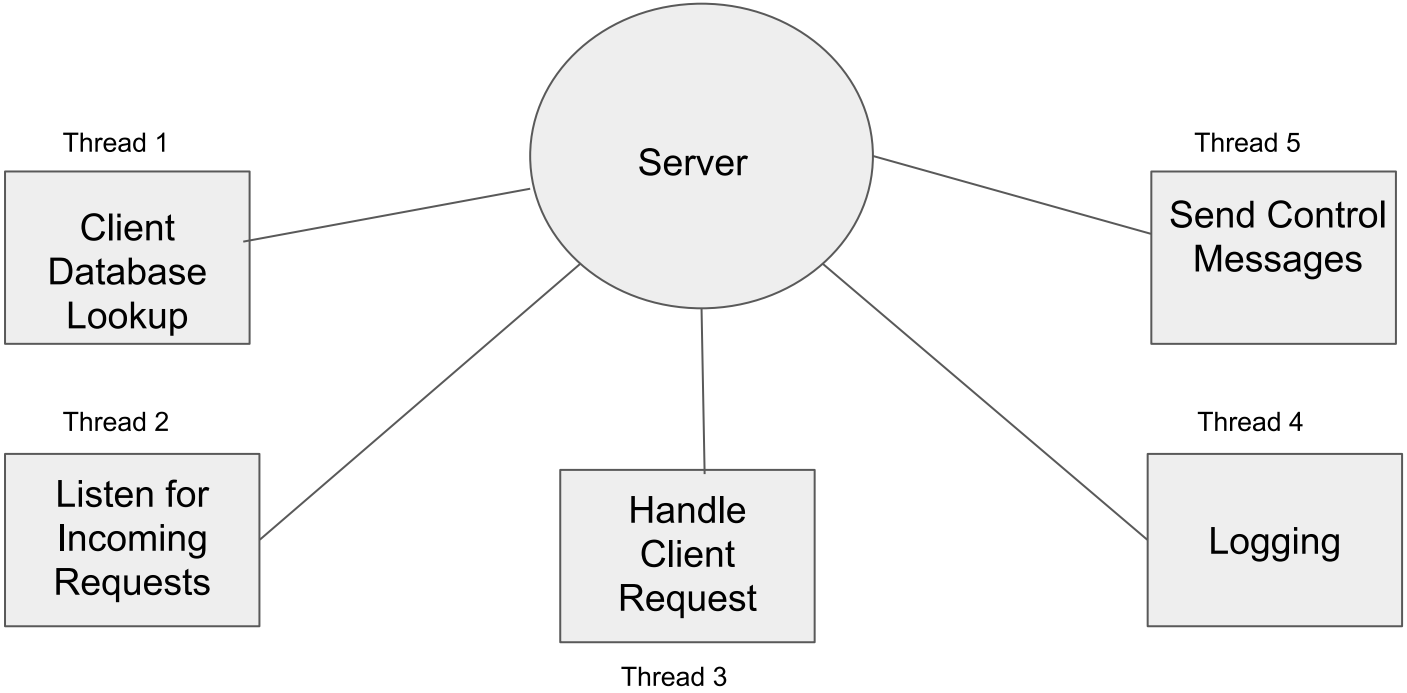
Multi-Threading

CS 425
Distributed Systems

What is MultiThreading?



POSIX Threads

Portable Operating System Interface (POSIX)

- Thread management
  - Creating, detaching, joining, etc. Set/query thread attributes
- Mutex and Semaphore
  - Synchronization
- Condition variables
  - Communications between threads that share a mutex

Compiling on GNU Linux Platform: *gcc MyProgram.c -o MyProgram -lpthread*

Thread Management: Creating and Terminating a Thread

```
int pthread_create (pthread_t* tid, pthread_attr_t* attr,
    void*(functionA), void* arg);
```

- `pthread_create()` takes a pointer to a function as one of its arguments
  - `functionA` is called with the argument specified by `arg`
  - `functionA` can only have one parameter of type `void *`
  - Complex parameters can be passed by creating a structure and passing the address of the structure
  - The structure can't be a local variable

Example: Creating and Terminating a Thread

```
#include <pthread.h>
#define NUM_THREADS 5
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; pthread_create() return code is %d\n", rc);
               exit(-1);
          }
     }
     pthread_exit(NULL);
}
```

```
void *PrintHello(void *threadid) {
     printf("\n%d: Hello World!\n", threadid);
     pthread_exit(NULL);
}
```

Thread Management: Joining and Detaching Threads

- **`pthread_join`** `(pthread_t ID, void **value_ptr):`
  - Blocks the calling thread until the specified thread ID terminates.
- Joinable Threads:
  - System retains information about the joinable threads after the the thread ends, so that other threads can join later.
- **`pthread_detach`** `(pthread_t ID):`
  - Marks the thread identified by *ID* as detached. When a detached thread terminates, its resources are automatically released back to the system

Thread Management: Joining and Detaching Threads

```
#include <pthread.h>
void* functionA (void*);
int counter = 0;
pthread_mutex_t mutexA = PTHREAD_MUTEX_INITIALIZER;

int main ()
{
     pthread_t thread_id [10];
     for (int i = 0; i < 10; i++)
    {
        pthread_create (&thread_id [i], NULL, functionA, NULL);
    }
    for (int j = 0; j < 10; j++)
   {
        pthread_join (thread_id [j], NULL);
   }
    printf("\n\nFinal counter value: %d\n,counter);
    return 0;
}
```

```
void* functionA (void* arg)
{
     pthread_mutex_lock (&mutexA);
     counter++;
     pthread_mutex_unlock (&mutexA);
     return 0;
}
```

Mutex and Semaphore

Mutex:

- ➢ Only one thread can access the critical section of a code
- ➢ Locks must be released by the thread that acquired the lock

Semaphore:

- ➢ Counting Semaphore
- ➢ Binary Semaphore
- ➢ A good example: “Producer-Consumer Problem”

POSIX Mutex

- int pthread_mutex_init(pthread_mutex_t **mutex*, const pthread_mutexattr_t **attr*);
- int pthread_mutex_destroy(pthread_mutex_t **mutex*);
- pthread_mutex_t *mutex* = PTHREAD_MUTEX_INITIALIZER;
- `pthread_mutex_lock (&mutexA)`
- `pthread_mutex_unlock (&mutexA);`

Mutex

```
#include <pthread.h>
void* functionA (void*);
int counter = 0;
pthread_mutex_t mutexA = PTHREAD_MUTEX_INITIALIZER;

int main ()
{
     pthread_t thread_id [10];
     for (int i = 0; i < 10; i++)
    {
        pthread_create (&thread_id [i], NULL, functionA, NULL);
    }
    for (int j = 0; j < 10; j++)
   {
        pthread_join (thread_id [j], NULL);
   }
    printf("\n\nFinal counter value: %d\n,counter);
    return 0;
}
```

```
void* functionA (void* arg)
{
     pthread_mutex_lock (&mutexA);
     counter++;
     pthread_mutex_unlock (&mutexA);
     return 0;
}
```

Barrier

```
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
#include <time.h>
#include <pthread.h>
#include <sys/neutrino.h>

pthread_barrier_t   barrier; // barrier synchronization object

int main () {
   time_t  now;
   // create a barrier object with a count of 3
   pthread_barrier_init (&barrier, NULL, 3);
   pthread_create (NULL, NULL, thread1, NULL);
   pthread_create (NULL, NULL, thread2, NULL);

   time (&now);
   printf ("main() waiting for barrier at %s", ctime (&now));
   pthread_barrier_wait (&barrier);

   // after this point, all three threads have completed.
   time (&now);
   printf ("barrier in main() done at %s", ctime (&now));
   pthread_exit( NULL );
   return (EXIT_SUCCESS);
}
```

```
void *
thread1 (void *not_used)
{
   time_t  now;

   time (&now);
   printf ("thread1 starting at %s", ctime (&now));

   // do the computation
   // let's just do a sleep here...
   sleep (20);
   pthread_barrier_wait (&barrier);
   // after this point, all three threads have completed.
   time (&now);
   printf ("barrier in thread1() done at %s", ctime (&now));
}
```

```
void *
thread2 (void *not_used)
{
   time_t  now;

   time (&now);
   printf ("thread2 starting at %s", ctime (&now));

   // do the computation
   // let's just do a sleep here...
   sleep (40);
   pthread_barrier_wait (&barrier);
   // after this point, all three threads have completed.
   time (&now);
   printf ("barrier in thread2() done at %s", ctime
(&now));
}
```

Condition Variables

Creating and Destroying Condition Variables:

- **pthread_cond_init (condition,attr)**
- **pthread_cond_destroy (condition)**
- **pthread_condattr_init (attr)**
- **pthread_condattr_destroy (attr)**

Waiting and Signaling on Condition Variables

- **pthread_cond_wait (condition,mutex)**
- **pthread_cond_signal (condition)**
- **pthread_cond_broadcast (condition)**

Example: Condition Variable

```
…………………

pthread_mutex_t count_mutex;
pthread_cond_t count_threshold_cv;


int main (int argc, char *argv[])

{  int i, rc;
  long t1=1, t2=2, t3=3;
  pthread_t threads[3];
  pthread_attr_t attr;

  /* Initialize mutex and condition variable objects */
  pthread_mutex_init(&count_mutex, NULL);
  pthread_cond_init (&count_threshold_cv, NULL);

  /* For portability, explicitly create threads in a joinable state */
  pthread_attr_init(&attr);
  pthread_attr_setdetachstate(&attr,
PTHREAD_CREATE_JOINABLE);
  pthread_create(&threads[0], &attr, watch_count, (void *)t1);
  pthread_create(&threads[1], &attr, inc_count, (void *)t2);
  pthread_create(&threads[2], &attr, inc_count, (void *)t3);

  /* Wait for all threads to complete */
  for (i=0; i<NUM_THREADS; i++) {
    pthread_join(threads[i], NULL);
  }
    /* Clean up and exit */
  ……………………..
}
```

```
void *watch_count(void *t)
{
  long my_id = (long)t;

  printf("Starting watch_count(): thread %
ld\n", my_id);

  pthread_mutex_lock(&count_mutex);
  while (count<COUNT_LIMIT) {
    pthread_cond_wait(&count_threshold_cv,
&count_mutex);
    printf("watch_count(): thread %ld
Condition signal received.\n", my_id);
    count += 125;
    printf("watch_count(): thread %ld count
now = %d.\n", my_id, count);
    }
  pthread_mutex_unlock(&count_mutex);
  pthread_exit(NULL);
}
```

```
void *inc_count(void *t)
{
  int i;
  long my_id = (long)t;

  for (i=0; i<TCOUNT; i++) {
    pthread_mutex_lock(&count_mutex);
    count++;
    if (count == COUNT_LIMIT) {
      pthread_cond_signal(&count_threshold_cv);

      }

    pthread_mutex_unlock(&count_mutex);

    sleep(1);
    }
  pthread_exit(NULL);
}
```

References

- https://computing.llnl.gov/tutorials/pthreads/#PthreadsAPI
- http://www.linuxquestions.org/questions/blog/anisha-kaul-445448/why-and-how-to-use-60pthread_join-60-pthreads-34775/
- http://linux.die.net/man/3/pthread_detach
- http://www.qnx.com/developers/docs/660/index.jsp?topic=%2Fcom.qnx.doc.neutrino.sys_arch%2Ftopic%2Fkernel_Barriers.html
- http://www.csee.wvu.edu/~jdm/classes/cs550/notes/tech/mutex/pc-sem.html
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