

Last Class: CPU Scheduling

- Pre-emptive versus non-preemptive schedulers
- Goals for Scheduling:
 - Minimize average response time
 - Maximize throughput
 - Share CPU equally
 - Other goals?
- **Scheduling Algorithms:**
 - Selecting a scheduling algorithm is a policy decision - consider tradeoffs
 - FSCS
 - Round-robin
 - SJF/SRTF
 - MLFQ
 - Lottery scheduler



Today: Threads

- What are threads?
- Where should we implement threads? In the kernel? In a user level threads package?
- How should we schedule threads (or processes) onto the CPU?

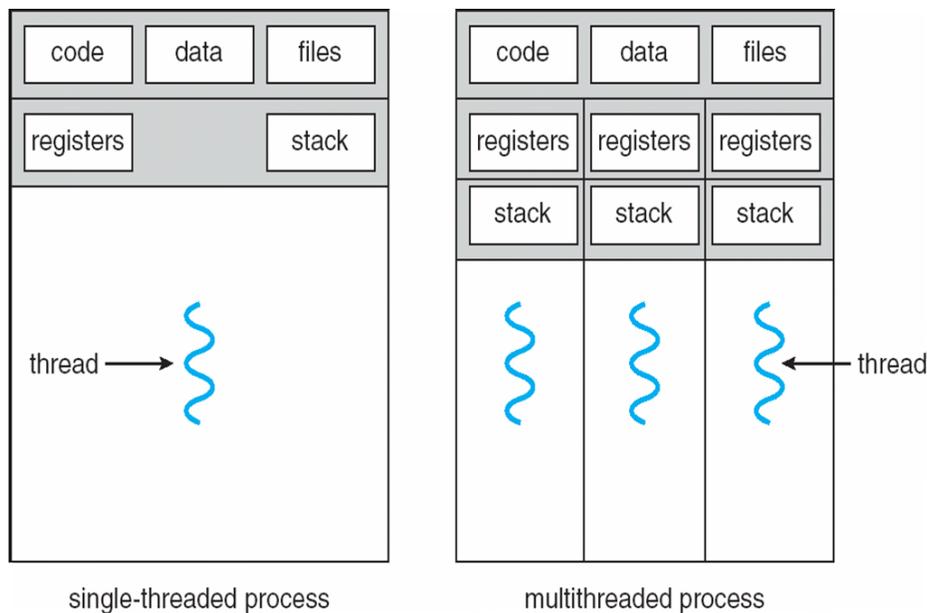


Processes versus Threads

- A **process** defines the address space, text, resources, etc.,
- A **thread** defines a single sequential execution stream within a process (PC, stack, registers).
- Threads extract the *thread of control* information from the process
- Threads are bound to a single process.
- Each process may have multiple threads of control within it.
 - The address space of a process is shared among all its threads
 - No system calls are required to cooperate among threads
 - Simpler than message passing and shared-memory

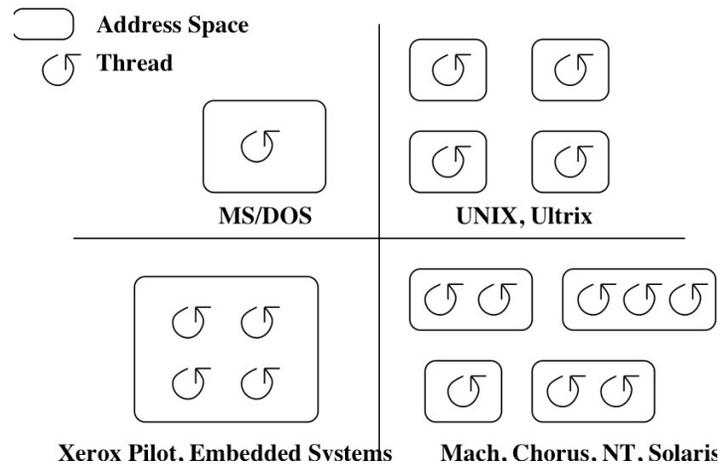


Single and Multithreaded Processes



Classifying Threaded Systems

Operating Systems can support one or many address spaces, and one or many threads per address space.



Example Threaded Program

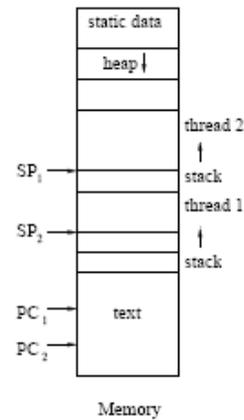
```

main()
  global in, out, n, buffer[n];
  in = 0; out = 0;
  fork_thread (producer());
  fork_thread (consumer());
end

producer
  repeat
    nextp = produced item
    while in+1 mod n = out do no-op
    buffer[in] = nextp; in = (in+1) mod n
  repeat

consumer
  repeat
    while in = out do no-op
    nextc = buffer[out]; out = (out+1) mod n
    consume item nextc
  repeat
  
```

One possible memory layout:



- Forking a thread can be a system call to the kernel, or a procedure call to a thread library (user code).



Kernel Threads

- A **kernel thread**, also known as a **lightweight process**, is a thread that the operating system knows about.
 - Switching between kernel threads of the same process requires a small context switch.
 - The values of registers, program counter, and stack pointer must be changed.
 - Memory management information does not need to be changed since the threads share an address space.
 - The kernel must manage and schedule threads (as well as processes), but it can use the same process scheduling algorithms.
- ➔ Switching between kernel threads is slightly faster than switching between processes.

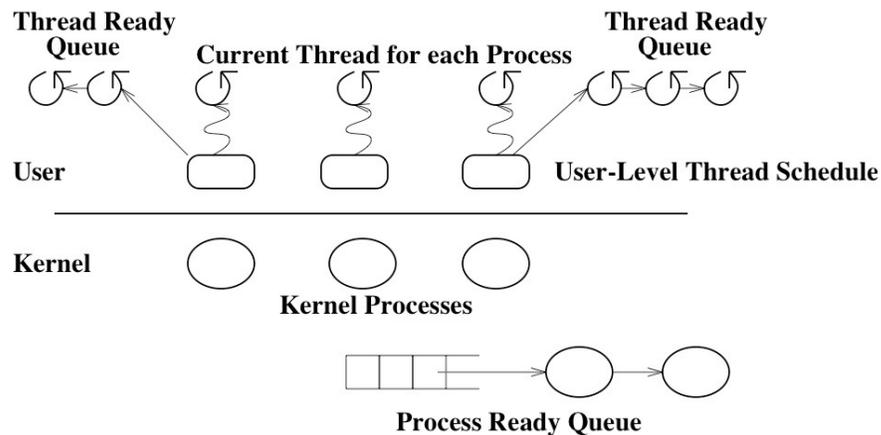


User-Level Threads

- A **user-level thread** is a thread that the OS does *not* know about.
- The OS only knows about the process containing the threads.
- The OS only schedules the process, not the threads within the process.
- The programmer uses a *thread library* to manage threads (create and delete them, synchronize them, and schedule them).



User-Level Threads



User-Level Threads: Advantages

- There is no context switch involved when switching threads.
 - User-level thread scheduling is more flexible
 - A user-level code can define a problem dependent thread scheduling policy.
 - Each process might use a different scheduling algorithm for its own threads.
 - A thread can voluntarily give up the processor by telling the scheduler it will *yield* to other threads.
 - User-level threads do not require system calls to create them or context switches to move between them
 - thread management calls are library calls and much faster than system calls made by kernel threads
- User-level threads are typically much faster than kernel threads

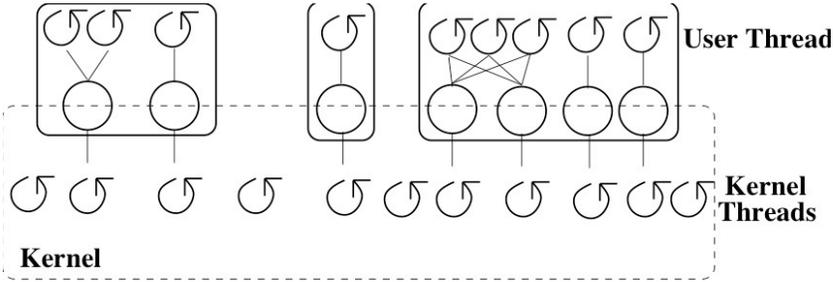


User-Level Threads: Disadvantages

- Since the OS does not know about the existence of the user-level threads, it may make poor scheduling decisions:
 - It might run a process that only has idle threads.
 - If a user-level thread is waiting for I/O, the entire process will wait.
 - Solving this problem requires communication between the kernel and the user-level thread manager.
- Since the OS just knows about the process, it schedules the process the same way as other processes, regardless of the number of user threads.
- For kernel threads, the more threads a process creates, the more time slices the OS will dedicate to it.



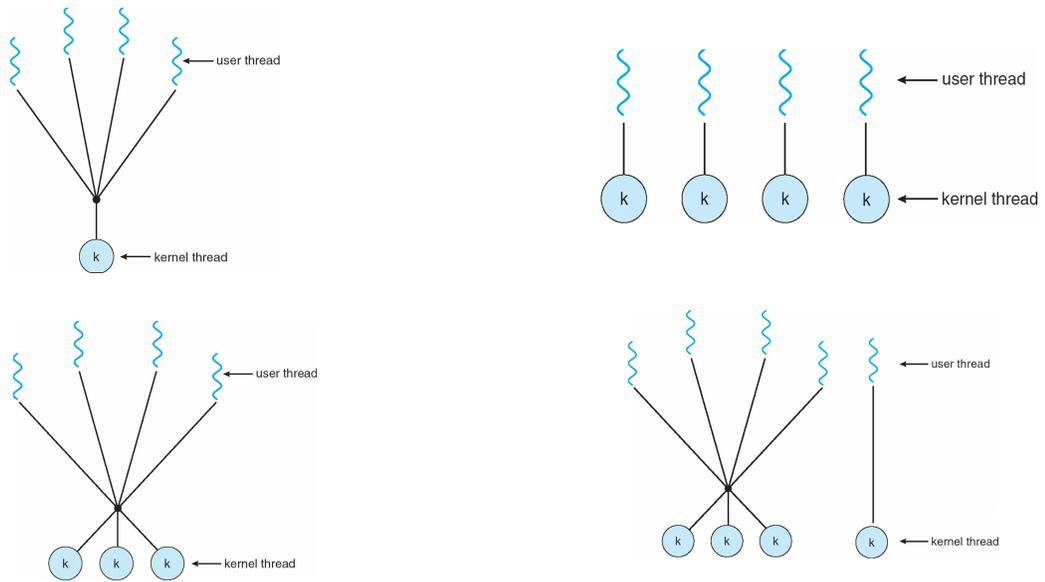
Example: Kernel and User-Level Threads in Solaris



- Address Space
- Lightweight process
- ⤵ Thread



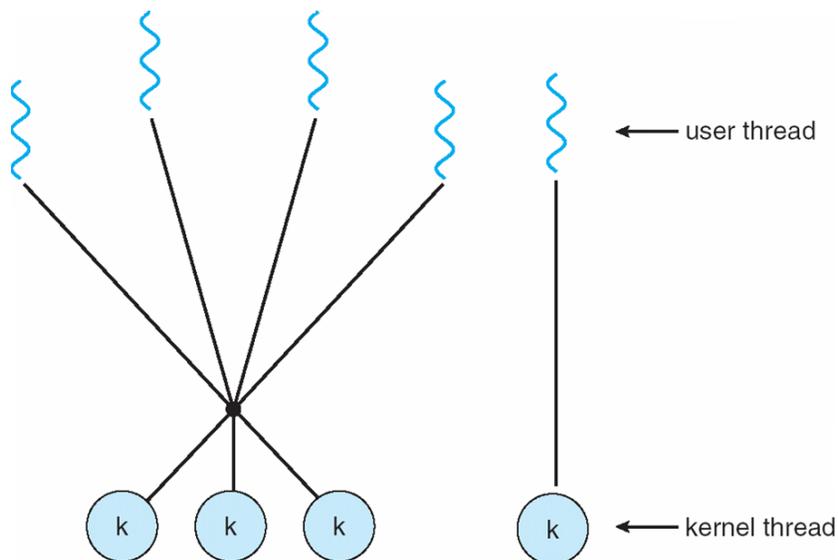
Threading Models



- Many-to-one, one-to-one, many-to-many and two-level



Two-level Model



Thread Libraries

- **Thread library** provides programmer with API for creating and managing threads
- Two primary ways of implementing
 - Library entirely in user space
 - Kernel-level library supported by the OS



Pthreads

- May be provided either as user-level or kernel-level
- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
- API specifies behavior of the thread library, implementation is up to development of the library
- Common in UNIX operating systems (Solaris, Linux, Mac OS X)

- WIN32 Threads: Similar to Posix, but for Windows



Java Threads

- Java threads are managed by the JVM
- Typically implemented using the threads model provided by underlying OS
- Java threads may be created by:
 - Extending Thread class
 - Implementing the Runnable interface



Examples

Pthreads:

```
pthread_attr_init(&attr); /* set default attributes */
pthread_create(&tid, &attr, sum, &param);
```

Win32 threads

```
ThreadHandle = CreateThread(NULL, 0, Sum, &Param, 0, &ThreadID);
```

Java Threads:

```
Sum sumObject = new Sum();
Thread t = new Thread(new Summation(param, sumObject));
t.start(); // start the thread
```



Summary

- Thread: a single execution stream within a process
- Switching between user-level threads is faster than between kernel threads since a context switch is not required.
- User-level threads may result in the kernel making poor scheduling decisions, resulting in slower process execution than if kernel threads were used.
- Many scheduling algorithms exist. Selecting an algorithm is a policy decision and should be based on characteristics of processes being run and goals of operating system (minimize response time, maximize throughput, ...).

