Announcements

● **Program #0**
  - Due on Friday
  - Limit should return 0 when called with correct parameters
  - Calling limit resets the counter, so a Limit(0,4) will be killed on the 5th system call after Limit.

● **Reading**
  - Today: Processes - Chapter 3 (ch 4, 6th Ed)
  - Thursday: Threads - Chapter 4 (ch 5, 6th Ed)
Multi-programming

- Systems that permit more than one process at once
  - virtually all computers today
- Permits more efficient use of resources
  - while one process is waiting another can run
- Provides natural abstraction of different activities
  - windowing system
  - editor
  - mail daemon
- Preemptive vs. non-preemptive multi-programming
  - preemptive means that a process can be forced off the processor by the OS
  - provides processor protection
Process State Transitions

- **new**
- **ready**
- **running**
- **waiting**
- **terminated**

Transitions:
- new → ready: admitted
- ready → running: dispatch
- running → waiting: I/O request or event
- running → terminated: exit
- waiting → running: I/O request or event wait
- ready → terminated: Kill

States:
- New
- Ready
- Running
- Waiting
- Terminated
Components of a Process

- **Memory Segments**
  - Program - often called the text segment
  - Data - global variables
  - Stack - contains activation records

- **Processor Registers**
  - Program counter - next instruction to execute
  - General purpose CPU registers
  - Processor status word
    - Results of compare operations
  - Floating point registers
Process Control Block

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

- Need to keep track of the different processes in the system
- Collection of PCBs is called a process table
- How to store the process table?
- First Option:

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ready</td>
<td>Waiting</td>
<td>New</td>
<td>Term</td>
<td>Waiting</td>
<td>Ready</td>
</tr>
</tbody>
</table>

- Problems with Option 1:
  - hard to find processes
  - how to fairly select a process
Queues of Processes

- Store processes in queues based on state

- Ready Queue
  - P1
  - P2

- Disk Queue
  - P3
  - P4

- Network Queue
  - P5
  - P6
forking a new process

- create a PCB for the new process
  - copy most entries from the parent
  - clear accounting fields
  - buffered pending I/O
  - allocate a pid (process id for the new process)

- allocate memory for it
  - could require copying all of the parents segments
  - however, text segment usually doesn’t change so that could be shared
  - might be able to 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
Variations on Creating a Process

- **Fork() [ often used with exec too]**
  - Create a new process with new address space
  - Parent address space copied into child
  - Child resumes at return of fork

- **Spawn(program)**
  - Create a new process with a new address space
  - Child starting running the passed program
  - Parent returns from spawn and continues execution

- **Clone(func, stack)**
  - Creates a new process that shares parents address space
  - Child starts running func using the passed stack for locals
  - Parent returns from clone and continues execution
Process Termination

- **Process can terminate self**
  - 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

- **What if a parent terminates before the child**
  - called an orphan process
  - in UNIX becomes child of the root process
  - in VMS - causes all descendants to be killed
Termination (cont.) - UNIX example

- **Kernel**
  - frees memory used by the process
  - moved process control block to the terminated queue

- **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