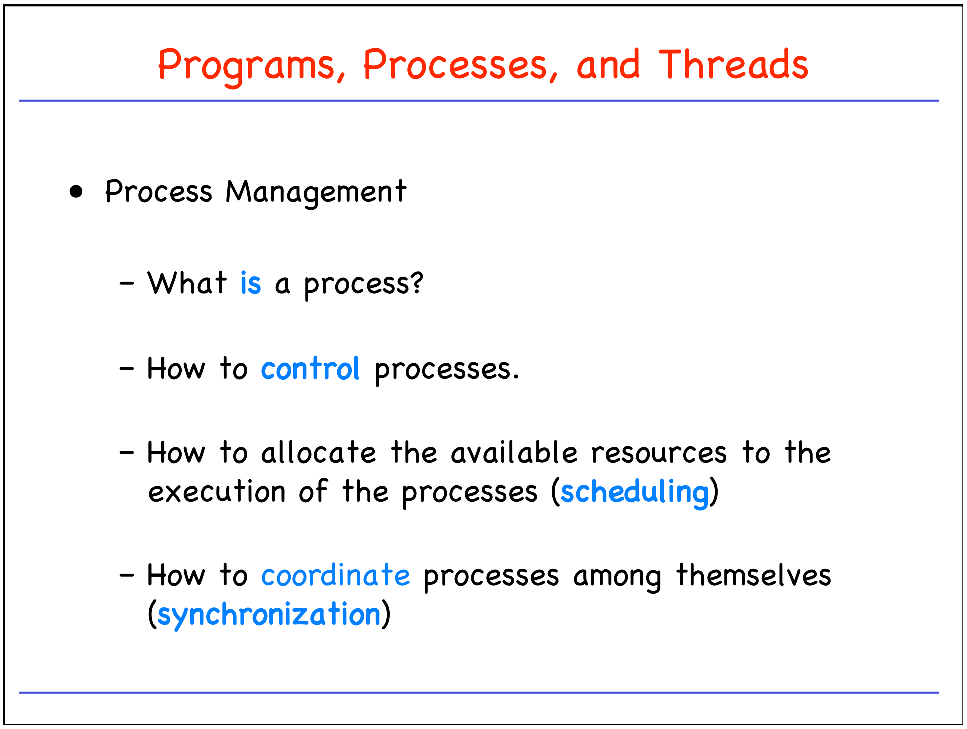
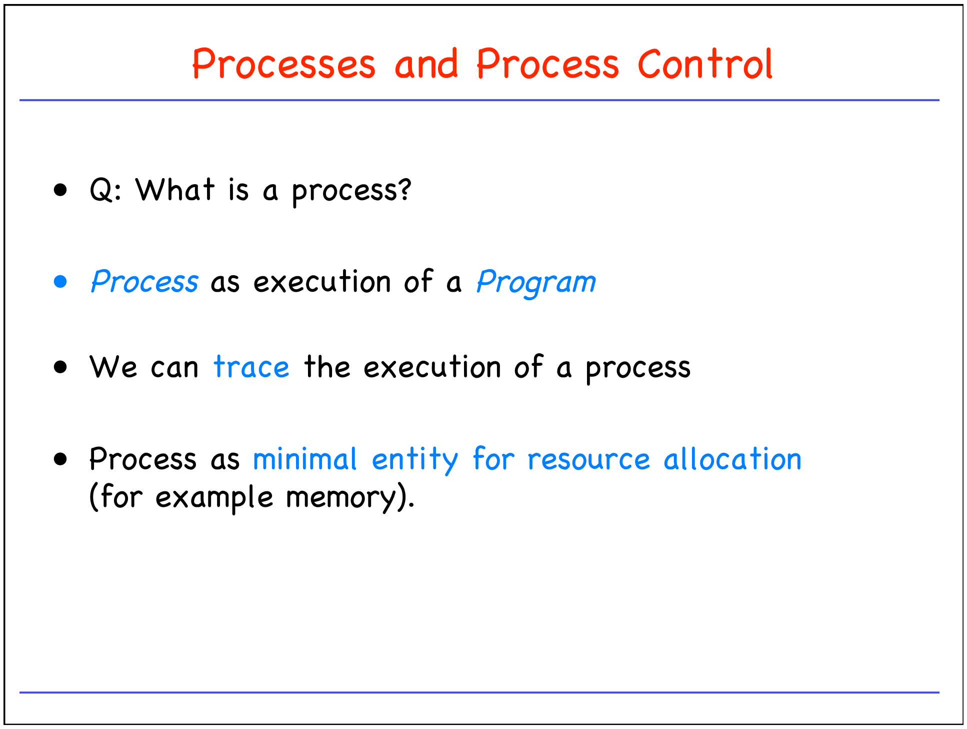


Programs, Processes, and Threads

- Process Management
  - What is a process?
  - How to control processes.
  - How to allocate the available resources to the execution of the processes (scheduling)
  - How to coordinate processes among themselves (synchronization)

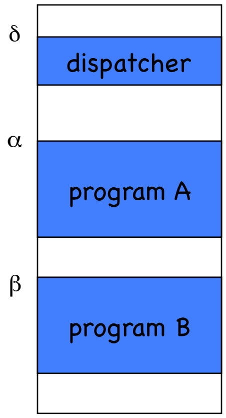


Processes and Process Control

- Q: What is a process?
- *Process* as execution of a *Program*
- We can trace the execution of a process
- Process as minimal entity for resource allocation (for example memory).

The Execution Trace of Processes

- Two processes and a dispatcher



Traces of processes A and B

α	β
α+1	β+1
α+2	β+2
α+3	β+3
α+4	β+4
α+5	β+5
α+6	β+6
α+7	β+7
α+8	β+8
α+9	β+9
α+10	β+10
α+11	β+11

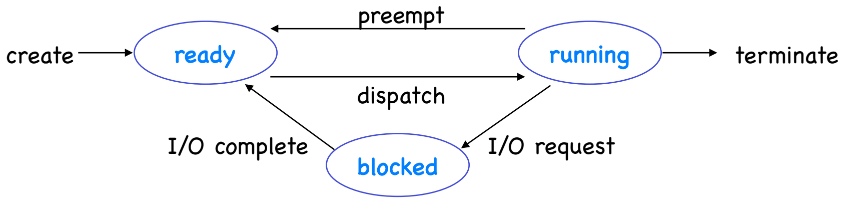
Trace of dispatcher

δ
δ+1
δ+2
δ+3
δ+4

β
β+1
β+2
β+3
β+4
δ
δ+1
δ+2
δ+3
δ+4
α
α+1
α+2
α+3
α+4
δ
δ+1
δ+2
δ+3
δ+4
β+5
β+6
β+7
...

States of a Process

- *User view*: A process is executing continuously
- *In reality*: Several processes compete for the CPU and other resources
- A process may be
  - running: it holds the CPU and is executing instructions
  - blocked: it is waiting for some I/O event to occur
  - ready: it is waiting to get back on the CPU

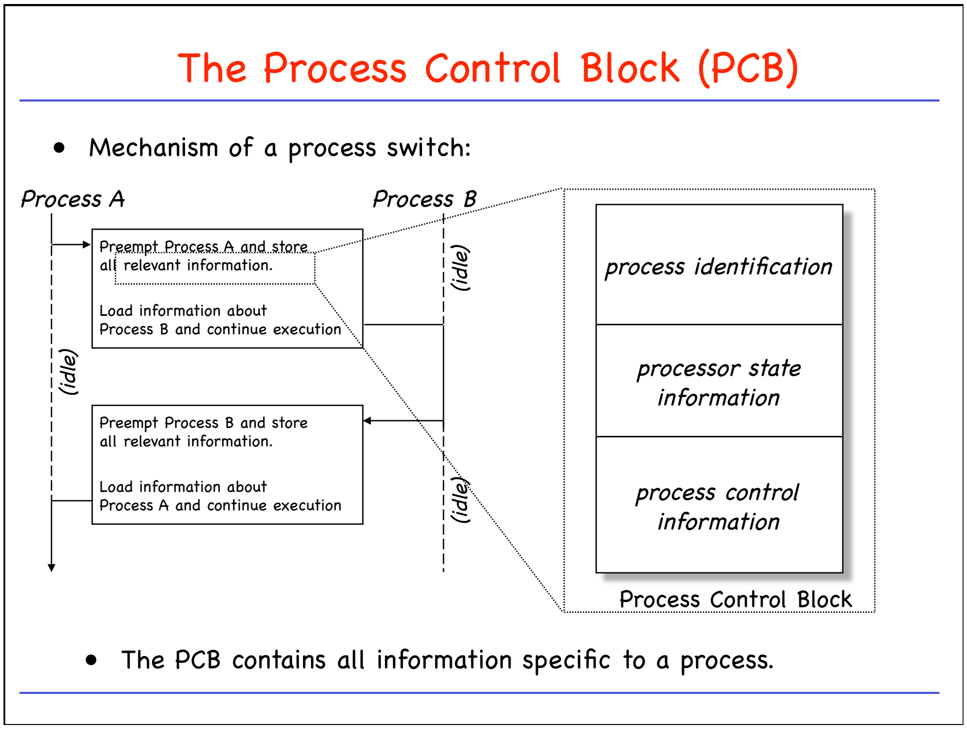


Process Creation

- When?
  - Submission of a batch job
  - User logs on
  - Create process to provide service such as printing
  - Spawned by existing processes
- How?
  - In UNIX:
    all processes created by fork() system call

Example: Vanilla Command Interpreter

```
char command[MAX_COMMAND_LENGTH];
do {
  command = read_command(stdin);
  if (fork() != 0) {
    /* parent */
    if (last_char(command) != ‘&’) {
      /* run in foreground, i.e. wait */
      waitpid(-1, &status, ...);
    }
  }
  else {
    /* child */
    execve(command, ...);
  }
} while (strcmp(command, “exit”) != 0); /* ?!? */
```

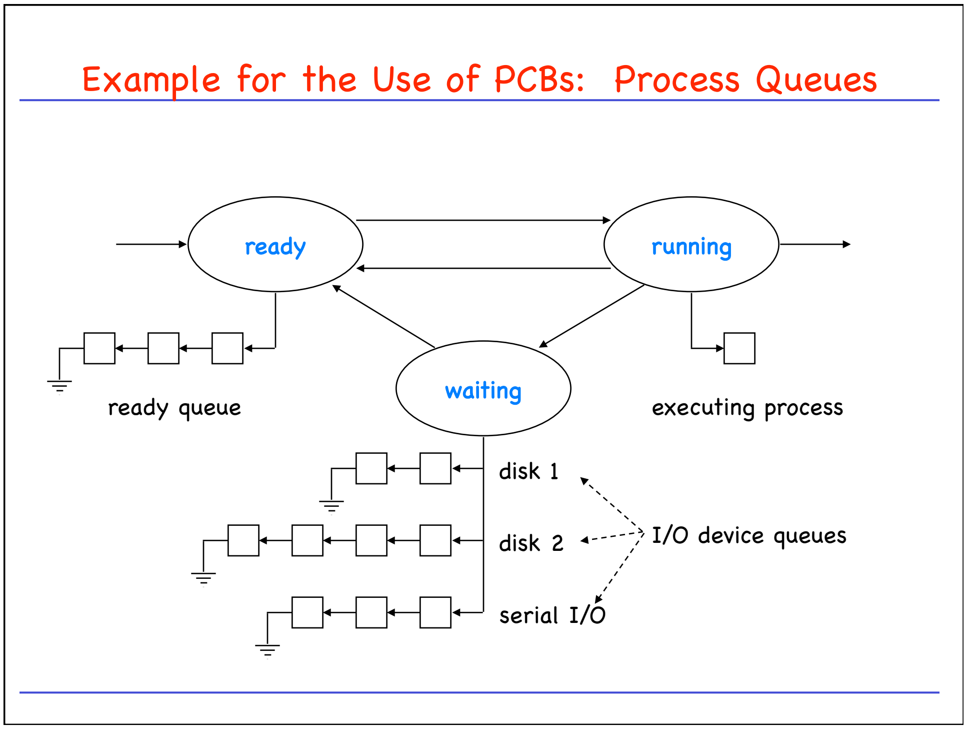


The Process Control Block (PCB)

- Mechanism of a process switch:

Process A
Process B
Preempt Process A and store all relevant information.
Load information about Process B and continue execution
(idle)
(idle)
Preempt Process B and store all relevant information.
Load information about Process A and continue execution
(idle)
process identification
processor state information
process control information
Process Control Block

- The PCB contains all information specific to a process.

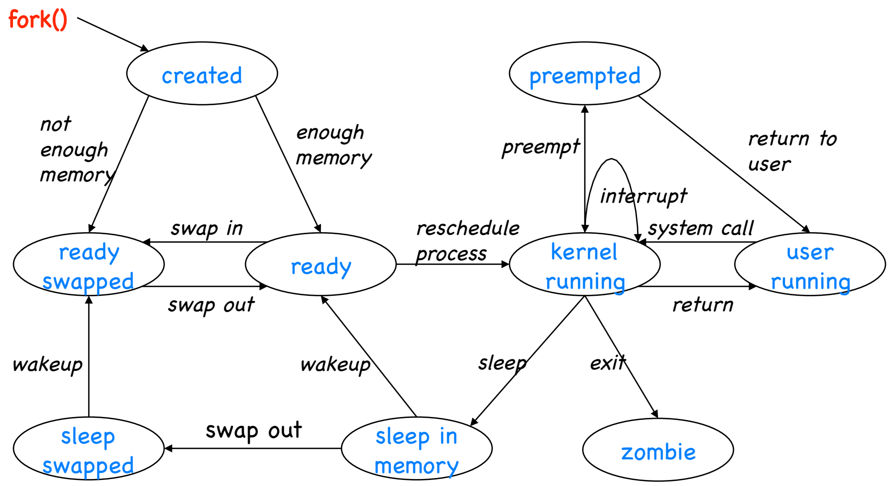


Example for the Use of PCBs: Process Queues

Elements of a PCB

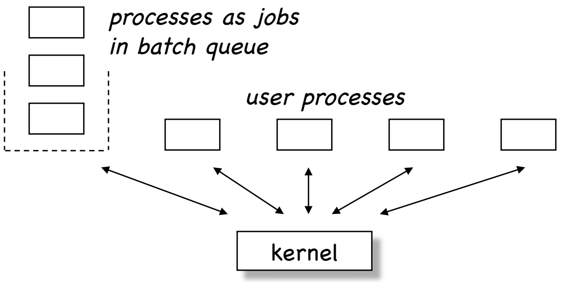
process identification	process id parent process id user id etc…
processor state information	register set condition codes processor status
process control information	process state scheduling information event (wait-for) memory-mgmt information owned resources

Processes in UNIX



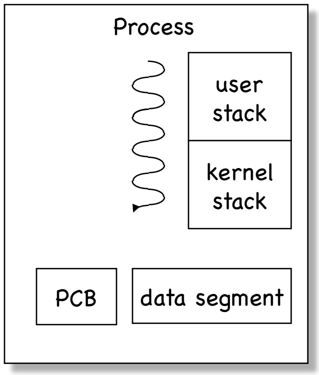
Threads

- Traditionally, processes interact very little:



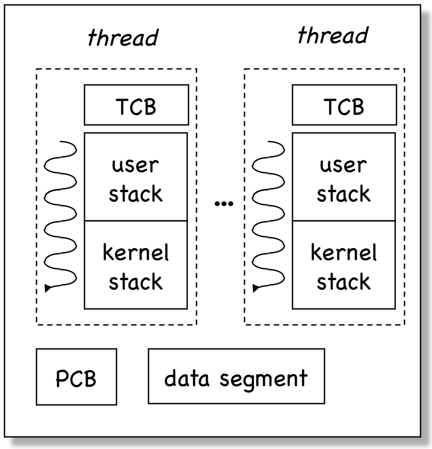
- This is not true in modern systems: Some applications may want to have multiple, tightly-coupled processes.

Problems with traditional (heavy-weight) processes



- Heavy-weight processes have separate address spaces:
  - Process creation is expensive
  - Process switch is expensive
  - Sharing memory areas among processes non-trivial

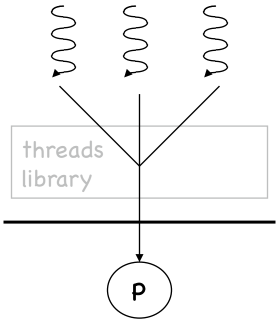
Threads

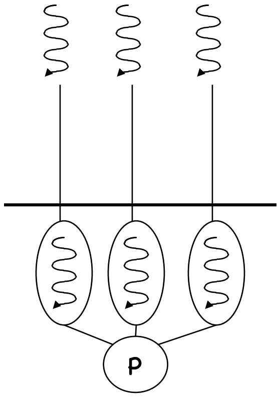


- Threads share address space:
  - Thread creation much simpler than process creation (no need to create and initialize address space, etc.)
  - Thread switch simple
  - Threads fully share the address space
- Convenience
  - communication between threads
- Efficiency
  - multiprogramming within a process (Netscape vs. Mosaic)
  - multiprocessors

User-Level *vs.* Kernel-Level Threads

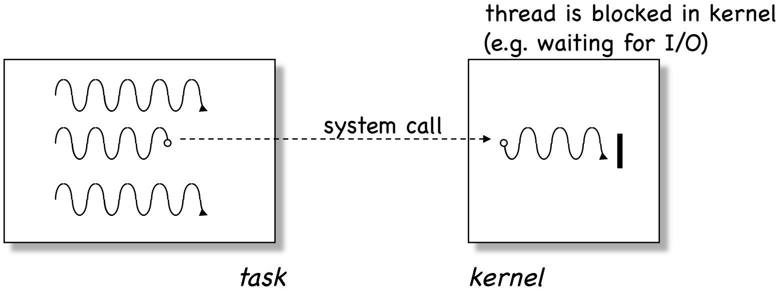
- User-level: kernel not aware of threads
- Kernel-level: all thread-management done in kernel



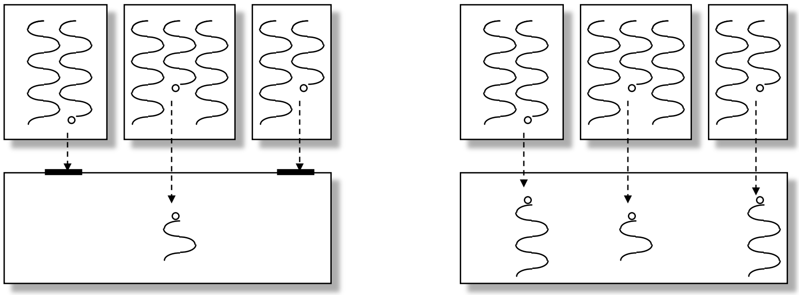


Potential Problems with Threads

- General: Several threads run in the same address space:
  - Protection must be explicitly programmed (by appropriate thread synchronization)
  - Effects of misbehaving threads limited to task
- User-level threads: Some problems at the interface to the kernel: With a single-threaded kernel, as system call blocks the entire task.

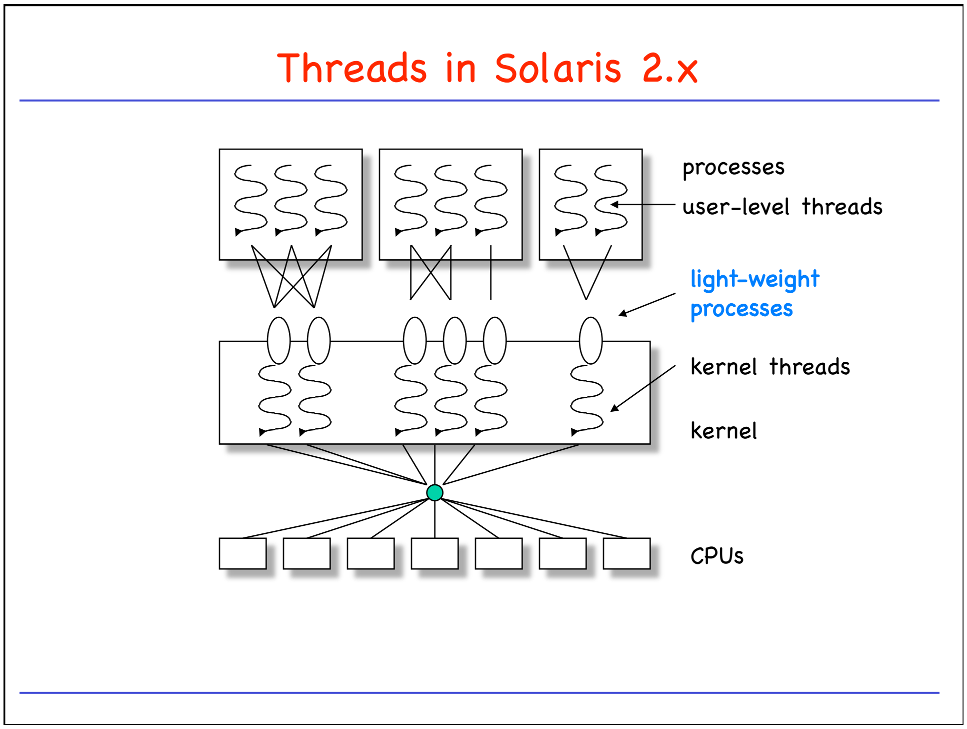


Singlethreaded vs. Multithreaded Kernel



- Protection of kernel data structures is trivial, since only one process is allowed to be in the kernel at any time.

- Special protection mechanism is needed for shared data structures in kernel.



Threads in Solaris 2.x