

Chapter 2

Operating System Overview

(based on original slides by Pearson)

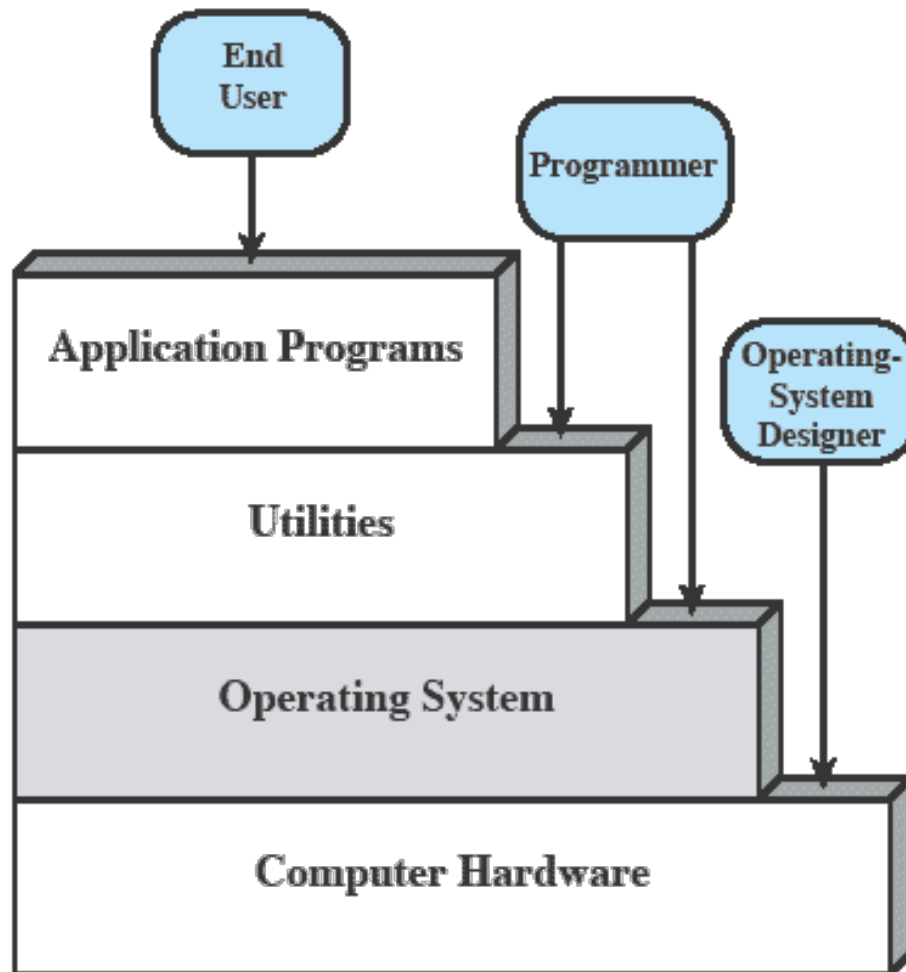
Operating System

A program that controls **the execution** of application programs and acts as an **standardized interface** between applications and hardware.

Operating System Objectives

- Convenience
 - Need no knowledge of the underlying hardware.
 - Provides an abstraction of standard services
- Efficiency
 - Move burden of optimization from developers to tools
- Ability to evolve (→ interfaces & components)
 - Can replace internals as long as the interface stays the same

Layers and Views



Note: doing all this for one application is an incredibly complex task.

Figure 2.1 Layers and Views of a Computer System

Examples of OS Services

- Program development
 - Editors and debuggers & dtrace
- Program execution
 - In multi programming OS
 - Also in micro-controllers (startup routine)
- Access I/O devices
 - Uniform interfaces
 - Reduce required knowledge to read() and write()

Examples of OS Services

- Controlled access to files
 - Basic I/O, but also protection mechanisms in multi-user environments
- System access control
 - Generalized form of controlled resource access
 - Protection from unauthorized access

Examples of OS Services

- Error detection and response
 - Internal and external hardware errors
 - Software errors
 - Operating system cannot grant request of application (e.g., insufficient resources)

Examples of OS Services

- Accounting
 - Collect usage statistics
 - Monitor performance
 - Used to anticipate future enhancements
 - Used for billing purposes
 - Try out 'psacct' and 'sa'

Operating System

- Responsible for managing the resources available in the computer
- Functions same way as ordinary computer software
 - It is a program that is executed
- Operating system relinquishes control of the processor

OS as Resource Manager

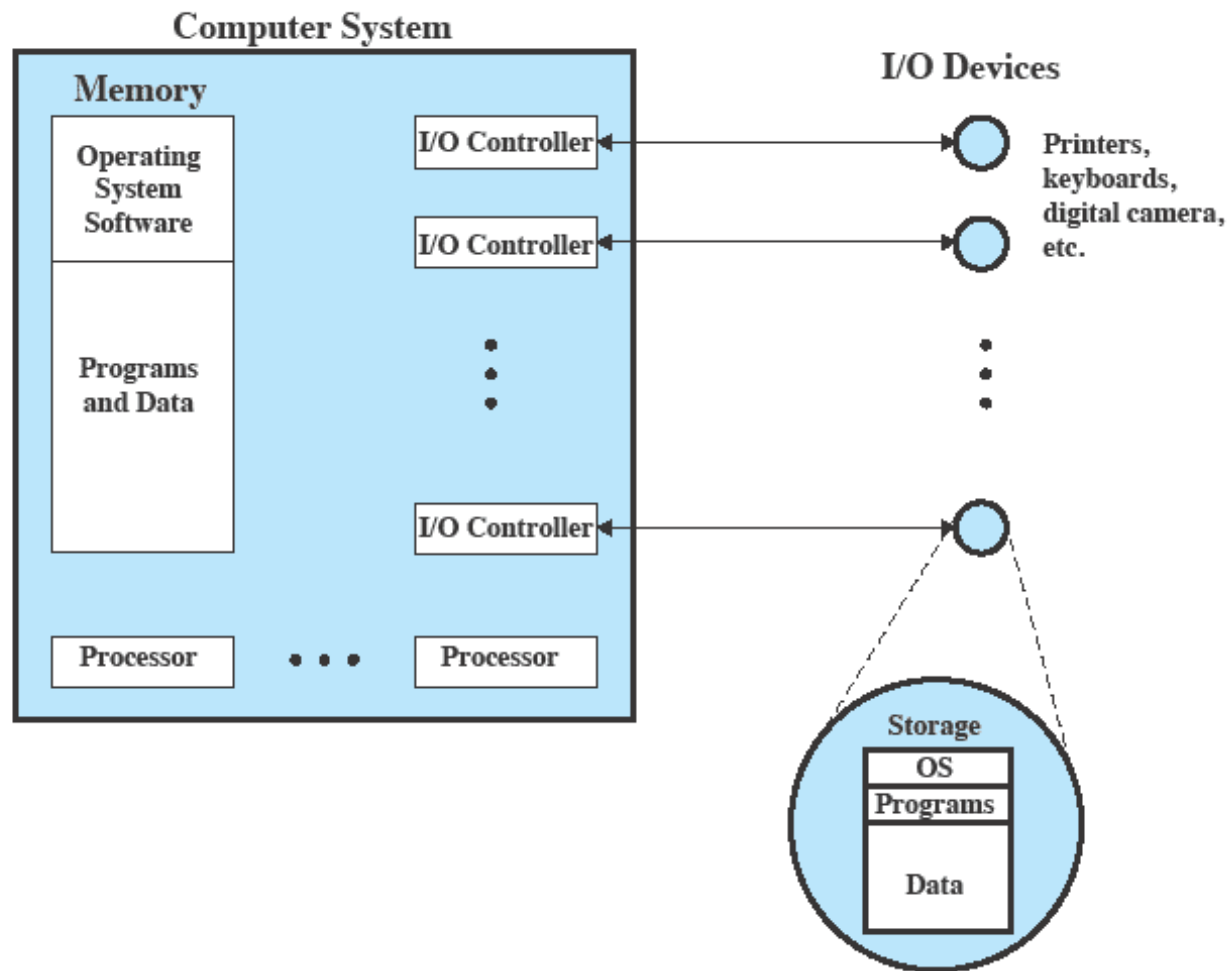


Figure 2.2 The Operating System as Resource Manager

Kernel

- Portion of operating system that is in main memory
- Contains most frequently used functions
- Also called the nucleus
- Embedded OSs are often only a nucleus.

Ease of Evolution in OSs

- Reasons for requiring the evolution:
 - Hardware upgrades plus new types of hardware
 - New services
 - Fixes

Evolution of OSs

- Serial processing (40-50s)
 - No operating system
 - Machines run from a console with display lights, toggle switches, input device, and printer

Evolution of OSs

- Serial processing shortcomings
 - Schedule time
 - Reserve time by means of hard copy sign-up sheets
 - Non-optimal work environment (forced interruptions)
 - Long lead times for programs
 - Setup included loading the compiler, source program, saving compiled program, and loading and linking

Evolution of OSs

- Simple batch system (goal: improve utilization)
 - Monitor
 - Software that controls the sequence of events
 - Batch jobs together
 - Program returns control to monitor when finished

Job Control Language

- 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
- Timer (duration)
 - Prevents a job from monopolizing the system

Hardware Features

- Privileged instructions
 - Certain machine level instructions can only be executed by the monitor (e.g., IO instructions)
- Interrupts
 - Early computer models did not have this capability

Modes of Operation

- Reason: protect users from each other, protect the kernel from users
[prevent cheating with scheduler]
- Two modes:
 - User mode
 - Certain instructions may not be executed
 - Kernel mode (monitor)
 - Privileged instructions
 - Access to protected memory areas

Batch Systems Not Good Enough

Automatic job sequencing improves throughput, but IO is still slow.

Read one record from file	15 μ s
Execute 100 instructions	1 μ s
Write one record to file	<u>15 μs</u>
TOTAL	31 μ s

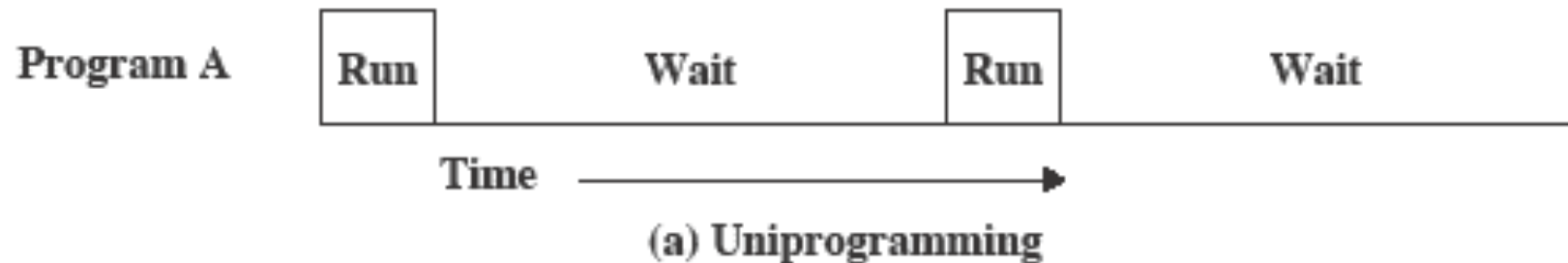
$$\text{Percent CPU Utilization} = \frac{1}{31} = 0.032 = 3.2\%$$

96.8% waiting!

Consider EEPROM: takes several ms (!) to write, no interrupts allowed!

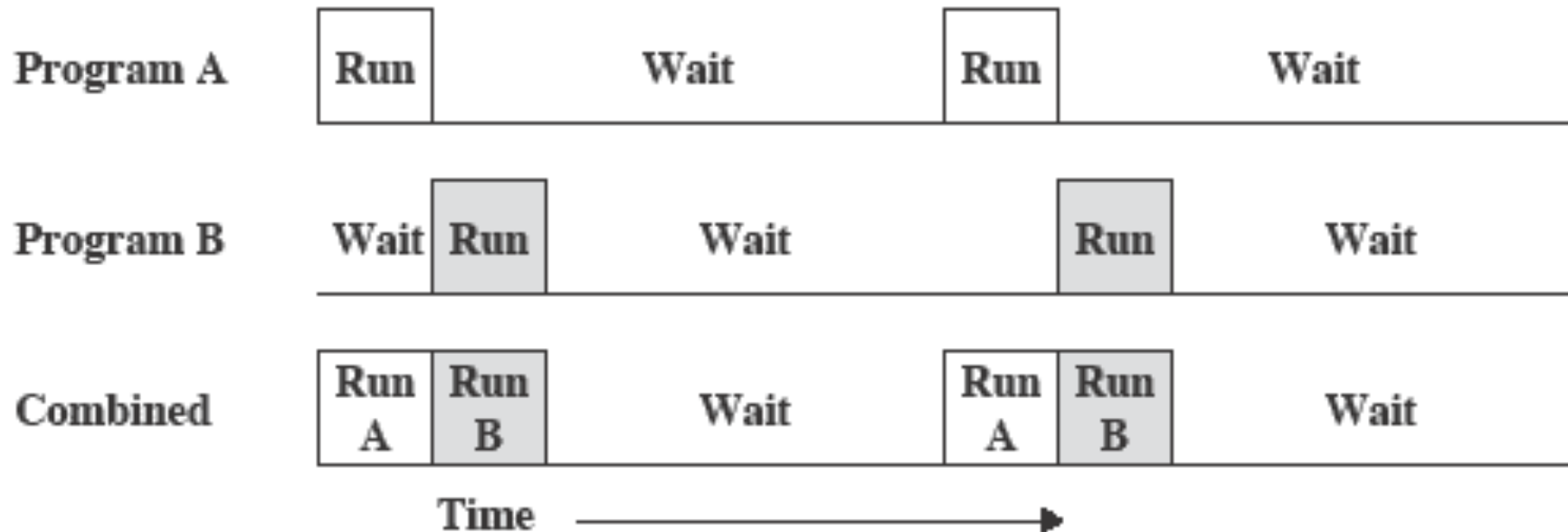
Uniprogramming

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



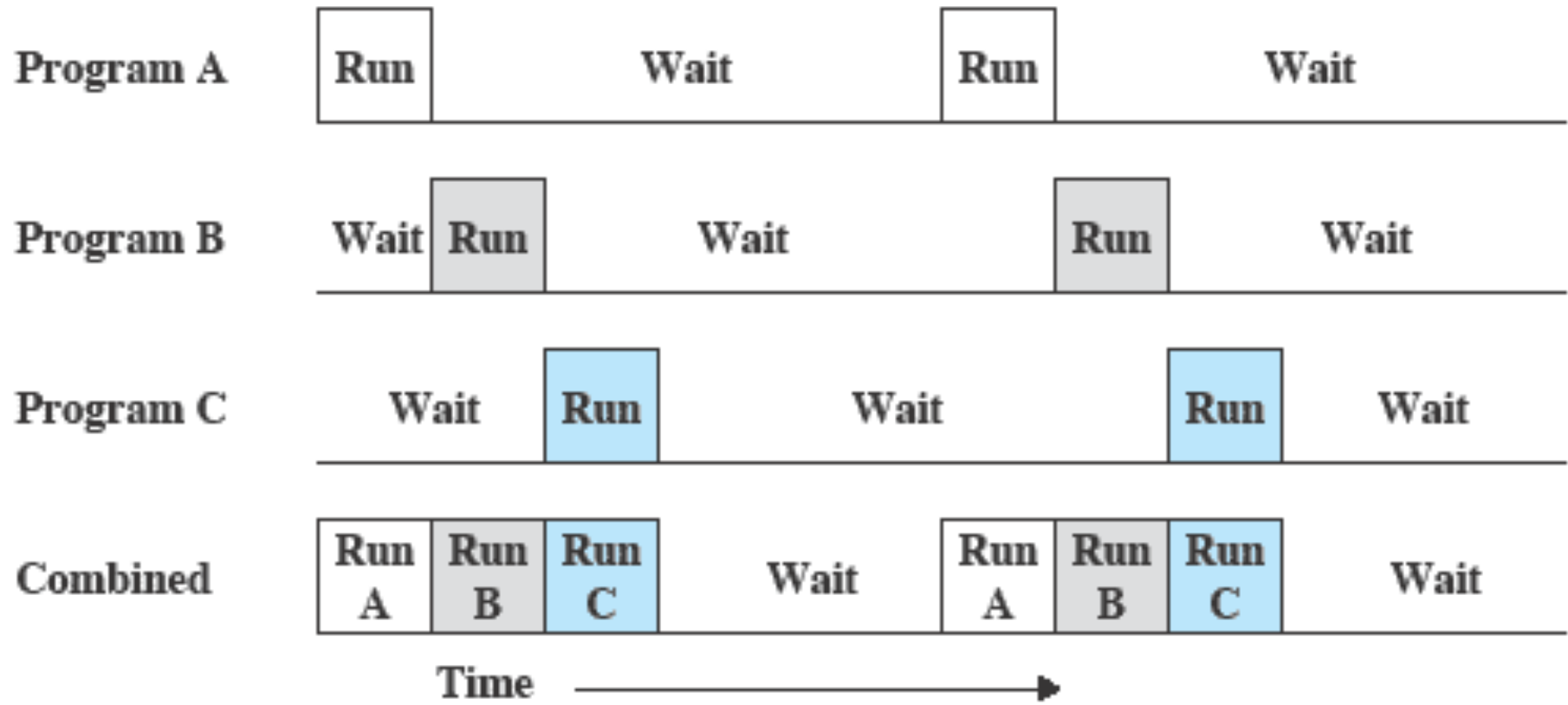
Multiprogramming

- 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

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

Utilization Histograms

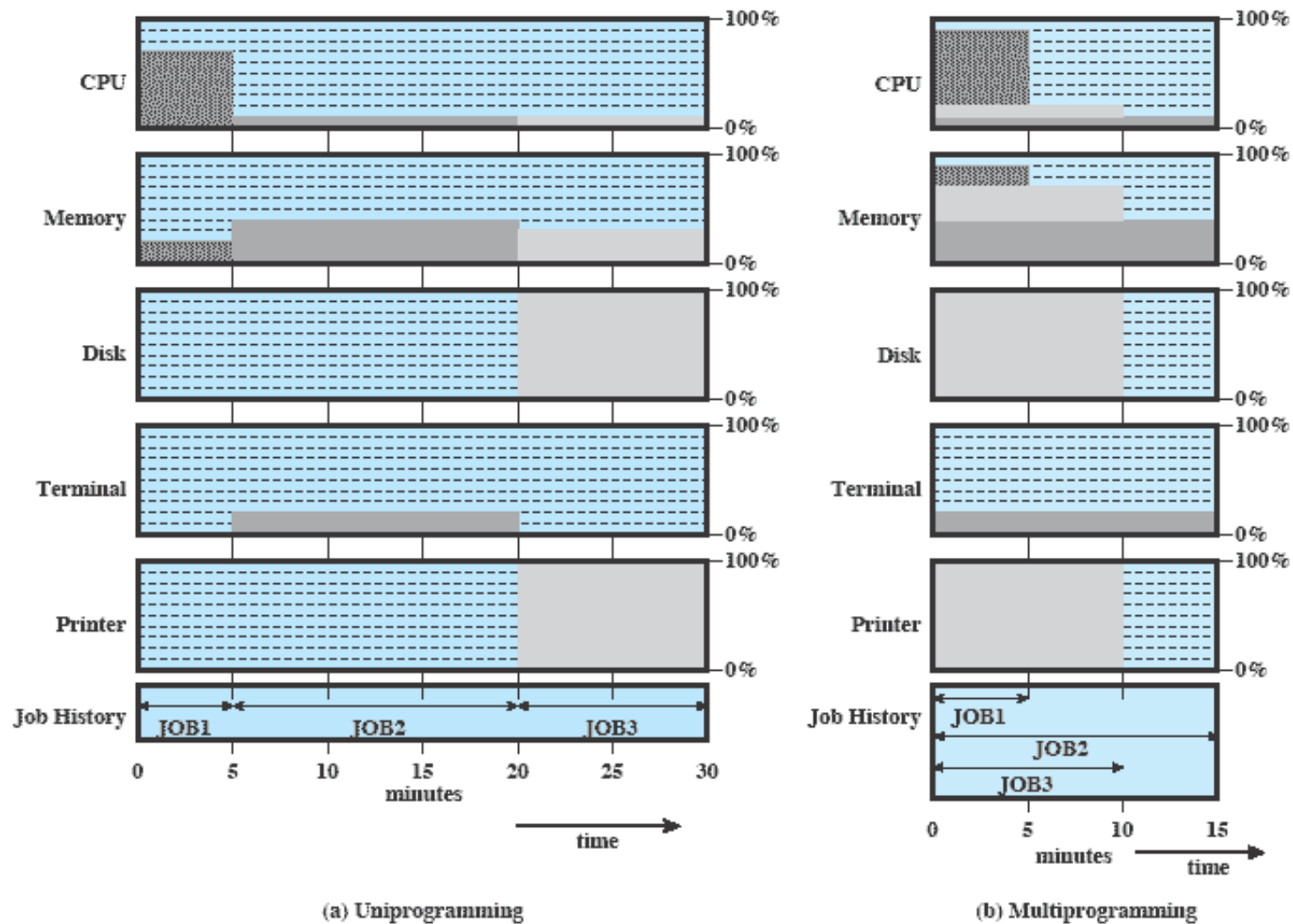


Figure 2.6 Utilization Histograms

Effects of Multi-Programming

	Uniprogramming	Multiprogramming
Processor use	20%	40%
Memory use	33%	67%
Disk use	33%	67%
Printer use	33%	67%
Elapsed time	30 min	15 min
Throughput	6 jobs/hr	12 jobs/hr
Mean response time	18 min	10 min

Time Sharing Systems

- Multiple users simultaneously access the system through terminals
 - Share time on the CPU
- Using multiprogramming to handle multiple interactive jobs
- Processor's time is shared among multiple users

Batch Multiprogramming vs Time Sharing

Table 2.3 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

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

- (Virtualization)

Process (possible definitions)

- 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

Process (possible definitions)

- A unit of activity characterized by
 - A single sequential thread of execution
 - A current state
 - An associated set of system resources

Difficulties with Designing System Software

- Mix: multiple programs, multiple threads, interrupts, IO, shared resources ...
- Common problems:
 - Improper synchronization (signaling availability of data → lost data or empty read)
 - Failed mutual exclusion (state corruption on shared memory)
 - Nondeterminate program operation (interference among programs in the OS due to memory allocation, IO access, ...)
 - Deadlocks (resource access)

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

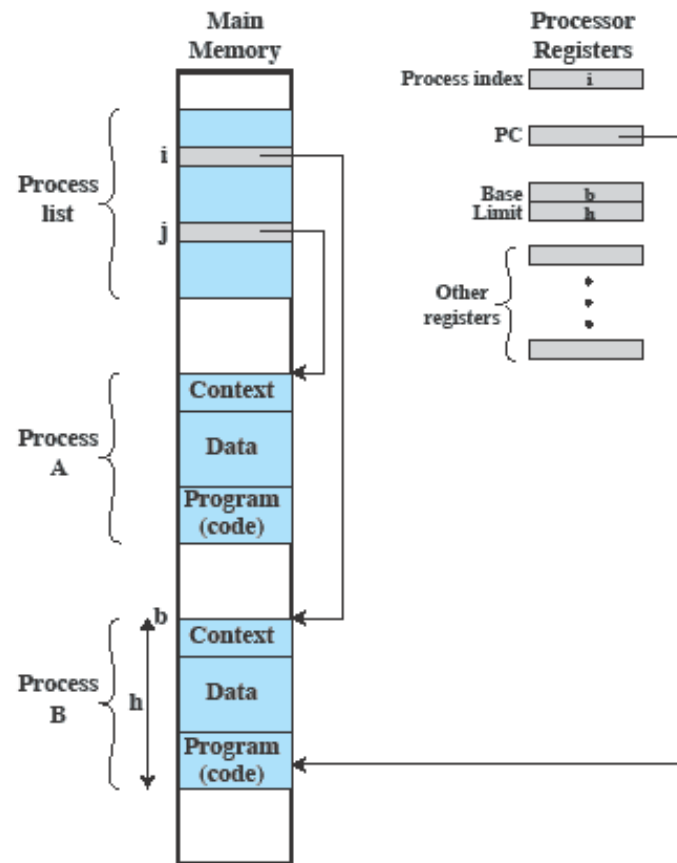


Figure 2.8 Typical Process Implementation

Responsibility of the OS wrt. Memory Management

- Process isolation
- Automatic allocation and management
(you allocate 1kb but you don't care how it's actually done)
- Support of modular programming
(swap program code)
- Protection and access control
(shared memory)
- Long-term storage

Virtual Memory

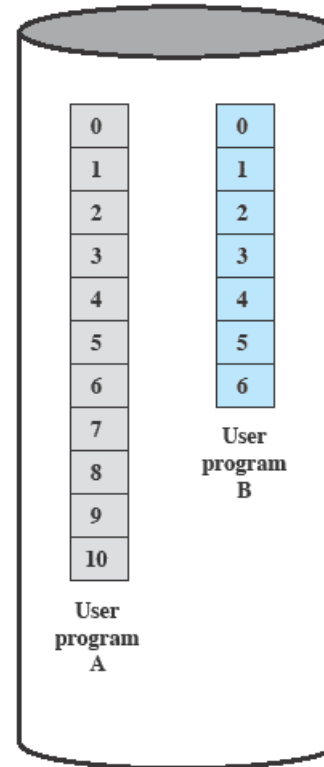
- Allows programmers to address memory from a logical point of view without regard to how much memory is available
- Virtual address: page number plus offset in the page
- Real address: physical address

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

A.1			
	A.0	A.2	
	A.5		
B.0	B.1	B.2	B.3
		A.7	
	A.9		
		A.8	
	B.5	B.6	

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

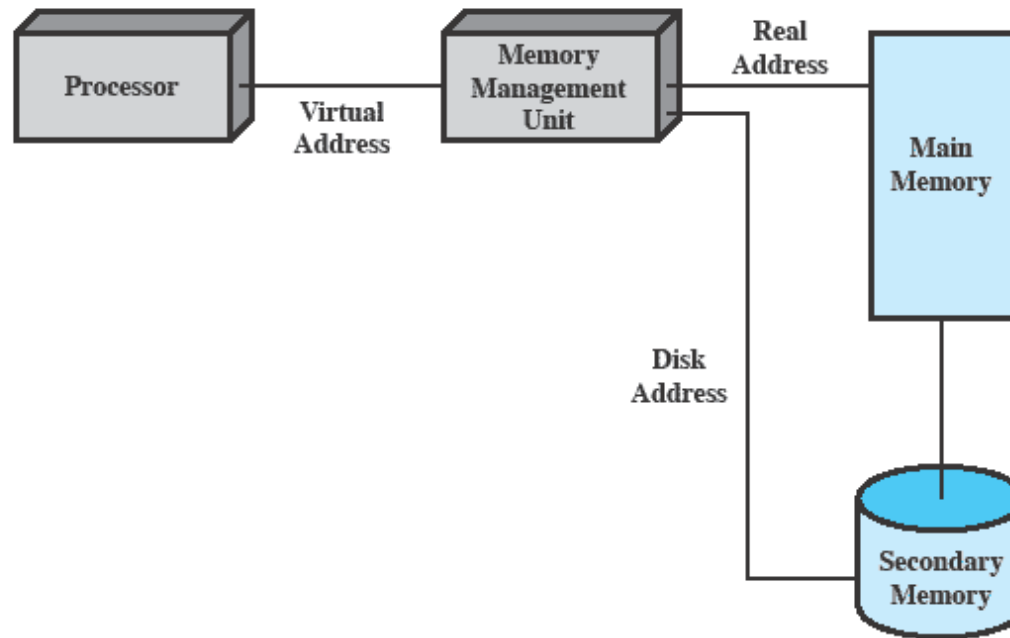


Figure 2.10 Virtual Memory Addressing

Information Protection and Security

- Availability
 - Concerned with protecting the system against interruption
- Confidentiality
 - Assuring that users cannot read data for which access is unauthorized

Information Protection and Security

- 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
 - Often called QoS
 - Necessity for real-time systems

Scheduling and Resource Management

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

Key Elements of an Operating System

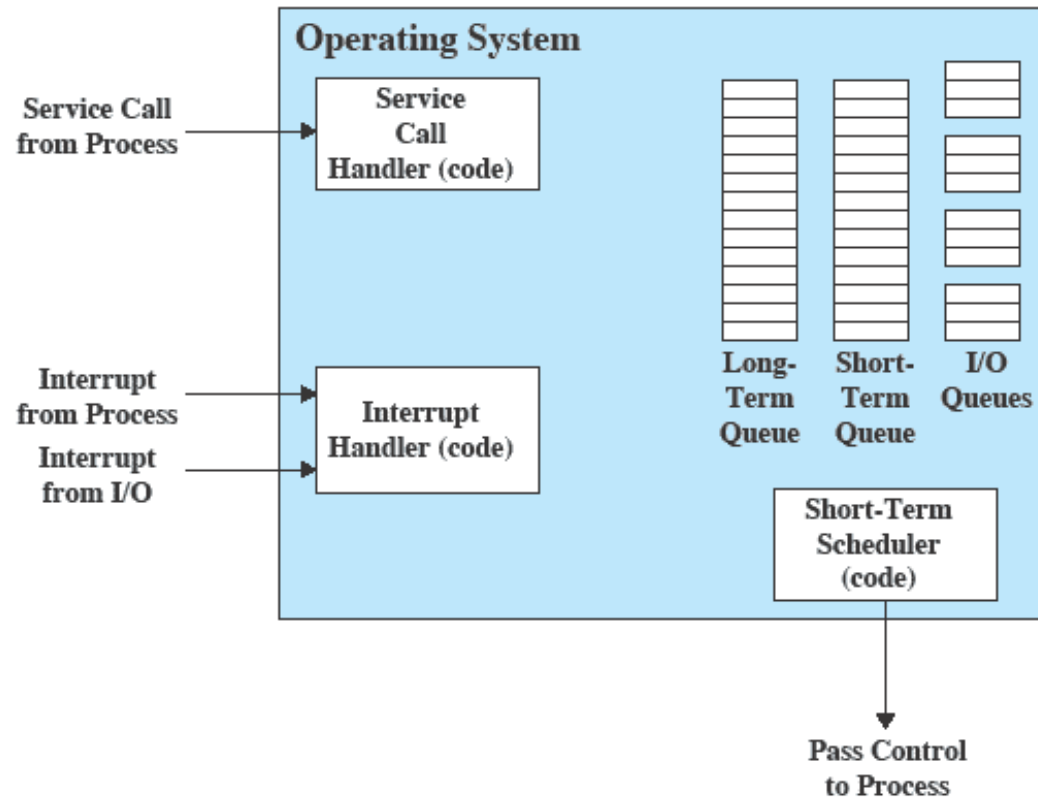


Figure 2.11 Key Elements of an Operating System for Multiprogramming

Problems with OSs

- Usually late on delivery
- Latent bugs (not quite banana products, but already close)
- Unexpectedly slow performance
- Security vulnerabilities
- => good structure might help

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

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 printers, 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
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 processes, semaphores, ready list	Suspend, resume, wait, signal
4	Interrupts	Interrupt-handling programs	Invoke, mask, unmask, retry
3	Procedures	Procedures, call stack, display	Mark stack, call, return
2	Instruction set	Evaluation stack, microprogram interpreter, scalar and array data	Load, store, add, subtract, branch
1	Electronic circuits	Registers, gates, buses, etc.	Clear, transfer, activate, complement

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

Levels

- 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

Concepts with Multiprogramming

- 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

Deal with External Objects

- 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 OS for the user

Modern Operating Systems

- Microkernel architecture
 - Assigns only a few essential functions to the kernel
 - Address spaces
 - Interprocess communication (IPC)
 - Basic scheduling
 - All other elements are in user space
 - QNX

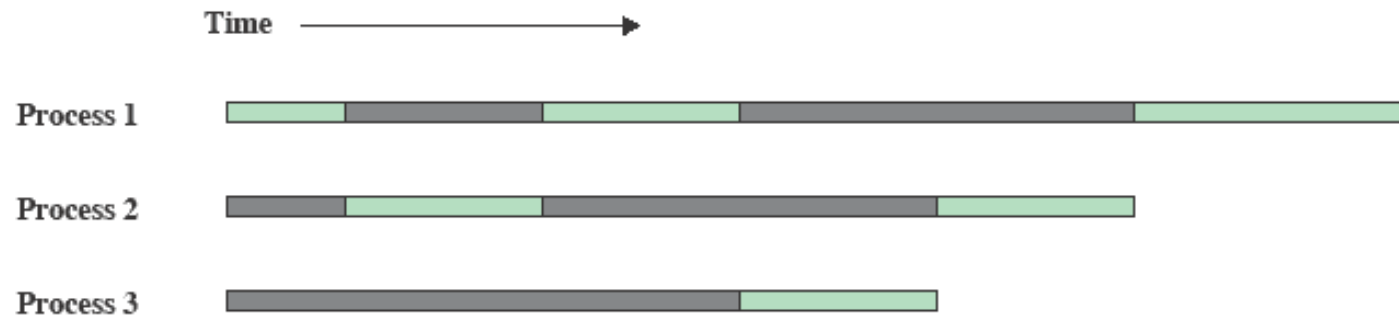
Modern Operating Systems

- 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

Modern Operating Systems

- 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



(a) Interleaving (multiprogramming, one processor)



(b) Interleaving and overlapping (multiprocessing; two processors)

Blocked Running

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
- Network on chip

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