Overview

- We take a look at how threads are implemented in Linux
- We examine the POSIX threads API and look at some examples of using the API to create and manipulate threads in C
- *Linux Kernel Development*, by Love, chapter 2
- *Programming with POSIX Threads*, by Butenhof

Threads in Linux

- Linux takes a unique approach to implementing threads: there is in fact no concept of a thread inside the kernel, there are only processes that can share certain resources
- Each thread appears as an ordinary process to the kernel and is scheduled as such
- There are no thread-specific data structures i.e. each thread is represented by a `task_struct` just like an ordinary process
- Threads (like processes) are created by invoking the `clone` system call (`fork` calls `clone`)

Threads in Linux

- `clone` forks a child process but allows control over which resources will be shared between the parent and child
- Other operating systems (Windows and Solaris) have explicit thread support built into the kernel
- Such support exploits the fact that a thread resides within a process to optimise the time required to context switch two threads from the same process
- The disadvantage of this approach is that the kernel becomes more complicated: extra data structures specific to threads are required and context switching code needs to take them into account

Threads in Linux

- In Linux all threads are represented as processes and some efficiency is sacrificed for the sake of simplicity
- In fact, experiment shows that the time taken to create a process in Linux compares favourably with the time taken to create a thread in some other operating systems
- Furthermore, the Linux scheduler makes no effort to successively schedule threads from the same process

POSIX Threads

- With many different thread support packages a standard became required to enable developers to write portable multithreaded applications
- By adhering to the standard developers were guaranteed their threads would behave in a standard way irrespective of how they were actually implemented
- IEEE defined the POSIX threads standard and thread packages that adhere to the defined API are `pthreads`

POSIX Threads

- Most Unix operating systems support `pthreads` and Linux is no exception
- The standard defines over 60 function calls but we will here limit ourselves to looking at only a subset
- To finish our look at POSIX threads we examine how a simple producer-consumer problem can be solved using `pthreads`

POSIX Threads

Some `pthread` functions

- `pthread_create`, `pthread_exit`
- `pthread_join`
- `pthread_mutex_init`, `pthread_mutex_lock`, `pthread_mutex_unlock`, `pthread_mutex_destroy`
- `pthread_cond_init`, `pthread_cond_wait`, `pthread_cond_timedwait`, `pthread_cond_signal`, `pthread_cond_broadcast`, `pthread_cond_destroy`
- `pthread_cancel`

POSIX Threads

```
int pthread_create(pthread_t *thread,
    const pthread_attr_t *attr,
    void *(*start_routine)(void*), void *arg);

void *
sayhello(void *p) {
    char *q = (char *)p;
    printf("Hello %s\n", q);
}

pthread_t t;
char *n = "Ruby";
pthread_create(&t, NULL, sayhello, (void *)n);
```

POSIX Threads

```
int pthread_join(pthread_t thread,
    void **value_ptr);

...
pthread_create(&t, NULL, sayhello, (void *)n);
pthread_join(t, NULL);
...
```

POSIX Threads

```
int pthread_mutex_destroy(pthread_mutex_t *mutex);
int pthread_mutex_init(pthread_mutex_t *mutex,
    const pthread_mutexattr_t *attr);

void *
foo(void *p) {
    pthread_mutex_lock(&mutex);
    /* Update p */
    pthread_mutex_unlock(&mutex);
}

pthread_mutex_t mutex;
pthread_mutex_init(&mutex, NULL);
pthread_create(&t1, NULL, foo, (void *)n);
pthread_create(&t2, NULL, foo, (void *)n);
```

POSIX Threads

- Clearly, creating and starting threads is straightforward
- However, the ability to terminate threads may also be useful:
  1. A user initiates a search for a document
  2. The application starts a thread to carry out the search
  3. The user gets sick of waiting and cancels the search
  4. The application will need to shut down the search thread
- A cancellation request is sent to a thread with `pthread_cancel` and acknowledged with `pthread_testcancel` at a cancellation point
- The following is a very simple example...

POSIX Threads

```
int pthread_cancel(pthread_t thread);
void pthread_testcancel(void);

void *
counter(void *p) {
    for (i = 0; ; i++) {
        /* Do something */
        pthread_testcancel();
    }
}

pthread_create(&t, NULL, counter, (void *)n);
/* Sick of waiting... */
pthread_cancel(t);
pthread_join(t);
```

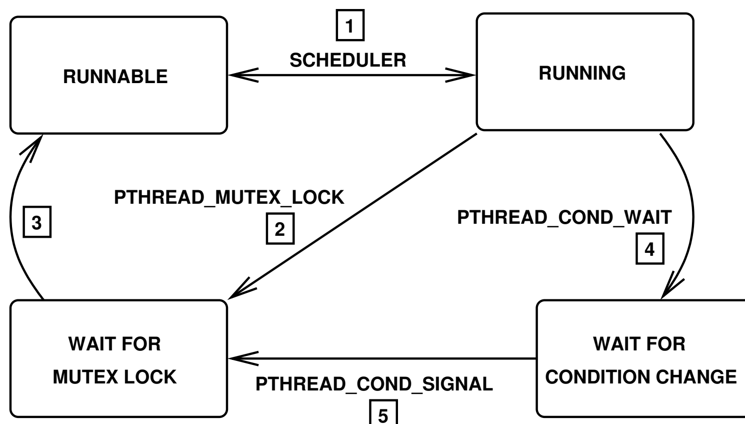
POSIX Threads

- Condition variables allow us to define if and when processes are to wait and on what conditions
- Common in producer-consumer problems
- Used to start and stop threads according to the state of some shared data structure

POSIX Threads

- The condition variable mechanism releases a held mutex when a thread waits on a condition (essential to allow other threads to alter the condition waited upon)
- Compare this with Java's `wait` and `notify` methods: the release of a lock was implicit in Java's `wait`, with a condition variable the release of a lock is made explicit
- To wait on some condition we use `pthread_cond_wait` and to notify waiters that some condition has changed we use `pthread_cond_signal` or `pthread_cond_broadcast`

POSIX Threads



POSIX Threads

```
typedef struct {
  int *buffer;
  int size;
  int occupied;
  int nextin;
  int nextout;
  int ins;
  int outs;
  pthread_mutex_t mutex;
  pthread_cond_t more;
  pthread_cond_t less;
} bb_t;
```

POSIX Threads

```
pthread_t p, c;
bb_t bb;

/* Initialise lock and condition variables */
pthread_mutex_init(&bb.mutex, NULL);
pthread_cond_init(&bb.more, NULL);
pthread_cond_init(&bb.less, NULL);

/* Create our threads */
pthread_create(&p, NULL, producer, (void *)&bb);
pthread_create(&c, NULL, consumer, (void *)&bb);

/* Wait for our threads */
pthread_join(p, NULL);
pthread_join(c, NULL);
```

POSIX Threads

```
void *
producer(void *bb_in)
{
  bb_t  *bb = (bb_t *)bb_in;

  while (1) {
    pthread_mutex_lock(&bb->mutex);
    while (bb->occupied == bb->size) {
      pthread_cond_wait(&bb->less, &bb->mutex);
    }

    /* Insert item */

    pthread_cond_signal(&bb->more);
    pthread_mutex_unlock(&bb->mutex);
  }
}
```