Processes & Threads

CS 256/456

Dept. of Computer Science, University of Rochester

Recap of the Last Class

- Hardware protection
  - kernel and user mode
- System components
  - process management, memory management, I/O system, file and storage, networking, …
- Operating system architectures
  - monolithic architecture, microkernel
  - … …

Microkernel System Architecture

- Microkernel architecture:
  - Moves as much from the kernel into "*user*" space (still protected from normal users).
  - Communication takes place between user modules using message passing.
- Benefits:
  - More reliable (less code is running in kernel mode)
  - More secure (less code is running in kernel mode)
- Disadvantage:
  - More overhead in inter-domain communications

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
- Disadvantage:
  - Weak integration results in performance penalty (similar to the microkernel structure).

Outline

- Process
  - Process concept
  - A process's image in a computer
  - Operations on processes
- Thread
  - Thread concept
  - Multithreading models
  - Types of threads

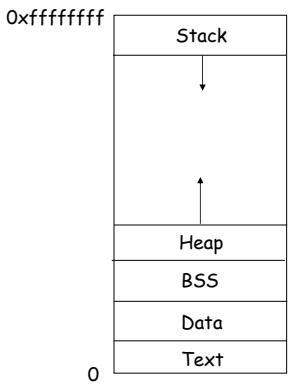
Process and Its Image

- An operating system executes a variety of programs:
  - A program that browses the Web
  - A program that serves Web requests
- Process – a program in execution.
- A process's state/image in a computer includes:
  - User-mode address space
  - Kernel data structure
  - Registers (including program counter and stack pointer)
- Address space and memory protection
  - Physical memory is divided into user memory and kernel memory
  - Kernel memory can only be accessed when in the kernel mode
  - Each process has its own exclusive address space in the user-mode memory space (sort-of)

User-mode Address Space

User-mode address space for a process:

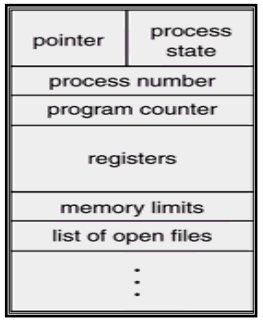
- Text: program code, instructions
- Data: initialized global and static variables (those data whose size is known before the execution)
- BSS (block started by symbol): uninitialized global and static variables
- Heap: dynamic memory (those being malloc-ed)
- Stack: local variables and other stuff for function invocations



Process Control Block (PCB)

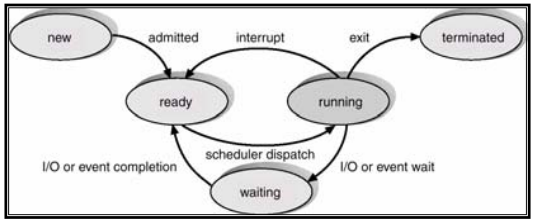
OS data structure (in kernel memory) maintaining information associated with each process.

- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- Information about open files
- maybe kernel stack?



Process State

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

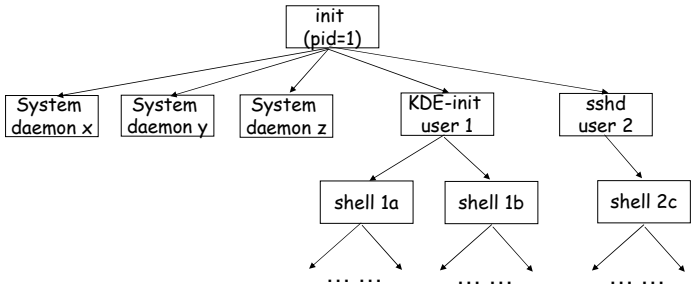


Process Creation

- When a process (parent) creates a new process (child)
  - Execution sequence?
  - Address space sharing?
  - Open files inheritance?
  - … …
- UNIX examples
  - **fork** system call creates new process with a duplicated copy of everything.
  - **exec** system call used after a **fork** to replace the process' memory space with a new program.
  - child and parent compete CPU like two normal processes.
- Copy-on-write

Process Tree on a Linux System

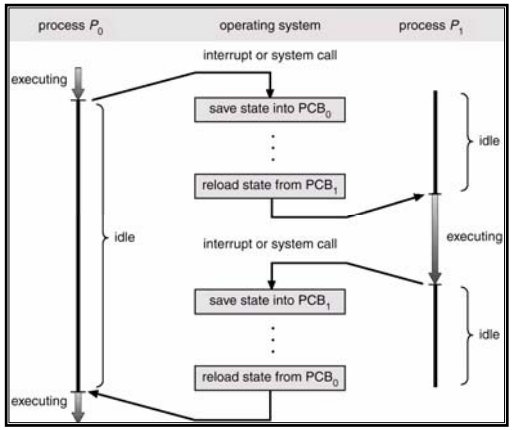
- Parent process creates children processes, which, in turn create other processes, forming a tree of processes.



CPU Switch From Process to Process

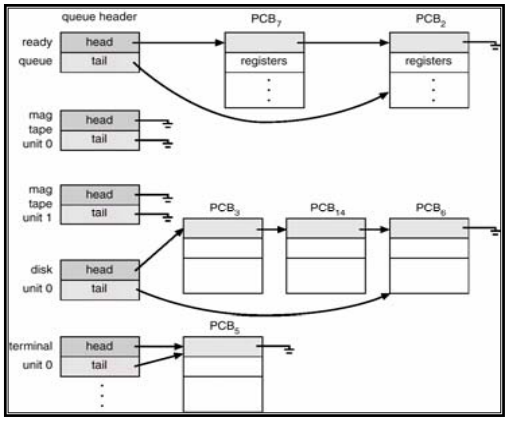
When can the OS switch the CPU from one process to another?

Which one to switch to? - scheduling



Queues for PCBs

- Ready queue – set of all processes ready for execution.
- Device queues – set of processes waiting for an I/O device.
- Process migration between the various queues.

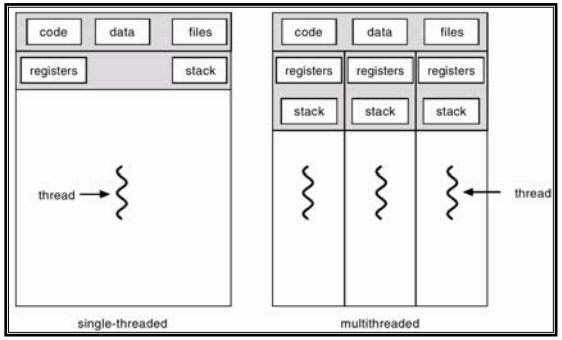


Process Termination

- Process executes last statement and gives the control to the OS (**exit**).
  - Notify parent if it is **wait**-ing.
  - Deallocate process' resources.
- The OS may forcefully terminate a process.
  - Software exceptions
  - Receiving certain signals

Processes and Threads

- Thread – a program in execution; without a dedicated address space.
- OS memory protection is only applied to processes.



Why Use Threads?

- Multithreading is used for parallelism/concurrency. But why not multiple processes?
- Memory sharing.
- Efficient synchronization between threads
- Less context switch overhead

User/Kernel Threads

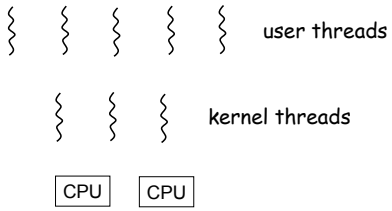
- What is really happening when the execution of one thread switches to another?
  - save the registers (including the SP) of the old thread;
  - restore the registers of the new thread;
  - set the new PC appropriately for the new thread;
- Does this need help from the OS kernel?
- Can you do it in C/Java?
- Does process switching need help from the OS kernel?
- User threads
  - Thread data structure is in user-mode memory
  - scheduling/switching done at user mode
- Kernel threads
  - Thread data structure is in kernel memory
  - scheduling/switching done by the OS kernel

User/Kernel Threads (cont.)

- Benefits of user threads
  - lightweight – less context switching overhead
  - more efficient synchronization??
  - flexibility – allow application-controlled scheduling
- Problems of user threads
  - can't use more than one processor
  - oblivious to kernel events, e.g., all threads in a process are put to wait when only one of them does I/O

Mixed User/Kernel Threads

- M user threads run on N kernel threads (M≥N)
  - N=1: pure user threads
  - M=N: pure kernel threads
  - M>N>1: mixed model



Solaris/Linux Threads

- Solaris
  - supports mixed model
- Linux
  - No standard user threads on Linux
  - Processes are treated similarly with threads (both called tasks)
  - Processes are tasks with exclusive address space
  - Tasks can also share the address space, open files, …

Pthreads

- Different OS has its own thread package with different Application Programming Interfaces ⇒ poor portability.
- Pthreads
  - A POSIX standard API for thread management and synchronization.
  - API specifies behavior of the thread library, not the implementation.
  - Commonly supported in UNIX operating systems.

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