpoint-recovery
7.	Data integrity	Short-term	Long-term
8.	Error detection	Autonomous	User assisted

Que 1.4. **Discuss essential properties of time-sharing operating system, real time operating system and distributed operating system.**

AKTU 2012-13, Marks 05

Answer

Properties of time-sharing operating system :

1. Uses CPU scheduling and multi-programming to provide economical interactive use of a system.
2. The CPU switches rapidly from one user to another *i.e.*, the CPU is shared between a number of interactive users.
3. Instead of having a job defined by spooled card images, each program reads its next control instructions from the terminal and output is normally printed immediately on the screen.

Properties of real time operating system :

1. Real time systems are usually dedicated, embedded systems.
2. They typically read from and react to sensor data.
3. The system must guarantee response to events within fixed periods of time to ensure correct performance.

Properties of distributed operating system :

1. Distributes computation among several physical processors.
2. The processors do not share memory or a clock, instead, each processor has its own local memory.
3. They communicate with each other through various communication lines.

Que 1.5. **Explain the following terms :**

i. Multi-programming system
ii. Multi-processor system

Answer

i. Multi-programming system : Refer Q. 1.2, Page 1–3B, Unit-1.

ii. Multi-processor system :

1. Multi-processor systems have more than one processor in close communication. They share the computer bus, system and input-output devices and sometimes memory.
2. In multi-processing system, it is possible for two processes to run in parallel.
3. Multi-processor systems are of two types : symmetric multi-processing and asymmetric multi-processing.

   a. In symmetric multi-processing, each processor runs identical copy of the operating system and they communicate with one another as needed. All the CPU shared the common memory.
   b. In asymmetric multi-processing, each processor is assigned a specific task. It uses master-slave relationship.

Que 1.6. **Explain the following terms clearly :**

i. Multi-programming
ii. Multi-threading

AKTU 2011-12, Marks 05

Answer

i. Multi-programming : Refer Q. 1.2, Page 1–3B, Unit-1.

ii. Multi-threading :

1. Multi-threading extends the idea of multi-tasking into applications, so we can sub-divide specific operations within a single application into individual threads.
2. Each of the threads can run in parallel.
3. The OS divides processing time not only among different applications, but also among each thread within an application.
4. In a multi-threaded program, an example application might be divided into four threads : a user interface thread, a data acquisition thread, network communication, and a logging thread.
5. We can prioritize each of these, so that they operate independently.
6. Thus, in multi-threaded applications, multiple tasks can progress in parallel with other applications that are running on the system.

Que 1.7. **Write down the difference between multi-processing and multi-programming operating system.**

AKTU 2013-14, Marks 05

Answer

S. No.	Multi-processing	Multi-programming
1.	Multi-processing refers to processing of multiple processes at same time by multiple CPUs.	Multi-programming keeps several programs in main memory at the same time and execute them concurrently utilizing single CPU.
2.	It utilizes multiple CPUs.	It utilizes single CPU.
3.	It permits parallel processing.	Context switching takes place.

4.	Less time taken to process the jobs.	More time taken to process the jobs.
5.	It facilitates much efficient utilization of devices of the computer system.	Less efficient than multi-processing.
6.	Usually more expensive.	Such systems are less expensive.

Que 1.8. **Describe the differences between symmetric and asymmetric multi-processing.** **AKTU 2014-15, Marks 05**

Answer

S.No.	Basis	Symmetric multi-processing	Asymmetric multi-processing
1.	Architecture	All processor in symmetric multi-processing has the same architecture.	All processor in asymmetric multi-processing may have same or different architecture.
2.	Communication	All processors communicate with another processor by a shared memory.	Processors need not to communicate as they are controlled by the master processor.
3.	Failure	If a processor fails, the computing capacity of the system reduces.	If a master processor fails, a slave is turned to the master processor to continue the execution. If a slave processor fails, its task is switched to other processors.
4.	Ease	Symmetric multi-processor is complex.	Asymmetric multi-processor is simple.

Que 1.9. **What is spooling ?**

OR

What is spooling ? What are the advantage of spooling over buffering ?

Answer

1. SPOOLING is acronym for Simultaneous Peripheral Operations Online.
2. Spooling refers to putting jobs in a buffer, a special area in memory or on a disk where a device can access them when it is ready.

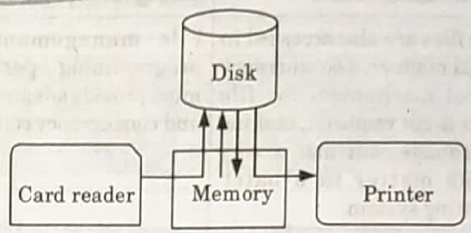

Fig. 1.9.1. Print spooling.

3. Spooling is useful because device access data at different rates.
4. The buffer provides a waiting station where data can rest while the slower device catches up.
5. The most common spooling application is print spooling.
6. In print spooling, documents are loaded into a buffer and then the printer pulls them off the buffer at its own rate.
7. Spooling is also used for processing data at remote sites. The CPU sends the data via communications path to a remote printer.

Advantages of spooling over buffering :

1. The spooling operation uses a disk as a very large buffer.
2. Spooling is capable of overlapping I/O operation for one job with processor operations for another job.

Que 1.10. **Differentiate between batch processing system and multi-programming system with example.**

Answer

S. No.	Batch processing system	Multi-programming system
1.	In batch systems, the instructions, data and some control information are submitted to the computer operator in the form of a job.	Multi-programming system allow concurrent execution of multiple programs, and hence multi-programming operating system require more sophisticated scheduling algorithms.

2.	Only one program is in execution at a time, any time-critical device management is not required, which simplifies the I/O management.	Multi-programming operating system allow sharing of I/O devices among multiple users, more sophisticated I/O management is required.
3.	Since files are also accessed in a serial manner, a concurrency control mechanism for file access is not required, making file management also a very simple matter in a batch operating system.	File management in multi-programming operating system must provide advanced protection, and concurrency control methods.
4.	The users are not allowed to interact with the computer system.	The programs should be scheduled in such a way that the CPU remains busy for maximum amount of time.
5.	**Example :** Execution of batch files such as autoexec.bat by the computer.	**Example :** Interleaved execution of two or more different and independent programs by the same computer.

PART-2

Operating System Structure, Layered Structure, System Components, Operating System, Services Re-entrant Kernels, Monolithic and Micro-kernel System.

CONCEPT OUTLINE : PART-2

- **Structure of OS :**
  - i. Simple structure
  - ii. Layered approach
  - iii. Micro-kernels
  - iv. Modules
- **System components :**
  - i. Memory management
  - ii. Processor management
  - iii. Device management
  - iv. File management

- **Operating system service :**
  - i. Program execution
  - ii. I/O operation
  - iii. File system manipulation
  - iv. Error detection
  - v. Protection and security

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.11. **What is an operating system ? Discuss the operating system structure.**

OR

Explain layered structure of an operating system. Also explain advantages and disadvantages of the layered approach to system design. **AKTU 2014-15, Marks 05**

Answer

Operating system : Refer Q. 1.1, Page 1–2B, Unit-1.

Structure of OS :

1. **Simple structure :** MS-DOS written to provide the most functionality in the least space :
   a. Not divided into modules.
   b. Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated.

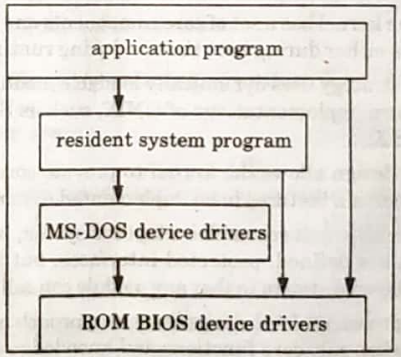

Fig. 1.11.1.

2. Layered approach :

a. The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer *N*) is the user interface.

b. With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers.

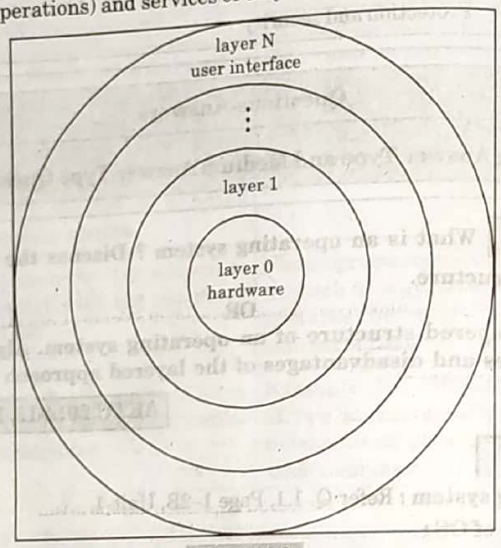

Fig. 1.11.2.

3. Micro-kernels :

a. Moves as much from the kernel into "user" space communication takes place between user modules using message passing.

4. Modules :

a. Here the kernel has a set of core components and links in additional services either during boot time or during runtime.

b. Such a strategy uses dynamically loadable modules and is common in modern implementations of UNIX, such as Solaris, Linux, and Mac OS X.

c. Such a design allows the kernel to provide core services yet also allows certain features to be implemented dynamically.

d. The overall result resembles a layered system in that each kernel section has defined, protected interfaces; but it is more flexible than a layered system in that any module can call any other module.

e. The approach is like the microkernel approach in that the primary module has only core functions and knowledge of how to load and

communicate with other modules; but it is more efficient, because modules do not need to invoke message passing in order to communicate.

Advantages :

1. The main advantage of the layered approach is simplicity of construction and debugging.
2. The layers are selected so that each uses functions (operations) and services of only lower-level layers.
3. This approach simplifies debugging and system verification.
4. The first layer can be debugged without any concern for the rest of the system, because, it uses only the basic hardware to implement its functions.
5. Once the first layer is debugged, its correct functioning can be assumed while the second layer is debugged, and so on.
6. If an error is found during the debugging of a particular layer, the error must be on that layer, because the layers below it are already debugged.
7. Thus, the design and implementation of the system is simplified.

Disadvantages :

1. The major difficulty with the layered approach involves appropriately defining the various layers. Because a layer can use only lower level layers, careful planning is necessary.
2. A final problem with layered implementations is that they tend to be less efficient than other types. At each layer, the parameters may be modified, data may need to be passed, and so on. Each layer adds overhead to the system call; the net result is a system call that takes longer than one on a non-layered system.
3. These limitations have caused a small backlash against layering. Fewer layers with more functionality are being designed, providing most of the advantages of modularized code while avoiding the difficult problems of layer definition and interaction.

Que 1.12. What is an operating system ? Define the components of an operating system. AKTU 2013-14, Marks 05

OR

Discuss various operating system components. AKTU 2014-15, Marks 05

Answer

Operating system : Refer Q. 1.1, Page 1–2B, Unit-1.

Components of an operating system are :

1. **Memory management :**

   An operating system does the following activities for memory management :

   a. Keeps tracks of primary memory, *i.e.*, what part of it are in use by whom, what part are not in use.

   b. In multi-programming, the OS decides which process will get memory when and how much.

   c. Allocates the memory when a process requests it to do so.

   d. De-allocates the memory when a process no longer needs it or has been terminated.

2. **Processor management :**

   An operating system does the following activities for processor management :

   a. Keeps tracks of processor and status of process. The program responsible for this task is known as traffic controller.

   b. Allocates the processor (CPU) to a process.

   c. De-allocates processor when a process is no longer required.

3. **Device management :**

   An operating system manages device communication via their respective drivers. It does the following activities for device management :

   a. Keeps tracks of all devices. Program responsible for this task is known as the I/O controller.

   b. Decides which process gets the device when and for how much time.

   c. Allocates the device in the efficient way.

   d. De-allocates devices.

4. **File management :**

   An operating system does the following activities for file management :

   a. Keeps track of information, location, uses, status etc. The collective facilities are often known as file system.

   b. Decides who gets the resources.

   c. Allocates the resources.

   d. De-allocates the resources.

Que 1.13. Define the services provided by the operating system.

AKTU 2013-14, Marks 05

OR

Explain the services provided by operating system.

AKTU 2016-17, Marks 10

Answer

Some of the services provided by operating system are as follows :

1. **Program execution :**

   a. The purpose of computer system is to allow the users to execute programs in an efficient manner.

   b. The operating system provides an environment where the user can conveniently run these programs.

   c. To run a program, the program is required to be loaded into the RAM first and then to assign CPU time for its execution.

2. **I/O operations :**

   a. Each program requires an input and after processing the input submitted by user it produces output.

   b. This involves the use of I/O devices.

   c. The I/O service cannot be provided by user-level programs and it must be provided by the operating system.

3. **File system manipulation :**

   a. While working on the computer, generally a user is required to manipulate various types of files like opening a file, saving a file and deleting a file from the storage disk.

   b. This is an important task that is also performed by the operating system.

4. **Communication :**

   a. Operating system performs the communication among various types of processes in the form of shared memory.

   b. Communications may be implemented via shared memory, in which two or more processes read and write to a shared section of memory, or message passing, in which packets of information in predefined formats are moved between processes by the operating system.

5. **Error detection :**

   a. The main function of operating system is to detect the errors like bad sectors on hard disk, memory overflow and errors related to I/O devices.

   b. After detecting the errors, operating system takes an appropriate action for consistent computing.

6. **Resource allocation :**
   a. In the multitasking environment, when multiple jobs are running at a time, it is the responsibility of an operating system to allocate the required resources (like CPU, main memory, tape drive or secondary storage etc.) to each process for its better utilization.

8. **Protection and security :**
   a. Protection involves ensuring that all access to system resources is controlled.
   b. Such security starts with requiring each user to authenticate him or her to the system, usually by means of a password, to gain access to system resources.

Que 1.14. **What is kernel ? Describe various operations performed by kernel ?**

AKTU 2016-17, Marks 10

Answer

1. Kernel is the main component of most computer operating systems.
2. It provides an interface between applications and actual data processing at the hardware level.
3. Kernel is considered as the heart of an operating system.
4. Kernel provides the lowest-level abstraction layer for the resources (especially processors and I/O devices) that application software must control to perform its function.

The various types of operations performed by the kernel are :

1. It controls the state of the process that is it checks whether the process is running or process is waiting for the request of the user.
2. It provides the memory for the processes those are running on the system that is kernel runs the allocation and de-allocation of process.
3. The kernel also maintains a time table for all the processes those are running that is the kernel also prepare the schedule time which will provide the time to various process of the CPU.
4. The kernel puts the waiting and suspended jobs into the different memory area.
5. When a kernel determines that the logical memory does not fit to store the programs, then it uses the concept of the physical memory which will store the programs into temporary manner. Therefore, physical memory of the system can be used as temporary memory.

Que 1.15. **Describe re-entrant kernels.**

Answer

1. A re-entrant kernel is one where many processes or threads can execute in the same kernel program concurrently without affecting one another.
2. In non-reentrant kernels, a process does not modify kernel programs, but modify global kernel data.
3. If a process is executing operating system programs, no other processes may be allowed to execute the programs, nor may system start another kernel path execution when the kernel access the global data.
4. An interrupts from I/O devices may not be handled immediately by the operating system.
5. Normally the operating system is composed of re-entrant and non-reentrant functions. The re-entrant functions may modify local data, but they do not modify any global data.
6. Concurrent executions of re-entrant functions do not affect the behaviour of one another. The operating system makes sure that non-reentrant functions are executed mutually exclusively by the kernel paths so that the function executions do not modify global data at the same time.

Que 1.16. **Differentiate between the following :**

i. Shell and kernel
ii. Monolithic kernel and micro-kernel

AKTU 2011-12, Marks 05

OR

What are the differences between shell and kernel ?

AKTU 2014-15, Marks 05

Answer

i. Shell and kernel :

S. No.	Shell	Kernel
1.	When a user logs in, the login program checks the username and password, and then starts another program called the shell.	The kernel is the hub of the operating system, it allocates time and memory to programs and handles the file storage and communications in response to system calls.
2.	Shell gives interface between user and kernel.	Kernel gives the hardware interaction with user.
3.	The shell is the GUI or interface to the kernel.	The kernel is the part of the operating system that interacts with the hardware.

ii. Monolithic kernel and micro-kernel :

S. No.	Monolithic kernel	Micro-kernel
1.	Kernel size is large.	Kernel size is small.
2.	OS is complex to design.	OS is easy to design, implement and install.
3.	All the operating system services are included in the kernel.	Kernel provides only IPC and low level device management services.
4.	Request may be serviced faster.	Request may be serviced slower than monolithic kernel.
5.	No message passing and no context switching are required while the kernel is performing the job.	Micro-kernel requires message passing and context switching.

Que 1.17. What do you understand by system call ? How is a system call made ? How is a system call handled by the system ? Choose suitable examples for explanation. AKTU 2011-12, Marks 05

Answer

System calls :

1. System calls provide an interface to the services made available by an operating system.
2. These calls are generally available as routines written in C and C++, although certain low-level tasks (for example, task where hardware must be accessed directly), may need to be written using assembly language instructions.

System call is made :

1. An operating system makes system calls available, let's first use an example to illustrate how system calls are used : writing a simple program to read data from one file and copy them to another file.
2. The first input that the program will need is the names of the two files : the input file and the output file.
3. One approach is for the program to ask the user for the names of the two files.
4. In an interactive system, this approach will require a sequence of system calls, first to write a prompting message on the screen and then to read from the keyboard the characters that define the two files.
5. Once the two file names are obtained, the program must open the input file and create the output file. Each of these operations requires another system call.
6. When the program tries to open the input file, it may find that there is no file of that name or that the file is protected against access.

7. In these cases, the program should print a message on the console and then terminate abnormally.
8. If the input file exists, then we must create a new output file.
9. We may find that there is already an output file with the same name. This situation may cause the program to abort, or we may delete the existing file and create a new one.
10. On input, the program may find that the end of the file has been reached or that there was a hardware failure in the read (such as a parity error.)
11. Finally, after the entire file is copied, the program may close both files, write a message to the console or window, and finally terminate normally.
12. Typically, application developers design programs according to an application programming interface (API).
13. The API specifies a set of functions that are available to an application programmer, including the parameter that are passed to each function and the return values the programmers can expect.
14. The functions that make up an API typically invoke the actual system calls on behalf of the application programmer.

System call handled by system :

1. The runtime support system for most programming languages provides a system call interface that serves as the link to system calls made available by the operating system.
2. The system call interface intercepts function calls in the API and invokes the necessary system calls within the operating system.
3. Typically, a number is associated with each system call, and the system call interface maintains a table indexed according to these numbers.
4. The system call interface then invokes the intended system calls in the operating system kernel and returns the status of the system call and any return values.
5. The caller need know nothing about how the system calls is implemented or what it does during execution.
6. Rather, it need only obey the API and understand what the operating system will do as a result of the execution of that system call.
7. Thus, most of the details of the operating system interface are hidden from the programmer by the API and are managed by the runtime support library.

Que 1.18. What do you understand by system call ? Enumerate five system calls used in process management.

AKTU 2013-14, Marks 05

OR

What do you understand by system call ? List and explain three system calls used for process management.

AKTU 2012-13, Marks 05

Answer

System call : Refer Q. 1.17, Page 1–17B, Unit-1.

System calls used for process management :

fork() : To create a new process
exec() : To execute a new program in a process
wait() : To wait until a created process completes its execution
exit() : To exit from a process execution
getpid() : To get a process identifier of the current process
getppid() : To get parent process identifier
brk() : To increase/decrease the data segment size of a process

Que 1.19. What are the advantages of the layered approach to the design of operating system ? **AKTU 2012-13, Marks 05**

1. The main advantage of the layered approach is simplicity of construction and debugging.
2. The layers are selected so that each uses functions (operations) and services of only lower-level layers.
3. This approach simplifies debugging and system verification.
4. The first layer can be debugged without any concern for the rest of the system, because, it uses only the basic hardware to implement its functions.
5. Once the first layer is debugged, its correct functioning can be assumed while the second layer is debugged, and so on.
6. If an error is found during the debugging of a particular layer, the error must be on that layer, because the layers below it are already debugged.
7. Thus, the design and implementation of the system is simplified.

Que 1.20. What is the reason behind dual mode operation of processors ? **AKTU 2011-12, Marks 05**

OR

Whether it is possible to construct a secure operating system without having dual mode of operation in the system ? Give arguments in favour of your answer. **AKTU 2012-13, Marks 05**

Answer

1. In dual mode operation, two separate modes are used for working of operating system. These modes are user mode and monitor mode.
2. For indicating mode of the system, mode bit is used in the computer hardware. The mode bit is 0 for monitor and 1 for user.
3. With the mode bit, we are able to distinguish between a task that is executed in user mode or monitor mode.
4. This feature helps to the operating system in many ways :
   a. At the booting time, the hardware starts in the monitor mode, then operating system is loaded. The hardware switches from user mode to monitor mode when interrupts occur. When the operating system gains control of the system, it is in monitor mode.
   b. The dual mode operation provides the protection to the operating system from unauthorized users.

   c. The privileged instructions are executed only in the monitor mode. The computer hardware is not allowed for executing the privilege instructions in other mode, *i.e.* user mode.
   d. These provide greater protection for the operating system. Fig. 1.20.1 shows the dual mode protecting.

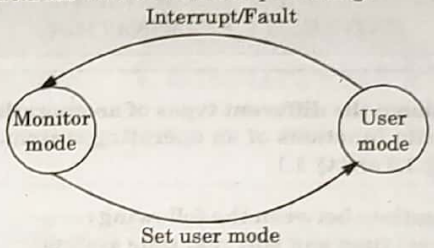

Fig. 1.20.1.

Que 1.21. Differentiate between process switch and mode switch. **AKTU 2012-13, Marks 2.5**

Answer

S. No.	Process switch	Mode switch
1.	Process switching occurs when the processor switches from one process to another.	Mode switching is the switching of a process between kernel mode and user mode. A process can execute in either of these two modes.
2.	When process switching occurs, the kernel saves the context of old process in its PCB and loads the saved context of new process scheduled to run.	Mode switching can be done using system call. This is a special instruction that sets the system's state to kernel mode.
3.	Example : If an interrupt occurs, the system needs to save the current context of running process on CPU, so that it can restore the saved context when processing of interrupt is over, *i.e.*, process switching is useful for suspending and resuming of a process.	Example : If a user process needs to access things controlled by kernel, it is necessary to perform mode switching.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Write down the different types of an operating system and also write functions of an operating system.

Ans. Refer Q. 1.2 and Q. 1.1.

Q. 2. Differentiate between the following :

i. Hard real time and soft real time system.

ii. Multi-processing and multi-programming.

Ans.

i. Refer Q. 1.3.

ii. Refer Q. 1.7.

Q. 3. Explain layered structure of an operating system.

Ans. Refer Q. 1.11.

Q. 4. Define the services provided by the operating system.

Ans. Refer Q. 1.13.

Q. 5. Differentiate between the following :

i. Shell and kernel

ii. Monolithic kernel and micro-kernel

Ans. Refer Q. 1.16.

Q. 6. How is a system call handled by the system ? Enumerate the five system calls used in process management.

Ans. Refer Q. 1.17 and Q. 1.18.

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2 UNIT

Concurrent Processes

PART-1

Concurrent Processes : Process Concept, Principle of Concurrency, Producer Consumer Problem, Mutual Exclusion, Critical Section Problem, Dekker's Problem, Peterson Solution.

CONCEPT OUTLINE : PART-1

- A process is a sequential program in execution.
- Requirements of a solution to critical section problem :
  - i. Mutual exclusion
  - ii. Progress
  - iii. Bounded waiting

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. **Explain the term process.** **AKTU 2011-12, Marks 05**

OR

What do you mean by process model or process ?

Answer

1. A process is a sequential program in execution.
2. A process defines the fundamental unit of computation for the computer.
3. Process contains four sections :
   a. Text
   b. Data
   c. Heap
   d. Stack
4. A process is an 'active entity' as opposed to program which is considered to be a 'passive entity'.
5. A process is more than the program code, which is sometimes known as the text section.
6. A process generally includes the process stack, which contains temporary data (such as function parameters, return addresses, and local variables), and a data section, which contains global variables.
7. A process may include a heap, which is memory that is dynamically allocated during process runtime.

8. The structure of a process in memory is shown in Fig. 2.1.1.

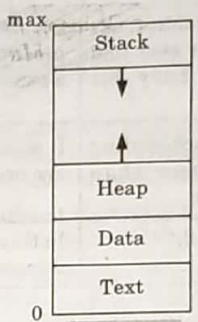


Fig. 2.1.1.

Que 2.2. **Differentiate between the following :**

i. Process and program

ii. Busy wait and blocking wait **AKTU 2012-13, Marks 05**

Answer

i. Process and program

S. No.	Process	Program
1.	Process is an operation which takes the given instruction and performs the manipulations as per the code called execution.	Program is a set of instructions that perform a designated task.
2.	A process is entirely dependent on program.	Programs are independent.
3.	Process is a module that executes concurrently. They are separable and loadable modules.	Program performs a task directly relating to an operation.
4.	A process includes program counter, a stack, a data section, and a heap.	A program is just a set of instructions stored on disk.
5.	It is an active entity.	It is a passive entity.

ii. Busy wait and blocking wait

S. No.	Busy wait	Blocking wait
1.	Busy wait is a loop that reads the status register over and over until the busy bit becomes clear.	Blocking is a situation where processes wait indefinitely within a semaphore.
2.	It occurs when scheduling overhead is larger than expected wait time.	It occurs when process resources are needed for another task.
3.	It is schedule based.	In this, schedule based algorithm is inappropriate.

Que 2.3. **What is the principle of concurrency ?**

OR

Explain the principle of concurrency. **AKTU 2014-15, Marks 05**

Answer

1. Concurrency is based on following principles :
   a. Relative speed of execution of processes is not predictable.
   b. System interrupts are not predictable.
   c. Scheduling policies may vary.
2. Concurrency is the tendency for things to happen at the same time in a system.
3. It also refers to techniques that makes program more usable.
4. Concurrency can be implemented and is used a lot on single processing units, it may benefit from multiple processing units with respect to speed.
5. If an operating system is called a multi-tasking operating system, this is a synonym for supporting concurrency.
6. If we can load multiple documents simultaneously in the tabs of our browser and we can still open menus and perform more actions, this is concurrency.
7. If we run distributed-net computations in the background, this is concurrency.

Que 2.4. **Discuss producer consumer problem.**

OR

State and describe the producer consumer problem with its suitable solution. **AKTU 2013-14, Marks 05**

Answer

1. Producer process produce data item that consumer process consumes later.
2. Buffer is used between producer and consumer. Buffer size may be fixed or variable. The producer portion of the application generates data and stores it in a buffer, and the consumer reads data from the buffer.
3. The producer cannot deposit its data if the buffer is full. Similarly, a consumer cannot retrieve any data if the buffer is empty.
4. If the buffer is not full, a producer can deposit its data. The consumer should be allowed to retrieve a data item if buffer contains.

Solution to producer consumer problem :

```
void main ()
{
count = 0;
}
int i;
binarysemphore s = 1;
int producer ();
{
While (true)
{
produce_data_item ();
semwaitB(s);
append ();
count = count + 1;
if (count = = 1)
semSignalB(delay);
semSignalB(s);
}
}
int consumer ()
{
int p;
semWaitB(delay);
while (true)
{
```

```
semWaitB(s);
consume();
count = count - 1;
p = count;
semSignalB(s);
consumedata();
if(p = = 0)
semWaitB(delay);
}
}
```

Que 2.5. What is mutual exclusion ? What are the four conditions of mutual exclusion ?

Answer

1. Mutual exclusion is a way to make sure that if one process is using a shared modifiable data, the other processes will be excluded from doing the same thing.
2. Formally, while one process executes the shared variable, all other processes desiring to do so at the same time should be kept waiting; when that process has finished executing the shared variable, one of the processes waiting to do so should be allowed to proceed.
3. Mutual exclusion needs to be enforced only when processes access shared modifiable data when processes are performing operations that do not conflict with one another, they should be allowed to proceed concurrently.
4. Thus in mutual exclusion, a single process temporarily excludes all other process from using a shared resource in order to ensure the system integrity.

Four conditions of mutual exclusion are :

a. No two processes may at the same moment be inside their critical sections.

b. No assumptions are made about relative speeds of processes or number of CPUs.

c. No process outside its critical section should block other processes.

d. No process should wait arbitrary long to enter its critical section.

Que 2.6. Discuss the requirements of mutual exclusion.

Answer

Mutual exclusion should meet the following requirements :

1. Mutual exclusion must be enforced by allowing only one process at a time into its critical section, among all processes that have critical sections for the same resource or shared object.
2. A process that halts in its non-critical section must do so without interfering with other processes.
3. It must not be possible for a process requiring access to a critical section to be delayed indefinitely, no deadlock or starvation.
4. When no process is in a critical section, any process that requests entry to its critical section must be permitted to enter without delay.
5. No assumptions are made about relative process speeds or number of processors.
6. A process remains inside its critical section for a finite time only.

Que 2.7. What do you understand by critical section problem ? What are the requirements of a solution to the critical section problem ?

OR

List the essential requirements of critical section implementation.

AKTU 2013-14, Marks 05

Answer

Critical section :

1. A critical section is a code segment in a process in which a shared resource is accessed.
2. Each process has a segment of code called a critical section. Critical section used to avoid race conditions on data items.
3. In critical section the process may be changing common variables, updating a table, writing a file and so on. At any moment at most one process can execute in critical section (CS).
4. When one process is executing in its critical section, no other process is to be allowed to execute in its critical section. The execution of critical section by the process is mutually exclusive in time.

A solution to the critical section problem must satisfy the following three requirements :

1. **Mutual exclusion :** If process P_i is executing in its critical section, then no other processes can be executing in their critical sections.
2. **Progress :** If no process is executing in its critical section and some processes wish to enter their critical sections, then only those processes that are not executing in their remainder sections can participate in deciding which will enter its critical section next, and this selection cannot be postponed indefinitely.

3. **Bounded waiting :** There exists a bound, or limit, on the number of times that other processes are allowed to enter their critical sections after a process has made a request to enter its critical section and before that request is granted.

Que 2.8. **What do you understand by critical section ? Discuss Bakery algorithm. Also, show how it satisfies the requirements of a mechanism to control access to critical section.**

AKTU 2014-15, Marks 05

Answer

Critical section : Refer Q. 2.7, Page 2–7B, Unit-2.

Bakery algorithm :

1. Bakery algorithm is used in multiple process solution.
2. It solves the problem of critical section for n processes.
3. Each process requesting entry to critical section is given a numbered token such that the number on the token is larger than the maximum number issued earlier.
4. This algorithm was developed for a distributed environment.
5. The algorithm permits processes to enter the critical section in the order of their token numbers.
6. The Bakery algorithm cannot guarantee that two processes do not receive the same number.
7. In this case, process with the lowest name is served first.
8. If P_i and P_j receive the same number and if $i < j$, then P_i is served first.

```
do
{
choosing [i] = true
number [i] = max(number [0], number [1]..... number[n – 1]) + 1;
choosing [i] = false;
for (j = 0; j < n ; j++)
{
   while (choosing [j]) ;
while ((number [j] != 0) && (number [j, j] < number [i, i])) ;
}
        critical section
        number [i] = 0;
      remainder section
}              while (1);
```


Que 2.9. **Explain the following terms briefly :**

i. **Dekker's solution**

ii. **Busy waiting**

AKTU 2014-15, Marks 05

AKTU 2011-12, Marks 05

OR

Describe Dekker's solution.

Answer

i. Dekker's solution :

1. Dekker's solution is for two processes based solely on software.
2. Each of these processes loop indefinitely, repeatedly entering and reentering its critical section.
3. A process (P_0 and P_1) that wishes to execute its critical section first enters the igloo and examines the blackboard.
4. The process number is written on the blackboard, and that process leaves the igloo and proceeds to critical section.
5. Otherwise that process will wait for its turn.
6. Process reenters in the igloo to check the blackboard.
7. It repeats this exercise until it is allowed to enter its critical section. This procedure is known as busy waiting.

ii. Busy waiting :

1. Busy waiting occurs when a process is in its critical section, any other process that tries to enter its critical section must loop continuously in the entry code.
2. This kind of problem occurs in multiprogramming system.

```
do
{
        wait(mutex);
            // critical section
        signal (mutex);
            //remainder section
}
while(TRUE);
```

3. Busy waiting wastes CPU cycles that some other process might be able to use productively.

Que 2.10. **Give the principle, mutual exclusion in critical section problem. Also discuss how well these principles are followed in Dekker's solution.**

AKTU 2016-17, Marks 10

Answer

Critical section : Refer Q. 2.7, Page 2–7B, Unit-2.

Mutual exclusion : Refer Q. 2.5, Page 2–6B, Unit-2.

Dekker's solution : Refer Q. 2.9, Page 2–9B, Unit-2.

Que 2.11. Describe Peterson solution.

OR

Write and explain Peterson solution to the critical section problem.

AKTU 2012-13, Marks 05

Answer

1. Peterson's solution is a classical software based solution to the critical section problem.
2. Peterson's solution preserves all three conditions :
   a. Mutual exclusion is assured as only one process can access the critical section at any time.
   b. Progress is also assured, as a process outside the critical section does not block other processes from entering the critical section.
   c. Bounded waiting is preserved as every process gets a fair chance.
3. It is a two process solution.
4. It assumes that the load and store instructions are atomic and cannot be interrupted.
5. In Peterson's solution, we have two shared variables :
   a. int turn : The process whose turn is to enter the critical section.
   b. boolean flag[2] : Initialized to FALSE, initially no one is interested in entering the critical section.

   The flag array is used to indicate if a process is ready to enter the critical section. Flag[i] = true implies that process p_i is ready.

Algorithm :

```
do {
        flag[i] = TRUE;
            turn = j;
while (flag[j] && turn == j);
                    critical section
flag[i] = FALSE;
                    remainder section
} while (TRUE);
```

Two processes executing concurrently :

PROCESS 1	PROCESS 2

do {
flag1 = TRUE;
turn = 2;
while (flag2 && turn == 2)
critical section
flag1 = FALSE;
remainder section
} while (1)
	do {
	flag2 = TRUE;
	turn = 1;
	while (flag1 && turn == 1)
	critical section
	flag2 = FALSE;
	remainder section
	} while (1)

Shared variables { flag 1, flag 2 ; turn

Que 2.12. Differentiate between the concurrent execution and parallel execution.

AKTU 2011-12, Marks 2.5

Answer

S. No.	Concurrent execution	Parallel execution
1.	A concurrent execution is one when operation can occur at the same time.	A parallel execution is one when the concurrent parts are executed at the same time on the separate processors.
2.	Concurrency is the property of the program.	Parallel execution is the property of the machine.
3.	Concurrency is most useful method for structuring a program that needs to respond to multiple asynchronous inputs.	If execution efficiency is important than we prefer parallel execution.

PART-2

Semaphores, Test and Set Operations, Classical Problem in Concurrency, Dining Philosophers Problem, Sleeping Barber Problem, Interprocess Communication Models and Schemes, Process Generation.

CONCEPT OUTLINE : PART-2

- A semaphore is a variable or abstract datatype used to control access to a common resource by multiple process in a concurrent system.

- Classical problem of concurrency :
  - i. Bounded buffer producer consumer problem
  - ii. Reader writers problem
  - iii. Dining philosopher problem
  - iv. Sleeping Barber problem
- Methods of interprocess communication :
  - i. Message passing systems
  - ii. Shared memory system

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.13. Define semaphore. Give a scheme for implementation of semaphore primitives. **AKTU 2012-13, Marks 05**

OR

Explain semaphores with suitable example. **AKTU 2013-14, Marks 05**

Answer

Semaphore :

1. A semaphore is a variable or abstract datatype used to control access to a common resource by multiple process in a concurrent system.
2. Semaphores provide a much more organized approach for controlling the interaction of multiple processes.
3. Semaphores are something like the goto statement in early programming languages; they can be used to solve a variety of problems, but they impose little structure on the solution and the results can be hard to understand without the aid of numerous comments.
4. The effective synchronization tools often used to realize mutual exclusion in more complex systems are semaphores.
5. A semaphore S is an integer variable which can be accessed only through two standard atomic operations: wait and signal.
6. The definition of the wait and signal operations are :

```
wait(s)
{
while (S<=0)
{
/*do nothing*/
}
S = S – 1;
}
signal(S)
{
S = S + 1;
}
```

7. It should be noted that the test ($S \leq 0$) and modification of the integer value of S which is $S = S - 1$ must be executed without interruption.

Example of semaphore :

1. Consider two currently running processes, P_1 with a statement S_1 and P_2 with a statement S_2.
2. Suppose that we require that S_2 be executed only after S_1 has completed.
3. This scheme can be implemented by letting P_1 and P_2 share a common semaphore synch, initialized to 0, and by inserting the statements :
   S_1;
   signal(synch);
   in the process P_1 and the statements :
   wait(synch);
   S_2;
   in the process P_2.
   Since synch is initialized to 0, P_2 will execute S_2 only after P_1 has involved signal (synch), which is after S_1.

Que 2.14. What are the disadvantages of semaphores and discuss a suitable technique to overcome them ?

Answer

Disadvantages of semaphore :

1. Simple algorithms require more than one semaphore. This increases the complexity of semaphore solutions to such algorithms.
2. Semaphores are too low level. It is easy to make programming mistakes.
3. The programmer must keep track of all calls to wait and to signal the semaphore. If this is not done in the correct order, programmer error can cause deadlock.
4. Semaphores are used for both condition synchronization and mutual exclusion. These are distinct and different events, and it is difficult to know which meaning any given semaphore may have.
5. It requires busy-waiting.

Technique to overcome the disadvantages of semaphore :

1. The main disadvantage of the semaphore is that it requires busy-waiting.
2. While a process is in its critical section, any other process that tries to enter its critical section must loop continuously in the entry code.

3. This continual looping is clearly a problem in a real multi-programming system, where a single CPU is shared among many processes.
4. Busy waiting wastes CPU cycles that some other process might be able to use productively.
5. This type of semaphore is also called a spinlock because the process "spins" while waiting for the lock.
6. To overcome busy-waiting, we modify the definition of the wait and signal operations.
7. When a process executes the wait operation and finds that the semaphore value is not positive, the process blocks itself.
8. The block operation places the process into a waiting state.
9. Using a scheduler the CPU then can be allocated to other processes which are ready to run.

Que 2.15. What is semaphore ? Define the primitive operations including in semaphore mechanism. Write the algorithm to solve the problem of mutual exclusion using semaphores and also explain.

Answer

Semaphore : Refer Q. 2.13, Page 2–12B, Unit-2.

Operation of semaphore :

1. Two standard operations, wait and signal are defined on the semaphore.
2. Entry to the critical section is controlled by the wait operation and exit from a critical region is taken care by signal operation.
3. The wait, signal operations are also called P and V operations. The manipulation of semaphore (S) takes place as following :
   a. The wait command $P(S)$ decrements the semaphore value by 1. If the resulting value becomes negative then P command is delayed until the condition is satisfied.
   b. The $V(S)$ *i.e.*, signals operation increments the semaphore value by 1.
4. Mutual exclusion on the semaphore is enforced within $P(S)$ and $V(S)$.
5. If a number of processes attempt $P(S)$ simultaneously, only one process will be allowed to proceed & the other processes will be waiting.
6. These operations are defined as :

$P(S)$ or wait(S) :
If $S > 0$ then
    Set S to $S - 1$
Else
    Block the calling process (*i.e.*, Wait on S)
$V(S)$ or signal(S) :
If any processes are waiting on S
    Start one of these processes

Else
    Set S to $S + 1$

Algorithm : We assume that the pool consists n buffers, each capable of holding one item. The mutex semaphore provides mutual exclusion for accesses to the buffer pool and is initialized to the value 1.

```
do {
wait(full) ;
wait(mutex);
. . .
// remove an item from buffer to nextc ?
. . .
signal(mutex);
signal(empty);
. . .
// consume the item in nextc
. . .
} while(TRUE);
```

Que 2.16. State the producer consumer problem. Give a solution to the problem using semaphores. **AKTU 2016-17, Marks 10**

Answer

Producer consumer problem : Refer Q. 2.4, Page 2–4B, Unit-2.

Solution :

Code for producer consumer problem :

```
#define buffercapacity 200
typedef int semaphore;
semaphore full = 0;
semaphore empty = buffercapacity;
semaphore mutex = 1;
void producer (void)
{
    int item;
    while (true)
    {
        item = produce_item( );
        down (& empty);
        down (& mutex);
        insert_item (item);
        up(& mutex);
        up(& full);
    }
```

```
}
void consumer (void)
{
    int item;
    while (true)
    {
        down(& full);
        down(& mutex);
        item = remove_item( );
        up(& mutex);
        up(& empty);
        consume_item(item);
    }
}
```

Que 2.17. State the finite buffer producer consumer problem. Give solution of the problem using semaphores.

AKTU 2011-12, Marks 10

Answer

1. Producers produce items to be stored in the buffer.
2. Consumers remove and consume items which have been stored.
3. Mutual exclusion must be enforced on the buffer itself.
4. Moreover, producers can store only when there is an empty slot, and consumers can remove only when there is a full slot.
5. Three semaphores are used :
   a. The binary semaphore mutex controls access to the buffer itself.
   b. The counting semaphore empty keeps track of empty slots.
   c. The counting semaphore full keeps track of full slots.
6. For example, the buffer is implemented as an array of size MAX treated as a circular (ring) buffer. Variables in and out give the index of the next position for putting in and taking out (if any). Variable count gives the number of items in the buffer.

Initialization :

```
shared binary semaphore mutex = 1;
shared counting semaphore empty = MAX;
shared counting semaphore full = 0;
shared anytype buffer[MAX];
shared int in, out, count;
Producer : anytype item;
repeat
{
```



```
/* produce something */
item = produce();
/* wait for an empty space */
P(empty);
    /* store the item */
            P(mutex);
      buffer[in] = item;
  in = in + 1 mod MAX;
    count = count + 1;
            V(mutex);
/* report the new full slot */
            V(full);
}
          until done;
Consumer : anytype item;
repeat
{
/* wait for a stored item */
            P(full);
  /* remove the item */
            P(mutex);
     item = buffer[out];
out = out + 1 mod MAX;
    count = count – 1;
            V(mutex);
/* report the new empty slot */
            V(empty);
      /* consume it */
      consume(item);
}
          until done;
```

Que 2.18. Discuss reader/writer problem.

Answer

1. It is a synchronization problem that is used to compare and contrast synchronization mechanisms.
2. It is also an eminently used practical problem.
3. Suppose that a database is to be shared among several concurrent processes. Some of these processes may want only to read the database, whereas others may want to update (that is, to read and write) the database.
4. We distinguish between these two types of processes by referring to the former as readers and to the latter as writers.

5. Obviously, if two readers access the shared data simultaneously, no adverse effects will result.
6. However, if a writer and some other process (either a reader or a writer) access the database simultaneously, chaos may ensure.
7. To ensure that these difficulties do not arise, we require that the writers have exclusive access to the shared database while writing to the database.
8. This synchronization problem is referred to as the readers/writers problem.

Que 2.19. Give a solution to reader/writer problem using semaphores.

OR

Give the solution of readers/writers problem by using the concept of semaphore. **AKTU 2015-16, Marks 10**

Answer

Reader/writer problem solution using semaphores :

1. Readers/writers problem has several variations, all involving priorities.
2. The simplest one, referred to as the first readers/writers problem, requires that no reader will be kept waiting unless a writer has already obtained permission to use the shared object.
3. In the solution to the first readers/writers problem, the reader processes share the following data structures :
   Semaphore mutex, wrt ; int readcount
4. The semaphores mutex and wrt are initialized to 1; readcount is initialized to 0.
5. The semaphore wrt is common to both reader and writer processes.
6. The mutex semaphore is used to ensure mutual exclusion when the variable readcount is updated.
7. The readcount variable keeps track of how many processes are currently reading the object.
8. The semaphore wrt functions as a mutual exclusion semaphore for the writers.
10. It is also used by the first or last reader that enters or exits the critical section.
11. It is not used by readers who enter or exit while other readers are in their critical sections.

```
do
{
wait(wrt);                    // writing is performed
signal (wrt);
}while (TRUE);
```

The writer process :

```
do {
```



```
wait(mutex);
readcount ++ ;
if (readcount == 1)
wait(wrt);
signal(mutex);            // reading is performed
wait (mutex);
readcount—;
if (readcount == 0)
signal(wrt);
signal(mutex);
}while (TRUE);
```

Que 2.20. What do you understand by critical section ? What are the requirements of a solution to the critical section problem ? Discuss mutual exclusion implementation with the help of Test and Set machine instruction. **AKTU 2011-12, Marks 10**

Answer

Critical section and its requirements : Refer Q. 2.7, Page 2–7B, Unit-2.

Test and Set :

1. In most synchronization schemes, a physical entity must be used to represent the resource.
2. This entity is often called a lock byte or semaphore.
3. Thus, for each shared database or device there should be a separate lock byte.
4. We will use the convention that lock byte = 0 means the resource is available, whereas lock byte = 1 means the resource is already in use.
5. Before operating on such a shared resource, a process must perform the following actions :
   a. Examine the value of the lock byte (either it is 0 or 1).
   b. Set the lock byte to 1.
   c. If the original value was 1, go back to step a.
   d. After the process has completed its use of the resource, it sets the lock byte to zero.
6. It is special machine instruction used to avoid mutual exclusion.
7. The test and set instruction can be defined as follows :

```
boolean test and set (boolean & target)
{
    boolean rv = target ;
        target = true ;
            return rv ;
}
```

8. Test and set instruction is used in implementing mutual exclusion.

Que 2.21. **State the readers/writers problem with readers having priority. Give solution of the problem using semaphores.**

AKTU 2012-13, Marks 10

Answer

Readers/writers problem : Refer Q. 2.18, Page 2–17B, Unit-2.

Readers/writers problem with readers having priority and its solution :

1. Here priority means, no reader should wait if the share is currently opened for reading. Three variables are used : mutex, wrt, readcnt to implement solution
2. semaphore mutex, wrt; // semaphore mutex is used to ensure mutual exclusion when readcnt is updated *i.e.* when any reader enters or exit from the critical section and semaphore wrt is used by both readers and writers
3. int readcnt; // readcnt tells the number of processes performing read in the critical section, initially 0

Functions for semaphore :

1. wait() : decrements the semaphore value.
2. signal() : increments the semaphore value.

Writer process :

1. Writer requests the entry to critical section.
2. If allowed *i.e.* wait() gives a true value, it enters and performs the write. If not allowed, it keeps on waiting.
3. It exits the critical section.

Reader process :

1. Reader requests the entry to critical section.
2. If allowed :
   a. It increments the count of number of readers inside the critical section. If this reader is the first reader entering, it locks the wrt semaphore to restrict the entry of writers if any reader is inside.
   b. It then, signals mutex as any other reader is allowed to enter while others are already reading.
   c. After performing reading, it exits the critical section. When exiting, it checks if no more reader is inside, it signals the semaphore 'wrt' as now, writer can enter the critical section.
3. If not allowed, it keeps on waiting.

Thus, the mutex 'wrt' is queued on both readers and writers in a manner such that preference is given to readers if writers are also there. Thus, no reader is waiting simply because a writer has requested to enter the critical section.

Que 2.22. **Describe classical problem of concurrency.**

Answer

Classical problem of concurrency are :

1. **Bounded buffer producer consumer problem :** Refer Q. 2.17, Page 2–16B, Unit-2.
2. **Readers/writers problem :** Refer Q. 2.18, Page 2–17B, Unit-2.
3. **Dining philosophers problem :**
   i. The Dining philosophers problems is a classic synchronization problem.
   ii. There is a dining room containing a circular table with five chairs. At each chair is a plate, and between each plate is a single chopstick.
   iii. In the middle of the table is a bowl of spaghetti.

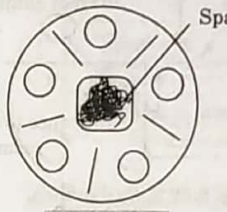


Fig. 2.22.1.

   iv. Near the room are five philosophers who spend most of their time thinking, but who occasionally get hungry and need to eat so they can think some more.
   v. In order to eat, a philosopher must sit at the table, pick up the two chopsticks to the left and right of a plate, then serve and eat the spaghetti on the plate.
   vi. Thus, each philosopher is represented by the following pseudocode :

```
process P[i]
while true do
{       THINK;
        PICKUP(CHOPSTICK[i], CHOPSTICK[i+1 mod 5]);
        EAT;
        PUTDOWN(CHOPSTICK[i], CHOPSTICK[i+1 mod 5]);
}
```

   vii. A philosopher may THINK indefinitely. Every philosopher who EATs will eventually finish.
   viii. Philosophers may PICKUP and PUTDOWN their chopsticks in either order, or nondeterministically, but these are atomic actions, and, of course, two philosophers cannot use a single CHOPSTICK at the same time.
   ix. The problem is to design a protocol to satisfy the liveness condition: any philosopher who tries to EAT, eventually does.

4. Sleeping barber problem :

1. A barbershop is designed so that there is a private room that contains the barber chair and an adjoining waiting room with a sliding door that contains N chairs.
2. If the barber is busy, the door to the private room is closed and arriving customers sit in one of the available chairs.
3. If a customer enters the shop and all chairs are occupied, the customer leaves without a haircut. If there are no customers to be served, the barber goes to sleep in the barber chair with the door to the waiting room open.
4. If the barber is asleep, the customer wakes the barber and has a haircut. Fig. 2.22.2 shows an implementation that uses semaphores.

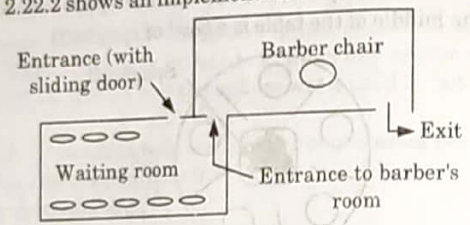


Fig. 2.22.2. Barbershop.

Que 2.23. **Write a short note on interprocess communication.**

AKTU 2011-12, Marks 10

OR

Define message passing and shared memory interprocess communication.

AKTU 2013-14, Marks 05

Answer

1. Interprocess communication (IPC) means the mechanism used by processes to communicate with each other while they are running.
2. IPC allows processes to synchronize their action without sharing the same address space.
3. Messages provide a basic communication capability between two processes.
4. IPC is particularly useful in a distributed environment where the communicating processes may reside on different computers connected with a network.
5. Interprocess communication is best provided by the two fundamental models :

a. Shared memory systems :

i. Interprocess communication using shared memory requires communicating processes to establish a region of shared memory.

ii. Typically, a shared memory region resides in the address space of the process creating the shared memory segment.

iii. Other processes that wish to communicate using this shared memory segment must attach it to their address space.

iv. The operating system tries to prevent one process from accessing another process's memory.

v. Shared memory requires that two or more processes agree to remove this restriction.

vi. They can then exchange information by reading and writing data in the shared areas.

vii. The form of the data and the location are determined by these processes and are not under the operating system's control.

viii. The processes are also responsible for ensuring that they are not writing to the same location simultaneously.

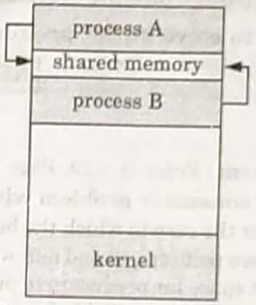


Fig. 2.23.1. Shared memory.

b. Message passing systems :

i. Message passing provides a mechanism to allow processes to communicate and to synchronize their actions without sharing the same address space.

ii. It is particularly useful in a distributed environment, where the communicating processes may reside on different computers connected by a network.

iii. A message passing facility provides at least two operations : send (message) and receive (message).

iv. Messages sent by a process can be either fixed or variable in size.

v. If processes P and Q want to communicate, they must send messages to and receive messages from each other : a communication link must exist between them.

vi. Here are several methods for logically implementing a link and the send () or receive () operations :

1. Direct or indirect communication
2. Synchronous or asynchronous communication
3. Automatic or explicit buffering

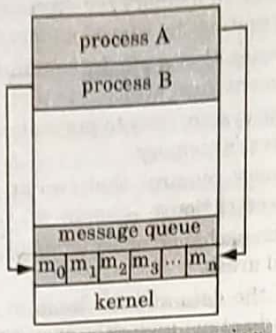


Fig. 2.23.2. Message passing.

Que 2.24. **Discuss message passing systems. Explain how message passing can be used to solve buffer producer consumer problem with infinite buffer.** **AKTU 2012-13, Marks 10**

Answer

Message passing system : Refer Q. 2.23, Page 2–22B, Unit-2.

Solution of producer consumer problem with infinite buffer :

1. Let us first consider the case in which the buffer is infinite.
2. Fig. 2.24.1 shows two pointers, in and out, which are used respectively indicating the next space for producers to put a newly created product and the next product that is available for consumers to consume.

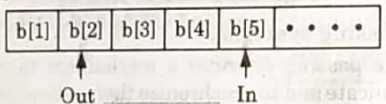


Fig. 2.24.1.

3. Instead of two pointers, in and out, an integer variable, n is used to indicate the number of products available for consumption and a set of functions are provided for convenience : produce(), consume(), append() and take().
4. The semaphore s is used to enforce the mutual exclusion; the semaphore delay is used to force the consumer to wait if the buffer is empty.

```
void producer (void)
  {
    while (TRUE) {
    -
    produce item
    -
    send (consumer, item) ;
    }
  }
```

```
void consumer (void)
  {
    while (TRUE) {
    recv (producer, item) ;
    -
    consume item ;
    -
    }
  }
```


Que 2.25. **A barber shop consists of a waiting room with n chairs and a barber room with one barber chair. If there are no customers to be served, the barber goes to sleep. If a customer enters the barber shop and all chairs are occupied, then the customer leaves the shop. If the barber is busy but chairs are available, then the customer sits in one of the free chairs. If the barber is asleep, the customer wakes up the barber. Write an algorithm for the above synchronization problem using semaphores.**

AKTU 2014-15, Marks 10

Answer

1. We use 3 semaphores. Semaphore 'customers' counts waiting customers; semaphore 'barbers' is the number of idle barbers (0 or 1); and mutex is used for 'mutual' exclusion.
2. A shared data variable 'customers1' also counts waiting customers, It is a copy of 'customers' but we need it here because we cannot access the value of semaphores directly.
3. We also need semaphore 'cutting' which ensures that the barber would not cut another customer's hair before the previous customer leaves.

```
// shared data
semaphore customers = 0;
semaphore barbers = 0;
semaphore cutting = 0;
semaphore mutex = 1;
int customers1 = 0;
void barber() {
                                while(true) {
                                wait(customers);
                              // sleep when there are no waiting
                                customers
                                wait(mutex);
// mutex for accessing customers1
                                customers1 = customers1 – 1;
                                signal(barbers);
                                signal(mutex);
                                cut_hair();
                              }
}
void customer() {
wait(mutex);                  // mutex for accessing customers1
if (customers1 < n) {
customers1 = customers1 + 1;
      signal(customers);
          signal(mutex);
           wait(barbers);
```

```
//wait for available barbers
        get_haircut();
}                   else { //      do nothing (leave) when all chairs
                                  are used.
        signal(mutex);
                    }
}
cut_hair( ){
    waiting(cutting);
}
get_haircut( ){
get hair cut for some time;
        signal(cutting);
}
```

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Discuss process model and principle of concurrency.

Ans. Refer Q. 2.1 and Q. 2.3.

Q. 2. Write short note on producer consumer problem along with its solution using semaphore.

Ans. Refer Q. 2.4 and Q. 2.16.

Q. 3. What is mutual exclusion ? What are the four conditions of mutual exclusion ?

Ans. Refer Q. 2.5.

Q. 4. Write and explain Peterson solution to the critical section problem.

Ans. Refer Q. 2.11.

Q. 5. Give a solution to reader/writer problem using semaphores.

Ans. Refer Q. 2.19.

Q. 6. Discuss classical problem of concurrency.

Ans. Refer Q. 2.22.

Q. 7. Write short note on interprocess communication.

Ans. Refer Q. 2.23.

3 UNIT

CPU Scheduling

PART-1

CPU Scheduling : Scheduling Concepts, Performance Criteria, Process States, Process Transition Diagram, Schedulers, Process Control Block (PCB), Process Address Space, Process Identification Information.

CONCEPT OUTLINE : PART-1

- CPU scheduling is the management of CPU resources.
- **Performance scheduling criteria :**
  i. CPU utilization
  ii. Throughput
  iii. Waiting time
  iv. Turnaround time
  v. Response time
- **Various states of process :**
  i. New
  ii. Running
  iii. Waiting
  iv. Ready
  v. Terminated
- **Types of scheduler :**
  i. Long term scheduler
  ii. Short term scheduler
  iii. Mid term scheduler

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. **What is CPU scheduling ? Give the criteria for scheduling.**

OR

Discuss the performance criteria for CPU scheduling.

AKTU 2015-16, Marks 10

Answer

1. CPU scheduling is the management of CPU resources.
2. The scheduling mechanism is the part of the process manager that handles the removal of the running process from the CPU and the selection of another process on the basis of a particular strategy.
3. CPU scheduling is the basis of multi-programmed operating systems.
4. The scheduler is responsible for multiplexing processes on the CPU.
5. CPU scheduling is used to increase CPU utilization.

Scheduling criteria : The scheduling policy determines the importance of each of the criteria. Some commonly used criteria are :

1. **CPU utilization :**
   a. CPU utilization is the average function of time, during which the processor is busy.
   b. The load on the system affects the level of utilization that can be achieved.
   c. CPU utilization may range from 0 % to 100 %. On large and expensive system *i.e.*, time shared system, CPU utilization may be the primary consideration.
2. **Throughput :**
   a. Throughput refers to the amount of work completed in a unit of time.
   b. The number of processes the system can execute in a period of time.
   c. The higher the number, the more work is done by the system.
3. **Waiting time :**
   a. The average period of time a process spends waiting.
   b. Waiting time may be expressed as turnaround time less the actual execution time.
4. **Turnaround time :**
   a. The interval from the time of submission of a process to the time of completion is the turnaround time.
   b. Turnaround time is the sum of the periods spent waiting to get into memory, waiting into the ready queue, executing on the CPU and doing I/O.
5. **Response time :**
   a. Response time is the time from the submission of a request until the first response is produced.
6. **Priority :**
   a. Give preferential treatment to processes with higher priorities.

7. **Balanced utilization :**
   a. Utilization of memory, I/O devices and other system resources are also considered.
   b. Not only CPU utilization considered for performance.
8. **Fairness :**
   a. Avoid the process from the starvation.
   b. All the processes must be given equal opportunity to execute.

Que 3.2. Discuss the objectives of CPU scheduling.

Answer

Objectives of CPU scheduling :

1. **Efficiency :** Keep the CPU busy all the time.
2. **Maximize throughput :** Service the largest possible number of jobs in a given amount of time; minimize the amount of time users must wait for their results.
3. **Minimize response time :** Interactive users should see good performance.
4. **Minimize overhead :** Do not waste too many resources. Keep scheduling time and context switch time at a minimum.
5. **Maximize resource use :** Favour processes that will use under-utilized resources.
6. **Avoid indefinite postponement :** Every process should get a chance to run eventually.
7. **Enforce priorities :** If the scheduler allows a process to be assigned a priority, it should be meaningful and enforced.

Que 3.3. What is the difference between pre-emptive and non pre-emptive scheduling ? State, why strict non pre-emptive scheduling is unlikely to be used in computer centre ? Explain the operation of multi-level scheduling.

Answer

Difference :

S. No.	Pre-emptive scheduling	Non pre-emptive scheduling
1.	Processor can be pre-empted to execute a different process in the middle of execution of any current process.	Once processor starts to execute a process it must finish it before executing the other. It cannot be paused in middle.

2.	CPU utilization is more compared to non pre-emptive scheduling.	CPU utilization is less compared to pre-emptive scheduling.
3.	Waiting time and response time is less.	Waiting time and response time is more.
4.	If a high priority process frequently arrives in the ready queue, low priority process may starve.	If a process with long burst time is running CPU, then another process with less CPU burst time may starve.
5.	Pre-emptive scheduling is flexible.	Non pre-emptive scheduling is rigid.
6.	For example, SRTF, Priority, Round-Robin, etc.	For example, FCFS, SJF, Priority, etc.

Non pre-emptive scheduling is unlikely to be used in computer centre :

1. Once the CPU has been allocated to a process, the process keeps the CPU until it releases the CPU either by terminating or by switching to the waiting state.
2. In a general purpose computer system, users share the CPU and care about system responsiveness.
3. If the system uses non pre-emptive scheduling, some users may sit before the monitor for several hours without doing anything other than waiting for the set of processes in front of them in the system queue to finish.
4. So, strictly non pre-emptive scheduling is unlikely to be used in a general purpose computer system.

Operation of multilevel scheduling :

1. A multilevel queue scheduling algorithm partitions the ready queue into several separate queues (Fig. 3.3.1).
2. The processes are permanently assigned to one queue, generally based on some property of the process, such as memory size, process priority, or process type.
3. Each queue has its own scheduling algorithm.
4. For example, separate queues might be used for foreground and background processes.
5. The foreground queue might be scheduled by an RR algorithm, while the background queue is scheduled by an FCFS algorithm.

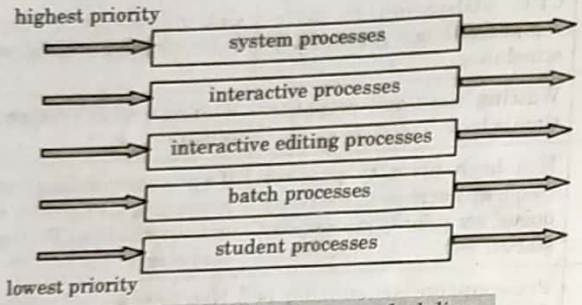


Fig. 3.3.1. Multilevel queue scheduling.

6. There must be scheduling among the queues, which is commonly implemented as fixed-priority pre-emptive scheduling.
7. For example, the foreground queue may have absolute priority over the background queue.

Que 3.4. **Explain the objectives and implementation of short term scheduling and long term scheduling.**

Answer

Objective and implementation of short term scheduling :

1. *The main objective is increasing system performance in accordance with the chosen set of criteria.*
2. *It is the change of ready state to running state of the process.*
3. *It is also called CPU scheduler.*
4. *CPU scheduler selects from among the processes that are ready to execute and allocates the CPU to one of them.*

Objective and implementation of long term scheduling :

1. The primary objective is to provide a balanced mix of jobs, such as I/O bound and processor bound.
2. It also controls the degree of multi-programming.
3. If the degree of multi-programming is stable, then the average rate of process creation must be equal to the average departure rate of processes leaving the system.
4. Long term scheduler determines which programs are admitted to the system for processing.
5. It is also called job scheduler.
6. Job scheduler selects processes from the queue and loads them into memory for execution. Process loads into the memory for CPU scheduler.

Que 3.5. **List out the various states of process.**

OR

Draw the process state diagram and describe the various process states.

OR

What are the various process states ? Depict process state diagram. What do you understand by context switching and various processes involved in it.

OR

Draw and explain the process state transition diagram.

AKTU 2011-12, Marks 05

Answer

Various process states are :

1. **New :** The process is being created.
2. **Running :** Instructions are being executed.
3. **Waiting :** The process is waiting for some event to occur (such as an I/O completion or reception of a signal).
4. **Ready :** The process is waiting to be assigned to a processor.
5. **Terminated :** The process has finished execution.

Process state diagram :

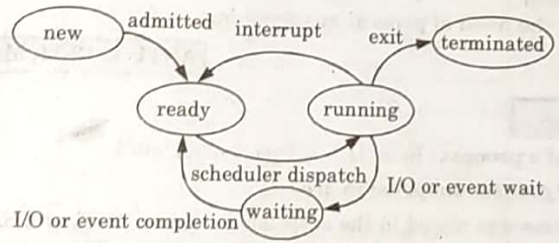


Fig. 3.5.1.

Context switching :

1. A context switching is the mechanism to store and restore the state or context of a CPU in process control block so that a process execution can be resumed from the same point at a later time.
2. Any operating system that allows for multitasking relies heavily on the use of context switching to allow different processes to run at the same time.
3. A context switch occurs when a computer's CPU switches from one process or thread to a different process or thread.

4. Context switching allows for one CPU to handle numerous processes or threads without the need for additional processors.

Process involved in context switching are :

The steps in a full process switch are :

1. Save the context of the processor, including program counter and other registers.
2. Update the process control block of the process that is currently in the running state. This includes changing the state of the process to one of the other states (Ready; Blocked; Ready/Suspend or Exit). Other relevant fields must also be updated, including the reason for leaving the running state and accounting information.
3. Move the process control block of this process to the appropriate queue (Ready; Blocked on Event *i*; Ready/Suspend).
4. Select another process for execution.
5. Update the process control block of the process selected. This includes changing the state of this process to running.
6. Update memory management data structures. This may be required, depending on how address translation is managed.
7. Restore the context of the processor to that which existed at the time the selected process was last switched out of the running state, by loading in the previous values of the program counter and other registers.

Que 3.6. **Define the different states of a process with diagram. Explain the need of process suspension.**

AKTU 2013-14, Marks 05

Answer

States of a process : Refer Q. 3.5, Page 3–7B, Unit-3.

Need of process suspension are :

The process was placed in the suspended state by itself, or OS, a parent process for the purpose of preventing its execution. There are following needs of process suspension :

1. **Parent process request :** A process may be suspended in order of parent process request in order to modify the process.
2. **Swapping :** If the process is ready and there is no place in the main memory, the process get suspended.
3. **Other OS reason :** When one process in main memory which was blocked and there is another process ready for execution, but waiting in secondary memory, then the process in main memory is suspended.

Que 3.7. **What is process control block ? Also list out the information it contains.**

OR

What is the process control block ? Explain all its components.

Answer

Process control block :

1. Process control block is a data structure used to store the information about the processes.
2. The information of the process is used by CPU at the runtime.

The following are the various information that is contained by process control block :

1. Naming the process
2. State of the process
3. Resources allocated to the process
4. Memory allocated to the process
5. Scheduling information
6. Input / output devices associated with process

Components of process control block :

Process Id
Process state
Program counter
Register information
Scheduling information
Memory related information
Accounting information
Status information related to I/O

Fig. 3.7.1. Structure of process control block.

The following are the various components that are associated with the process control block (PCB) :

1. **Process ID :**
   a. In computer system, there are various processes running simultaneously and each process has its unique Id.
   b. This Id helps system in scheduling the processes.
   c. This Id is provided by the process control block.
   d. In other words, it is an identification number that uniquely identifies the processes of computer system.

2. **Process state :**
   a. As we know that the process state of any process can be new, running, waiting, executing, blocked, suspended, terminated.
   b. Process control block is used to define the process state of any process.
   c. In other words, process control block refers the states of the processes.
3. **Program counter :**
   a. Program counter is used to point to the address of the next instruction to be executed in any process.
   b. This is also managed by the process control block.
4. **Register information :**
   a. It comprises of the various registers, such as index and stack that are associated with the process.
   b. This information is also managed by the process control block.
5. **Scheduling information :**
   a. Scheduling information is used to set the priority of different processes.
   b. This is very useful information which is set by the process control block.
   c. The priority of primary feature of RAM is higher than other secondary features.
   d. Scheduling information is very useful in managing any computer system.
6. **Memory related information :**
   a. This section of the process control block comprises of page and segment tables.
   b. It also stores the data contained in base and limit registers.
7. **Accounting information :**
   a. This section of process control block stores the details relate to central processing unit (CPU) utilization and execution time of a process.
8. **Status information related to input / output :**
   a. This section of process control block stores the details pertaining to resource utilization and file opened during the process execution.

Que 3.8. **Differentiate between long term, short term and mid term schedulers.**

OR

With a diagram, explain the different states of a process. Differentiate between long term and short term schedulers.

Answer

Different states of process : Refer Q. 2.2, Page 2–3B, Unit-2.

Difference between various schedulers :

S. No.	Long term	Short term	Mid term
1.	It is job scheduler.	It is CPU scheduler.	It is process swapping scheduler.
2.	Speed is less than short term scheduler.	Speed is very fast.	Speed is in between both.
3.	It controls degree of multi-programming.	Less control over degree of multi-programming.	Reduced the degree of multi-programming.
4.	Absent or minimal in time sharing system.	Minimal in time sharing system.	Time sharing system use mid term scheduler.
5.	It selects process from pool and loads them into memory for execution.	It select among the processes that are ready to execute.	Process can be reintroduced into memory and its execution can be continued.

Que 3.9. **Describe process address space.**

Answer

1. Process address space means a space that is allocated in memory for a process.
2. Address space is a space in computer memory.
3. Every process has an address space.
4. Address space can be of two types :
   a. **Physical address space :** Physical address space is created in RAM.
   b. **Virtual address space :** Virtual address space is an address space that is created outside the main memory inside the virtual memory, and it is created in hard disk.

Que 3.10. **Write a short note on process identification information.**

Answer

1. Process registration involves recording all information necessary to identify a registered process and to differentiate it from other processes

in the system. This information is called process identification information.

2. This information is recorded right after the process is created or born.
3. Usually, every process is also given a unique identifier, called a process ID, in order to make future references easier and unambiguous.
4. Process identification information is usually static, which means it does not change as time goes by and as the process moves from one state of life to another, for that purpose, the system will record process state information.
5. Process identification information use following numeric identifiers :
   a. **Unique process identifier (PID) :** PID provide index id to the process.
   b. **User identifier (UID) :** UID identifies the user who is responsible for the job.

PART-2

Threads and their Management, Scheduling Algorithms, Multiprocessor Scheduling, Deadlock : System Model, Deadlock Characterization, Prevention, Avoidance and Detection, Recovery from Deadlock.

CONCEPT OUTLINE : PART-2

- A thread is a flow of execution through the process code, with its own program counter, system registers and stack.
- **Types of thread :**
  i. User level thread ii. Kernel level thread
- **Scheduling algorithm :**
  i. FCFS ii. SJF
  iii. Priority scheduling
  iv. Round Robin scheduling
  v. Multilevel queue scheduling
  vi. Multilevel feedback queue scheduling
- **Necessary conditions for deadlock :**
  i. Mutual exclusion ii. Hold and wait
  iii. Circular wait iv. No pre-emption

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.11. What is thread ? Discuss its advantages.

Answer

1. A thread is a flow of execution through the process code, with its own program counter, system registers and stack.
2. Threads represent a software approach to improving performance of operating system by reducing the overhead of process switching.
3. Each thread belongs to exactly one process and no thread can exist outside a process. Each thread represents a separate flow of control.
4. They also provide a suitable foundation for parallel execution of applications on shared memory multi-processors.

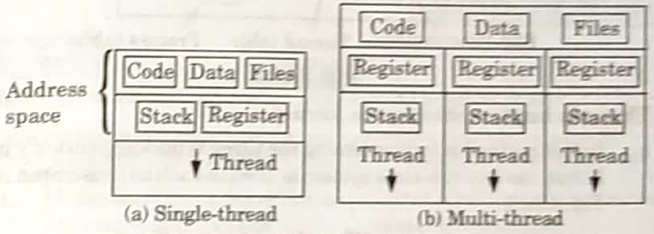


Fig. 3.11.1. Single and multi-thread processes.

Advantages of thread :

1. Thread minimize context switching time.
2. Use of thread provides concurrency within a process.
3. Efficient communication.
4. It is more economical to create and context switch threads.
5. The benefits of multi-threading can be greatly increased in a multi-processor architecture.

Que 3.12. How threads are implemented ?

Answer

To implement a threads package, there are the following three ways :

1. **Threads implementation in user space :**
   a. Threads could be implemented at the user level.

b. A user-level thread is known only to the user or actually the process that has created it.

c. These tasks include but are not restricted to : CPU assignment, device assignment, state transition, etc.

d. To be clearer, the operating system will not know that a process has created any threads and hence cannot help managing them.

e. What the operating system does, in respect to user-level threads, is to provide a set of basic routines for creation, manipulation, and destruction of threads.

f. These can be used by the user whenever needed, without any managerial responsibility as the part of the operating system.

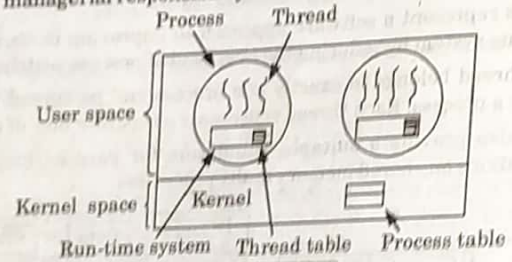


Fig. 3.12.1.

2. **Threads implementation in kernel :**

a. In this method of implementing the threads package entirely in the kernel, no any run-time system is need in each as illustrated in the Fig. 3.12.2.

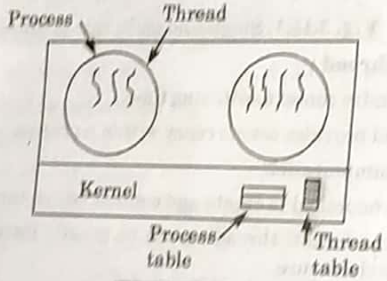


Fig. 3.12.2.

b. In this, there is no any thread table in each process. But to keep track of all the threads in the system, the kernel has the thread table.

c. Whenever a thread wants to create a new thread or destroy an existing thread, then it makes a kernel call, which does the creation or destruction just by updating the kernel thread table.

d. The thread table of the kernel holds each registers, state, and some other useful information of the thread.

e. Here the information is the same as with the user level threads.

f. This information is a subset of the information that traditional kernels maintain about each of their single-threaded processes, that is, the process state.

g. In addition to these, to keep track of processes, the kernel also maintains the traditional process table.

3. **Hybrid implementation :**

a. The third type of thread implementation is hybrid implementation that is the implementation of a combination of user level and kernel level threads.

b. The managerial responsibility of this kind of thread is performed partially by the user who has created the thread and partially by the operating system.

Que 3.13. **Differentiate between user level and kernel level thread.**

AKTU 2012-13, Marks 2.5

Answer

Difference between user level and kernel level thread :

S. No.	User level threads	Kernel level threads
1.	User level threads are faster to create and manage.	Kernel level threads are slower to create and manage.
2.	Implemented by a thread library at the user level.	Operating system support directly to kernel threads.
3.	User level thread can run on any operating system.	Kernel level threads are specific to the operating system.
4.	Support provided at the user level called user level thread.	Support may be provided by kernel is called kernel level thread.
5.	Multi-thread application cannot take advantage of multi-processing.	Kernel routines themselves can be multi-threaded.

Que 3.14. **What are the types of thread ? Give advantages and disadvantages.**

Answer

Types of thread are :

1. **User level thread :**
   i. In a user level thread, all of the work of thread management is done by the application.
   ii. The thread library contains code for creating and destroying threads, for passing message and data between threads, for threads, for passing message and data between threads, for scheduling thread execution and for saving and restoring thread contexts.
   iii. The application begins with a single thread and begins running in that thread.

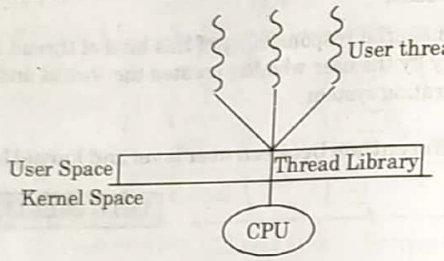


Fig. 3.14.1. User level thread.

Advantages of user level thread :

i. Thread switching does not require kernel mode privileges.
ii. User level thread can run on any operating system.
iii. Scheduling can be application specific.
iv. User level threads are fast to create and manage.

Disadvantages of user level thread :

i. In a typical operating system, most system calls are blocking.
ii. Multi-threaded application cannot take advantage of multi-processing.

2. **Kernel level thread :**
   i. In kernel level thread, thread management is done by the kernel. There is no thread management code in the application area.
   ii. Kernel threads are supported directly by the operating system.
   iii. All of the threads within an application are supported within a single process.
   iv. Scheduling by the kernel is done on a thread basis.
   v. The kernel performs thread creation, scheduling and management in kernel space.

Advantages of kernel level thread :

i. Kernel can simultaneously schedule multiple threads from the same process on multiple processes.
ii. If one thread in a process is blocked, the kernel can schedule another thread of the same process.
iii. Kernel routines themselves can multithread.

Disadvantages of kernel level thread :

i. Kernel threads are generally slower to create and manage than the user threads.
ii. Transfer of control from one thread to another within same process requires a mode switch to the kernel.

Que 3.15. What is a thread ? How thread is different from a process ? What resources are used when a thread is created ?

AKTU 2014-15, Marks 10

Answer

Thread : Refer Q. 3.11, Page 3–13B, Unit-3.

Difference between thread and process :

S. No.	Thread	Process
1.	Thread is called light weight process.	Process is called heavy weight process.
2.	Thread switching does not need to call an operating system and cause an interrupt to the kernel.	Process switching needs interface with operating system.
3.	All threads can share same set of open files, child processes.	In multiple process implementation each process executes the same code but has its own memory and file resources.
4.	While one server thread is blocked and waiting, second thread in the same task could run.	If one server process is blocked no other server process can execute until the first process unblocked.
5.	One thread can read, write or even completely wipe out another threads stack.	In multiple process each process operates independently of the other.

Resources used when thread is created : When a thread is created, the thread does not require any new resource to execute, the thread shares the resources like memory of the process to which they belong to.

Que 3.16. **Differentiate between user thread and kernel thread. What is thread cancellation ?** **AKTU 2013-14, Marks 05**

Answer

User thread vs Kernel thread : Refer Q. 3.13, Page 3–15B, Unit-3.

Thread cancellation :

1. Thread cancellation is the task of terminating a thread before it has completed.
2. For example, if multiple threads are concurrently searching through a database and one thread returns the result, the remaining threads might be canceled.
3. Another situation might occur when a user presses a button on a web browser that stop a web page from loading any further.
4. Often, a web page is loaded using several threads and each image is loaded in a separate thread.
5. When a user presses the stop button on the browser, all threads loading the page are canceled.

Que 3.17. **Discuss First Come First Serve (FCFS) scheduling algorithm. Give its advantages and disadvantages.**

Answer

1. The simplest scheduling algorithm is the First Come First Served (FCFS) algorithm, *i.e.*, the process, which requests the CPU first is allocated the CPU first.
2. The FCFS algorithm is simply realized with a FIFO queue. It functions as follows :
   a. When a process enters the ready queue, its Process Control Block (PCB) is linked onto the tail of the queue.
   b. As soon as the CPU is free, it is allocated to the process at the head of the ready queue.
   c. The running process is then removed from the ready queue.

Advantages of First Come First Served (FCFS) algorithm :

1. Better for long processes.
2. Simple method (*i.e.*, minimum overhead on processor).
3. No starvation.

Disadvantages of First Come First Served (FCFS) algorithm :

1. Convoy effect occurs. Even very small process should wait for its turn to come to utilize the CPU.

2. Short process behind long process results in lower CPU utilization.
3. Throughput is not emphasized.

Que 3.18. **Discuss Shortest Job First (SJF) scheduling algorithm. Also, write its advantages and disadvantages.**

Answer

1. SJF algorithm associates with each process the length of the process's next CPU burst.
2. When the CPU is available, it is assigned to the process that has the smallest next CPU burst.
3. If the next CPU bursts of two processes are the same, FCFS scheduling is used to break the tie.
4. The appropriate term for this scheduling method would be the shortest-next-CPU-burst algorithm, because scheduling depends on the length of the next CPU burst of a process, rather that it's total length.
5. The SJF algorithm can be either preemptive or non-preemptive.
6. The choice arises when a new process arrives at the ready queue while a previous process is still executing.
7. The next CPU burst of the newly arrived process may be shorter than what is left of the currently executing process.
8. A preemptive SJF algorithm will preempt the currently executing process, whereas a non-preemptive SJF algorithm will allow the currently running process to finish its CPU burst.
9. Preemptive SJF scheduling is sometimes called shortest remaining time first scheduling.

Advantages of Shortest Job First (SJF) algorithm :

1. It gives superior turnaround time performance to shortest process next because a short job is given immediate preference to a running longer job.
2. Throughput is high.

Disadvantages of Shortest Job First (SJF) algorithm :

1. Elapsed time (*i.e.*, execution-completed-time) must be recorded, it results an additional overhead on the processor.
2. Starvation may be possible for the longer processes.

Que 3.19. **Discuss priority scheduling algorithm. What are its advantages and disadvantages ?**

Answer

1. Priority scheduling is a non pre-emptive algorithm and one of the most common scheduling algorithms in batch systems.

2. Each process is assigned a priority. Process with highest priority is to be executed first and so on.
3. Processes with same priority are executed on FCFS basis.
4. Priority can be decided based on memory requirements, time requirements or any other resource requirements.

Advantages of priority scheduling algorithm :

1. The priority of a process can be selected based on memory requirement, time requirement or user preference.
2. For example, a high end game will have better graphics that means the process which updates the screen in a game will have higher priority so as to achieve better graphics performance.
3. Priority scheduling provides a good mechanism where the relative importance of each process may be precisely defined.

Disadvantages of priority scheduling algorithm :

1. If high priority processes use up a lot of CPU time, lower priority processes may starve and be postponed indefinitely.
2. The situation where a process never gets scheduled to run is called starvation.
3. Another problem with priority scheduling is deciding which process gets which priority level assigned to it.

Que 3.20. Discuss Round Robin scheduling algorithm. Give its advantages and disadvantages.

Answer

1. The Round Robin (RR) scheduling algorithm is designed especially for time sharing systems.
2. It is similar to FCFS scheduling, but pre-emption is added to enable the system to switch between processes.
3. The ready queue is treated as a circular queue.
4. The CPU scheduler goes around the ready queue, allocating the CPU to each process for a time interval of up to 1 time quantum.
5. A small unit of time is called a time quantum or time slice.
6. A time quantum is generally from 10 to 100 milliseconds in length.
7. To implement RR scheduling, we again treat the ready queue as a FIFO queue of processes.
8. New processes are added to the tail of the ready queue.
9. The CPU scheduler picks the first process from the ready queue, sets a timer to interrupt after 1 time quantum, and dispatches the process.

Advantages of Round Robin (RR) algorithm :

1. Round-Robin is effective in a general-purpose, time sharing system or transaction processing system.
2. Fair treatment for all the processes.
3. Overhead on processor is low.
4. Good response time for short processes.

Disadvantages of Round Robin (RR) algorithm :

1. Care must be taken in choosing quantum value.
2. Processing overhead is there in handling clock interrupt.
3. Throughput is low if time quantum is too small.

Que 3.21. What is CPU scheduling ? Discuss the multilevel feedback queue scheduling. **AKTU 2012-13, Marks 10**

OR

Explain the functioning of multilevel feedback queue scheduling. **AKTU 2013-14, Marks 10**

Answer

CPU scheduling : Refer Q. 3.1, Page 3–2B, Unit-3.

Multilevel feedback queue scheduling :

1. Multilevel Feedback Queue (MFQ) scheduling algorithm overcomes the problem of multilevel queue scheduling algorithm.
2. MFQ means to separate processes with different CPU burst time. If a process uses too much CPU time, it will be moved to a lower priority queue.
3. MFQ allows a process to move between the queues.
4. MFQ implements two or more scheduling queues.

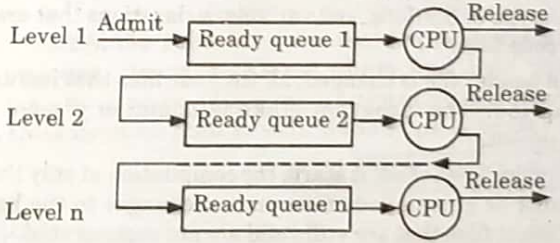


Fig. 3.21.1. Multilevel feedback queue.

5. For example, each process may start at the top level queue. If the process is completed within a given time slice, it departs the system.
6. Processes that need more than one time slice may be reassigned by the operating system to a lower priority queue, which gets a lower percentage of the processor time.

Multilevel feedback queue scheduler is defined by the following parameters :

1. The number of queues.
2. Scheduling algorithm for each queue.
3. Method used to determine when to denote a process to a lower priority queue.
4. Method used to determine when to upgrade a process to a higher priority queue.
5. Method used to determine which queue a process will enter when that process needs service.

Que 3.22. Explain the following scheduling algorithms :

i. Multilevel feedback queue scheduling

ii. Multiprocessor scheduling **AKTU 2014-15, Marks 10**

Answer

i. Multilevel feedback queue scheduling : Refer Q. 3.21, Page 3–21B, Unit-3.

ii. Multiprocessor scheduling :

1. On a multiprocessor, scheduling is two dimensional. The scheduler has to decide which process to run and which CPU to run it on. This extra dimension greatly complicates scheduling on multiprocessors.
2. Another complicating factor is that in some systems, all the processes are unrelated whereas in others they come in groups.
3. An example of the former situation is a timesharing system in which independent users start up independent processes. The processes are unrelated and each one can be scheduled without regard to the other ones.
4. Large systems often consist of some number of header files containing macros, type definitions, and variable declarations that are used by the actual code files.
5. When a header file is changed, all the code files that include it must be recompiled. The program make is commonly used to manage development.
6. When make is invoked, it starts the compilation of only those code files that must be recompiled on account of changes to the header or code files. Object files that are still valid are not regenerated.
7. The original version of make did its work sequentially, but newer versions designed for multiprocessors can start up all the compilations at once.

Que 3.23. Consider a variant of Round Robin scheduling algorithm where the entries in the ready queue are pointers to the processes. What would be the effect of putting two pointers to the same process in the ready queue ? What would be advantages and disadvantages of this scheme ? **AKTU 2012-13, Marks 05**

Answer

1. Process appears twice in the ready queue and is scheduled twice as often as other processes.
2. In effect, that process will have increased its priority since by getting time more often it is receiving preferential treatment. It will double the time given to that process.
3. The advantage of this scheme is that more important jobs could be given more time. It will provide higher priority with minimal modification to scheduler.
4. The disadvantage of this scheme is that the shorter job will suffer because important jobs will execute with more time. There will be overhead for managing pointers. It may also increase overhead if same process runs back-to-back.

Que 3.24. Consider the set of the processes given in the table and the following scheduling algorithms :

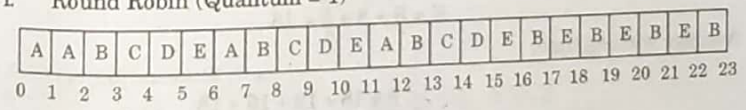
i. Round Robin (Quantum = 1)
ii. Round Robin (Quantum = 2)
iii. Shortest Remaining Job First

Process Id	Arrival Time	Execution Time
A	0	4
B	2	7
C	3	3
D	3.5	3
E	4	5

If there is tie within the processes, the tie is broken in the favour of the oldest process. Draw the Gantt chart and find the average waiting time, response time and turnaround time for the algorithms. Comment on your result. Which one is better and why ? **AKTU 2013-14, Marks 10**

Answer

i. Round Robin (Quantum = 1)



Waiting time for process,

$A = 0 + 4 + 4 = 8$

$B = 2 + 4 + 4 + 3 + 1 + 1 + 1 = 16$

$C = 3 + 4 + 4 = 11$

$D = 4 + 4 + 4 = 12$

$E = 5 + 4 + 4 + 1 + 1 + 1 = 16$

$$\text{Average waiting time} = \frac{8 + 16 + 11 + 12 + 16}{5} = 12.6$$

Turnaround time for process,

$A = 12$

$B = 21$

$C = 11$

$D = 11.5$

$E = 18$

Average turnaround time,

$$= \frac{12 + 21 + 11 + 11.5 + 18}{5} = 14.7$$

Response time for process,

$A = 0$

$B = 0$

$C = 0$

$D = 4 - 3.5 = 0.5$

$E = 5 - 1 = 4$

Average response time,

$$= \frac{0.5 + 4}{5} = 0.9$$

iii. Round Robin (Quantum = 2)

A	B	C	D	E	A	B	C	D	E	B	E	B
0	2	4	6	8	10	12	14	15	16	18	20	21	22

Waiting time for process,

$A = 8$

$B = 2 + 8 + 6 + 2 = 18$

$C = 4 + 8 = 12$

$D = 8 + 8 = 16$

$E = 8 + 8 + 2 = 18$

Average waiting time,

$$= \frac{8 + 18 + 12 + 16 + 18}{5} = 14.4$$

Turnaround time for process,

$A = 12$

$B = 20$

$C = 11$

$D = 12.5$

$E = 17$

Average turnaround time,

$$= \frac{12 + 20 + 11 + 12.5 + 17}{5} = 14.5$$

Response time for process,

$A = 0$

$B = 0$

$C = 4 - 3 = 1$

$D = 6 - 3.5 = 2.5$

$E = 8 - 4 = 4$

Average response time,

$$= \frac{7.5}{5} = 1.5$$

iii. Shortest Remaining Job First

A	A	A	C	D	E	B
0	2	3	4	7	10	15	22

Waiting time for process,

$A = 0$

$B = 15$

$C = 4$

$D = 7$

$E = 10$

Average waiting time,

$$= \frac{0 + 15 + 4 + 7 + 10}{5} = 7.2$$

Turnaround time for process,

$A = 4$

$B = 20$

$C = 4$

$D = 6.5$

$E = 6$

Average turnaround time,

$$= \frac{4 + 20 + 4 + 6.5 + 6}{5} = 8.1$$

Response time for process,

$A = 0$

$B = 15 - 2 = 13$

$C = 4 - 3 = 1$

$D = 7 - 3.5 = 3.5$

$E = 10 - 4 = 6$

Average response time $= \frac{23.5}{5} = 4.7$

SJF gives the minimum average waiting time as compared to RR algorithm. So, it is the best scheduling algorithm.

Que 3.25. Consider the processes, CPU burst time and arrival time given below :

Processes	CPU burst time	Arrival time
P_1	8	0
P_2	4	1
P_3	9	2
P_4	5	3

Draw the Gantt chart and calculate the following by using SRTF CPU scheduling algorithm,

i. Average waiting time

ii. Average turnaround time **AKTU 2015-16, Marks 10**

Answer

Processes	Arrival time	Burst time
P_1	0	8
P_2	1	4
P_3	2	9
P_4	3	5

Gantt Chart :

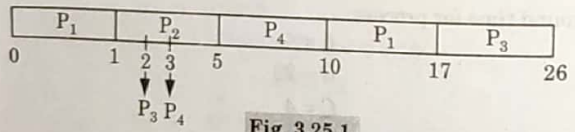


Fig. 3.25.1.

Waiting time,

$P_1 = 10 - 1 - 0 = 9$

$P_2 = 1 - 1 = 0$

$P_3 = 17 - 2 = 15$

$P_4 = 5 - 3 = 2$

Average waiting time $= \frac{9+0+15+2}{4}$

$= \frac{26}{4}$

$= 6.5$

Turnaround time (TAT),

$P_1 = 17 - 0 = 17$

$P_2 = 5 - 1 = 4$

$P_3 = 26 - 2 = 24$

$P_4 = 10 - 3 = 7$

Average turnaround time $= \frac{17+4+24+7}{4}$

$= \frac{52}{4}$

$= 13$

Que 3.26. List various performance criteria for scheduling algorithms. Five processes A, B, C, D, E require CPU burst of 3, 5, 2, 5 and 5 units respectively. Their arrival times in the system are 0, 1, 3, 9 and 12 respectively. Draw Gantt Chart and compute the average turnaround time and average waiting time of these processes for the Shortest Job First (SJF) and Shortest Remaining Time First (SRTF) scheduling algorithms.

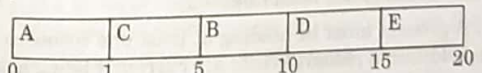
AKTU 2011-12, Marks 10

Answer

Performance criteria for scheduling algorithm : Refer Q. 3.1, Page 3–2B, Unit-3.

Numerical :

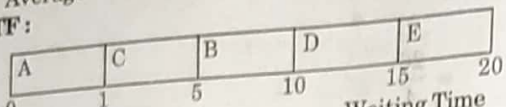
SJF :



Turnaround Time	Waiting Time
A = 3	0
B = 9	4
C = 2	0
D = 6	1

E = 8	3
Average turnaround time	(3 + 9 + 2 + 6 + 8)/5 = 5.6 ms
Average waiting time	(0 + 4 + 0 + 1 + 3)/5 = 1.6 ms

SRTF :



	Waiting Time
Turnaround Time	0
A = 3	4
B = 9	0
C = 2	1
D = 6	3
E = 8	(3 + 9 + 2 + 6 + 8)/5 = 5.6 ms
Average turnaround time	(0 + 4 + 0 + 1 + 3)/5 = 1.6 ms
Average waiting time	

Que 3.27. What is deadlock ? What are the necessary conditions for deadlock ?

OR

What are the necessary conditions to hold a deadlock in a system ?

AKTU 2013-14, Marks 05

OR

What is a deadlock ? Discuss the necessary conditions for deadlock with examples.

AKTU 2016-17, Marks 7.5

Answer

1. A deadlock is a situation where a group of processes are permanently blocked as a result of each process having acquired a subset of the resources needed for its completion and waiting for release of the remaining resource held by other in the same group, thus making it impossible for any of the processes to proceed.
2. Resource managers and other operating system, processes can be involved in a deadlock situation.

A deadlock situation can arise if the following four conditions holds simultaneously in a system :

1. **Mutual exclusion :** At least one resource must be held in a non-sharable mode; that is, only one process at a time can use the resource. If another process requests that resource, the requesting process must be delayed until the resource has been released.
2. **Hold and wait :** A process must be holding at least one resource and waiting to acquire additional resources that are currently being held by other processes.
3. **No pre-emption :** Resources cannot be pre-empted; *i.e.*, a resource can be released only voluntarily by the process holding it, after that process has completed its task.

4. **Circular wait :** A set $\{P_0, P_1, ..., P_n\}$ of waiting processes must exist such that P_0 is waiting for a resource held by P_1, P_1 is waiting for a resource held by P_2, ..., P_{n-1} is waiting for a resource held by P_n, and P_n is waiting for a resource held by P_0.

Que 3.28. How deadlock are prevented ?

OR

Define and explain the deadlock prevention.

OR

What are the approaches that can be used for prevention of deadlock ?

AKTU 2013-14, Marks 05

Answer

Deadlock prevention is an approach which ensures that system will never enter in deadlock state.

These are following approaches of deadlock prevention :

1. **Mutual exclusion :**
   a. Mutual exclusion condition must hold for non-sharable resources.
   b. If access to a resource requires mutual exclusion, then mutual exclusion must be supported by the operating system.
2. **Hold and wait :**
   a. The hold and wait condition can be eliminated by forcing a process to release all resources held by it, whenever it requests a resource that is not available.
   b. For example, process copies data from a floppy disk to a hard disk, sort a disk file and then prints the results to a printer.
   c. If all the resources must be requested at the beginning of the process, then the process must initially request the floppy disk, hard disk and a printer.
   d. It will hold the printer for its entire execution, even though it needs the printer only at the end.
3. **No pre-emption :**
   a. If a process holding certain resources is denied a further request. That process must release its original resources and if necessary request them again, together with additional resource.
   b. If a process requests a resource that is currently held by another process, the operating system may preempt the second process and require it to release its resources.
   c. Pre-emption is possible for certain types of resources, such as CPU and main memory.
4. **Circular wait :**
   a. One way to prevent the circular wait condition is by linear ordering of different types of system resources.

b. In this, system resources are divided into different classes.

c. If a process has been allocated resources of type R, then it may subsequently request only those resource types following R in the ordering.

Que 3.29. What is deadlock avoidance ? Define all states of a system.

Answer

1. Deadlock avoidance allows the three necessary conditions but makes judicious choices to assure that the deadlock point is never reached.
2. Deadlock avoidance therefore allows more concurrency than prevention does.
3. Deadlock avoidance requires additional information about how resources are to be requested.
4. With deadlock avoidance, a decision is made dynamically whether the current resource allocation request could, if granted, potentially lead to a deadlock.

Two approaches are used to avoid the deadlock :

1. Do not start a process if its demands might lead to deadlock.
2. Do not grant an incremental resource request to a process if this allocation might lead to deadlock.

System can be in one of the following states :

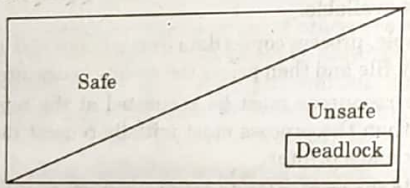


Fig. 3.29.1. Relationship between safe, unsafe and a deadlock state.

1. **Safe state :** Such a state occurs when the system can allocate resources to each process (up to its maximum) in some order and avoid a deadlock. This state will be characterized by a safe sequence.
2. **Unsafe state :** If the system did not follow the safe sequence of resource allocation from the beginning and it is now in a situation, which may lead to a deadlock, then it is in an unsafe state.
3. **Deadlock state :** If the system has some circular wait condition existing for some processes, then it is in deadlock.

Que 3.30. Describe resource-allocation graph.

Answer

1. Resource-allocation graph is used to describe the deadlock. It is also called system resource allocation graph.
2. Graph consists of a set of vertices (V) and set of edges (E).
3. All the active processes in the system denoted by $P = \{P_1, P_2, ... P_n\}$ and set consisting of all resource type in the system is denoted by $R = \{R_1, R_2, R_3, ... R_m\}$.
4. Request edge is an edge from process to resource and denoted by $P_i \rightarrow R_j$.
5. An assignment edge is an edge from resource to process and denoted by $R_j \rightarrow P_i$.
6. Holding of resource by process is denoted by assignment edge.
7. Requesting of resource by process is denoted by request edge.
8. For representing process and resource in the resource allocation graph is shown by square and circle. Each process is represented by circle and resource by square. Dot within the square represents the number of instance.
9. Consider the following system which consists of three processes *i.e.*, P_1, P_2 and P_3 and four resources *i.e.*, R_1, R_2, R_3 and R_4. Resource R_1 and R_3 have one instance, R_2 has two instance and R_4 has three instances.
   i. Process P_1 is holding an instance of resource type R_2 and is waiting for an instance of resource type R_1.
   ii. Process P_2 is holding an instance of R_1 and R_2 and waiting for an instance of resource type R_3.
   iii. Process P_3 is holding an instance of R_3.

$$P = \{P_1, P_2, P_3\}$$
$$R = \{R_1, R_2, R_3, R_4\}$$
$$E = \{P_1 \rightarrow R_1, P_2 \rightarrow R_3, R_1, \rightarrow P_2, R_2 \rightarrow P_2, R_2, \rightarrow P_1, R_3 \rightarrow P_3\}$$

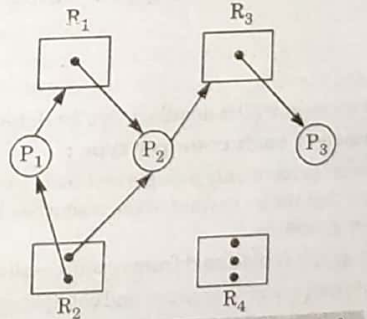


Fig. 3.30.1. Resource-allocation graph.

Que 3.31. **Define deadlock detection. Write an algorithm for deadlock detection.**

Answer

1. Deadlock detection is the process of actually determining that a deadlock exists and identifying the processes and resources involved in the deadlock.
2. The deadlock detection algorithm is invoked when the allocation cannot be granted immediately and this condition occurs frequently.
3. The basic idea is to check allocation against resource availability for all possible allocation sequences to determine if the system is in deadlocked state.

Deadlock detection algorithm :

Step 1 : Let work and finish be vector of length m and n respectively.

Initialize
Work = Available
If $\text{Allocation}_i \neq 0$, then Finish[i] = false
Otherwise, Finish[i] = true For $i = 1, 2, \ldots n$

Step 2 : Find an index i such that both
Finish[i] = false
$\text{Request}_i \leq \text{Work}$

Step 3 : If no such i exists, go to step 4.

Step 4 : Work = Work + Allocation_i
Finish[i] = true
Go to step 2

Step 5 : If [i] = false, for some i, $1 \leq i \leq n$ then system is in deadlock state.

Moreover, if Finish [i] = false, then P_i is deadlocked.

Que 3.32. **What are the two ways in which deadlock can be detected ?**

Answer

Following are the ways in which deadlock can be detected :

i. **Single instance of each resource type :**
   1. If all resources have only a single instance, then deadlock detection algorithm that uses a variant of the resource-allocation graph, called a wait-for graph.
   2. Wait-for graph is obtained from resource-allocation graph.
   3. Nodes of resource are removed and collapsing the appropriate edge *i.e.*, assignment and request edge.

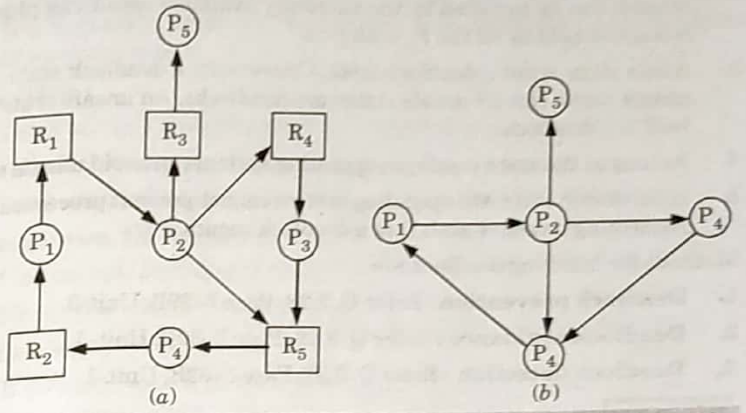


Fig. 3.32.1. Resource-allocation graph with corresponding wait-for graph.

   4. The assumptions made in the wait-for graph are as follows :
      a. An edge from P_i to P_j in a wait-for graph implies that process P_i is waiting for process P_j to release a resource that P_i needs.
      b. An edge $P_i \rightarrow P_j$ exists in a wait-for graph if and only if the corresponding resource-allocation graph contains two edges $P_i \rightarrow R_q$ and $R_q \rightarrow P_i$ for some resource R_q.
   5. If WFG contains cycle then the system is deadlocked otherwise is in safe state.

ii. **Several instances of a resource type :**
   1. Unmark all active processes from Allocation, Max and Available in accordance with the system state.
   2. Find an unmarked process i such that
      Max $\leq$ Available
      If found, mark process i, update Available
      Available : = Available + Allocation
      and repeat this step.
      If no process is found, then go to next step.
   3. If all processes are marked, the system is not deadlocked.

Que 3.33. **"A safe state is not a deadlock state but a deadlock state is an unsafe state". Explain. Discuss the different methods for handling deadlocks.**

Answer

1. A safe state is a state in which there is at least one order in which all the processes can be run to completion without resulting in a deadlock.
2. A sequence of processes $< P_1, P_2 \ldots P_n >$ is a safe sequence for the current allocation state if, for each P_i the resources that P_j can still

request can be satisfied by the currently available resources plus the resources held by all the P_j, with $j < i$.

3. A safe state is not a deadlock state. Conversely, a deadlock state is an unsafe state. Not all unsafe states are deadlocks. An unsafe state may lead to a deadlock.
4. As long as the state is safe, an operating system can avoid unsafe state.
5. In an unsafe state, the operating system cannot prevent processes from requesting resource such that a deadlock occurs.

Methods for handling deadlock are :

1. **Deadlock prevention :** Refer Q. 3.28, Page 3–29B, Unit-3.
2. **Deadlock avoidance :** Refer Q. 3.29, Page 3–30B, Unit-3.
3. **Deadlock detection :** Refer Q. 3.31, Page 3–32B, Unit-3.

Que 3.34. **Define deadlock. List four necessary conditions for occurrence of deadlock. A system contains 6 units of resource, and n processes that use the resource. What is the maximum value of n for which the system will be deadlock free if the maximum requirement of each process is 3 ?** **AKTU 2012-13, Marks 05**

Answer

Deadlock and its four necessary conditions : Refer Q. 3.27, Page 3–28B, Unit-3.

Maximum value of n :

The maximum value of n for which the system is guaranteed to be deadlock free is 2. Two processes can never lead to deadlock as the peak time demand of (3 + 3 = 6) resources can be satisfied. But 3 processes can lead to deadlock if each process holds 2 resources and then demand on more.

Que 3.35. **Write an algorithm for detection of deadlock in a system having several instances of multiple resource types.** **AKTU 2012-13, Marks 10**

Answer

The algorithm uses several time-varying data structures which are as follows :

1. **Available :** A vector of length m indicates the number of available resources of each type.
2. **Allocation :** An $n \times m$ matrix defines the number of resources of each type currently allocated to each process.

3. **Request :** An $n \times m$ matrix indicates the current request of each process. If it Request[i][j] equals k, then process P_i is requesting k more instances of resource type R_j.

Algorithm :

1. Let Work and Finish be vectors of length m and n, respectively.
   Initialize Work = Available.
   For $i = 0, 1, ..., n-1$, if $\text{Allocation}_i \neq 0$, then Finish[$i$] = false; otherwise, Finish[i] = true.
2. Find an index i such that both
   Finish[i] = = false
   $\text{Request}_i \leq \text{Work}$
   If no such i exists, go to step (4).
3. Work = Work + Allocation_i
   Finish[i] = true
   Go to step (2).
4. If Finish[i] = = false for some i, $0 \leq i < n$ then the system is in a deadlock state.
   Moreover if Finish[i] == false then process P_i is deadlock.
   This algorithm requires an order of $m \times n^2$ operations to detect whether the system is in deadlock state.

Que 3.36. **Write the Banker's algorithm and how it can be used to avoid can be used to avoid deadlock.**

OR

Describe Banker's algorithm for safe allocation. **AKTU 2016-17, Marks 7.5**

OR

Write and explain Banker's algorithm for avoidance of deadlock. **AKTU 2011-12, Marks 10**

Answer

Banker's algorithm :

The banker's algorithm is a resource allocation and deadlock avoidance algorithm that tests for safety by simulating the allocation for pre-determined maximum possible amounts of all resources, then makes an "s-state" check to test for possible activities, before deciding whether allocation should be allowed to continue.

Following data structures are used to implement the Banker's algorithm :

Let 'n' be the number of processes in the system and 'm' be the number of resources types.

1. **Available :** It is a 1D array of size 'm' indicating the number of available resources of each type.

   Available[j] = k means there are 'k' instances of resource type R_j

2. **Max :** It is a 2D array of size 'n*m' that defines the maximum demand of each process in a system.

   Max[i, j] = k means process P_i may request at most 'k' instances of resource type R_j

3. **Allocation :** It is a 2D array of size 'n*m' that defines the number of resources of each type currently allocated to each process.

   Allocation[i, j] = k means process P_i is currently allocated 'k' instances of resource type R_j

4. **Need :** It is a 2D array of size 'n*m' that indicates the remaining resource need of each process.

   Need [i, j] = k means process P_i currently allocated 'k' instances of resource type R_j

   Need [i, j] = Max [i, j] – Allocation [i, j]

   Allocation$_i$ specifies the resources currently allocated to process P_i and Need$_i$ specifies the additional resources that process P_i may still request to complete its task.

Banker's algorithm is used to avoid deadlock by following algorithms :

a. **Safety algorithm :**

   1. Let work and finish be vector of length m and n respectively. Initialize Work = Available and Finish [i] = False for i = 1, 2, 3, 4, ... n.
   2. Find an i such that both
      a. Finish [i] = False
      b. Need [i] ≤ Work

      If no such i exist, goto step 4.
   3. Work = Work + Allocation$_i$

      Finish [i] = True

      Goto step 2
   4. If Finish [i] = True for all i, then the system is in a safe state.

b. **Resource request algorithm :** Let Request$_i$ be the request array for process P_i. Request$_i$ [j] = k means process P_i wants k instances of resource type R_j. When a request for resources is made by process P_i, the following actions are taken :

   1. If Request$_i$ ≤ Need$_i$

      Goto step 2; otherwise, raise an error condition, since the process has exceeded its maximum claim.
   2. If Request$_i$ ≤ Available

   Goto step 3; otherwise, P_i must wait, since the resources are not available.
   3. Have the system pretend to have allocated the requested resources to process P_i by modifying the state as follows :

      Available = Available – Request$_i$

      Allocation$_i$ = Allocation$_i$ + Request$_i$

      Need$_i$ = Need$_i$ – Request$_i$

Que 3.37. **Describe Banker's algorithm for deadlock avoidance. Consider a system with three processes and three resources. The snapshot of a system at time t_0 is given below :**

Processes	Allocation			Max			Available		
	A	B	C	A	B	C	A	B	C
P_0	2	2	3	3	6	8	7	7	10
P_1	2	0	3	4	3	3			
P_2	1	2	4	3	4	4			

i. **Is the current allocation in safe state ?**

ii. **Would the following requests be granted in the current state :**
   a. **Process P_2 requests (1, 0, 0)**
   b. **Process P_1 requests (1, 0, 0)** **AKTU 2014-15, Marks 10**

Answer

Banker's algorithm : Refer Q. 3.36, Page 3–35B, Unit-3.

i. First find the available resources in the system

Available = Number of instance - sum of allocation

Process	Current allocation		
	A	B	C
P_0	2	2	3
P_1	2	0	3
P_2	1	2	4
	5	4	10

Available = (7 7 10) – (5 4 10)

Available resources = (2 3 0)

Content of need matrix is :

Process	Need		
P_0	1	4	5
P_1	2	3	0
P_2	2	2	0

Safe sequence $< P_2, P_1, P_0 >$.

The system is in safe state.

ii. a. Process P_2 request (1, 0, 0), this request is less than need. Need for process P_2 is (2, 2, 0), available resource is (2, 3, 0) and request is (1, 0, 0).

Request < Available, (1, 0, 0) < (2, 3, 0)

After allocating (1, 0, 0) to process P_2 the need becomes as follows :

Process	Need		
P_0	1	4	5
P_1	2	3	0
P_2	1	2	0

And available resource is (1, 3, 0). We see that system is in safe state with safe sequence $< P_2, P_1, P_0 >$. Hence request of P_2 (1, 0, 0) will be granted.

b. Process P_1 request (1, 0, 0), this request is less than need. Need for process P_1 is (2, 3, 0). Available resource is (1, 3, 0) and request is (1, 0, 0).

Request <Available, (1, 0, 0) < (1, 3, 0)

After allocating (1, 0, 0) to process P_1 the need becomes as follows :

Process	Need		
P_0	1	4	5
P_1	1	3	0
P_2	1	2	0

And available resource is (0, 3, 0). Need of any process is never satisfied after granting the P_1 request (1, 0, 0). So, the system will be blocked. Therefore, request of P_1 (1, 0, 0) cannot be granted.

Que 2.28. Consider the following snapshot of the system :

	Allocation				Max				Available			
	A	B	C	D	A	B	C	D	A	B	C	D
P_0	0	0	1	2	0	0	1	2	1	5	2	0
P_1	1	0	0	0	1	7	5	0				
P_2	1	3	5	4	2	3	5	6				
P_3	0	6	3	2	0	6	5	2				
P_4	0	0	1	4	0	6	5	6				

Answer the following questions using the banker's algorithm :

i. What is the content of the matrix need ?

ii. Is the system in a safe state ? If yes then find the safe sequence.

iii. If a request from process P_1 arrives for (0, 4, 2, 0) can the request be granted immediately ?

AKTU 2015-16, Marks 10

Answer

i. The need matrix can be calculated according to Banker's algorithm.

$Need_i = Max_i - Allocation_i$

Need matrix

	A	B	C	D
P_0	0	0	0	0
P_1	0	7	5	0
P_2	1	0	0	2
P_3	0	0	2	0
P_4	0	6	4	2

ii. Yes, system is in safe state. This can be seen as below :

Since, we have available = (1, 5, 2, 0) which can be allocated to P_0 or P_2 to satisfy the need or request

According to safety algorithm,

Work = A B C D = 1 5 2 0 (Available)

Need $[P_0]$ = A B C D = 0 0 0 0 < A B C D = 1 5 2 0 (Available)

Hence, process P_0 will release the allocated resources. Hence,

Work = Work + allocation

= A B C D + A B C D = 1 5 2 0 + 0 0 1 2

= A B C D = 1 5 3 2 (Available)

This can satisfy the request of process P_2. Since

	A	B	C	D		A	B	C	D	
Need $[P_2]$ =	1	0	0	2	<	1	5	3	2	(Available)

Hence, process P_2 will also release the resource. Hence

Work = Work + Allocation

	A	B	C	D		A	B	C	D	
						1	3	5	4	
=	1	5	3	2	+					
=	2	8	8	6						(Available)

This (Available) can satisfy the request process P_3.

Hence, resources will be allocated to it

Work = Work + Allocation

	A	B	C	D		A	B	C	D	
						0	6	3	2	
=	2	8	8	6	+					
	A	B	C	D						
=	2	14	11	8						(Available)

This (Available) resource, can be allocated to Process P_4. Since

	A	B	C	D		A	B	C	D
Need $[P_4]$ =	0	6	4	2	<	2	14	11	8

Hence, after completion processes P_4 will also release the resource.

Work = Work + Allocation

	A	B	C	D		A	B	C	D
						0	0	1	4
=	2	14	11	8	+				
	A	B	C	D					
=	2	14	12	12					

These resource, can be allocated to process P_1

	A	B	C	D		A	B	C	D
Since, Need $[P_1]$	0	7	5	0	<	2	14	12	12

Hence safe sequence will be $\langle P_0, P_2, P_3, P_4, P_1 \rangle$

iii. Since process P_1 requests for the resources (0, 4, 2, 0)

Now, the matrixes will be

	Allocation				Max				Available			
	A	B	C	D	A	B	C	D	A	B	C	D
P_0	0	0	1	2	0	0	1	2	1	1	0	0
P_1	1	4	2	0	1	7	5	0				
P_2	1	3	5	4	2	3	5	6				
P_3	0	6	3	2	0	6	5	2				
P_4	0	0	1	4	0	6	5	6				

Here, Available

	A	B	C	D		A	B	C	D		A	B	C	D
=	1	5	2	0	–	0	4	2	0	=	1	1	0	0

Now the need matrix can be represented as

$Need_i = Max_i - Allocation_i$

A	B	C	D
0	0	0	0
0	3	3	0
1	0	0	2
0	0	2	0
0	6	4	2

Now again calculate the safe sequence as in previous section of this question. The safe sequence will be

$\langle P_0, P_2, P_3, P_1, P_4 \rangle$

Que 3.39. **In a system, n processes share m resource units that can be reserved and released only one at a time. The maximum need of each process does not exceed m and sum of all maximum need is less than $m + n$. Show that a deadlock cannot occur.**

AKTU 2011-12, Marks 05

Answer

i. $\sum_{i=1}^{n} Max_i < m + n$

ii. $Max_i \geq 1$ for all i

Proof : $Need_i = Max_i - Allocation_i$

iii. If there exists a deadlock state then :

$$\sum_{i=1}^{n} Allocation_i = m$$

Use (i) to get : $\sum Need_i + \sum Allocation_i = \sum Max_i < m + n$

Use (iii) to get : $\sum Need_i + m < m + n$

Rewrite to get : $\sum_{i=1}^{n} Need_i < n$

This implies that there exists a process P_i such that $Need_i = 0$. Since $Max_i \geq 1$ it follows that P_i has at least one resource that it can release. Hence, the system cannot be in a deadlock state.

Que 3.40. **Describe the Banker's algorithm for safe allocation. Consider a system with five processes and three resource types and at time T_0 the following snapshot of the system has been taken :**

Process Id	Allocated			Maximum			Available		
	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
P_1	1	1	2	4	3	3	3	1	0
P_2	2	1	2	3	2	2			
P_3	4	0	1	9	0	2			
P_4	0	2	0	7	5	3			
P_5	1	1	2	11	2	3			

i. **Determine the total amount of resources of each type.**
ii. **Compute the need matrix.**
iii. **Determine if the state is safe or not using Banker's algorithm.**
iv. **Would the following request be granted in the current state ?**
a. $P_1 < 3, 3, 1 >$
b. $P_2 < 2, 1, 0 >$

AKTU 2013-14, Marks 10

Answer

Banker's algorithm for safe allocation :
When a new process enters the system, it must declare the maximum number of instances of each resource type that it may need. This number may not exceed the total number of resources in the system. When a user requests a set of resources will leaves the system in a safe state. If it will, the resources are allocated; otherwise, the process must wait until some other process releases enough resources.

Safety algorithm : Refer Q. 3.36, Page 3–35B, Unit-3.

Numerical :

i. Total resource = total allocated (Sum of columns of allocation + available)
= [8 5 7] + [3 1 0] = [11 6 7]

ii. Need = Maximum – Allocation

A	B	C	–	A	B	C	=	Need		
4	3	3		1	1	2	=	3	2	1
3	2	2		2	1	2	=	1	1	0
9	0	2		4	0	1	=	5	0	1
7	5	3		0	2	0	=	7	3	3
11	2	3		1	1	2	=	10	1	1

iii. Need is compared with Available. If need ≤ available, then resources are allocated to that process and process will release the resource.

If Need is greater than Available, next process need is taken for comparison. Need for process P_1 is (321) and Available is (310).

Need > Available → False

So, system will move to next process.

Need for P_2 is (110) and available is (310)

Need ≤ Available → True

Request for P_2 is granted.

Available = Available + Allocation
= 310 + 212 = 522

Next Process P_3 needs 501 and available is 522.

Available = 522 + 401 = 923

So, request is granted 501 ≤ 522 → true

Next process P_4 needs 733 and available is 923.

So, request is granted.

Now Available = 923 + 020 = 943

Next process P_5 needs (10, 1, 1) and available is 943.

Need > Available

Hence, no sequence is possible thus the state is unsafe.

iv. a. $P_1 < 3, 3, 1 >$

Need > Available → 331 ≮ 310

Hence, resource will not be granted.

b. $P_2 < 2,1, 0 >$

Need < Available → True

210 < 310

Hence, the request will be granted.

Que 3.41. Differentiate between deadlock and starvation.

AKTU 2011-12, Marks 2.5

Answer

Basis for Comparison	Deadlock	Starvation
Basic	Deadlock is where no process proceeds, and get blocked.	Starvation is where low priority processes get blocked, and high priority process proceeds.
Arising condition	The occurrence of mutual exclusion, hold and wait, no preemption and circular wait simultaneously.	Enforcement of priorities, uncontrolled resource management.
Other name	Circular wait.	Lifelock.
Resources	In deadlocked, requested resources are blocked by the other processes.	In starvation, the requested resources are continuously used by high priority processes.
Prevention	Avoiding mutual exclusion, hold and wait, and circular wait and allowing preemption.	Ageing.

Que 3.42. **Discuss the techniques to recover from deadlock.**

Answer

There are two options for recovering from a deadlock :

1. **Process termination :** To eliminate deadlocks by aborting a process, we use one of two methods.
   a. **Abort all deadlocked processes :** This method clearly will break the deadlock cycle, but the deadlocked processes may have computed for a long time, and the results of these partial computations must be discarded and probably will have to be recomputed later.
   b. **Abort one process at a time until the deadlock cycle is eliminated :** This method incurs considerable overhead, since after each process is aborted, a deadlock-detection algorithm must be invoked to determine whether any processes are still deadlocked.
2. **Resource pre-emption :** To eliminate deadlocks using resource pre-emption, we successively preempt some resources from processes and give these resources to other processes until the deadlock cycle is broken.
   a. **Selecting a victim :**
      i. Which resources and which processes are to be preempted ? As in process termination, we must determine the order of pre-emption to minimize cost.
      ii. Cost factors may include such parameters as the number of resources a deadlocked process is holding and the amount of time the process has thus far consumed during its execution.
   b. **Rollback :**
      i. If we preempt a resource from a process, then it cannot continue with its normal execution.
      ii. It is missing some needed resource.
      iii. We must roll back the process to some safe state and restart it from that state.
      iv. Since, in general, it is difficult to determine what a safe state is, the simplest solution is a total rollback, abort the process and then restart it.
      v. Although it is more effective to roll back the process only as far as necessary to break the deadlock, this method requires the system to keep more information about the state of all running processes.
   c. **Kill the process.**

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Explain performance criteria of CPU scheduling.
Ans. Refer Q. 3.1.

Q. 2. What is CPU scheduling ? Write the difference between pre-emptive and non pre-emptive scheduling.
Ans. Refer Q. 3.1 and Q. 3.3.

Q. 3. Explain process transition diagram.
Ans. Refer Q. 3.5.

Q. 4. Discuss Process Control Block (PCB).
Ans. Refer Q. 3.7.

Q. 5. Write short notes on process identification information.
Ans. Refer Q. 3.10.

Q. 6. Write short notes on following :
i. FCFS scheduling
ii. SJF scheduling
iii. Round robin scheduling
Ans.
i. Refer Q. 3.17. ii. Refer Q. 3.18. iii. Refer Q. 3.20.

Q. 7. Write the difference between following :
1. Thread and process
2. User level thread and kernel level thread
3. Long term, short term and mid term scheduler
Ans.
1. Refer Q. 3.15. 2. Refer Q. 3.13. 3. Refer Q. 3.8.

Q. 8. Explain Banker's algorithm for avoidance of deadlock.
Ans. Refer Q. 3.36.

Q. 9. Explain the following :
1. Deadlock prevention
2. Deadlock avoidance
3. Deadlock detection
Ans.
1. Refer Q. 3.28.
2. Refer Q. 3.29.
3. Refer Q. 3.31.

☺☺☺

4 UNIT

Memory Management

PART-1

Memory Management : Basic Bare Machine, Resident Monitor, Multiprogramming with Fixed Partitions, Multiprogramming with Variable Partitions, Protection Schemes, Paging, Segmentation, Paged Segmentation.

CONCEPT OUTLINE : PART-1

- Memory management is mainly concerned with the allocation of main memory to requesting process. No process can ever run, before a certain amount of memory is allocated to it.
- Paging is a memory management scheme that permits the physical address space of a process to be non contiguous.
- Segmentation is a memory management scheme that supports the programmer view of memory.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. Explain memory management and its requirements.

Answer

1. Memory management is mainly concerned with the allocation of main memory to requesting process. No process can ever run, before a certain amount of memory is allocated to it.
2. The overall resource utilization and other performance criteria of a computer system are largely affected by the performance of the memory management module.

Five requirements of memory management are :

1. **Relocation :**
   a. Programmers do not know where the program will be placed in memory when it is executed.
   b. While the program is executing, it may be swapped to disk and returned to main memory at different location (relocated).
   c. Memory references must be translated in the code to actual memory address.

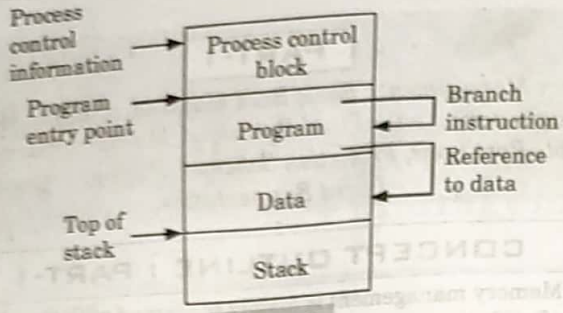


Fig. 4.1.1.

2. **Sharing :**
   a. Any protection mechanism must have the flexibility to allow several processes to access the same portion of main memory.
   b. For example if the number of processes are executing the same program then it is advantageous to allow each process to access the same copy of the program rather than its own separate copy.
3. **Protection :**
   a. Every process should protect against unwanted interference by other processes.
   b. Satisfaction of the relocation requirement increases the difficulty of satisfying the protection requirement.
   c. It is not possible to check the absolute address at compile time.
   d. Most of the programming languages allow the dynamic calculation of address at runtime.
4. **Logical organization :**
   a. Main memory is organized as a linear or one-dimensional address space that consists of sequence of bytes or words.
   b. Secondary memory at its physical level is similarly organized.
   c. Most of the programs are organized into modules.
5. **Physical organization :**
   a. The computer memory is organized as main memory and secondary memory.
   b. The main memory provides fast access but high cost.
   c. It is slow volatile. However the secondary memory is slower, cheaper and non-volatile.
   d. As a result, secondary memory is used for long term storage with large capacity.

Que 4.2. **What do you mean by address binding?**

Answer

1. Computer memory uses both logical addresses and physical addresses.
2. Address binding allocates a physical memory location to a logical pointer by associating a physical address to a logical address, which is also known as a virtual address.
3. Address binding is part of computer memory management and it is performed by the operating system on behalf of the applications that need access to memory.
4. Instructions and data to memory addresses can be done in following ways :
   i. **Compile time :** When it is known at compile time where the process will reside, compile time binding is used to generate the absolute code.
   ii. **Load time :** When it is not known at compile time where the process will reside in memory, then the compiler generates re-locatable code.
   iii. **Execution time :** If the process can be moved during its execution from one memory segment to another, then binding must be delayed to be done at run time.

Que 4.3. **Write a short note on :**

i. **Dynamic loading**
ii. **Dynamic linking**

Answer

i. **Dynamic loading :**
   1. In dynamic loading, a routine of a program is not loaded until it is called by the program.
   2. All routines are kept on disk in a re-locatable load format. The main program is loaded into memory and is executed.
   3. Other routines methods or modules are loaded on request.
   4. Dynamic loading makes better memory space utilization and unused routines are never loaded.
   5. It is useful when large amounts of code are needed to handle infrequently occurring cases.
   6. No special support from the operating system is required implemented through program design.

ii. Dynamic linking :

1. Linking is the process of collecting and combining various modules of code and data into a executable file that can be loaded into memory and executed.
2. Operating system can link system level libraries to a program.
3. When it combines the libraries at load time, the linking is called static linking and when this linking is done at the time of execution, it is called as dynamic linking.
4. In static linking, libraries linked at compile time, so program code size becomes bigger whereas in dynamic linking libraries linked at execution time so program code size remains smaller.

Que 4.4. Write the short note on

i. Overlays
ii. Swapping

Answer

i. Overlays :

1. Overlays is used to keep in memory only those instructions and data that are needed at any given time.
2. When other instructions are needed, they are loaded into space that was occupied previously by instructions that are no longer needed.
3. Overlays are implemented by user, no special support needed from operating system, programming design of overlay structure is complex.

ii. Swapping :

1. A process must be in memory to be executed.
2. A process, however, can be swapped temporarily out of memory to a backing store and then brought back into memory for continued execution.
3. Swapping makes it possible for the total physical address space of all processes to exceed the real physical memory of the system, thus increasing the degree of multiprogramming in a system.
4. Sometimes swap out process also known as roll-out and swap-in process known as roll-in.

Que 4.5. Discuss logical versus physical address space.

Answer

1. Logical address space is set of all logical addresses generated by program.

2. Physical address space is a set of all physical addresses corresponding to these logical addresses.
3. Logical address is generated by CPU. Physical address is the address of main memory and it is loaded into the memory address register.
4. Compile time and load time address binding methods generate same logical and physical addresses.
5. Execution time address binding scheme results in different logical and physical addresses.
6. Generally logical address is referred as a virtual address.

Que 4.6. Consider a logical address space of eight pages of 1024 words, each mapped onto a physical memory of 32 frames then :
a. How many bits are in logical address ?
b. How many bits are in physical address ?

AKTU 2013-14, Marks 05

Answer

1. The logical address is split into two parts : the page address and then the offset.
2. The page address must be able to reference 8 (or 2^3) distinct pages. This requires 3 address bits.
3. The offset must be able to reference 1,024 (or 2^{10}) distinct words on each page. This requires 10 address bits. Therefore, 13 bits are required for the logical address.
4. The physical address is also split into two parts : the frame address and then the offset.
5. The number of frames is 32 (or 2^5), so that will require 5 bits.
6. The size of the frame is same as the size of the page, therefore this will require 10 bits.
7. Therefore, 15 bits are required for the physical address.

Que 4.7. Define the terms :

i. Bare machine
ii. Resident monitor

Answer

i. Bare machine :

1. This is the simplest form of memory management.
2. It used by hardware diagnostics, by system boot code, real time/ dedicated systems.

3. User can have complete control. Commensurably, the operating system has none.
4. No protection, no utilities, no overhead.

ii. Resident monitor :

1. It usually in low memory where interrupt vectors are placed.
2. It must check each memory reference against fence (fixed or variable) in hardware or register. If user generated address < fence, then illegal.
3. User program starts at fence -> fixed for duration of execution.
4. Then user code has fence address built in. But only works for static-sized monitor.
5. If monitor can change in size, start user at high end and move back, use fence as base register that requires address binding at execution time.
6. Add base register to every generated user address. Isolate user from physical address space using logical address space.

Que 4.8. Briefly discuss holes in memory partitioning.

Answer

1. In the variable-partition scheme, the operating system keeps a table indicating which parts of memory are available and which are occupied.
2. Initially, all memory is available for user processes and is considered one large block of available memory, known as hole.
3. When a part of memory is occupied by a process and left rest of the memory also known as hole.
4. A hole can be created when a process is completed and leaves the memory.

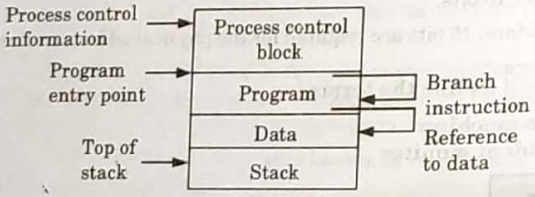


Fig. 4.8.1.

Que 4.9. Discuss about fixed/static partitioning ?

Answer

Fixed partitioning :

1. Partition main memory into a set of non-overlapping memory regions called partitions.
2. Fixed partitions can be of equal or unequal sizes.
3. Leftover space in partition space in partition, after program assignment, is called internal fragmentation.

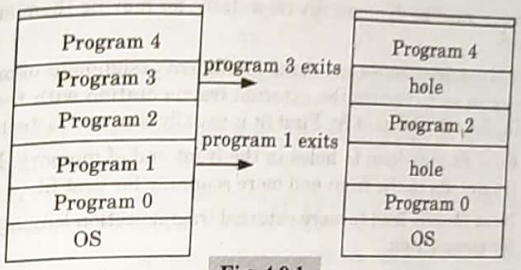


Fig. 4.9.1.

Placement algorithm with partitions :

a. Equal-size partitions :

i. In this algorithm, if there is an available partition, a process can be loaded into that partition.

ii. Because all partitions are of equal size, it does not matter which partition is used.

iii. If all partitions are occupied by blocked processes, choose one process to swap out to make room for the new process.

b. Unequal-size partitions, use of multiple queues :

i. This algorithm assigns each process to the smallest partition within which it will fit.

ii. A queue exists for each partition size.

iii. It tries to minimize internal fragmentation.

iv. Problem with this algorithm is that some queues might be empty while some might be loaded.

c. Unequal-size partitions, use of a single queue :

i. In this algorithm, when it's time to load a process into memory, the smallest available partition that will hold the process is selected.

ii. It increases the level of multiprogramming at the expense of internal fragmentation.

Que 4.10. Describe variable/dynamic partitioning.

Answer

Dynamic partitioning :

1. Dynamic partition leads to external fragmentation where portion of memory outside the variable size partition are fragmented.
2. Solution to external fragmentation problem is compaction *i.e.*, to move the free space together.
3. It is a time consuming process and complete overhead.
4. Processes must be dynamically relocatable for moving them around in memory.
5. To avoid compaction we can make intelligent assignment of process to memory so as to reduce the external fragmentation with the help of best fit, first fit and next fit. First fit is usually best and fastest.
   a. First fit may lead to holes in the front end of memory. More the fragments in the front end more scanning for first fit.
   b. Next fit may lead to more external fragmentation leaving the need for compaction.
   c. Best fits leads to many smaller memory holes leading to more frequent compaction.

Que 4.11. Describe memory allocation.

Answer

1. One of the simplest methods for allocating memory is to divide memory into several fixed-sized partitions.
2. Each partition may contain exactly one process.
3. Thus, the degree of multiprogramming is bound by the number of partitions.
4. In this multiple-partition method, when a partition is free, a process is selected from the input queue and is loaded into the free partition. When the process terminates, the partition becomes available for another process.
5. In the variable-partition scheme, the operating system keeps a table indicating which parts of memory are available and which are occupied.
6. Initially, all memory is available for user processes and is considered one large block of available memory, a hole.
7. Memory contains a set of holes of various sizes.
8. At any given time, then, we have a list of available block sizes and an input queue.
9. The operating system can order the input queue according to a scheduling algorithm.

10. Memory is allocated to processes until, finally, the memory requirements of the next process cannot be satisfied that is, no available block of memory or hole is large enough to hold that process.
11. The operating system can then wait until a large enough block is available, or it can skip down the input queue to see whether the smaller memory requirements of some other process can be met.
12. The memory blocks available comprise a set of holes of various sizes scattered throughout memory.
13. When a process arrives and needs memory, the system searches the set for a hole that is large enough for this process.
14. If the hole is too large, it is split into two parts. One part is allocated to the arriving process; the other is returned to the set of holes.
15. When a process terminates, it releases its block of memory, which is then placed back in the set of holes.
16. If the new hole is adjacent to other holes, these adjacent holes are merged to form one larger hole.
17. At this point, the system may need to check whether there are processes waiting for memory and whether this newly freed and recombined memory could satisfy the demands of any of these waiting processes.

Que 4.12. Discuss dynamic memory allocations techniques.

OR

Discuss first fit, best fit and worst fit memory allocation techniques.

Answer

1. First fit, best fit, and worst fit are the most common strategies used to select a free hole from the set of available holes.
2. First fit and best fit are better than worst fit in terms of speed and storage utilization respectively.

Dynamic memory allocation techniques :

1. **First fit :** Allocate the first hole that is big enough. Searching can start either at the beginning of the set of holes or at the location where the previous first fit search ended. We can stop searching as soon as we find a free hole that is large enough.
2. **Best fit :** Allocate the smallest hole that is big enough. We must search the entire list, unless the list is ordered by size. This strategy produces the smallest leftover hole.
3. **Worst fit :** Allocate the largest hole. Again, we must search the entire list, unless it is sorted by size. This strategy produces the largest leftover hole, which may be more useful than the smaller leftover hole from a best fit approach.

Que 4.13. **Explain the difference between internal and external fragmentation.** **AKTU 2013-14, Marks 05**

Answer

S.No.	Basis for comparison	Internal fragmentation	External fragmentation
1.	Basic	It occurs when fixed sized memory blocks are allocated to the processes.	It occurs when variable size memory space is allocated to the processes dynamically.
2.	Occurrence	When the memory assigned to the process is slightly larger than the memory requested by the process, this creates free space in the allocated block causing internal fragmentation.	When the process is removed from the memory, it creates the free space in the memory causing external fragmentation.
3.	Solution	The memory must be partitioned into variable sized blocks and assign the best fit block to the process.	Compaction, paging and segmentation.

Que 4.14. **What are the different techniques to remove fragmentation in case of multiprogramming with fixed partitions and variables partitions ?** **AKTU 2015-16, Marks 10**

Answer

Fixed partitions : Refer Q. 4.9, Page 4–7B, Unit-4.

Variable partitions : Refer Q. 4.10, Page 4–8B, Unit-4.

Que 4.15. **Given memory partitions of 100 K, 500 K, 200 K, 300 K and 600 K (in order). How would each of the first fit, best fit and worst fit algorithms place processes of 212 K, 417 K, 112 K and 426 K (in order) ? Which algorithm makes the most efficient use of memory ?** **AKTU 2012-13, Marks 05**

Answer

Process number	Memory requested
P1	212 K
P2	417 K
P3	112 K
P4	426 K

First fit :

Memory partition	Process number	Memory requested	Status	Internal fragmentation
100 K	—	—	Free	—
500 K	P1	212 K	Busy	288 K
200 K	P3	112 K	Busy	88 K
300 K	—	—	Free	—
600 K	P2	417 K	Busy	183 K

Total Available : 1700 K Total used : 741 K

Process P4 has no memory partition allocated to it.

Two memory partition of size 100 K and 300 K are free which cannot be allocated to P4 because it has size more than these memory partitions.

Best fit :

Memory partition	Process number	Memory requested	Status	Internal fragmentation
100 K	—	—	Free	—
500 K	P2	417 K	Busy	83 K
200 K	P3	112 K	Busy	88 K
300 K	P1	212 K	Busy	88 K
600 K	P4	426 K	Busy	174 K

Total Available : 1700 K Total used : 1167 K

Only one memory partition is free but all the processes are allocated the memory partitions.

Worst fit :

Memory partition	Process number	Memory requested	Status	Internal fragmentation
100 K	—	—	Free	—
500 K	P2	417 K	Busy	83 K
200 K	—	—	Free	—
300 K	P3	112 K	Busy	188 K
600 K	P1	212 K	Busy	388 K

Total Available : 1700 K Total used : 741 K

Process P4 has no memory partition allocated to it. Two memory partitions of 100 K and 200 K are free but it cannot be allocated to P4 because it has size more than these memory partitions.

Best fit algorithm makes most efficient use of memory, because in this, all the processes are allocated memory partition with minimum internal fragmentation.

Que 4.16. What do you mean by paging ? How page table can be implemented ?

Answer

Paging :

1. Paging is a memory management scheme that permits the physical address space of a process to be non-contiguous.
2. Paging avoids external fragmentation and the need for compaction.
3. The basic method for implementing paging involves breaking physical memory into fixed-sized blocks called frames and breaking logical memory into blocks of the same size called pages.
4. When a process is to be executed, its pages are loaded into any available memory frames from their source (a file system or the backing store).
5. The backing store is divided into fixed-sized blocks that are the same size as the memory frames or clusters of multiple frames.

Page table implementation :

1. The hardware support for paging is illustrated in Fig. 4.16.1.

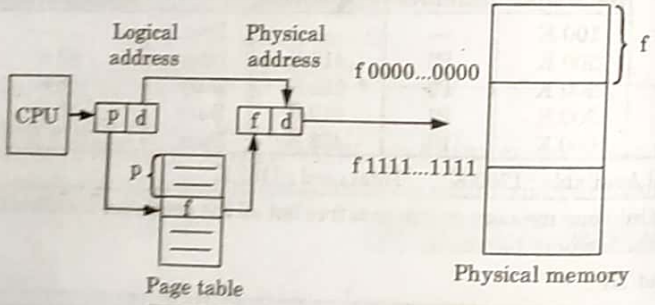


Fig. 4.16.1. Paging hardware.

2. Every address generated by the CPU is divided into two parts : a page number (p) and a page offset (d).
3. The page number is used as an index into a page table. The page table contains the base address of each page in physical memory.
4. This base address is combined with the page offset to define the physical memory address that is sent to the memory unit.
5. The paging model of memory is shown in Fig. 4.16.2.

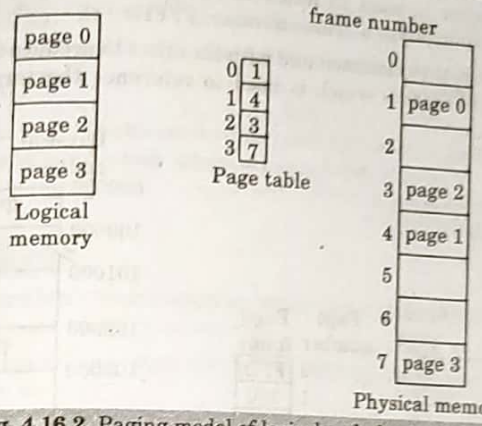
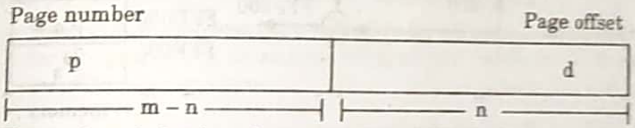


Fig. 4.16.2. Paging model of logical and physical memory.

6. If the size of the logical address space is 2^m, and a page size is 2^n bytes, then the high-order $m - n$ bits of a logical address designate the page number, and the n low-order bits designate the page offset.
7. Thus, the logical address is :



Where p is an index into the page table and d is the displacement within the page.

Que 4.17. What is paging ? Describe how logical address is translated to physical address in a paged system. Further give reasons as to why page sizes are always kept in powers of 2.

AKTU 2011-12, Marks 10

Answer

Paging : Refer Q. 4.16, Page 4–13B, Unit-4.

Translation of logical address to physical address :

1. The logic of the address translation process in paged system is shown in the following Fig. 4.17.1.
2. For example, the virtual address is 03200H.
3. This virtual address is split by hardware into the page number and offset within that page.
4. High order 12 bit is used as page number *i.e.* 003H and lower order 12 bit is used for the offset *i.e.*, (200H).

5. Page number is used to index the page table and to obtain the corresponding physical frame number (FFFH).
6. This value is then concatenated with the offset to produce the physical address (FFF200H) which is used to reference the target item in memory.

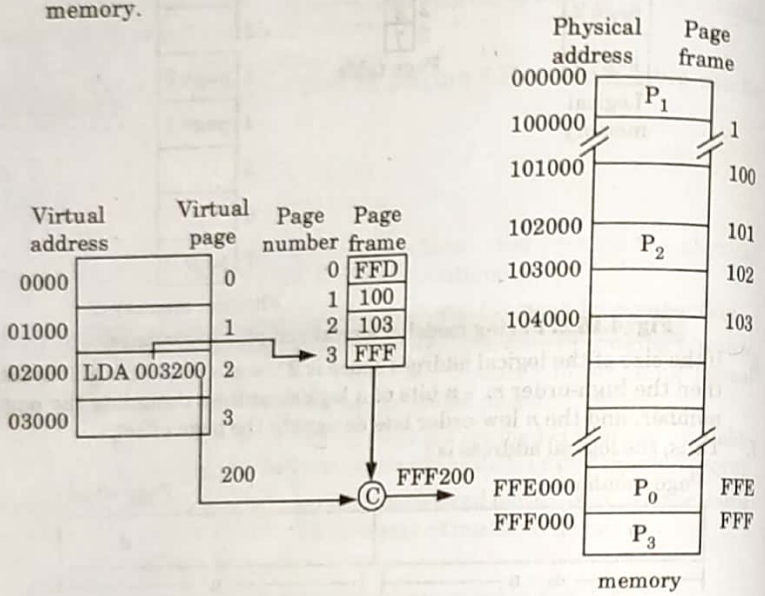


Fig. 4.17.1. Virtual address to physical address paging.

7. The operating system keeps track of the status of each page frame by means of a physical memory map that may be structured as a static table.
8. The logical address space may be the same size as the physical address space or it may be of smaller.
9. If logical address space is small, it prevents one process from monopolizing all of the memory.
10. If the logical address space is larger than the physical address space, all page could not be resident in physical memory.

Reason :

1. The size of page is typically a power of 2, varying between 512 bytes and 16 MB per page, depending on the computer architecture.
2. Page size is always a power of 2 because all addresses are binary and are divided into page or page frame number and offset can be determined by looking at particular bits in the address; no mathematical calculations are required.
3. The physical address can be generated by concatenating the offset to the frame number.

Que 4.18. **Under what circumstances do page faults occur ? Describe the actions taken by the operating system when a page fault occurs ?**

OR

When do page faults occur ? Describe in detail the actions taken by the operating system when a page fault occurs.

AKTU 2012-13, Marks 05

Answer

1. A page fault occurs when an access to a page that has not been brought into main memory takes place.
2. The operating system verifies the memory access, aborting the program if it is invalid.
3. If it is valid, a free frame is located and I/O is requested to read the needed page into the free frame.
4. Upon completion of I/O, the process table and page table are updated and the instruction is restarted.

Steps in handling a page fault by operating system :

1. We check an internal table (usually kept with the process control block) for the process to determine whether the reference is a valid or an invalid memory access.

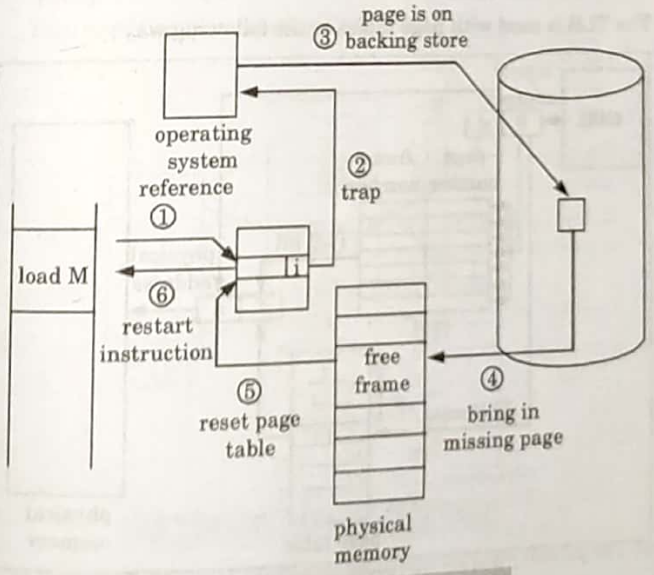


Fig. 4.18.1. Step in handling a page fault.

2. If the reference is invalid, we terminate the process. If it is valid, but we have not yet brought in that page, we now page it in.
3. We find a free frame (by taking one from the free frame list).
4. We schedule a disk operation to read the desired page into the newly allocated frame.
5. When the disk read is complete, we modify the internal table kept with the process and the page table to indicate that the page is now in memory.
6. We restart the instruction that was interrupted by the trap. The process can now access the page as though it had always been in memory.

Que 4.19. Discuss the paging hardware with TLB.

Answer

1. Translation look aside buffer (TLB) is a special, small, fast-lookup hardware cache.
2. The TLB is associative, high-speed memory.
3. Each entry in the TLB consists of two parts: a key (or tag) and a value.
4. When the associative memory is presented with an item, the item is compared with all keys simultaneously.
5. If the item is found, the corresponding value field is returned.
6. Typically, the number of entries in a TLB is small, often numbering between 64 and 1,024.
7. The TLB is used with page tables in the following way :

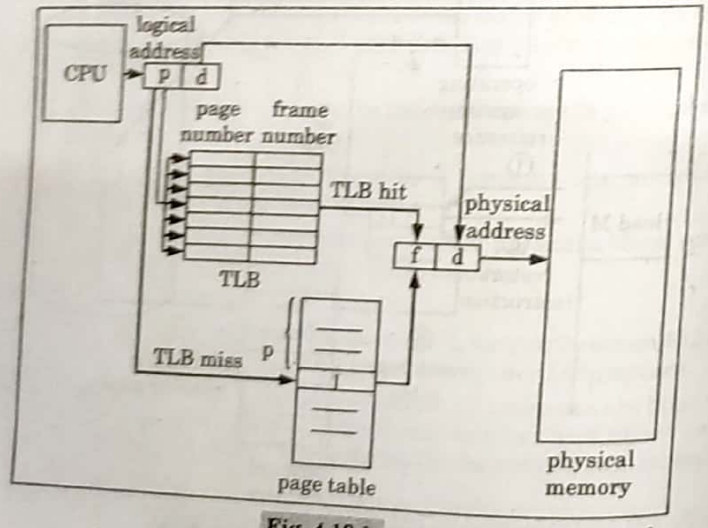


Fig. 4.19.1.

8. The TLB contains only a few of the page-table entries. When a logical address is generated by the CPU, its page number is presented to the TLB.
9. If the page number is found (known as TLB hit), its frame number is immediately available and is used to access memory.
10. If the page number is not in the TLB (known as a TLB miss) a memory reference to the page table must be made.
11. When the frame number is obtained, we can use it to access memory.
12. In addition, we add the page number and frame number to the TLB, so that they will be found quickly on the next reference.
13. If the TLB is already full of entries, the operating system must select one for replacement.
14. Replacement policies range from least recently used (LRU) to random.

Que 4.20. Discuss various structures of page table.

Answer

Some of the most common structures of page tables are :

1. **Hierarchical page table :**
   a. Under hierarchical page table the logical address space is divided into multiple page tables.
   b. A simple technique used is a two-level page table.
   c. Two-level paging as shown in Fig. 4.20.1.

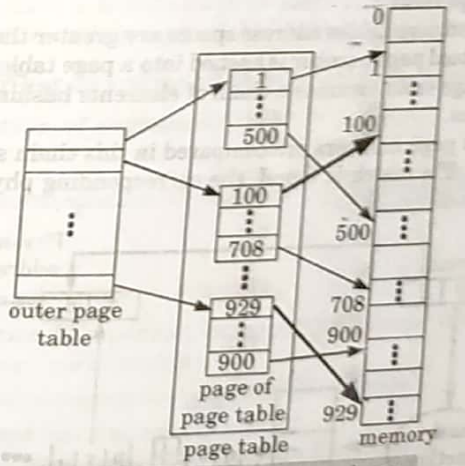


Fig. 4.20.1. Two-level paging scheme.

   d. A logical address (on 32-bit machine with 4K page size) in two-level is divided into following two parts :

i. A page number consisting of 20 bits.
ii. A page offset consisting of 12 bits.

e. Now since the page table is paged, the page number is further divided into following two parts :
i. A 10-bit page number
ii. A 10-bit page offset

f. Thus, a logical address is as follows :

page number		page offset
p_1	p_2	d
10	10	12

where p_1 is an index into the outer page table and p_2 is the displacement within the page of the outer page table.

g. The address-translation scheme for a two-level 32-bit paging architecture.

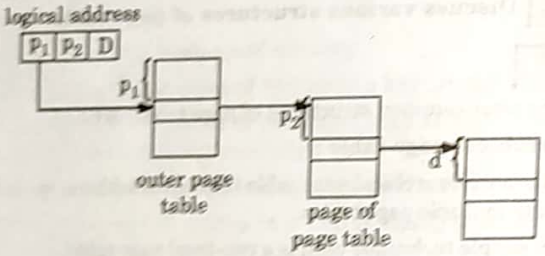


Fig. 4.20.2.

2. Hashed page table :

a. In hashed page tables address spaces are greater than (>) 32 bits.
b. The virtual page number is hashed into a page table.
c. This page table contains a chain of elements hashing to the same locations.
d. Virtual page numbers are compared in this chain searching for a match. If a match is found, the corresponding physical frame is extracted.

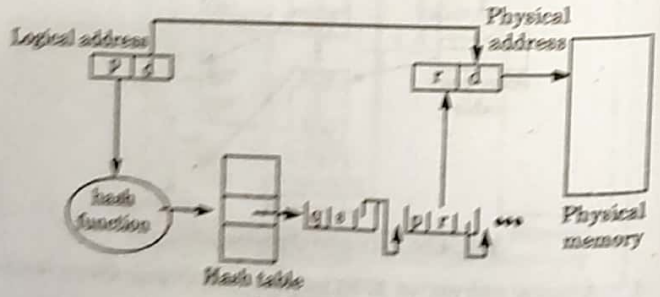


Fig. 4.20.3.

3. Inverted page table :

a. In paging, page tables are quite large, one for each process and thus consume large amounts of memory.
b. One solution is the use of inverted page table that has one entry for each frame of physical memory.
c. Each entry contains virtual address of page stored in that real memory location with information about process that owns the page.
d. The working of inverted page table is shown Fig. 4.20.4.

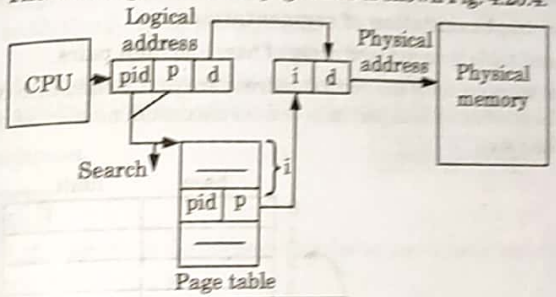


Fig. 4.20.4.

e. Each logical address consists of triplet as :
<process-id, page number, offset>
f. When a memory references occurs, <part of logical address consisting of pair ><process-id, page number > is presented to memory table and it is then searched for a match.
g. If a match is found say at entry i, then the physical address $< i$, offset > is generated. If no match if found, error is indicated.

Que 4.21. What do you mean by segmentation ? Give the hardware implementation of segmentation.

OR

Explain segmentation with diagram. **AKTU 2014-15, Marks 10**

Answer

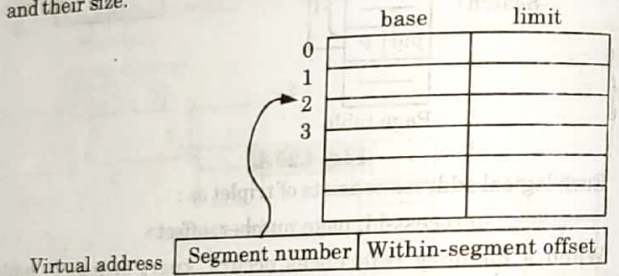
Segmentation :

1. Segmentation is a memory-management scheme that supports the programmer view of memory.
2. A logical address space is a collection of segments.
3. Each segment has a name and a length.
4. The addresses specify both the segment name and the offset within the segment.
5. The programmer therefore specifies each address by two quantities : a segment name and an offset.

6. For simplicity of implementation, segments are numbered and are referred to by a segment number, rather than by a segment name.
7. Thus, a logical address consists of a two tuple :
   <segment-number, offset>
8. Segment number indexes a process segment table.
9. Each entry in segment table has segment base and segment limit.
10. Segment base contains the physical address where segment resides in memory, whereas segment limit specifies the length of segment.

Hardware implementation of segmentation :

1. Segment table is an indexed array of base and limit pairs.
2. In this segment table the virtual address are partitioned into two parts and the position of each partition defines maximum number of segments and their size.



3. Other information which is also present in each index entry are :
   a. **Presence bit :** Whether this segment exists and has a valid base and limit.
   b. **Protection bit :** To allow read/write/execute, etc., for this segment.
   c. **Cacheable bit :** To allow data in this segment to be cached or not.
4. The use of segment table is shown in Fig. 4.21.1.

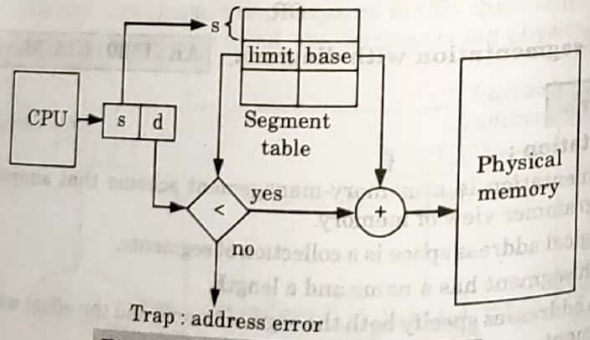


Fig. 4.21.1. Segmentation hardware.

5. The segment number is used as an index into segment table.
6. The offset d of logical address must be between 0 and segment limit.
7. If it is not, we trap to OS (logical addressing beyond end of segment).
8. If the offset is legal it is added to segment base to produce the physical address.

Que 4.22. Explain the address translation scheme in segmented-paging with the help of a diagram.

OR

Discuss the paged segmentation scheme of memory management and explain how logical address is translated to physical address in such a scheme. **AKTU 2012-13, Marks 10**

Answer

1. Fig. 4.22.1 presents the address translation mechanism under the paged segmentation scheme.

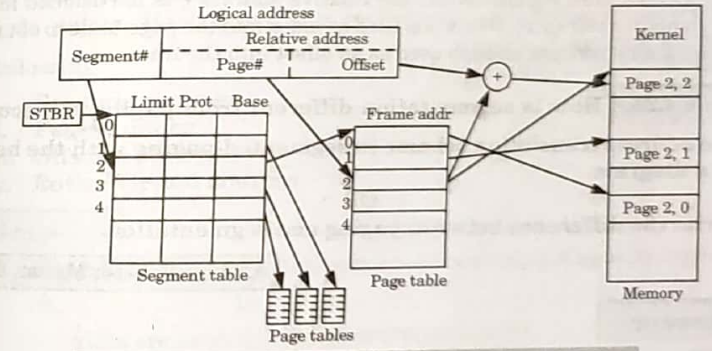


Fig. 4.22.1. Address translation in paged segmentation.

2. Each segment is treated as a single, small linear address space within the container logical address space proper, and this mini address space is paged.
3. The address translation in the mini address space is done following the pure paging scheme.
4. A page table is associated with the mini address space, which helps in the address translation task.
5. As in the pure segmentation scheme, segment related information is structured into segment descriptors that are stored in a segment table.
6. Unlike pure segmentation, each segment descriptor contains the physical base address of the segment's page table.

7. The descriptor also has the segment limit and some protection information.
8. For every process, there is a single segment table and one page table for each segment in the address space.
9. The physical address of the segment table base of the running process is stored in the STBR register.
10. When a process is scheduled for execution, the STBR is reinitialized as a part of the process context switch-in action.
11. Like pure segmentation, a logical address is partitioned into two components $\langle s, r \rangle$, where s is a segment number, and r is a relative address within the segment.
12. The segment number s is used as an index into the segment table to obtain the base of the segment's page table, and the relative address r is checked against the segment limit value.
13. If r is greater than the limit value, the translation hardware circuit generates an illegal address violation exception.
14. Unlike pure segmentation, the relative address r is partitioned into another pair $\langle p, o \rangle$, where p is used as index into the page table to obtain a frame address and o is used as an offset into the frame.

Que 4.23. **How is segmentation different from paging ? Discuss the address translation scheme in segmented-paging with the help of a diagram.**

OR

Write the difference between paging and segmentation.

AKTU 2013-14, Marks 05

Answer

Difference between segmentation and paging :

S. No.	Segmentation	Paging
1.	Program is divided into variable size segments.	Program is divided into fixed size pages.
2.	User (or compiler) is responsible for dividing the program into segments.	Division into pages is performed by the operating system.
3.	Segmentation is slower than paging.	Paging is faster than segmentation.
4.	Segmentation is visible to the user.	Paging is invisible to the user.

5.	Segmentation eliminates internal fragmentation.	Paging suffers from internal fragmentation.
6.	Segmentation suffers from external fragmentation.	There is no external fragmentation.
7.	Processor uses page number, offset to calculate absolute address.	Processor uses segment number, offset to calculate absolute address.
8.	OS maintain a list of free holes in main memory.	OS must maintain a free frame list.

Address translation in segmented-paging : Refer Q. 4.22, Page 4–22B, Unit-4.

Que 4.24. **On a system using paging and segmentation the virtual address space consists of upto 16 segments where each segment can be upto 216 bytes long. The hardware pages each segment into 512 byte pages. How many bits in the virtual address specify the following ?**

AKTU 2014-15, Marks 05

i. **Segment number**
ii. **Page number**
iii. **Offset within page**
iv. **Entire virtual address**

Answer

i. **Segment number :** Virtual address space consists of upto 16 segments

So, $16 = 2^4$

$\therefore$ 4 bits are needed to specify segment number.

ii. **Page number :** Hardware pages each segment into 512 bytes pages.

$512 = 2^9$ byte pages

Size of segment is 2^{16} bytes.

$\therefore$ $2^{16} / 2^9 = 2^{16-9} = 2^7 = 7$ pages

$\therefore$ 7 bits are required to specify the page number.

iii. **Offset within page :** For 2^9 byte page, 9 bits are needed.

iv. **Entire virtual address :** Segment number + Page number + offset

$= 4 + 7 + 9 = 20$

Que 4.25. **Why are segmentation and paging sometimes combined into one scheme ?**

Answer

1. Segmentation and paging are often combined in order to improve upon each other.
2. Segmented paging is helpful when the page table becomes very large.
3. A large contiguous section of the page table that is unused can be collapsed into a single-segment table entry with a page-table address of zero.
4. Paged segmentation handles the case of having very long segments that require a lot of time for allocation.
5. By paging the segments, we reduce wasted memory due to external fragmentation as well as simplify the allocation.

PART-2

Virtual Memory Concepts, Demand Paging, Performance of Demand Paging, Page Replacement Algorithms, Thrashing, Cache Memory Organization, Locality of Reference.

CONCEPT OUTLINE : PART-2

- Virtual memory is a technique that allows the execution of processes which are not completely available in memory.
- The process of loading the page into memory on demand (whenever the page fault occurs) is known as demand paging.
- Page replacement algorithms.
  - i. FIFO
  - ii. LRU
  - iii. Optimal
- Locality of reference is a term for the phenomenon in which the same values or related storage locations are frequently accessed, depending on the memory access pattern.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.26. **What is virtual memory ?**

OR

Explain the concept of virtual memory and also discuss its advantages.

Answer

Virtual memory :

1. Virtual memory is a memory management capability of an OS that uses hardware and software to allow a computer to compensate for physical memory shortages by temporarily transferring data from Random Access Memory (RAM) to disk storage.
2. Virtual address space is increased using active memory in RAM and inactive memory in Hard Disk Drives (HDDs) to form contiguous addresses that hold both the application and its data.
3. A system using virtual memory can load larger programs or multiple programs running at the same time, allowing each one to operate as if it has infinite memory and without having to purchase more RAM.
4. Virtual memory is a facility that allows program to address memory from local point of view, without regard to the amount of main memory.
5. Virtual memory is used to give programmers the illusion that they have a very large memory at their disposal, even though the computer actually has a relatively small main memory.
6. A virtual memory system provides a mechanism for translating program generated addresses into correct main memory locations.
7. This is done dynamically, while programs are being executed in the CPU.

Advantages of virtual memory :

1. Allows us to fit many large programs into a relatively small RAM.
2. Only part of a program needs to be loaded into memory.
3. Memory can be used efficiently because a section of program loaded only when it is needed in CPU.
4. Virtual memory allows sharing of code and data, unlimited amounts of multi-programming.

Que 4.27. **Explain the process of demand paging.**

Answer

The process of loading the page into memory on demand (whenever page fault occurs) is known as demand paging. The process includes the following steps :

1. If CPU tries to refer a page that is currently not available in the main memory, it generates an interrupt indicating memory access fault.
2. The OS puts the interrupted process in a blocking state. For the execution to proceed the OS must bring the required page into the memory.

3. The OS will search for the required page in the logical address space.
4. The required page will be brought from logical address space to physical address space. The page replacement algorithms are used for the decision making of replacing the page in physical address space.
5. The page table will updated accordingly.
6. The signal will be sent to the CPU to continue the program execution and it will place the process back into ready state.

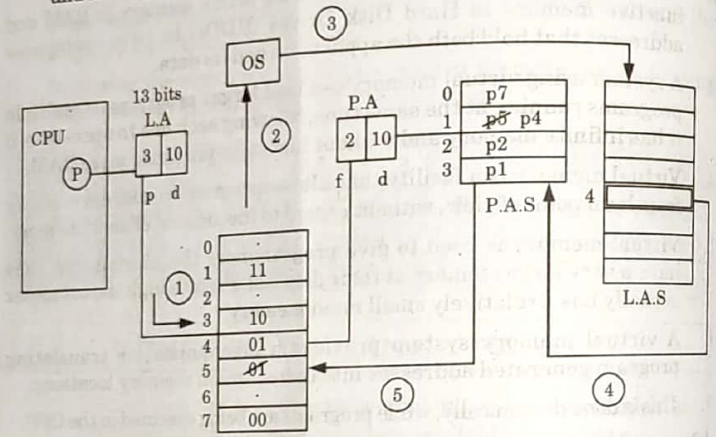


Fig. 4.27.1.

Que 4.28. What are the advantages and disadvantages of demand paging ?

Answer

Advantages of demand paging :

1. Large virtual memory.
2. More efficient use of memory.
3. Unconstrained multiprogramming. There is no limit on degree of multiprogramming.

Disadvantages of demand paging :

1. Number of tables and amount of processor over head for handling page interrupts are greater than in the case of the simple paged management techniques.
2. Due to the lack of an explicit constraint on a job's address space size or amount of multiprogramming, it is necessary to develop approaches to prevent thrashing.

Que 4.29. Discuss performance of demand paging.

Answer

1. Demand paging can have a significant effect on the performance of a computer system.
2. Let us calculate effective access time for a demand paged memory. Let p be the probability of a page fault ($0 \le p \le 1$).

   Effective access time = $(1-p) \times ma + p \times$ page fault time

   where,

   p = page fault

   ma = memory access time
3. Effective access time is directly proportional to the page fault rate.
4. It is important to keep the page-fault rate low in a demand paging system. Otherwise, the effective access time increases, slowing process execution dramatically.

Que 4.30. Consider a demand paged system. Page tables are held in registers. It takes 8 milliseconds to service a page fault if an empty page is available or the replaced page is not modified, and 20 milliseconds if the replaced page is modified. Memory access time is 100 nanoseconds. Assume that the page to be replaced is modified 70 percent of the time. What is the maximum acceptable page fault rate for an effective access time of not more than 200 nanoseconds ?

AKTU 2012-13, Marks 05

Answer

From the given conditions, we get

$$0.2\ \mu s = (1-p) \times 0.1\ \mu s + (0.3p) \times 8 \text{ millisec} + (0.7P) \times 20 \text{ millisec}$$

or $$1 = -p + 2400\,P + 14000\,p$$

[$\because$ 100 ns = 0.1 μsec and 200 ns = 0.2 μsec]

or $$1 = 16399p$$

or $$p = 0.00006$$

Que 4.31. Consider a demand paged system. Page tables are stored in main memory which has an access time of 100 nanoseconds. The TLB can hold 8 page table entries and has an access time of 10 nanoseconds. During the execution of a process, it is found that 80 % of the time, a required page table entry exists in TLB and only 2 % of the references cause page faults. The average time to service page fault is 2 milliseconds. Compute the effective memory access time.

AKTU 2011-12, Marks 10

Answer

TLB lookup takes 10 nanoseconds

Effective access time = Page fault time × p + ma × (1 – P)

$$= (10 \times 10^{-9} + 100 \times 10^{-9}) \times 0.8 + (10 \times 10^{-9} + 100 \times 10^{-9} + 2 \times 10^{-3}) \times 0.2$$

$$= (88 + 400022) \times 10^{-9}$$

$$= 400110 \times 10^{-9}$$

$$= 400.110 \ \mu sec$$

Que 4.32. Discuss page replacement algorithms with suitable examples.

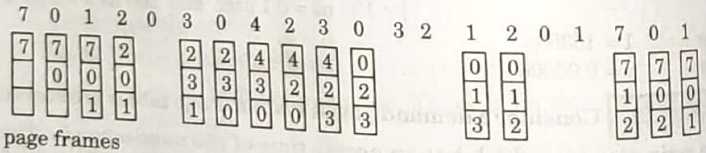
Answer

The basic page replacement algorithms are as follows :

1. **First In First Out (FIFO) algorithm :**
   - i. The simplest page replacement algorithm is a First In First Out (FIFO) algorithm.
   - ii. A FIFO replacement algorithm associates with each page the time when that page was brought into memory.
   - iii. When a page must be replaced, the oldest page is chosen.
   - iv. We can create a FIFO queue to hold all pages in memory. We replace the page at the head of the queue. When a page is brought into memory, we insert it at the tail of the queue.

For example :

reference string



page frames

i. Reference string, our three frames are initially empty. The first three references (7, 0, 1) cause page faults and are brought into these empty frames.

ii. The next reference (2) replaces page 7, because page 7 was brought in first. Since 0 is the next reference and 0 is already in memory, we have no fault for this reference.

iii. The first reference to 3 results in replacement of page 0, since it is now first in line.

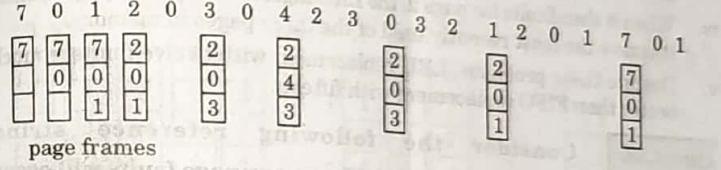
iv. Because of this replacement, the next reference, to 0, will fault. Page 1 is then replaced by page 0. This process continues.

v. Every time a fault occurs, we show which pages are in our three frames. There are fifteen faults altogether.

2. **Optimal algorithm :**
   - i. The optimal policy selects for replacement that page for which the time to the next reference is the longest.
   - ii. An optimal page replacement algorithm has the lowest page fault rate of all algorithms and will never suffer from Belady's anomaly.
   - iii. This algorithm is impossible to implement because it would require the operating system to have perfect knowledge of future events.

For example :

reference string



page frames

i. The optimal page replacement algorithm would yield nine page faults.

ii. The first three references cause faults that fill the three empty frames.

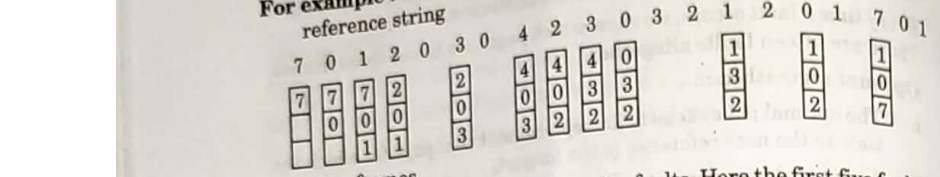
iii. The reference to page 2 replaces page 7, because page 7 will not be used until reference 18, whereas page 0 will be used at 5, and page 1 at 14.

iv. The reference to page 3 replaces page 1, as page 1 will be the last of the three pages in memory to be referenced again.

v. With only nine page faults, optimal replacement is much better than a FIFO algorithm, which results in fifteen faults.

3. **LRU page replacement :**
   - i. If the optimal algorithm is not feasible, perhaps an approximation of the optimal algorithm is possible.
   - ii. The key distinction between the FIFO and OPT algorithms (other than looking backward versus forward in time) is that the FIFO algorithm uses the time when a page was brought into memory, whereas the OPT algorithm uses the time when a page is to be used.
   - iii. If we use the recent past as an approximation of the near future, then we can replace the page that has not been used for the longest period of time.
   - iv. This approach is the least recently used (LRU) algorithm.

For example :



i. The LRU algorithm produces twelve faults. Here the first five faults are the same as those for optimal replacement.

ii. When the reference to page 4 occurs, however, LRU replacement sees that, of the three frames in memory, page 2 was used least recently.

iii. Thus, the LRU algorithm replaces page 2, not knowing that page 2 is about to be used.

iv. When it then faults for page 2, the LRU algorithm replaces page 3, since it is now the least recently used of the three pages in memory.

v. Despite these problems, LRU replacement with twelve faults is much better than FIFO replacement with fifteen.

Que 4.33. **Consider the following reference string 1,2,3,4,2,1,5,6,2,1,2,3, 7,6,3,2,1,2,3,6. How many page faults will occur for :**

i. FIFO

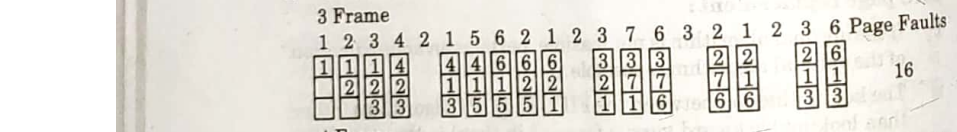
ii. LRU page replacement algorithm ?

Assuming three and four frames in each case and frames are initially empty.

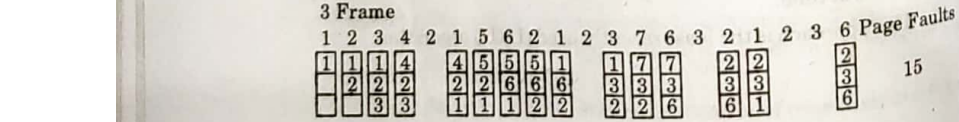
AKTU 2015-16, Marks 10

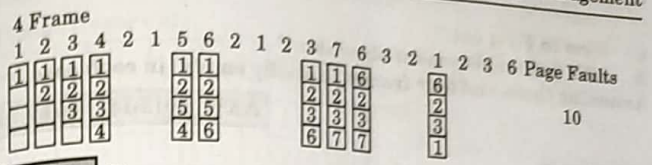
Answer

i. FIFO



ii. LRU





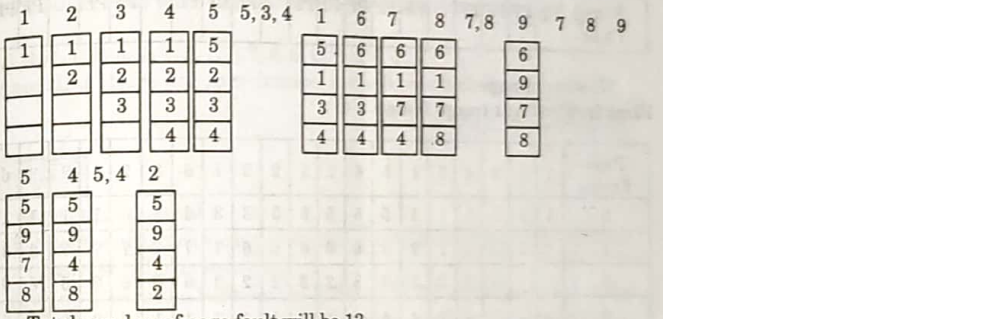
Que 4.34. **How many page faults would occur for the following reference string for four page frames using LRU and FIFO algorithms ?**

1, 2, 3, 4, 5, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 7, 8, 9, 5, 4, 5, 4, 2

AKTU 2014-15, Marks 10

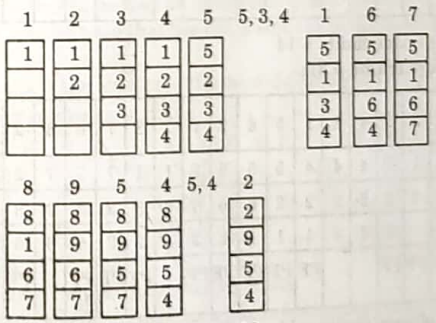
Answer

LRU :



Total number of page fault will be 13.

FIFO :



Total number of page fault will be 13.

Que 4.35. **Consider the following reference string 1 2 3 4 2 1 5 6 2 1 2 3 7 6 3 2 1 2 3 6. How many page faults will occur for :**

i. First in First out ?
ii. LRU page replacement algorithm ?
Assuming three and four frames (initially empty) in each case.

AKTU 2013-14, Marks 10

Answer

i. **First In first out (page frame = 3) :**

Page Frame	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
0	1	1	1	4	4	4	4	6	6	6	6	3	3	3	3	2	2	2	2	6
1	-	2	2	2	2	1	1	1	2	2	2	2	7	7	7	7	1	1	1	1
2	-	-	3	3	3	3	5	5	5	1	1	1	1	6	6	6	6	6	3	3
Page Fault	PF	PF	PF	PF		PF	PF	PF	PF	PF		PF	PF	PF		PF	PF		PF	PF

Number of page faults = 16

First In First out (page frame = 4) :

Page Frame	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
0	1	1	1	1	1	1	5	5	5	5	5	3	3	3	3	3	1	1	1	1
1	-	2	2	2	2	2	2	6	6	6	6	6	7	7	7	7	7	7	3	3
2	-	-	3	3	3	3	3	3	2	2	2	2	2	6	6	6	6	6	6	6
3	-	-	-	4	4	4	4	4	4	1	1	1	1	1	1	2	2	2	2	2
Page Fault	PF	PF	PF	PF			PF	PF	PF	PF		PF	PF	PF		PF	PF		PF	

Number of page faults = 14

ii. **LRU (page frame = 3) :**

Page Frame	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
0	1	1	1	4	4	4	5	5	5	1	1	1	7	7	7	2	2	2	2	2
1	-	2	2	2	2	2	2	6	6	6	6	3	3	3	3	3	3	3	3	3
2	-	-	3	3	3	1	1	1	2	2	2	2	2	6	6	6	1	1	1	6
Page Fault	PF	PF	PF			PF	PF	PF	PF	PF		PF	PF	PF		PF	PF			PF

Number of page faults = 14

LRU (page frame = 4) :

Page Frame	1	2	3	4	2	1	5	6	2	1	2	3	7	6	3	2	1	2	3	6
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	6
1	-	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6
2	-	-	3	3	3	3	5	5	5	5	5	3	3	3	3	3	3	3	3	3
2	-	-	-	4	4	4	4	6	6	6	6	6	7	7	7	7	1	1	1	1
Page Fault	PF	PF	PF	PF			PF	PF				PF	PF	PF			PF			

Number of page faults = 10

Que 4.36. **Discuss the LRU page replacement policy. Prove that this policy do not suffer from Belady's anomaly. How many page faults would occur with LRU policy for the following reference string :**

1, 2, 3, 3, 4, 1, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 8, 7, 8, 9, 5, 4, 5, 4, 2

Assume that there are four frames which are initially empty.

AKTU 2011-12, Marks 10

Answer

LRU page replacement :

1. If the optimal algorithm is not feasible, perhaps an approximation of the optimal algorithm is possible.
2. The key distinction between the FIFO and OPT algorithms is that the FIFO algorithm uses the time when a page was brought into memory, whereas the OPT algorithm uses the time when a page is to be used.
3. If we use the recent past as an approximation of the near future, then we can replace the page that has not been used for the longest period of time.
4. This approach is the least recently used (LRU) algorithm.
   Consider the reference string :

   page frames
5. The LRU algorithm produces twelve faults.
6. The LRU policy is often used as a page replacement algorithm and is considered to be good.
7. The major problem is how to implement LRU replacement.
8. An LRU page replacement algorithm may require substantial hardware assistance.

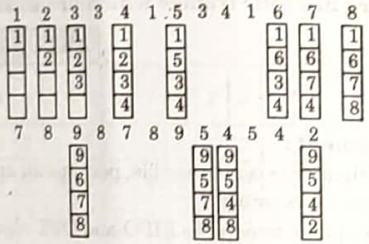
9. The problem is to determine an order for the frames defined by the time of last use.

Proof :

1. LRU replacement does not suffer from Belady's anomaly.
2. It belongs to a class of page replacement algorithms, called stack algorithms that can never exhibit Belady's anomaly.
3. A stack algorithm is an algorithm for which it can be shown that the set of pages in memory for n frames is always a subset of the set of pages in memory with $n + 1$ frames.
4. For LRU replacement, the set of pages in memory would be the n most recently referenced pages.
5. If the number of frames is increased, these n pages will still be the most recently referenced and so will still be in memory.

Numerical :

1, 2, 3, 3, 4, 1, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 8, 7, 8, 9, 5, 4, 5, 4, 2



Total number of page faults = 12.

Que 4.37. What is thrashing ? State the cause of thrashing and discuss its solution. **AKTU 2015-16, Marks 10**

Answer

Thrashing :

1. Thrashing occurs when a system spends more time in processing page faults rather than executing transactions.
2. While processing page faults it is necessary to be in order to appreciate the benefits of virtual memory, thrashing has a negative effect on the system.
3. As the page fault rate increases, more transactions need processing from the paging device.
4. The queue at the paging device increases, resulting in increased service time for a page fault.

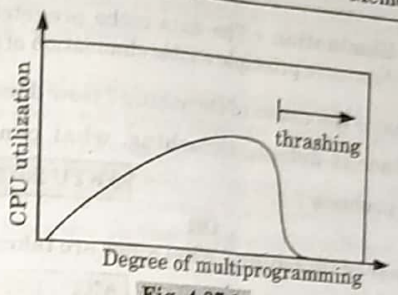


Fig. 4.37.1.

5. While the transactions in the system are waiting for the paging device, CPU utilization, system throughput and system response time decrease, resulting in below optimal performance of a system.
6. Thrashing becomes a greater threat as the degree of multiprogramming of the system increases.
7. Therefore, to increase CPU utilization multiprogramming should be reduced.

Cause of thrashing :

1. A system thrashes if physical memory is too small to hold the working sets of all the processes running.
2. The upshot of thrashing is that pages always spend their time waiting for the backing store to fetch their pages.

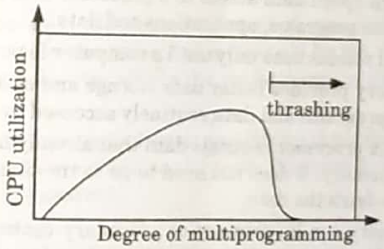


Fig. 4.37.2.

3. Thrashing is a discrete phenomenon.
4. Usually, there is a phase transition from no thrashing to thrashing.
5. Scheduler brought in new process whenever CPU utilization goes down.
6. Eventually the size of the working sets becomes larger than physical memory, and processes start to page.
7. The CPU utilization drops even further, so more processes come in, and the system starts to thrash.
8. Thrashing is busy swapping pages in and out or doing more paging than executing.
9. A process is thrashing if it is spending more time in paging than executing.

Solution / Elimination : The data cache pre-fetching and single assignment data move principle enable elimination of cache thrashing.

Que 4.38. **What is the cause of thrashing ? How does system detect thrashing ? Once it detects thrashing, what can system do to eliminate this problem ?** **AKTU 2012-13, Marks 05**

OR

What is the cause of thrashing ? What steps are taken by the system to eliminate this problem ? **AKTU 2016-17, Marks 10**

Answer

Causes of thrashing : Refer Q. 4.37, Page 4–35B, Unit-4.

Detection of thrashing : The system can detect thrashing by evaluation the level of CPU utilization as compared to the level of multiprogramming.

Elimination of thrashing : Refer Q. 4.37, Page 4–35B, Unit-4.

Que 4.39. **Write short note on cache memory.**

Answer

1. Cache memory is a small-sized type of volatile computer memory that provides high-speed data access to a processor and stores frequently used computer programs, applications and data.
2. It stores and retains data only until a computer is powered up.
3. Cache memory provides faster data storage and access by storing an instance of programs and data routinely accessed by the processor.
4. Thus, when a processor requests data that already has an instance in the cache memory, it does not need to go to the main memory or the hard disk to fetch the data.
5. Cache memory can be primary or secondary cache memory, where primary cache memory is directly integrated or closest to the processor.
6. In addition to hardware-based cache, cache memory also can be a disk cache, where a reserved portion on a disk stores and provide access to frequently accessed data/applications from the disk.

Que 4.40. **Discuss the design issues in cache design.**

Answer

The primary elements having strong influence on cache design are :

i. **Cache size :** There are two important factor in deciding cache size at the time of its design.
   a. Size should be small enough so that its cost is very close to the main memory.
   b. Size should be large enough so that most of the memory reference should be available in the cache so that average access time will be close to cache alone.

ii. **Block size :**
   a. Block size of cache is an important factor in cache performance.
   b. Larger block size could store the desired word as well as some adjacent word also. As a result hit ratio will increase automatically.
   c. A small block size result in frequent replacement of data shortly after it is fetched increasing the overhead in cache operation.
   d. As the block size increases from smaller to larger, the hit ratio will increase first and on increasing the block size further the hit ratio began to decrease.

iii. **Associativity :** It is a basic tradeoff between parallel searching versus constraints on which addresses can be stored.

iv. **Write strategy :** Its main concern is related to when do we write cache contents to main memory.

Que 4.41. **Describe the different mapping techniques for cache memory.**

OR

What is meant by cache mapping ? What are different types of mapping ? Discuss different mapping techniques with examples.

Answer

Cache mapping :

1. Cache mapping is the method by which the contents of main memory are brought into the cache and referenced by the CPU. The mapping method used directly affects the performance of the entire computer system.
2. Mapping is a process to discuss possible methods for specifying where memory blocks are placed in the cache. Mapping function dictates how the cache is organized.

Types of mapping :

i. **Direct mapping :**
   1. The direct mapping technique is simple and inexpensive to implement.
   2. When the CPU wants to access data from memory, it places an address. The index field of CPU address is used to access address.
   3. The tag field of CPU address is compared with the associated tag in the word read from the cache.
   4. If the tag-bits of CPU address are matched with the tag-bits of cache, then there is a hit and the required data word is read from cache.

5. If there is no match, then there is a miss and the required data word is stored in main memory. It is then transferred from main memory to cache memory with the new tag.

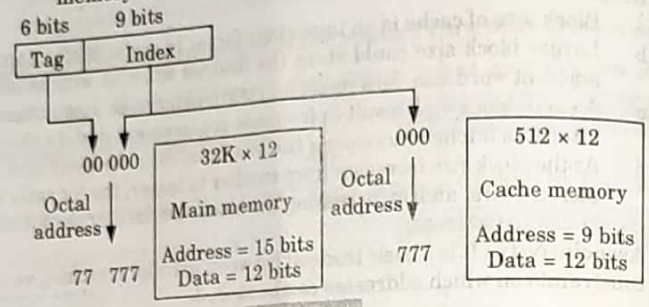


Fig. 4.41.1.

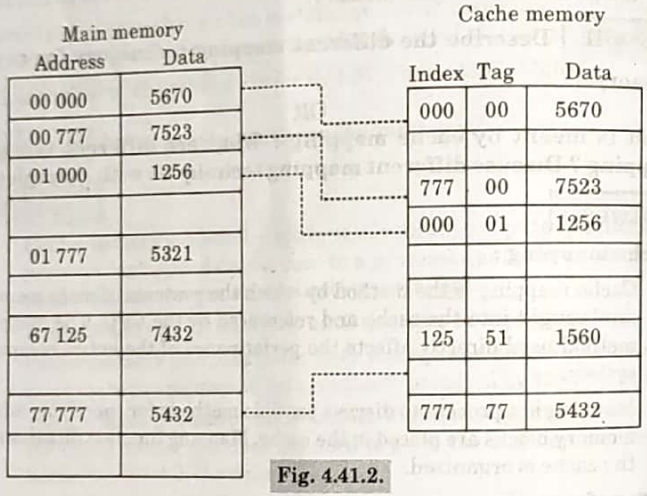


Fig. 4.41.2.

ii. Associative mapping :

1. An associative mapping uses an associative memory.
2. This memory is being accessed using its contents.
3. Each line of cache memory will accommodate the address (main memory) and the contents of that address from the main memory.
4. That is why this memory is also called Content Addressable Memory (CAM). It allows each block of main memory to be stored in the cache.

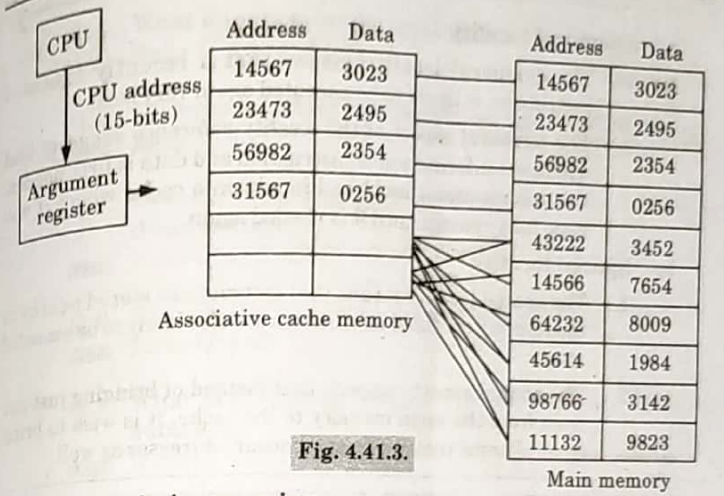


Fig. 4.41.3.

iii. Set associative mapping :

1. That is the easy control of the direct mapping cache and the more flexible mapping of the fully associative cache.
2. In set associative mapping, each cache location can have more than one pair of tag + data items.
3. That is more than one pair of tag and data are residing at the same location of cache memory. If one cache location is holding two pair of tag + data items, that is called 2-way set associative mapping.

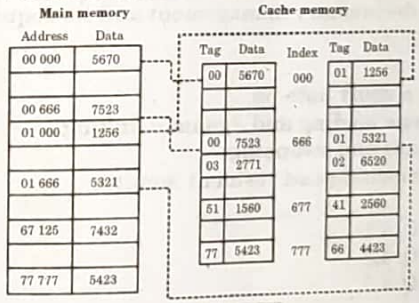


Fig. 4.41.4.

Que 4.42. Write short notes on locality of reference ?

Answer

1. Locality of reference is a term for the phenomenon in which the same values or related storage locations are frequently accessed, depending on the memory access pattern.
2. There are two basic types of reference locality :

a. Temporal locality :

1. The temporal locality means that a recently executed instruction is likely to be executed again very soon.
2. The temporal aspect of the locality reference suggests that whenever information of instruction and data is first needed, this information should be brought into cache where it will hope fully remain until it is needed again.

b. Spatial locality :

1. The spatial locality means that instructions stored nearby to the recently executed instructions are also likely to be executed soon.
2. The spatial aspect suggests that instead of bringing just one item from the main memory to the cache, it is wise to bring several items that reside at adjacent addresses as well.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Describe memory management and its requirement.
Ans. Refer Q. 4.1.

Q. 2. Write a short note on
i. Dynamic loading and dynamic linking
ii. Overlaps and swapping
iii. Bare machine and resident monitor
Ans.
i. Refer Q. 4.3.
ii. Refer Q. 4.4.
iii. Refer Q. 4.7.

Q. 3. Explain the following terms :
i. Fixed / static partitioning
ii. Variable / dynamic partitioning
Ans.
iii. Refer Q. 4.9.
iii. Refer Q. 4.10.

Q. 4. Differentiate between internal fragmentation and external fragmentation.
Ans. Refer Q. 4.13.

Q. 5. What do you mean by paging and segmentation ?
Ans. Refer Q. 4.16 and 4.21.

Q. 6. Differentiate between paging and segmentation.
Ans. Refer Q. 4.23.

Q. 7. Describe demand paging. What are its advantages and disadvantages ?
Ans. Refer Q. 4.27 and Q. 4.28.

Q. 8. Discuss the page replacement algorithms.
Ans. Refer Q. 4.32.

Q. 9. What is thrashing ? State the cause of thrashing and its solution.
Ans. Refer Q. 4.37.

☺☺☺

5 UNIT

I/O Management and Disk Scheduling

PART-1

I/O Management and Disk Scheduling : I/O Devices, and I/O Subsystem, I/O Buffering, Disk Storage and Disk Scheduling, RAID.

CONCEPT OUTLINE : PART-1

- I/O devices are the collection of interfaces that different functional units of an information processing system use to communicate with each other.
- Types of I/O buffering schemes :
  i. Single buffer
  ii. Double buffer
  iii. Circular buffer
- Various disk scheduling algorithms :
  i. FCFS scheduling
  ii. SSTF scheduling
  iii. SCAN scheduling
  iv. C-SCAN scheduling
  v. LOOK scheduling

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. Explain the terms I/O devices. What are the categories of I/O devices ?

Answer

1. Input/output, or I/O, is the collection of interfaces that different functional units (sub-systems) of an information processing system use to communicate with each other, or the signals (information) sent through those interfaces.
2. Inputs are the signals received by the unit, and outputs are the signals sent from it.
3. The term can also be used as part of an action; to "do I/O" is to perform an input or output operation.
4. I/O devices are used by a person (or other system) to communicate with a computer.

5. For instance, keyboard and mouse are considered input devices of a computer and monitors and printers are considered output devices of a computer.
6. Typical devices for communication between computers are for both input and output, such as modems and network cards.

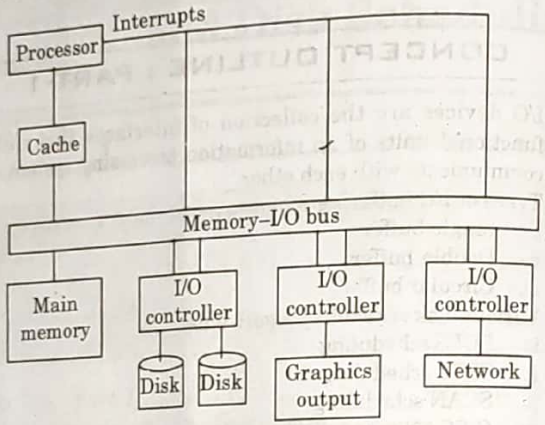


Fig. 5.1.1. Input / Output (I/O) Device.

Categories of I/O devices are :

1. **Human readable :** It is suitable for communicating with the computer user.

   For example : Printers, video display terminals, keyboard etc.
2. **Machine readable :** It is suitable for communicating with electronic equipment.

   For example : Disk and tape drives, sensors, controllers and actuators.
3. **Communication :** It is suitable for communicating with remote devices.

   For example : Digital line drivers and modems.

Que 5.2. **What are the techniques for performing I/O ?**

OR

Describe the organization of I/O function.

Answer

1. **Programmed I/O :**
   i. Programmed I/O takes place under direct control of CPU.
   ii. CPU issues a command on behalf of a process to an I/O module.
   iii. CPU then waits for the operation to be completed before proceeding.

2. **Interrupt driven I/O :**
   i. In interrupt driven I/O CPU issues a command on behalf of a process to an I/O module.
   ii. If the I/O instruction is non-blocking, CPU continues to execute next instruction[s] from the same process.
   iii. If the I/O instruction is blocking, OS takes over, suspends the current process, and assigns CPU to another process.
3. **Direct Memory Access (DMA) :**
   i. DMA module controls exchange of data between memory and an I/O module.
   ii. CPU sends a request to transfer a block of data to the DMA module and is interrupted only after the entire block has been transferred.
   iii. DMA module takes over control of system bus to perform the transfer.
   iv. CPU initiates the I/O by sending the following information to DMA module :
      a. Read or write request using the read or write control line between the CPU and DMA module.
      b. Address of the I/O device, on the data line.
      c. Starting location in memory for read/write which are communicated on data lines and stored by DMA module in its address register.
      d. Number of words to read/write which are communicated on data lines and stored in the data count register.
   v. DMA may ignore the paging circuitry and access the address bus directly to transfer several disk sectors in a single I/O operation.

   This requires the requested buffers to be located in contiguous page frames.

Que 5.3. **What is buffer in devices ?**

OR

Write short note on I/O buffering.

AKTU 2013-14, 2015-16, Marks 05

Answer

1. A buffer is a memory area that stores data being transferred between two devices or between a device and an application.
2. Buffering is done to cope with a speed mismatch between the producer and consumer of a data stream.
3. A buffer is created in main memory to accumulate the bytes received from the modem.

4. When an entire buffer of data has arrived, the buffer can be written to disk in a single operation.
5. Since the disk write is not instantaneous and the modem still needs a place to store additional incoming data, two buffers are used.
6. After the modem fills the first buffer, the disk write is requested. The modem then starts to fill the second buffer while the first buffer is written to disk.
7. By the time the modem has filled the second buffer, the disk write from the first one should have completed, so the modem can switch back to the first buffer while the disk writes the second one.
8. This double buffering decouples the producer of data from the consumer, thus relaxing timing requirements between them.
9. Another use of buffering is to provide adaptations for devices that have different data transfer sizes.

Que 5.4. What are the types of I/O buffering schemes ?

Answer

Types of I/O buffering schemes :

1. **Single buffer :** Operating system assigns a buffer in the system portion of main memory.

   Block oriented device :

   i. Input transfers are made to the system buffer.
   ii. After transferring, the process moves the block into user space and request for another block.
   iii. User process can be processing one block of data while the next block is being read in.
   iv. OS is able to swap the process out.
   v. OS must keep track of the assignment of system buffers to user processes.

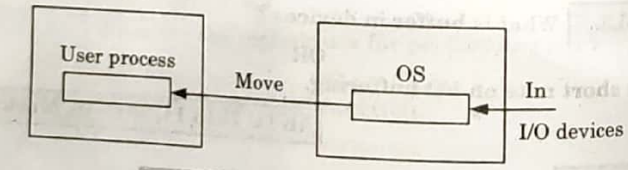
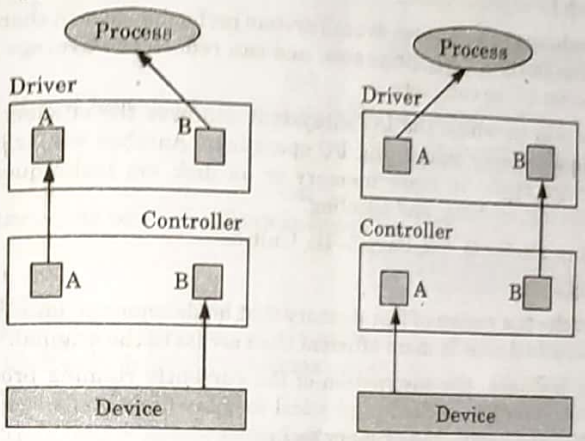


Fig. 5.4.1. Single buffering.

2. **Double buffer :**

   i. There are two buffers in the system.
   ii. One buffer is for the driver or controller to store data while waiting for it to be retrieved by higher level of the hierarchy.
   iii. Other buffer is to store data from the lower level module.

   iv. Double buffering is also called buffer swapping.
   v. Double buffering improvement comes at the cost of increased complexity.
   vi. Double buffering may be inadequate if the process performs rapid bursts of I/O.



(a) Reading into driver buffer A (b) Reading into driver buffer B

Fig. 5.4.2. Double buffering in the driver.

3. **Circular buffer :**

   i. When more than two buffers are used, the collection of buffers is itself referred to as a circular buffer.
   ii. In this, the producer cannot pass the consumer because it would overwrite buffers before they had been consumed.
   iii. The producer can only fill up to buffer $j-1$ while data in buffer j is waiting to be consumed.

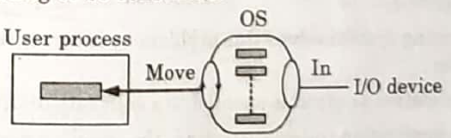


Fig. 5.4.3. Circular buffering.

Que 5.5. Discuss the services provided in kernel I/O subsystem.

OR

What do you mean by caching, spooling and error handling ? Explain in detail. **AKTU 2016-17, Marks 15**

Answer

Kernels provide many services related to I/O. Several services such as scheduling, buffering, caching, spooling, device reservation, and error

handling are provided by the kernel's I/O subsystem and build on the hardware and device driver infrastructure.

I/O scheduling :

1. To schedule a set of I/O requests means to determine a good order in which to execute them.
2. Scheduling can improve overall system performance, can share device access fairly among processes, and can reduce the average waiting time for I/O to complete.
3. One way in which the I/O subsystem improves the efficiency of the computer is by scheduling I/O operations. Another way is by using storage space in main memory or on disk via techniques called buffering, caching, and spooling.

Buffering : Refer Q. 5.3, Page 5–4B, Unit-5.

Caching :

1. A cache is a region of fast memory that holds copies of data. Access to the cached copy is more efficient than access to the original.
2. For instance, the instruction of the currently running process are stored on disk, cached in physical memory and copied again in the CPU's secondary and primary caches.
3. The difference between a buffer and a cache is that a buffer may hold the only existing copy of a data item, whereas a cache, by definition, holds a copy on faster storage of an item that resides elsewhere.

Spooling :

1. A spool is a buffer that holds output for a device, such as a printer, that cannot accept interleaved data streams.
2. Although a printer can serve only one job at a time, several applications may wish to print their output concurrently without having their output mixed together.
3. The operating system solves this problem by intercepting all output to the printer.
4. Each application's output is spooled to a separate disk file.
5. When an application finishes printing, the spooling system queues the corresponding spool file for output to the printing, the spooling system copies the queued spool files to the printer one at a time.

Error handling :

1. An operating system that uses protected memory can guard against many kinds of hardware and application errors, so that a complete system failure is not the usual result of each minor mechanical glitch.
2. Devices and I/O transfers can fail in many ways, either for transient reasons, as when a network becomes overloaded, or for "permanent" reasons, as when a disk controller becomes defective.

3. Operating system can often compensate effectively for transient failures.
4. As a general rule, an I/O system call will return one bit of information about the status of the call, signifying either success of failure.

Que 5.6. Explain FCFS, SCAN & C-SCAN scheduling with example.

AKTU 2016-17, Marks 15

OR

Discuss disk scheduling algorithms with example.

AKTU 2014-15, Marks 10

OR

Write short note on disk scheduling policies.

AKTU 2012-13, Marks 10

Answer

Various disk scheduling algorithms are :

i. FCFS scheduling :

1. The simplest form of disk scheduling is the First-Come First-Served (FCFS) algorithm.

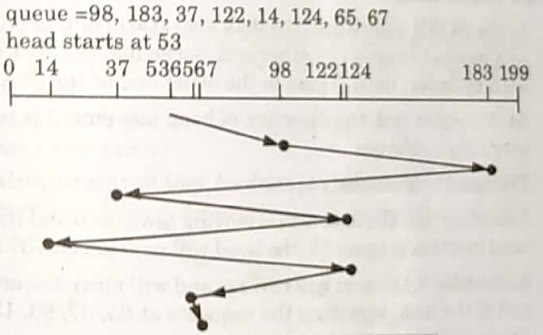


Fig. 5.6.1. FCFS disk scheduling.

2. This algorithm is intrinsically fair, but it generally does not provide the fastest service.
3. Consider, for example, a disk queue with requests for I/O to blocks on cylinders 98, 183, 37, 122, 14, 124, 65, 67 in that order.
4. If the disk head is initially at cylinder 53, it will first move from 53 to 98, then to 183, 37, 122, 14, 124, 65, and finally to 67.

ii. SSTF scheduling :

1. The SSTF algorithm selects the request with the least seek time from the current head position.

2. For our example request queue, the closest request to the initial head position (53) is at cylinder 65.
3. Once we are at cylinder 65, the next closest request is at cylinder 67. From there, the request at cylinder 37 is closer than the one at 98, so 37 is served next.

queue = 98, 183, 37, 12, 14, 124, 65, 67
head starts at 53

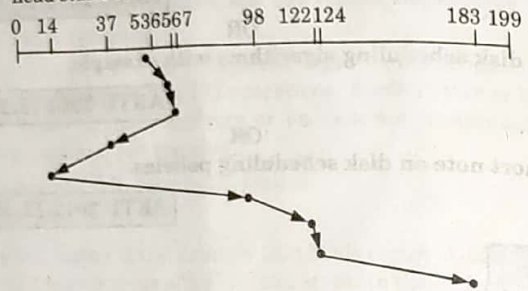


Fig. 5.6.2. SSTF disk scheduling.

4. Continuing, we service the request at cylinder 14, then 98, 122, 124, and finally 183.

iii. SCAN scheduling :

1. In the SCAN algorithm, the disk arm starts at one end of the disk and moves towards the other end, servicing requests as it reaches each cylinder, until it gets to the other end of the disk.
2. At the, other end, the direction of head movement is reversed, and servicing continues.
3. The head continuously scans back and forth across the disk.
4. Assuming that the disk arm is moving towards 0 and that the initial head position is again 53, the head will next service 37 and then 14.
5. At cylinder 0, the arm will reverse and will move towards the other end of the disk, servicing the requests at 65, 67, 98, 122, 124, and 183.
6. If a request arrives in the queue just in front of the head, it will be serviced almost immediately; a request arriving just behind the head will have to wait until the arm moves to the end of the disk, reverses direction, and comes back.

queue = 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53

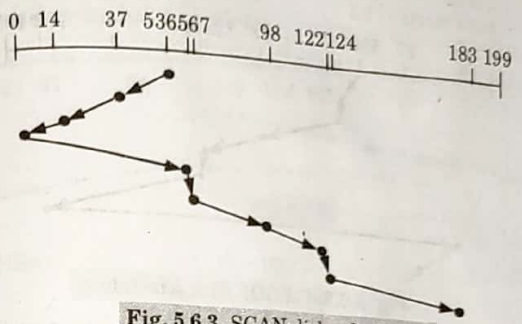


Fig. 5.6.3. SCAN disk scheduling.

iv. C-SCAN scheduling :

1. Circular SCAN (C-SCAN) scheduling is a variant of SCAN designed to provide a more uniform wait time.
2. Like SCAN, C-SCAN moves the head from one end of the disk to the other, servicing requests along the way.
3. When the head reaches the other end, however, it immediately returns to the beginning of the disk without servicing any requests on the return trip.
4. The C-SCAN scheduling algorithm essentially treats the cylinders as a circular list that wraps around from the final cylinder to the first one.

queue = 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53

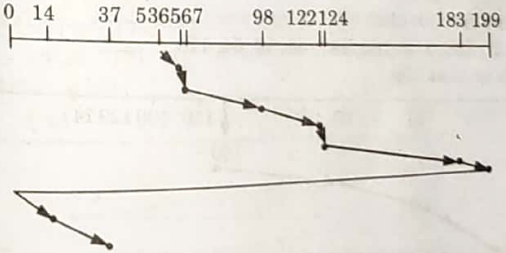


Fig. 5.6.4. C-SCAN disk scheduling.

v. LOOK scheduling :

1. In this the disk arm reverses direction immediately, without going all the way to the end of the disk.
2. Versions of SCAN and C-SCAN that follow this pattern are called LOOK and C-LOOK scheduling, because they look for a request before continuing to move in a given direction.

queue = 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53

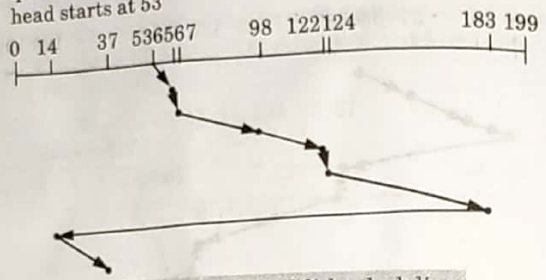


Fig. 5.6.5. C-LOOK disk scheduling.

Que 5.7. **Explain the SSTF and SCAN disk scheduling policies. Obtain the total number of head movements needed to satisfy the following sequence of track requests for each of the two policies:**
27, 129, 110, 186, 147, 41, 10, 64, 120
Assume that the disk head is initially positioned over track 100 and is moving in the direction of decreasing track number.

AKTU 2011-12, Marks 10

Answer

SSTF and SCAN disk scheduling algorithm : Refer Q. 5.6, Page 5–8B, Unit-5.

Numerical :

SCAN disk scheduling policy :

Disk initially at 100
Track's are from 0 – 199
queue = 27, 129, 110, 186, 147, 41, 10, 64, 120
currently head at 100.

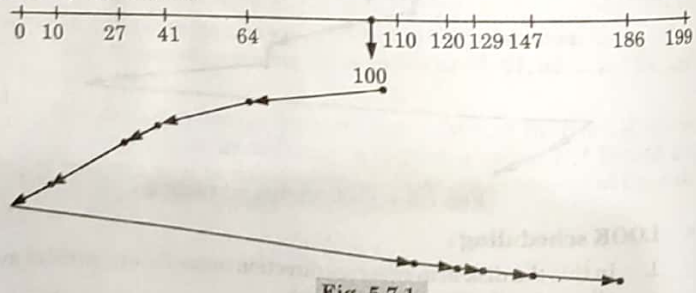


Fig. 5.7.1.

Total head movement,

$$= (100 - 64) + (64 - 41) + (41 - 27) + (27 - 10) + (10 - 0) + (110 - 0) + (120 - 110) + (129 - 120) + (147 - 129) + (186 - 147)$$

$$\Rightarrow = 36 + 23 + 14 + 17 + 10 + 110 + 10 + 9 + 18 + 39$$
$$\Rightarrow = 286$$

SSTF disk scheduling policies :

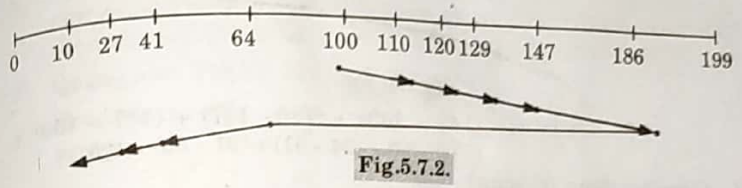


Fig.5.7.2.

Total time $= (110 - 100) + (120 - 110) + (129 - 120) + (147 - 129) + (186 - 147) + (186 - 64) + (64 - 41) + (41 - 27) + (27 - 10)$
$= 10 + 10 + 9 + 18 + 39 + 122 + 23 + 14 + 17$
$= 262$

Que 5.8. **Suppose the moving head disk with 200 tracks is currently serving a request for track 143 and has just finished a request for track 125. If the queue of request is kept in FIFO order 86, 147, 91, 177, 94, 150. What is total head movement for the following scheduling :**

i. **FCFS**
ii. **SSTF**
iii. **C-Scan**

AKTU 2013-14, 2015-16; Marks 10

Answer

i. **First Come, First Serve (FCFS) scheduling :**

queue = 86, 147, 91, 177, 94, 150
head start = 143

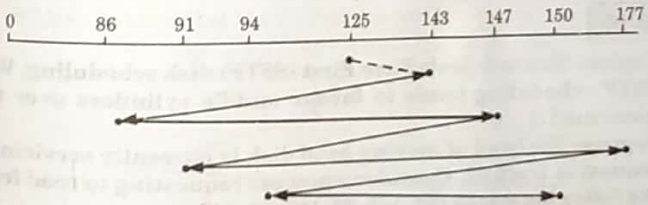


Fig. 5.8.1.

Total distance = $(143 - 86) + (147 - 86) + (147 - 91) + (177 - 91) + (177 - 94) + (150 - 94) = 399$

ii. Shortest Seek Time First (SSTF) :

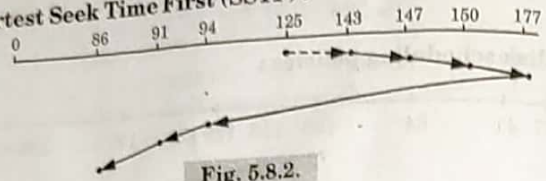


Fig. 5.8.2.

Total distance = (147 – 143) + (150– 147) + (177 – 150) + (177 – 94) + (94 – 91) + (91 – 86) = 125

iii. Circular Scan (C-scan) :

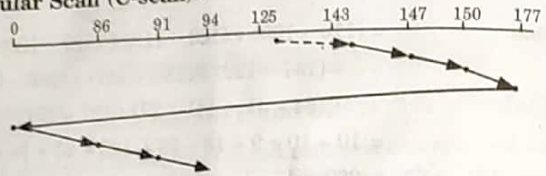


Fig. 5.8.3.

Total distance = (147 – 143) + (150 – 147) + (177 – 150) + (177 – 0) + (86 – 0) + (91 – 86) + (94 – 91) = 305

Que 5.9. Discuss in what sense is SCAN fairer than SSTF in disk scheduling.

Answer

1. In SCAN, the drive head sweeps across the entire surface of the disk, visiting the outermost cylinders before changing direction and sweeping back to the innermost cylinders.
2. It selects the next waiting requests whose location it will reach on its path backwards and forwards across the disk.
3. Thus, the movement time should be less than FCFS but the policy is clearly fairer than SSTF.

Que 5.10.

i. Explain Shortest-Seek-Time First (SSTF) disk scheduling. Why SSTF scheduling tends to favour middle cylinders over the innermost ?

ii. Suppose the head of moving head disk is currently servicing a request at track 62. Consider a process requesting to read from the following tracks : 66, 165, 32, 120, 12, 142.

1. Draw track chart for FCFS, SSTF and SCAN algorithms of disk scheduling.

2. Calculate total head movement in tracks in each case.

Answer

i. SSTF disk scheduling : Refer Q. 5.6, Page 5–8B, Unit-5.

SSTF tends to favour middle cylinders over the innermost :

a. The current location of the head divides the cylinders into two groups.

b. If the head is not in the center of the disk and a new request arrives, the new request is more likely to be in the group that includes the center of the disk; thus, the head is more likely to move in that direction.

ii. Queue = 66, 165, 32, 120, 12, 142

Head start = 62

FCFS :

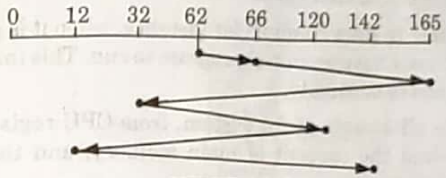


Fig. 5.10.1.

Total head movement
= (66 – 62) + (165 – 66) + (165 – 32) + (120 – 32) + (120 – 12) + (142 – 12)
= 4 + 99 + 133 + 88 + 108 +130 = 562

SSTF :

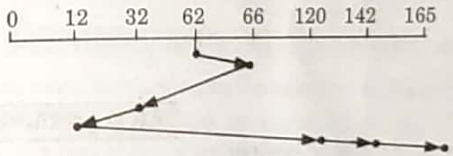


Fig. 5.10.2.

Total head movement
= (66 – 62) + (66 – 32) + (32 – 12) + (120 – 12) + (142 – 120) + (165 – 142)
= 4 + 34 + 20 + 108 + 22 + 23 = 211

SCAN : Assume that head initially moves towards zero.

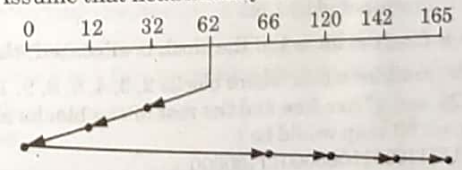


Fig. 5.10.3.

Total head movement
= (62 – 32) + (32 – 12) + (12 – 0) + (66 – 0) + (120 – 66) + (142 – 120) + (165 – 142)
= 30 + 20 + 12 + 66 + 54 + 22 +23
= 227

Que 5.11. Discuss boot blocks. **AKTU 2014-15, Marks 05**

Answer

1. Operating system requires some information while booting. If the disk is divided into number of partitions, the operating system is stored in the first partition of the disk.
2. If the disk does not contain an operating system, this block can be empty. This is called boot block.
3. For a computer to start running, for instance, when it is powered up or rebooted, it must have an initial program to run. This initial bootstrap program tends to be simple.
4. It initializes all aspects of the system, from CPU registers to device controllers and the content of main memory, and then starts the operating system.
5. To do its job, the bootstrap program finds the operating system kernel on disk, loads that kernel into memory, and jumps to an initial address to begin the operating system execution.

Que 5.12. Explain the following methods :

i. Bit vector
ii. Linked list
iii. Grouping
iv. Counting **AKTU 2015-16, Marks 10**

OR

Discuss free space management in disk.

Answer

i. Bit vector :

1. Frequently, the free-space list is implemented as a bit map or bit vector.
2. Each block is represented by 1 bit.
3. If the block is free, the bit is 1; if the block is allocated, the bit is 0.
4. For example, consider a disk where blocks 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 17, 18, 25, 26, and 27 are free and the rest of the blocks are allocated. The free-space bit map would be :
   001111001111110001100000011100000...
5. The main advantage of this approach is its relative simplicity and its efficiency in finding the first free block or n consecutive free blocks on the disk.
6. Indeed, many computers supply bit-manipulation instructions that can be used effectively for that purpose.

ii. Linked list :

1. Another approach to free-space management is to link together all the free disk blocks, keeping a pointer to the first free block in a special location on the disk and caching it in memory.

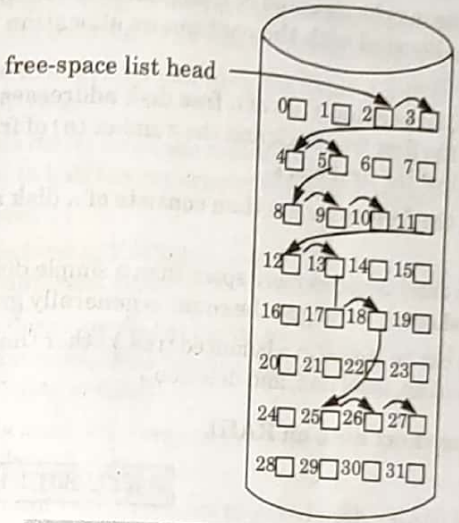


Fig. 5.12.1. Linked free-space list on disk.

2. This first block contains a pointer to the next free disk block, and so on.
3. For example, blocks 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 17, 18, 25, 26, and 27 were free and the rest of the blocks were allocated.
4. In this situation, we would keep a pointer to block 2 as the first free block. Block 2 would contain a pointer to block 3, which would point to block 4, which would point to block 5, which would point to block 8, and so.
5. This scheme is not efficient; to traverse the list, we must read each block, which requires substantial I/O time.
6. However, traversing the free list is not a frequent action.
7. Usually, the operating system simply needs a free block so that it can allocate that block to a file, so the first block in the free list is used.
8. The FAT method incorporates free-block accounting into the allocation data structure.
9. No separate method is needed.

iii. Grouping :

1. A modification of the free list approach stores the addresses of n free blocks in the first free block.
2. The first $n-1$ of these blocks is actually free.
3. The last block contains the addresses of another n free block, and so on.

4. The addresses of a large number of free blocks can now be found quickly, unlike the situation when the standard linked list approach is used.

iv. Counting :

1. Another approach takes advantage of the fact that, generally, several contiguous blocks may be allocated or freed simultaneously, particularly when space is allocated with the contiguous allocation algorithm or through clustering.
2. Thus, rather than keeping a list of n free disk addresses, we can keep the address of the first free block and the number (n) of free contiguous blocks that follow the first block.
3. Each entry in the free-space list then consists of a disk address and a count.
4. Although each entry requires more space than a simple disk address, the overall list is shorter, as long as the count is generally greater than 1.
5. These entries can be stored in a balanced tree, rather than a linked list, for efficient lookup, insertion, and deletion.

Que 5.13. Write short note on RAID.

AKTU 2012-13, Marks 10

Answer

1. RAID (Redundant Arrays of Independent Disks) is a variety of disk-organization techniques, commonly used to address the performance and reliability issues.
2. In the past RAIDS composed of small, cheap disks were viewed as a cost-effective alternative to large, expensive disks.
3. Today, RAIDS are used for their higher reliability and higher data-transfer rate, rather than for economic reasons.
4. Hence, the I in RAID, which once stood for "inexpensive," now stands for "independent".

RAID level configurations : There are almost dozen RAID level schemes prevailing in RAID technology. But only the most prevailing RAID level schemes are summarized below.

1. **RAID Level 0 :**
   a. This RAID level 0 configuration does not provide redundancy and so it does not exactly fit into the arrays of RAID technology.
   b. In this RAID level 0, two disks are used to write data to two drives in an alternating way, which is striping.
   c. This splitting of data will allow doubling of speed of a single hard drive and will also enhance its performance.
   d. But if one drive fails in this array, then data loss is incurred. The capacity of RAID 0 is equal to the whole sum of the individual drives.

2. **RAID Level 1 :**
   a. From this RAID level 1, the redundancy factor becomes influential.
   b. Minimum use of hard drives in this level will be two and the data is written to both drives.
   c. It is like cloning or mirroring the data of the first drive to the second one and making drive one identical to the second one.
   d. If the first drive fails, then the data backup will be available from the drive 2.
   e. In this RAID level, the actual capacity of RAID 1 level array will be equal to half the capacity of the sum of individual drives.
3. **RAID Level 2 :**
   a. In this form of RAID data is striped in a way that each sequential bit is on different drive.
   b. Each data word is having its own hamming code and on each read, the Hamming code verifies the data accuracy and also corrects the single disk errors.
   c. In this level, the array can recover from multiple and simultaneous hard drive failures.
   d. Minimum two drives are required in this RAID level 2.
4. **RAID Level 3 :**
   a. In this level of RAID a minimum of three drives is required for implementation.
   b. The data block is split and is written on data disks.
   c. Stripe parity is generated on writes and this writing is recorded on parity disks and can be checked on reads.
   d. A RAID 3 array can recover from hard drive failures and is deployed in environments where applications need high speed throughputs, which can be video production, video editing and live streaming.
   e. In this level the read/write speed is high.
5. **RAID Level 4 :**
   a. In this RAID level the requirement of three drives is seen and in this level, the entire block is written on a disk.
   b. Parity is generated in writes and recorded on parity disks and checked on reads.
   c. This level of RAID has high reading speeds and is highly efficient.
6. **RAID Level 5 :**
   a. In this RAID 5 level, three drives are implemented and data block is written on a data disks and parity which is generated from writes is distributed onto three drives and is checked on reads.

b. In the situation of drive failure, the reads can be calculated from the distributed parity and the drive failure is masked from the user.

c. But in situations of single drive failure, the performance of the entire array gets depleted.

7. **RAID Level 6 :**
   a. This level of RAID 6, offers fault tolerance in case of two drive failures and still the system functions.
   b. In this level, block level stripping is observed along with double distributed parity.
   c. In case of data recovery, the time for recovery takes place on the size of the disk drive.
   d. Double parity offers additional time for rebuilding the array without the data being at risk if single additional drive fails, while the data recovery through rebuild is happening.

8. **RAID Level 10 (1 + 0) :**
   a. In this level of RAID minimum requirement of drives is 4.
   b. RAID 10 will also have fault tolerance and will also have redundancy.
   c. It will have the splitting of data feature seen in RAID 0 level and will also have mirroring feature seen in RAID 1 level.
   d. RAID 10 array can recover from multiple and simultaneous hard drive failures and is ideal for high end server applications.

9. **RAID Level 0 + 1 :**
   a. This level of RAID requires a minimum of 4 drives and multiple drive failures can be handled by this RAID level.
   b. This level is a combination of RAID 0 and RAID 1 level and is used in imaging applications meant file servers.
   c. It offers high performance and reduces emphasis on reliability.
   d. In the RAID 0 + 1 a second stripped set to mirror the primary set is created.
   e. The array continues to operate with one or more drives failure in mirror set.

PART-2

File System : File Concept, File Organization and Access Mechanism, File Directories, and File Sharing, File System Implementation Issues, File System Protection and Security.

CONCEPT OUTLINE : PART-2

- File organization refers to the way the data is stored in file.
- Four methods of organizing file :
  i. Sequential file organization ii. Direct file organization
  iii. Serial file organization iv. Indexed file organization
- Directory can be viewed as a symbol table that translates file names into their directory structure.
- Types of directory :
  i. Single level directory ii. Two level directory
  iii. Tree structured directory iv. Acyclic graph directory
- File sharing is the sharing of files among several users, while working together on a project.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.14. Write a short note on file systems.

Answer

1. The file system permits users to create data collections, called files, with desirable properties :
   i. **Long term existence :** Files are stored on disk or other secondary storage and do not disappear when a user logs off.
   ii. **Sharable between processes :** Files have names and can have associated access permissions that permit controlled sharing.
   iii. **Structure :** Depending on the file system, a file can have an internal structure that is convenient for particular applications.
2. File is the collection of data created by user.
3. It provides a means to store data organized as file as well as a collection of function that can be performed on file.
4. It maintains a set of attributes associated with the file.

Operation included in file system are :

1. Create 2. Delete
3. Open 4. Close
5. Read 6. Write

In file system, files contain various attributes which are following :

1. **Name :** It is the only information which is in human-readable form.

2. **Identifier :** The file is identified by a unique tag(number) within file system.
3. **Type :** It is needed for systems that support different types of files.
4. **Location :** Pointer to file location on device.
5. **Size :** The current size of the file.
6. **Protection :** This controls and assigns the power of reading, writing, executing.
7. **Time, date, and user identification :** This is the data for protection, security, and usage monitoring.

Que 5.15. Write a short note on file organization.

Answer

File organization refers to the way data is stored in a file. File organization is very important because it determines the methods of access, efficiency, flexibility and storage devices to use.

Four methods of organizing files :

1. **Sequential file organization :**
   a. Records are stored and accessed in a particular sorted order using a key field.
   b. Retrieval requires searching sequentially through the entire file record by record to the end.
2. **Random or direct file organization :**
   a. Records are stored randomly but accessed directly.
   b. To access a file which is stored randomly, a record key is used to determine where a record is stored on the storage media.
   c. Magnetic and optical disks allow data to be stored and accessed randomly.
3. **Serial file organization :**
   a. Records in a file are stored and accessed one after another.
   b. This type of organization is mainly used on magnetic tapes.
4. **Indexed-sequential file organization method :**
   a. Almost similar to sequential method only that, an index is used to enable the computer to locate individual records on the storage media.
   b. For example, on a magnetic drum, records are stored sequentially on the tracks. However, each record is assigned an index that can be used to access it directly.

Que 5.16. Explain file organization and access mechanism.

AKTU 2016-17, Marks 10

Answer

File organization : Refer Q. 5.15, Page 5–21B, Unit-5.

Access mechanism :

Following are the access mechanism which are provided to access a file from the operating system are as follows :

1. **Sequential Access :**
   a. It is the simplest access mechanism, in which information stored in a file are accessed in an order such that one record is processed after the other.
   b. For example editors and compilers usually access files in this manner.
2. **Direct Access :**
   a. It is an alternative method for accessing a file, which is based on the disk model of a file, since disk allows random access to any block or record of a file.
   b. For this method, a file is viewed as a numbered sequence of blocks or records which are read/written in an arbitrary manner, *i.e.*, there is no restriction on the order of reading or writing.
   c. It is well suited for Database management System.
3. **Index Access :**
   a. In this method an index is created which contains a key field and pointers to the various blocks.
   b. To find an entry in the file for a key value, we first search the index and then use the pointer to directly access a file and find the desired entry.

Que 5.17. What do you mean by directory ? What are the operations that can be performed on a directory ?

OR

What is a directory ? Define any two ways to implement the directory.

AKTU 2013-14, Marks 10

OR

What is directory ? Explain any two ways to implement the directory.

AKTU 2015-16, Marks 15

Answer

1. The directory can be viewed as a symbol table that translates file names into their directory entries.
2. If we take such a view, we see that the directory itself can be organized in many ways.
3. The organization must be allowed to insert entries, to delete entries, to search for a named entry, and to list all the entries in the directory.

Directory implementation :

Directory is implemented in two ways :

1. **Linear list :**
   - i. Linear list is a simplest method.
   - ii. It uses a linear list of file names with pointers to the data blocks.
   - iii. Linear list uses a linear search to find a particular entry.
   - iv. Simple for programming but time consuming to execute.
   - v. For creating new file, it searches the directory for the name whether same name already exists.
   - vi. Linear search is the main disadvantage.
   - vii. Directory information is used frequently and users would notice a slow implementation of access to it.
2. **Hash table :**
   - i. Hash table decreases the directory search time.
   - ii. Insertion and deletion are also fairly straightforward.
   - iii. Hash table takes the value computed from the file name.
   - iv. Then it returns a pointer to the file name in the linear list.
   - v. Hash table uses fixed size.

Operations performed on a directory are :

1. **Search :** Directory structure is searched for finding particular file in the directory. Files have symbolic names and similar names may indicate a relationship between files.
2. **Create a file :** When a new file is created, an entry must be added to the directory.
3. **Delete a file :** When a file is deleted, an entry must be removed from the directory.
4. **Rename a file :** Name of the files must be changeable when the content or use of the file changes. Renaming a file may also allow its position within the directory structure to be changed.
5. **List directory :** All or portion of the directory may be requested. Request is made by a user and result in a listing of all files owned by that user plus some of the attributes of each file.

Que 5.18. Describe schemes for defining logical structure of directory.

AKTU 2014-15, Marks 10

Answer

Different types of directory structure are :

1. **Single-level directory :**
   - a. The simplest directory structure is the single-level directory.

   - b. All files are contained in the same directory, which is easy to support and understand.
   - c. A single-level directory has significant limitations, when the number of files increases or when the system has more than one user.
   - d. Since all files are in the same directory, they must have unique names. If two users call their data file test.txt, then the unique name rule is violated.
   - e. Fortunately, most file systems support file names of up to 255 characters, so it is relatively easy to select unique file names.
   - f. Even a single user on a single-level directory may find it difficult to remember the names of all the files as the number of file increases.

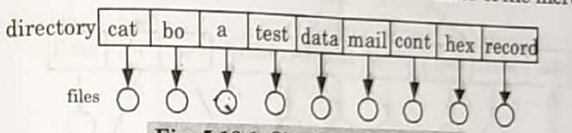


Fig. 5.18.1. Single-level directory.

2. **Two-level directory :**
   - a. In the two-level directory structure, each user has his own User File Directory (UFD).
   - b. The UFDs have similar structures, but each lists only the files of a single user.
   - c. When a user job starts or a user logs in, the system's Master File Directory (MFD) is searched.
   - d. The MFD is indexed by user name or account number, and each entry points to the UFD for that user.

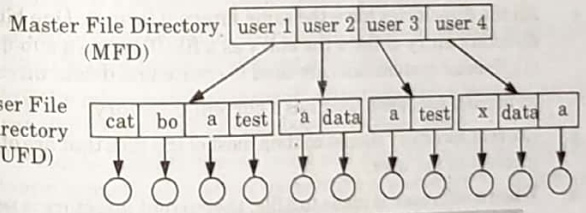


Fig. 5.18.2. Two-level directory structure.

   - e. When a user refers to a particular file, only his own UFD is searched.
   - f. Thus, different users may have files with the same name, as long as all the file names within each UFD are unique.
   - g. To create a file for a user, the operating system searches only that user's UFD to ascertain whether another file of that name exists.
   - h. To delete a file, the operating system confines its search to the local UFD; thus, it cannot accidentally delete another user's file that has the same name.

3. **Tree structured directories :**
   a. MS-DOS system is a tree structure directory.
   b. It allows users to create their own sub-directory and to organize their files accordingly.
   c. A sub-directory contains a set of files or sub-directories.
   d. A directory is simple another file, but it is treated in a special way. Fig. 5.18.3 shows tree structured directories.

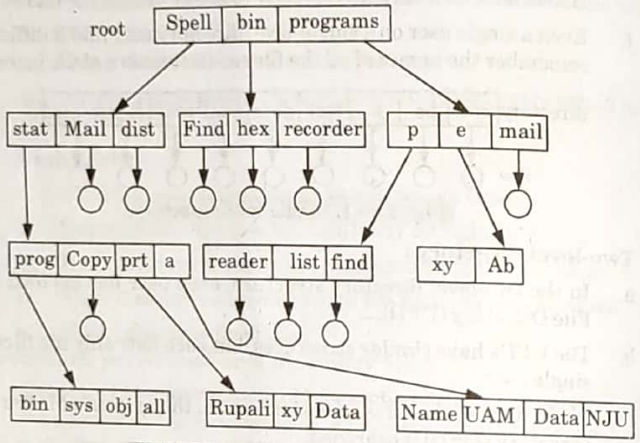


Fig. 5.18.3. Tree structure directory.

   e. All the directories have the same internal format. One bit in each directory entry defines the entry as a file (0) or as a sub-directory (1). Special system calls are used to create and delete directories.
   f. In normal use, each user has a current directory.
   g. Current directory should contain most of the files that are of current interest to the user.
   h. When a reference is made to a file, the current directory is searched.
   i. Path name is used to search of for any operation on file with another directory.

4. **Acyclic graph directories :**
   a. It allows directories to have shared subdirectories and files.
   b. Same file or directory may be in two different directories.
   c. Graph with no cycles is a generalization of the tree structured subdirectory scheme.
   d. Shared files and subdirectories can be implemented by using links.

   e. A link is effectively a pointer to another file or subdirectory.
   f. A link is implemented as an absolute or relative path name.
   g. An acyclic graph directory structure is more flexible than is a simple tree structure, but sometimes it is more complex.
   h. Fig. 5.18.4 shows a acyclic graph directory structure.

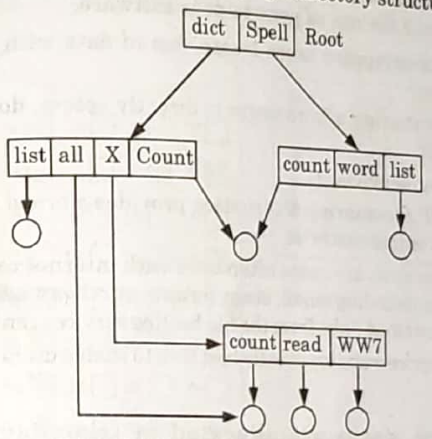


Fig. 5.18.4. Acyclic graph directory structure.

Que 5.19. **Explain the concept of file sharing.**

Answer

1. File sharing is the sharing of files among several users, while working together on a project.
2. It is the private or public distribution of data or resources in a network with different levels of sharing privileges.
3. With the advent of the Internet, a file transfer system called the File Transfer Protocol (FTP) has become widely-used.
4. FTP can be used to access (read and possibly write to) files shared among a particular set of users with a password to gain access to files shared from an FTP server site.
5. Many FTP sites offer public file sharing or at least the ability to view or copy files by downloading them, using a public password (which happens to be "anonymous").
6. File sharing implies a system in which users write to as well as read files or in which users are allotted some amount of space for personal files on a common server, giving access to other users as they see fit.
7. File sharing can be viewed as part of file systems and their management.

8. Operating systems also provide file-sharing methods, such as network file sharing (NFS).

Most file-sharing tasks use two basic sets of network criteria, as follows :

a. Peer-to-Peer (P2P) file sharing :

i This is the most popular, but controversial, method of file sharing because of the use of peer-to-peer software.

ii. Network computer users locate shared data with third-party software.

iii. P2P file sharing allows users to directly access, download and edit files.

b. File hosting services :

i. This P2P file-sharing alternative provides a broad selection of popular online material.

ii. These services are quite often used with internet collaboration methods, including email, blogs, forums, or other mediums, where direct download links from the file hosting services can be included.

iii. These service websites usually host files to enable users to download them.

Que 5.20. How blocks are allocated in secondary storage management ?

OR

What are the different methods of allocating disk space ?

OR

Describe the various file allocation methods with their relative advantages and disadvantages. AKTU 2011-12, Marks 10

Answer

Methods of allocating disk space are :

i. Contiguous allocation :

1. Contiguous allocation requires that each file occupy a set of contiguous blocks on the disk.
2. Due to this reason, it is also known as continuous file access. Disk addresses define a linear ordering on the disk. With this ordering, assuming that only one job is accessing the disk, accessing block $b \pm 1$ after block b normally requires no head movement.
3. When head movement is needed (from the last sector of one cylinder to the first sector of the next cylinder), the head need only move from one track to the next.
4. Thus, the number of disk seeks required for accessing contiguously allocated files is minimal, as is seek time when a seek is finally needed.

5. Contiguous allocation of a file is defined by the disk address and length (in block units) of the first block.
6. If the file is n blocks long and starts at location b, then it occupies blocks $b, b+1, b+2, \ldots b+n-1$.
7. The directory entry for each file indicates the address of the starting block and the length of the area allocated for this file.

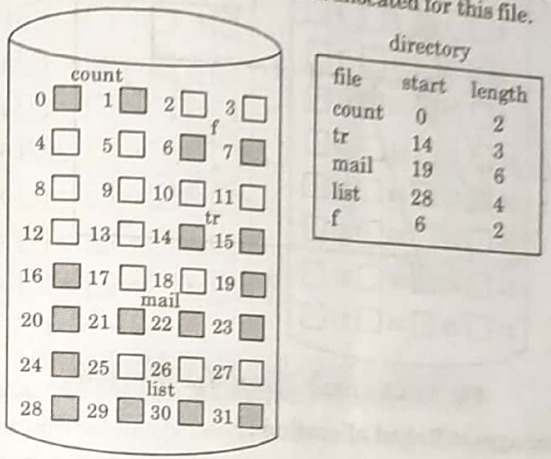


Fig. 5.20.1. Contiguous allocation of disk space.

Advantages of contiguous allocation :

1. It is the simplest allocation scheme and can be implemented easily.
2. Gives excellent performance.

Disadvantages of contiguous allocation :

1. The size of the file up to maximum limit must be known at the creation time.
2. Some disk space is wasted due to fragmentation. Compaction is required to remove fragmentation.

ii. Linked allocation :

1. With linked allocation, each file is a linked list of disk blocks; the disk blocks may be scattered anywhere on the disk.
2. The directory contains a pointer to the first and last blocks of the file.
3. For example, a file of five blocks might start at block 9 and continue at block 16, then block 1, then block 10, and finally block 25.
4. Each block contains a pointer to the next block.
5. These pointers are not made available to the user.
6. Thus, if each block is 512 bytes in size, and a disk address (the pointer) requires 4 bytes, then the user sees blocks of 508 bytes.

7. To create a new file, we simply create a new entry in the directory. With linked allocation, each directory entry has a pointer to the first disk block of the file.

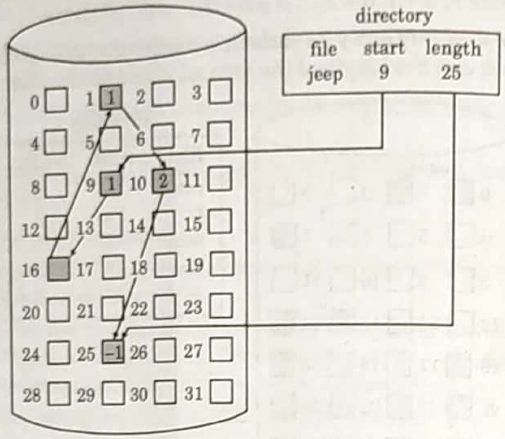


Fig. 5.20.2. Linked allocation of disk space.

Advantages of linked allocation :

1. There is no waste of memory.
2. There is no external fragmentation. Only internal fragmentation is possible in the last block.
3. Directories are required to recognize only starting block address and end block address.
4. There is no need to declare size of the file at the time of its creation.

Disadvantages of linked allocation :

1. Space is wasted in storing pointers.
2. Access time, seek time and latency time are higher than the contiguous allocation.

iii. Indexed allocation :

1. Indexed allocation solves the problems caused by linked allocation by bringing all the pointers together into one location: the index block.
2. Each file has its own index block, which is an array of disk-block addresses.
3. The i^{th} entry in the index block points to the i^{th} block of the file.
4. The directory contains the address of the index block. To find and read the i^{th} block, we use the pointer in the i^{th} index-block entry.
5. When the file is created, all pointers in the index block are set to null.

6. When the i^{th} block is first written, a block is obtained from the free-space manager, and its address is put in the i^{th} index block entry.

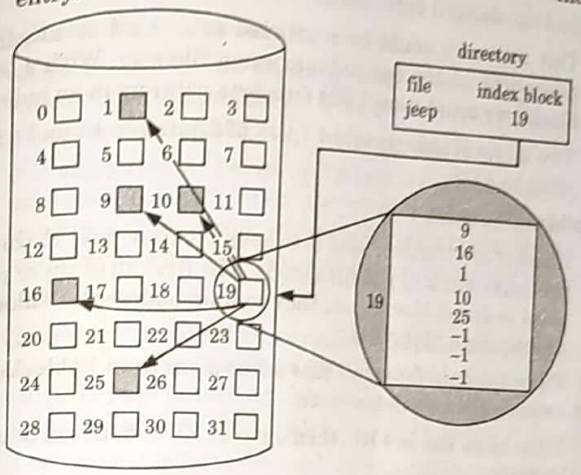


Fig. 5.20.3. Indexed allocation of disk space.

Advantages of index allocation :

1. The entire block is available for data using this method.
2. There is no external fragmentation using this method.
3. Directory entry needs only to keep the starting block number of a file.

Disadvantage of index allocation :

1. The entire index table must be in memory all the time to make it work.
2. Large space overhead (index).

Que 5.21. Discuss the mechanisms used for indexed allocation.

Answer

Mechanisms used for indexed allocation :

1. **Linked scheme :**
   - i. In this an index block is normally one disk block. Thus, it can be read and written directly by itself.
   - ii. To allow for large files, we can link together several index blocks.
   - iii. For example, an index block might contain a small header giving the name of the file and a set of the first 100 disk-block addresses.
2. **Multi-level index :**
   - i. A variant of linked representation uses a first-level index block to point to a set of second-level index blocks, which in turn point to the file blocks.

ii. To access a block, the operating system uses the first-level index to find a second-level index block and then uses that block to find the desired data block.

iii. This approach could be continued to a third or fourth level, depending on the desired maximum file size. With 4,096-byte blocks, we could store 1,024 four-byte pointers in an index block.

iv. Two levels of indexes allow 1,048,576 data blocks and a file size of up to 4 GB.

3. **Combined scheme :**

i. Another alternative, used is to keep the first, say, 15 pointers of the index block in the files inode. The first 12 of these pointers point to direct blocks; *i.e.*, they contain addresses of blocks that contain data of the file.

ii. Thus, the data for small files (of no more than 12 blocks) do not need a separate index block.

iii. If the block size is 4 KB, then up to 48 KB of data can be accessed directly.

iv. The next three pointers point to indirect blocks.

v. Under this method, the number of blocks that can be allocated to a file exceeds the amount of space addressable by the four-byte file pointers used by many operating systems.

Que 5.22. Write short notes on :

i. Sequential file

ii. Indexed file **AKTU 2013-14, 2015-16; Marks 10**

Answer

i. Sequential file :

1. Sequential file uses fixed format for records. All records are of the same length, consisting of the same number of fixed length field in a particular order.
2. Fig. 5.22.1 shows the sequential file.

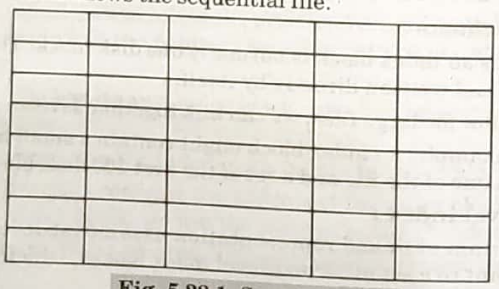


Fig. 5.22.1. Sequential file.

3. First field in the each record is referred as the key field. The key field uniquely identifies the record; thus key values for different records are always different.
4. All records are stored in key sequence.
5. Sequential files are typically used in batch applications. The sequential file organization is the only one that is easily stored on tapes as well as disk.
6. Normally read and write operations are done on the files. A read operation reads the next portion of the file and automatically advances a file pointer, which tracks I/O location, write operation appends the end of file and such file can be reset to the beginning.

ii. Indexed file :

1. To achieve the flexibility, a structure is needed that employs multiple indexes. In general indexed file, the concept of sequentiality and a single key are abandoned. Records are only accessed through their indexes. Records of variable lengths can be used in this access.
2. Two types of indexes are used. An exhaustive index contains one entry for every record in the main file.
3. An index is itself organized as a sequential file for ease of searching. A partial index contains entries to record where the field of interest exists.
4. With records of variable length, some records will not contain all fields.
5. When a new record is added to the main file, all the index file must be updated.
6. Fig. 5.22.2 shows the index with relative files.
7. Indexed file are used mostly in applications where timelines of information are critical and where data are rarely processed exhaustively. Examples are airline reservation systems and inventory control system.

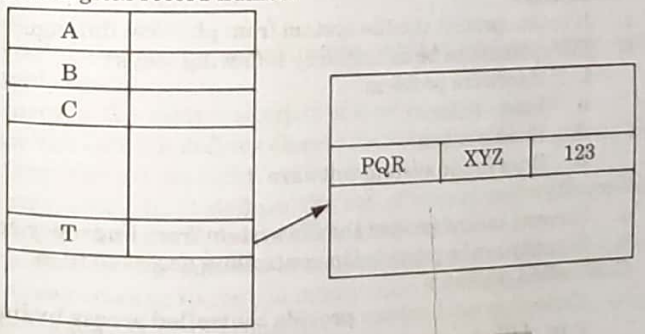


Fig. 5.22.2. Index with relative files.

Que 5.23. Write a short note on file system implementation.

Answer

File system is implemented on the disk and memory. If the file system is implemented on the disk, it contains following information :

1. **Boot block control :**
   a. Operating system requires some information while booting.
   b. If the disk is divided into number of partitions, the operating system is stored in the first partition of the disk.
   c. If the disk does not contain an operating system, this block can be empty. In UFS (Unix File System), this is called the boot block, in NTFS, it is the partition boot sector.
2. **Partition control block :**
   a. It contains the detail information about partition.
   b. It includes block size, free block pointers, free block count and free PCB count and PCB pointers.
   c. In Unix file system this is called a superblock ; in NTFS, it is the master file table.
3. A directory structure is used to organize the files.
4. PCB contains many other information about files, such as size of file, ownership of files, file permission and location of the data blocks. Inode is the name in Unix. In NTFS, this information is actually stored within the master file table, which uses a relational database structure, with a row per file.

Que 5.24. Write short note on file system protection.

AKTU 2011-12, Marks 10

Answer

In file system computer file needs protection which is of two types :

1. **Reliability :**
   a. It means protect the file system from physical damage
   b. File system can be damaged by following ways :
      i. Hardware problem
      ii. Power failure
      iii. Head crashes
      iv. Bugs in file system software
2. **Security :**
   a. Security means protect the file system from improper access.
   b. Security can be provided by controlling access to files.
3. **Controlled access :**
   a. Protection mechanisms provide controlled access by limiting the type of file access that can be made.

   b. Access is permitted or denied depending on several factors, one of which is the type of access required.
   c. Different types of operations many be controlled in access type. These are :
      i. **Read :** Read from the file
      ii. **Write :** Write the file
      iii. **Execute :** Load the file into memory and execute it.
      iv. **Append :** Write a new information at the end of the file.
      v. **Delete :** Delete the file and free its space for possible reuse.
      vi. **List :** List the name and attributes of the file.
4. **Access control :**
   a. Various users may need different types of access to a file or directory.
   b. When a user requests a particular file, the operating system checks the access list associated with that file.
   c. If that user is listed for the requested access, the access is allowed. Otherwise a protection violation occurs, and the user job is denied access to the file.
   d. Many system recognize three classifications of users in connection with each file for access control which are following :
      i. **Owner :** User who created the file.
      ii. **Group :** Set of users who are sharing the file and need similar access.
      iii. **Universe :** All other users in the system constitute the universe.

Que 5.25. Discuss access matrix. **AKTU 2014-15, Marks 05**

OR

What is access matrix ? How it can be represented ?

Answer

1. General model of protection can be viewed abstractly as a matrix, called an access matrix.
2. The rows of the access matrix represent domains, and the columns represent objects.
3. Each entry in the matrix consists of a set of access rights.
4. Because the column defines objects explicitly, we can omit the object name from the access right.
5. The entry access(i, j) defines the set of operations that a process executing in domain D_i can invoke on object O_j.
6. A protection system consists of mechanisms to control user access to system resources or to control information flow in the system.
7. The access matrix model consists of the following three components :

a. **Current objects :** Current object are a finite set of entities to which access is to be controlled. The set is denoted by '*O*'. A typical example of an object is a file.

b. **Current subjects :** Current subjects are a finite set of entities that access current objects. The set is denoted by '*S*'. A typical example of a subject is a process.

c. **Generic rights :** A finite set of generic rights, $R = \{r_1, r_2, r_3, ..., r_m\}$, gives various access rights that subjects can have to objects. Typical examples of such rights are read, write, execute, own, delete etc.

Que 5.26. Write short note on implementation of access matrix.

AKTU 2012-13, Marks 10

Answer

1. In general, the matrix will be sparse; that is, most of the entries will be empty.
2. Although data structure techniques are available for representing sparse matrices, they are not particularly useful for this application, because of the way in which the protection facility is used.

Following are four methods for implementing the access matrix :

1. **Global table :**
   a. The simplest implementation of the access matrix is a global table consisting of a set of ordered triples <domain, object, rights-set>.
   b. Whenever an operation M is executed on an object O_j within domain D_i, the global table is searched for a triple $<D_i, O_j, R_k>$, with $M \in R_k$.
   c. If this triple is found, the operation is allowed to continue; otherwise, an exception (or error) condition is raised.
2. **Access lists for objects :**
   a. Each column in the access matrix can be implemented as an access list for one object.
   b. Obviously, the empty entries can be discarded.
   c. The resulting list for each object consists of ordered pairs <domain, rights-set>, which define all domains with a non-empty set of access rights for that object.
   d. This approach can be extended easily to define a list plus a default set of access rights.
3. **Capability lists for domains :**
   a. Rather than associating the columns of the access matrix with the objects as access lists, we can associate each row with its domain.
   b. A capability list for a domain is a list of objects together with the operations allowed on those objects.
   c. An object is often represented by its physical name or address, called a capability.

   d. The capability list is associated with a domain, but it is never directly accessible to a process executing in that domain.
   e. Rather, the capability list is itself a protected object, maintained by the operating system and accessed by the user only indirectly.
4. **A Lock-key mechanism :**
   a. The lock-key scheme is a compromise between access lists and capability lists.
   b. Each object has a list of unique bit patterns, called locks.
   c. Similarly, each domain has a list of unique bit patterns, called keys.
   d. A process executing in a domain can access an object only if that domain has a key that matches one of the locks of the object.
   e. As with capability lists, the list of keys for a domain must be managed by the operating system on behalf of the domain.
   f. Users are not allowed to examine or modify the list of keys (or locks) directly.

Que 5.27. Explain the need of system protection with the help of examples.

AKTU 2013-14, Marks 05

Answer

The need of system protection is due to following reason :

1. To prevent malicious misuse of the system by users or programs.
2. To ensure that each shared resource is used only in accordance with system policies, which may be set either by system designers or by system administrators.
3. To ensure that errant programs cause the minimal amount of damage possible.
4. Protection systems only provide the mechanisms for enforcing policies and ensuring reliable systems. It is up to administrators and users to implement those mechanisms effectively.

An example : UNIX

UNIX associates domains with users.

1. Certain programs operate with the SUID bit set, which effectively changes the user ID, and therefore the access domain, while the program is running (and similarly for the SGID bit). Unfortunately this has some potential for abuse.
2. An alternative used on some systems is to place privileged programs in special directories, so that they attain the identity of the directory owner when they run.
3. This prevents crackers from placing SUID programs in random directories around the system.
4. Yet another alternative is to not allow the changing of ID at all. Instead, special privileged daemons are launched at boot time, and user processes send messages to these daemons when they need special tasks performed.

VERY IMPORTANT QUESTIONS

Following questions are very important. These questions may be asked in your SESSIONALS as well as UNIVERSITY EXAMINATION.

Q. 1. Define I/O devices. Describe the techniques for performing I/O.

Ans. Refer Q. 5.1 and Q. 5.2.

Q. 2. Explain I/O buffering with its types.

Ans. Refer Q. 5.3 and Q. 5.4.

Q. 3. Discuss disk scheduling algorithm with example.

Ans. Refer Q. 5.6.

Q. 4. Discuss the following terms :

i. **Cashing**
ii. **Spooling**
iii. **Error handling**
iv. **Boot block**
v. **Bit vector**
vi. **Counting**
vii. **Grouping**

Ans. Refer Q. 5.5, Q. 5.11 and Q. 5.12.

Q. 5. Explain RAID.

Ans. Refer Q. 5.13.

Q. 6. Explain file organization and access mechanism.

Ans. Refer Q. 5.16.

Q. 7. Define directory. Define different ways to implement the directory.

Ans. Refer Q. 5.17.

Q. 8. Write short note on :

i. **Sequential file**
ii. **Indexed file**

Ans. Refer Q. 5.22.

Q. 9. Define access matrix. Define implementation and representation of access matrix.

Ans. Refer Q. 5.25 and Q. 5.26.

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