CMSC 412

Fall 2004

Processes and Threads

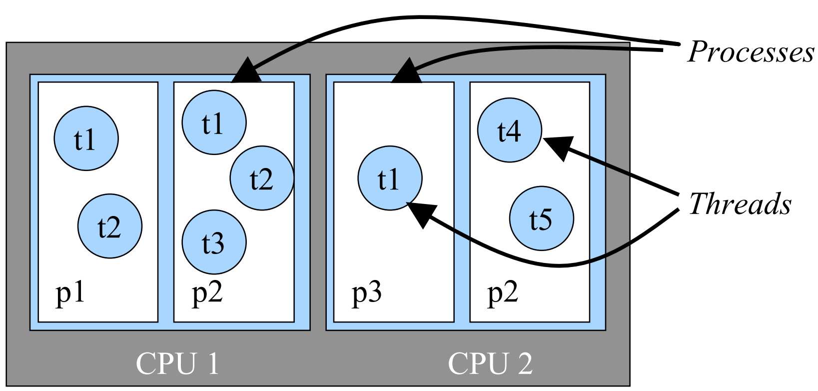
Announcements

- Project #1
  - Due Friday
- Reading
  - Chapter 4 (parts), 5 (parts)
  - Chapter 7 (for Monday)

Processes

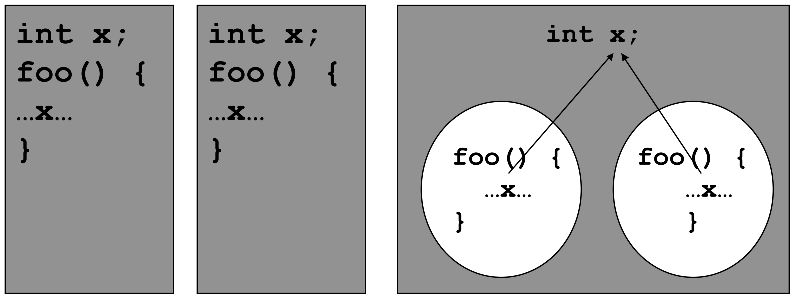
- What is a process?
  - A program in execution
    - Either sequentially or with multiple “threads of control.”
- What’s not a process?
  - A program on a disk - a process is an active object, but a program is just a file

Computation Abstractions



A dual-processor computer

Processes vs. Threads



Processes do not share data

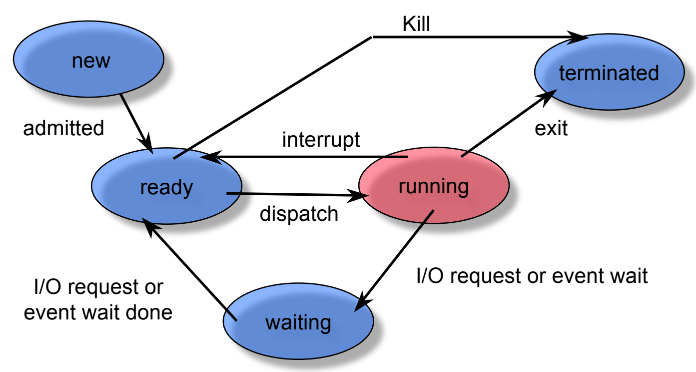
Threads share data within a process

More on threads later …

Process State

- Processes switch between different states based on internal and external events
- Each process is in exactly one state at a time
- Typical States of Processes (varies with OS)
  - New: just been created
  - Running: instructions are being executed
    - only one process per processor may be running
  - Waiting: waiting for an event to occur
    - examples: I/O events, signals
  - Ready: waiting to be assigned the CPU
  - Terminated: finished execution

Process State Transitions



Components of a Process

- Memory Segments
  - Program - often called the text segment
  - Data - global variables
  - Stack - contains activation records
  - Heap - contains dynamically-allocated data
- Processor Registers
  - Control registers
    - program counter - next instruction to execute
    - stack pointer
    - processor status word (from *cmp* instructions)
  - General purpose registers
  - Floating-point registers

Scheduling

- OS must decide when a process is allowed to run; I.e. it must schedule processes
- 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. A.k.a the dispatcher.

Schedulers

- Short-term scheduler is invoked very frequently (milliseconds) $\Rightarrow$ (must be fast).
- Long-term scheduler is invoked very infrequently (seconds, minutes) $\Rightarrow$ (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.

Scheduling Policy

- How should the scheduler choose a process to run?
- Can simply pick the first item in the queue
  - called round-robin scheduling
  - is round-robin scheduling fair?
- Various scheduling criteria
  - Process class (I/O bound vs. CPU bound)
  - Priority
  - Resources consumed
  - Etc.

Scheduling Implementation

- Use alarm interrupts to switch between processes
  - when time is up, a process is put back on the end of the ready queue
  - frequency of these interrupts (a.k.a. the *quantum*) is an important parameter
    - typically 3-10ms on modern systems
    - need to balance overhead of switching vs. responsiveness

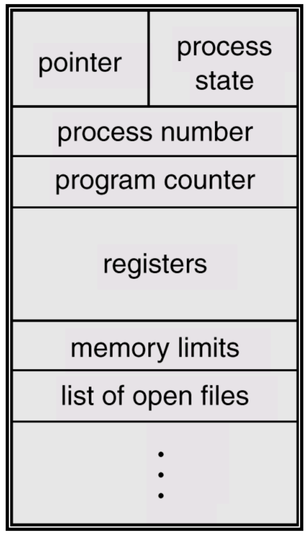
Context Switch

- When the OS switches a CPU to another process, it is called a context switch.
- 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.
  - Total time depends on hardware support.
  - Writing context-switch routines almost always requires some assembly language

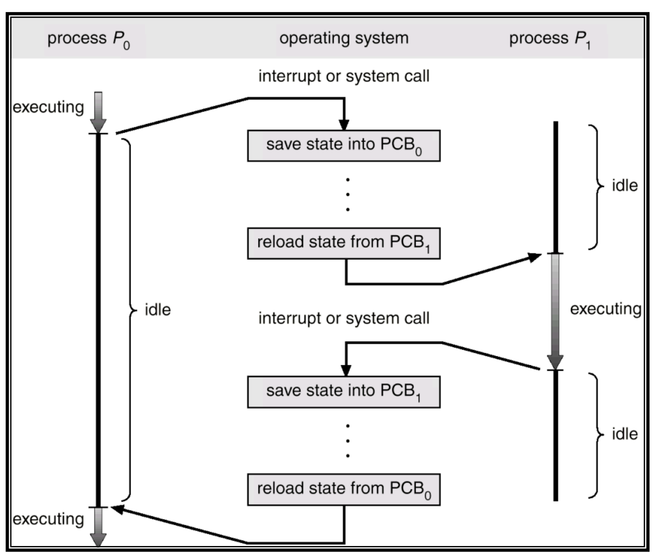
OS Process Control Block

- Stores all of the information about a process
- PCB contains
  - Process state: new, ready, etc.
  - (saved) processor registers
  - Memory Management Information
    - page tables, limit registers for segments
  - CPU scheduling information
    - process priority; pointers to process queues
  - Accounting information
    - time used (and limits); files used; program owner; parent process id
  - I/O status information
    - list of open files; pending I/O operations

Sample PCB



Context Switch using PCBs



8

GeekOS PCB (part I)

- **`struct Kernel_Thread`**, contains
  - Process Identifier (PID)
  - Scheduling criteria (priority)
  - Accounting info (CPU clock ticks)
  - Kernel stack pointer
    - Context-switch information stored here; I.e. general-purpose registers, program counter, etc.
- User processes in GeekOS are a special kind of kernel thread

GeekOS PCB (part II)

- **`struct User_Context`**, contains
  - Pointer to process (physical) memory
    - Includes all the segments you set up in Project 1; I.e. code segment, data segment, etc.
  - Pointers to initial program entry point, initial argument, and initial stack.
  - Information for managing address space protection
    - Ix86 descriptor tables and selectors
- You'll set this up in Project 2

Storing PCBs

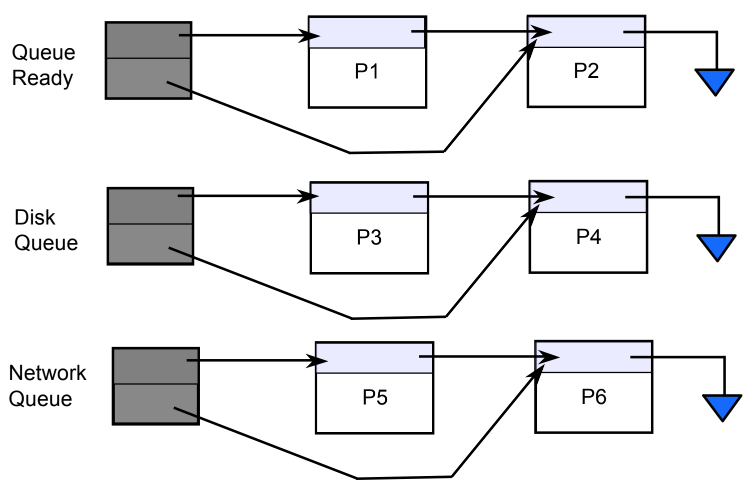
- Track which processes are in which states
  - Collection of PCBs is called a process table
- How to store the process table?
- First Option:

P1 Ready	P2 Waiting	P2 New	P3 Term	P4 Waiting	P5 Ready

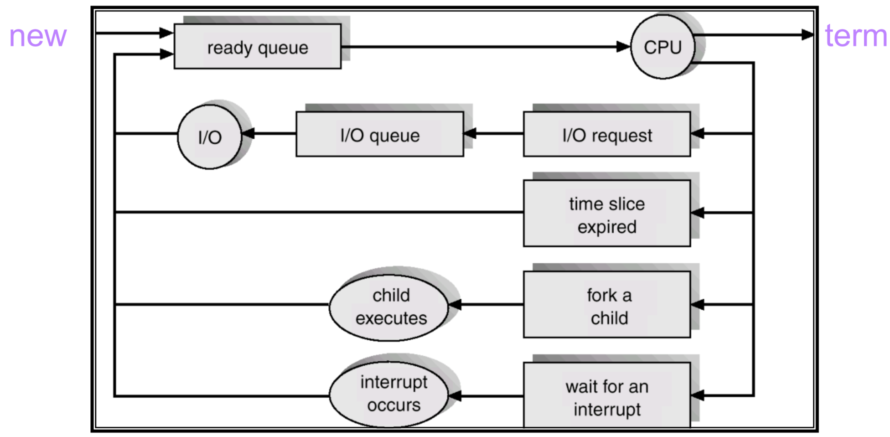
  - Simple, but slow to find processes
  - Also need additional datastructures for fairness

Queues of Processes

- Store processes in state-based queues



State Transitions with Queues



Forking a New Process

- New process is called the child; the process that created it is the parent
- Create a PCB for the new process
  - copy most entries from the parent
  - clear accounting fields
  - buffer pending I/O
  - allocate a *PID* for the new process

Forking a New Process

- Allocate memory for it
  - Might copy all of the parents' segments
  - Text segment could be shared
    - rarely changes
  - Use memory mapping hardware to help
    - will talk more about this in the memory management part of the class
- Add it to the ready queue

Process Termination

- Process can terminate itself
  - via the *exit* system call
- One process can terminate another process
  - use the *kill* system call
  - can any process kill any other process?
    - No, that would be bad.
    - Normally an ancestor can terminate a descendant
- OS kernel can terminate a process
  - exceeds resource limits
  - tries to perform an illegal operation

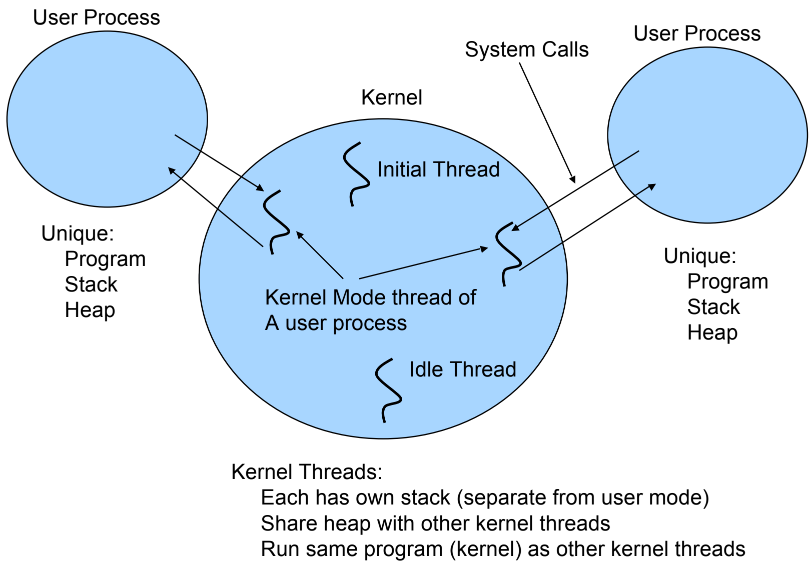
Orphan Processes

- What if a parent terminates before the child?
  - the child called an orphan process
    - in UNIX - becomes child of the root process
    - in VMS - terminated

UNIX example

- Terminated process
  - signals parent of its death (SIGCHILD)
  - is called a zombie in UNIX
  - remains around waiting to be reclaimed
- Parent process
  - wait system call retrieves info about the dead process
    - exit status
    - accounting information
  - signal handler is generally called the *reaper*
    - since its job is to collect the dead processes

Kernel Mode and User Mode

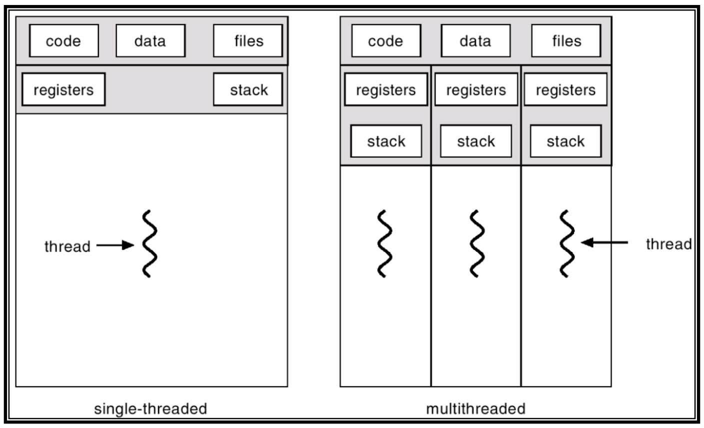


Threads

- Processes can be a heavy (expensive) object
- Threads are like processes but generally a collection of threads will share
  - memory (except stack)
  - open files (and buffered data)
  - signals
- Can be user or system level
  - user level: kernel sees one process
    - \+ easy to implement by users
    - \- I/O management is difficult
    - \- in an multi-processor can't get parallelism
  - system level: kernel schedules threads

14

Single and Multithreaded Processes



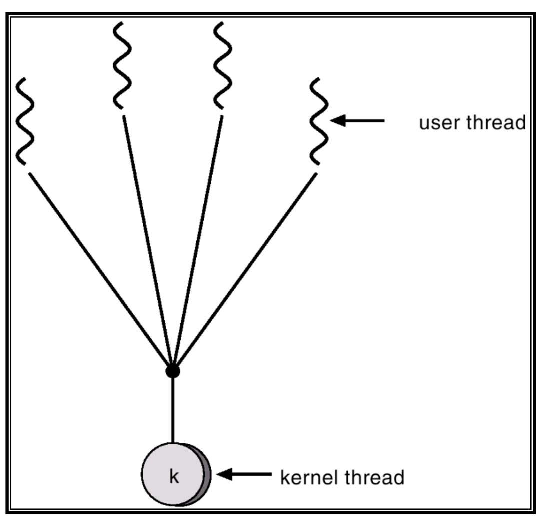
Execution Abstractions

- Kernel Threads
  - Threads that run with kernel privileges
- User Threads
  - Threads running in user space
  - Kernel may not be aware of them
- Processes
  - An execution context *with an address space*
  - Visible to and scheduled by the kernel
- Light-Weight Processes
  - An execution context sharing an address space
  - Visible to and scheduled by the kernel

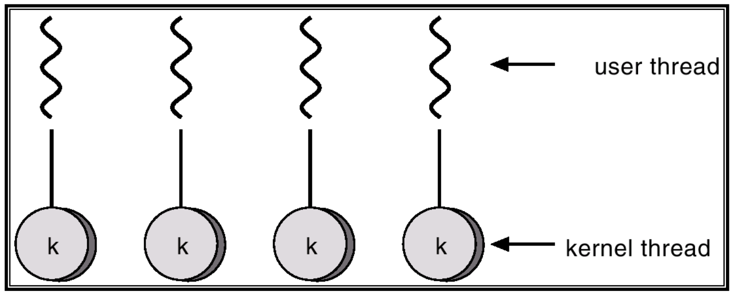
Multithreading Models

- Many-to-One
- One-to-One
- Many-to-Many

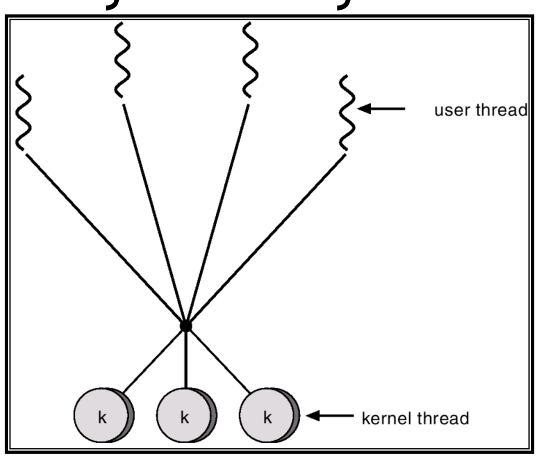
Many-to-One Model



One-to-one Model



Many-to-Many Model



17

Why multiple threads?

- Performance:
  - Parallelism on multiprocessors
  - Concurrency of computation and I/O
- Can easily express some programming paradigms
  - Event processing
  - Simulations
- Keep computations separate

Why not multiple threads?

- Complexity:
  - Dealing with safety, liveness, composition
- Overhead
  - Higher resource usage

- Check out CMSC 433 for lots of information on threads and their alternatives!