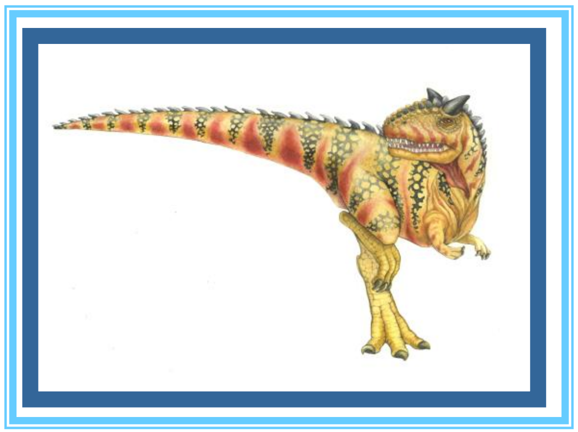
Chapter 4: Threads（线程）



Chapter 4: Threads

- Overview
- Multithreading Models
- Thread Libraries
- Threading Issues
- Operating System Examples
- Windows XP Threads
- Linux Threads

Objectives

- To introduce the notion of a thread — a fundamental unit of CPU utilization that forms the basis of multithreaded computer systems
- To discuss the APIs for the Pthreads, Win32, and Java thread libraries
- To examine issues related to multithreaded programming

4.1 Overview

- The concept of a process as embodying two characteristics :
  - Unit of Resource ownership （资源拥有单位）
    - 给每个进程分配一虚拟地址空间，保存进程映像，控制一些资源（文件，I/O设备），有状态、优先级、调度
  - Unit of Dispatching （调度单位）
    - 进程是由一个或多个程序的一次执行
    - 可能会与其他进程交替执行
- These two characteristics are treated independently by the operating system
  - Dispatching is referred to as a thread or lightweight process （轻型进程LWP）
  - Resource of ownership is referred to as a processor task

线程(Thread)概念

- These two characteristics are treated independently by the operating system
  - 资源拥有单元称为进程（或任务），调度的单位称为**线程**、又称**轻型进程**（light weight process）。
  - 线程只拥有一点在运行中必不可少的资源（程序计数器、一组寄存器和栈），但它可与同属一个进程的其它线程共享进程拥有的全部资源。
- **线程定义为进程内一个执行单元或一个可调度实体。**

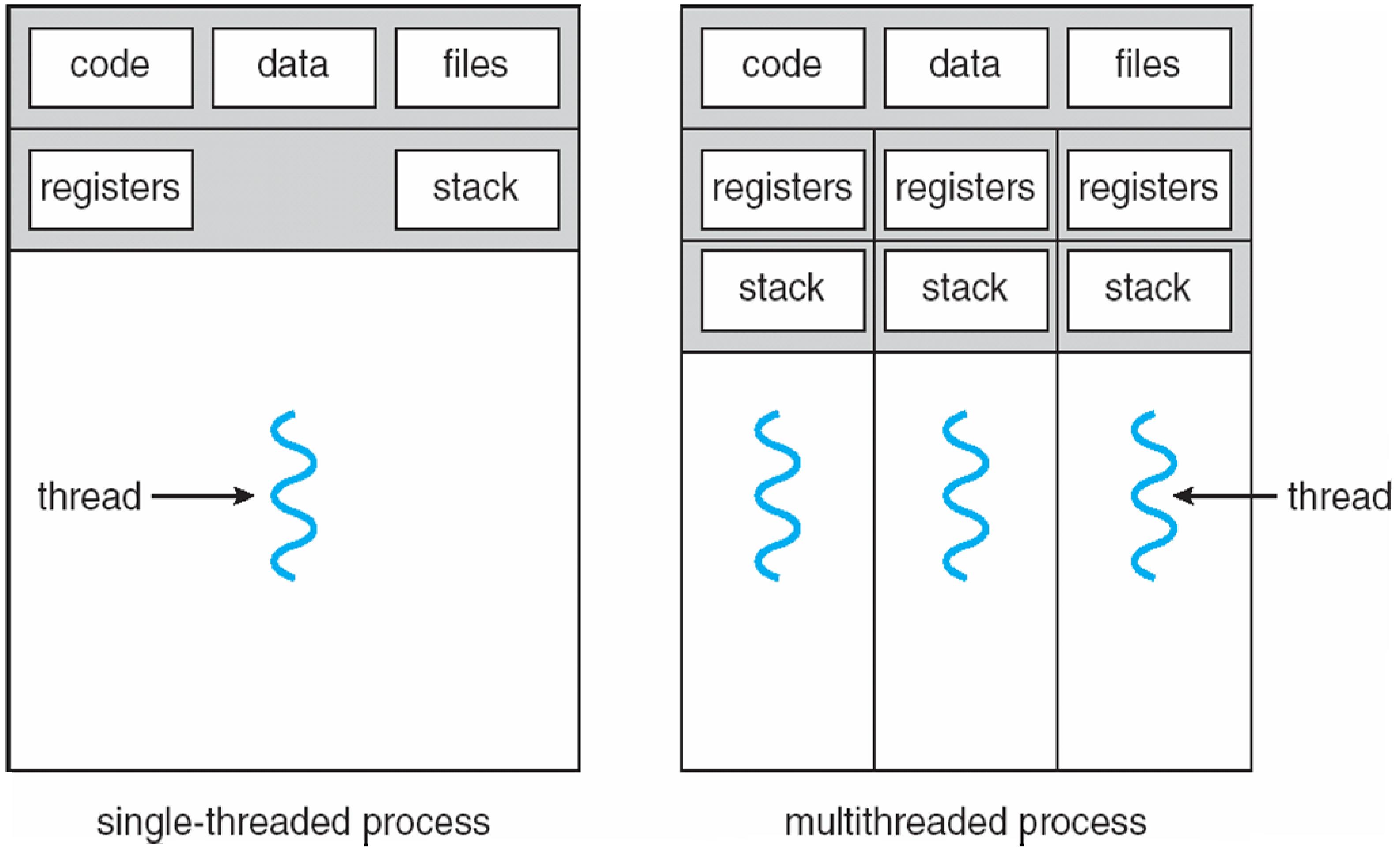
线程

- 线程：
  - 有执行状态（状态转换）
  - 不运行时保存上下文
  - 有一个执行栈
  - 有一些局部变量的静态存储
  - 可存取所在进程的内存和其他资源
  - 可以创建、撤消另一个线程

线程的特点

- 是进程的一个实体，可作为系统独立调度和分派的基本单位。
- 不拥有**系统资源**（只拥有少量的资源，资源是分配给进程）
- 一个进程中的多个线程可并发执行。（进程可创建线程执行同一程序的不同部分）
- 系统开销小、切换快。（进程的多个线程都在进程的地址空间活动）

Single and Multithreaded Processes

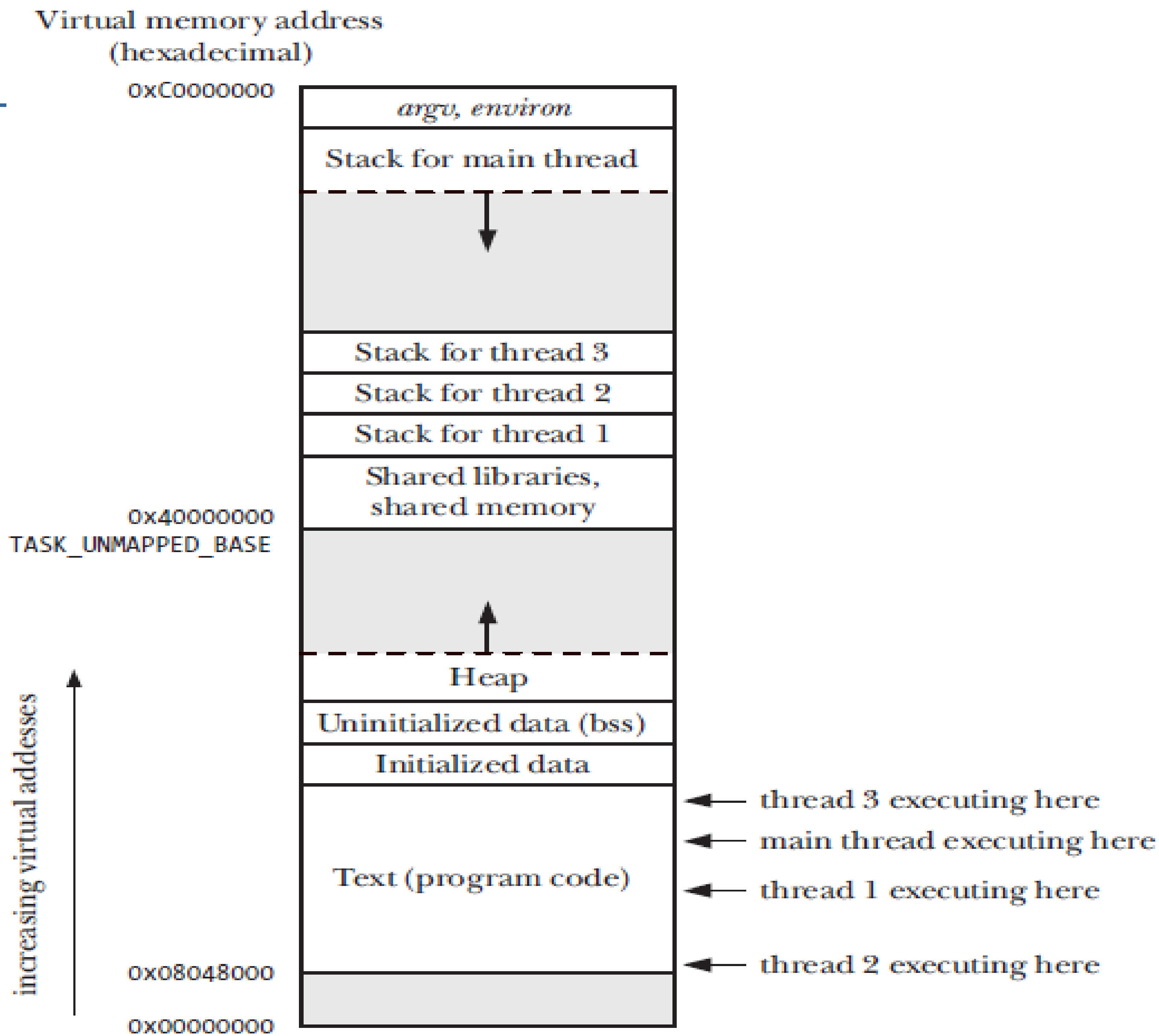


Motivation (Cont.)

- A thread **shares with** threads belonging to the same process its:
  - code section
  - data section
  - operating-system resources

(Process Have a virtual address space which holds the process image Protected access to processors, other processes, files, and I/O resources)

- A **traditional** or ***heavyweight* process** （重型线程）is equal to a task with one thread



Four threads executing in a process (Linux/x86-32)

Benefits

- **创建一个新线程花费时间少**（结束亦如此）
- **两个线程的切换花费时间少**

  （如果机器设有“存储[恢复]所有寄存器”指令，则整个切换过程用几条指令即可完成）
- 因为同一进程内的**线程共享内存和文件**，因此它们之间相互通信无须调用内核
- **适合多处理机系统**

例子1：

- LAN中的一个文件服务器，在一段时间内需要处理几个文件请求
  - 有效的方法是：为每一个请求创建一个线程
  - 在一个SMP机器上：多个线程可以同时在不同的处理器上运行

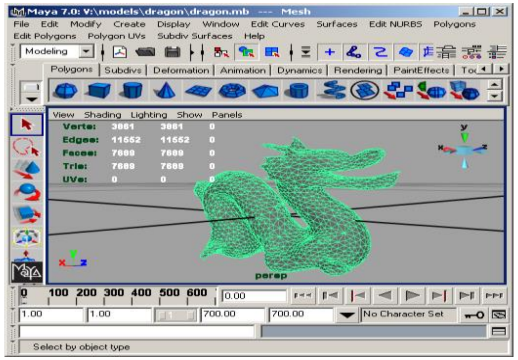
例子2:

- 一个线程显示菜单，并读入用户输入；另一个线程执行用户命令
  - 考虑一个应用：由几个独立部分组成，这几个部分不需要顺序执行，则每个部分可以以线程方式实现
  - 当一个线程因I/O阻塞时，可以切换到同一应用的另一个线程

Example：createthread.cpp

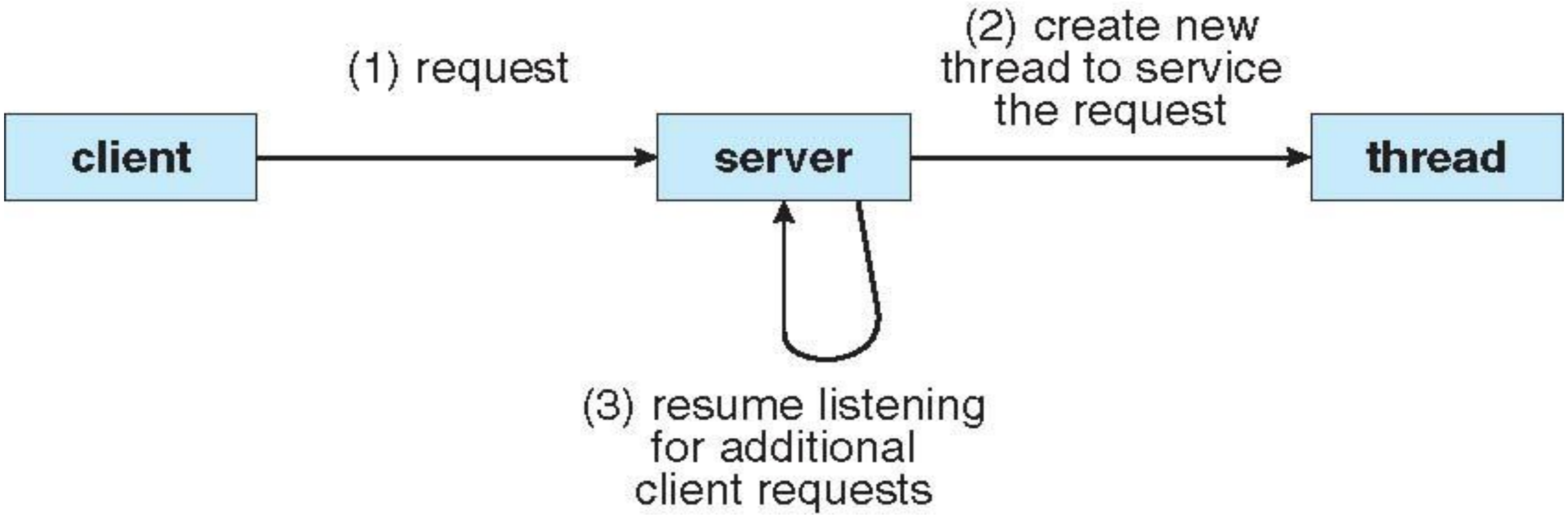
Multicore Programming

- Multicore systems putting pressure on programmers, challenges include
  - Dividing activities
  - Balance
  - Data splitting
  - Data dependency
  - Testing and debugging

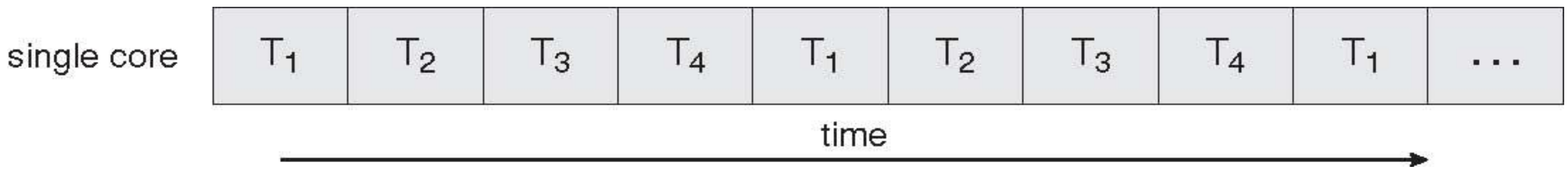


Each can run on its own core

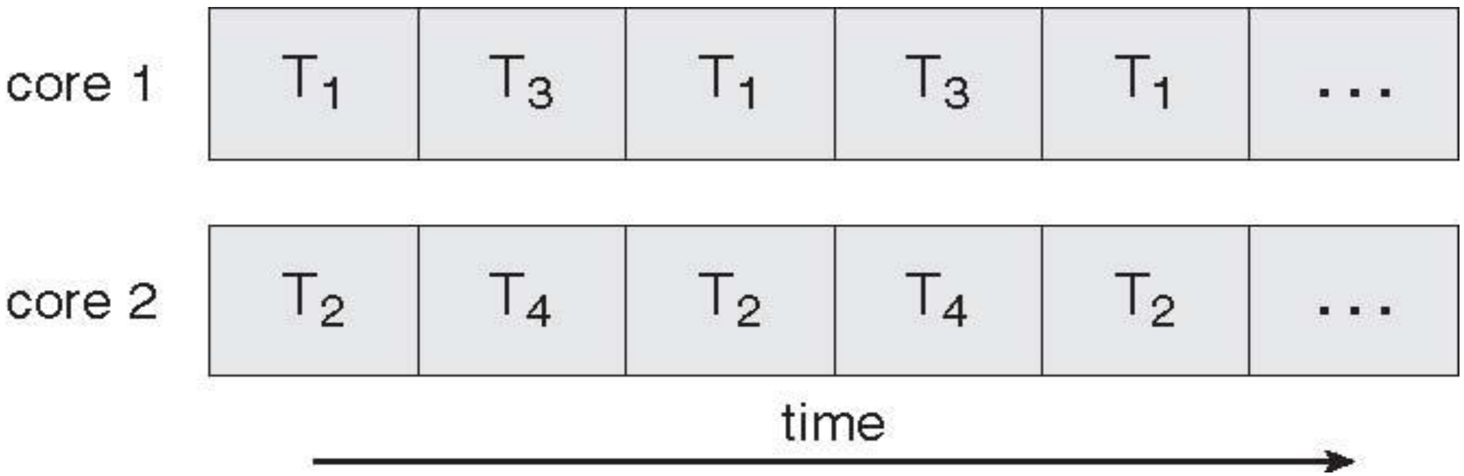
Multithreaded Server Architecture



Concurrent Execution on a Single-core System



Parallel Execution on a Multicore System



线程的实现机制

- 用户级线程 user-level thread
- 核心级线程 kernel-level thread
- 两者结合方法

User Threads（用户级线程）

- **用户级线程：**不依赖于OS核心（内核不了解用户线程的存在），应用进程利用线程库提供创建、同步、调度和管理线程的函数来控制用户线程。

  如：数据库系统informix，图形处理Aldus PageMaker。调度由应用软件内部进行，通常采用非抢先式和更简单的规则，也无需用户态/核心态切换，所以速度特别快。一个线程发起系统调用而阻塞，则整个进程在等待。

  - 用户线程的维护由应用进程完成；
  - 内核不了解用户线程的存在；
  - 用户线程切换不需要内核特权；
  - 用户线程调度算法可针对应用优化；
  - 一个线程发起系统调用而阻塞，则整个进程在等待。

- Three primary thread libraries:
  - POSIX Pthreads 、 Win32 threads、 Java threads

Kernel Threads （内核级线程）

- **内核级线程**：依赖于OS核心，由内核的内部需求进行创建和撤销，用来执行一个指定的函数。一个线程发起系统调用而阻塞，不会影响其他线程。时间片分配给线程，所以多线程的进程获得更多CPU时间。
  - 内核维护进程和线程的上下文信息；
  - 线程切换由内核完成；
  - 时间片分配给线程，所以多线程的进程获得更多CPU时间；
  - 一个线程发起系统调用而阻塞，不会影响其他线程的运行。
- **Examples**
  - Windows XP/2000 及以后
  - Solaris
  - Linux
  - POSIX Pthreads
  - Mac OS X

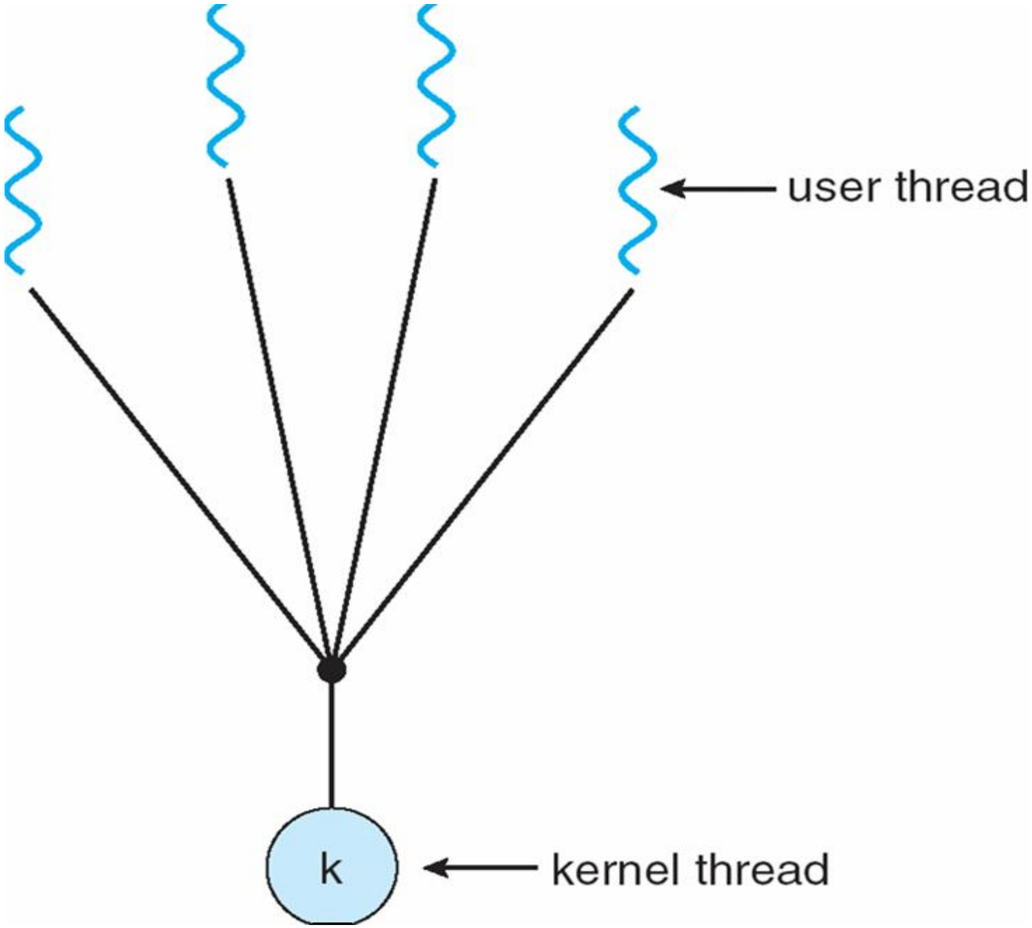
4.2 Multithreading Models

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

Many-to-One

- Many user-level threads mapped to single kernel thread
- Implemented by user-level runtime libraries
  - Create, schedule, synchronize threads at user-level
- OS is not aware of user-level threads
  - OS thinks each process contains only a single thread of control
- Examples:
  - Solaris Green Threads
  - GNU Portable Threads

Many-to-One Model

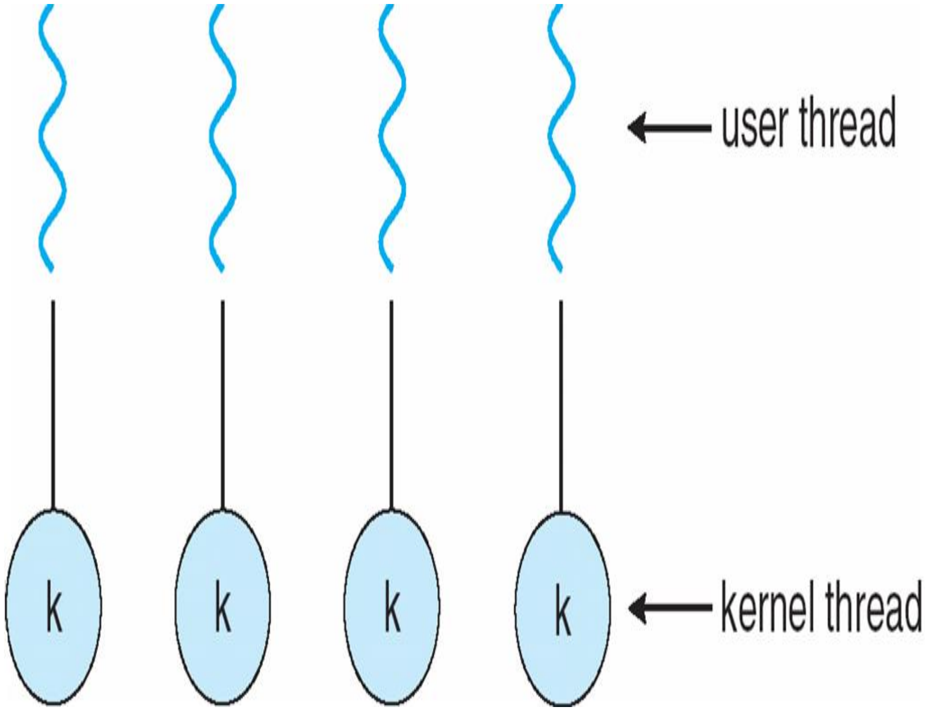


- **Advantages**
  - **Does not require OS support**
  - **Can tune scheduling policy to meet application (user level) demands**
  - **Lower overhead thread operations since no system calls**
- **Disadvantages**
  - **Cannot leverage multiprocessors (no true parallelism)**
  - **Entire process blocks when one thread blocks**

One-to-One

- Each user-level thread maps to kernel thread
- OS provides each user-level thread with a kernel thread
- Each kernel thread scheduled independently
- Thread operations (creation, scheduling, synchronization) performed by OS
- Examples
  - Windows NT/XP/2000
  - Linux
  - Solaris 9 and later

One-to-one Model



- Advantages
  - Each kernel-level thread can run in **parallel on a multiprocessor**
  - When one thread blocks, **other threads from process can be scheduled**
- Disadvantages
  - **Higher overhead** for thread operations
  - OS must scale well with increasing number of threads

Many-to-Many Model

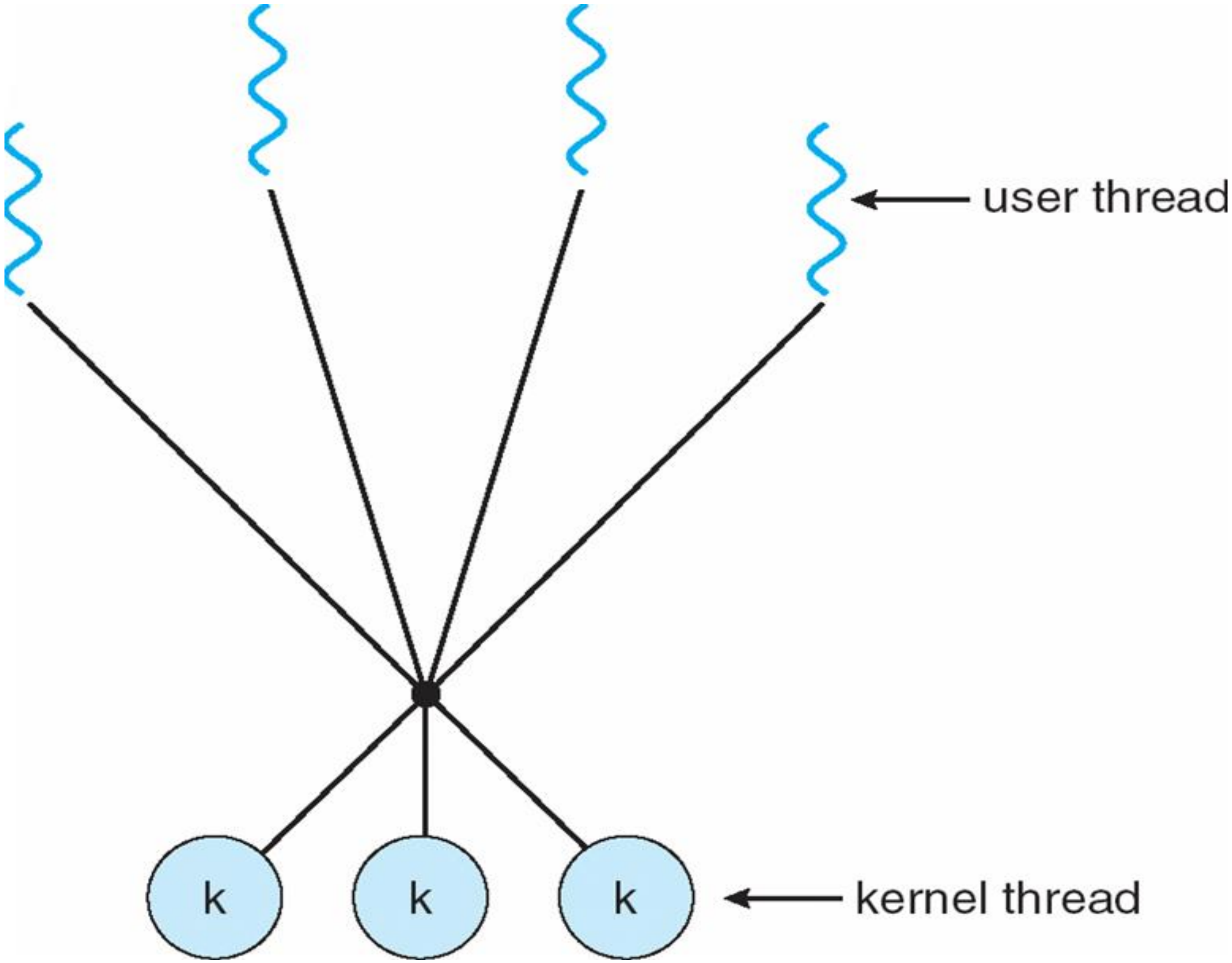
- **Allows many user level threads to be mapped to many kernel threads**
- **Allows the operating system to create a sufficient number of kernel threads**

- **Examples：**

  Solaris prior to version 9

  Windows NT/2000 with the ThreadFiber

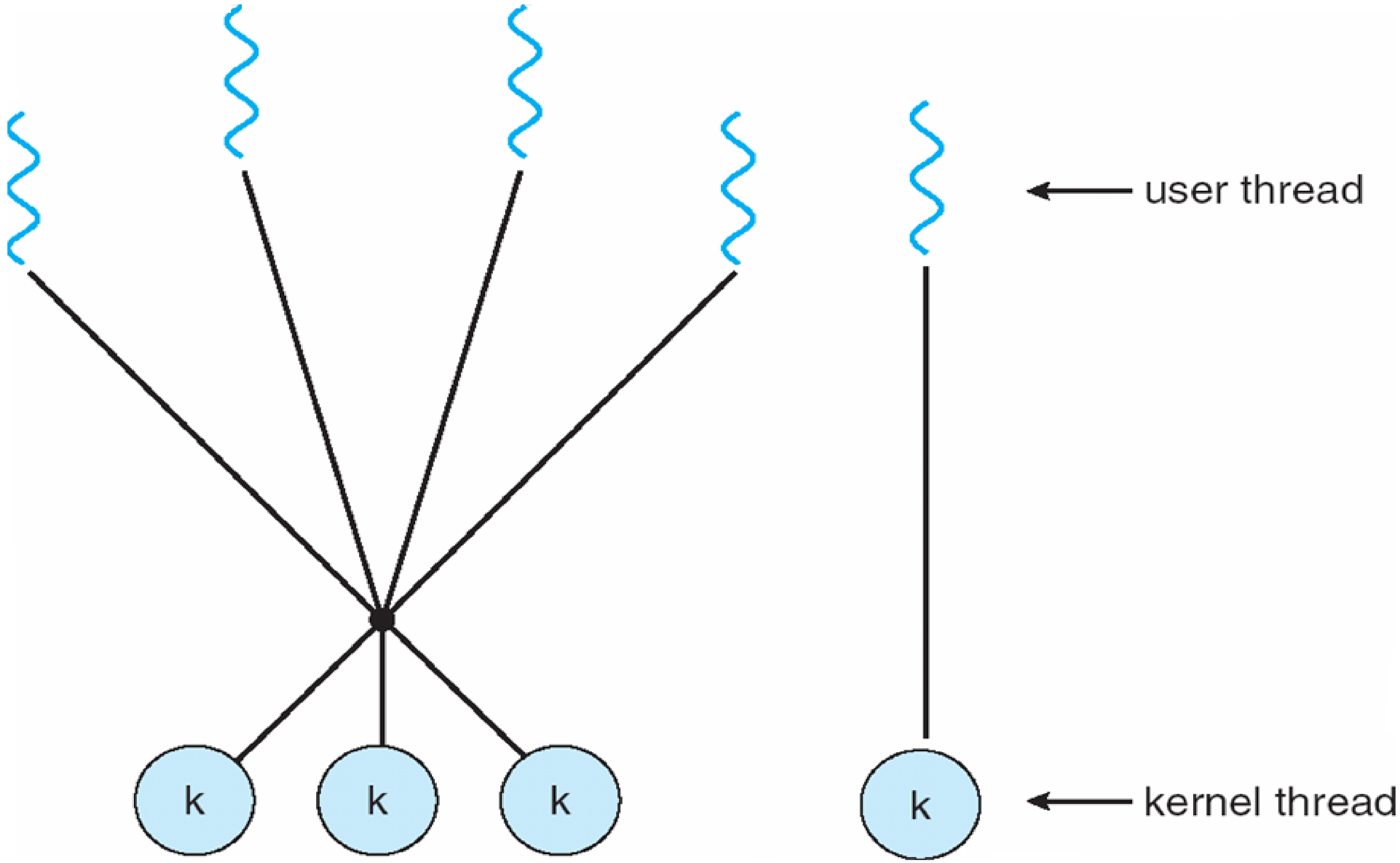
Many-to-Many Model



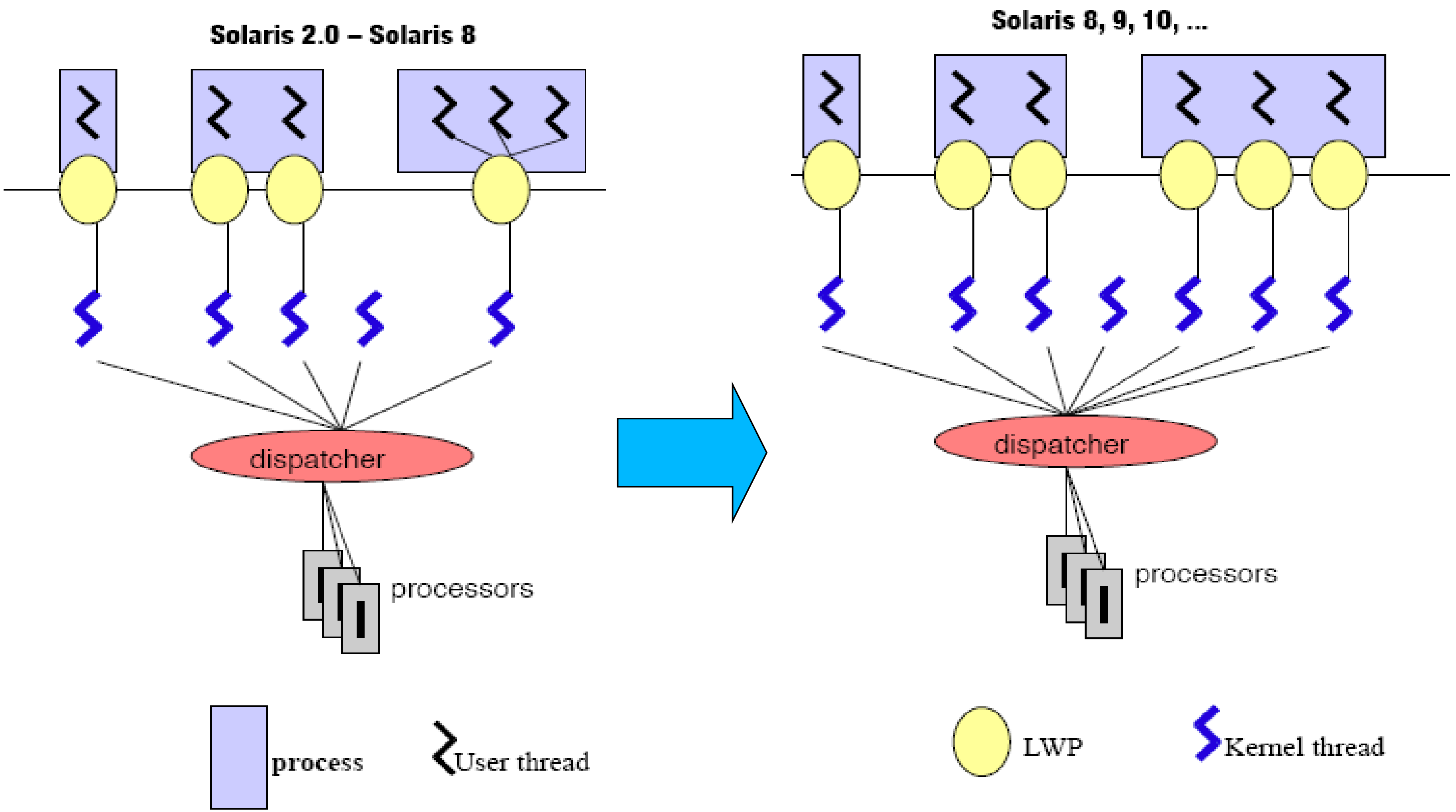
Two-level Model

- **Similar to M:M, except that it allows a user thread to be bound to kernel thread**
- **Examples**
  - **IRIX**
  - **HP-UX**
  - **Tru64 UNIX**
  - **Solaris 8 and earlier**

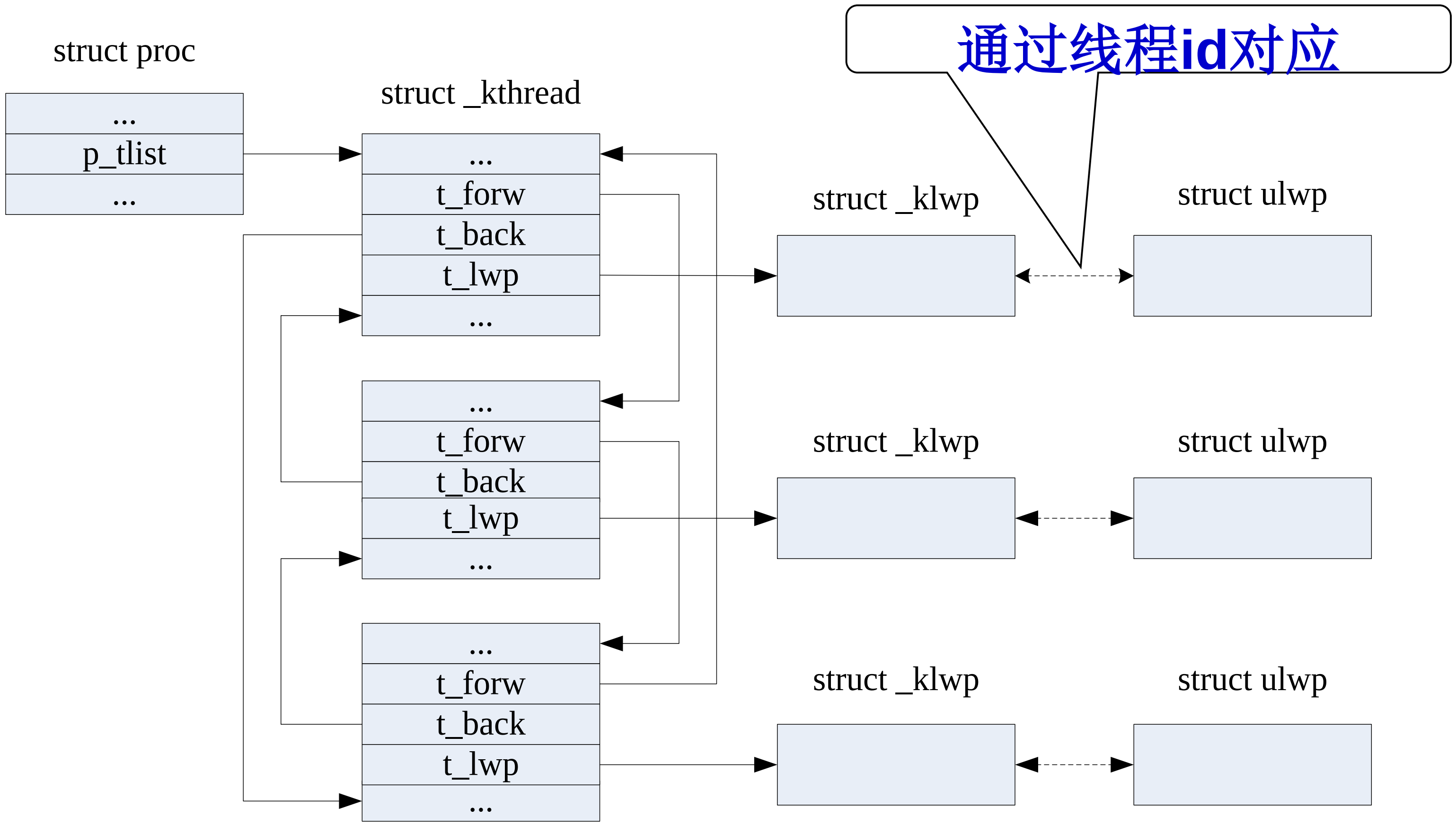
Two-level Model



Solaris多线程模型的发展 - M:N -> 1:1



Solaris用户线程、内核线程、lwp三者之间的关系



4.3 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 （Portable Operating System Interface） standard (IEEE 1003.1c) API for thread creation and synchronization

  http://standards.ieee.org/reading/ieee/stad_public/description/posix
- 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

- 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

4.4 Threading Issues

- Semantics of fork() and exec() system calls
- Thread cancellation of target thread
  - Asynchronous or deferred
- Signal handling
- Thread pools
  - Thread-specific data
- Scheduler activations

Semantics of fork() and exec()

fork()

- **duplicate only the calling thread or all threads?**

exec()

- **Replaces the process - including all threads?**

Thread Cancellation

- Terminating a thread before it has finished
- Two general approaches:
  - **Asynchronous** cancellation terminates the target thread immediately
  - **Deferred cancellation** allows the target thread to periodically check if it should be cancelled

Signal Handling（信号处理）

- Signals are used in UNIX systems to notify a process that a particular event has occurred
- A signal handler is used to process signals
  1. Signal is generated by particular event
  2. Signal is delivered to a process
  3. Signal is handled
- Options:
  - Deliver the signal to the thread to which the signal applies
  - Deliver the signal to every thread in the process
  - Deliver the signal to certain threads in the process
  - Assign a specific threa to receive all signals for the process

Thread Pools（线程池）

- Create a number of threads in a pool where they await work
- Advantages:
  - Usually slightly faster to service a request with an existing thread than create a new thread
  - Allows the number of threads in the application(s) to be bound to the size of the pool

Thread Specific Data（线程特有数据）

- Allows each thread to have its own copy of data
- Useful when you do not have control over the thread creation process (i.e., when using a thread pool)

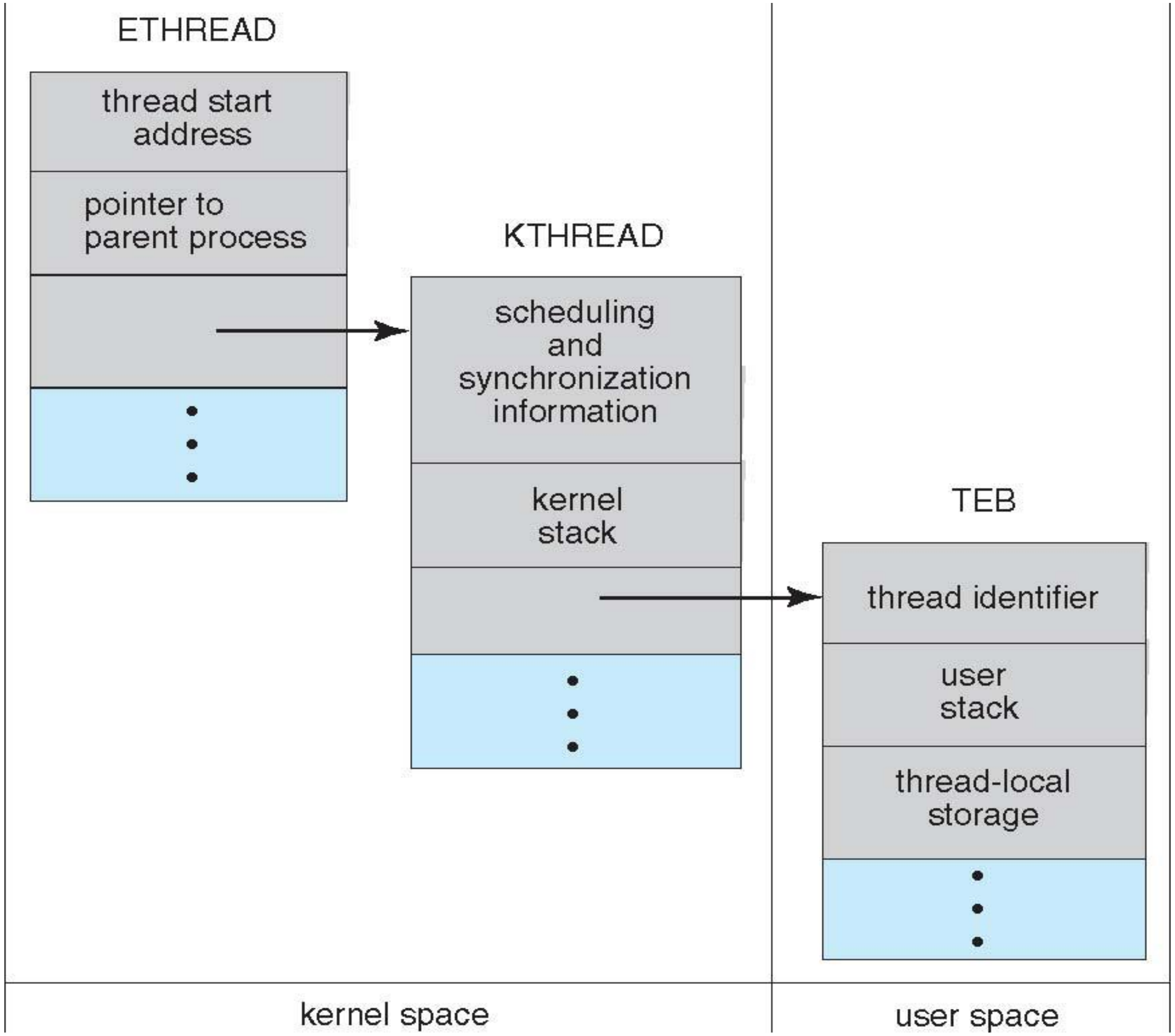
Scheduler Activations

- Both M:M and Two-level models require communication to maintain the appropriate number of kernel threads allocated to the application
- Scheduler activations provide upcalls - a communication mechanism from the kernel to the thread library
- This communication allows an application to maintain the correct number kernel threads

Operating System Examples

- **Windows XP Threads**
- **Linux Thread**

Windows XP Threads



Windows XP Threads

- Implements the one-to-one mapping, kernel-level
- Each thread contains
  - A thread id
  - Register set
  - Separate user and kernel stacks
  - Private data storage area
- The register set, stacks, and private storage area are known as the context of the threads
- The primary data structures of a thread include:
  - ETHREAD (executive thread block)
  - KTHREAD (kernel thread block)
  - TEB (thread environment block)

CreateThread.cpp

Linux Threads

- Linux refers to them as ***tasks*** rather than ***threads***
- Thread creation is done through **clone()** system call
- **clone() allows a child task to share the address space of the parent task (process)**

Linux Threads

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.

Exercise

- ex_ch3-4.doc

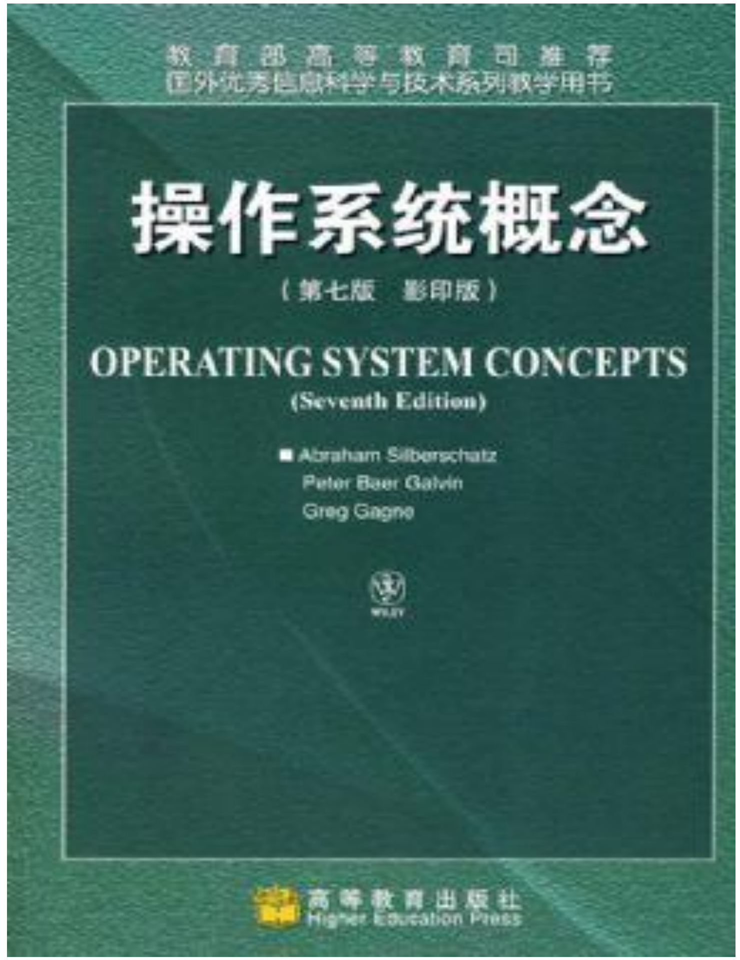
Homework

- 按时完成“作业系统”的作业

  4.4、4.7

Reading Assignments

- Read for this week:
  - Chapters 4
    of the text book:
- Read for next week:
  - Chapters 5
    of the text book:



End of Chapter 4