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

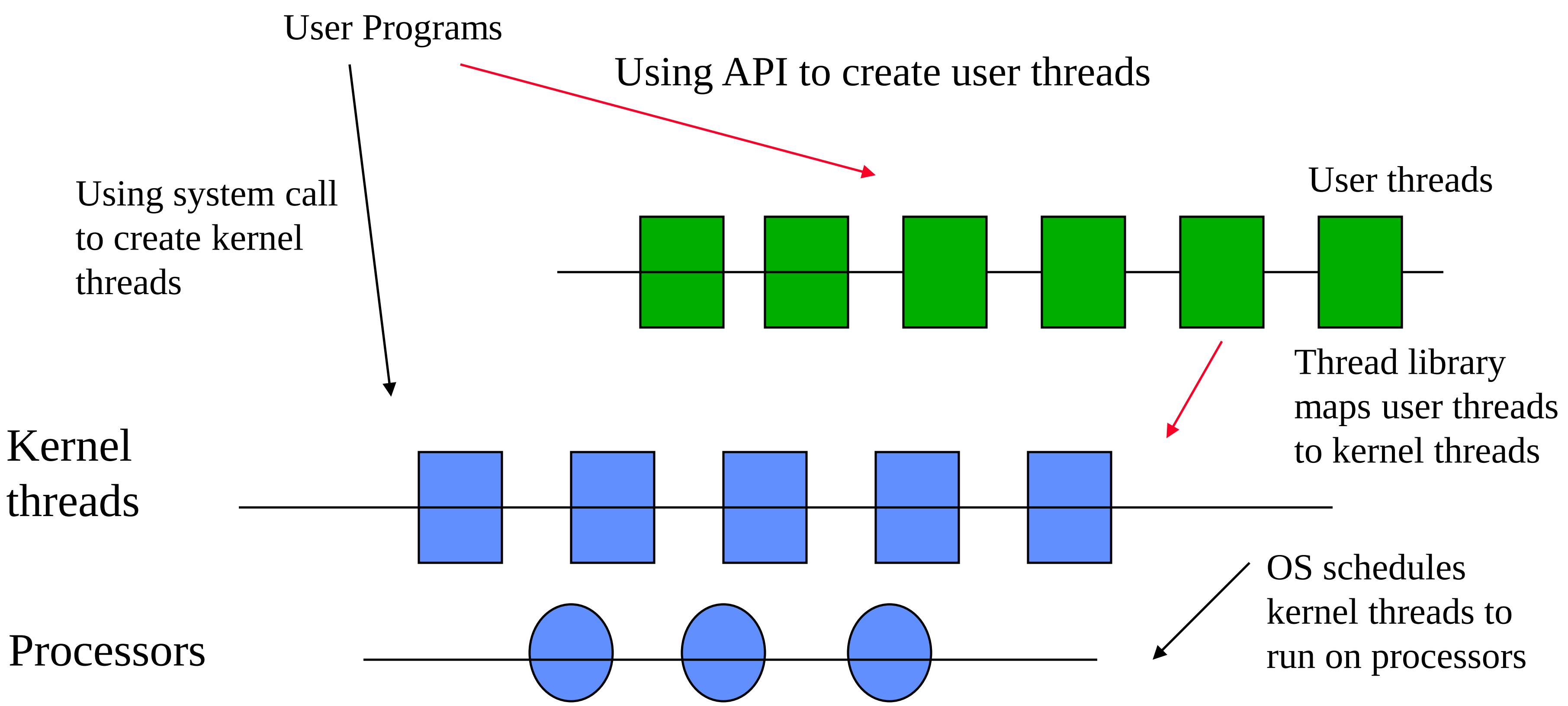
```
public class Driver{
    public static void main(String[ ] args){
        if (args.length >0){
          if (Integer.parseInt(args[0])<0)
            System.err.println(args[0]+"must be >=0");
          else{
            int upper = Integer.parseInt(args[0]);
            Summation sumObj = new Summation(upper,0);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



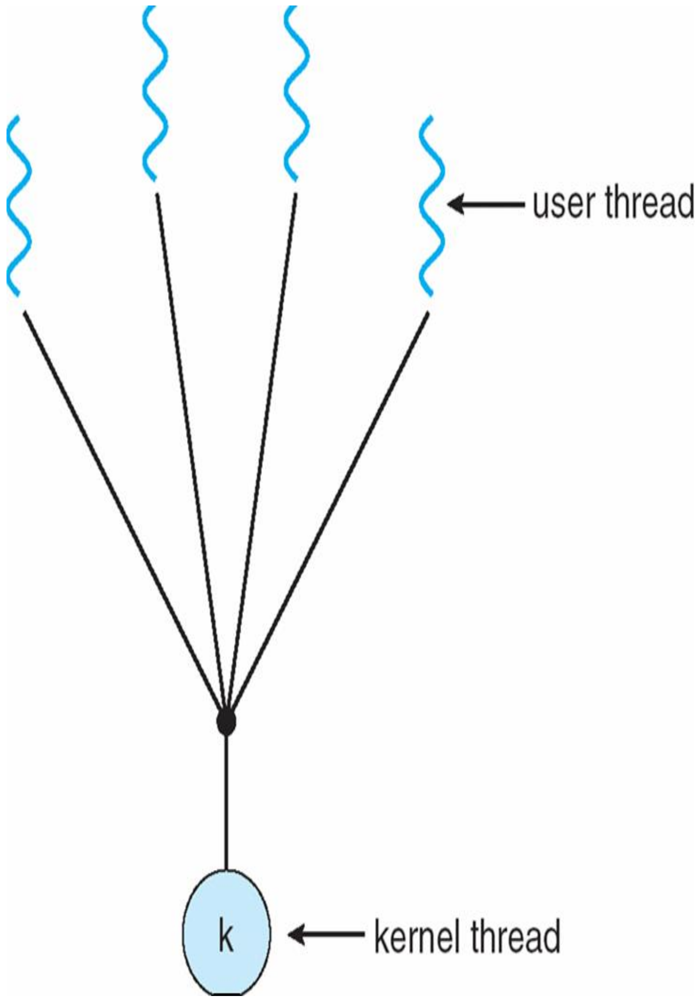
Kernel Threads vs. User Threads

- 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

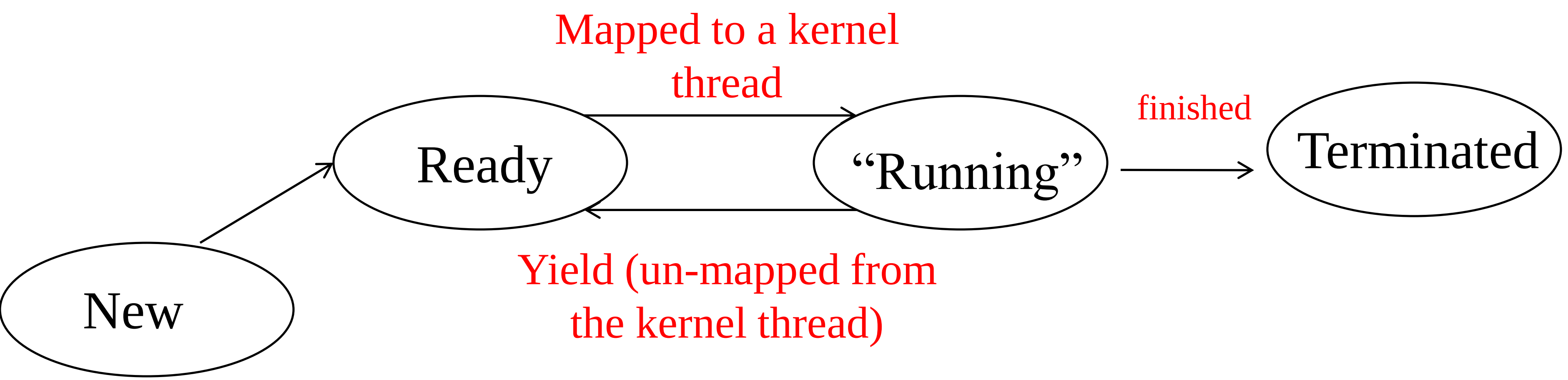
Many-to-One



- 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

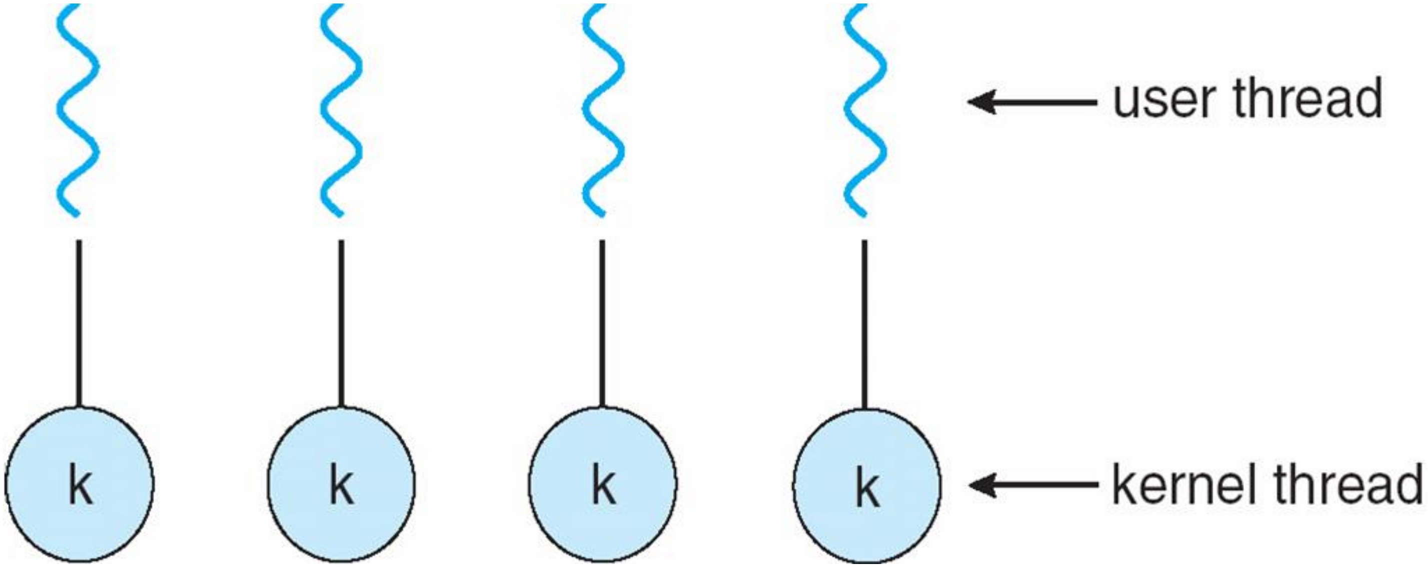
- User-space scheduling: managing the (dynamic) mapping from user threads to kernel threads.



Lifetime of a user thread

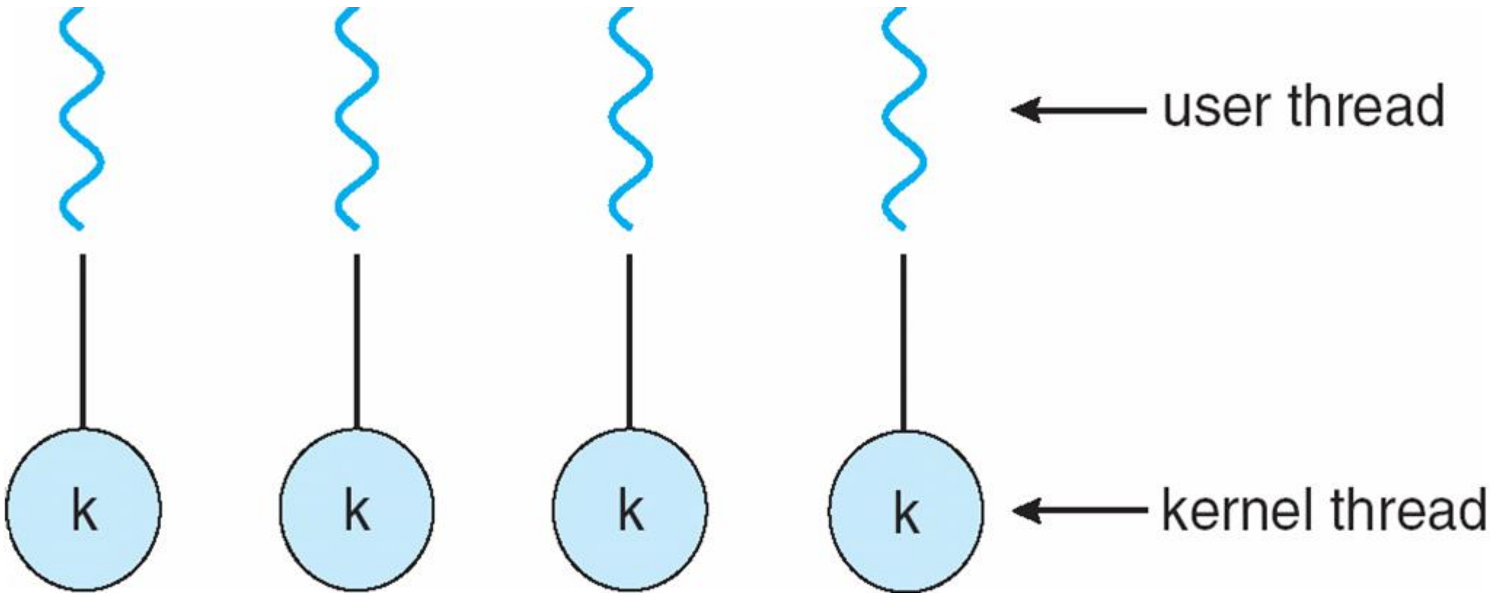
One-to-One

- 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)

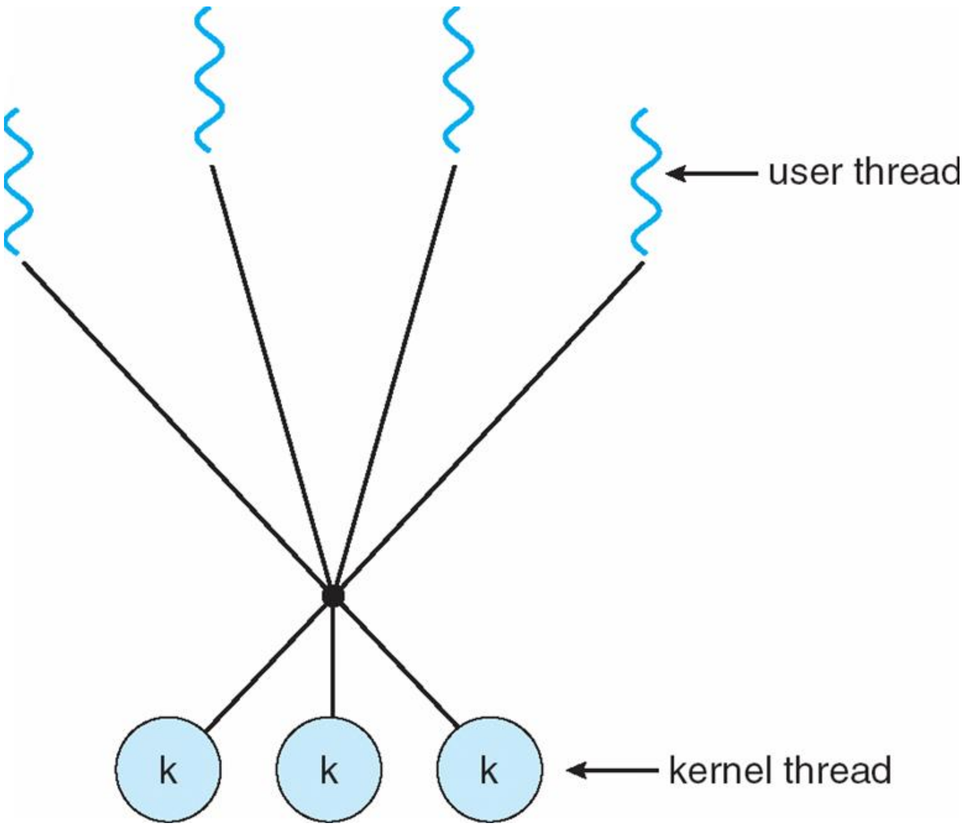


One-to-One

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

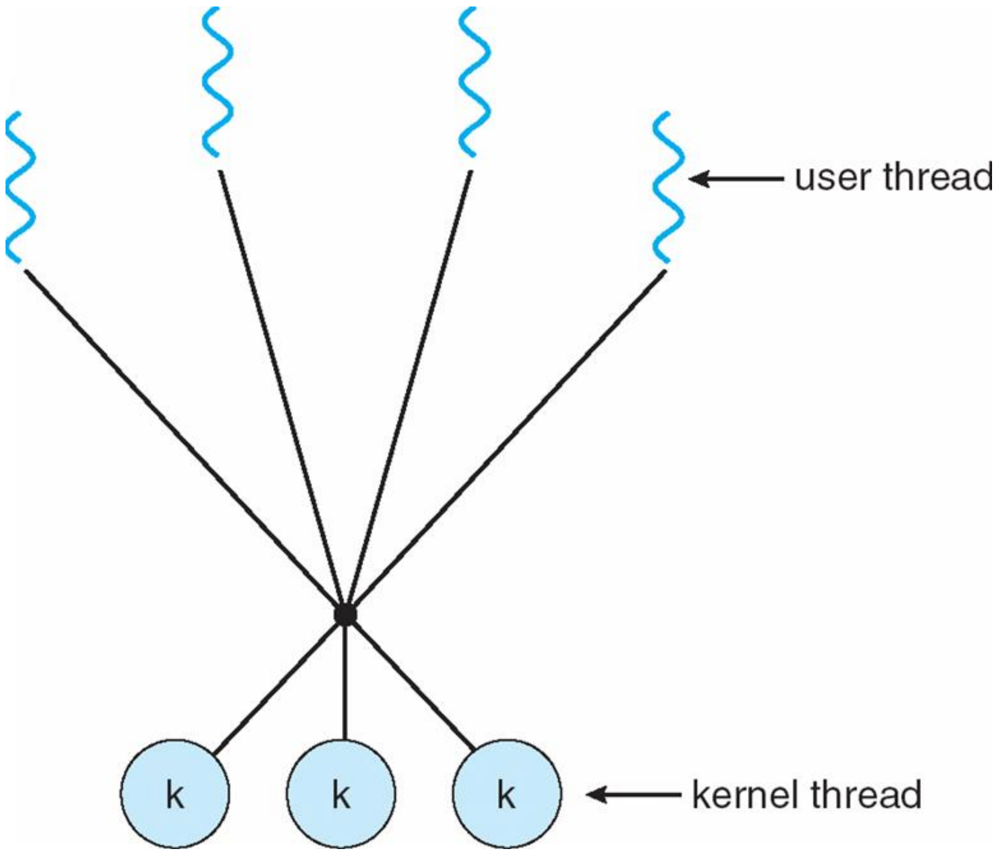


Many-to-Many Model



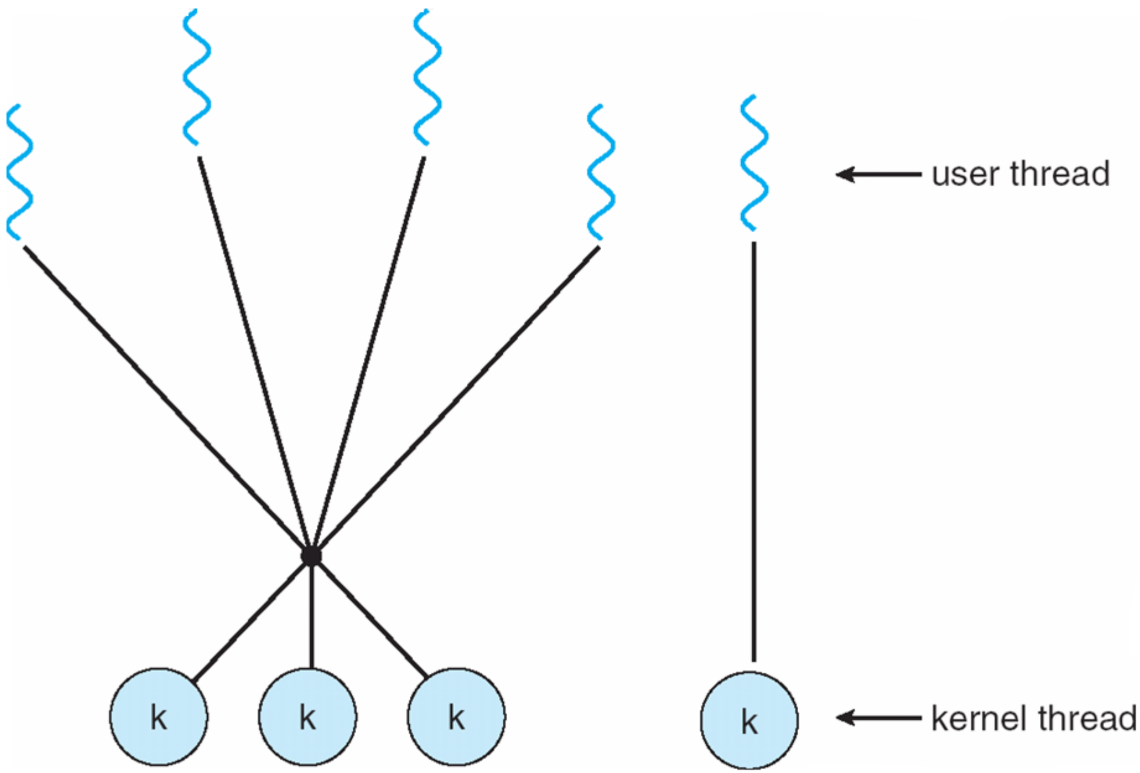
- Allows many user level threads to be mapped to many kernel threads
- User thread library schedules user threads to kernel threads

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

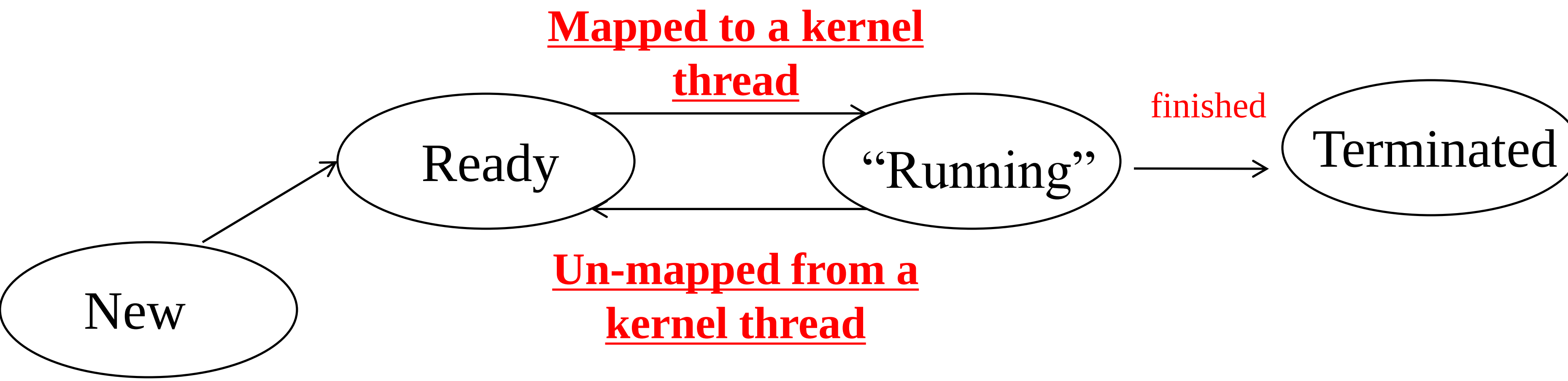
Thread Context and User/Kernel Thread Mapping

- Thread context
  - Each thread has a "context": User Stack + Thread Control Block (TCB: register values, etc.)
  - A kernel thread's context is managed by the OS kernel
  - A user thread's context is managed by the user thread library

- Mapping a user thread to a kernel thread is achieved by copying the user thread's context to the kernel thread's context.

Thread Scheduling in User Space

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



Lifetime of a user thread

Linux Supports for Thread Context Management

- Data structure ucontext_t
- System calls
  - getcontext
  - makecontext
  - setcontext
  - swapcontext
- All declared in ucontext.h

Data Type "ucontext_t"

```
typedef struct ucontext{
    struct ucontext      *uc_link;
        //points to the context that will be restored
        //when the current one terminates
    …
    stack_t              uc_stack;
        //the stack used by this context
    … register value, etc. …
}ucontext_t;
```

System Call “getcontext”

int getcontext(ucontext_t *ucp)

To initialize the structure pointed by ucp to contain a copy fo the currently-active kernel thread’s context

```
#include <ucontext.h>
…
ucontext_t *ucp;
ucp = (ucontext_t *)malloc(sizeof(ucontext_t));
…
getcontext(ucp);
…
```

System Call "makecontext"

void makecontext(ucontext_t *ucp, void (*func)())

To make a thread context (stored in the structure pointed by ucp) for function func(); the resulting context becomes the context for a thread running this func().

```
#include <ucontext.h>
void func(){…}
ucontext_t *ucp;
ucp = (ucontext_t *)malloc(sizeof(ucontext_t));
getcontext(ucp); //initialize the structure
ucp->uc_stack.ss_sp = malloc(16384); //create a new stack space for
    the new thread
ucp->uc_stack.ss_size = 16384;
makecontext(ucp, func);
```

System Call “setcontext”

int setcontext(ucontext_t *ucp)

- The function updates the context of the currently-running thread with the context pointed by ucp; as the effect, the thread with context *ucp starts/resumes its execution.
- This can be used to implement mapping from a user thread (thread with conext *ucp) to a kernel thread (currently active one)!
- A successful call does not return.
- The context should be a valid one (i.e., obtained by a call of context or make context)

System Call "setcontext"

```
…
int cloned_func(){
    …
    setcontext(ucp); //user thread with context ucp is run
        //(i.e., the user thread is mapped to this kernel thread
    …
}
…
main(){
    …
    clone(cloned_func, …); //creates a kernel thread
    …
}
```

System Call "swapcontext"

int swapcontext(ucontext_t *oucp, ucontext_t *ucp)

- This function saves the context of the currently-active kernel thread to the structure pointed by oucp (you should have already allocated the space for the structure); as the effect, the thread with context *oucp is started or resumed.