Chapter 2

Processes and Threads

Last lecture review

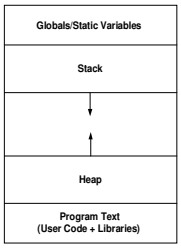
- Resource Descriptors
  - File
  - Process
- Process Vs Threads
- fork() Vs exec()

Process

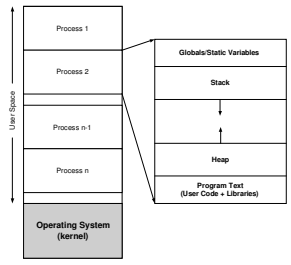
- `Heavy-weight' unit of computation
- Process descriptor
  - Object program (Program text)
  - Data segment
  - Stack
  - Heap
  - Process Status Word (PSW) – executing, waiting, ready
  - Resources acquired

Process contents

- Memory for each process contains
  - Program text
  - Globals/static variables
  - Stack
  - Heap



Main Memory



Process Control Block (PCB)

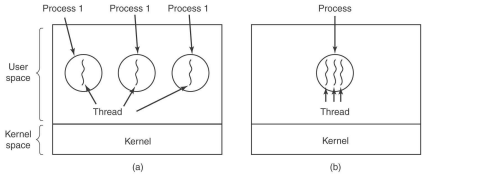
- Also called Process Descriptor
- Each process has per-process state maintained by the OS
  - Identification: process, parent, user, group, etc.
  - Address space: virtual memory, memory limits
  - I/O state: file handles (file system), communication endpoints (network), etc.
  - Accounting information
  - Program counter, Stack counter
- Details in later chapter

Thread

- Thread: light-weight process
  - OS maintains minimal internal state information
- Usually instantiated from a process
- Each thread has its OWN unique descriptor
  - Data, Thread Status Word (TSW)
- SHARES with the parent process (and other threads)
  - Program text
  - Resources
  - Parent process data segment

Process Vs Threads

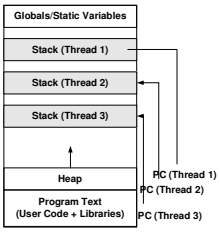
- Processes require substantially more OS overhead in creation and maintenance



Taken from Modern Operating Systems, 2nd Ed, Tanenbaum, 2001

Thread space

- Data is shared among all threads
- Each thread maintains it's own stack
- Each thread has its own Program Counter (PC)



wait()

- Used by parent process to wait on ONE child process to finish
- `int wait(&status);`
- return value of wait is the process id of child process that just finished
- if no child processes, wait returns –1 immediately

wait() … ctd

- wait returns value if child process
  - called function exit()… or terminated normally
  - gets terminated by a signal
- returns exit status of child in variable `status`

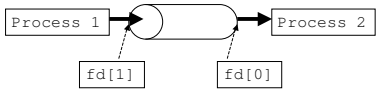
waitpid()

- Used by parent to wait on a specific child process to terminate indicated by pid
- `int waitpid(pid, &status, options)`
- `pid`: process id of the child process parent waits on

pipes

- One form of inter-process communication (IPC)
- follows message-passing paradigm of IPC

pipes….ctd




```
int fds[2];
retval = pipe(fd);
```

- creates two file descriptors, one for reading, the second for writing

pipes…ctd

```
int fds[2]; char s[100];
retval = pipe(fds);
pid = fork();
if(pid != 0){ /* parent process */
  write(fds[1], "hello", 6);
}
else { /* child process */
  read(fds[0], s, 100);
  printf("Read %s\n", s);
}
```


What are pthreads?

- A standardized programming interface
- For UNIX systems, specified by the IEEE POSIX 1003.1c standard (1995).
- Implementations which adhere to this standard are referred to as POSIX threads, or Pthreads.

Why pthreads over fork()?

- Primary reason is performance gains
- Less OS overhead in creating a new thread
- All threads use same address space, so communication between threads is easier
- `$gcc –o firstthread firstthread.c –lpthread`

pthread creation

- Use `pthread_create` function

`pthread_create(thread,attr,routine,arg)`

- `thread`: Name of this thread
- `attr`: Thread attributes
- `routine`: function that gets executed once thread is started
- `arg`: A single argument to be passed to routine, cast as pointer of type void, passed by reference.
  - For multiple arguments, bundle them up in a struct and pass struct to routine

First pthread program

```
#include <pthread.h>
#include <stdio.h>
#define NUM_THREADS     5
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);
   }
   pthread_exit(NULL);
}
```


First pthread program… ctd

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

- `pthread_exit(void *status)`: Used to explicitly terminate a thread
- Thread can use the `status` variable to specify its status; pass data to `joining' threads

pthreads… ctd

- `pthread_join()`: Analogous to wait() for processes.
- Allows threads to `join' to form single thread of execution

Second example

```
#include <pthread.h>
#include <stdio.h>

int main(void) {
int N = 8;
pthread_t hThread;  int fact;
pthread_create(&hThread,NULL,(void *)ChildThread,
   (void *)N);
pthread_join(hThread,(void *)&fact);

printf("Factorial of N = %d\n",fact); return 0;
}
```


Second example… ctd

```
void ChildThread(int N) {
     int i;  int fact = 1;

     for(i=1;i<=N;++i)
       {  fact*=i; }

     pthread_exit((void *)fact);
}
```


Reference for pthreads

- Posix threads programming
http://www.llnl.gov/computing/tutorials/workshops/workshop/pthreads/MAIN.html#Pthread
- Introduction to pthreads
http://phoenix.liunet.edu/~mdevi/pthread/Intro.htm