Operating System

A program that controls the execution of application programs

An interface between applications and hardware

Objectives:

- Convenience: makes the computer more convenient to use
- Efficiency: allows computer system resources to be used in an efficient manner
- Ability to evolve: permits effective development, testing, and introduction of new system functions without interfering with service

Responsible for managing resources

Functions same way as ordinary computer software

It is program that is executed

Operating system relinquishes control of the processor

Layers of Computer System

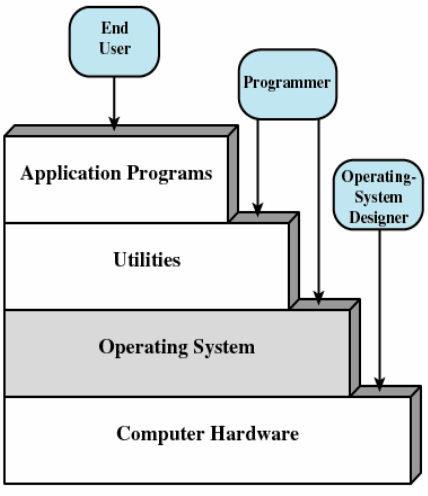


Figure 2.1 Layers and Views of a Computer System

Services Provided by the Operating System

- Program development
  - Editors and debuggers
- Program execution
- Access to I/O devices
- Controlled access to files
- System access

- Error detection and response
  - Internal and external hardware errors
    - Memory error
    - Device failure
  - Software errors
    - Arithmetic overflow
    - Access forbidden memory locations
  - Operating system cannot grant request of application

- Accounting
  - Collect usage statistics
  - Monitor performance
  - Used to anticipate future enhancements
  - Used for billing purposes

OS as Resource Manager

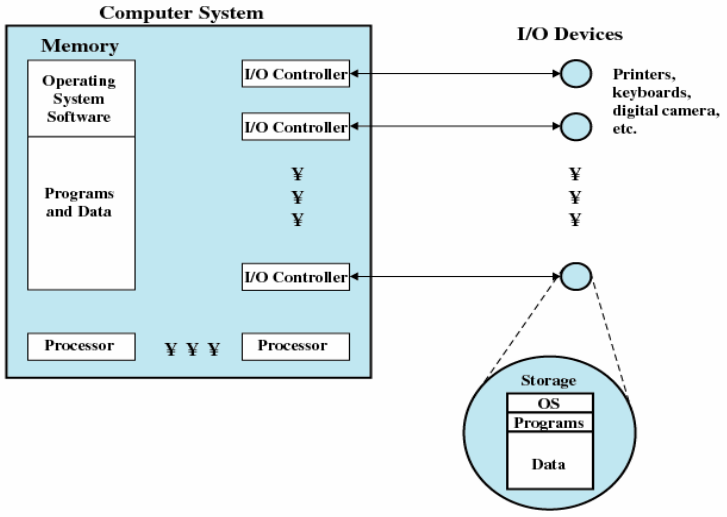


Figure 2.2 The Operating System as Resource Manager

OS Kernel

Portion of operating system that is in main memory

Contains most frequently used functions

Also called the nucleus

Evolution of an Operating System

Serial Processing

- No operating system
- Machines run from a console with display lights, toggle switches, input device, and printer
- Schedule time
- Setup included loading the compiler, source program, saving compiled program, and loading and linking

Simple Batch Systems

- Monitors
  - Software that controls the sequence of events
  - Batch jobs together
  - Program branches back to monitor when finished

Job control language (JCL)

- Special type of programming language
- Provides instruction to the monitor
  - What compiler to use
  - What data to use

Hardware Features

Memory protection: do not allow the memory area containing the monitor to be altered

-User program executes in user mode

- Certain instructions may not be executed

- Monitor executes in system (kernel) mode
  - Privileged instructions are executed
  - Protected areas of memory may be accessed

Timer

- Prevents a job from monopolizing the system

Privileged instructions

Certain machine level instructions can only be executed by the monitor

Interrupts

Early computer models did not have this capability

I/O Devices are Slow

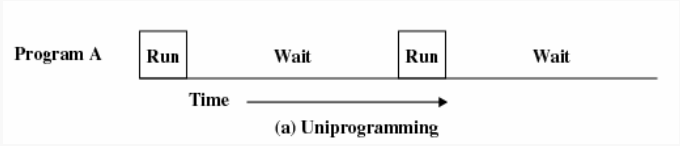
Read one record from file	15 µs
Execute 100 instructions	1 µs
Write one record to file	15 µs
TOTAL	31 µs

Percent CPU Utilization $= \frac{1}{31} = 0.032 = 3.2\%$

Figure 2.4 System Utilization Example

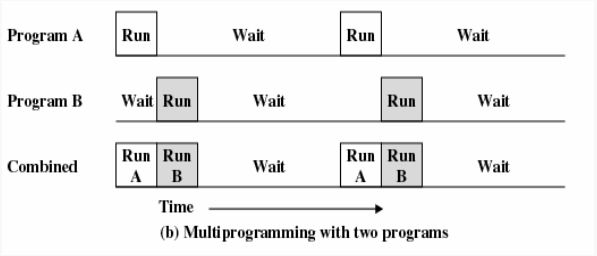
Uni-programming Environment

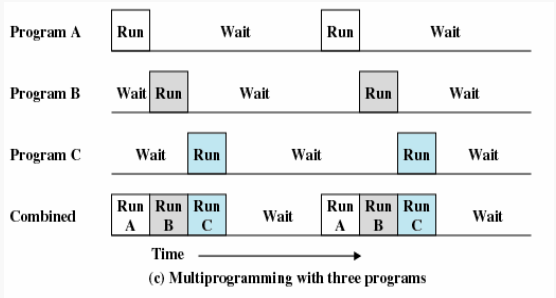
Processor must wait for I/O instruction to complete before preceding



Multi-programming Environment

When one job needs to wait for I/O, the processor can switch to the other job





Utilization Histograms

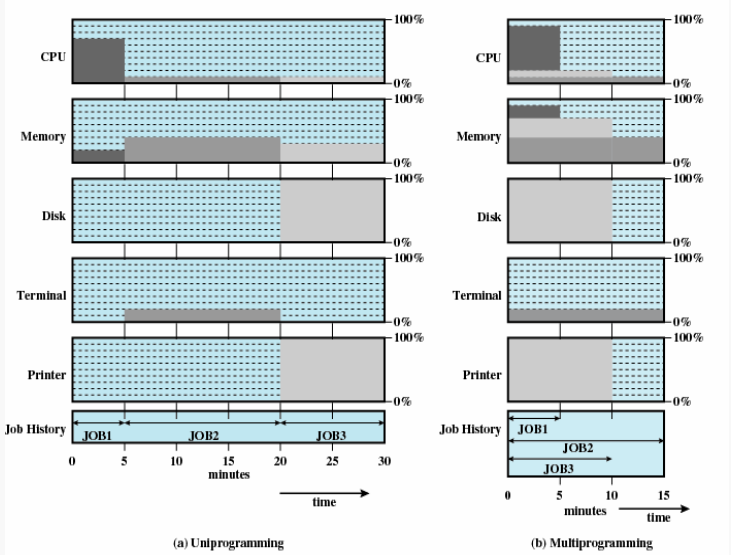


Figure 2.6 Utilization Histograms

Example

Table 2.1 Sample Program Execution Attributes

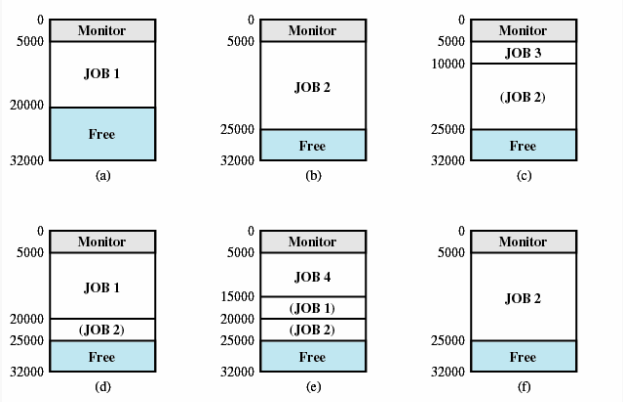
	JOB1	JOB2	JOB3
Type of job	Heavy compute	Heavy I/O	Heavy I/O
Duration	5 min	15 min	10 min
Memory required	50 M	100 M	75 M
Need disk?	No	No	Yes
Need terminal?	No	Yes	No
Need printer?	No	No	Yes

Time Sharing

Using multiprogramming to handle multiple interactive jobs

Processor's time is shared among multiple users

Multiple users simultaneously access the system through terminals



CTSS: first time-sharing system developed at MIT

Figure 2.7 CTSS Operation

Major Achievements

Processes

Memory Management

Information protection and security

Scheduling and resource management

System structure

Process

A program in execution

An instance of a program running on a computer

The entity that can be assigned to and executed on a processor

A unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources

A process consists of three components:

- An executable program
- Associated data needed by the program
- Execution context of the program
  - All information the operating system needs to manage the process

Process Representation

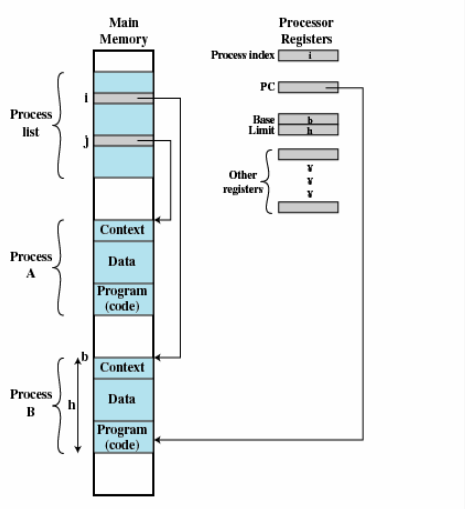


Figure 2.8 Typical Process Implementation

Difficulties with Designing System Software

Improper synchronization

- Ensure a process waiting for an I/O device receives the signal

Failed mutual exclusion

Nondeterminate program operation

- Program should only depend on input to it, not on the activities of other programs

Deadlocks

Memory Management

Process isolation

Automatic allocation and management

Support of modular programming

Protection and access control

Long-term storage

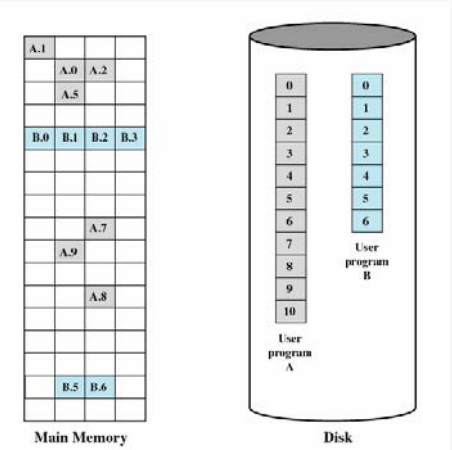
Virtual Memory

- Allows programmers to address memory from a logical point of view
- No hiatus between the execution of successive processes while one process was written out to secondary store and the successor process was read in
- Interacts with file system

Paging

- Allows process to be comprised of a number of fixed-size blocks, called pages
- Virtual address is a page number and an offset within the page
- Each page may be located any where in main memory
- Real address or physical address in main memory

Virtual Memory



Main memory consists of a number of fixed-length frames, each equal to the size of a page. For a program to execute, some or all of its pages must be in main memory.

Secondary memory (disk) can hold many fixed-length pages. A user program consists of some number of pages. Pages for all programs plus the operating system are on disk, as are files.

Figure 2.9 Virtual Memory Concepts

Virtual Memory Addressing

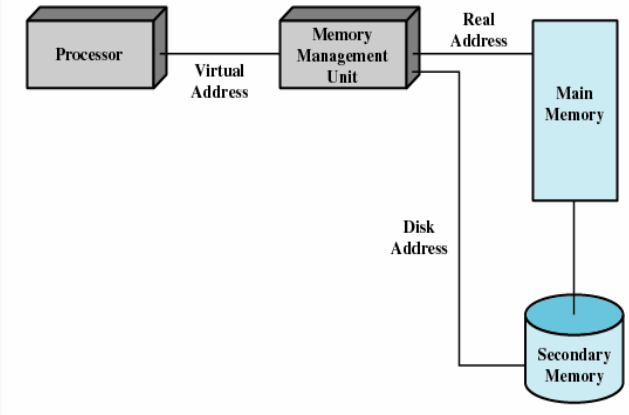


Figure 2.10 Virtual Memory Addressing

Information Protection and Security

Availability

Concerned with protecting the system against interruption

Confidentiality

Assuring that users cannot read data for which access is unauthorized

Data integrity

Protection of data from unauthorized modification

Authenticity

Concerned with the proper verification of the identity of users and the validity of messages or data

Scheduling and Resource Management

Fairness

Give equal and fair access to resources

Differential responsiveness

Discriminate among different classes of jobs

Efficiency

Maximize throughput, minimize response time, and accommodate as many uses as possible

Key Elements of Operating System

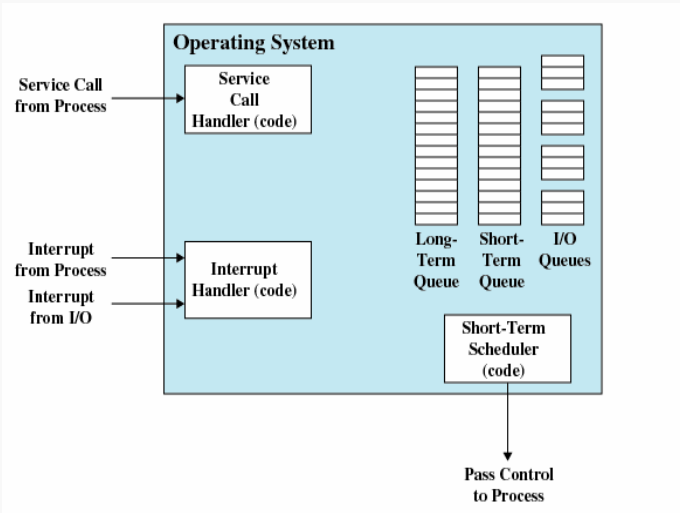


Figure 2.11 Key Elements of an Operating System for Multiprogramming

System Structure

View the system as a series of levels

Each level performs a related subset of functions

Each level relies on the next lower level to perform more primitive functions

This decomposes a problem into a number of more manageable subproblems

Process Hardware Levels

Level 1
- Electronic circuits
- Objects are registers, memory cells, and logic gates
- Operations are clearing a register or reading a memory location

Level 2
- Processor's instruction set
- Operations such as add, subtract, load, and store

Level 3
- Adds the concept of a procedure or subroutine, plus call/return operations

Level 4
- Interrupts

Concepts with Multiprogramming

Level 5
- Process as a program in execution
- Suspend and resume processes

Level 6
- Secondary storage devices
- Transfer of blocks of data

Level 7
- Creates logical address space for processes
- Organizes virtual address space into blocks

Deal with External Objects

Level 8
- Communication of information and messages between processes

Level 9
- Supports long-term storage of named files

Level 10
- Provides access to external devices using standardized interfaces

Level 11
- Responsible for maintaining the association between the external and internal identifiers

Level 12
- Provides full-featured facility for the support of processes

Level 13
- Provides an interface to the operating system for the user

Modern Operating Systems

Microkernel architecture
- Assigns only a few essential functions to the kernel
  - Address spaces
  - Interprocess communication (IPC)
  - Basic scheduling

Multithreading
- Process is divided into threads that can run concurrently
  - Thread
    - Dispatchable unit of work
    - executes sequentially and is interruptable
  - Process is a collection of one or more threads

Symmetric multiprocessing (SMP)
- There are multiple processors
- These processors share same main memory and I/O facilities
- All processors can perform the same functions

Multiprogramming and Multiprocessing

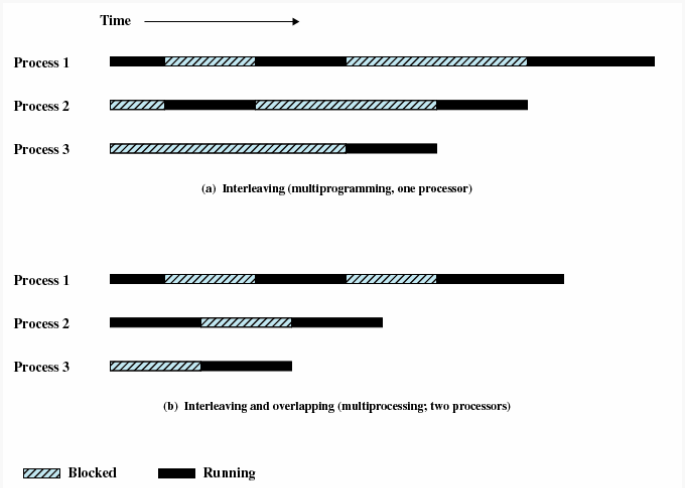


Figure 2.12 Multiprogramming and Multiprocessing

Modern Operating Systems

Distributed operating systems

- Provides the illusion of a single main memory space and single secondary memory space

Object-oriented design

- Used for adding modular extensions to a small kernel
- Enables programmers to customize an operating system without disrupting system integrity

Windows Architecture

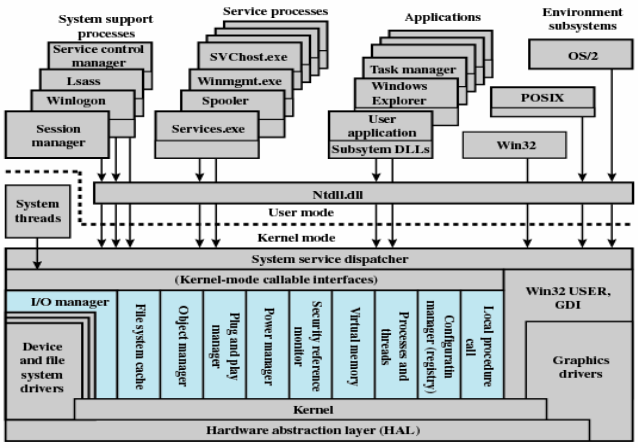


Figure 2.13 Windows 2000 Architecture [SOLO00]

Windows OS Organization

Modified microkernel architecture

- Not a pure microkernel
- Many system functions outside of the microkernel run in kernel mode

Any module can be removed, upgraded, or replaced without rewriting the entire system

Executive

- Contains base operating system services
  - Memory management
  - Process and thread management
  - Security
  - I/O
  - Interprocess communication

Kernel

- Consists of the most used components

Kernel-Mode Components

Hardware abstraction layer (HAL)

- Isolates the operating system from platform-specific hardware differences

Device drivers

- Translate user I/O function calls into specific hardware device I/O requests

Windowing and graphics systems

- Implements the graphical user interface (GUI)

UNIX

Hardware is surrounded by the operating system software

Operating system is called the system kernel

Comes with a number of user services and interfaces

- Shell
- Components of the C compiler

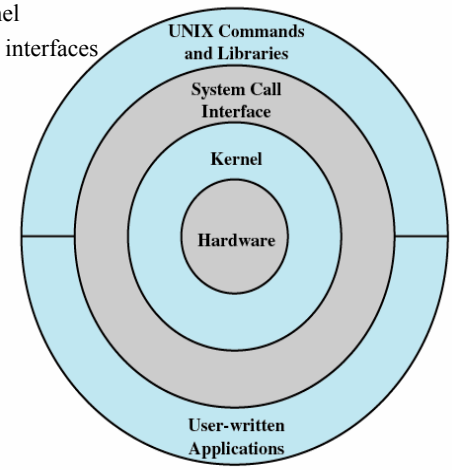


Figure 2.14 General UNIX Architecture

UNIX Kernel

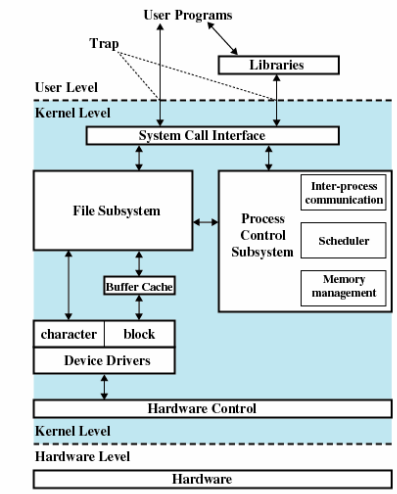


Figure 2.15 Traditional UNIX Kernel [BACH86]

Modern UNIX Kernel

System V Release 4 (SVR4)
Solaris 9
4.4BSD
Linux

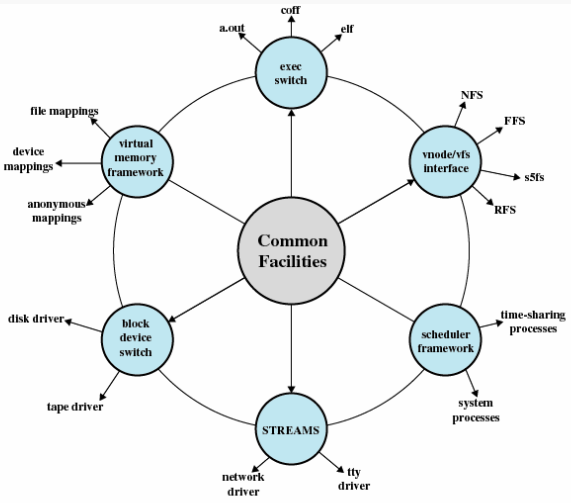


Figure 2.16 Modern UNIX Kernel [VAHA96]