CSC 4103 - Operating Systems
Spring 2007

Lecture - III
- OS Design & Implementation - Processes

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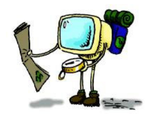
Roadmap

- OS Design and Implementation
  - Different Design Approaches
  - Virtual Machines
- Processes
  - Basic Concepts
  - Context Switching
  - Process Queues
  - Process Scheduling
  - Process Termination



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Operating System Design and Implementation

- Start by defining goals and specifications
- Affected by choice of hardware, type of system
  - Batch, time shared, single user, multi user, distributed
- *User* goals and *System* goals
  - User goals – operating system should be convenient to use, easy to learn, reliable, safe, and fast
  - System goals – operating system should be easy to design, implement, and maintain, as well as flexible, reliable, error-free, and efficient
- No unique solution for defining the requirements of an OS
  - → Large variety of solutions
  - → Large variety of OS

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Operating System Design and Implementation (Cont.)

- Important principle: to separate policies and mechanisms

  Policy: What will be done?
  Mechanism: How to do something?
- Eg. to ensure CPU protection
  - Use Timer construct (mechanism)
  - How long to set the timer (policy)
- The separation of policy from mechanism is allows maximum flexibility if policy decisions are to be changed later

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OS Design Approaches

- Simple Structure
- Layered Approach
- Microkernels
- Modules

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Simple Structure

- No well defined structure
- Start as small, simple, limited systems, and then grow
- MS-DOS – written to provide the most functionality in the least space
  - Not divided into modules
  - Its interfaces and levels of functionality are not well separated
  - e.g. application programs can access low level drivers directly
    - ➔ Vulnerable to errant (malicious) programs

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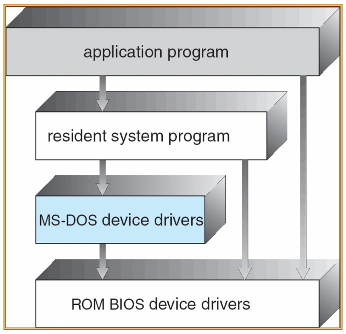
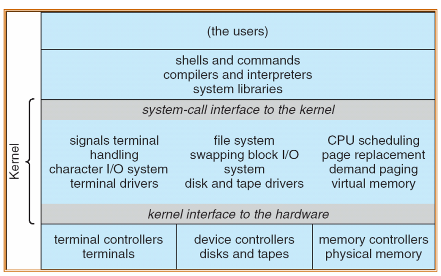
MS-DOS Layer Structure



UNIX

- UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts
  - Systems programs
  - The kernel
    - Consists of everything below the system-call interface and above the physical hardware
    - Provides the file system, CPU scheduling, memory management, and other operating-system functions; a large number of functions for one level

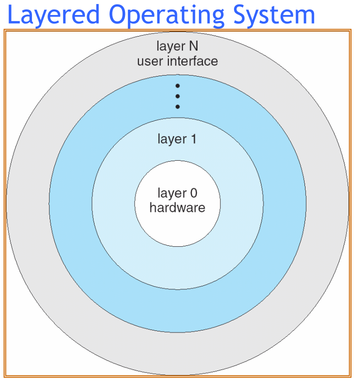
UNIX System Structure



Layered Approach

- 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.
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers
  - GLUnix: Global Layered Unix

Layered Operating System



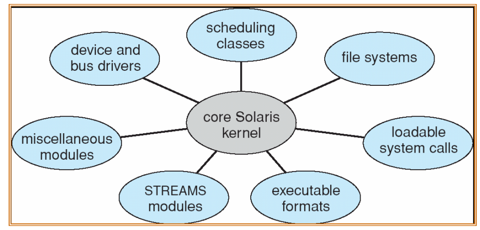
Microkernel System Structure

- Move all non-essential components from the kernel into "*user*" space
- Main function of microkernel: Communication between client programs and various services which are run in user space
  - Uses message passing (never direct interaction)
- Benefits:
  - Easier to extend the OS
  - Easier to port the OS to new architectures
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication
- Examples: QNX, Tru64 UNIX

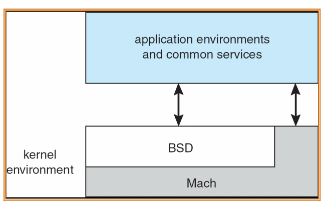
Modules

- Most modern operating systems implement kernel modules
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
- Overall, similar to layers but more flexible
  - Any module can call any other module

Solaris Modular Approach



Mac OS X Structure - Hybrid



- BSD: provides support for command line interface, networking, file system, POSIX API and threads
- Mach: memory management, RPC, IPC, message passing

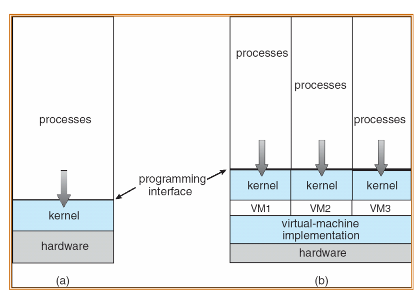
Virtual Machines

- A *virtual machine* takes the layered approach to its logical conclusion. It treats hardware and the operating system kernel as though they were all hardware
- A virtual machine provides an interface *identical* to the underlying bare hardware
- The operating system creates the illusion of multiple processes, each executing on its own processor with its own (virtual) memory

Virtual Machines (Cont.)

- The resources of the physical computer are shared to create the virtual machines
  - CPU scheduling can create the appearance that users have their own processor
  - Spooling and a file system can provide virtual card readers and virtual line printers
  - A normal user time-sharing terminal serves as the virtual machine operator's console

Virtual Machines (Cont.)

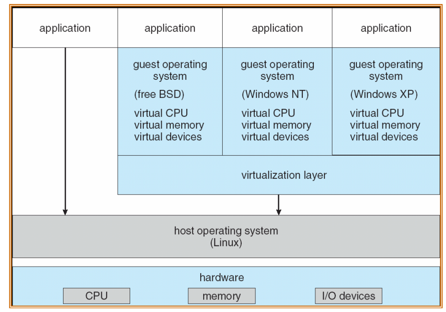


(a) Nonvirtual machine (b) Virtual machine

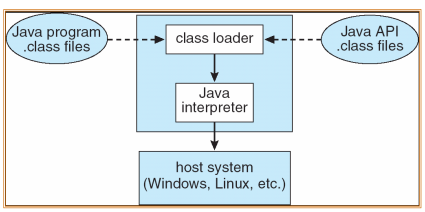
Virtual Machines (Cont.)

- The virtual-machine concept provides complete protection of system resources since each virtual machine is isolated from all other virtual machines. This isolation, however, permits no direct sharing of resources.
- A virtual-machine system is a perfect vehicle for operating-systems research and development. System development is done on the virtual machine, instead of on a physical machine and so does not disrupt normal system operation.
- The virtual machine concept is difficult to implement due to the effort required to provide an *exact* duplicate to the underlying machine

VMware Architecture



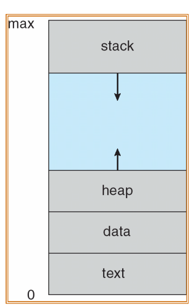
The Java Virtual Machine



Processes

Process Concept

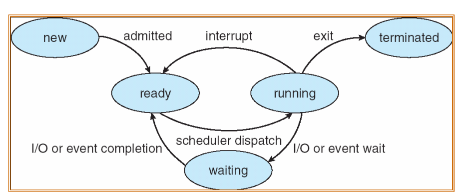
- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- Process – a program in execution; process execution must progress in sequential fashion
- A process includes:
  - program counter
  - stack: temporary data
  - heap: dynamic memory
  - data section: global variables



Process in Memory

Process State

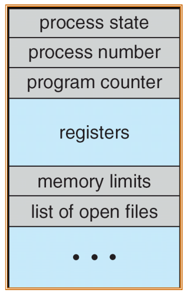
- As a process executes, it changes *state*
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned to a process
  - **terminated**: The process has finished execution



Process Control Block (PCB)

Information associated with each process

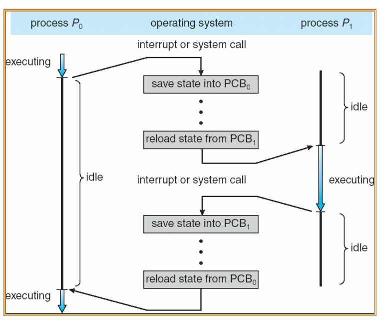
- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information



Context Switch

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process
- Context-switch time is overhead; the system does no useful work while switching
- Time dependent on hardware support

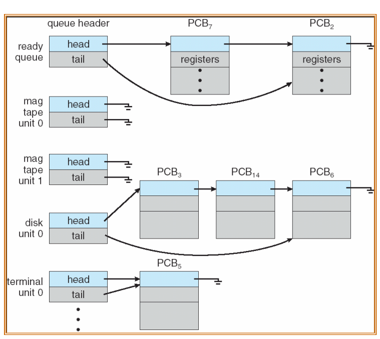
CPU Switch From Process to Process



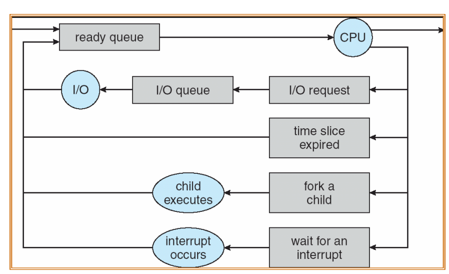
Process Scheduling Queues

- **Job queue** - set of all processes in the system
- **Ready queue** - set of all processes residing in main memory, ready and waiting to execute
- **Device queues** - set of processes waiting for an I/O device
- Processes migrate among the various queues

Ready Queue And Various I/O Device Queues



Representation of Process Scheduling



Schedulers

- **Long-term scheduler** (or job scheduler) – selects which processes should be brought into the ready queue
- **Short-term scheduler** (or CPU scheduler) – selects which process should be executed next and allocates CPU

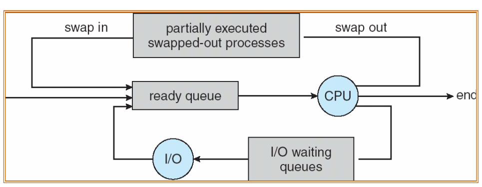
Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) ⇒ (must be fast)
- Long-term scheduler is invoked very infrequently (seconds, minutes) ⇒ (may be slow)
- The long-term scheduler controls the *degree of multiprogramming*
- Processes can be described as either:
  - **I/O-bound process** – spends more time doing I/O than computations, many short CPU bursts
  - **CPU-bound process** – spends more time doing computations; few very long CPU bursts

➔long-term schedulers need to make careful decision

Addition of Medium Term Scheduling

- In time-sharing systems: remove processes from memory "temporarily" to reduce degree of multiprogramming.
- Later, these processes are resumed ➔ Swaping

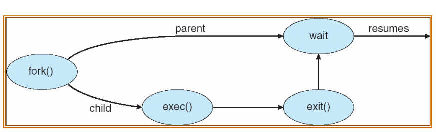


Process Creation

- Parent process create children processes, which, in turn create other processes, forming a tree of processes
- Resource sharing
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- Execution
  - Parent and children execute concurrently
  - Parent waits until children terminate

Process Creation (Cont.)

- Address space
  - Child duplicate of parent
  - Child has a program loaded into it
- UNIX examples
  - **fork** system call creates new process
  - **exec** system call used after a **fork** to replace the process' memory space with a new program



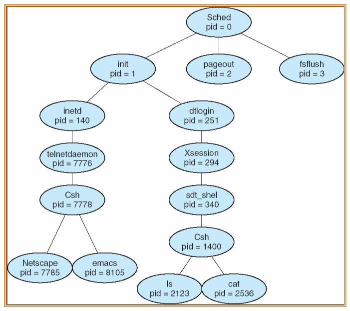
C Program Forking Separate Process

```
int main()
{
Pid_t  pid;
    /* fork another process */
    pid = fork();
    if (pid < 0) { /* error occurred */
          fprintf(stderr, "Fork Failed");
          exit(-1);
    }
    else if (pid == 0) { /* child process */
          execlp("/bin/ls", "ls", NULL);
    }
    else { /* parent process */
          /* parent will wait for the child to complete */
          wait (NULL);
          printf ("Child Complete");
          exit(0);
    }
}
```

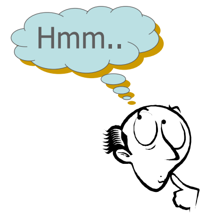
A tree of processes on a typical Solaris

- sched: root process for OS
- pageout: manages memory
- fsflush: manages file system
- init: root for user processes
- inetd: Networking
- dtlogin: user login screen
- …

➔ Unique process id's



Any Questions?



Reading Assignment

- Read chapter 3 from Silberschatz.

Acknowledgements

- “Operating Systems Concepts” book and supplementary material by Silberschatz, Galvin and Gagne.