Threads

Operating Systems

Kartik Gopalan

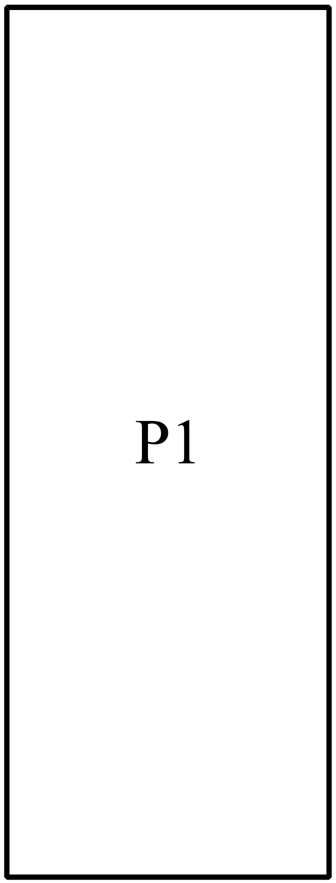
Chapter 2 Modern Operating Systems, Andrew Tanenbaum

Chapters 26 and 27, OSTEP book

Chapter 11 Advanced Programming in Unix Environment, By Richard Stevens

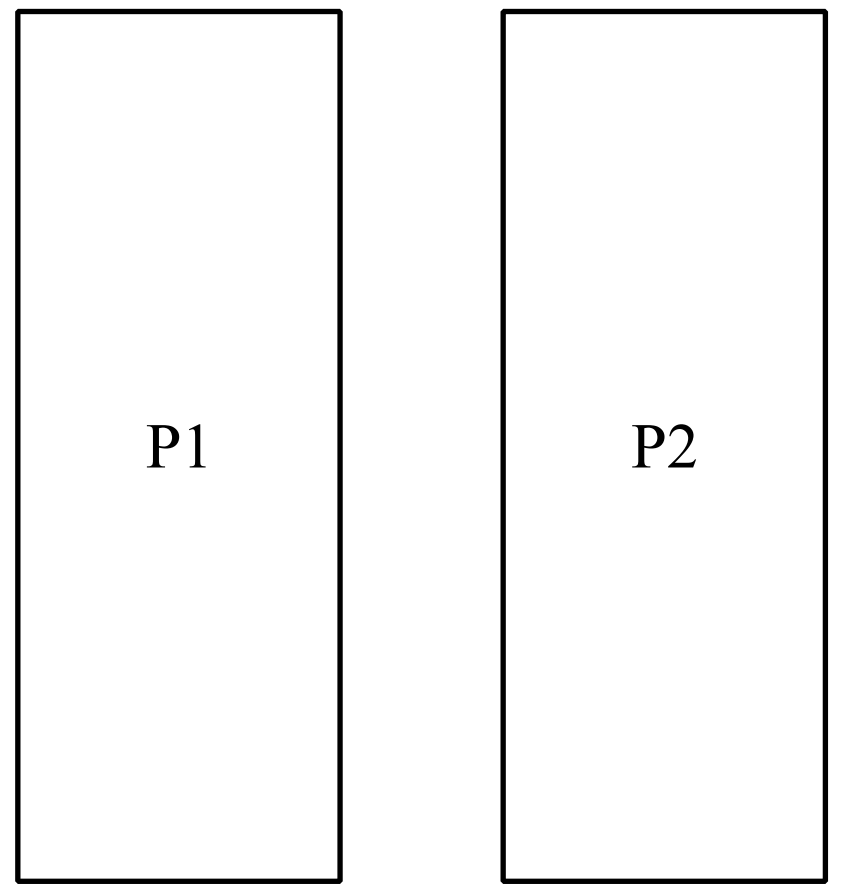
If you want to do one task

- Start one process



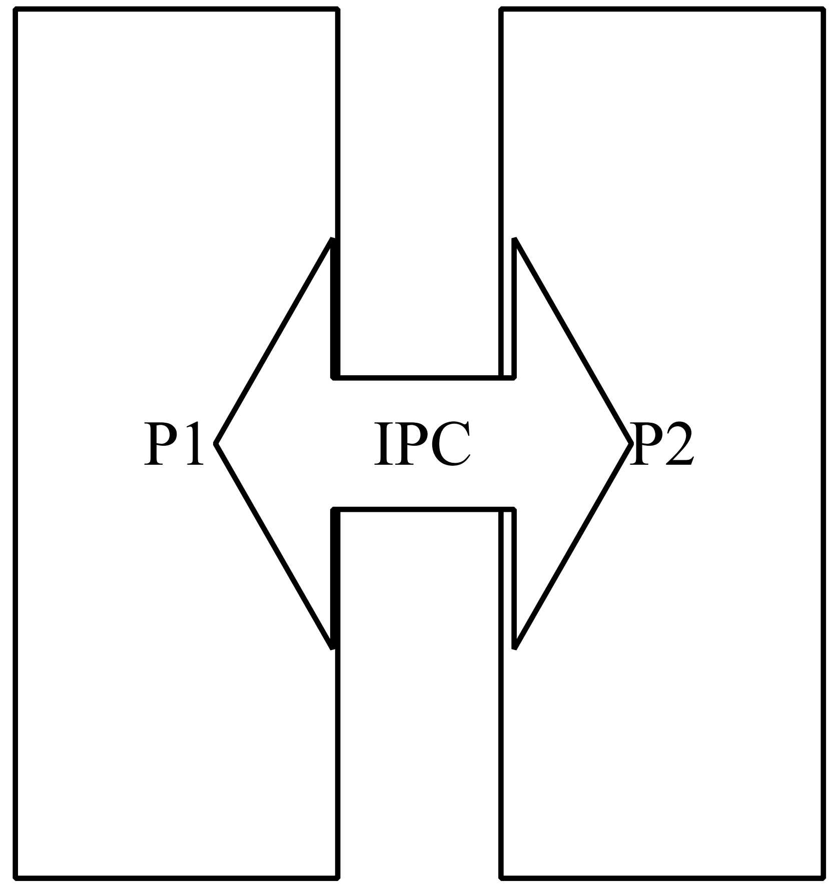
If you want to do two task “concurrently”

- Start two processes
  - Maybe P1 forks P2
  - and P3…PN etc if more than two tasks
- Problem:
  - fork is expensive
  - cold-start penalty



If P1 and P2 want to talk to each other?

- E.g. access the same data or synchronize?
- Two different address spaces
  - Need to use IPC
  - shared memory, pipes, sockets, signals
- Problem
  - kernel transitions are expensive
  - May need to copy data
    - user—->kernel—>user
  - Inter-process Shared memory is a pain to set up.



Option 1:Event-driven programming

- Make one process do all the tasks
- Busy loop polls for events and executes tasks for each event
- No IPC needed
- Length of the busy loop determines response latency
- Stateful event responses complicate the code
  - What if i^{th} occurrence of event 1 effects the j^{th} event processing ?

P1

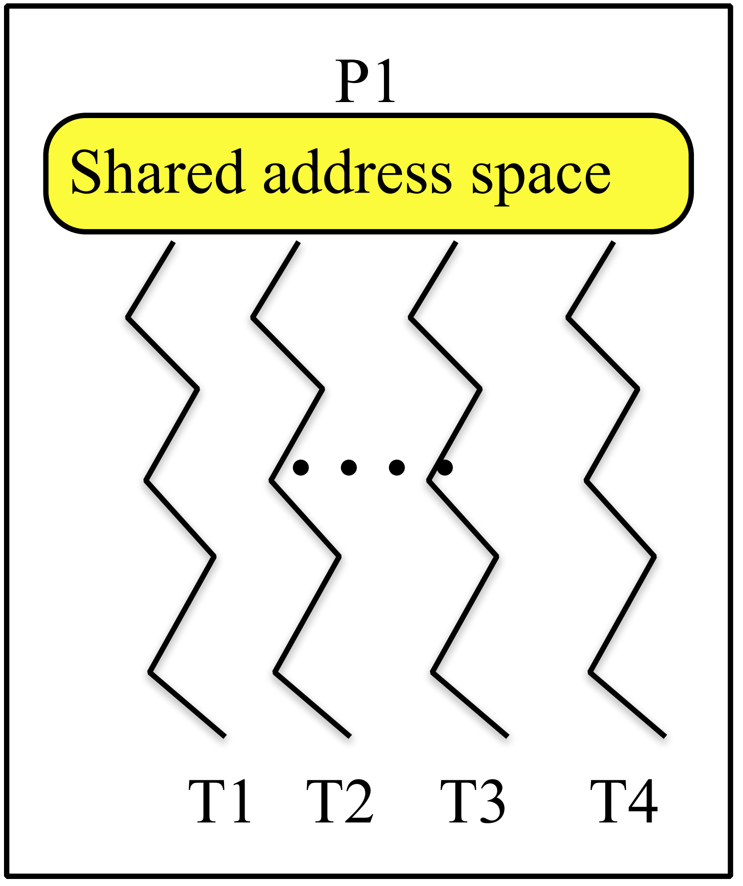
```
while(1)
{
    Check pending events;
    if (event 1) do task 1;
    if (event 2) do task 2;
    …
    if (event N) do task N;
}
```

Option 2: Use threads

- Multiple threads of execution per process

- Each thread has its own
  - Program counter
  - Stack, stack pointer
  - Registers

- All threads share
  - one virtual address space
    - code, heap and static data



Other Shared and non-shared components

- Shared components
  - Open descriptors (files, sockets etc)
  - Signals and Signal handlers

- Not shared
  - Thread ID
  - Errno
  - Priority

Address space layout

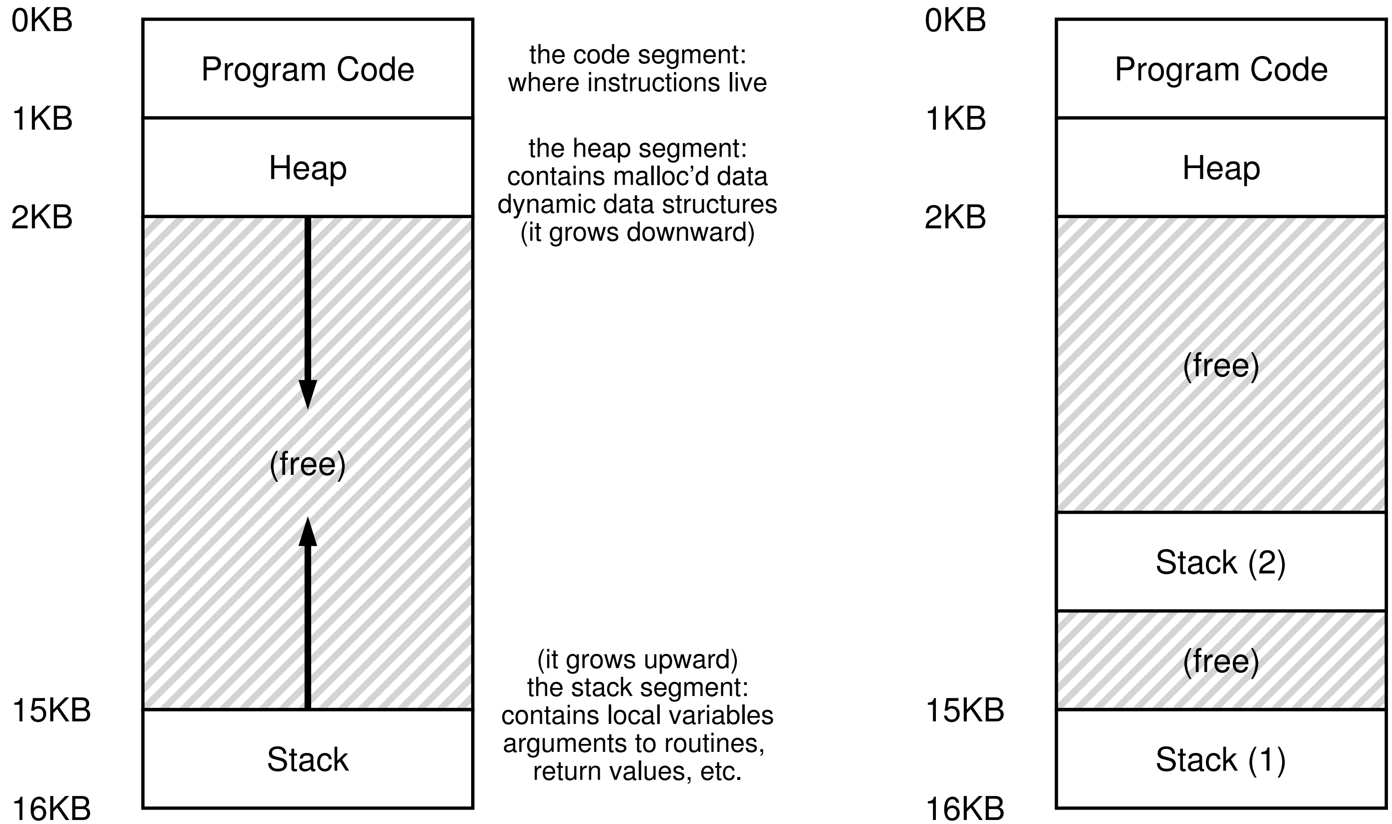
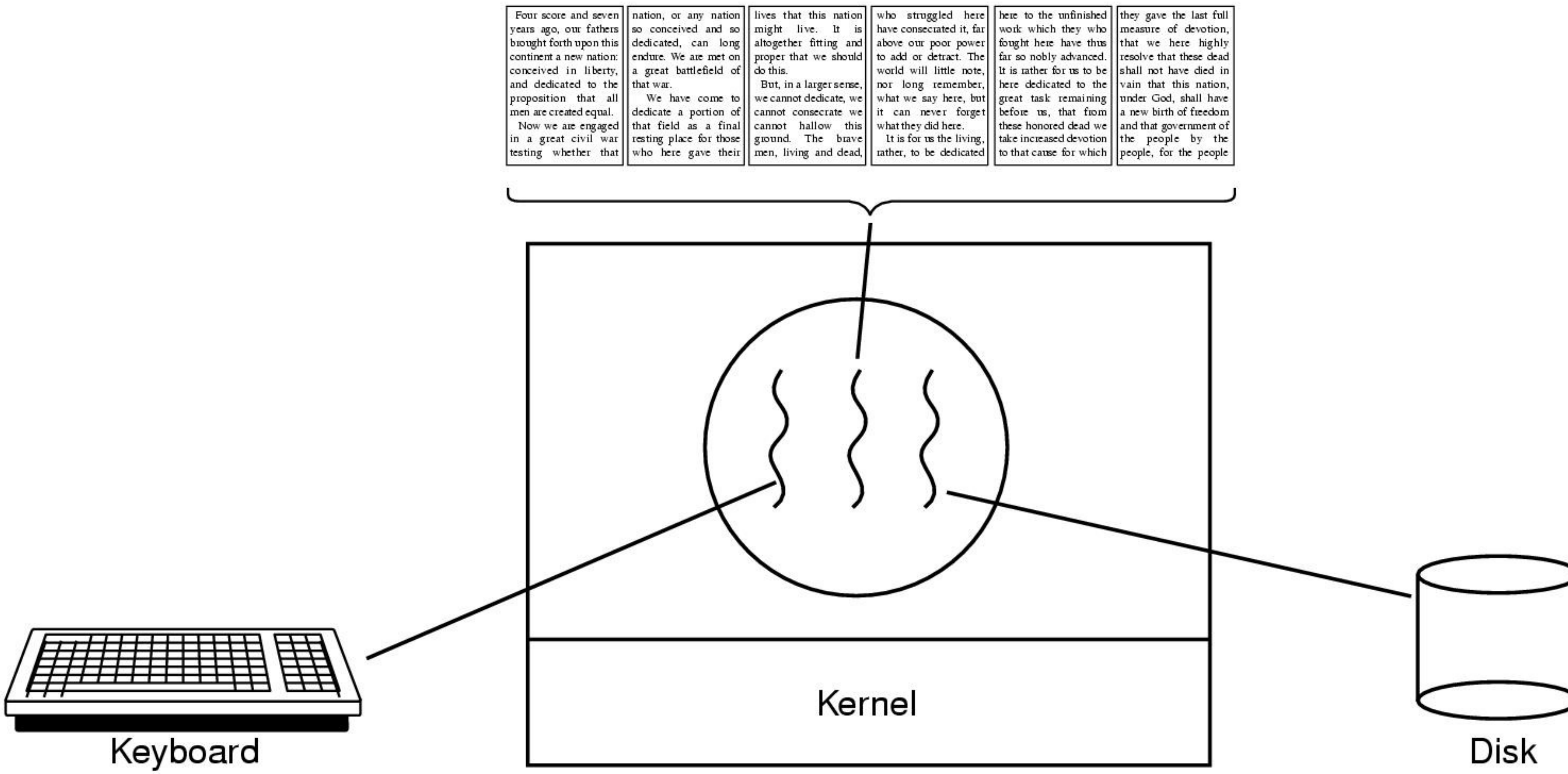


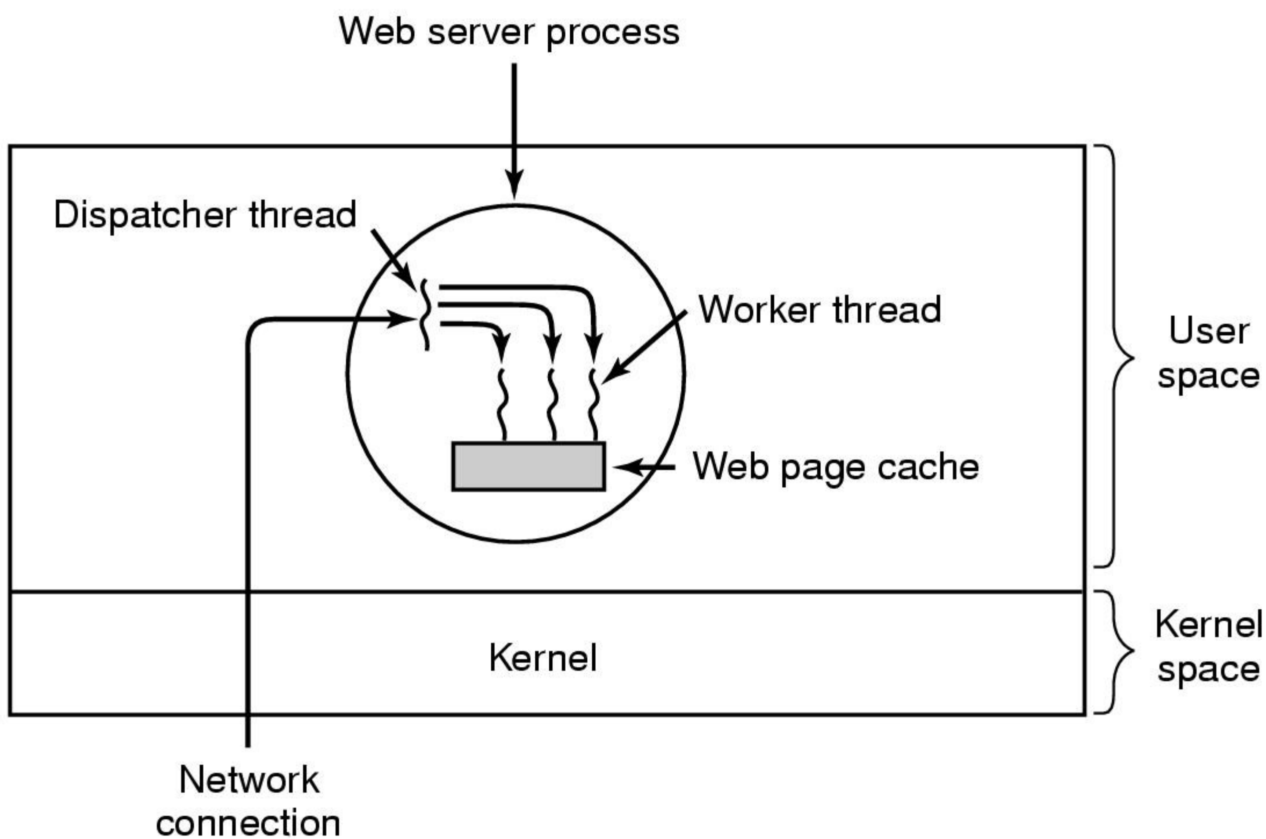
Figure 26.1: **Single-Threaded And Multi-Threaded Address Spaces**

Example: A word processor with three threads



- First thread handles keyboard input
- Second thread handles screen display
- Third thread handles saving the document to disk

Example: a multi-threaded web server



- A dispatcher thread waits for and accepts network connections
- Several worker threads
    - Each worker processes one network connection concurrently

Advantages of threads

- Lower inter-thread context switching overhead than processes

- No Inter-process communication
  - Zero data transfer cost between threads
  - Only need inter-thread synchronization

- Threads can be pre-empted at any point
  - Long-running threads are OK
  - As opposed to event-driven tasks that must be short.

- Threads can exploit parallelism
  - But it depends…more later

- Threads could block without blocking other threads
  - But it depends…more later

Disadvantages of Threads

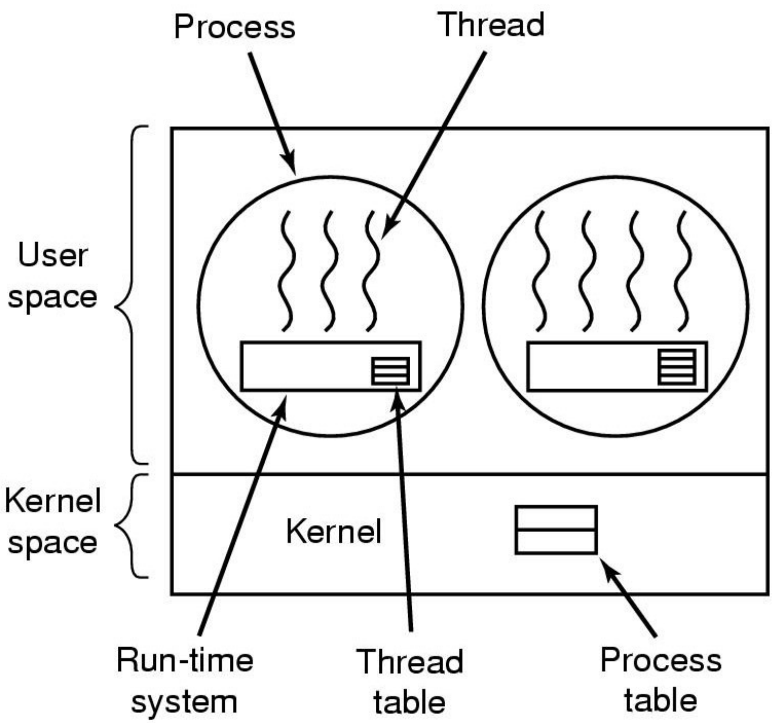
- Shared State!
  - Global variables are shared between threads.
  - Accidental data changes can cause errors.

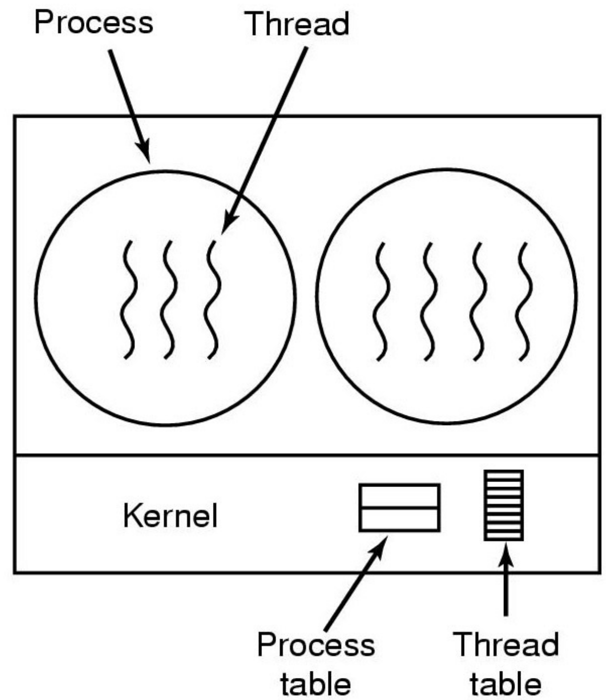
- Threads and signals don’t mix well
  - Common signal handler for all threads in a process
  - Which thread to signal? Everybody!
  - Royal pain to program correctly.

- Lack of robustness
  - Crash in one thread will crash the entire process.

- Some library functions may not be thread-safe
  - Library Functions that return pointers to static internal memory. E.g. gethostbyname()
  - Less of a problem these days.

Two types of threads: user-level and kernel-level





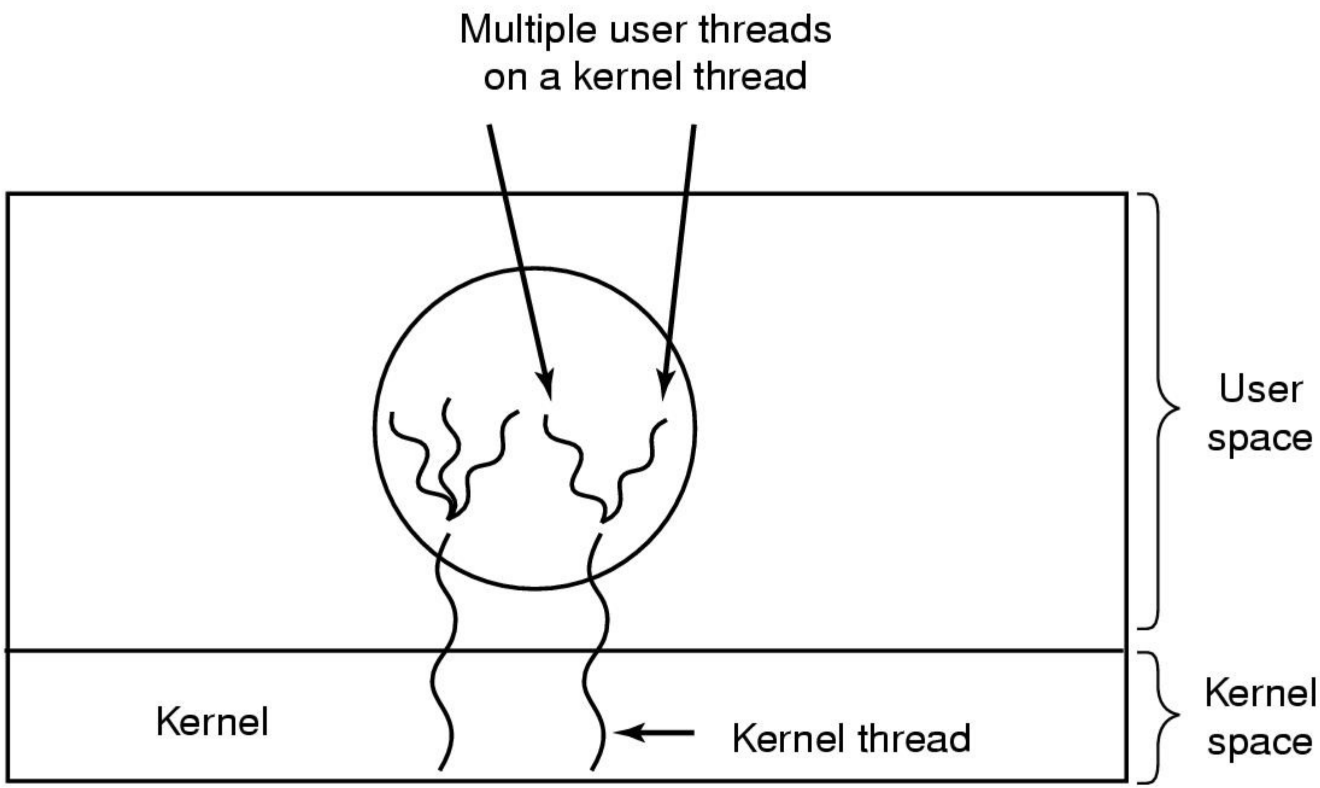
User-level threads

- User-level libraries provide multiple threads,
- OS kernel does not recognize user-level threads
- Threads execute when the process is scheduled

Kernel-level threads

- OS kernel provides multiple threads per process
- Each thread is scheduled independently by the kernel's CPU scheduler

Hybrid Implementations



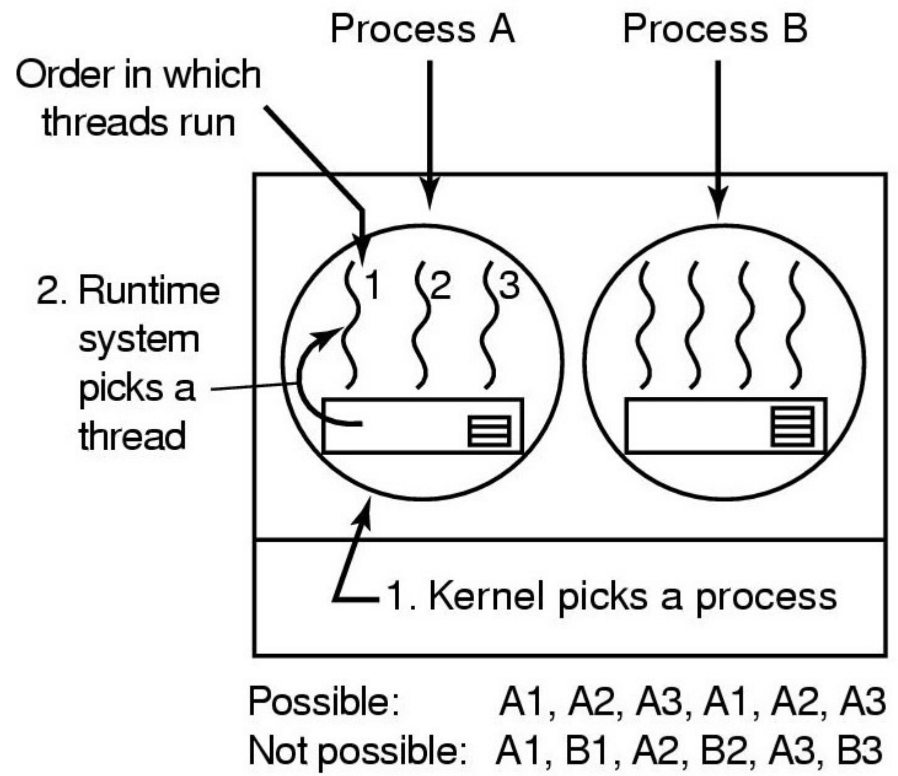
Multiplexing user-level threads within each kernel- level threads

Local Thread Scheduling

- Next thread is picked from among the threads belonging to the current process
- Each process gets a timeslice from kernel.
- Then the timeslice is divided up among the threads within the current process

- Local scheduling can be implemented with either
  - Kernel-level threads OR
  - User-level threads.

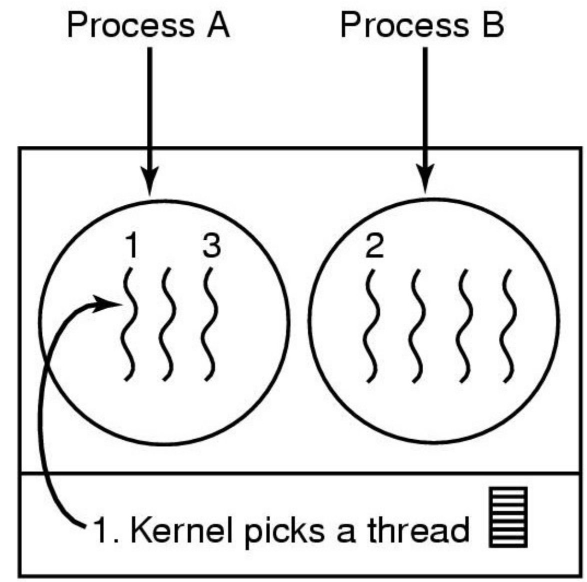
- Scheduling decision requires only local knowledge of threads within the current process.



- For example, say process timeslice may be 50ms, and each thread within the process runs for 5 msec/CPU burst

Global Thread scheduling

- Next thread to be scheduled is picked up from ANY process in the system.
  - Not just the current process
- Timeslice is allocated at the granularity of threads
  - No notion of per-process timeslice
- Global scheduling can be implemented only with kernel-level threads
  - Picking the next thread requires global knowledge of threads in all processes.



Possible: A1, A2, A3, A1, A2, A3
Also possible: A1, B1, A2, B2, A3, B3

- For example each thread runs for 10msec per CPU burst

Thread Creation and termination

- Creation
  - int pthread_create(pthread_t * thread, pthread_attr_t * attr, void * (*start_routine)(void *), void * arg);

- Two ways to perform thread termination
  1. Return from initial function.
  2. void pthread_exit(void * status)

- Waiting for child thread in parent
  - pthread_join(…)
  - equivalent to waitpid

Threaded program - example

```
// shared counter to be incremented by each thread
int counter = 0;

main()
{
   pthread_t tid[N];

   for (i=0;i<N;i++) {

      /*Create a thread in thread_func routine*/
      Pthread_create(&tid[i], NULL, thread_func, NULL);
   }

   for(i=0;i<N;i++)
      /* wait for child thread */
      Pthread_join(tid[i], NULL);
}


void *thread_func(void *arg)
{

   /* unprotected code - race condition*/
   counter = counter + 1;

   return NULL; // thread dies upon return
}
```

pthread synchronization operations

- Mutex operation
  - **pthread_mutex_init**(…)
  - **pthread_mutex_lock**(…)
  - **pthread_mutex_unlock** (…)
  - **pthread_mutex_trylock** (…)

- Condition variables
  - pthread_cond_wait (…)
  - pthread_cond_signal (…)
  - pthread_cond_broadcast (…)
  - pthread_cond_timedwait (…)