1 Introduction

1.1 What is an Operating System?

The 1960's definition of an operating system is "the software that controls the hardware". However, today, due to microcode we need a better definition. We see an operating system as the programs that make the hardware useable. In brief, an operating system is the set of programs that controls a computer. Some examples of operating systems are UNIX, Mach, MS-DOS, MS-Windows, Windows/NT, Chicago, OS/2, MacOS, VMS, MVS, and VM.

Controlling the computer involves software at several levels. We will differentiate kernel services, library services, and application-level services, all of which are part of the operating system. Processes run Applications, which are linked together with libraries that perform standard services. The kernel supports the processes by providing a path to the peripheral devices. The kernel responds to service calls from the processes and interrupts from the devices. The core of the operating system is the kernel, a control program that functions in privileged state (an execution context that allows all hardware instructions to be executed), reacting to interrupts from external devices and to service requests and traps from processes. Generally, the kernel is a permanent resident of the computer. It creates and terminates processes and responds to their request for service.

Operating Systems are resource managers. The main resource is computer hardware in the form of processors, storage, input/output devices, communication devices, and data. Some of the operating system functions are: implementing the user interface, sharing hardware among users, allowing users to share data among themselves, preventing users from interfering with one another, scheduling resources among users, facilitating input/output, recovering from errors, accounting for resource usage, facilitating parallel operations, organizing data for secure and rapid access, and handling network communications.

1.2 Objectives of Operating Systems

Modern Operating systems generally have following three major goals. Operating systems generally accomplish these goals by running processes in low privilege and providing service calls that invoke the operating system kernel in high-privilege state.

- **To hide details of hardware by creating abstraction**
  An abstraction is software that hides lower level details and provides a set of higher-level functions. An operating system transforms the physical world of devices, instructions, memory, and time into virtual world that is the result of abstractions built by the operating system. There are several reasons for abstraction.
  First, the code needed to control peripheral devices is not standardized. Operating systems provide subroutines called device drivers that perform operations on behalf of programs for example, input/output operations.
  Second, the operating system introduces new functions as it abstracts the hardware. For instance, operating system introduces the file abstraction so that programs do not have to deal with disks.
  Third, the operating system transforms the computer hardware into multiple virtual computers, each belonging to a different program. Each program that is running is called a process. Each process views the hardware through the lens of abstraction.
  Fourth, the operating system can enforce security through abstraction.

- **To allocate resources to processes (Manage resources)**
  An operating system controls how **processes** (the active agents) may access **resources** (passive entities).

- **Provide a pleasant and effective user interface**
  The user interacts with the operating systems through the user interface and usually interested in the "look and feel" of the operating system. The most important components of the user interface are the command interpreter, the file system, on-line help, and application integration. The recent trend has been toward increasingly integrated graphical user interfaces that encompass the activities of multiple processes on networks of computers.

One can view Operating Systems from two points of views: Resource manager and Extended machines. Form Resource manager point of view Operating Systems manage the different parts of the system efficiently and from extended machines point of view Operating Systems provide a virtual machine to users that is more convenient to use. The structurally Operating Systems can be design as a monolithic system, a hierarchy of layers, a virtual machine system, an exokernel, or using the client-server model. The basic concepts of Operating Systems are processes, memory management, I/O management, the file systems, and security.

2 History of Operating Systems

Historically operating systems have been tightly related to the computer architecture, it is good idea to study the history of operating systems from the architecture of the computers on which they run.
Operating systems have evolved through a number of distinct phases or generations which corresponds roughly to the decades.

2.1 The 1940's - First Generations

The earliest electronic digital computers had no operating systems. Machines of the time were so primitive that programs were often entered one bit at time on rows of mechanical switches (plug boards). Programming languages were unknown (not even assembly languages). Operating systems were unheard of .

2.2 The 1950's - Second Generation

By the early 1950's, the routine had improved somewhat with the introduction of punch cards. The General Motors Research Laboratories implemented the first operating systems in early 1950's for their IBM 701. The system of the 50's generally ran one job at a time. These were called single-stream batch processing systems because programs and data were submitted in groups or batches.

2.3 The 1960's - Third Generation

The systems of the 1960's were also batch processing systems, but they were able to take better advantage of the computer's resources by running several jobs at once. So operating systems designers developed the concept of multiprogramming in which several jobs are in main memory at once; a processor is switched from job to job as needed to keep several jobs advancing while keeping the peripheral devices in use.
For example, on the system with no multiprogramming, when the current job paused to wait for other I/O operation to complete, the CPU simply sat idle until the I/O finished. The solution for this problem that evolved was to partition memory into several pieces, with a different job in each partition. While one job was waiting for I/O to complete, another job could be using the CPU.
Another major feature in third-generation operating system was the technique called spooling (simultaneous peripheral operations on line). In spooling, a high-speed device like a disk interposed between a running program and a low-speed device involved with the program in input/output. Instead of writing directly to a printer, for example, outputs are written to the disk. Programs can run to completion faster, and other programs can be initiated sooner when the printer becomes available, the outputs may be printed.
Note that spooling technique is much like thread being spun to a spool so that it may be later be unwound as needed.
Another feature present in this generation was time-sharing technique, a variant of multiprogramming technique, in which each user has an on-line (i.e., directly connected) terminal. Because the user is present and interacting with the computer, the computer system must respond quickly to user requests, otherwise user productivity could suffer. Timesharing systems were developed to multiprogram large number of simultaneous interactive users.

2.3.1 Fourth Generation

With the development of LSI (Large Scale Integration) circuits, chips, operating system entered in the system entered in the personal computer and the workstation age. Microprocessor technology evolved to the point that it become possible to build desktop computers as powerful as the mainframes of the 1970s. Two operating systems have dominated the personal computer scene: MS-DOS, written by Microsoft, Inc. for the IBM PC and other machines using the Intel 8088 CPU and its successors, and UNIX, which is dominant on the large personal computers using the Motorola 6899 CPU family.

3 Operating Systems Structure

3.1 System Components

Even though, not all systems have the same structure many modern operating systems share the same goal of supporting the following types of system components.

3.1.1 Process Management

The operating system manages many kinds of activities ranging from user programs to system programs like printer spooler, name servers, file server etc. Each of these activities is encapsulated in a process. A process includes the complete execution context (code, data, PC, registers, OS resources in use etc.).
It is important to note that a process is not a program. A process is only ONE instant of a program in execution. There are many processes can be running the same program. The five major activities of an operating system in regard to process management are

- Creation and deletion of user and system processes.
- Suspension and resumption of processes.
- A mechanism for process synchronization.
- A mechanism for process communication.
- A mechanism for deadlock handling.

3.1.2 Main-Memory Management

Primary-Memory or Main-Memory is a large array of words or bytes. Each word or byte has its own address. Main-memory provides storage that can be access directly by the CPU. That is to say for a program to be executed, it must in the main memory.
The major activities of an operating in regard to memory-management are:

- Keep track of which part of memory are currently being used and by whom.
- Decide which process are loaded into memory when memory space becomes available.
- Allocate and deallocate memory space as needed.

3.1.3 File Management

A file is a collected of related information defined by its creator. Computer can store files on the disk (secondary storage), which provide long term storage. Some examples of storage media are magnetic tape, magnetic disk and optical disk. Each of these media has its own properties like speed, capacity, data transfer rate and access methods.
A file systems normally organized into directories to ease their use. These directories may contain files and other directions.
The five main major activities of an operating system in regard to file management are

- The creation and deletion of files.
- The creation and deletion of directions.
- The support of primitives for manipulating files and directions.
- The mapping of files onto secondary storage.
- The back up of files on stable storage media.

3.1.4 I/O System Management

I/O subsystem hides the peculiarities of specific hardware devices from the user. Only the device driver knows the peculiarities of the specific device to whom it is assigned.

3.1.5 Secondary-Storage Management

Generally speaking, systems have several levels of storage, including primary storage, secondary storage and cache storage. Instructions and data must be placed in primary storage or cache to be referenced by a running program. Because main memory is too small to accommodate all data and programs, and its data are lost when power is lost, the computer system must provide secondary storage to back up main memory. Secondary storage consists of tapes, disks, and other media designed to hold information that will eventually be accessed in primary storage (primary, secondary, cache) is ordinarily divided into bytes or words consisting of a fixed number of bytes. Each location in storage has an address; the set of all addresses available to a program is called an address space.
The three major activities of an operating system in regard to secondary storage management are:

- Managing the free space available on the secondary-storage device.
- Allocation of storage space when new files have to be written.
- Scheduling the requests for memory access.

3.1.6 Networking

A distributed systems is a collection of processors that do not share memory, peripheral devices, or a clock. The processors communicate with one another through communication lines called network. The communication-network design must consider routing and connection strategies, and the problems of contention and security.

3.1.7 Protection System

If a computer systems has multiple users and allows the concurrent execution of multiple processes, then the various processes must be protected from one another's activities. Protection refers to mechanism for controlling the access of programs, processes, or users to the resources defined by a computer systems.

3.1.8 Command Interpreter System

A command interpreter is an interface of the operating system with the user. The user gives commands with are executed by operating system (usually by turning them into system calls). The main function of a command interpreter is to get and execute the next user specified command. Command-Interpreter is usually not part of the kernel, since multiple command interpreters (shell, in UNIX terminology) may be support by an operating system, and they do not really need to run in kernel mode. There are two main advantages to separating the command interpreter from the kernel.

- If we want to change the way the command interpreter looks, i.e., I want to change the interface of command interpreter, I am able to do that if the command interpreter is separate from the kernel. I cannot change the code of the kernel so I cannot modify the interface.
- If the command interpreter is a part of the kernel it is possible for a malicious process to gain access to certain part of the kernel that it showed not have to avoid this ugly scenario it is advantageous to have the command interpreter separate from kernel.

3.2 Operating System Services

Following are the five services provided by an operating systems to the convenience of the users.

3.2.1 Program Execution

The purpose of a computer systems is to allow the user to execute programs. So the operating systems provides an environment where the user can conveniently run programs. The user does not have to worry about the memory allocation or multitasking or anything. These things are taken care of by the operating systems.
Running a program involves the allocating and deallocating memory, CPU scheduling in case of multiprocess. These functions cannot be given to the user-level programs. So user-level programs cannot help the user to run programs independently without the help from operating systems.

3.2.2 I/O Operations

Each program requires an input and produces output. This involves the use of I/O. The operating systems hides the user the details of underlying hardware for the I/O. All the user sees is that the I/O has been performed without any details. So the operating systems by providing I/O makes it convenient for the users to run programs.
For efficiently and protection users cannot control I/O so this service cannot be provided by user-level programs.

3.2.3 File System Manipulation

The output of a program may need to be written into new files or input taken from some files. The operating systems provides this service. The user does not have to worry about secondary storage management. User gives a command for reading or writing to a file and sees his her task accomplished. Thus operating systems makes it easier for user programs to accomplished their task.
This service involves secondary storage management. The speed of I/O that depends on secondary storage management is critical to the speed of many programs and hence I think it is best relegated to the operating systems to manage it than giving individual users the control of it. It is not difficult for the user-level programs to provide these services but for above mentioned reasons it is best if this service s left with operating system.

3.2.4 Communications

There are instances where processes need to communicate with each other to exchange information. It may be between processes running on the same computer or running on the different computers. By providing this service the operating system relieves the user of the worry of passing messages between processes. In case where the messages need to be passed to processes on the other computers through a network it can be done by the user programs. The user program may be customized to the specifics of the hardware through which the message transits and provides the service interface to the operating system.

3.2.5 Error Detection

An error is one part of the system may cause malfunctioning of the complete system. To avoid such a situation the operating system constantly monitors the system for detecting the errors. This relieves the user of the worry of errors propagating to various part of the system and causing malfunctioning.
This service cannot allowed to be handled by user programs because it involves monitoring and in cases altering area of memory or deallocation of memory for a faulty process. Or may be relinquishing the CPU of a process that goes into an infinite loop. These tasks are too critical to be handed over to the user programs. A user program if given these privileges can interfere with the correct (normal) operation of the operating systems.

3.3 System Calls and System Programs

System calls provide an interface between the process an the operating system. System calls allow user-level processes to request some services from the operating system which process itself is not allowed to do. In handling the trap, the operating system will enter in the kernel mode, where it has access to privileged instructions, and can perform the desired service on the behalf of user-level process. It is because of the critical nature of operations that the operating system itself does them every time they are needed. For example, for I/O a process involves a system call telling the operating system to read or write particular area and this request is satisfied by the operating system.
System programs provide basic functioning to users so that they do not need to write their own environment for program development (editors, compilers) and program execution (shells). In some sense, they are bundles of useful system calls.

3.4 Layered Approach Design

In this case the system is easier to debug and modify, because changes affect only limited portions of the code, and programmer does not have to know the details of the other layers. Information is also kept only where it is needed and is accessible only in certain ways, so bugs affecting that data are limited to a specific module or layer.

3.5 Mechanisms and Policies

The policies what is to be done while the mechanism specifies how it is to be done. For instance, the timer construct for ensuring CPU protection is mechanism. On the other hand, the decision of how long the timer is set for a particular user is a policy decision.
The separation of mechanism and policy is important to provide flexibility to a system. If the interface between mechanism and policy is well defined, the change of policy may affect only a few parameters. On the other hand, if interface between these two is vague or not well defined, it might involve much deeper change to the system.
Once the policy has been decided it gives the programmer the choice of using his/her own implementation. Also, the underlying implementation may be changed for a more efficient one without much trouble if the mechanism and policy are well defined. Specifically, separating these two provides flexibility in a variety of ways. First, the same mechanism can be used to implement a variety of policies, so changing the policy might not require the development of a new mechanism, but just a change in parameters for that mechanism, but just a change in parameters for that mechanism from a library of mechanisms. Second, the mechanism can be changed for example, to increase its efficiency or to move to a new platform, without changing the overall policy.

4 Process

4.1 Definition of Process

The notion of process is central to the understanding of operating systems. There are quite a few definitions presented in the literature, but no "perfect" definition has yet appeared.

4.1.1

4.1.2 Definition

The term "process" was first used by the designers of the MULTICS in 1960's. Since then, the term process, used somewhat interchangeably with 'task' or 'job'. The process has been given many definitions for instance

- A program in Execution.
- An asynchronous activity.
- The 'animated sprit' of a procedure in execution.
- The entity to which processors are assigned.
- The 'dispatchable' unit.

and many more definitions have given. As we can see from above that there is no universally agreed upon definition, but the definition "*Program in Execution*" seem to be most frequently used. And this is a concept are will use in the present study of operating systems.
Now that we agreed upon the definition of process, the question is what is the relation between process and program. It is same beast with different name or when this beast is sleeping (not executing) it is called program and when it is executing becomes process. Well, to be very precise. Process is not the same as program. In the following discussion we point out some of the difference between process and program. As we have mentioned earlier.
Process is not the same as program. A process is more than a program code. A process is an 'active' entity as oppose to program which consider to be a 'passive' entity. As we all know that a program is an algorithm expressed in some suitable notation, (e.g., programming language). Being a passive, a program is only a part of process. Process, on the other hand, includes:

- Current value of Program Counter (PC)
- Contents of the processors registers
- Value of the variables
- The process stack (SP) which typically contains temporary data such as subroutine parameter, return address, and temporary variables.
- A data section that contains global variables.

A process is the unit of work in a system.
In Process model, all software on the computer is organized into a number of sequential processes. A process includes PC, registers, and variables. Conceptually, each process has its own virtual CPU. In reality, the CPU switches back and forth among processes. (The rapid switching back and forth is called multiprogramming).

4.2 Process State

The process state consist of everything necessary to resume the process execution if it is somehow put aside temporarily. The process state consists of at least following:

- Code for the program.
- Program's static data.
- Program's dynamic data.
- Program's procedure call stack.
- Contents of general purpose registers.
- Contents of program counter (PC)
- Contents of program status word (PSW).
- Operating Systems resource in use.

A process goes through a series of discrete process states.

- **New State:** The process being created.
- **Running State:** A process is said to be running if it has the CPU, that is, process actually using the CPU at that particular instant.
- **Blocked (or waiting) State:** A process is said to be blocked if it is waiting for some event to happen such that as an I/O completion before it can proceed. Note that a process is unable to run until some external event happens.
- **Ready State:** A process is said to be ready if it use a CPU if one were available. A ready state process is runable but temporarily stopped running to let another process run.
- **Terminated state:** The process has finished execution.

Logically, the 'Running' and 'Ready' states are similar. In both cases the process is willing to run, only in the case of 'Ready' state, there is temporarily no CPU available for it. The 'Blocked' state is different from the 'Running' and 'Ready' states in that the process cannot run, even if the CPU is available.

4.3 Process Operations

4.3.1 Process Creation

In general-purpose systems, some way is needed to create processes as needed during operation. There are four principal events led to processes creation.

- System initialization.
- Execution of a process Creation System calls by a running process.
- A user request to create a new process.
- Initialization of a batch job.

Foreground processes interact with users. Background processes that stay in background sleeping but suddenly springing to life to handle activity such as email, webpage, printing, and so on. Background processes are called daemons. This call creates an exact clone of the calling process.

A process may create a new process by some create process such as 'fork'. It choose to does so, creating process is called parent process and the created one is called the child processes. Only one parent is needed to create a child process. Note that unlike plants and animals that use sexual representation, a process has only one parent. This creation of process (processes) yields a hierarchical structure of processes like one in the figure. Notice that each child has only one parent but each parent may have many children. After the fork, the two processes, the parent and the child, have the same memory image, the same environment strings and the same open files. After a process is created, both the parent and child have their own distinct address space. If either process changes a word in its address space, the change is not visible to the other process.

<Figure 3.2 pp.55 From Dietel>

Following are some reasons for creation of a process

- User logs on.
- User starts a program.
- Operating systems creates process to provide service, e.g., to manage printer.
- Some program starts another process, e.g., Netscape calls *xv* to display a picture.

4.3.2 Process Termination

A process terminates when it finishes executing its last statement. Its resources are returned to the system, it is purged from any system lists or tables, and its process control block (PCB) is erased i.e., the PCB's memory space is returned to a free memory pool. The new process terminates the existing process, usually due to following reasons:

- **Normal Exist** Most processes terminates because they have done their job. This call is exist in UNIX.
- **Error Exist** When process discovers a fatal error. For example, a user tries to compile a program that does not exist.

- **Fatal Error** An error caused by process due to a bug in program for example, executing an illegal instruction, referring non-existing memory or dividing by zero.
- **Killed by another Process** A process executes a system call telling the Operating Systems to terminate some other process. In UNIX, this call is kill. In some systems when a process kills all processes it created are killed as well (UNIX does not work this way).

4.4 Process Control Block

A process in an operating system is represented by a data structure known as a process control block (PCB) or process descriptor. The PCB contains important information about the specific process including

- The current state of the process i.e., whether it is ready, running, waiting, or whatever.
- Unique identification of the process in order to track "which is which" information.
- A pointer to parent process.
- Similarly, a pointer to child process (if it exists).
- The priority of process (a part of CPU scheduling information).
- Pointers to locate memory of processes.
- A register save area.
- The processor it is running on.

The PCB is a certain store that allows the operating systems to locate key information about a process. Thus, the PCB is the data structure that defines a process to the operating systems.

5 Threads

Despite of the fact that a thread must execute in process, the process and its associated threads are different concept. Processes are used to group resources together and threads are the entities scheduled for execution on the CPU.
A thread is a single sequence stream within in a process. Because threads have some of the properties of processes, they are sometimes called *lightweight processes*. In a process, threads allow multiple executions of streams. In many respect, threads are popular way to improve application through parallelism. The CPU switches rapidly back and forth among the threads giving illusion that the threads are running in parallel. Like a traditional process i.e., process with one thread, a thread can be in any of several states (Running, Blocked, Ready or Terminated). Each thread has its own stack. Since thread will generally call different procedures and thus a different execution history. This is why thread needs its own stack. An operating system that has thread facility, the basic unit of CPU utilization is a thread. A thread has or consists of a program counter (PC), a register set, and a stack space. Threads are not independent of one other like processes as a result threads shares with other threads their code section, data section, OS resources also known as task, such as open files and signals.

5.1 Processes Vs Threads

As we mentioned earlier that in many respect threads operate in the same way as that of processes. Some of the similarities and differences are:
Similarities

- Like processes threads share CPU and only one thread active (running) at a time.
- Like processes, threads within a processes, threads within a processes execute sequentially.
- Like processes, thread can create children.
- And like process, if one thread is blocked, another thread can run.

Differences

- Unlike processes, threads are not independent of one another.
- Unlike processes, all threads can access every address in the task .
- Unlike processes, thread are design to assist one other. Note that processes might or might not assist one another because processes may originate from different users.

5.2 Why Threads?

Following are some reasons why we use threads in designing operating systems.

- A process with multiple threads make a great server for example printer server.
- Because threads can share common data, they do not need to use interprocess communication.
- Because of the very nature, threads can take advantage of multiprocessors.

Threads are cheap in the sense that

- They only need a stack and storage for registers therefore, threads are cheap to create.
- Threads use very little resources of an operating system in which they are working. That is, threads do not need new address space, global data, program code or operating system resources.
- Context switching are fast when working with threads. The reason is that we only have to save and/or restore PC, SP and registers.

But this cheapness does not come free - the biggest drawback is that there is no protection between threads.

5.3 User-Level Threads

User-level threads implement in user-level libraries, rather than via systems calls, so thread switching does not need to call operating system and to cause interrupt to the kernel. In fact, the kernel knows nothing about user-level threads and manages them as if they were single-threaded processes.

Advantages:

The most obvious advantage of this technique is that a user-level threads package can be implemented on an Operating System that does not support threads. Some other advantages are

- User-level threads does not require modification to operating systems.
- Simple Representation: Each thread is represented simply by a PC, registers, stack and a small control block, all stored in the user process address space.
- Simple Management: This simply means that creating a thread, switching between threads and synchronization between threads can all be done without intervention of the kernel.
- Fast and Efficient: Thread switching is not much more expensive than a procedure call.

Disadvantages:

- There is a lack of coordination between threads and operating system kernel. Therefore, process as whole gets one time slice irrespect of whether process has one thread or 1000 threads within. It is up to each thread to relinquish control to other threads.

- User-level threads requires non-blocking systems call i.e., a multithreaded kernel. Otherwise, entire process will blocked in the kernel, even if there are runable threads left in the processes. For example, if one thread causes a page fault, the process blocks.

5.4 Kernel-Level Threads

In this method, the kernel knows about and manages the threads. No runtime system is needed in this case. Instead of thread table in each process, the kernel has a thread table that keeps track of all threads in the system. In addition, the kernel also maintains the traditional process table to keep track of processes. Operating Systems kernel provides system call to create and manage threads.

Advantages:

- Because kernel has full knowledge of all threads, Scheduler may decide to give more time to a process having large number of threads than process having small number of threads.
- Kernel-level threads are especially good for applications that frequently block.

Disadvantages:

- The kernel-level threads are slow and inefficient. For instance, threads operations are hundreds of times slower than that of user-level threads.
- Since kernel must manage and schedule threads as well as processes. It require a full thread control block (TCB) for each thread to maintain information about threads. As a result there is significant overhead and increased in kernel complexity.

5.5 Advantages of Threads over Multiple Processes

- **Context Switching** Threads are very inexpensive to create and destroy, and they are inexpensive to represent. For example, they require space to store, the PC, the SP, and the general-purpose registers, but they do not require space to share memory information, Information about open files of I/O devices in use, etc. With so little context, it is much faster to switch between threads. In other words, it is relatively easier for a context switch using threads.
- **Sharing** Treads allow the sharing of a lot resources that cannot be shared in process, for example, sharing code section, data section, Operating System resources like open file etc.

5.6 Disadvantages of Threads over Multiprocesses

- **Blocking** The major disadvantage if that if the kernel is single threaded, a system call of one thread will block the whole process and CPU may be idle during the blocking period.
- **Security** Since there is, an extensive sharing among threads there is a potential problem of security. It is quite possible that one thread over writes the stack of another thread (or damaged shared data) although it is very unlikely since threads are meant to cooperate on a single task.

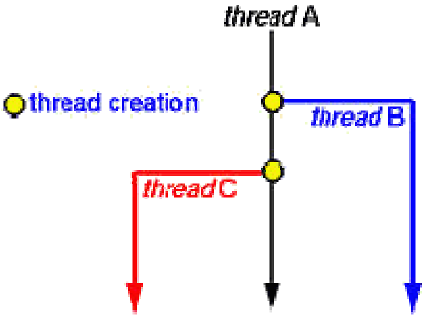
5.7 Application that Benefits from Threads

A proxy server satisfying the requests for a number of computers on a LAN would be benefited by a multi-threaded process. In general, any program that has to do more than one task at a time could benefit from multitasking. For example, a program that reads input, process it, and outputs could have three threads, one for each task.

5.8 Application that cannot Benefit from Threads

Any sequential process that cannot be divided into parallel task will not benefit from thread, as they would block until the previous one completes. For example, a program that displays the time of the day would not benefit from multiple threads.

5.9 Resources used in Thread Creation and Process Creation



When a new thread is created it shares its code section, data section and operating system resources like open files with other threads. But it is allocated its own stack, register set and a program counter.
The creation of a new process differs from that of a thread mainly in the fact that all the shared resources of a thread are needed explicitly for each process. So though two processes may be running the same piece of code they need to have their own copy of the code in the main memory to be able to run. Two processes also do not share other resources with each other. This makes the creation of a new process very costly compared to that of a new thread.

5.10 Context Switch

To give each process on a multiprogrammed machine a fair share of the CPU, a hardware clock generates interrupts periodically. This allows the operating system to schedule all processes in main memory (using scheduling algorithm) to run on the CPU at equal intervals. Each time a clock interrupt occurs, the interrupt handler checks how much time the current running process has used. If it has used up its entire time slice, then the CPU scheduling algorithm (in kernel) picks a different process to run. Each switch of the CPU from one process to another is called a context switch.

5.10.1 Major Steps of Context Switching

- The values of the CPU registers are saved in the process table of the process that was running just before the clock interrupt occurred.
- The registers are loaded from the process picked by the CPU scheduler to run next.

In a multiprogrammed uniprocessor computing system, context switches occur frequently enough that all processes appear to be running concurrently. If a process has more than one thread, the Operating System can use the context switching technique to schedule the threads so they appear to execute in parallel. This is the case if threads are implemented at the kernel level. Threads can also be implemented entirely at the user level in run-time libraries. Since in this case no thread scheduling is provided by the Operating System, it is the responsibility of the programmer to yield the CPU frequently enough in each thread so all threads in the process can make progress.

5.10.2 Action of Kernel to Context Switch Among Threads

The threads share a lot of resources with other peer threads belonging to the same process. So a context switch among threads for the same process is easy. It involves switch of register set, the program counter and the stack. It is relatively easy for the kernel to accomplished this task.

5.10.3 Action of kernel to Context Switch Among Processes

Context switches among processes are expensive. Before a process can be switched its process control block (PCB) must be saved by the operating system. The PCB consists of the following information:

- The process state.
- The program counter, PC.
- The values of the different registers.
- The CPU scheduling information for the process.
- Memory management information regarding the process.
- Possible accounting information for this process.
- I/O status information of the process.

When the PCB of the currently executing process is saved the operating system loads the PCB of the next process that has to be run on CPU. This is a heavy task and it takes a lot of time