TI III: Operating Systems & Computer Networks

Processes

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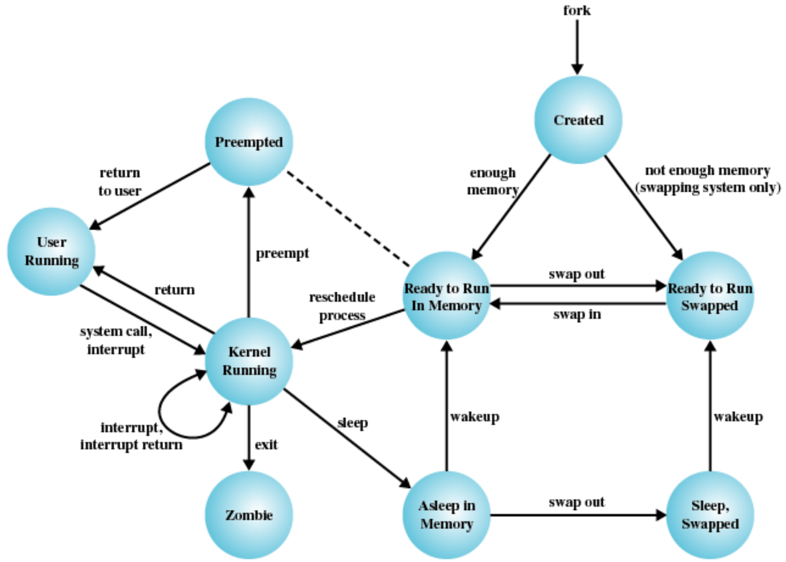


Content

Definitions of a Process

Program in execution

Instance of a program running on a computer
- There may be multiple instances of the same program, each as a separate process

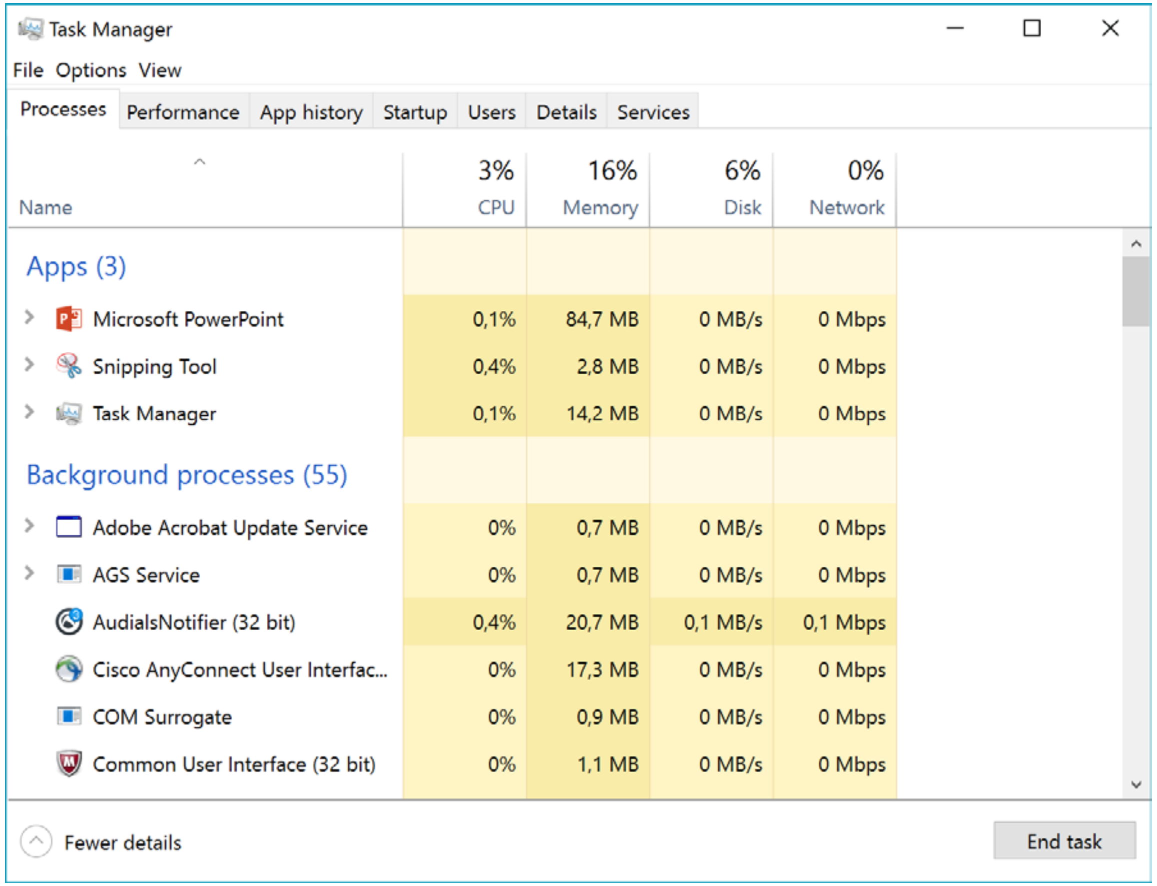
Unit characterized by
- Execution of a sequence of instructions
- Current state
- Associated block of memory

Related Concepts to “Process”

Thread: One (of several) runtime entities that share the same address space

- Easy cooperation, requires explicit synchronization
- A process may consist of several threads

Application: User-visible entity, one or more processes



Program vs. Process

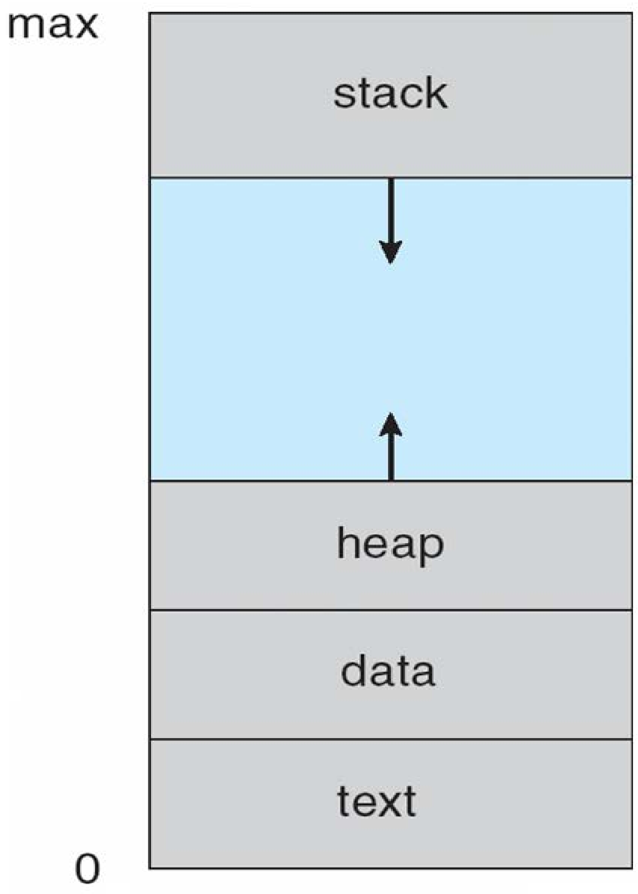
Multiple parts

- Program code ➞ text section
- Current activity ➞ program counter, processor registers
- Stack ➞ temporary data
- Data section ➞ global variables
- Heap ➞ dynamic memory

Program is passive entity, process is active

- Program becomes process when executable file loaded into memory

One program can be several processes



Tasks of an OS concerning processes

Interleaved execution (by scheduling) of multiple processes

- Maximization of processor utilization
- Reduction of response time

Allocation of resources for processes

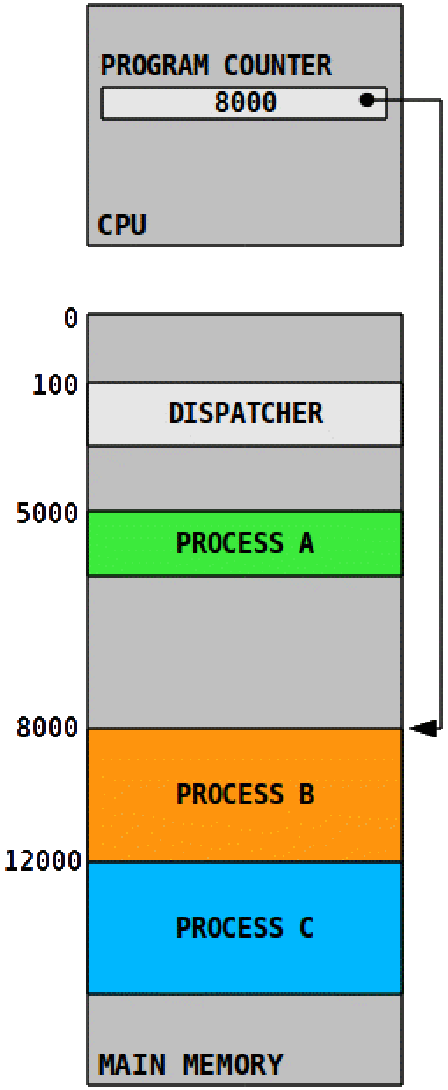
- Consideration of priorities
- Avoidance of deadlocks

Support for Inter-Process Communication (IPC)

On-demand user-level process creation

- Structuring of applications

Process execution (Trace)

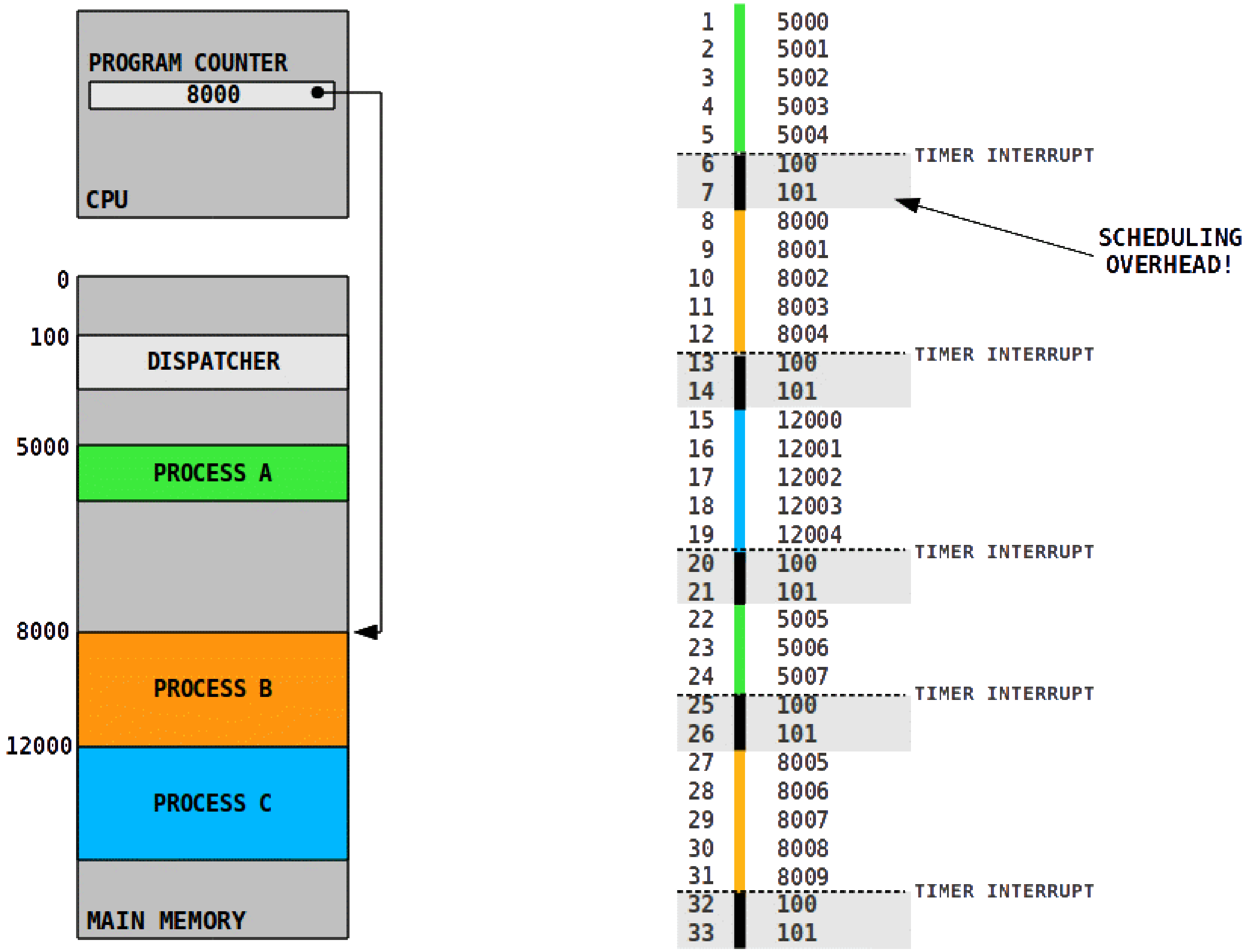


5000	8000	12000
5001	8001	12001
5002	8002	12002
5003	8003	12003
5004		12004
5005		12005
5006		12006
5007		12007
5008		12008
5009		12009
5010		12010
5011		12011
(a) Trace of Process A	(b) Trace of Process B	(c) Trace of Process C

5000 = Starting address of program of Process A
8000 = Starting address of program of Process B
12000 = Starting address of program of Process C

Figure 3.3 Traces of Processes of Figure 3.2

Process execution (Trace)



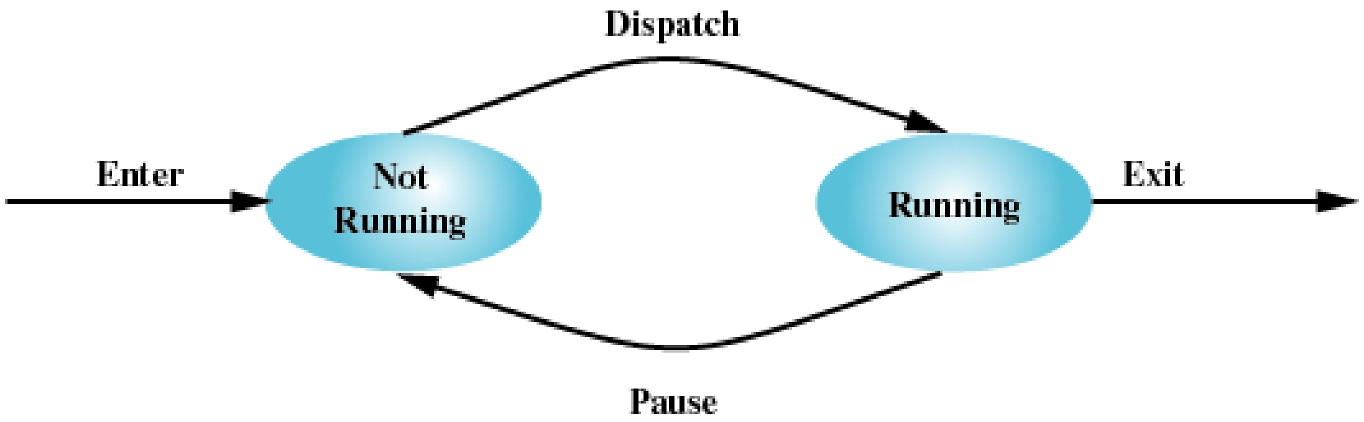
Questions & Tasks

- Check the number and type of processes and threads running on your computer – surprised?
- What are many of the “invisible” processes used for? Who started them?
- Why can several instances of the same program running as individual processes make sense?
    - What could be disadvantages?
- Who is responsible for the “interleaved execution” of multiple processes?
    - But how can this be done if we assume a single processor running a single process that does not want to leave this processor?
- Name some criteria for schedulers!

Simple Process Model

Process is in one of two states:

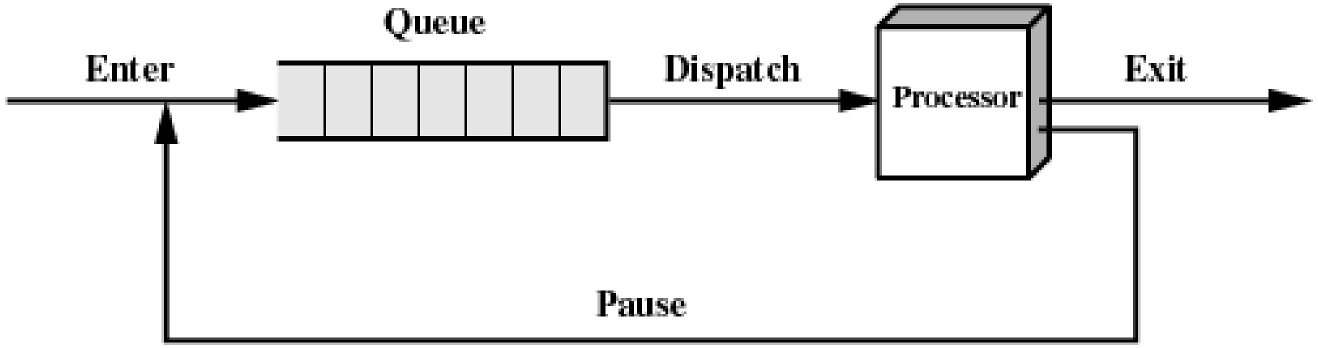
- running
- not running



How to implement?

Simple Process Model

Running processes managed in queue:



What information required?

Process Control Block (PCB)

Definition: OS data structure which contains the information needed to manage a process (one PCB per process)

Process identifiers	• IDs of process, parent process, and user

CPU state	• User-visible registers
	• Control and status registers:
	  • Stack pointer (SP)
	  • Program counter (PC)
	  • Processor status word (PSW)

Control information	• Scheduling information:
	  • Process state, priority, awaited event
	• Accounting information:
	  • Amount of memory used, CPU time elapsed
	• Memory management:
	  • Location and access state of all user data
	• I/O management:
	  • Devices currently opened (files, sockets)

Process Control Block (PCB)

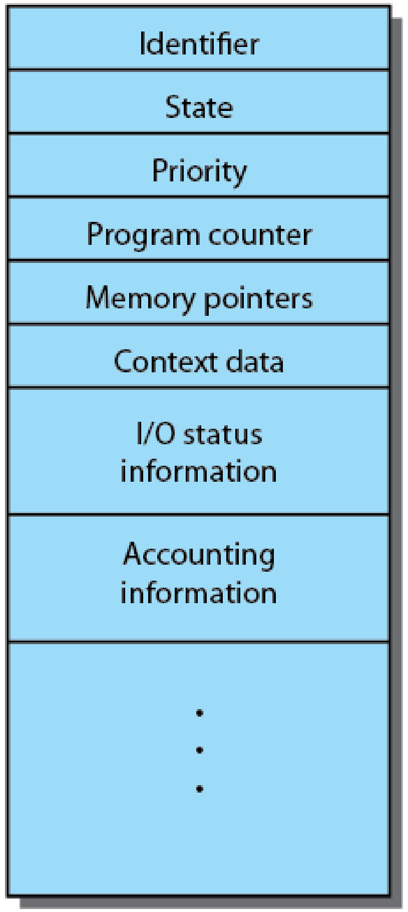


Figure 3.1 Simplified Process Control Block

Reasons for Process Creation

Interactive logon

- User logs onto a terminal
- May create several processes as part of logon procedure (e.g. GUI)

Created by the OS to provide a service

- Provide a service to user program in the background (e.g. printer spooling)
- Either at boot time or dynamically in response to requests (e.g. HTTP)

Spawned at application start-up

- Separation of a program into separate processes for algorithmic purposes

Always spawned by existing process

- Operating system creates first process at boot time
- Processes are organized in a tree-like structure (`pstree`)

Process Termination

Execution of process is completed
- process terminates itself by system call

Other user process terminates the process
- Parent process or other authorized processes

OS terminates process for protection reasons
- Invalid instruction (process tries to execute data)
- Privileged instruction in user mode
- Process tries to access memory without permission
- I/O-Error
- Arithmetic error

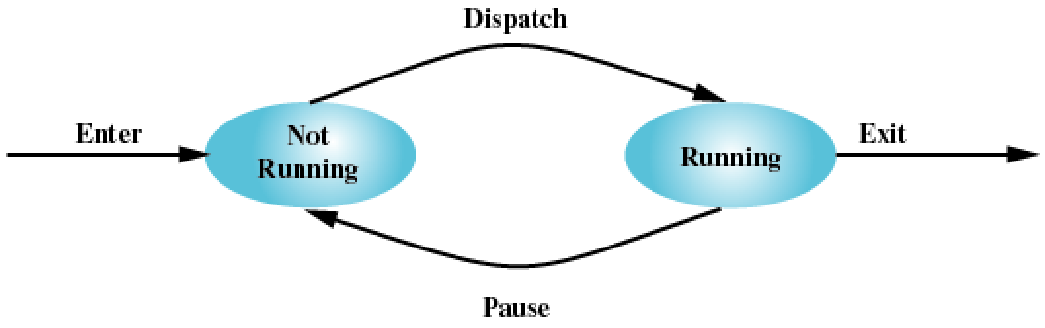
Some exceptions can be caught and handled by the process.

Questions & Tasks

- What are disadvantages of the simple FIFO-queue in our simple process model?
  - What could be alternatives?
- Start your favorite process monitor, then start programs, use them, terminate them and monitor the list of current processes and threads to get a better understanding of your system!
- How can you kill a process that goes crazy?
  - Can you (as a normal user) kill all processes? Try it and see what happens! PLEASE: Do not do this while running anything important, save all files before you do this …
  - What is the role of a administrator/root/superuser in this context?

Process Model

Simple model with two states



Problems

- Most of the processes will be waiting for IO
- Different IO devices
- Different priorities

➔ Extend the model

Extended Process Model

Five states including creation, termination, and resource handling:

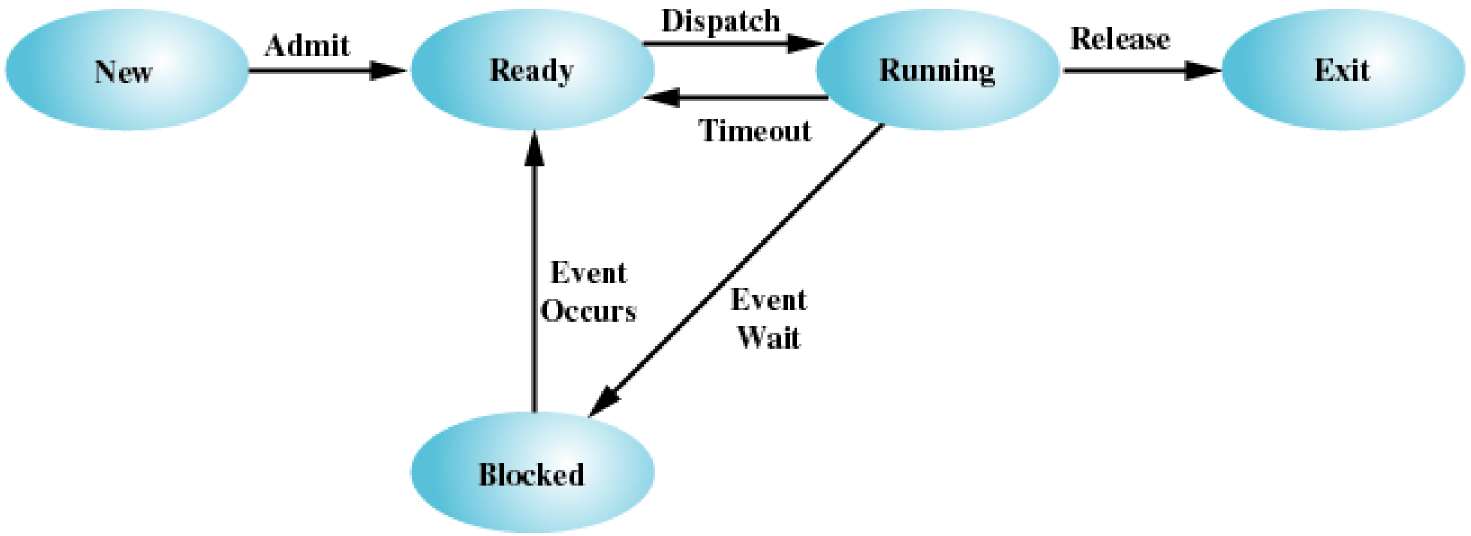
Running: currently being executed

Ready: ready to run, waiting for execution

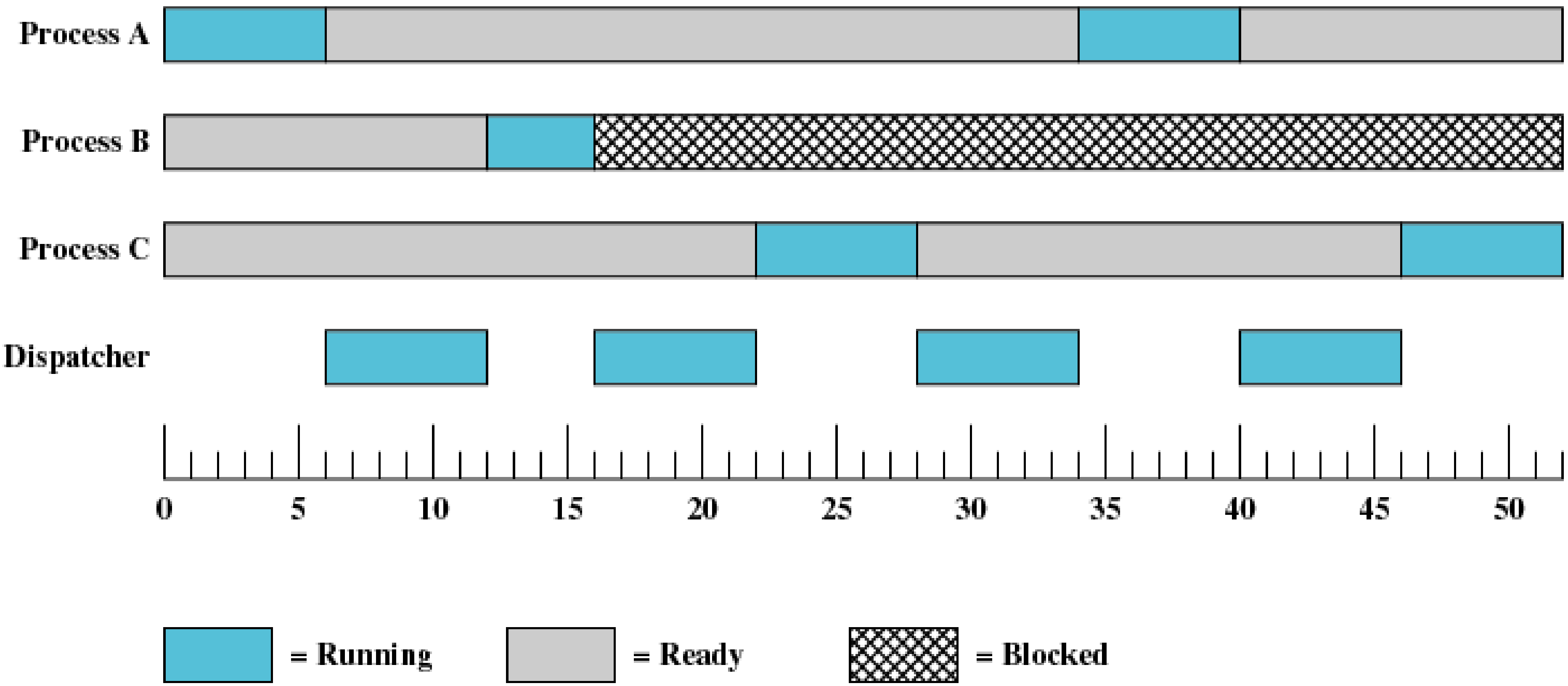
Blocked: not ready to run, waiting for external event, e.g., completion of I/O operation

New: newly created process, not yet in running set

Exit: completed/terminated process, removed from running set



Process States over Time

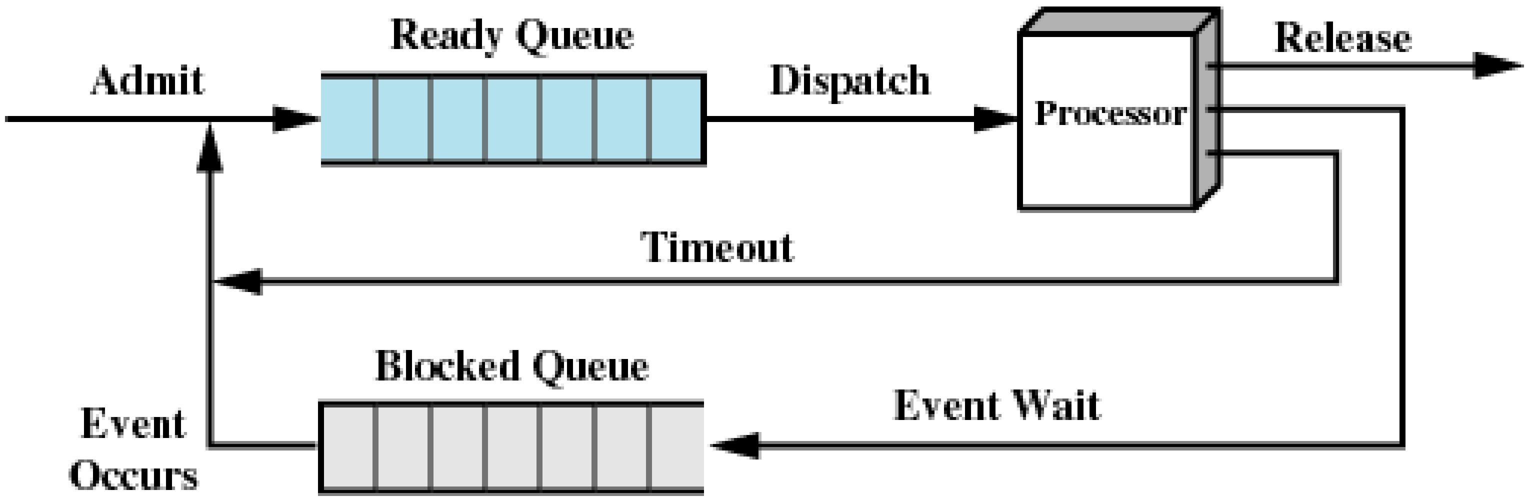


Implementation of Process States

Assign process to different queues based on state of required resources

Two queues:

- Ready processes (all resources available)
- Blocked processes (at least one resource busy)



But what happens if processes need different resources?

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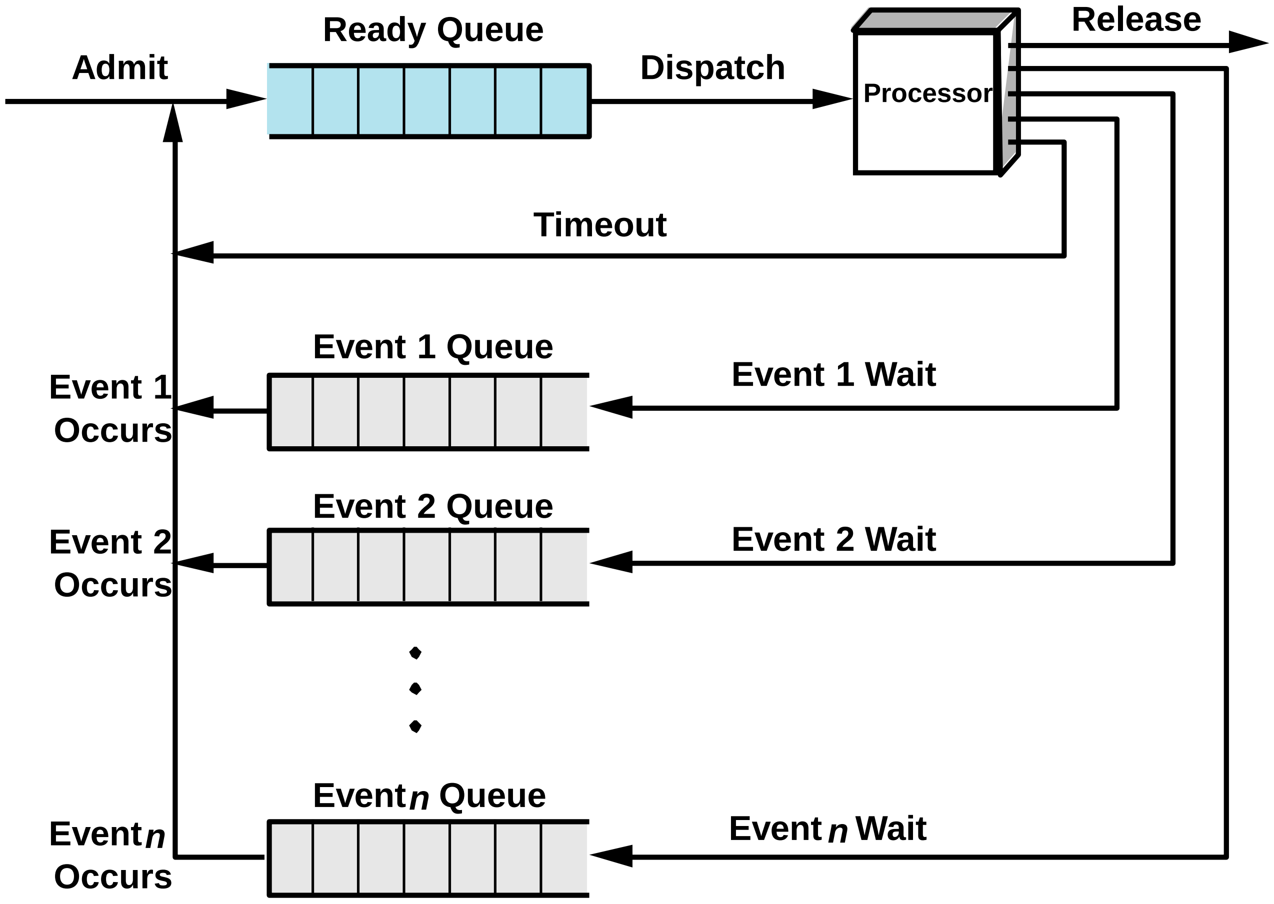
Improved Implementation

Several queues one for each resource / type of resource



(b) Multiple blocked queues

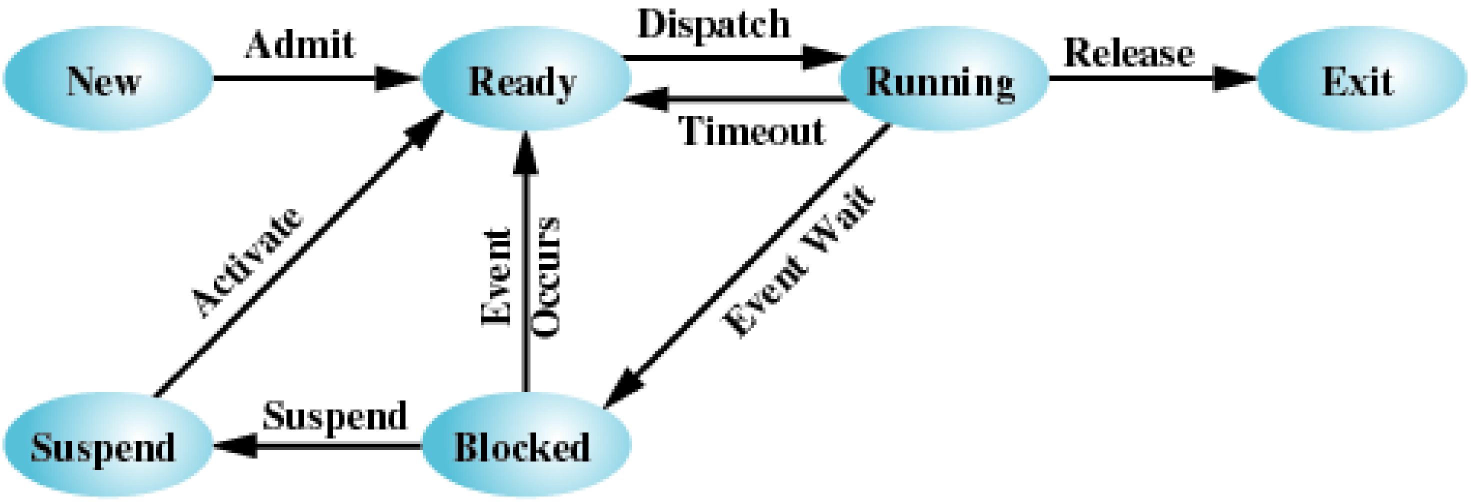
More efficient, but fairness issues must be considered

Suspension / Swapping of Processes

Swapping motivated by two observations:

- Physical main memory is (was) a scarce resource
- Blocked processes may wait for longer periods of time (e.g. during I/O, while waiting for requests, ...)

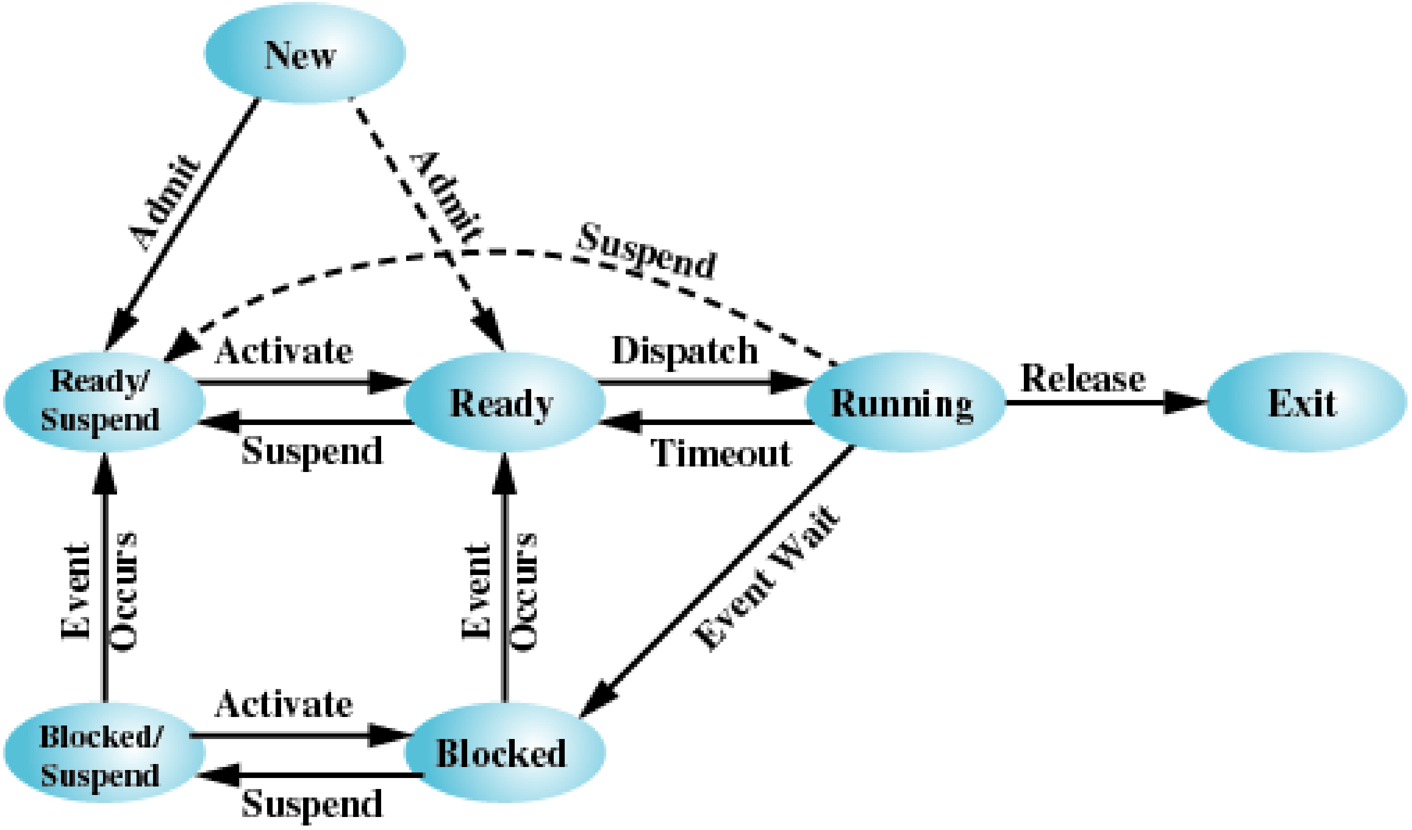
➔ Swap blocked processes to secondary storage thereby reducing memory usage



Extended Process State Diagram

Two additional considerations

- Blocked/swapped processes may become ready to run when event occurs
- Ready and/or running processes may be swapped even without waiting for event

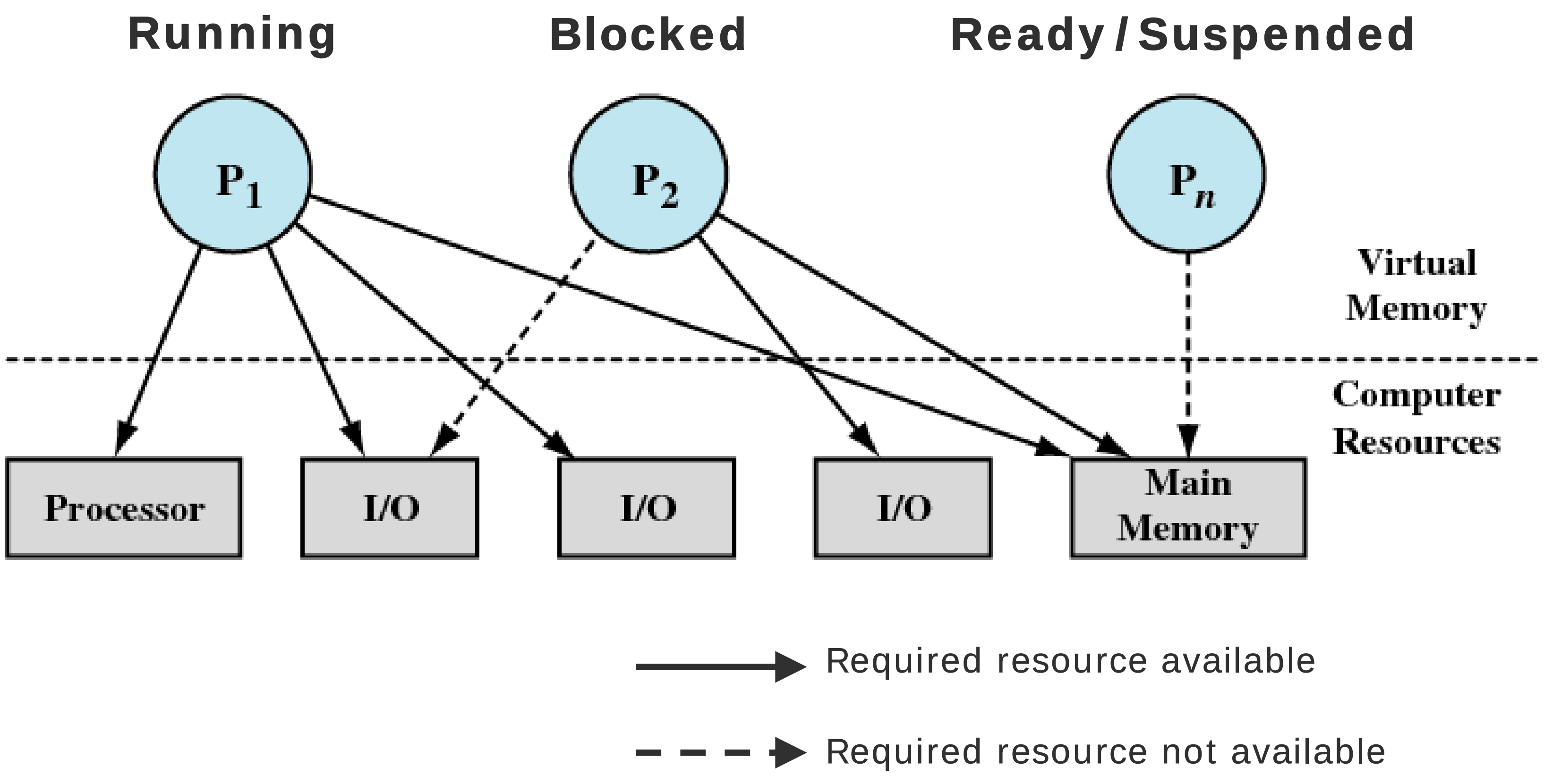


Questions & Tasks

- What is a typical state for a typical program you use, such as e.g. text processing, email, chat etc.?
  - So what is your computer normally doing (unless you are an active gamer…)?
- How do interrupts fit into the picture of processes, queues, scheduling?
- How and where to implement different priorities?
- What does swapping involve? Think of the memory hierarchy!
  - Can you notice swapping?
- Can we swap all processes?

Processes and Resource Allocation

Process state reflects allocated resources:



Global data structures for processes and resources usage

Process tables:

- Process Control Block (PCB)
- Location of process image in memory
- Resources (process-specific view)

Memory tables:

- Allocation of primary and secondary memory
- Protection attributes of blocks of (shared) memory
- Virtual memory management

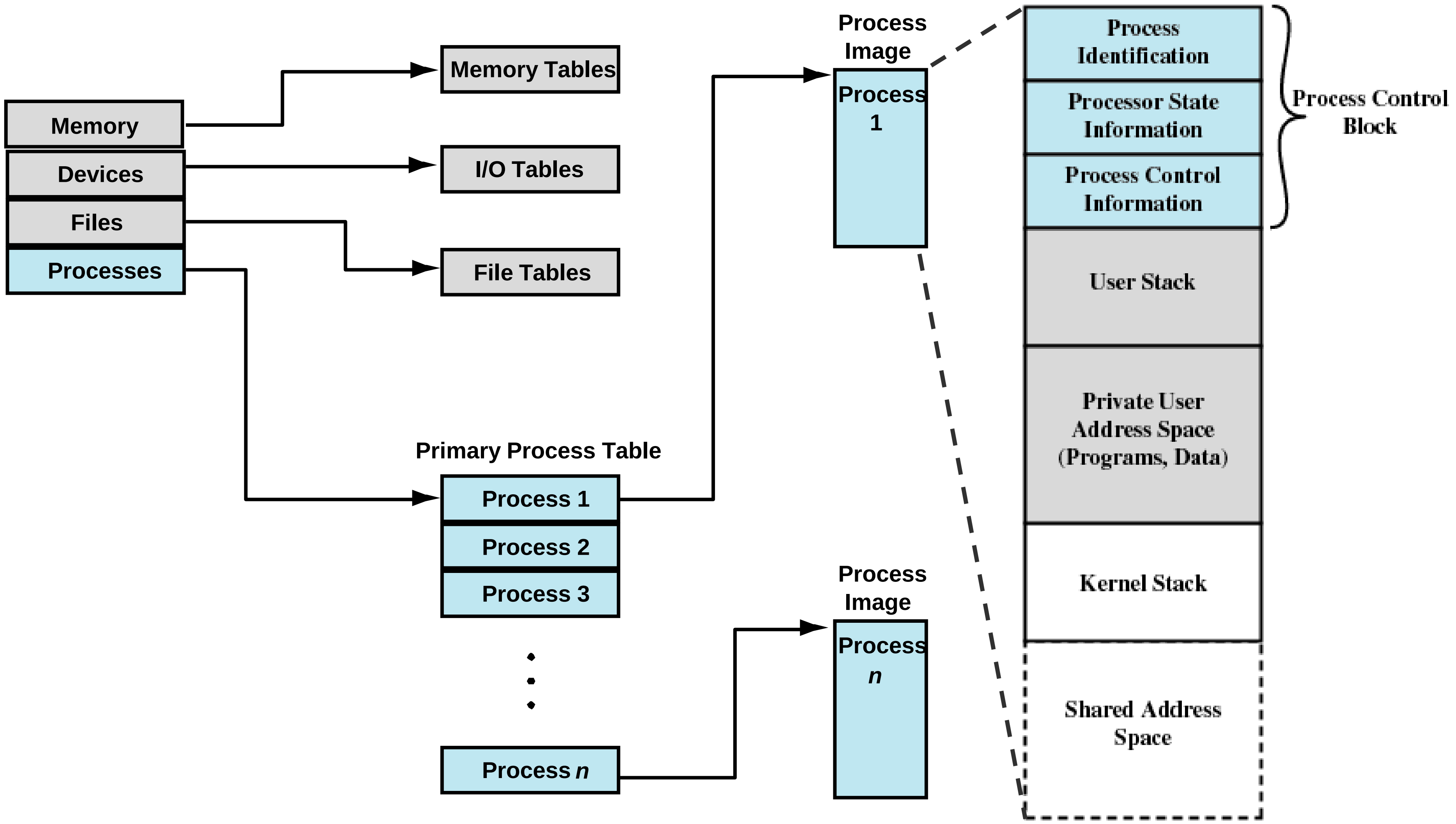
I/O tables:

- Allocation of I/O devices, assignment to processes
- State of current operation and corresponding memory region

File tables:

- Currently open files
- Location on storage media / secondary memory
- State and attributes

Process Control Table and Image

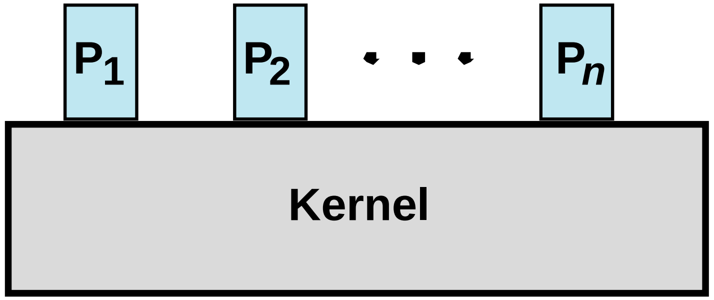


Kernel / Process Implementations

Separated kernel and processes:

- Separate memory and stack for kernel
- Kernel is no process

➔ Expensive and unsafe



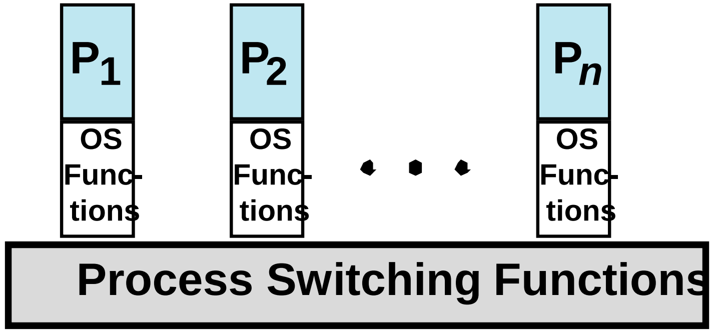
(a) Separate kernel

Kernel / Process Implementations

Execution of system calls as part of user process, but in kernel mode:

- Kernel functions use same address space
- Same process switches into privileged mode (Ring 0)

➔ Less expensive and quite safe



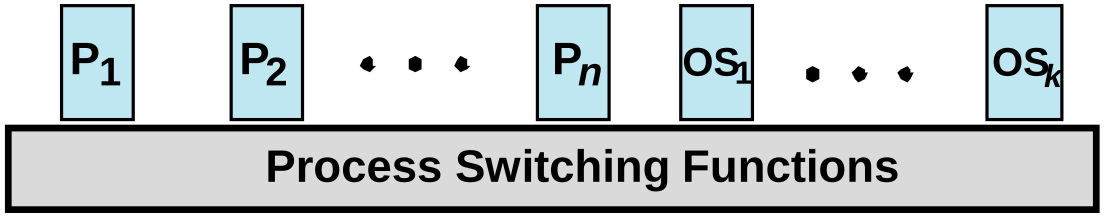
(b) OS functions execute within user processes

Kernel / Process Implementations

Microkernel:

- Collection of system processes that provide OS services

➔ Quite expensive but very safe



(c) OS functions execute as separate processes

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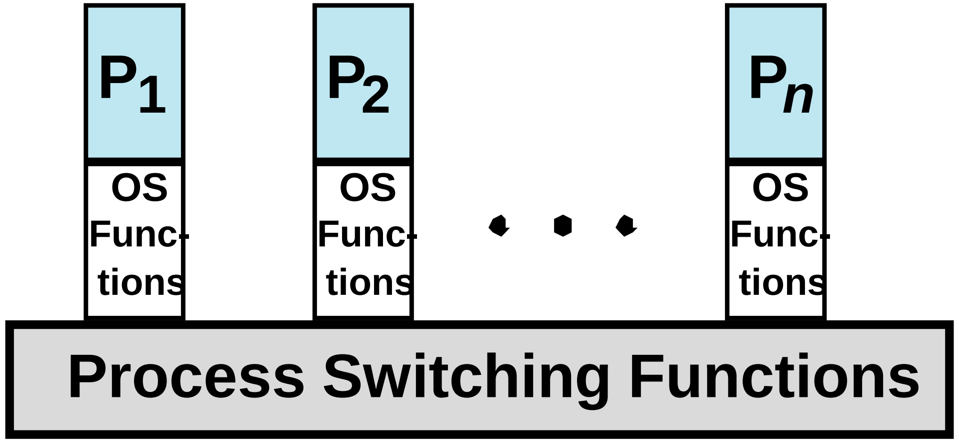
Questions & Tasks

- Make sure you understand how to implement tables, references to tables, pointers etc.!
- What is “expensive” when it comes to certain kernel/process implementations?
- What can be “unsafe”?
- Read e.g. https://www.oreilly.com/library/view/understanding-the-linux/0596002130/ch01s06.html to get more insight! (Understanding the Linux Kernel, Daniel P. Bovet, Marco Cesati, O’Reilly)

Example: UNIX – Architecture

Process architecture that executes kernel functions in the context of a user process

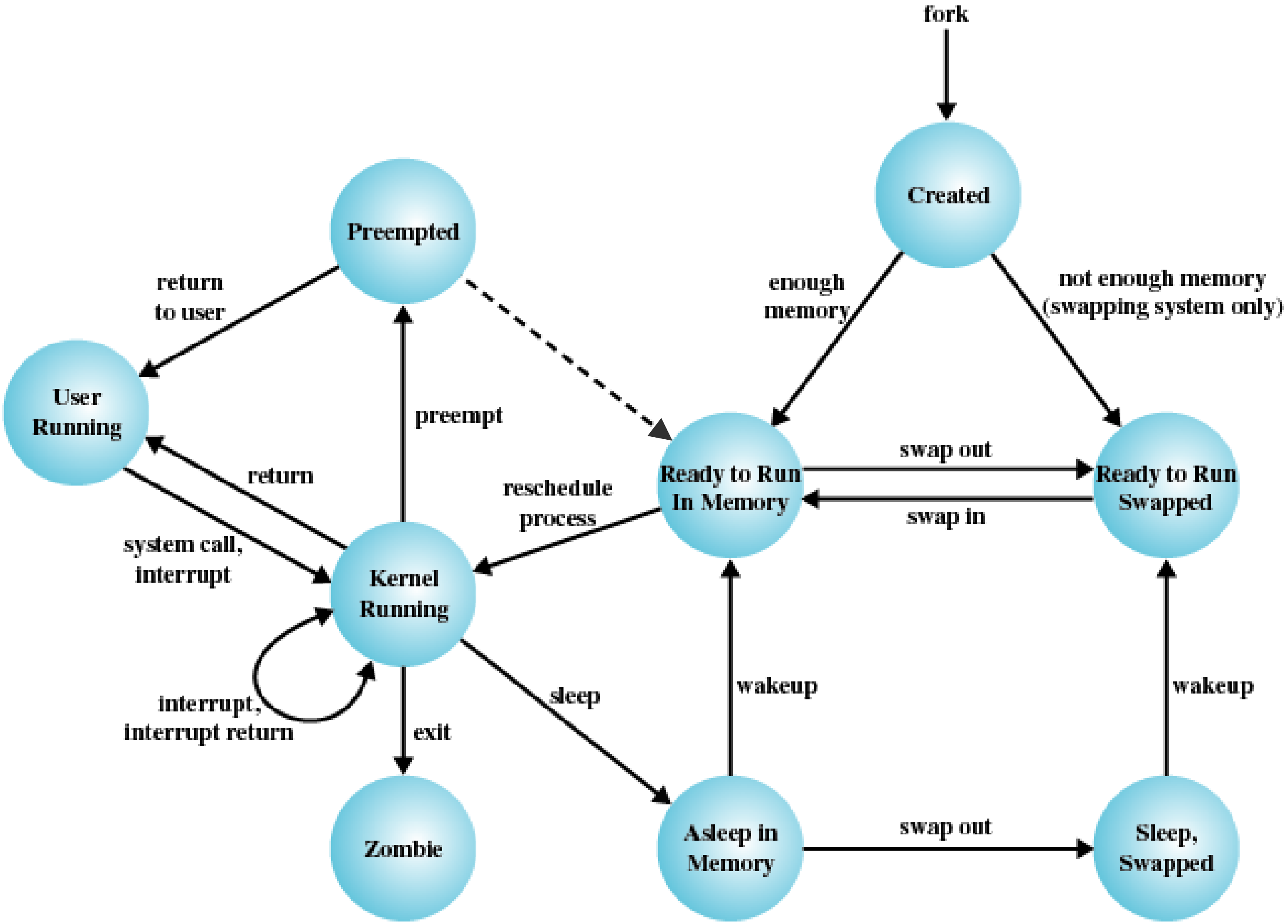


Two modes are used: user / kernel mode (Ring 3/Ring 0)

Two types of processes: system / user processes

➔ System processes are implemented as part of kernel to run background services, e.g. swapping

Example: UNIX – Process State Diagram



Example: UNIX – Process States

User Running	Executing in user mode.
Kernel Running	Executing in kernel mode.
Ready to Run, in Memory	Ready to run as soon as the kernel schedules it.
Asleep in Memory	Unable to execute until an event occurs; process is in main memory (a blocked state).
Ready to Run, Swapped	Process is ready to run, but the swapper must swap the process into main memory before the kernel can schedule it to execute.
Sleeping, Swapped	The process is awaiting an event and has been swapped to secondary storage (a blocked state).
Preempted	Process is returning from kernel to user mode, but the kernel preempts it and does a process switch to schedule another process.
Created	Process is newly created and not yet ready to run.
Zombie	Process no longer exists, but it leaves a record for its parent process to collect.

Related System Calls

`int execve(const char *filename, char *const argv[], char *const envp[])`

- Executes program pointed to by **`filename`** with arguments **`argv`** and environment **`envp`** (in the form of key=value)
- Effectively replaces the current program with another one

➔ **`exec()`** family of library function

`pid_t fork(void)`

- Creates child process that differs from parent only in its PID (process identifier) and PPID (parent process identifier)
- Returns 0 for child process and child's PID for parent process

`void _exit(int status)`

- Terminates calling process; closes open file descriptors; children are adopted by process 1; signals termination to parent

➔ **`exit()`** library function

`pid_t wait(int *status)`

- Wait for state change in child of calling process

Programming Example

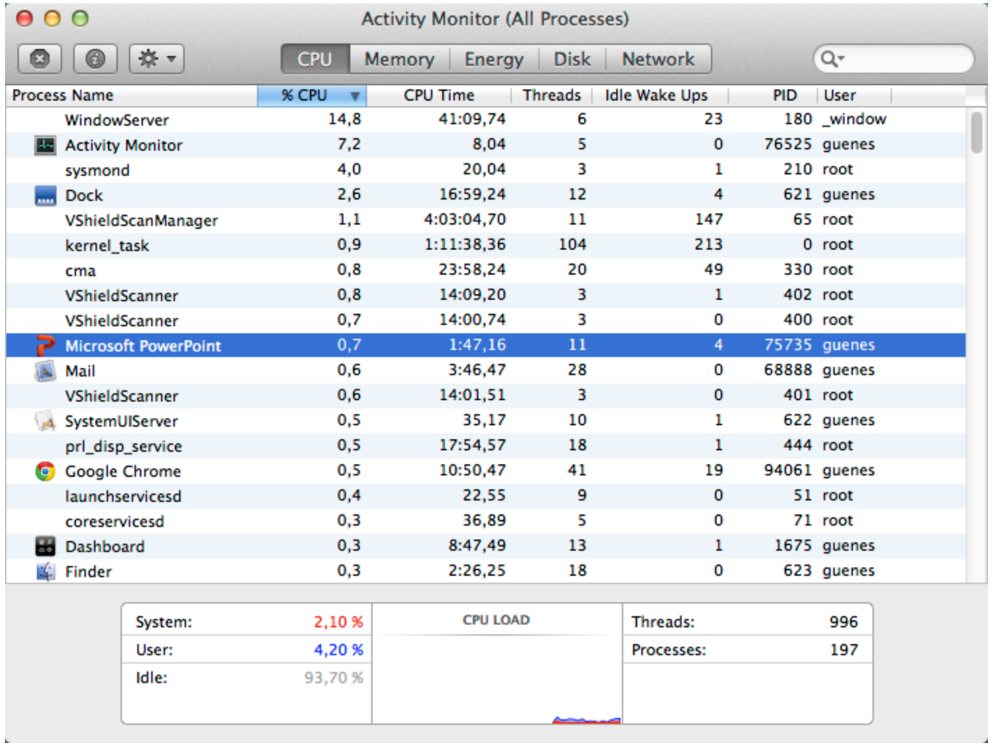
```
#include <stdio.h>
#include <stdlib.h>
#include <sys/wait.h>

main()
{
   int status;
   pid_t pid;

   pid = fork();
   if(pid == 0) {
     printf("Child process running...\n");
     // Do something...
     printf("Child process done.\n");
     exit(123);
   }
   else if(pid > 0) {
     printf("Parent process, waiting for child %d...\n", pid);
     pid = wait(&status);
     printf("Child process %d terminated, status %d.\n", pid, WEXITSTATUS(status));
     exit(EXIT_SUCCESS);
   }
   else {
     printf("fork() failed\n");
     exit(EXIT_FAILURE);
   }
}
```

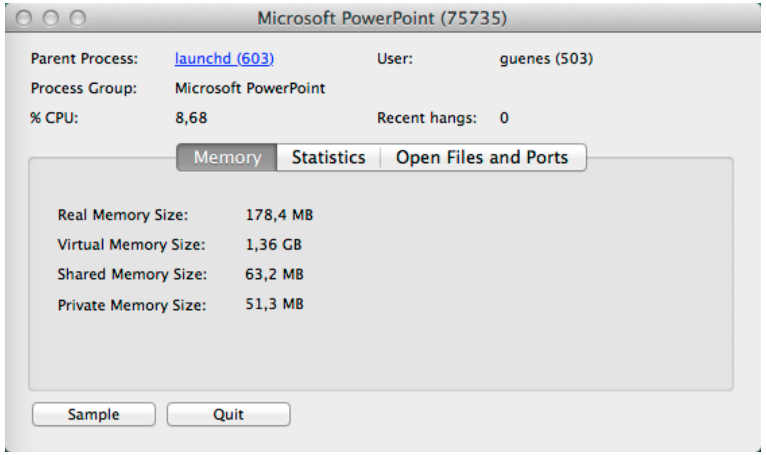
User-Level Process Control

wittenbu@vienna: /home/datsche/wittenbu - Shell - Konsole

```
wittenbu@vienna:~$ ps
  PID TTY          TIME CMD
19047 pts/1    00:00:00 csh
19050 pts/1    00:00:00 bash
19243 pts/1    00:00:00 ps
wittenbu@vienna:~$ kword &
[1] 19244
wittenbu@vienna:~$ ps
  PID TTY          TIME CMD
19047 pts/1    00:00:00 csh
19050 pts/1    00:00:00 bash
19244 pts/1    00:00:01 kword
19245 pts/1    00:00:00 ps
wittenbu@vienna:~$ kill -9 19244
wittenbu@vienna:~$ ps
  PID TTY          TIME CMD
19047 pts/1    00:00:00 csh
19050 pts/1    00:00:00 bash
19246 pts/1    00:00:00 ps
[1]+  Killed                  kword
wittenbu@vienna:~$
```

User-Level Process Control





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