

Thread (I)

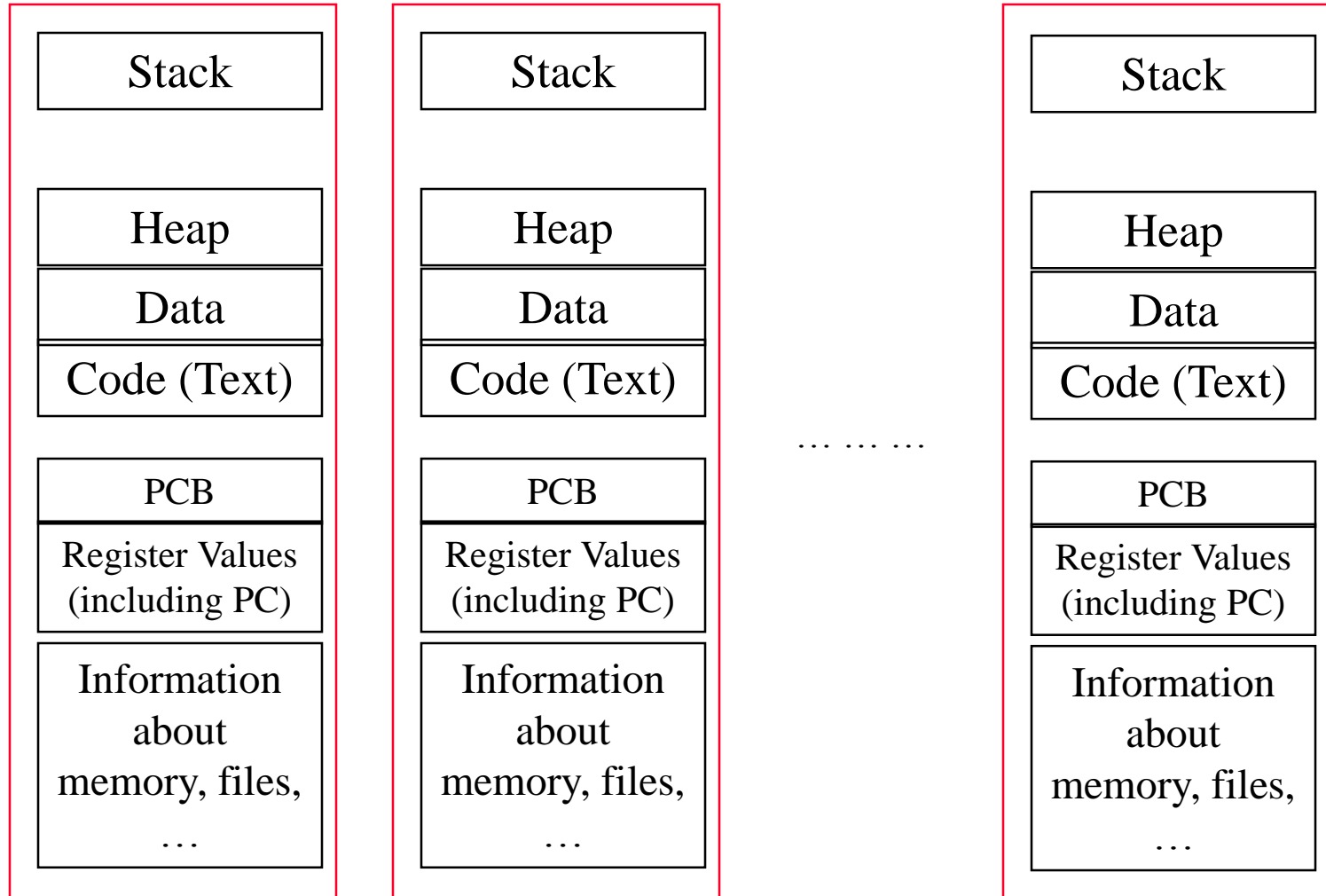
Kernel Threads

Example of Multi-Process Collaboration

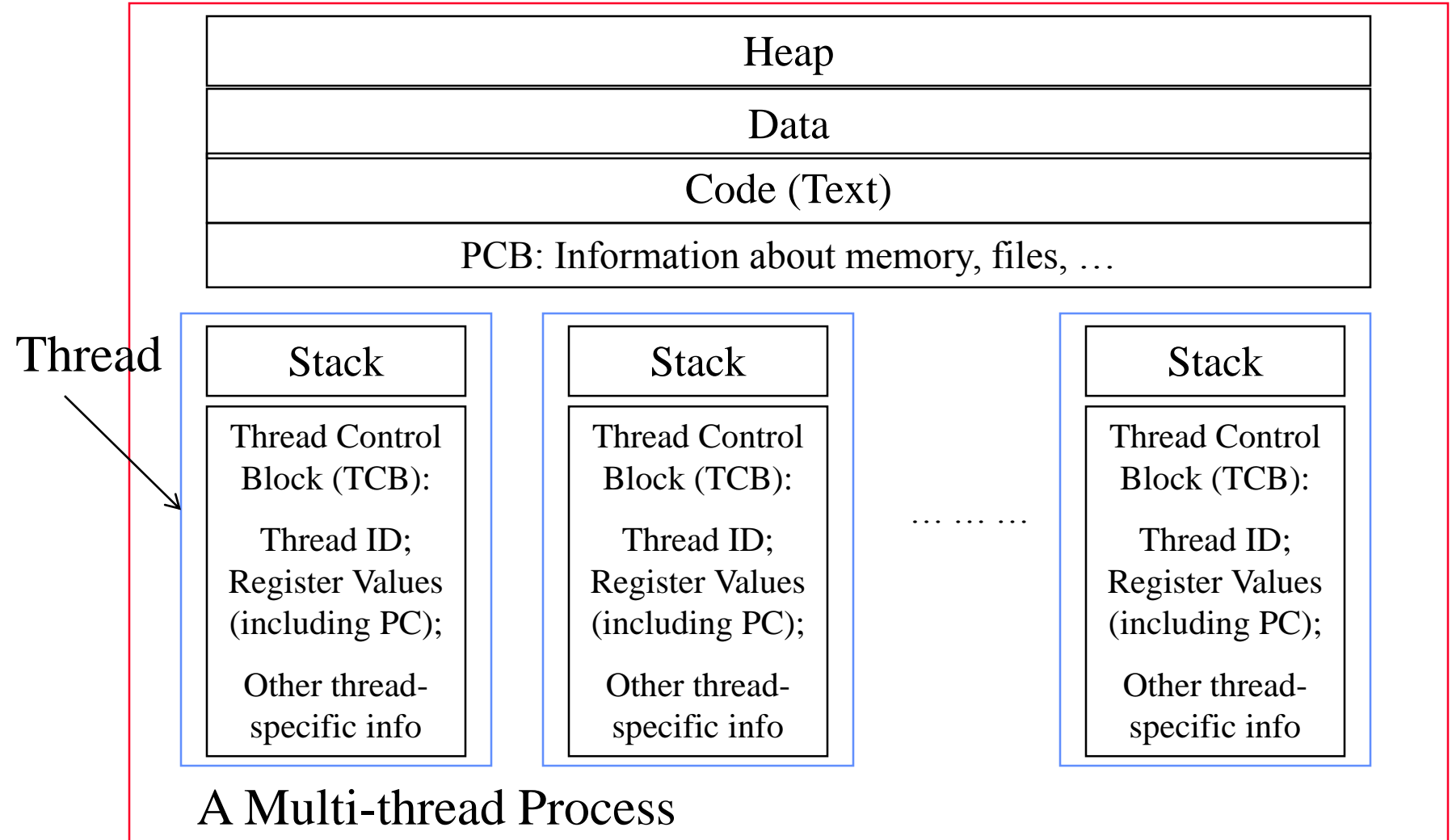
- ❏ Finding the lines containing key word “Linux” in all .txt files in the current directory
- ❏ Linux command line:
 grep “Linux” *.txt
- ❏ Using multi-process collaboration to do the job?

```
...
int numFiles; //total number of files
char fileNames[MAX_NUM_FILES][255]; //array storing the file names
int i;
for(i=0; i<numFiles; i++)
    if (fork() == 0){
        FILE *fp = fopen(fileNames[i], “r”);
        ... //search for lines containing “Linux” in the file
        exit(0);
    }
```

Multi-Process





A Process with Multiple Threads



Benefits

Responsiveness (similar to multi-process)

-  Allowing a program to continue running even if part of it is blocked
-  Allowing a program to perform multiple tasks concurrently


Resource sharing

-  Threads of the same process share the memory and resources

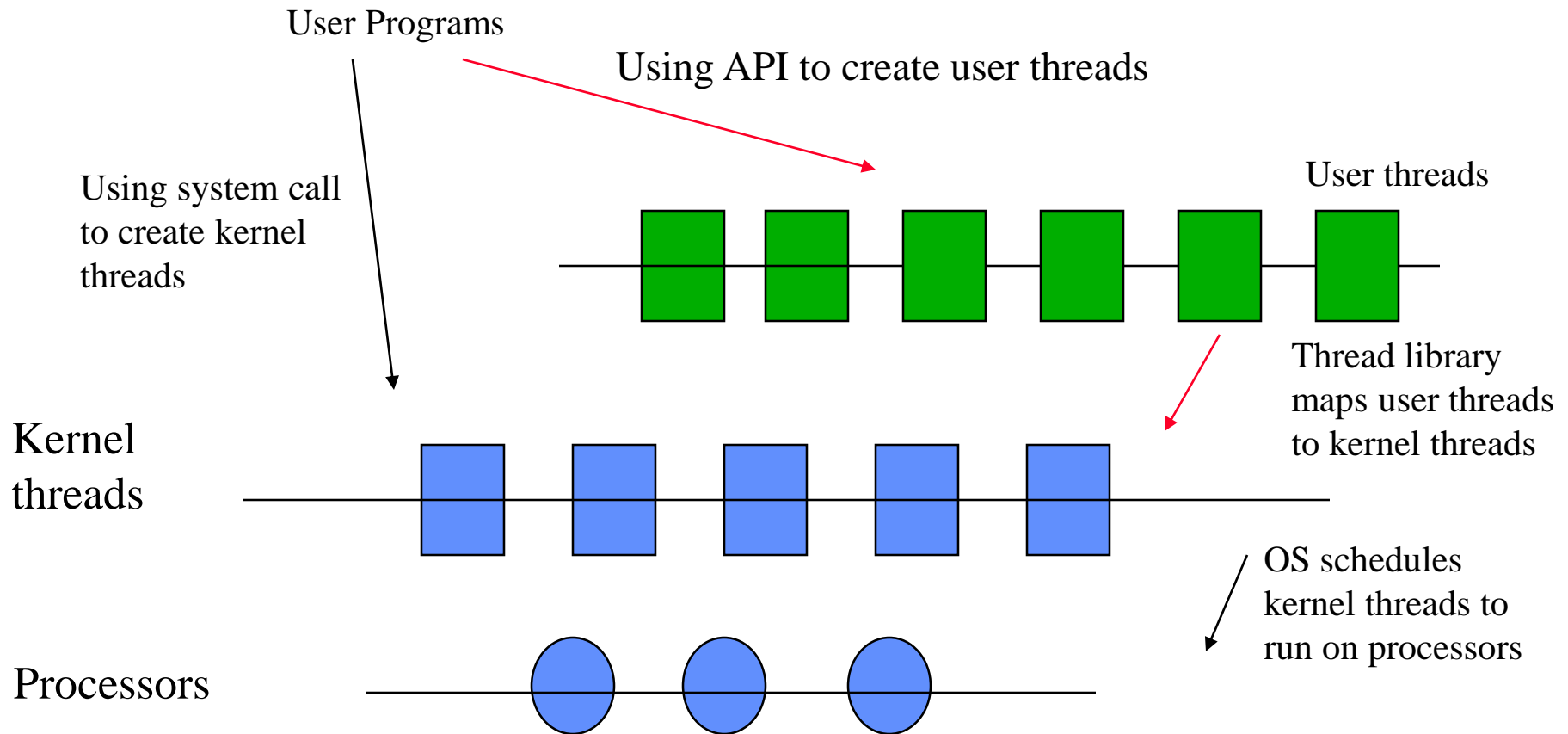
Economy

-  Allocating memory and resources for process creation is costly.

Scalability (similar to multi-process)

-  A single-thread process can only run on one processor regardless how many are available; multi-threaded process can increase parallelism on a multi-processor machine.

Threads in a Computer System



Kernel Threads

- ❏ Directly created/managed/scheduled by the OS kernel
- ❏ Virtually all contemporary OSes support kernel threads

Linux Kernel Threads

- Linux refers to them as *tasks* rather than *threads*
- Thread creation is done through **clone()** system call

```
#define _GNU_SOURCE
```

```
#include <sched.h>
```

```
int clone(int (*fn)(void *), void *child_stack, int flags, void *arg);
```

flag	meaning
CLONE_FS	File-system information is shared.
CLONE_VM	The same memory space is shared.
CLONE_SIGHAND	Signal handlers are shared.
CLONE_FILES	The set of open files is shared.

Example

```
#include _GNU_SOURCE
```

```
#include <stdio.h>
```

```
#include <sched.h>
```

```
#include <unistd.h>
```

```
#include <stdlib.h>
```

```
#include <fcntl.h>
```

```
int variable, fd;
```

```
int do_something(); //function to be executed by the new task (thread)
```

Example

```
int main() {
void *child_stack;
char tempch;
variable = 9;
fd = open("test.file", O_RDONLY);
child_stack = (void *)malloc(16384); child_stack += 16383;
printf("The variable was %d\n", variable);
clone(do_something, child_stack, CLONE_VM|CLONE_FILES, NULL); /*A*/
sleep(1);
printf("The variable is now %d\n", variable);
if (read(fd, &tempch, 1) < 1) {
    perror("File Read Error"); exit(1);}
    printf("Parent could read from the file\n");}
}
```

Example

```
int do_something() {  
    char tempch;  
    variable = 42;  
    if (read(fd, &tempch, 1) < 1) {  
        perror("File Read Error");  
        _exit(1);  
    }  
    printf("Child could read from the file\n");  
    close(fd);  
    _exit(0);  
}
```

Example

1. What is the output of the program?

2. What if Line A is changed to:

```
clone(do_something, child_stack, CLONE_VM, NULL);
```

or

```
clone(do_something, child_stack, CLONE_FILES, NULL);
```

or

```
Clone(do_something, child_stack, 0, NULL);
```

Thread (II)




User Threads & User/Kernel Mapping

User Threads





- Created by a thread library and scheduling is managed by the library itself in user space (the existence of user threads is unknown to the OS)

User Thread Libraries

Pthreads (POSIX Threads)

-  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)

Java Threads

-  Managed by the JVM
-  May be created by:
 -  Extending Thread class
 -  Implementing the Runnable interface

Win32 Threads

-  Similar to pthread, differing in function names

PThreads

include <pthread.h>

✧ int **pthread_create** (pthread_t * thread,
pthread_attr_t * attr,
void * (*start_routine)(void *),
void *arg)

- ✧ Creates a new thread
- ✧ 1st argument: the address of the created thread
- ✧ 2nd argument: the address of the structure containing the attributes of the created thread
 - ✧ For default attribute values, make this argument as **NULL**
- ✧ 3rd argument: the pointer to the function that is the code for the created thread
- ✧ 4th argument: the pointer to the argument of the start_routine function. If multiple arguments are needed, define a data structure that contains all arguments.

PThreads

include <pthread.h>

✧ void **pthread_exit** (void *status)

✧ Terminate execution of the calling thread

✧ 1st argument: Points to an optional termination status. If no termination status is desired, its value should be NULL.

✧ pthread_t **pthread_self** (void)


✧ returns the *pthread* handle (ID) of the calling thread

PThreads

include <pthread.h>

- ✧ int **pthread_join** (pthread_t tid, void **status)
 - ✧ "Joining" is one way to accomplish synchronization between threads.
 - ✧ Blocks the caller until the specified thread terminates
 - ✧ 1st argument: the *id* of the thread to be waited
 - ✧ 2nd argument: the address of the variable to receive the thread's exit status
 - ✧ Usually set to ***NULL*** or ***int****

Example: Hello World!

 This simple example code creates 5 threads with the `pthread_create()` routine. Each thread prints a "Hello World!" message, and then terminates with a call to `pthread_exit()`.

```
#include <pthread.h>
#include <stdio.h>
#define NUM_THREADS    5

void *PrintHello(void *threadid)
{
    printf("\n%d: Hello World from Thread #%d !\n",
          threadid, pthread_self());
    pthread_exit(NULL);
}
```

Example: Hello World! (con't)

```
int main (int argc, char *argv[])
{
    pthread_t threads[NUM_THREADS];
    int rc, t;
    for (t=0;t < NUM_THREADS;t++) {
        printf("Creating thread %d\n", t);
        rc = pthread_create(&threads[t], NULL, PrintHello, (void *) t);
        if (rc){
            printf("ERROR; return code from pthread_create() is %d\n", rc);
            exit(-1);
        }
    }


    for(t=0; t<NUM_THREADS;t++) pthread_join(threads[t],NULL);
    pthread_exit(NULL);
}
```






Example: Compilation

Suppose the program file is named: HelloWorld.c

```
$gcc -o HelloWorld HelloWorld.c -lpthread
```

Java Threads

-  Defining a class X that implements the **Runnable** interface to contain the implementation of a thread

```
public interface Runnable
{
    public abstract void run( );
}
```
-  Creating a Thread object to wrap the class X
-  Manipulate the Thread object by calling its methods
 -  run() method
 -  join() method
 - 

Example: Summation

```
class Summation implements Runnable
```

```
{
```

```
    private int upper;
```

```
    public int sum;
```

```
    public Summation(int upper, int sum) {
```

```
        this.upper = upper;
```

```
        this.sum = sum;
```

```
    }
```

```
    public void run() {
```

```
        int sum = 0;
```

```
        for (int i=0; i<=upper; i++) sum += i;
```

```
        System.out.println("Sum of 1 through " + upper + " is " + sum);
```

```
    }
```

```
}
```

Example: Summation

```
public class Driver{  
    public static void main(String[ ] args) {  
        if (args.length >0) {  
            if (Integer.parseInt(args[0])<0)  
                System.err.println(args[0]+"must be >=0");  
            else{  
                int upper = Integer.parseInt(args[0]);  
                Summation sumObj = new Summation(upper,0);  
                Thread thrd=new Thread(sumObj);  
                thrd.start( );  
                try {thrd.join( );} catch (InterruptedException ie) { }  
            }  
        }  
    }  
}
```


Example: Summation

```
$javac Summation.java
```

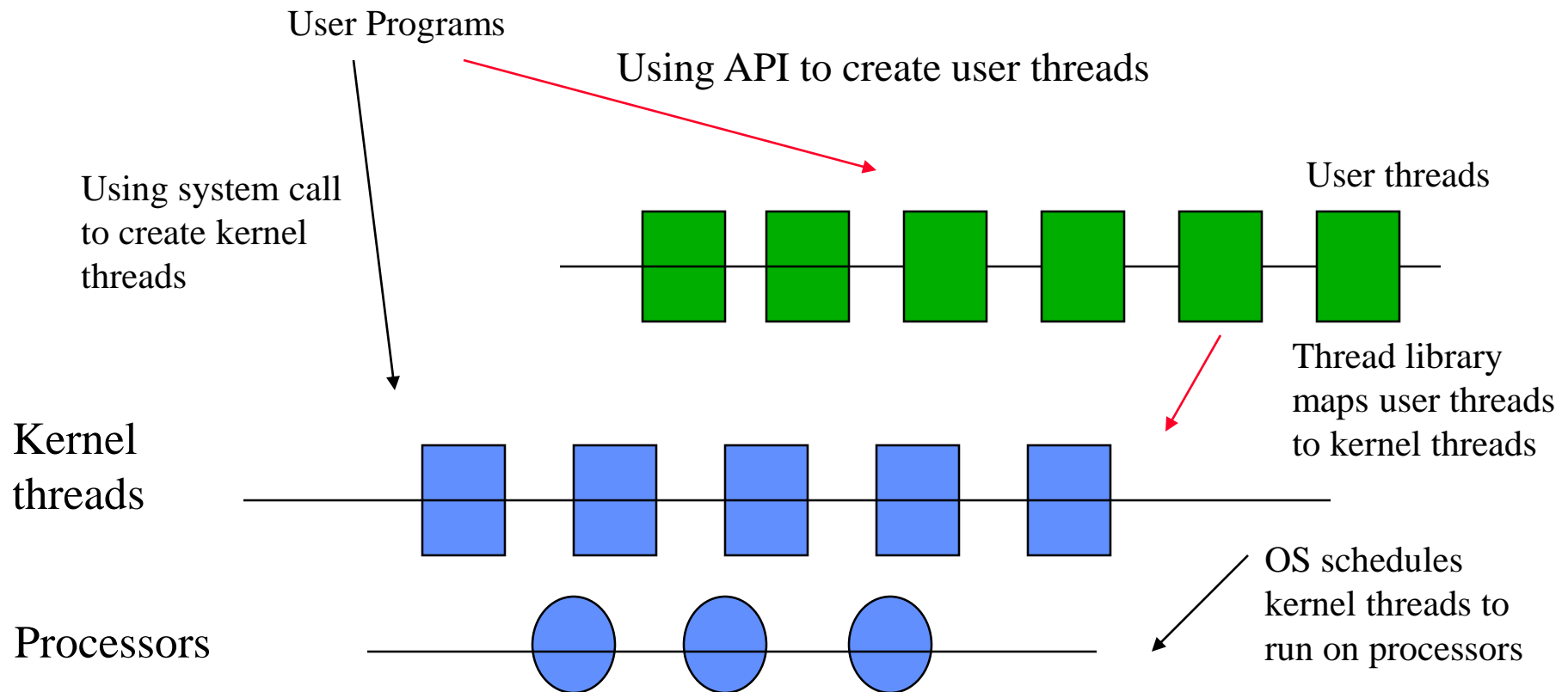
```
$javac Driver.java
```

```
$java Driver 100
```

```
Sum of 1 through 100 is 5050
```

Threads in a Computer System

- A thread library provides the programmer with an API for creating and managing threads.



Kernel Threads vs. User Threads

- Kernel threads:

- Directly created/managed by the OS kernel

- User threads




- created by a thread library and scheduling is managed by the library itself (the existence of user threads is unknown to the OS)

- low-cost in thread creation; portable

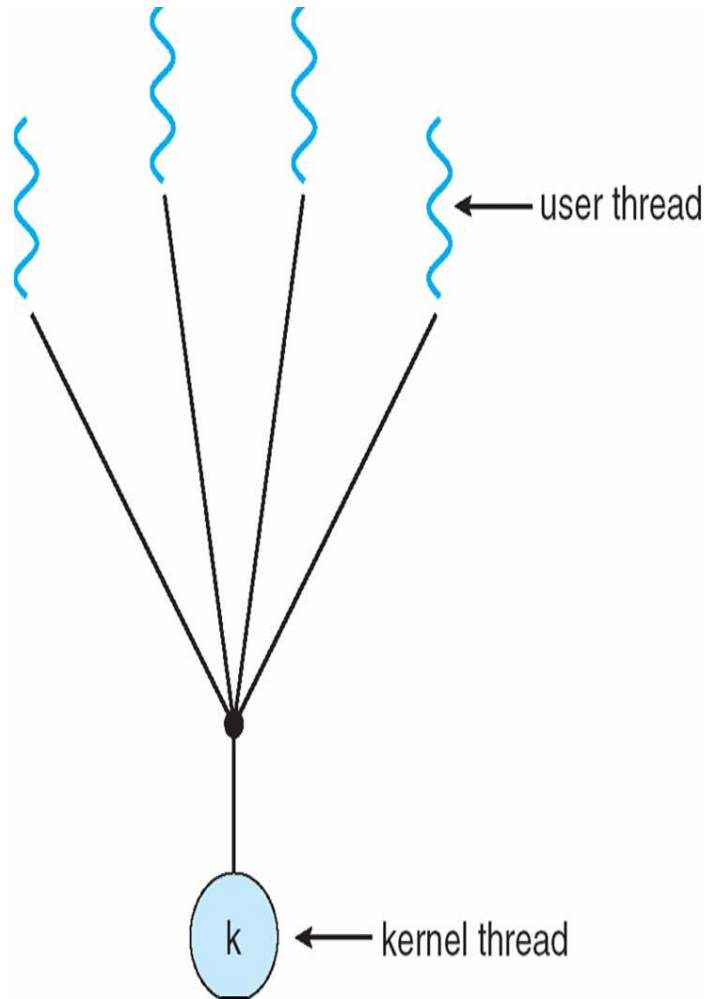
- may not utilize multi-processors efficiently (depends on mapping strategy between user and kernel threads)

- When executed, must be mapped to kernel threads

Mapping User Threads to Kernel Threads

-  Many to One
-  One to One
-  Many to Many

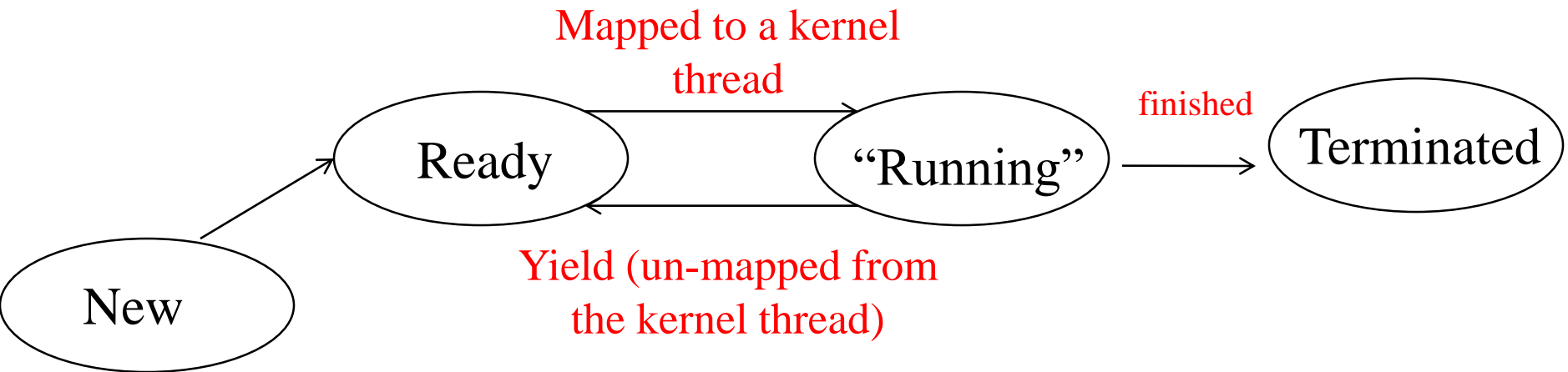
Many-to-One



- Many user-level threads within the same process are mapped to single kernel thread
- User thread library schedules user threads to the kernel thread
- The multiple threads “time-share” the single kernel thread
 - A kernel thread is created for a process
 - Upon the thread yields, switch to another thread in the same process (kernel is unaware of it)
 - Upon the thread blocks, all threads in the process block

Thread Scheduling in User Space

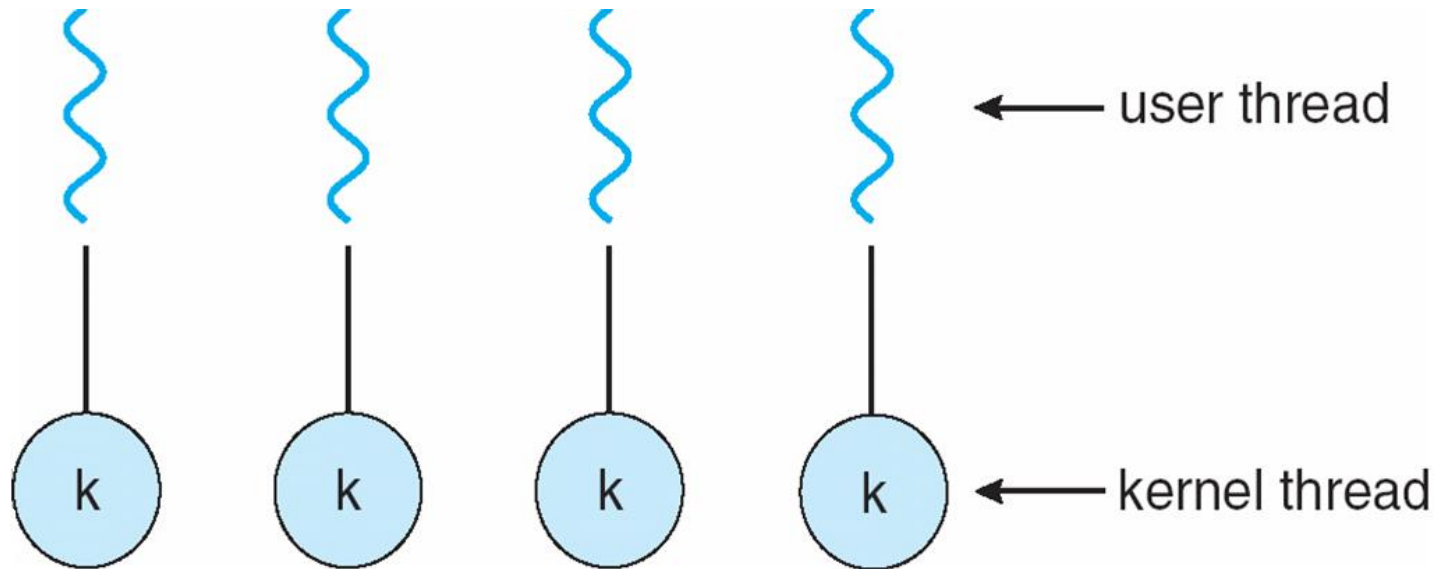
- 📖 User-space scheduling: managing the (dynamic) mapping from user threads to kernel threads.



Lifetime of a user thread

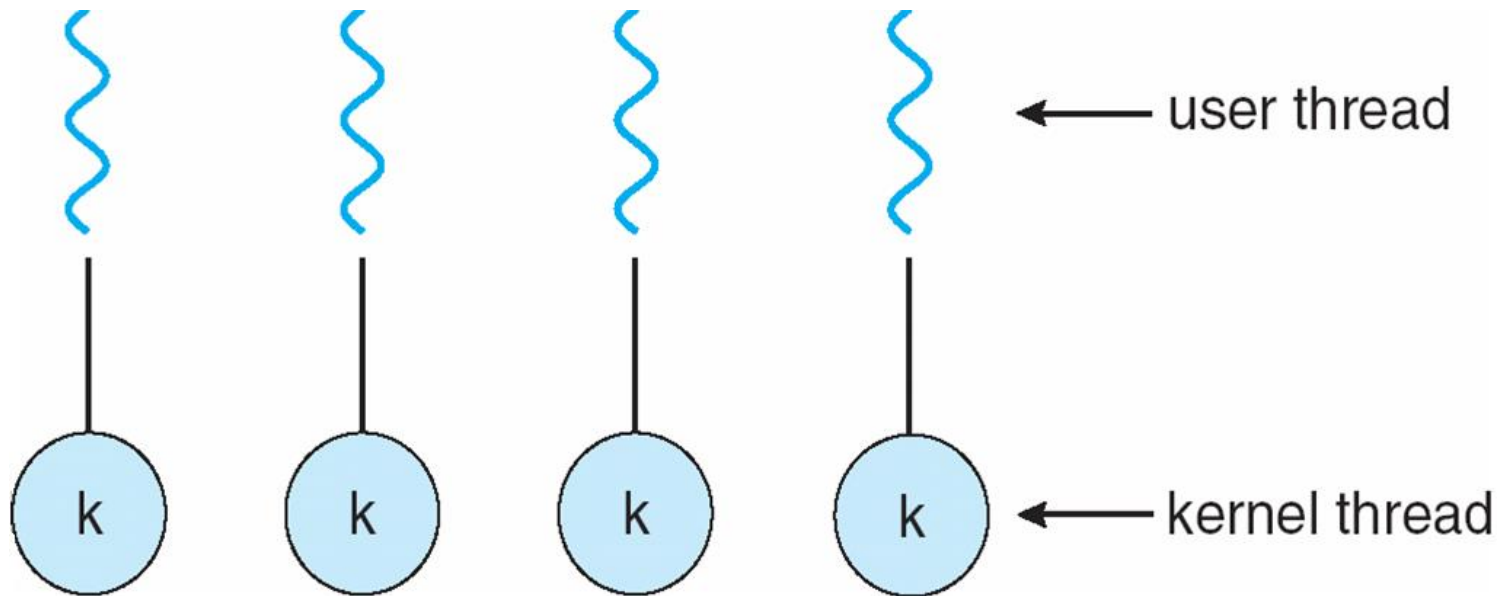
One-to-One

- Each user-level thread maps to a kernel thread
- User thread library simply provides a portable interface for thread creation/management, of which the implementation rely on the kernel thread (kernel of the OS)

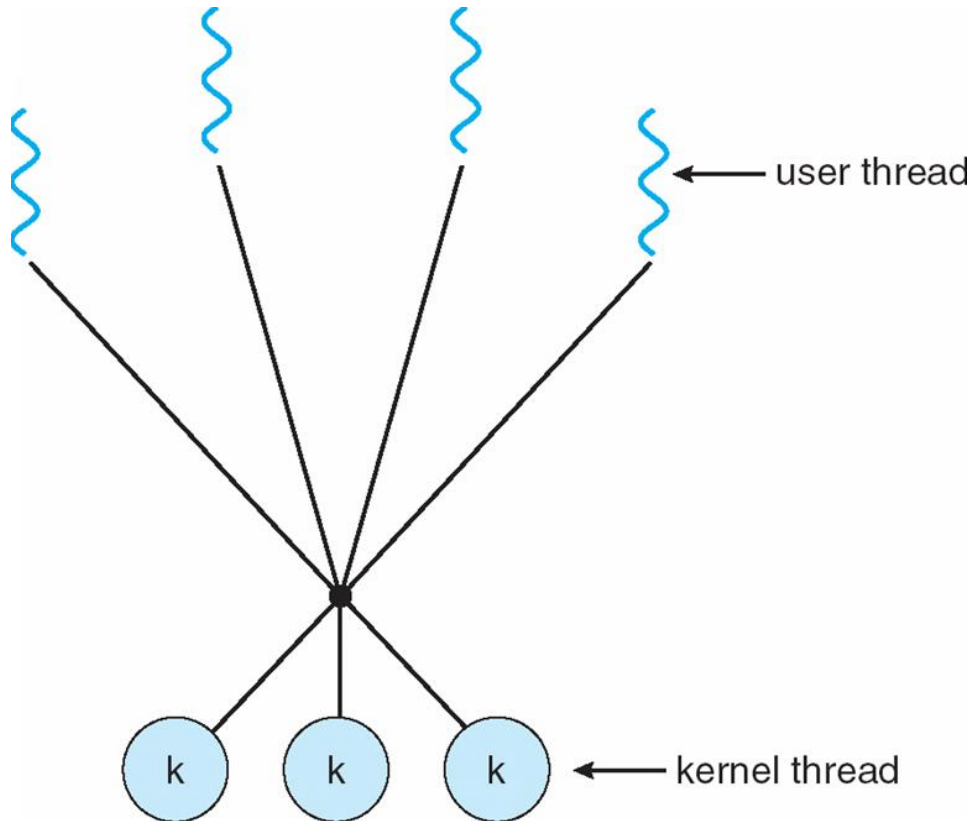


One-to-One

- Upon a thread currently running on a CPU yields or blocks, CPU can be switched to another thread (kernel is aware of this)

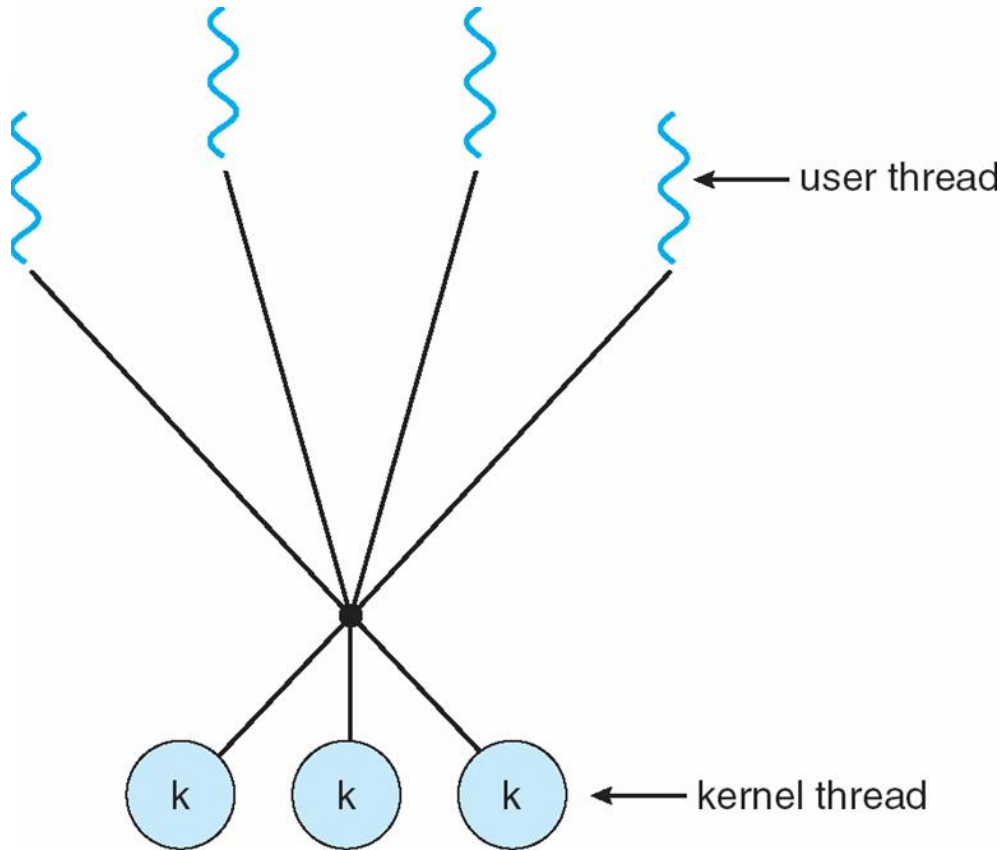


Many-to-Many Model



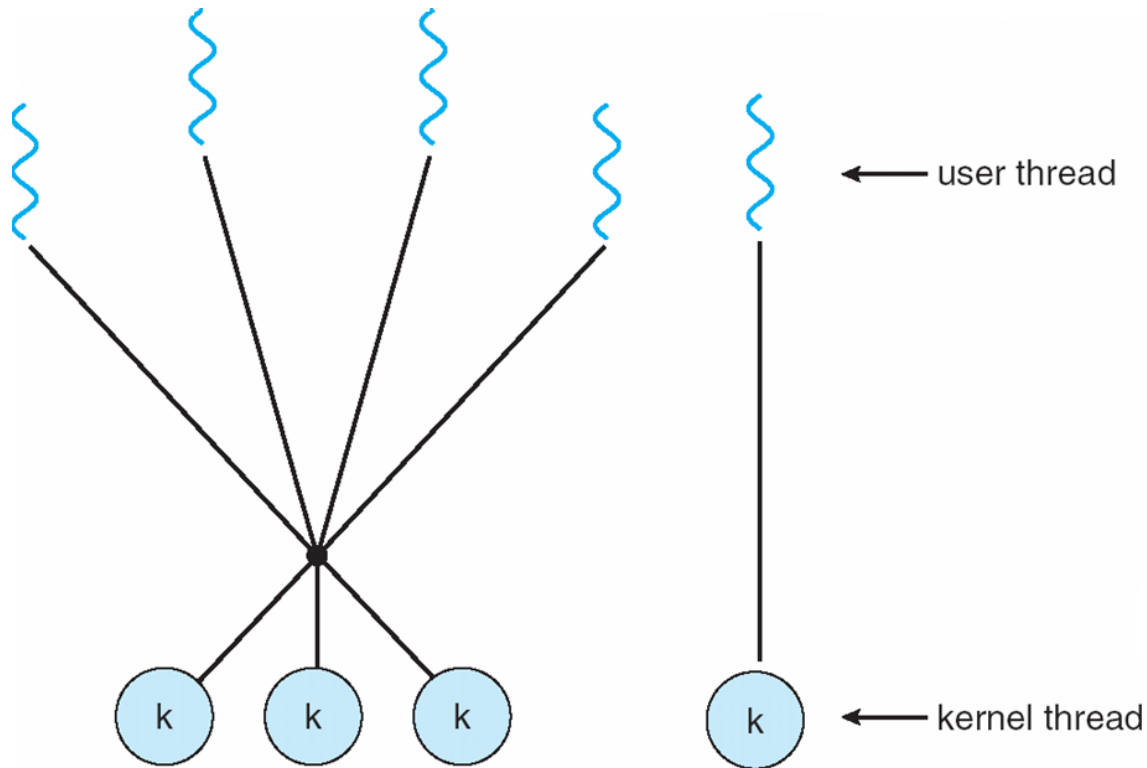
- Allows many user level threads to be mapped to many kernel threads
- User thread library schedules user threads to kernel threads

Many-to-Many Model



- Upon a currently-running user thread yields, another thread may be mapped to the yielding user thread's kernel thread and runs
- Upon a currently-running user thread blocks, other thread may run on the CPU

Two-level Model



- 📖 A sub-type of M:M
- 📖 It allows a user thread (e.g., with high priority) to be **bound** to a kernel thread