Threads

CSE 410 - Computer Systems

November 16, 2001

Readings and References

- Reading
  - › Chapter 5, *Operating System Concepts*, Silberschatz, Galvin, and Gagne

- Other References
  - › *Inside Microsoft Windows 2000*, Third Edition, Solomon and Russinovich
  - › *Pthreads Programming*, Nichols, Buttlar and Farrell

A Process

- A complete process includes numerous things
  - › address space (all the code and data pages)
  - › OS resources and accounting information
  - › a “thread of control”, which defines where the process is currently executing
    - the Program Counter
    - CPU registers

Processes are heavyweight objects

- Creating a new process is costly
  - › lots of data must be allocated and initialized
  - › operating system control data structures
  - › memory allocation for the process
- Communicating between processes is costly
  - › most communication goes through the OS
  - › need a context switch for each process

Parallelism using Processes

- Why build a parallel program?
  - › responsiveness to user
  - › web server handling simultaneous web requests
  - › execute faster on a multiprocessor
- One approach using heavyweight processes
  - › create several processes to execute in parallel
  - › map each process to the same address space
  - › specify starting address and initial parameters

Parallel processes are expensive

- There’s a lot of cost
  - › creating these processes
  - › coordinating them
- There’s a lot of duplication
  - › same program code, protection, etc…
- It may be time for a little refinement and complexity ...

What is fundamental in a process?

- What do our parallel processes share?
  - › Same code and data (address space)
  - › Same privileges
  - › They share almost everything in the process
- What don’t they share?
  - › Program Counter, registers, and stack
- Separate the idea of “process” from the idea of a “thread of control” (PC, SP, registers)

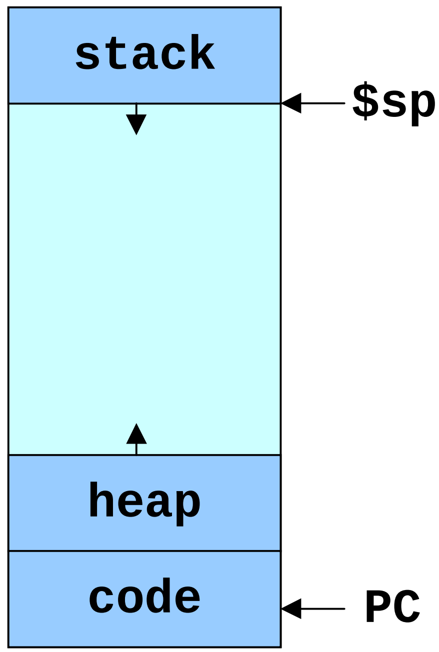
Threads are “Lightweight Processes”

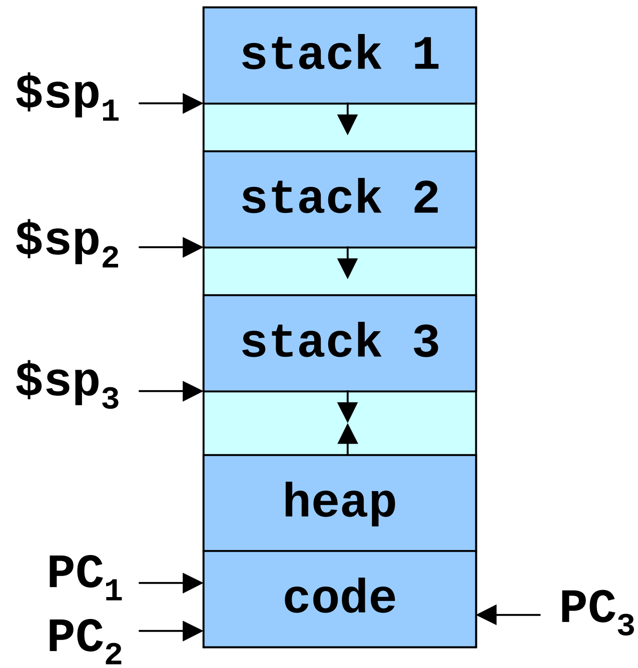
- Most operating systems now support two entities
  - the <u>process</u>, which defines the <u>address space</u> and general process attributes
  - the <u>thread</u>, which defines one or more <u>execution paths</u> within a process
- Threads are the unit of scheduling
- Processes are the “containers” in which threads execute

Multi-threaded design benefits

- Separating execution path from address space simplifies design of parallel applications
- Some benefits of threaded designs
  - › improved responsiveness to user actions
  - › handling concurrent events (e.g., web requests)
  - › simplified program structure (code, data)
  - › more efficient and so less impact on system
  - › map easily to multi-processor systems

One thread   Three threads





Cookbook Analogy

- Think of a busy kitchen over the holiday
  - › 3 cooks and 1 cookbook
- Each cook maintains a pointer to where they are in the cookbook (the Program Counter)
- Two cooks could both be making the same thing (threads running the same procedure)
- The cooks must coordinate access to the kitchen appliances (resource access control)

Implementation

- A thread is bound to the process that provides its address space
- Each process has one or more threads
- How are threads actually implemented?
  - › In the kernel and user mode libraries combined
  - › In user mode libraries alone

Kernel Threads

- The operating system knows about and manages the threads in every program
- Thread operations (create, yield, ...) all require kernel involvement
- Major benefit is that threads in a process are scheduled independently
  - › one blocked thread does not block the others
  - › threads in a process can run on different CPUs

Kernel Thread Performance

- Kernel threads have performance issues
- Even though threads avoid process overhead, operations on kernel threads are still slow
  - › a thread operation requires a kernel call
  - › kernel threads may be overly general, in order to support needs of different users, languages, etc.
  - › the kernel doesn’t trust the user, so there must be lots of checking on kernel calls

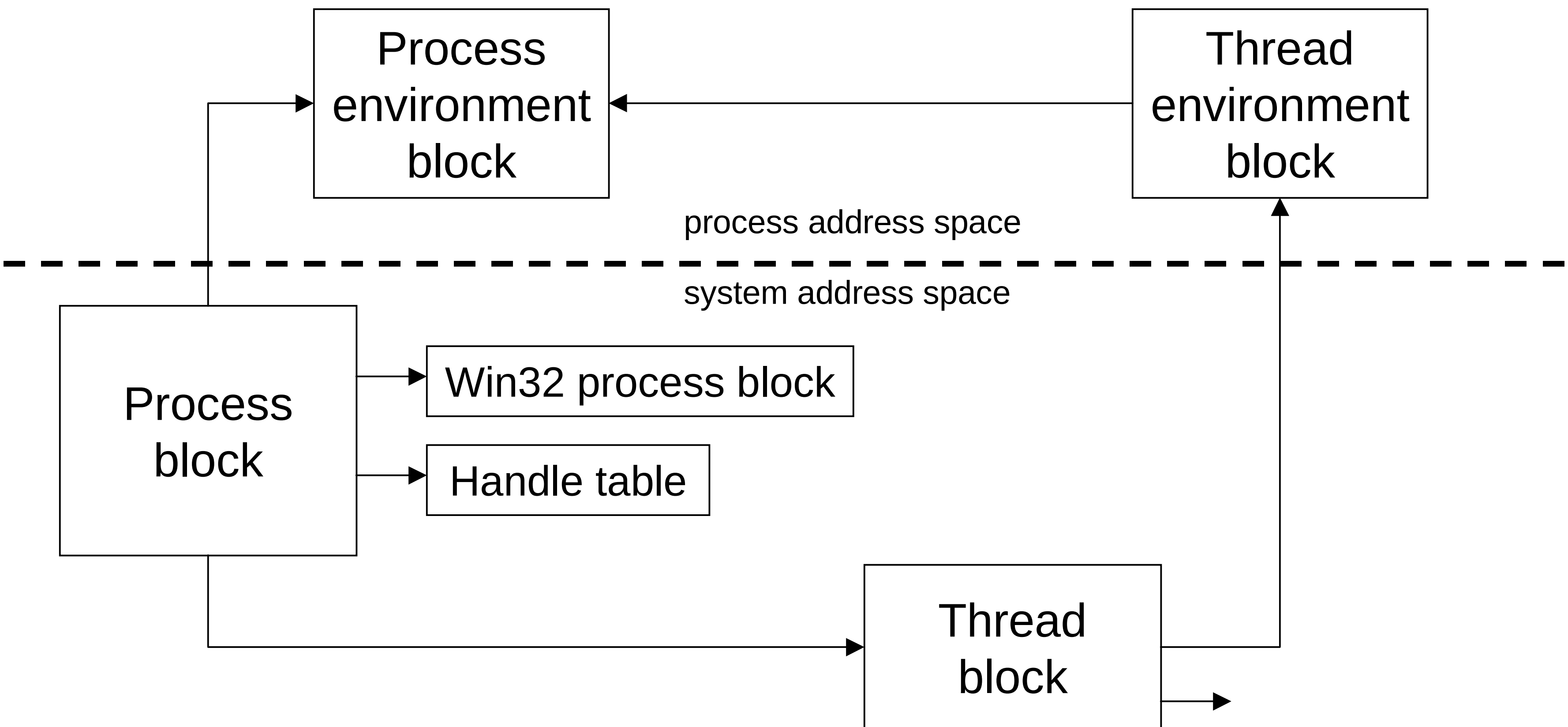
User Threads

- To make thread operations faster, they can be implemented at the user level
  - › Each thread is managed by the run-time system
  - › user-mode libraries are linked with your program
- Each thread is represented simply by a PC, registers, stack and a control block, managed in the user's address space

User Thread Performance

- All activities happen in user address space so thread operations can be faster
- But OS scheduling takes place at process level
  - › block entire process if a single thread is I/O blocked
  - › may run a process that is just running an idle thread
- Win2K provides “fibers” as user mode threads
  - › application can schedule its own “lightweight threads” in user mode code

Simplified W2K Process Data



Copied from *Inside Windows 2000*

Simplified Thread Interface

- t = thread_create(), thread_start(t)
  - › create a new thread of control and start it
- thread_yield()
  - › voluntarily give up the processor for awhile
- thread_exit()
  - › terminate the calling thread

Win2K Thread/Fiber API

- Thread Functions
  - **AttachThreadInput CreateRemoteThread CreateThread ExitThread GetCurrentThread GetCurrentThreadId GetExitCodeThread GetThreadPriority GetThreadPriorityBoost GetThreadTimes ResumeThread SetThreadAffinityMask SetThreadIdealProcessor SetThreadPriority SetThreadPriorityBoost Sleep SleepEx SuspendThread SwitchToThread TerminateThread ThreadProc TlsAlloc TlsFree TlsGetValue TlsSetValue WaitForInputIdle**
- Fiber Functions
  - **ConvertThreadToFiber CreateFiber DeleteFiber FiberProc GetCurrentFiber GetFiberData SwitchToFiber**