

Posix Threads

Thread state

- Each thread has its own stack and local variables
 - Globals are shared.
 - File descriptors are shared. If one thread closes a file, all other threads can't use
 - The file I/O operations block the calling thread.
 - Some other functions act on the whole process.
 - For example, the `exit()` function operates terminates the entire and all associated threads.
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Thread Implementation

- The most important of these APIs, in the Unix world, is the one developed by the group known as POSIX.
- POSIX is a standard API supported
- Portable across most UNIX platforms.
- PTHREAD library contains implementation of POSIX standard
- To link this library to your program use ***-lpthread***
 - `gcc MyThreads.c -o MyThreadExecutable - lpthread`

Thread Creation

- **pthread_create(pthread_t *threadid, const pthread_attr_t *attr, void *(*start_routine)(void *), void *arg);**
 - This routine creates a new thread and makes it executable.
 - Thread stack is allocated and thread control block is created
 - Once created, a thread may create other threads.
 - Note that an "initial thread" exists by default and is the thread which runs main.
 - Returns zero, if ok
 - Returns Non-zero if error
 - **threadid**
 - The routine returns the new thread ID via the **threadid**
 - The caller can use this thread ID to perform various operations
 - This ID should be checked to ensure that the thread was successfully created.

Thread Creation

- **pthread_create**(pthread_t ***threadid**, const pthread_attr_t ***attr**, void *(***start_routine**)(void *), void ***arg**);
- **attr**
 - ❑ used to set thread attributes.
 - ❑ NULL for the default values.
- **start_routine**
 - ❑ The C routine that the thread will execute once it is created.
- **arg**
 - ❑ Arguments are passed to *start_routine* via *arg*.
 - ❑ Arguments must be passed by reference as pointers
 - ❑ These pointers must be cast as pointers of type void.

Attribute Object

- When an attribute object is not specified, it is NULL, and the *default* thread is created with the following attributes:
 - ❑ It is non-detached
 - ❑ It has a default stack and stack size
 - ❑ It inherits the parent's priority

Thread Termination

- **pthread_exit(status)**
 - Several ways of termination:
 - ❑ The thread returns from its starting routine (the main routine for the initial thread).
 - ❑ The thread makes a call to the **pthread_exit** subroutine.
 - ❑ The thread is canceled by another thread via the **pthread_cancel** routine.
 - ❑ The entire process is terminated due to a call to the exit subroutines.
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Thread Termination

- The **pthread_exit()** routine does not close files; any files opened inside the thread will remain open after the thread is terminated.
 - If the "initial thread" exits with **pthread_exit()** instead of `exit()`, other threads will continue to execute.
 - The programmer may specify a termination *status*, which is stored as a void pointer for any thread that may join the calling thread i.e wait for this thread.
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```
#include <pthread.h>
#include <stdio.h>
#define NUM_THREADS 5
void * PrintHello(void *threadid)
{ printf("\n%d: Hello World!\n", threadid);
  pthread_exit(NULL);
}
int main()
{
  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; return code from pthread_create() is %d\n", rc);
      exit(-1);
    }
  }
  pthread_exit(NULL); }
```

Passing Arguments To Threads

- The `pthread_create()` routine permits the programmer to pass one argument to the thread start routine.
- What if we want to pass multiple arguments.
- Create a structure which contains all of the arguments
- Pass a pointer to the structure in the `pthread_create()` routine.
- Argument must be passed by reference and cast to `(void *)`.
- Important:
 - Threads initially access their data structures in the parent thread's memory space.
 - That data structure must not be corrupted/modified until the thread has finished accessing it.

Incorrect pthread_create() argument passing

```
for(t=0; t < NUM_THREADS; t++)  
{  
    printf("Creating thread %d\n", t);  
    rc = pthread_create(&threads[t],  
        NULL, printHello, (void *) &t);  
    ...  
}
```

Correct pthread_create() argument passing

```
int *task_ids[NUM_THREADS];
for(t=0;t < NUM_THREADS;t++)
{
    task_ids[t] = new int;
    *task_ids[t] = t;
    printf("Creating thread %d\n", t);
    rc = pthread_create(&threads[t], NULL,
        PrintHello, (void *) task_ids[t]);
    ...
}
```

Passing a structure as an argument

```
struct thread_data
{
    int thread_id;
    int sum;
};
thread_data thread_data_array[NUM_THREADS];
void *PrintHello(void *threadarg)
{
    thread_data *my_data;

    ...
    my_data = (struct thread_data *) threadarg;
    taskid = my_data->thread_id;
    sum = my_data->sum;
    ...
}
```

Passing a structure as an argument

```
int main()
{ ...
  thread_data_array[t].thread_id = t;
  thread_data_array[t].sum = sum;
  rc = pthread_create(&threads[t], NULL,
    PrintHello, (void *)&thread_data_array[t])
  ;
  ...
}
```

Thread ID

- **pthread_self()**
 - Returns the unique thread ID of the calling thread.
- **pthread_equal(threadid1, threadid2)**
 - Compares two thread IDs:
 - If the two IDs are different 0 is returned, otherwise a non-zero value is returned.

Thread Suspension and Termination

- Similar to UNIX processes, threads have the equivalent of the `wait()` and `exit()` system calls
- `pthread_join()`
 - Used to block threads
- `pthread_exit()`
 - Used to terminate threads
- To instruct a thread to block and wait for a thread to complete, use the **`pthread_join()`** function.
- This is also the mechanism used to get a return value from a thread
- Any thread can call join on (and hence wait for) any other thread.

Detached State

- Each thread can be either *joinable* or *detached*.
- **Detached**: on termination all thread resources are released by the OS.
- A detached thread cannot be joined.
- No way to get at the return value of the thread.

Joining thread

- **Joinable:** on thread termination the thread ID and exit status are saved by the OS.
- Joining a thread means waiting for a thread
- **pthread_join(threadid, status)**
 - "Joining" is one way to accomplish synchronization between threads.
 - subroutine blocks the calling thread until the specified *threadid* thread terminates.
 - The programmer is able to obtain the target thread's termination return status (if specified) in the *status* parameter.
- It is impossible to join a detached thread

Joining thread

- Multiple threads cannot wait for the same thread to terminate.
- If they try to, one thread returns successfully
- The others fail with an error of ESRCH
- After `pthread_join()` returns, any stack storage associated with the thread can be reclaimed by the application.
- Threads which have exited but have not been joined are equivalent to zombie processes.
- Their resources cannot be fully recovered.

pthread_detach()

- By default threads are created joinable.
- Instead of waiting for a child, a parent thread can specify that
 - it does not require a return value
 - or any explicit synchronization with that thread.
- To do this, the parent thread uses the **pthread_detach()** function.
- After this call, there is no thread waiting for the child – it executes independently until termination.
- To avoid memory leaks a thread should
 - either be *joined*
 - Or detached by a call to **pthread_detach()**
- `int pthread_detach(pthread_t tid);`
 - Returns 0 on OK, nonzero on error
- Threads can detach themselves by calling *pthread_detach* with an argument of *pthread_self*