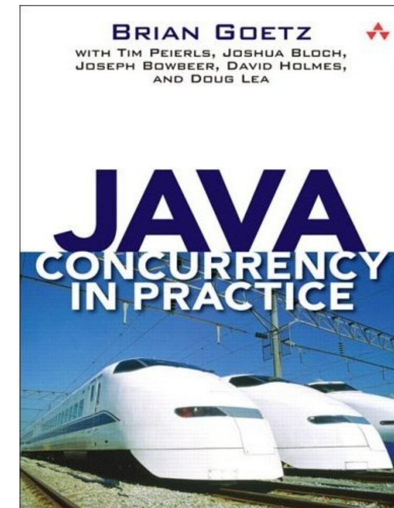
Chapter 4
Threads

Images from Silberschatz

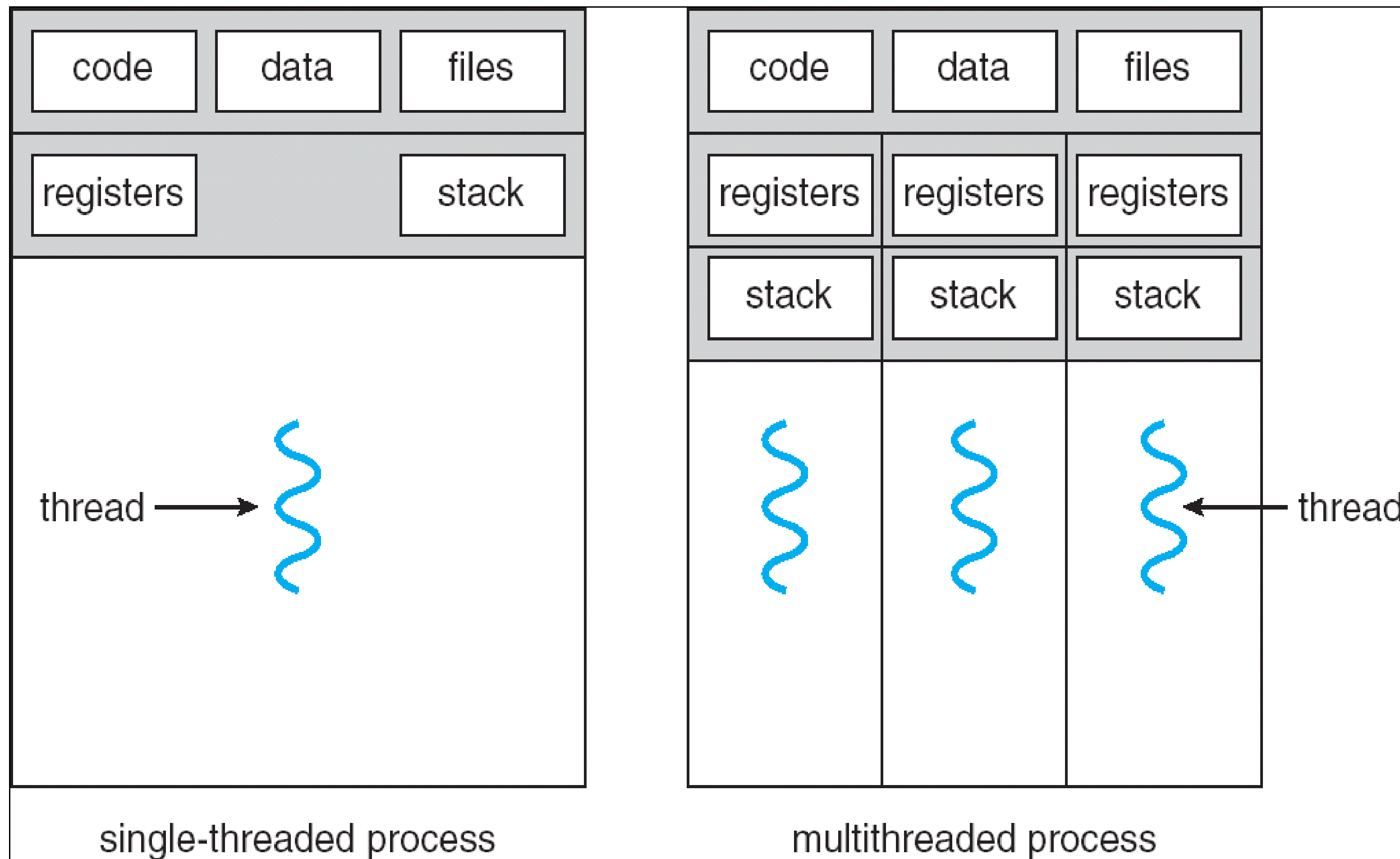


Java Concurrency in Practice,
Goetz, Peierls, Josh **Bloch**, Bowbeer,
Holmes, Doug **Lea**

http://jcip.net/

Threads

- Multiple lines of control *inside one process*
- What is shared?
- How many PCBs?



Typical Usages

- Word Processor

- Web Server

Benefits

- Why multithread?

Risks

- Scheduling

- Synchronization

- Hazards

Safety

- An entity (class, method, function, ...) is thread-safe if it behaves correctly when accessed from multiple threads, regardless of the scheduling/interleaving of those threads, with no additional synchronization on the part of the calling code.[1]

- Synchronization:

Atomic
Race Condition

[1] Adapted from Goetz, et al, page 18.

thread safe function calls

*name*_r()

- strtok_r()

- strtok() - non-thread safe
  - exactly, why is this?
  - what data is shared?
  - who has access to it?

Multicore

- More people have multicores
  - pressure on developers to write multithreaded code
- Multithreaded coding challenges:

User vs Kernel Threads

- User:

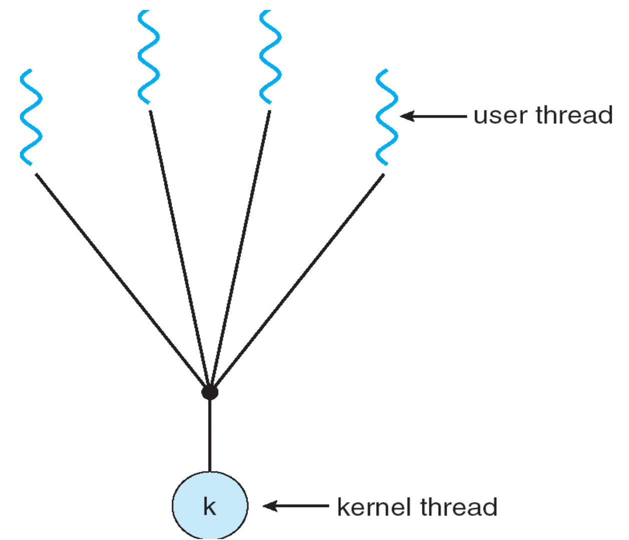
- Kernel:

	User Level Threads	Kernel Level Threads	Processes
Create Time	34	948	11,300

(chart from Stallings, W., *Operating Systems Internals and Design Principles*, 5th Edition, page 169.)

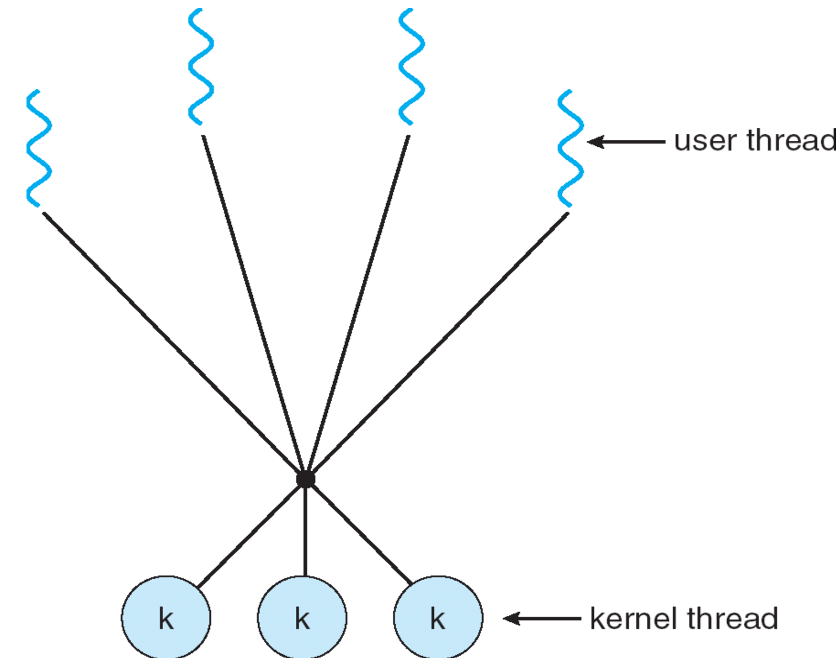
Models

- Many-to-One



- One-to-One

- Many-to-Many



blocking system call?

Thread Libraries

- User vs Kernel

- POSIX Pthreads

- Win32

- Java

Pthreads

- Linux, cygwin, Solaris, etc.
  - gcc -g -o appName appname.c -lpthread
  - what shared library contains the PThread implementation?

```c
/* This code works on Zeus!
 * link with -lpthread
 * gcc -o app -g app.o -lpthread
 */
#include <pthread.h>
#include <stdio.h>

int gSum; /* this data is shared by the thread(s) */

void *runner(void *param); /* the thread */

int main(int argc, char *argv[])
{
  pthread_t tid; /* the thread identifier */
  pthread_attr_t attr; /* set of attributes for the thread */
  int *pResult;

  if (argc != 2)
  {
    fprintf(stderr,"usage: a.out <integer value>\n");
    /*exit(1);*/
    return -1;
  }

/* page 133 of Silberschatz */
```

```c
  if (atoi(argv[1]) < 0)
  {
    fprintf(stderr,"Argument %d must be nonneg\n",atoi(argv[1]));
    /*exit(1);*/
    return -1;
  }
  gSum = 0;

  /* get the default attributes */
  pthread_attr_init(&attr);

  /* create the thread */
  pthread_create(&tid,&attr,runner,argv[1]);

  /* now wait for the thread to exit */
  pthread_join(tid,  &pResult); // why a handle?

  printf("sum = %d OR %d\n",gSum, *pResult);
}
/* page 133 of Silberschatz */
```

```c
/**
 * The thread will begin control
 * in this function
 */
void *runner(void *param)
{
  int i, upper = atoi(param);


  if (upper > 0)
  {
    for (i = 1; i <= upper; i++)
    {
      gSum += i;
    }
  }

  pthread_exit((void*) &gSum);
}
/* page 133 of Silberschatz */
```

Mutex!

```
/* This code works on Zeus!
 * link with -lpthread
 * gcc -o app -g app.o -lpthread
 */
#include <pthread.h>
#include <stdio.h>

int gSum; /* this data is shared by the thread(s) */
pthread_mutex_t gMutex;

void *runner(void *param); /* the thread */

int main(int argc, char *argv[])
{
  pthread_t tid1, tid2; /* the thread identifier */
  pthread_attr_t attr; /* set of attributes for the thread */
  const int THREAD_PARAM_ONE = 5;
  const int THREAD_PARAM_TWO = 6;

  gSum = 0;


/* adapted from page 133 of Silberschatz */
```

```c
  /* init the mutex */
  pthread_mutex_init(&gMutex, NULL);

  /* get the default attributes */
  pthread_attr_init(&attr);

  /* create the threads */
  pthread_create(&tid1, &attr, runner, &THREAD_PARAM_ONE);
  pthread_create(&tid2, &attr, runner, &THREAD_PARAM_TWO);

  /* now wait for the threads to exit */
  pthread_join(tid1, NULL);
  pthread_join(tid2, NULL);

  pthread_mutex_destroy(&gMutex);
  pthread_attr_destroy(&attr);

  printf("sum = %d\n",gSum);
}

/* adapted from page 133 of Silberschatz */
```

```c
/**
 * The thread will begin control in this function
 */
void *runner(void *param)
{
   int i;
   // gSum = 0; // ???

   for (i = 1; i <= *(int*)param; i++)
   {
      pthread_mutex_lock(&gMutex);
      gSum += i;
      //nanosleep(100);
      pthread_mutex_unlock(&gMutex);
   }

   pthread_exit((void*) &gSum);
}
/* page 133 of Silberschatz */
```

Pthread Functions

- pthread_create
- pthread_cond_init
- pthread_mutex_init
- pthread_attr_init
- pthread_mutex_lock / unlock
- pthread_cond_wait / pthread_cond_timedwait
- pthread_cond_signal / pthread_cond_broadcast
- pthread_mutex_destroy
- pthread_attr_destroy
- pthread_cond_destroy
- pthread_exit/pthread_join
- pthread_kill / pthread_detach
- pthread_setaffinity_np   sched_setaffinity

Typical usage

- Message Queues, thread safe/concurrent
- Cancellation
  - asynchronous
  - deferred
- Thread Pools
- Scheduler

Java Threads

- http://java.sun.com/docs/books/tutorial/essential/concurrency/index.html
- Startup/creation
- Synchronization

Threads

```
public class MyThread implements Runnable
{

   @Override
   public void run()
   {
   }

}

MyThread myThread = new MyThread();
Thread listenThread = new Thread(myThread);

listenThread.start(); // call run
```

Synchronization

- Some data structures are thread safe:
  - ConcurrentHashMap<K, V>
  - ConcurrentLinkedQueue<E>

- Often threads will pass messages to each other through Queues

```
ConcurrentLinkedQueue<String> messageQueue =
   new ConcurrentLinkedQueue<String>();
```

Sychronization

- synchronized method

```
public synchronized void once()
{
     // only one thread can be executing this
    // method, per object!
}
```

- synchronized block

```
synchronized(this) // every object contains a lock
{
     this.x++;
}
```

Producer/Consumer

- Design Pattern
- One thread produces data, the other consumes data.

```
public void consume()
{
    synchronized (queue)
    {
        while(queue.isEmpty())
        {
            queue.wait();
            // wait releases the lock until
            // notify is used
        }
        msg = queue.remove();
    }
    // do work with msg
}
```

```
public void produce(msg)
{
    synchronized (queue)
    {
        queue.add(msg);
        queue.notify()
    }
}
```

pthreads

- pthread_cond_wait() / pthread_cond_timedwait()
- pthread_cond_signal() / pthread_cond_broadcast()
- pthread_cond_t

pthreads

- pthread_rwlock_t
- pthread_rwlock_rdlock / pthread_rwlock_wrlock
- pthread_relock_unlock