Unit-2

Operating System Structure

Kernel

Kernel is central component of an operating system that manages operations of computer and hardware. It basically manages operations of memory and CPU time. It is core component of an operating system. Kernel acts as a bridge between applications and data processing performed at hardware level using inter-process communication and system calls.

Kernel loads first into memory when an operating system is loaded and remains into memory until operating system is shut down again. It is responsible for various tasks such as disk management, task management, and memory management.

It decides which process should be allocated to processor to execute and which process should be kept in main memory to execute. It basically acts as an interface between user applications and hardware. The major aim of kernel is to manage communication between software i.e. user-level applications and hardware i.e., CPU and disk memory.

Objectives of kernel

- To establish communication between user level application and hardware.
- To decide state of incoming processes.
- To control disk management.
- To control memory management.
- To control task management

Different types of kernel are

1. Monolithic kernel
2. Microkernel
3. Exokernel
4. Nanokernel

A system as large and complex as a modern operating system must be engineered carefully if it is to function properly and be modified easily. A common approach is to partition the task into small components, or modules, rather than have one monolithic system. Each of these modules should be a well-defined portion of the system with carefully defined inputs, outputs and functions.

Monolithic kernel

In the monolithic approach the entire operating system runs as a single program in kernel mode. The operating system is written as a collection of procedures, linked together into a single large executable binary program. When this technique is used, each procedure in the system is free to call any other one, if the latter provides some useful computation that the former needs. Being able to call any procedure you want is very efficient, but having thousands of procedures that can call each other without restriction may also lead to a system that is unwieldy and difficult to understand. Also, a crash in any of these procedures will take down the entire operating system.

To construct the actual object program of the operating system when this approach is used, one first compiles all the individual procedures (or the files containing the procedures) and then binds them all together into a single executable file using the system linker. In terms of information hiding, there is essentially none—every procedure is visible to every other procedure (as opposed to a structure containing modules or packages, in which much of the information is hidden away inside modules, and only the officially designated entry points can be called from outside the module).

Even in monolithic systems, however, it is possible to have some structure. The services (system calls) provided by the operating system are requested by putting the parameters in a well-defined place (e.g., on the stack) and then executing a trap instruction. This instruction switches the machine from user mode to kernel mode and transfers control to the operating system. The operating system then fetches the parameters and determines which system call is to be carried out. After that, it indexes into a table that contains in slot k a pointer to the procedure that carries out system call k.

This organization suggests a basic structure for the operating system:

1. A main program that invokes the requested service procedure.
2. A set of service procedures that carry out the system calls.
3. A set of utility procedures that help the service procedures.

In this model, for each system call there is one service procedure that takes care of it and executes it. The utility procedures do things that are needed by several service procedures, such as fetching data from user programs. This division of the procedures into three layers is shown in Figure.

In addition to the core operating system that is loaded when the computer is booted, many operating systems support loadable extensions, such as I/O device drivers and file systems. These components are loaded on demand. In UNIX they are called **shared libraries**. In Windows they are called **DLLs** (**Dynamic-Link Libraries**). They have file extension *.dll* and the *C:\Windows\system32* directory on Windows systems has well over 1000 of them.

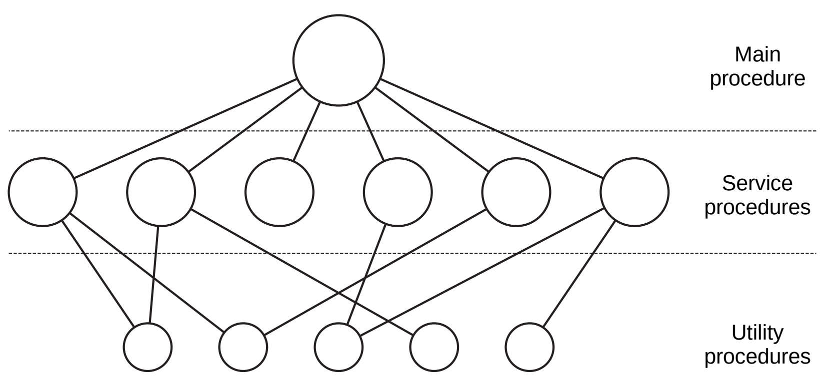


Fig: A simple structuring model for a monolithic system.

Advantages:

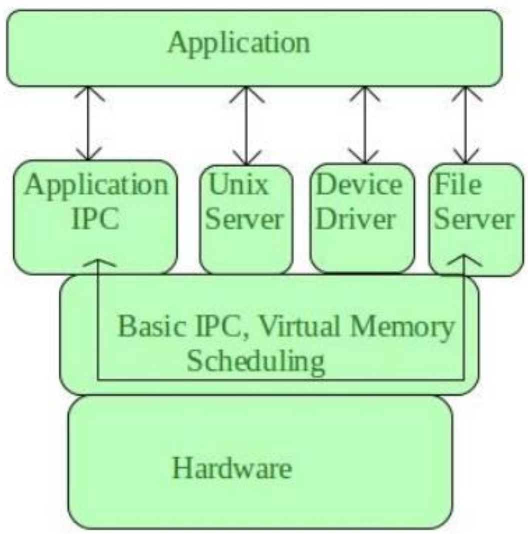
- It provides CPU scheduling, memory scheduling, file management through System calls only.
- Execution of the process is fast because there is no separate memory space for user and kernel.

Disadvantages:

- If any service fails, then it leads to system failure.
- If new services are to be added then the entire Operating System needs to be modified.

Microkernel

Microkernel is one of the classifications of the kernel. Being a kernel, it manages all system resources. But in a microkernel, the **user services** and **kernel services** are implemented in different address space. The user services are kept in **user address space**, and kernel services are kept under **kernel address space**, thus also reduces the size of kernel and size of operating system as well.



It provides minimal services of process and memory management. The communication between client program/application and services running in user address space is established through message passing, reducing the speed of execution microkernel. The Operating System **remains unaffected** as user services and kernel services are isolated so if any user service fails it does not affect kernel service. Thus, it adds to one of the advantages in a microkernel. It is easily **extendable** i.e. if any new services are to be added they are added to user address space and hence requires no modification in kernel space. It is also portable, secure and reliable.

Microkernel is solely responsible for the most important services of operating system they are named as follows:

- Inter process-Communication
- Memory Management
- CPU-Scheduling

Advantages:

- If new services are to be added then it can be easily added.

Disadvantages:

- Since we are using User Space and Kernel Space separately, so the communication between these can reduce the overall execution time.

Exokernel

Rather than cloning the actual machine, as is done with virtual machines, another strategy is partitioning it, in other words, giving each user a subset of the resources. Thus one virtual machine might get disk blocks 0 to 1023, the next one might get blocks 1024 to 2047, and so on.

At the bottom layer, running in kernel mode, is a program called the exokernel (Engler et al., 1995). Its job is to allocate resources to virtual machines and then check attempts to use them to make sure no machine is trying to use somebody else's resources. Each user-level virtual machine can run its own operating system, as on VM/370 and the Pentium virtual 8086s, except that each one is restricted to using only the resources it has asked for and been allocated.

The advantage of the exokernel scheme is that it saves a layer of mapping. In the other designs, each virtual machine thinks it has its own disk, with blocks running from 0 to some maximum, so the virtual machine monitor must maintain tables to remap disk addresses (and all other resources). With the exokernel, this remapping is not needed. The exokernel need only keep track of which virtual machine has been assigned which resource. This method still has the advantage of separating the multiprogramming (in the exokernel) from the user operating system code (in user space), but with less overhead, since all the exokernel has to do is keep the virtual machines out of each other's hair.

Nanokernel

In a Nanokrnel, as the name suggests, the whole code of the kernel is very small i.e. the code executing in the privileged mode of the hardware is very small. The term nanokernel is used to describe a kernel that supports a nanosecond clock resolution.

Advantages:

- It offers hardware abstractions without system services.

Disadvantages:

- It is quite same as Micro kernel hence it is less used.

Layered System

The system had six layers, as shown in Figure. Layer 0 dealt with allocation of the processor, switching between processes when interrupts occurred or timers expired. Above layer 0, the system consisted of sequential processes, each of which could be programmed without having to worry about the fact that multiple processes were running on a single processor. In other words, layer 0 provided the basic multiprogramming of the CPU.

Layer	Function
5	The operator
4	User programs
3	Input/output management
2	Operator-process communication
1	Memory and drum management
0	Processor allocation and multiprogramming

Fig: Structure of the Operating System

Layer 1 did the memory management. It allocated space for processes in main memory and on a 512K word drum used for holding parts of processes (pages) for which there was no room in main memory. Above layer 1, processes did not have to worry about whether they were in memory or on the drum; the layer 1 software took care of making sure pages were brought into memory at the moment they were needed and removed when they were not needed.

Layer 2 handled communication between each process and the operator console (that is, the user). On top of this layer each process effectively had its own operator console. Layer 3 took care of managing the I/O devices and buffering the information streams to and from them. Above layer 3 each process could deal with abstract I/O devices with nice properties, instead of real devices with many peculiarities. Layer 4 was where the user programs were found. They did not have to worry about process, memory, console, or I/O management. The system operator process was located in layer 5.

Client-Server Model

A slight variation of the microkernel idea is to distinguish two classes of processes, the **servers**, each of which provides some service, and the **clients**, which use these services. This model is known as the **client-server** model. Often the lowest layer is a microkernel, but that is not required. The essence is the presence of client processes and server processes.

Communication between clients and servers is often by message passing. To obtain a service, a client process constructs a message saying what it wants and sends it to the appropriate service. The service then does the work and sends back the answer. If the client and server happen to run on the same machine, certain optimizations are possible, but conceptually, we are still talking about message passing here.

An obvious generalization of this idea is to have the clients and servers run on different computers, connected by a local or wide-area network, as depicted in Figure. Since clients communicate with servers by sending messages, the clients need not know whether the messages are handled locally on their own machines, or whether they are sent across a network to servers on a remote machine. As far as the client is concerned, the same thing happens in both cases: requests are sent and replies come back. Thus the client-server model is an abstraction that can be used for a single machine or for a network of machines.

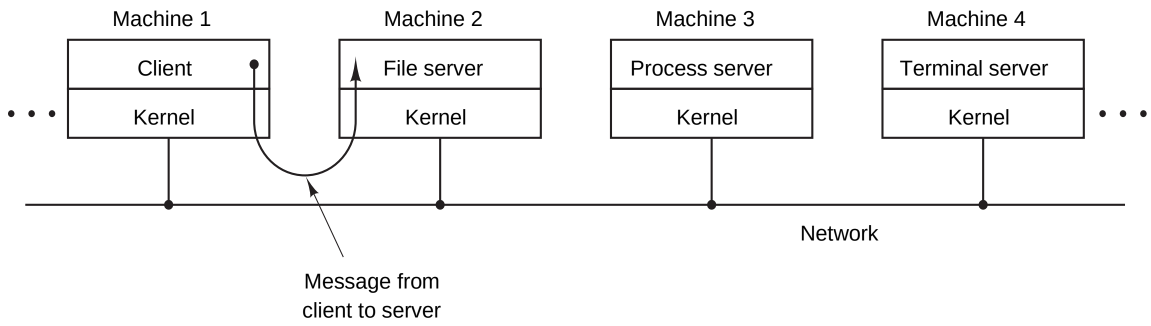


Fig: Client-Server Model over a network

Increasingly many systems involve users at their home PCs as clients and large machines elsewhere running as servers. In fact, much of the Web operates this way. A PC sends a request for a Web page to the server and the Web page comes back. This is a typical use of the client-server model in a network.

Virtual Machines

The initial releases of OS/360 were strictly batch systems. Nevertheless, many 360 users wanted to be able to work interactively at a terminal, so various groups, both inside and outside IBM, decided to write timesharing systems for it. The official IBM timesharing system, TSS/360, was delivered late, and when it finally arrived it was so big and slow that few sites converted to it.

VM/370 was based on a smart observation: a timesharing system provides (1) multiprogramming and (2) an extended machine with a more convenient interface than the bare hardware. The essence of VM/370 is to completely separate these two functions.

The heart of the system, known as the **virtual machine monitor**, runs on the bare hardware and does the multiprogramming, providing not one, but several virtual machines to the next layer up, as shown in Fig. 1-28. However, unlike all other operating systems, these virtual machines are not extended machines, with files and other nice features. Instead, they are *exact* copies of the bare hardware, including kernel/user mode, I/O, interrupts, and everything else the real machine has.

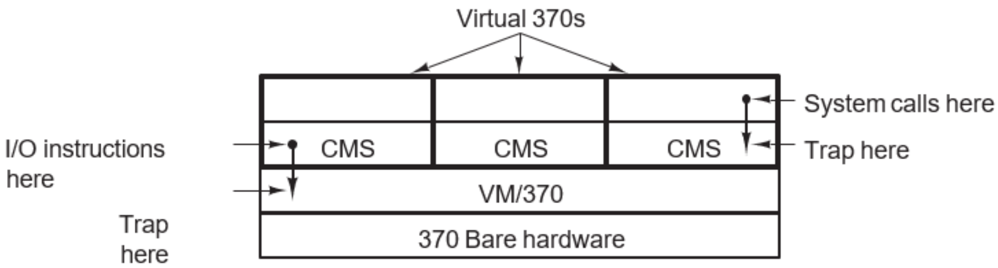


Fig: The structure of VM/370 with CMS

Because each virtual machine is identical to the true hardware, each one can run any operating system that will run directly on the bare hardware. Different virtual machines can, and frequently do, run different operating systems. On the original IBM VM/370 system, some ran OS/360 or one of the other large batch or transaction-processing operating systems, while others ran a single-user, interactive system called **CMS** (**Conversational Monitor System**) for interactive timesharing users. The latter was popular with programmers.

When a CMS program executed a system call, the call was trapped to the operating system in its own virtual machine, not to VM/370, just as it would be were it running on a real machine instead of a virtual one. CMS then issued the normal hardware I/O instructions for reading its virtual disk or whatever was needed to carry out the call. These I/O instructions were trapped by VM/370, which then performed them as part of its simulation of the real hardware. By completely separating the functions of multiprogramming and providing an extended machine, each of the pieces could be much simpler, more flexible, and much easier to maintain.

The Shell

The operating system is the code that carries out the system calls. Editors, compilers, assemblers, linkers, utility programs, and command interpreters definitely are not part of the operating system, even though they are important and useful. At the risk of confusing things somewhat, in this section we will look briefly at the UNIX command interpreter, the shell. Although it is not part of the operating system, it makes heavy use of many operating system features and thus serves as a good example of how the system calls are used. It is also the main interface between a user sitting at his terminal and the operating system, unless the user is using a graphical user interface. Many shells exist, including *sh*, *csh*, *ksh*, and *bash*. All of them support the functionality described below, which derives from the original shell (*sh*).

When any user logs in, a shell is started up. The shell has the terminal as standard input and standard output. It starts out by typing the **prompt**, a character such as a dollar sign, which tells the user that the shell is waiting to accept a command. If the user now types `date`

for example, the shell creates a child process and runs the *date* program as the child. While the child process is running, the shell waits for it to terminate. When the child finishes, the shell types the prompt again and tries to read the next input line.

The user can specify that standard output be redirected to a file, for example, `date >file`

Similarly, standard input can be redirected, as in `sor t <file1 >file2`

which invokes the sort program with input taken from *file1* and output sent to *file2*.

The output of one program can be used as the input for another program by connecting them with a pipe. Thus `cat file1 file2 file3 | sort >/dev/lp`

invokes the *cat* program to con*cat*enate three files and send the output to *sort* to arrange all the lines in alphabetical order. The output of *sort* is redirected to the file */dev/lp*, typically the printer.

If a user puts an ampersand after a command, the shell does not wait for it to complete. Instead it just gives a prompt immediately. Consequently, `cat file1 file2 file3 | sort >/dev/lp &`

starts up the sort as a background job, allowing the user to continue working normally while the sort is going on. The shell has a number of other interesting features, which we do not have space to discuss here. Most books on UNIX discuss the shell at some length (e.g., Kernighan and Pike, 1984; Quigley, 2004; Robbins, 2005).

Most personal computers these days use a GUI. In fact, the GUI is just a program running on top of the operating system, like a shell. In Linux systems, this fact is made obvious because the user has a choice of (at least) two GUIs: Gnome and KDE or none at all (using a terminal window on X11). In Windows, it is also possible to replace the standard GUI desktop (*Windows Explorer*) with a different program by changing some values in the registry, although few people do this.