Threads

Operating Systems Course

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Spring 2011

What is a Thread?

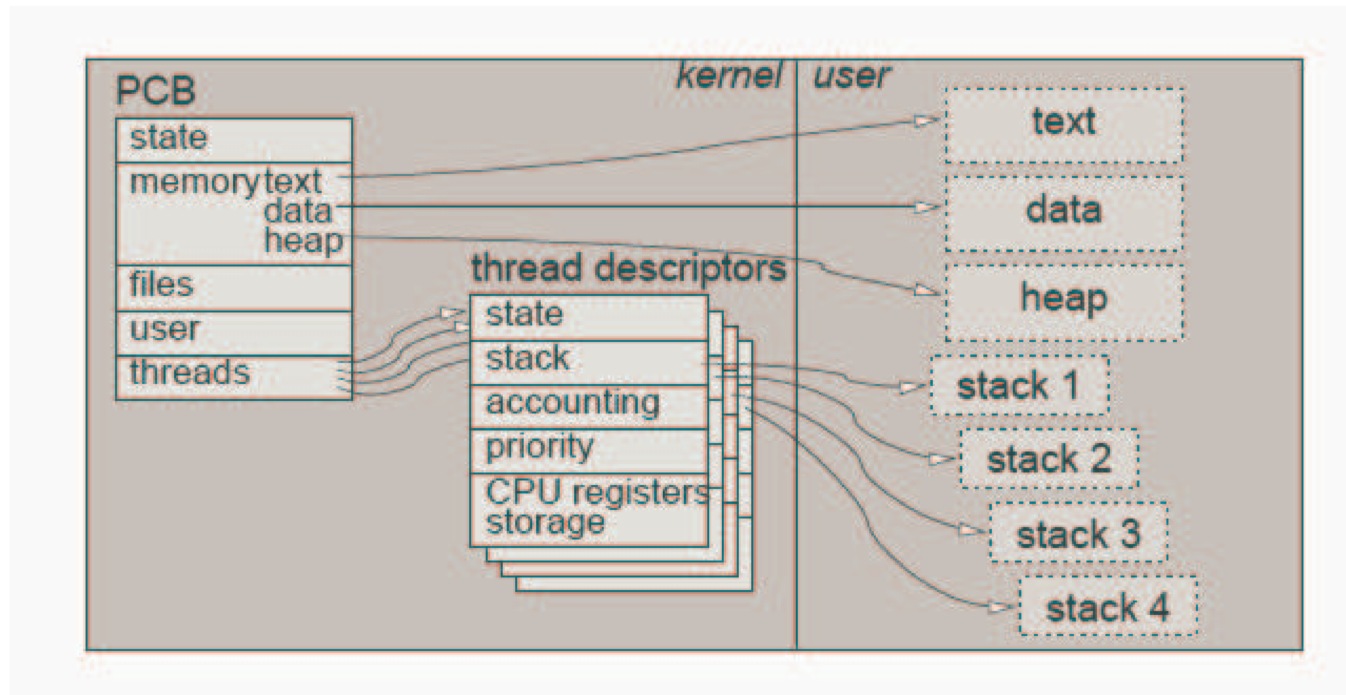
- A thread lives within a process;
- A process can have several threads.
- A thread possesses an independent flow of control, and can be scheduled to run separately from other threads, because it maintains its own:
  - Stack.
  - Registers. (CPU state)
- The other resources of the process are shared by all its threads.
  - Code
  - Memory
  - Open files
  - And more...

Thread Implementations

- Kernel level threads (lightweight processes):
  - thread management done by the kernel.
- User level threads:
  - kernel unaware of threads.

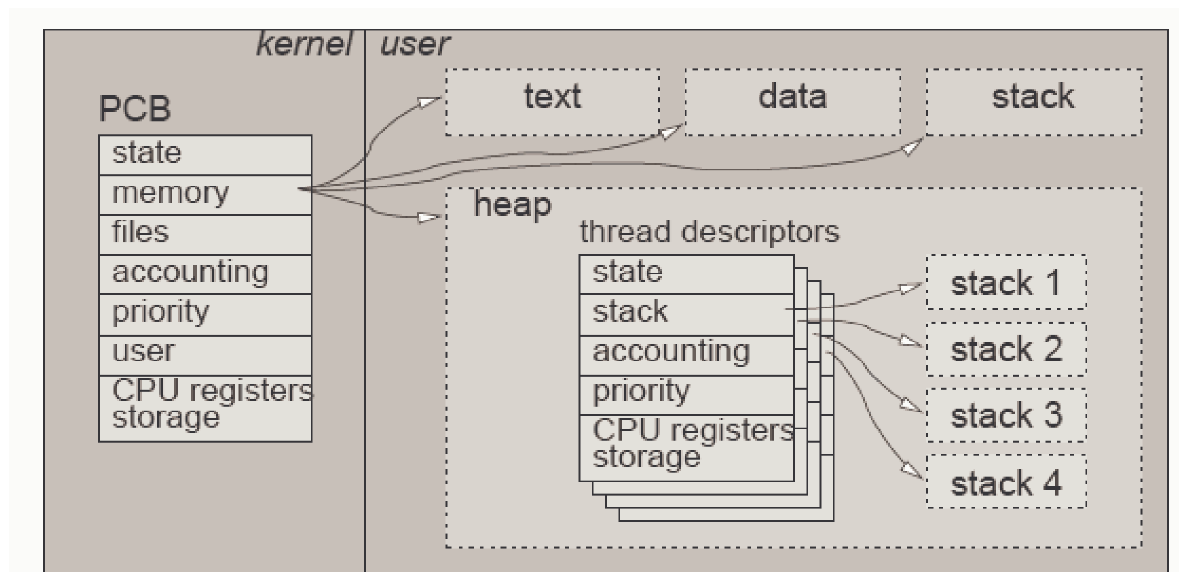
Kernel Level Threads

- Kernel level threads (lightweight processes)
  - thread management done by the kernel



User Level Threads

- User level threads
  - implemented as a thread library, which contains the code for thread creation, termination, scheduling and switching
  - kernel sees one process and it is unaware of its thread activity.



Implementing a thread library

- Maintain a thread descriptor for each thread
- Switch between threads:
  1. Stop running current thread
  2. Save current state of the thread
  3. Jump to another thread
     - continue from where it stopped before, by using its saved state
- This requires special functions: `sigsetjmp` and `siglongjmp`
  - `sigsetjmp` saves the current location, CPU state and signal mask
  - `siglongjmp` goes to the saved location, restoring the state and the signal mask.

sigsetjmp – save a “bookmark”

`sigsetjmp(sigjmp_buf env, int savesigs)`

- Saves the stack context and CPU state in `env` for later use.
- If `savesigs` is non-zero, saves the current signal mask as well.
- We can later jump to this code location and state using `siglongjmp`.
- Return value:
  - 0 if returning directly.
  - A user-defined value if we have just arrived here using **`siglongjmp`**.

siglongjmp – use a “bookmark”

`siglongjmp(sigjmp_buf env, int val)`

- Jumps to the code location and restore CPU state specified by `env`
- The jump will take us into the location in the code where the `sigsetjmp` has been called.
- If the signal mask was saved in `sigsetjmp`, it will be restored as well.
- The return value of `sigsetjmp` after arriving from `siglongjmp`, will be the user-defined `val`.

A Demo

- Functions `f()` and `g()`
  - Each representing a different thread
- `switchThreads()`
  - A function that switches between the threads using `sigsetjmp` and `siglongjmp`
- `main()`
  - Initialization and starting the threads.

Demo Code : the threads

```
void f()
{
    int i=0;
    while(1) {
        ++i;
        printf("in f (%d)\n",i);
        if (i % 3 == 0) {
            printf("f: switching\n");
            switchThreads();
        }
        usleep(SECOND);
    }
}

void g()
{
   ... //similar code
}
```

Demo Code: the switch

```
sigjmp_buf jbuf[2];

void switchThreads()
{
    static int curThread = 0;
    int ret_val =
      sigsetjmp(jbuf[curThread],1);
    printf("SWITCH: ret_val=%d\n", ret_val);
    if (ret_val == 1) {
        return;
    }
    curThread = 1 - curThread;
    siglongjmp(jbuf[curThread],1);
}
```

The switch

Thread 0:

```
void switchThreads()
{
    static int curThread = 0;
    int ret_val =
     sigsetjmp(jbuf[curThread],1);
    if (ret_val == 1) {
        return;
    }
    curThread =
      1 - curThread;
    siglongjmp(jbuf[curTh],1);
}
```

Thread 1:

```
void switchThreads()
{
    static int curThread = 0;
    int ret_val =
     sigetjmp(jbuf[curThread],1);
    if (ret_val == 1) {
        return;
    }
    curThread =
      1 - curThread;
    siglongjmp(jbuf[curThread],1);
}
```

What is saved in `jbuf`?

- Program Counter
  - Location in the code
- Stack pointer
  - Locations of local variables
  - Return address of called functions
- Signal Mask – if specified
- Rest of environmant (CPU state)
  - Calculations can continue from where they stopped.

- Not Saved:
  - Global variables
  - Variables allocated dynamically
  - Values of local variables
  - Any other global resources

Demo Code: initialization

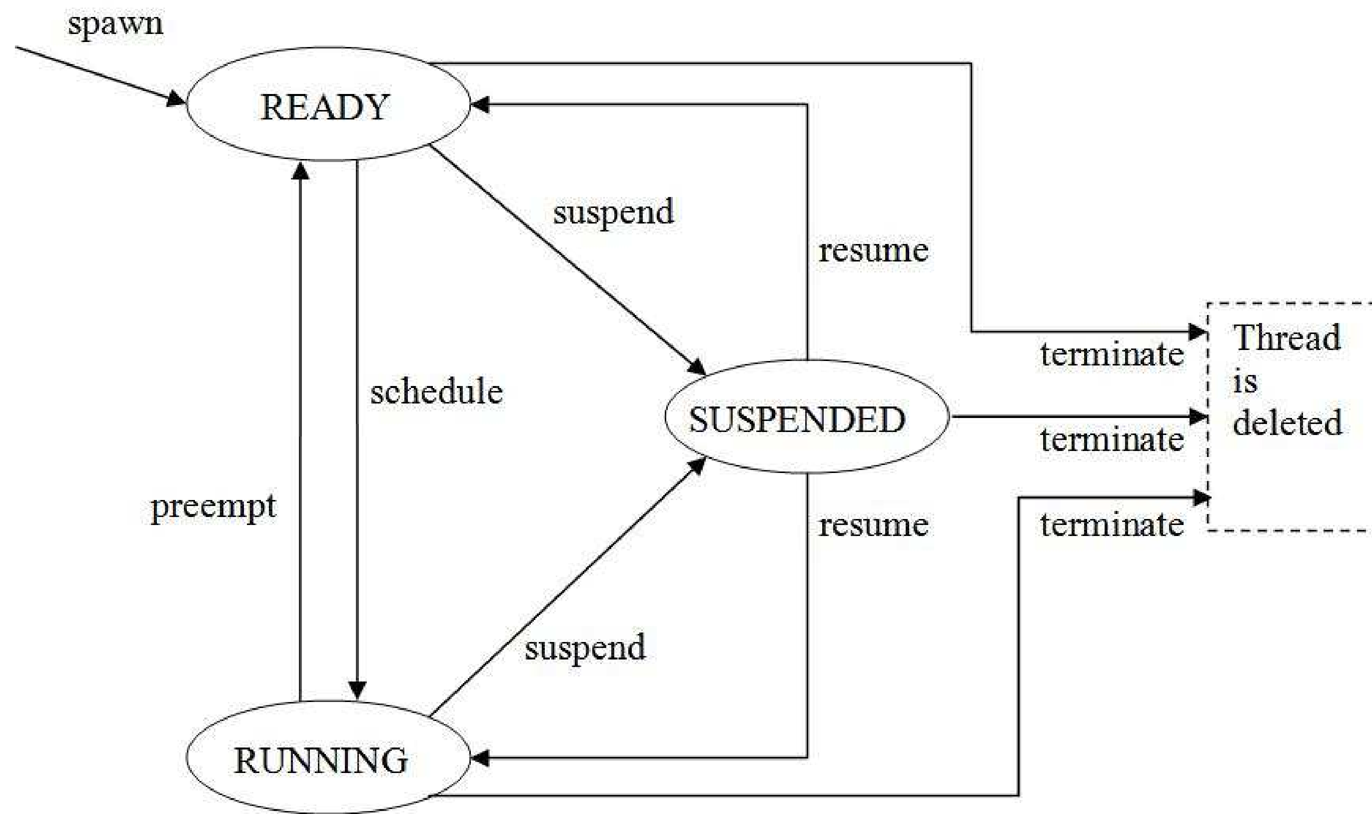
```
char stack1[STACK_SIZE];
char stack2[STACK_SIZE];

typedef unsigned long address_t; //64bit address
#define JB_SP 6
#define JB_PC 7

void setup()
{
    unsigned int sp, pc;
    sp = (address_t)stack1 + STACK_SIZE - sizeof(address_t);
    pc = (address_t)f;

    sigsetjmp(jbuf[0],1);
    (jbuf[0]->__jmpbuf)[JB_SP] = translate_address(sp);
    (jbuf[0]->__jmpbuf)[JB_PC] = translate_address(pc);
    sigemptyset(&jbuf[0]->__saved_mask);//empty saved signal mask

    ... //the same for jbuf[1] with g
}

int main() {
   setup();
    siglongjmp(jbuf[0],1);
   return 0;
}
```

Ex2

Implement a user-threads library

- The library should provide thread manipulation functions.
  - Init
  - Spawn
  - Sleep
  - Sync
  - Terminate
  - Get pid
- Library users can create their own threads and use the library functions to manipulate them.
- The library is in charge of thread management and scheduling.

Thread State Diagram



The scheduler

- The running thread is always the one with the highest id (i.e. the one created last) compared to all the ready threads.
- If a running thread becomes suspended, the scheduler needs to decide which thread will run instead.
- Use code demos for examples of
  - Thread switching,
  - Using timers and timer signals.

This exercise is difficult,
so start early!

Good Luck!