To optimize Solaris performance, developers have refined and fine-tuned the locking methods. Because locks are used frequently and typically are used for crucial kernel functions, tuning their implementation and use can produce great performance gains.

5.9.4 Pthreads Synchronization

Although the locking mechanisms used in Solaris are available to user-level threads as well as kernel threads, basically the synchronization methods discussed thus far pertain to synchronization within the kernel. In contrast, the Pthreads API is available for programmers at the user level and is not part of any particular kernel. This API provides mutex locks, condition variables, and read–write locks for thread synchronization.

Mutex locks represent the fundamental synchronization technique used with Pthreads. A mutex lock is used to protect critical sections of code—that is, a thread acquires the lock before entering a critical section and releases it upon exiting the critical section. Pthreads uses the `pthread_mutex_t` data type for mutex locks. A mutex is created with the `pthread_mutex_init()` function. The first parameter is a pointer to the mutex. By passing `NULL` as a second parameter, we initialize the mutex to its default attributes. This is illustrated below:

```
#include <pthread.h>

pthread_mutex_t mutex;

/* create the mutex lock */
pthread_mutex_init(&mutex,NULL);
```

The mutex is acquired and released with the `pthread_mutex_lock()` and `pthread_mutex_unlock()` functions. If the mutex lock is unavailable when `pthread_mutex_lock()` is invoked, the calling thread is blocked until the owner invokes `pthread_mutex_unlock()`. The following code illustrates protecting a critical section with mutex locks:

```
/* acquire the mutex lock */
pthread_mutex_lock(&mutex);

/* critical section */

/* release the mutex lock */
pthread_mutex_unlock(&mutex);
```

All mutex functions return a value of 0 with correct operation; if an error occurs, these functions return a nonzero error code. Condition variables and read–write locks behave similarly to the way they are described in Sections 5.8 and 5.7.2, respectively.

Many systems that implement Pthreads also provide semaphores, although semaphores are not part of the Pthreads standard and instead belong to the POSIX SEM extension. POSIX specifies two types of semaphores—**named** and

unnamed. The fundamental distinction between the two is that a named semaphore has an actual name in the file system and can be shared by multiple unrelated processes. Unnamed semaphores can be used only by threads belonging to the same process. In this section, we describe unnamed semaphores.

The code below illustrates the `sem_init()` function for creating and initializing an unnamed semaphore:

```
#include <semaphore.h>
sem_t sem;

/* Create the semaphore and initialize it to 1 */
sem_init(&sem, 0, 1);
```

The `sem_init()` function is passed three parameters:

1. A pointer to the semaphore
2. A flag indicating the level of sharing
3. The semaphore's initial value

In this example, by passing the flag 0, we are indicating that this semaphore can be shared only by threads belonging to the process that created the semaphore. A nonzero value would allow other processes to access the semaphore as well. In addition, we initialize the semaphore to the value 1.

In Section 5.6, we described the classical `wait()` and `signal()` semaphore operations. Pthreads names these operations `sem_wait()` and `sem_post()`, respectively. The following code sample illustrates protecting a critical section using the semaphore created above:

```
/* acquire the semaphore */
sem_wait(&sem);

/* critical section */

/* release the semaphore */
sem_post(&sem);
```

Just like mutex locks, all semaphore functions return 0 when successful, and nonzero when an error condition occurs.

There are other extensions to the Pthreads API — including spinlocks — but it is important to note that not all extensions are considered portable from one implementation to another. We provide several programming problems and projects at the end of this chapter that use Pthreads mutex locks and condition variables as well as POSIX semaphores.

5.10 Alternative Approaches

With the emergence of multicore systems has come increased pressure to develop multithreaded applications that take advantage of multiple processing