Operating Systems

Operating System Overview

Chapter 2

Outline

- Operating System Objectives and Functions
- Evolution of Operating Systems
- Major Achievements
- Characteristics of modern Operating Systems

Operating System

- A program that controls the execution of application programs
- An interface between applications and hardware

Operating System Objectives

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

Layers of Computer System

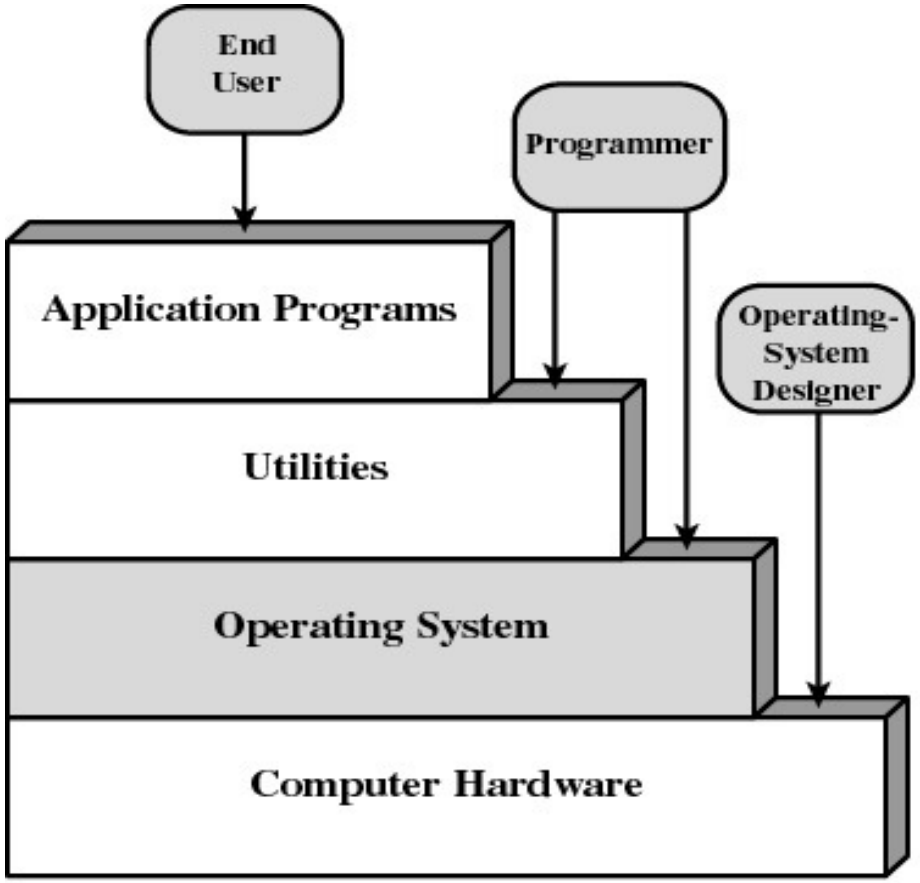


Figure 2.1 Layers and Views of a Computer System

Services Provided by the Operating System

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

Services Provided by the Operating System

- 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

Services Provided by the Operating System

- Accounting
  - collect statistics
  - monitor performance
  - used to anticipate future enhancements
  - used for billing users

OS as a Resource Manager

- Functions same way as ordinary computer software
  - It is program that is executed
- OS directs the processor in the use of the other system resources and in the timing of its execution of other programs
- Operating system relinquishes control of the processor to execute other programs

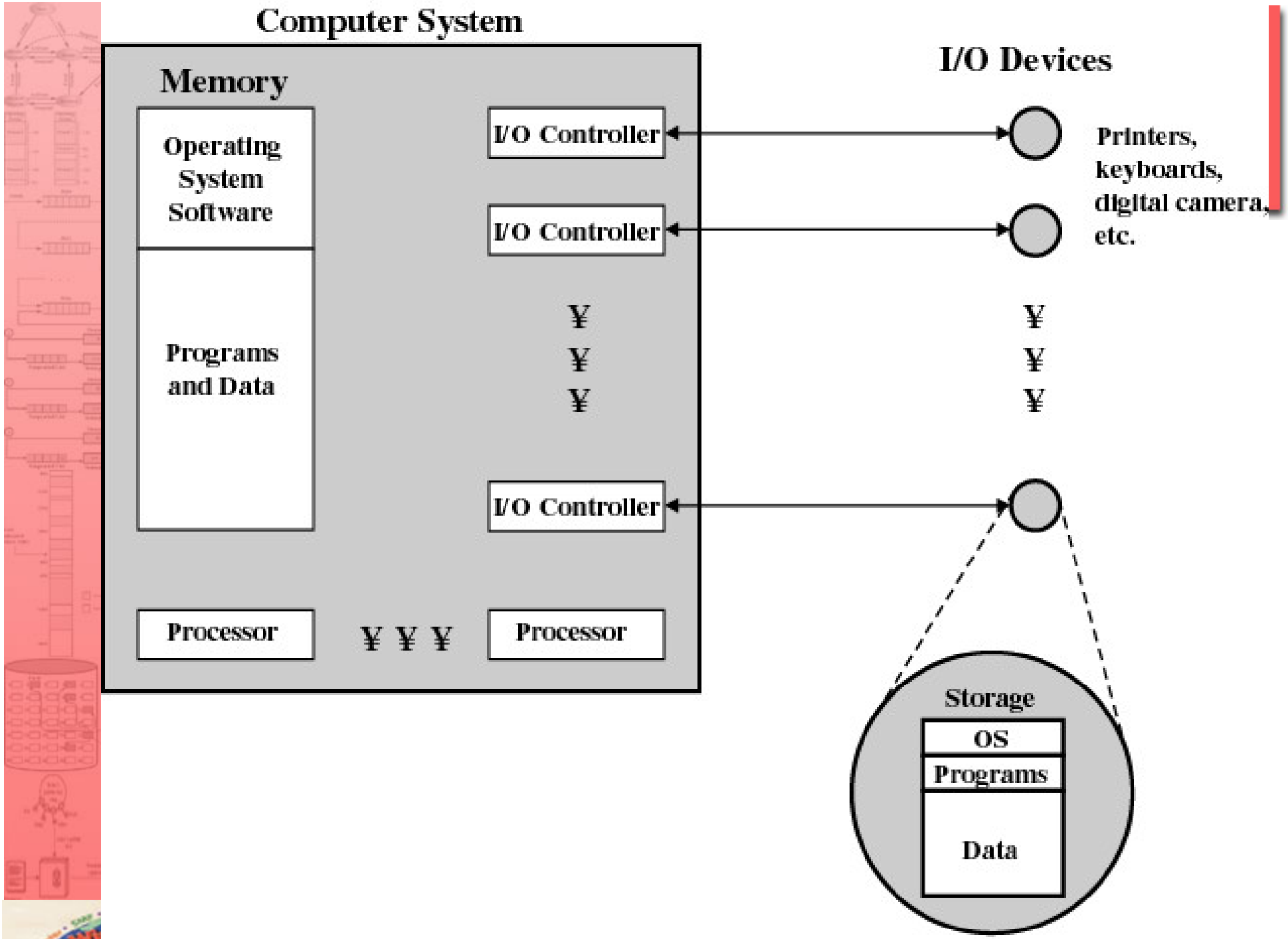


Figure 2.2 The Operating System as Resource Manager

Kernel

- Portion of operating system that is in main memory
- Contains most-frequently used functions
- Also called the nucleus

Evolution of an Operating System

- Hardware upgrades and new types of hardware
- New services (new tools and new applications)
- Fixes (faults are discovered and fixes are made)

Evolution of Operating Systems

- *Serial Processing*
  - No operating system
  - Programmer interacted directly with hardware
  - Machines run from a console with display lights and toggle switches, input device (a card reader), and printer
  - *Scheduling* dilemma
  - *Setup* included loading the compiler, source program, saving compiled program, and loading and linking

Evolution of Operating Systems

- Simple Batch Systems
  - Monitors
    - Software that controls the running programs
    - Batch jobs together
    - Program constructed to branch back to monitor when finished
    - Resident monitor is in main memory and available for execution
    - *Handles the scheduling problem, and improves job setup time*

Job Control Language (JCL)

- Special type of programming language
- Provides instructions to the monitor
  - what compiler to use
  - Loading object programs into memory
  - what data to use

Desirable Hardware Features

- Memory protection
  - do not allow the memory area containing the monitor to be altered
- Timer
  - prevents a job from monopolizing the system

Problems with Simple Batch Systems

- Processor is often idle (I/O devices slow compared to processor)

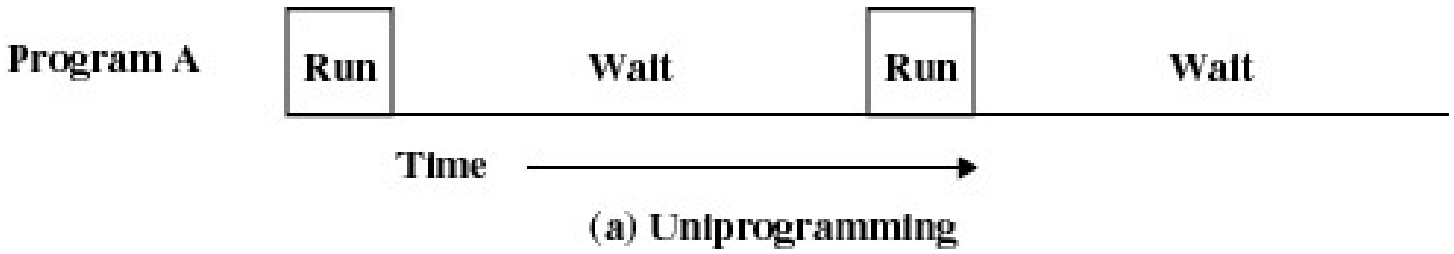
Read one record from file	0.0015 sec
Execute 100 instructions	0.0001 sec
Write one record to file	0.0015 sec
Total	0.0031 sec

Percent CPU utilization

$$0.0001/0.0031 = 3.2\%$$

Uniprogramming

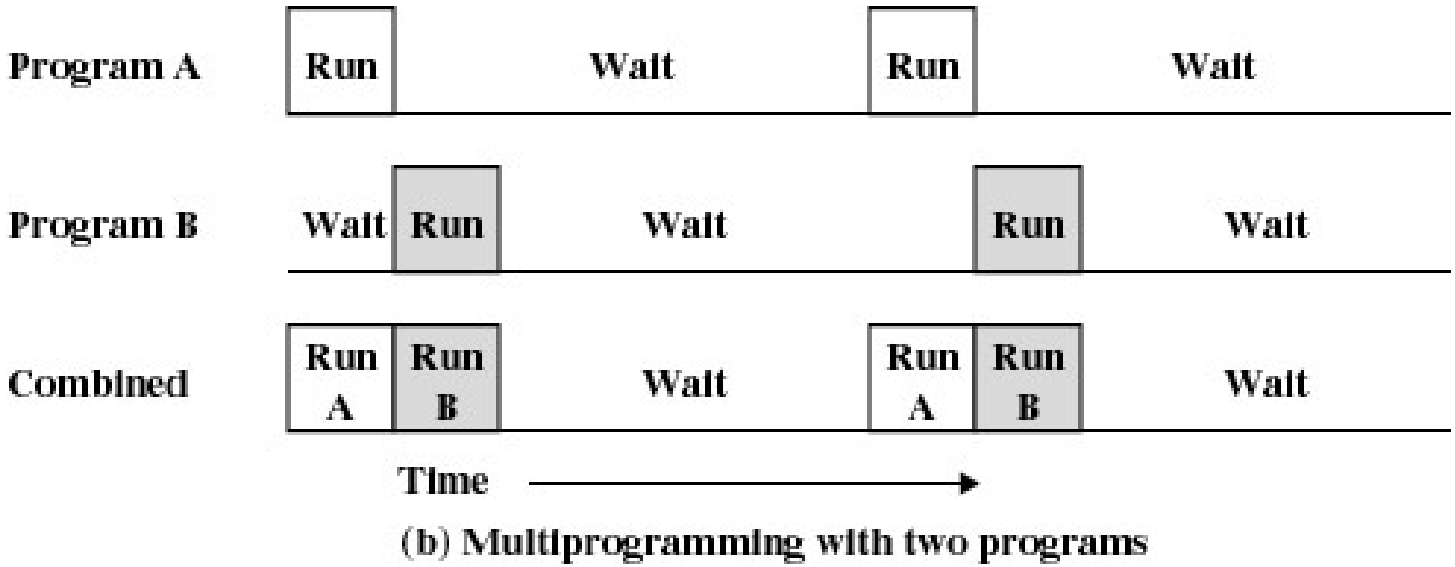
- Processor must wait for I/O instruction to complete before preceding



(a) Uniprogramming

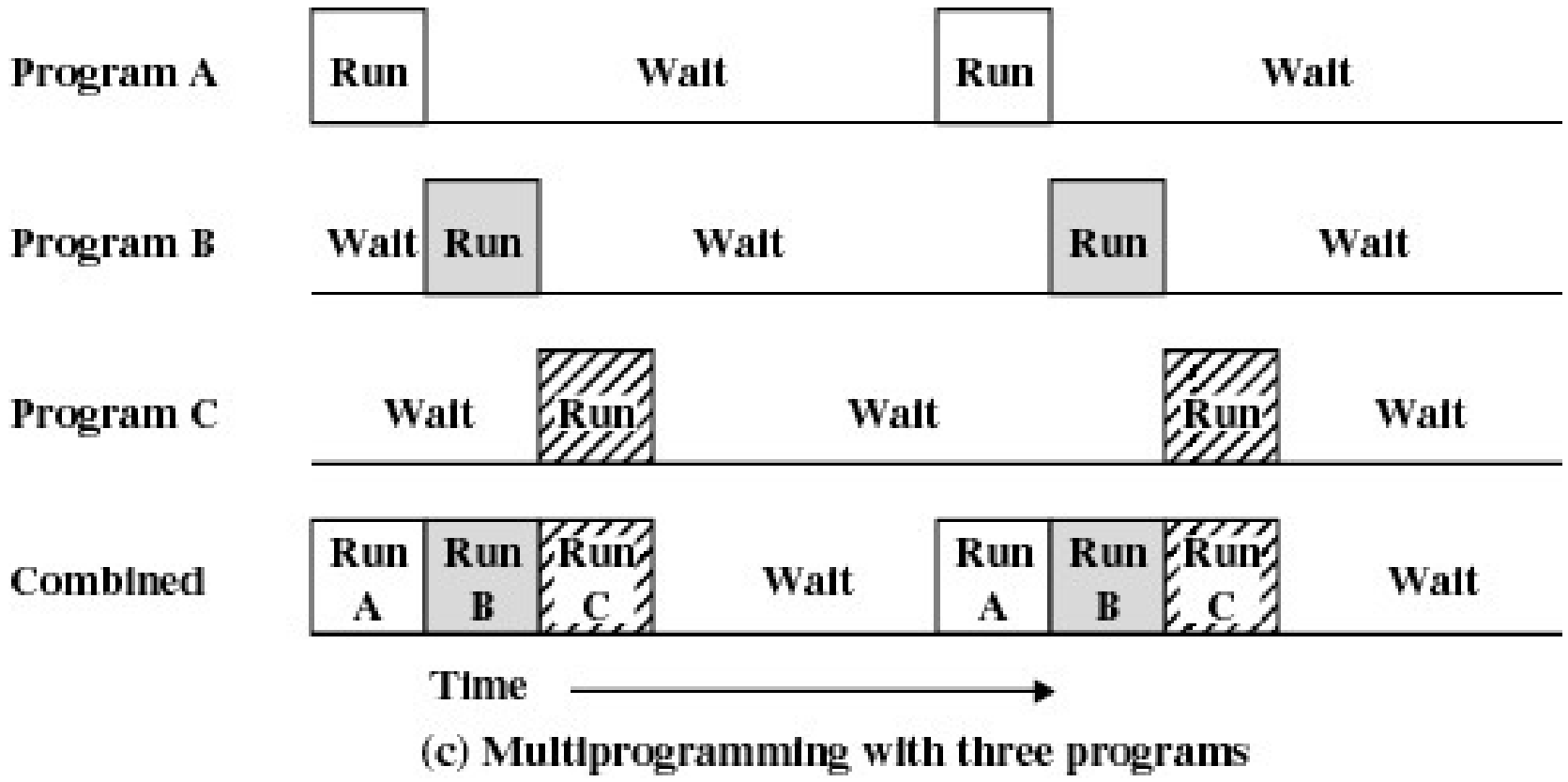
Multiprogramming

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



(b) Multiprogramming with two programs

Multiprogramming



(c) Multiprogramming with three programs

Example

	JOB1	JOB2	JOB3
Type of job	Heavy compute	Heavy I/O	Heavy I/O
Duration	5 min.	15 min.	10 min.
Memory required	50K	100 K	80 K
Need disk?	No	No	Yes
Need terminal	No	Yes	No
Need printer?	No	No	Yes

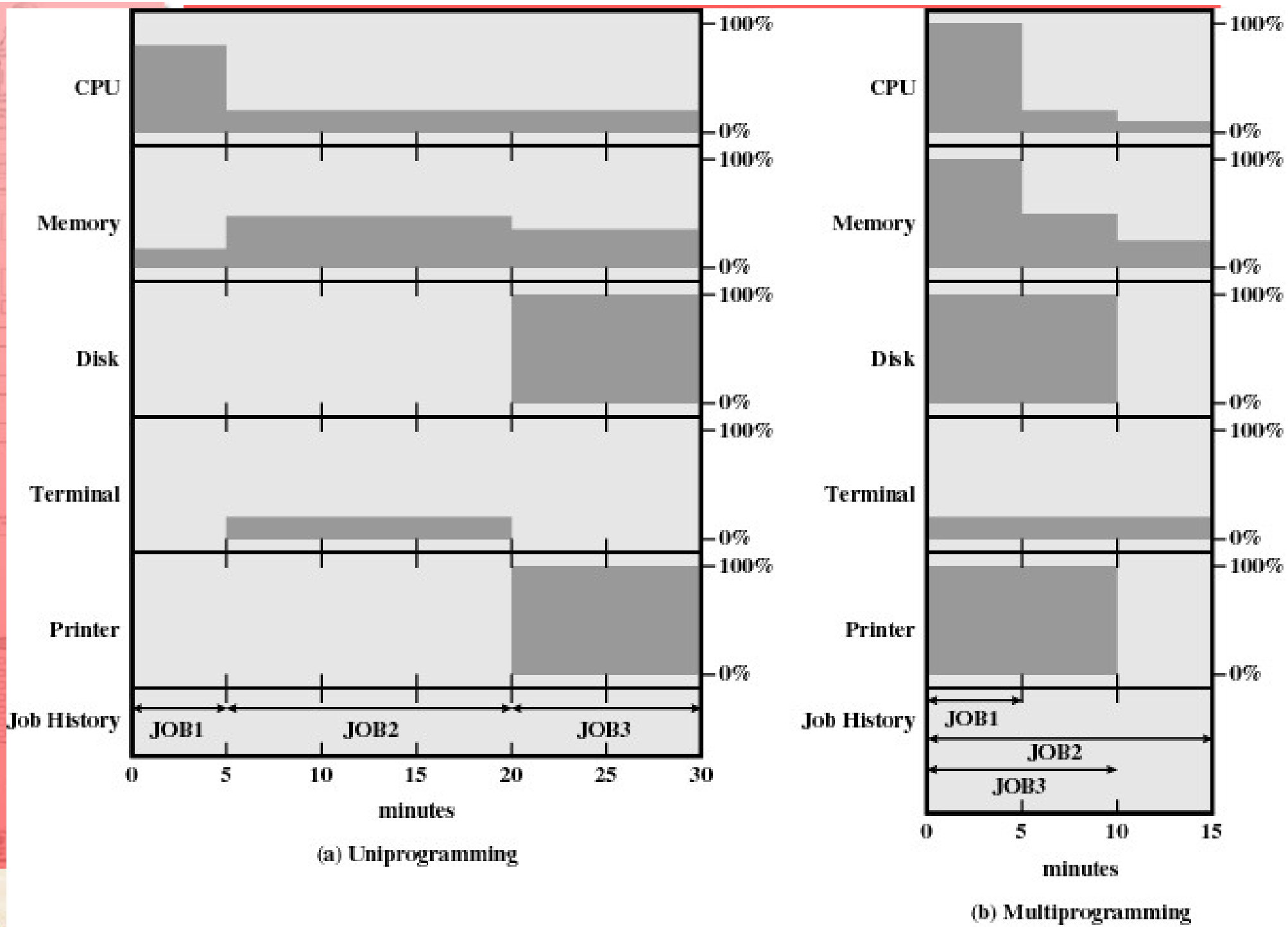


Figure 2.6 Utilization Histograms

Effects of Multiprogramming

	Uniprogramming	Multiprogramming
Processor use	22%	43%
Memory use	30%	67%
Disk use	33%	67%
Printer use	33%	67%
Elapsed time	30 min.	15 min.
Throughput rate	6 jobs/hr	12 jobs/hr
Mean response time	18 min.	10 min.

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
- OS interleaving execution of each user program in a short burst or *quantum* of computation

Batch Multiprogramming versus Time Sharing

	Batch Multiprogramming	Time Sharing
Principal objective	Maximize processor use	Minimize response time
Source of directives to operating system	Job control language commands provided with the job	Commands entered at the terminal

Major Achievements

Theoretical advances in development of OS

- Processes
- Memory Management
- Information protection and security
- Scheduling and resource management
- System structure

Processes

- 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
- Factors contributing to development of process concept: multiprogramming batch operation, time sharing, and real-time transaction processing

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 relying on common memory areas
- Deadlocks

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 state)
      - Contents of various processor registers such as PC
      - Process priority
      - Whether the process is waiting for the completion of an I/O event

Process

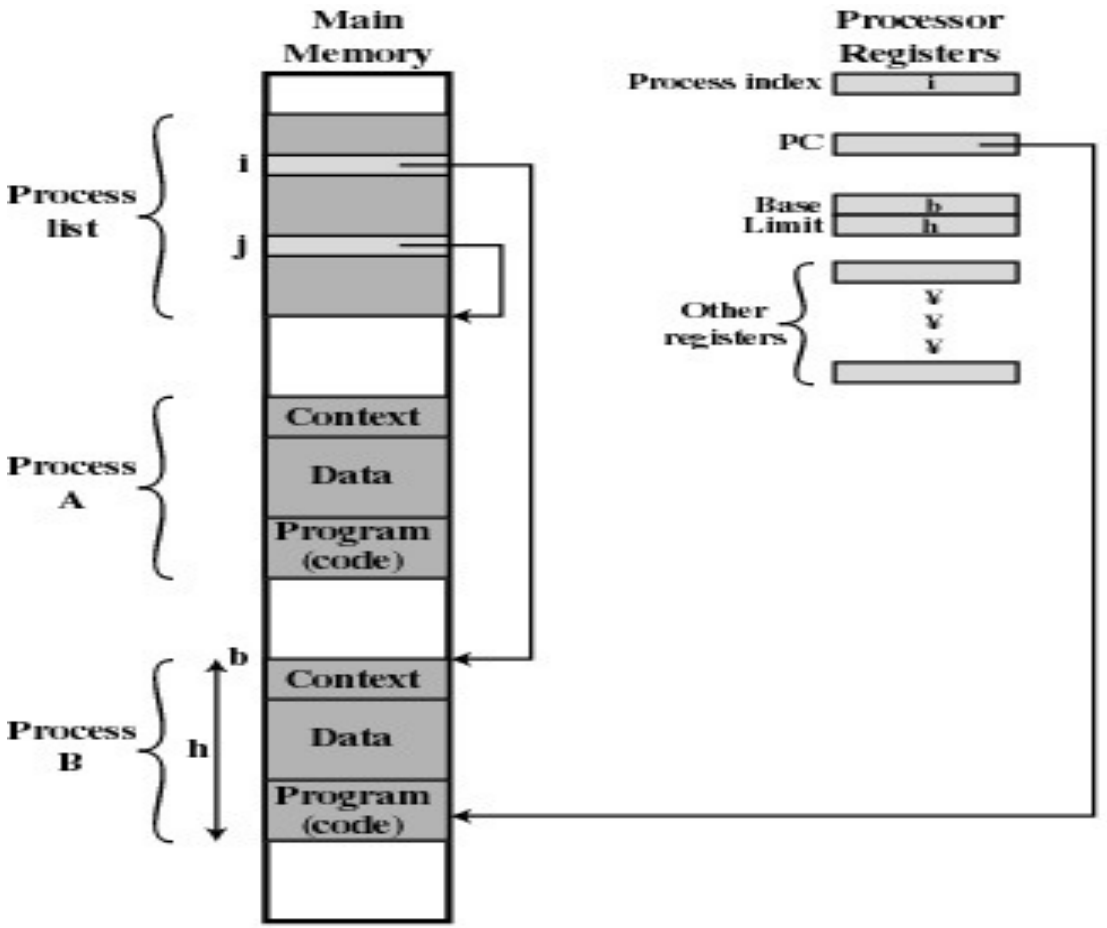


Figure 2.8 Typical Process Implementation

Memory Management

- Process isolation
- Automatic allocation and management
- Support for modular programming
- Protection and access control
- Long-term storage

Virtual Memory

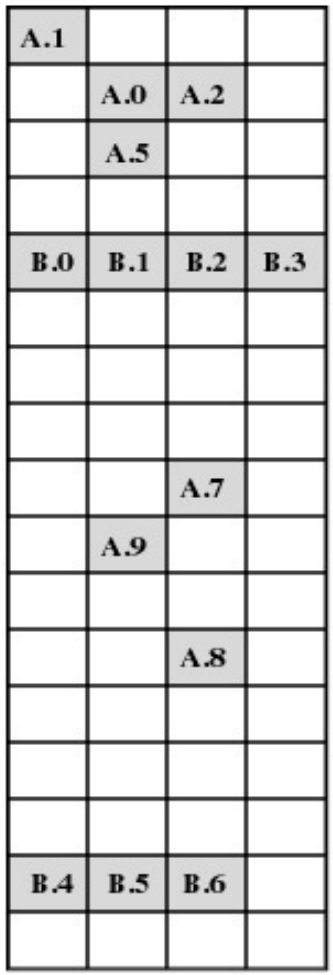
- Allows programmers to address memory from a logical point of view
- While one process is written out to secondary store and the successor process read in there in no hiatus

File System

- Implements long-term store
- Information stored in named objects called files

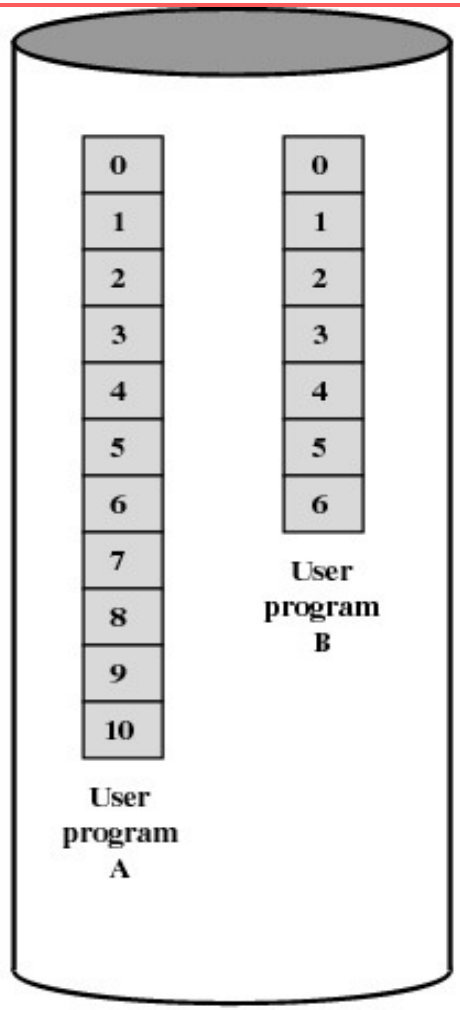
Paging

- 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



Main Memory

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



Disk

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

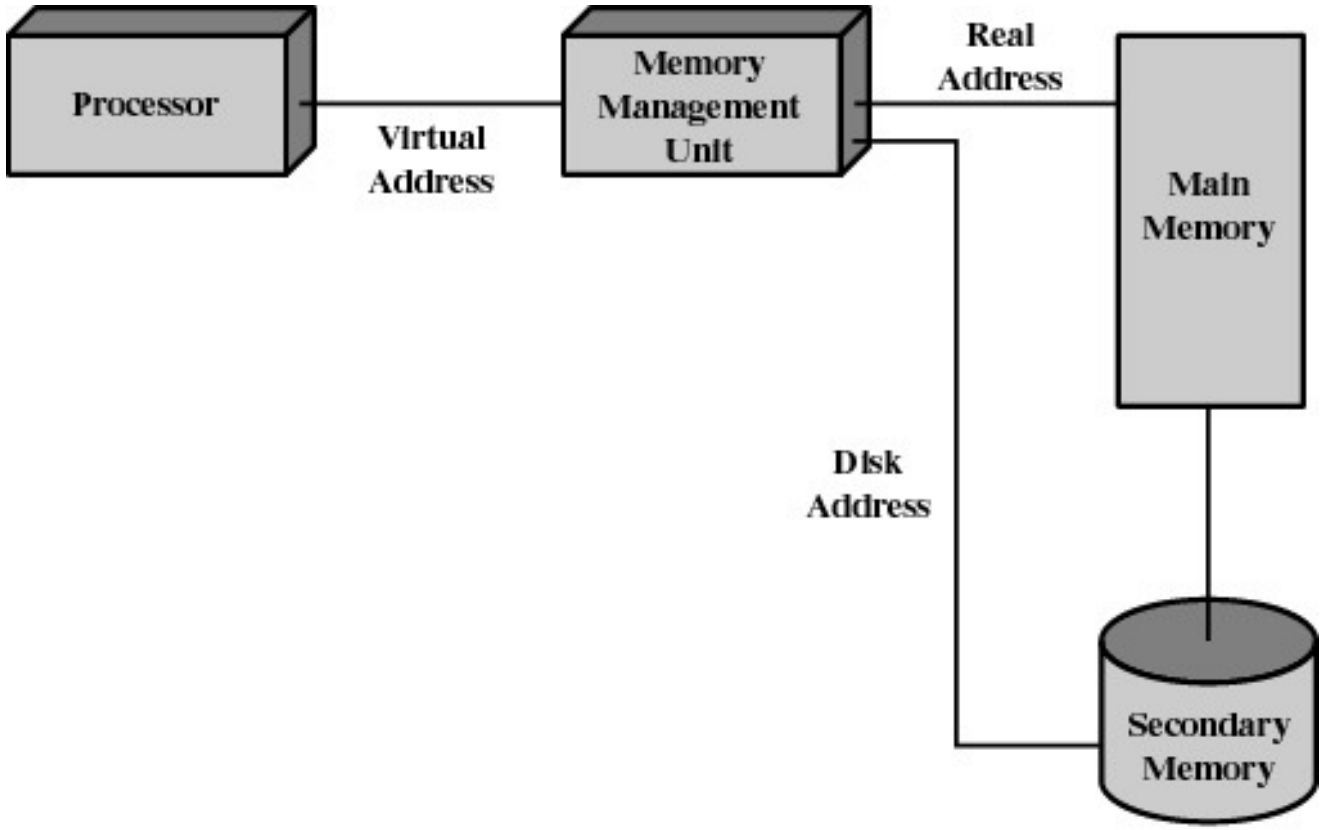


Figure 2.10 Virtual Memory Addressing

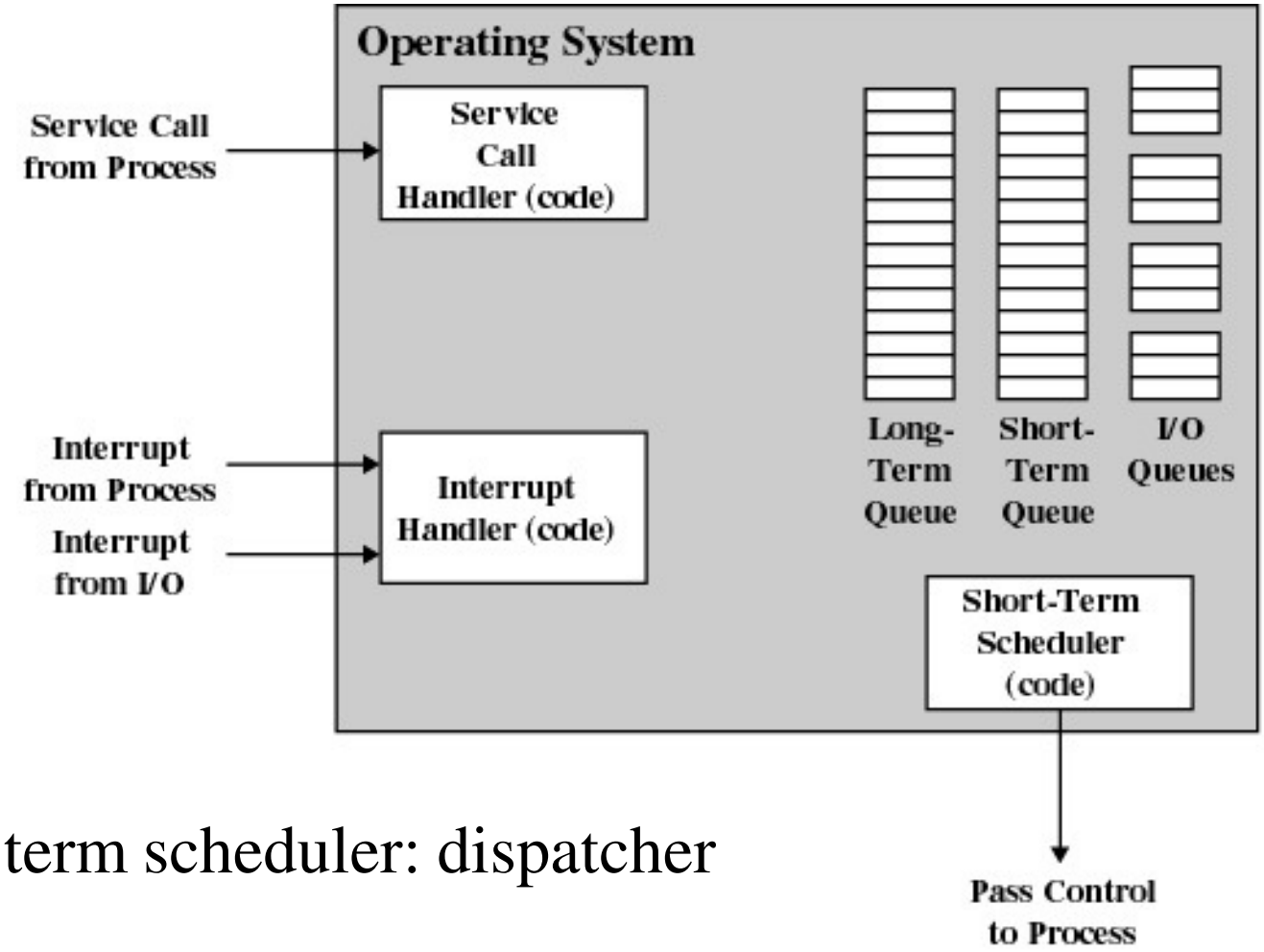
Information Protection and Security

- Access control
  - regulate user access to the system
- Information flow control
  - regulate flow of data within the system and its delivery to users
- Certification
  - proving that access and flow control perform according to specifications

Scheduling and Resource Management

- Fairness
  - give equal and fair access to all processes
- Differential responsiveness
  - discriminate between different classes of jobs
- Efficiency
  - maximize throughput, minimize response time, and accommodate as many uses as possible

Major Elements of Operating System



Short-term scheduler: dispatcher

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

Operating System Design Hierarchy

Level	Name	Objects	Example Operations
13	Shell	User programming environment	Statements in shell language
12	User processes	User processes	Quit, kill, suspend, resume
11	Directories	Directories	Create, destroy, attach, detach, search, list
10	Devices	External devices, such as printer, displays and keyboards	Open, close, read, write
9	File system	Files	Create, destroy, open, close read, write
8	Communications	Pipes	Create, destroy, open. close, read, write

Operating System Design Hierarchy

Level	Name	Objects	Example Operations
7	Virtual Memory	Segments, pages	Read, write, fetch
6	Local secondary store	Blocks of data, device channels	Read, write, allocate, free
5	Primitive processes	Primitive process, semaphores, ready list	Suspend, resume, wait, signal

Resources of a single processor

Operating System Design Hierarchy

Level	Name	Objects	Example Operations
4	Interrupts	Interrupt-handling progs	Invoke, mask, unmask,retry
3	Procedures	Procedures, call stack, display	Mark stack, call, return
2	Instruction Set	Evaluation stack, micro-program interpreter, scalar and array data	Load, store, add, subtract branch
1	Electronic circuits	Registers, gates, buses, etc.	Clear, transfer, activate, complement

Hardware levels

An example: UNIX

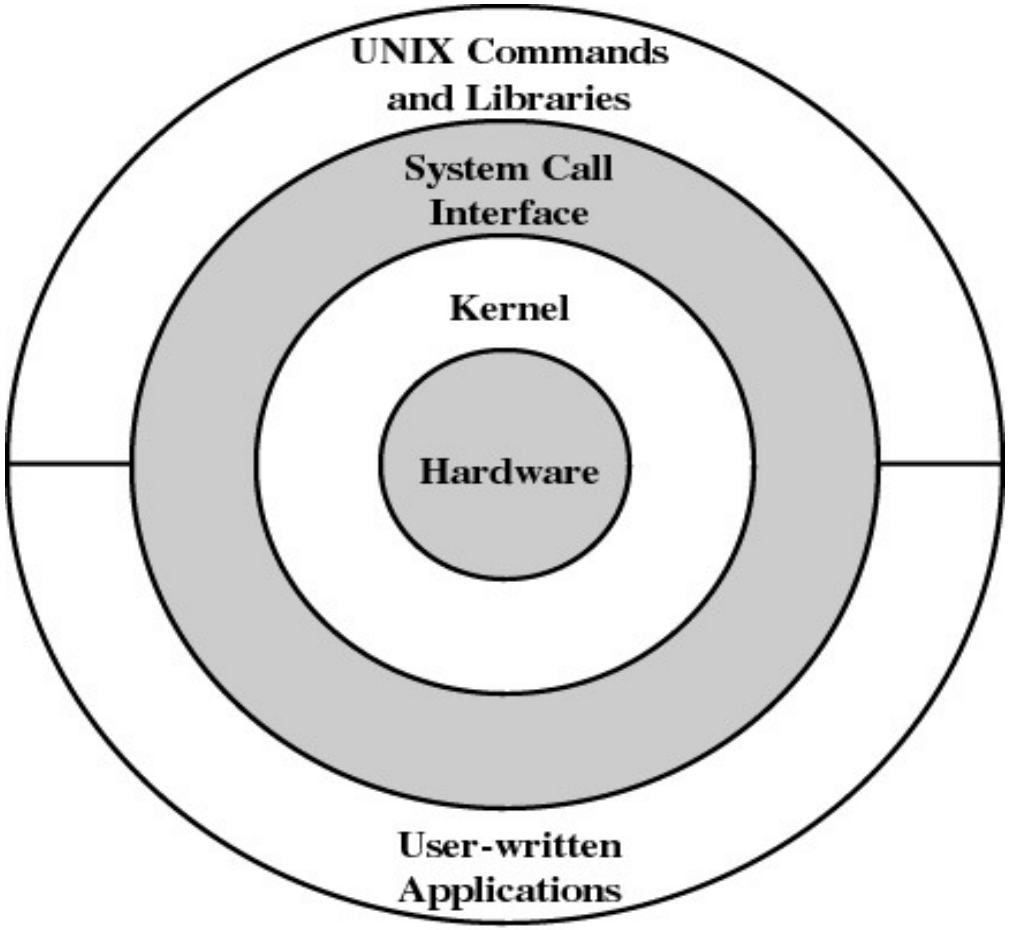


Figure 2.15 General UNIX Architecture

Characteristics of Modern Operating Systems

- Microkernel architecture
  - assigns only a few essential functions to the kernel
    - address space
    - interprocess communication (IPC)
    - basic scheduling
  - Other OS services provided by processes (called servers) that run in user mode
  - Decouple kernel and server development
  - Servers may be customized to specific application or environment requirements

Characteristics of Modern Operating Systems

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

Characteristics of Modern Operating Systems

- Symmetric multiprocessing
  - there are multiple processors
  - these processors share same main memory and I/O facilities
  - All processors can perform the same functions

Characteristics of Modern Operating Systems

- Distributed operating systems
  - provides the illusion of a single main memory and single secondary memory space
  - used for distributed file system

Characteristics of Modern Operating Systems

- Object-oriented design
  - used for adding modular extensions to a small kernel
  - enables programmers to customize an operating system without disrupting system integrity

Traditional UNIX Kernel

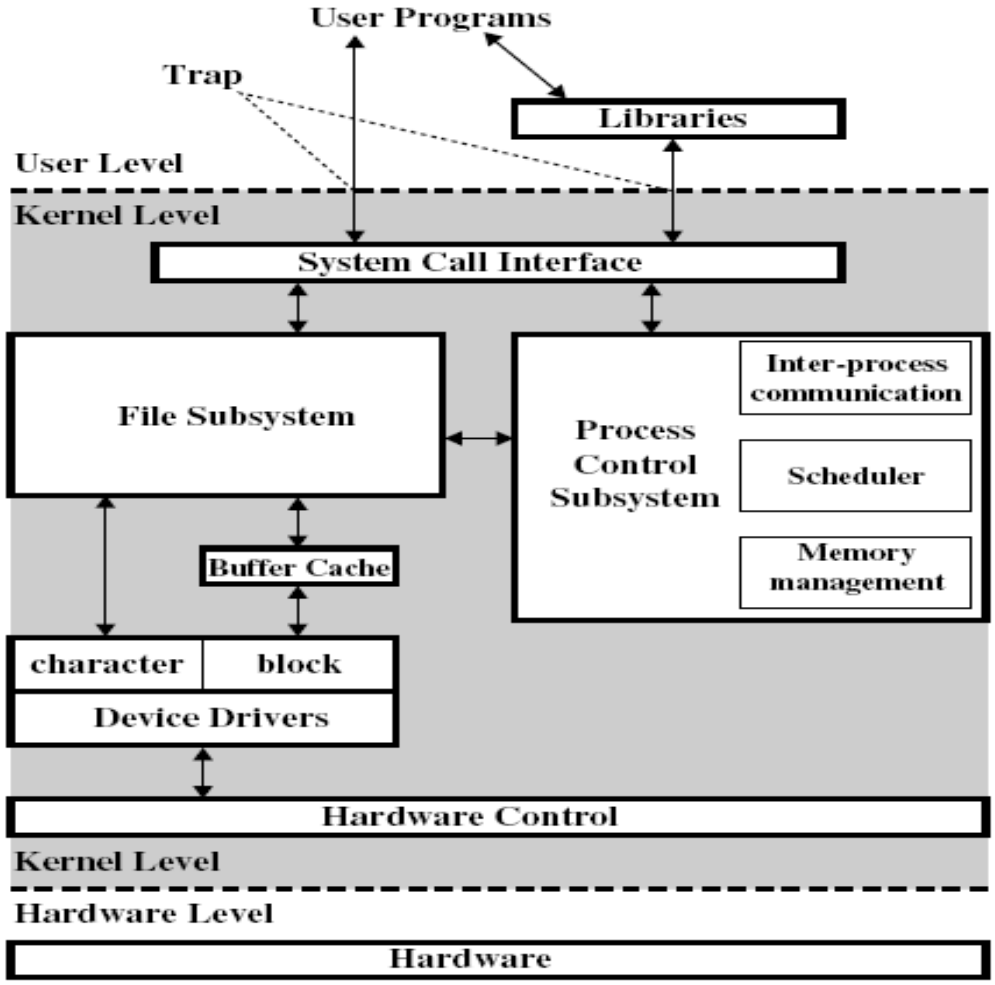


Figure 2.16 Traditional UNIX Kernel [BACH86]

Modern UNIX Kernel

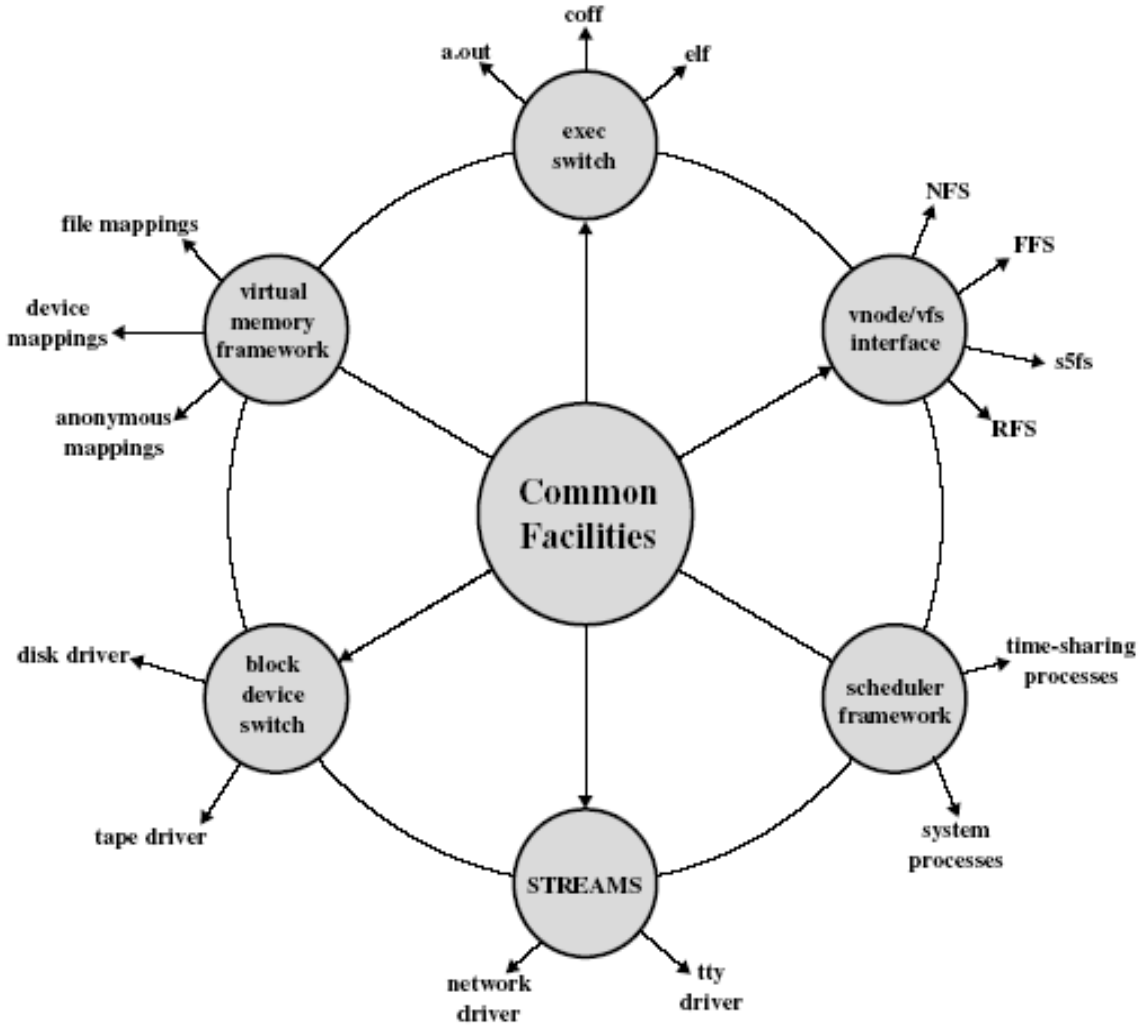


Figure 2.17 Modern UNIX Kernel [VAHA96]