Operating System Overview

Chapter 1.5 – 1.9
Learning Outcomes

• A high-level understanding of the structure of operating systems, applications, and the relationship between them.
• Some knowledge of the services provided by operating systems.
• Exposure to some details of major OS concepts.
Operating System

• A program that controls execution of applications
  – The resource manager

• An interface between applications and hardware
  – The extended machine
Structure of a Computer System

User Mode

Operating System

Kernel Mode

Hardware
Structure of a Computer System

User Mode

Kernel Mode

Operating System

Hardware

Interacts via load and store instructions to CPU and device registers, and interrupts
Structure of a Computer System

User Mode

Application

System Libraries

Interaction via function calls to library procedures

Kernel Mode

Operating System

Hardware
Structure of a Computer System

User Mode
- Application
- System Libraries

Interaction via System Calls

Kernel Mode
- Operating System
- Hardware
A note on System Libraries

- System libraries are just that, libraries of support functions (procedures, subroutines)
  - Only a subset of library functions are actually systems calls
    - strcmp(), memcpy(), are pure library functions
    - open(), close(), read(), write() are system calls
  - System call functions are in the library for convenience
Operating System Objectives

• Convenience
  – Make the computer more convenient to use

• Abstraction
  – Hardware-independent programming model

• Efficiency
  – Allows the computer system to be used in an efficient manner

• Ability to evolve
  – Permit effective development, testing, and introduction of new system functions without interfering with existing services

• Protection
Services Provided by the Operating System

• Program development
  – Editors, compilers, debuggers
    • Not so much these days

• Program execution
  – Load a program and its data

• Access to I/O devices

• Controlled access to files
  – Access protection

• System access
  – User authentication
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
Operating System Software

• Fundamentally, OS functions the same way as ordinary computer software
  – It is a program that is executed (just like apps)
  – It has more privileges

• Operating system relinquishes control of the processor to execute other programs
  – Reestablishes control after
    • System calls
    • Interrupts (especially timer interrupts)
Kernel

- Portion of the operating system that is running in *privileged mode*
- Usually resident in main memory
- Contains fundamental functionality
  - Whatever is required to implement other services
  - Whatever is required to provide security
- Contains most-frequently used functions
- Also called the nucleus or supervisor
Major OS Concepts

• Processes
• Concurrency and deadlocks
• Memory management
• Files
• Information Security and Protection
• Scheduling and resource management
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 resource ownership
- A unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources
  - Nowadays the execution abstraction is separated out: *Thread*
  - Single process can contain many threads
Process

- Consist of three segments
  - Text
    - contains the code (instructions)
  - Data
    - Global variables
  - Stack
    - Activation records of procedure
    - Local variables

- Note:
  - data can dynamically grow up
  - The stack can dynamically grow down
Process

• Consists of three components
  – An executable program
    • text
  – Associated data needed by the program
    • Data and stack
  – Execution context of the program
    • All information the operating system needs to manage the process
      – Registers, program counter, stack pointer, etc…
    • A multithread program has a stack and execution context for each thread
Multiple processes creates concurrency issues

(a) A potential deadlock. (b) an actual deadlock.
Memory Management

• The view from thirty thousand feet
  – Process isolation
    • Prevent processes from accessing each other's data
  – Automatic allocation and management
    • Don't want users to deal with physical memory directly
  – Support for modular programming
  – Protection and access control
    • Still want controlled sharing
  – Long-term storage
  – OS services
    • Virtual memory
    • File system
Virtual Memory

- Allows programmers to address memory from a logical point of view
  - Gives apps the illusion of having RAM to themselves
  - Logical addresses are independent of other processes
  - Provides isolation of processes from each other
- Can overlap execution of one process while swapping in/out others.
Virtual Memory Addressing

![Virtual Memory Addressing Diagram]

**Figure 2.10** Virtual Memory Addressing
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 anywhere in main memory
- A page may actually exist only on disk
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.

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
File System

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

The diagram illustrates a directory structure with the following hierarchy:

- Root directory
  - Students
    - Robbert
    - Matty
    - Leo
  - Faculty
    - Prof. Brown
    - Prof. Green
    - Prof. White
    - Courses
      - CS101
      - CS105
    - Papers
    - Grants
    - Committees
      - SOSP
      - COST-11
Information Protection and Security

• Access control
  – regulate user access to the system
  – Involves authentication

• Information flow control
  – regulate flow of data within the system and its delivery to users
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
Operating System Structure

- The layered approach
  a) Processor allocation and multiprogramming
  b) Memory Management
  c) Devices
  d) File system
  e) Users

- Each layer depends on the inner layers
Operating System Structure

• In practice, layering is only a guide
  – Operating Systems have many interdependencies
    • Scheduling on virtual memory
    • Virtual memory on I/O to disk
    • VM on files (page to file)
    • Files on VM (memory mapped files)
    • And many more…
The Monolithic Operating System Structure

- Also called the “spaghetti nest” approach
  - Everything is tangled up with everything else.
- Linux, Windows,
  ....
The Monolithic Operating System Structure

• However, some reasonable structure usually prevails
UNIX

• Provides a good hardware abstraction
  – Everything is a file (mostly)
• Runs on most hardware
• Comes with a number of user services and interfaces
  – shell
  – C compiler
Traditional UNIX Structure

- UNIX Commands and Libraries
- System Call Interface
- Kernel
- Hardware
- User-written Applications

Figure 2.15 General UNIX Architecture
Traditional UNIX Kernel
Microkernel-based Systems

- Assigns only a few essential functions to the kernel
  - Address space
  - Interprocess Communication (IPC)
  - Basic scheduling
  - Minimal hardware abstraction
- Other services implemented by user-level servers
- Traditional “system calls” become IPC requests to servers
- Extreme view of a microkernel
  - A feature is only allowed in the kernel if required for security
Server
File

documents
windows
symbols
stacks & heaps
arrays & structures
variables

threads
coroutines
modules
procedures
statements

Address Space  Thread
μ-kernel

Bit  Byte  Word  Register
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