

Conventional View of Processes

- A process can be viewed two ways:
 - A unit of **resource ownership**
 - A process has an address space, containing program code and data
 - A process may have open files, may be using an I/O device, etc.
 - A unit of **scheduling**
 - The CPU scheduler dispatches one process at a time onto the CPU
 - Associated with a process are values in the PC, SP, and other registers
- Insight (~1988) — these two are usually linked, but they don't have to be
- In many recent operating systems (UNIX, Windows NT), the two are independent:
 - Process = unit of resource ownership
 - Thread = unit of scheduling

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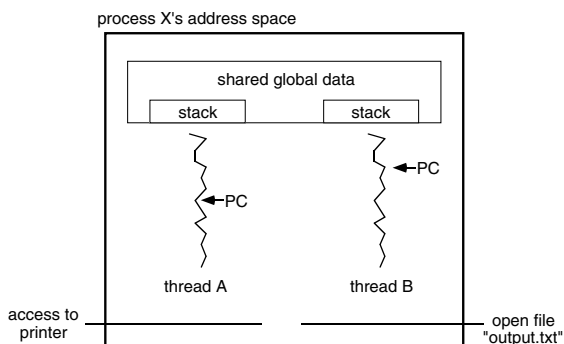
Processes vs. Threads

- *Process* = unit of resource ownership
 - A process (sometimes called a *heavyweight process*) has:
 - Address space
 - Program code
 - Global variables, heap, stack
 - OS resources (files, I/O devices, etc.)
- *Thread* = unit of scheduling
 - A thread (sometimes called a *lightweight process*) is a single sequential execution stream within a process
 - A thread **shares** with other threads:
 - Address space, program code
 - Global variables, heap
 - OS resources (files, I/O devices)
 - A thread has its own:
 - Registers, Program Counter (PC)
 - Stack, Stack Pointer (SP)

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Processes vs. Threads



- A thread is bound to a particular process
 - A process may contain multiple threads of control inside it
 - Threads can block, create children, etc.
- All of the threads in a process:
 - Share address space, program code, global variables, heap, and OS resources
 - Execute concurrently (has its own register, PC, SP, etc. values)

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Why Threads?

- A process with multiple threads makes a great server (e.g., printer server):
 - Have one server process, many "worker" threads — if one thread blocks (e.g., on a read), others can still continue executing
 - Threads can share common data; don't need to use inter-process communication
 - Can take advantage of multiprocessors
- Threads are cheap!
 - Cheap to create — only need a stack and storage for registers
 - Use very little resources — don't need new address space, global data, program code, or OS resources
 - Context switches are fast — only have to save / restore PC, SP, and registers
- But... no protection between threads!

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User-Level Threads

- User-level threads = provide a library of functions to allow user processes to create and manage their own threads
 - ✓ Doesn't require modification to the OS
 - ✓ Simple representation — each thread is represented simply by a PC, registers, stack, and a small control block, all stored in the user process' address space
 - ✓ Simple management — creating a new thread, switching between threads, and synchronization between threads can all be done without intervention of the kernel
 - ✓ Fast — thread switching is not much more expensive than a procedure call
 - ✓ Flexible — CPU scheduling (among those threads) can be customized to suit the needs of the algorithm

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User-Level Threads (cont.)

- User-level threads = provide a library of functions to allow user processes to create and manage their own threads
 - ✗ Lack of coordination between threads and OS kernel
 - Process as a whole gets one time slice
 - Same time slice, whether process has 1 thread or 1000 threads
 - Also — up to each thread to relinquish control to other threads in that process
 - ✗ Requires non-blocking system calls (i.e., a multithreaded kernel)
 - Otherwise, entire process will be blocked in the kernel, even if there are runnable threads left in the process
 - ✗ If one thread causes a page fault, the entire process blocks

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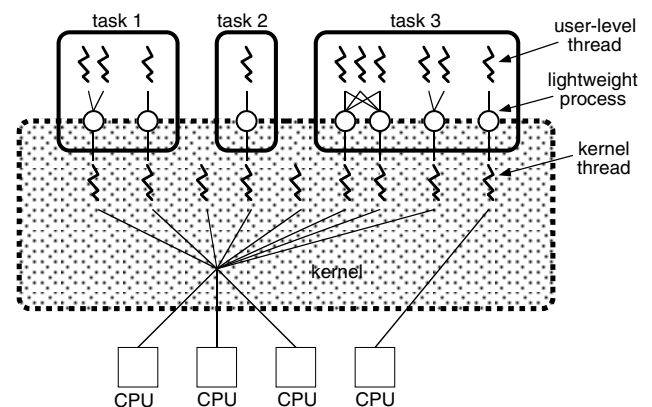
Kernel-Level Threads

- Kernel-level threads = kernel provides system calls to create and manage threads
 - ✓ Kernel has full knowledge of all threads
 - Scheduler may choose to give a process with 10 threads more time than process with only 1 thread
 - ✓ Good for applications that frequently block (e.g., server processes with frequent interprocess communication)
 - ✗ Slow — thread operations are 100s of times slower than for user-level threads
 - ✗ Significant overhead and increased kernel complexity — kernel must manage and schedule threads as well as processes
 - Requires a full thread control block (TCB) for each thread

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Two-Level Thread Model (Digital UNIX, Solaris, IRIX, HP-UX)



- User-level threads for user processes
 - “Lightweight process” (LWP) serves as a “virtual CPU” where user threads can run
- Kernel-level threads for use by kernel
 - One for each LWP
 - Others perform tasks not related to LWPs
- OS supports multiprocessor systems

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