

Computer System Organization

CS 256/456

Dept. of Computer Science, University of Rochester

1/23/2006

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Overview

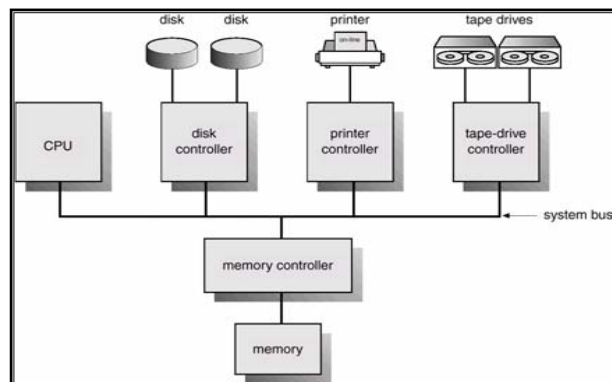
- Recap of last class
 - What is operating system (architecturally)?
 - Functionalities of operating system?
 - Types of operating systems.
- Computer hardware issues
 - Hardware interface to OS
 - Hardware support for OS mechanisms
- Operating system organization
 - OS components
 - OS architectures

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Computer-System Architecture

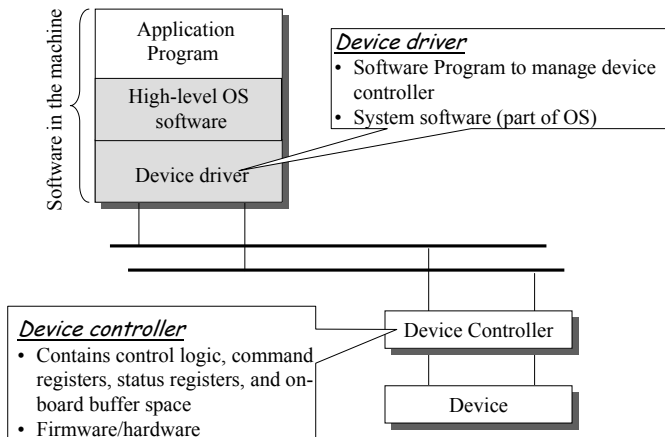


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The Device-Controller-Software Relationship



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I/O Operations

- How is I/O done?
 - I/O devices are much slower than CPU
- Synchronous (polling)
 - After I/O starts, busy polling the device status register until it shows the operation completes.
- Asynchronous (interrupt-driven)
 - After I/O starts, control returns to user program without waiting for I/O completion.
 - Device controller later informs CPU that it has finished its operation by causing an *interrupt*.
 - When an interrupt occur, current execution is put on hold; the CPU jumps to a service routine called "interrupt handler".

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System Protection

- User programs (programs not belonging to the OS) are generally not trusted
 - A user program may use unfair amount of resource
 - A user program may maliciously cause other programs or the OS to fail
- Need protection against untrusted user programs; the system must differentiate between at least two modes of operations
 1. *User mode* - execution of user programs
 - untrusted
 - not allowed to have complete/direct access to hardware resources
 2. *Kernel mode* (also *system mode* or *monitor mode*) - execution of the operating system
 - trusted
 - allowed to have complete/direct access to hardware resources
- Hardware support is needed in such protection

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Memory Protection

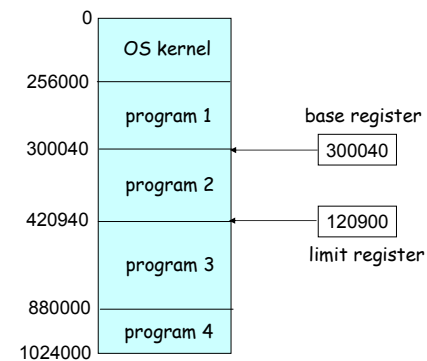
- Goal of memory protection?
 - A user program can't use arbitrary amount of memory
 - A user program can't access data belonging to the operating system or other user programs.
- How to achieve memory protection?
 - Indirect memory access
 - Memory access with a virtual address which needs to be translated into physical address
 - Add two registers that determine the range of legal addresses a program may access:
 - Base register - holds the smallest legal physical memory address
 - Limit register - contains the size of the range
 - Memory outside the defined range is protected.

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Hardware Address Protection



- Address of each memory address is checked against "base" and "base+limit"
- Trap to the OS kernel if it falls outside of the range (an exception)

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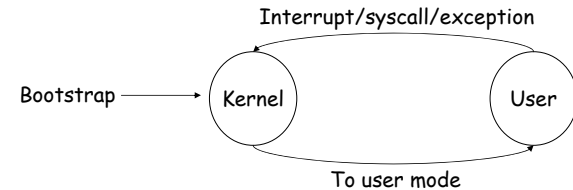
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Protection of I/O Devices

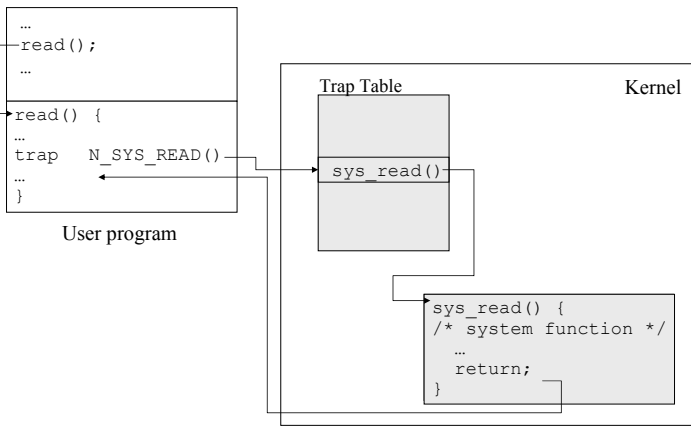
- User programs are not allowed to directly access I/O devices
 - Special I/O instructions can only be used in kernel mode
 - Controller registers can only be accessed in kernel mode
- So I/O interrupt handlers must run in kernel mode.
- How does a user program perform I/O?

Transition between User/Kernel Mode

- When does the machine run in kernel mode?
 - after machine boot
 - interrupt handler
 - system call
 - exception



System Call Using the Trap Instruction



CPU Protection

- Goal of CPU protection
 - A user program can't hold the CPU for ever
- *Timer* - interrupts computer after specified period to ensure the OS kernel maintains control.
 - Timer is decremented every clock tick.
 - When timer reaches the value 0, an interrupt occurs.
 - CPU time sharing is implemented in the timer interrupt.

Operation System Organization

- System Components
 - process management
 - memory management
 - I/O system
 - file and storage
 - networking, ...
- Operating System Architectures
 - monolithic architecture
 - microkernel architecture
 - layered architecture
 - virtual machines

Process Management

- A *process* is a program in execution. A process needs certain resources, including CPU time, memory, files, and I/O devices, to accomplish its task.
- OS responsibilities for process management:
 - Process creation and deletion.
 - Process scheduling, suspension, and resumption.
 - Process synchronization, inter-process communication

Memory Management

- Memory
 - A large array of addressable words or bytes.
 - A data repository shared by the CPU and I/O devices.
- OS responsibility for memory management:
 - Allocate and deallocate memory space as requested.
 - Keep track of which parts of memory are currently being used and by whom.
 - Efficient utilization when the memory resource is heavily competed.

I/O System Management

- A computer needs I/O to interact with outside world:
 - Console/terminal
 - Non-volatile secondary storage - disks
 - Networking
- The I/O system consists of:
 - A buffer-caching system
 - A general device-driver interface
 - Drivers for specific hardware devices

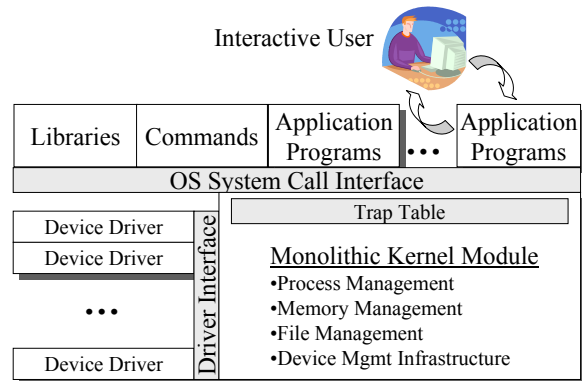
File and Secondary Storage Management

- A file is a collection of information defined by its user. Commonly, both programs and data are stored as files.
- OS responsibility for file management:
 - Manipulation of files and directories.
 - Map files onto (nonvolatile) secondary storage - disks.
- OS responsibility for disk management:
 - Free space management and storage allocation.
 - Disk scheduling.
- They are not all always together
 - Not all files are mapped to secondary storage!
 - Not all disk space are used for the file system!

Networking (Distributed Systems)

- A *distributed system*
 - A collection of processors that do not share memory.
 - Processors are connected through a communication network.
 - Communication takes place using a *protocol*.
- A distributed system provides user access to various shared system resources, which allows:
 - Computation speed-up
 - Enhanced reliability
- How much of it is in OS?

OS Architecture: Monolithic Structure



Most modern OSes fall into this category!

Microkernel System Architecture

- Microkernel architecture:
 - Moves as much from the kernel into "user" space.
 - Communication takes place between user modules using message passing.
- What must be in the kernel and what can be in user space?
 - Mechanisms determine how to do something.
 - Policies decide what will be done.
- Benefits:
 - More reliable (less code is running in kernel mode)
 - More secure (less code is running in kernel mode)
- Disadvantage?

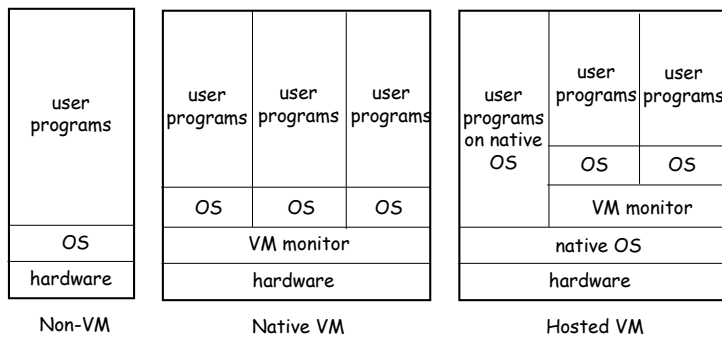
Layered Structure

- Layered structure
 - The operating system is divided into a number of layers (levels), each built on top of lower layers.
 - The bottom layer (layer 0), is the hardware.
 - The highest (layer N) is the user interface.
 - Decreased privileges for higher layers.
- Benefits:
 - more reliable
 - more secure
 - more flexibility, easier to extend
- Disadvantage?
 - Weak integration results in performance penalty (similar to the microkernel structure).

Virtual Machines

- A virtual machine
 - **Virtualization:** It is a piece of software that provides an interface *identical* to the underlying bare hardware.
 - **Multiplexing:** It provides several copies of this interface on top of a single piece of hardware.
 - **Resource management:** The resources of the physical computer are shared to create the virtual machines.
 - e.g., CPU scheduling can create the appearance that each piece of upper-layer software has its own processor.
- It is not an operating system in the strict sense
 - It is a resource manager, but not an extended machine

VM Models



Usage of Virtual Machines

- Running several different OSes on a single machine
- Education
- Research and development of operating systems and computer architecture
- Enhanced reliability and security
- Allow general management of "machines" at software level

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