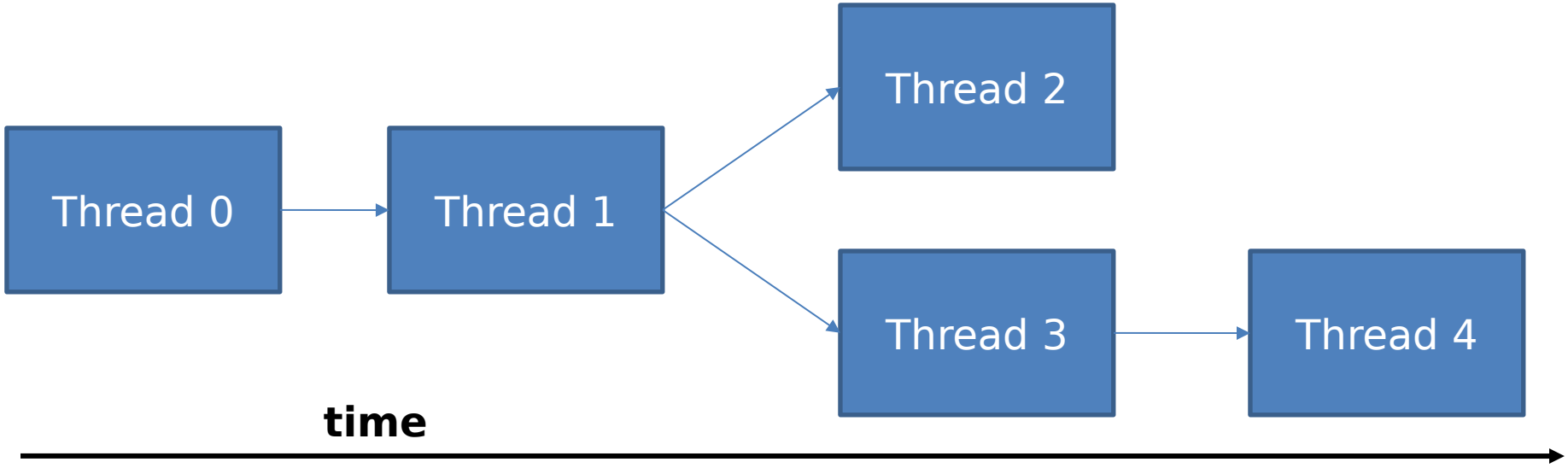
Thread

- A thread is a sequence of related instructions executed independently of other instruction sequences.
- A thread can create another threads.
- Each thread maintains its current state of execution.
- Three types of thread
  - User level
  - Kernel level
  - Hardware level

Thread

- Threads share same address space but have their own private stacks.
- Thread states: ready, running, waiting (blocked), or terminated.



POSIX Thread (Pthread)

- POSIX: Portable Operating System Inyerface
  - It defines standards for APIs for maintaining compatibility between operating systems.
- POSIX Threads, commonly known as pthreads, is a parallel execution model that exists independently from a language.
  - It allows a program to control multiple different flows of work
  - It is an API defined by standard POSIX.1c.

POSIX Thread (Pthread)

- Native threading interface for Linux
- C language programming types and procedure calls implemented with a pthread.h header.
- It assumes shared memory.
- To compile with GNU compiler:
  - gcc/g++ <progname> –lpthread
  - gcc/g++ -pthread <progname>

Pthread Management

- Routines:
  - pthread_create (thread, attr, start_routine, arg)
  - pthread_join (threadid, status)
  - pthread_exit (status)
  - pthread_cancel (thread)
  - pthread_attr_init (attr)
  - pthread_attr_destroy (attr)

Pthread Management

- pthread_create (thread, attr, start_routine, arg) creates a new thread and makes it executable. This routine can be called any number of times from anywhere within your code.

- pthread_create arguments:
  - ✓ thread: An unique identifier for the new thread returned by the subroutine.
  - ✓ attr: can be used to set thread attributes. NULL: default, specified only at thread creation time.
  - ✓ start_routine: the C routine that the thread will execute once it is created.
  - ✓ arg: A single argument that may be passed to start_routine.

Pthread Management

- pthread_join (threadid, status) accomplishes synchronization between threads.
- pthread_join(threadid, status) 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 it was specified in the target thread's call to pthread_exit().

Pthread Management

- pthread_exit (status) allows the programmer to specify an optional termination status parameter. If any file is open inside the thread, it will remain after the thread termination.

- A thread may be terminated:
  - ✓The thread returns normally from its starting routine.
  - ✓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 exit() .
  - ✓If main() finishes first.

Pthread Management

- pthread_cancel (thread) cancels the specified thread.
- pthread_attr_init (thread) allows to initialize the attribute thread.
- pthread_attr_destroy (thread) allows to free library resources used by the attribute.

```
#include <pthread.h>
#include <stdio.h>
#define NUM_THREADS 5

void *PrintHello(void *threadid) {
   int tid;
   tid = (int) threadid;
   printf("Hello World! It's me, thread: %d!\n", tid);
   pthread_exit(NULL);
}
int main (int argc, char *argv[]) {
   pthread_t threads[NUM_THREADS];
   int rc;
   for(int t=0; t<NUM_THREADS; t++){
      printf("In main: 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);
   return  0;
}
```

By having main() explicitly call pthread_exit() as the last thing it does,
main() will block and be kept alive to support
the threads it created until they are

```
#include <pthread.h>
#include <stdio.h>
#define NUM_THREADS 5
void *PrintHello(void *threadid) {
	int tid;
	tid = (int) threadid;
	printf("Hello World! It's me, thread: %d!\n", tid);
	}
int main (int argc, char *argv[]) {
	pthread_t threads[NUM_THREADS];
	int rc;
	for(int t=0; t<NUM_THREADS; t++){
		printf("In main: 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);
		    }
	}
	for (int i=0; i<NUM_THREADS; i++)
		    pthread_join (threads[i], NULL);
	return  0;
}
```

main() will block until all the threads[i] threads terminate.

Mutual Exclusion (Mutex)

- One of the primary means of implementing thread synchronization and for protecting shared data when multiple writes occur.
- A mutex acts like a lock protecting access to a shared data resource.
- Only one thread can lock (or own) a mutex variable at any given time.

Mutual Exclusion (Mutex)

- Routines:
  - pthread_mutex_init (mutex, attr)
  - pthread_mutex_destroy (mutex)
  - pthread_mutex_lock (mutex)
  - pthread_mutex_unlock (mutex)

Mutual Exclusion (Mutex)

- pthread_mutex_init (mutex, attr) initiates the mutex and permits setting mutex object attributes attr.
- pthread_mutex_destroy (mutex) should be used to free a mutex object which is no longer needed.

Mutual Exclusion (Mutex)

- pthread_mutex_lock (mutex) routine is used by a thread to acquire a lock on the specified mutex variable. If the mutex is already locked by another thread, this call will block the calling thread until the mutex is unlocked.
- pthread_mutex_unlock (mutex) will unlock a mutex if called by the owning thread. An error will be returned if:
  - ✓ If the mutex was already unlocked
  - ✓ If the mutex is owned by another thread

```
#include <pthread.h>
#include <stdio.h>
pthread_mutex_t mutex;
int sum_value;
void *doSum (void *arg) {
	int sum = (int) arg;
	while(true){
		pthread_mutex_lock(&mutex);
		sum_value += sum;
		printf("After sum in thread %d = %d\n", sum, sum_value);
		pthread_mutex_unlock (&mutex);
		Sleep(5);}
}
int main (int argc, char *argv[]) {
	pthread_t thread1, thread2;
	int t1 = 1, t2 = 2;
	pthread_mutex_init(&mutex, NULL);
	pthread_create(&thread1, NULL, doSum, (void *)t1);
	pthread_create(&thread2, NULL, doSum, (void *)t2);
	pthread_join (thread1, NULL);
	pthread_join (thread2, NULL);
	return  0;
}
```

Semaphores

- permit a limited number of threads to execute a section of the code
- similar to mutexes
- should include the semaphore.h header file
- semaphore functions have sem_ prefixes

Semaphores

- Routines:
  - sem_init (sem, pshared, value)
  - sem_destroy (sem)
  - sem_wait (sem)
  - sem_post (sem)

Semaphores

- sem_init (sem, pshared, value) initializes a semaphore object pointed to by sem
  - ✓ pshared is a sharing option; a value of 0 means the semaphore is local to the calling process
  - ✓ gives an initial value value to the semaphore
- sem_destroy (sem) frees the resources allocated to the semaphore sem and this routine is usually called after pthread_join().

Semaphores

- sem_wait (sem) atomically decreases the value of a semaphore sem by 1, if it is negative, the calling process blocks
  - one of the blocked processes wakes up when another process calls sem_post.
- sem_post (sem) atomically increases the value of a semaphore sem by 1.