Operating Systems | **CSI3131 Assignment 1** | Winter 2019

Process/thread creation and inter-process communication

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Goals

Practise:

1. process creation in Linux using fork() and exec() system calls
2. thread creation in Linux with the pthread API
3. inter-process communication using pipes

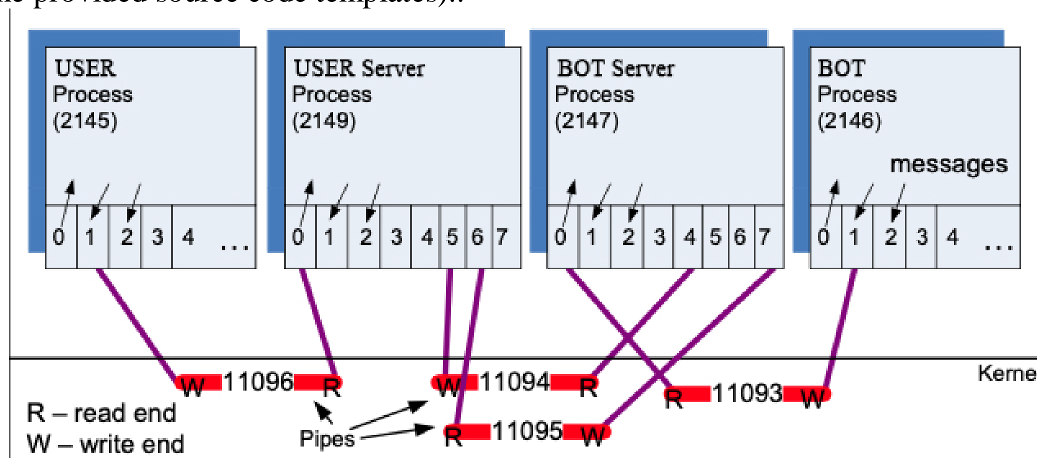
Posted: Jan 28, 2019
Due: Feb 11, 2019, 23:59

Description (Please read the complete assignment document before starting.)

Two programs have been provided: `user.c` and `server.c`. Your task shall be to complete these two programs such that the execution of the program `user` creates four processes as follows:

1. User process: this is the original process invoked when `user` is run. It is responsible for creating the other three processes after which is simulates User that exchanges messages with Bot (simulated by the Bot process).
2. Bot process: this is a child process of the User process that simulates Bot who exchanges messages with User.
3. User Server process: This process (that runs the `server` program) provides a server service that services the User process. It shall use one thread to read text messages from its standard input which is then send to a communications channel to the Bot process. A second thread is used to send to its standard output any text messages received from the Bot process over a communications channel.
4. Bot Server process: This process (that runs the `server` program) provides server service that services the Bot process. It shall use one thread to read text messages from its standard input which is then send to a communications channel to the User process. A second thread is used to send any text messages received from the User process over a communications channel to its standard output.
5. Message Flow: User sends the first message and Bot responds with two messages(two options).User selects one and Bot sends Another two options and so on…

The `user` program is designed to test the `server` program by simulating a User and a Bot that exchange a sequence of text messages. Four pipes are used as shown below: two pipes allow the User and Bot processes to send messages to the standard inputs of the User Server and Bot Server processes respectively. Two other pipes are used as the communication channel between the Servers. The User process that spawns the Server processes creates the pipes and passes the file descriptors of the communication channel pipes to the `server` programs (see section To complete the assignment and comments in the provided source code templates)..



The pipe identifiers and process identifiers (PIDS) shown in the above diagram are specific to a run and correspond to the identifiers shown in the output of item 4 in the

section “Background Information”. All standard error file descriptors (2) and the standard outputs of the Server processes are connected to the terminal. The path of messages from Bot process is shown (a similar path is taken for messages from the User process).

To complete the assignment:

1. Start with the provided files `user.c` and `server.c`. Complete the documentation in each file to indicate your name and student number. Take the time to document well your code. Consider taking the time to design your code before you start coding.
2. Complete the following functions:
   ```
   a. user.c: setupBot(),initUserServer(),
                initBotServer(),setupUser()
                (also complete main to have these functions run
                properly)
   b. server.c: generateThreads()
   ```
3. The programs should be compiled using the commands “`cc -o user user.c`” and “`cc -o server server.c -lpthreads`” (note that for server compilation, the pthreads library must be explicitly specified). The file `makefile` has been provided to compile both files – simply type in the command `make`.
4. To submit the assignment, upload the files *user.c* and *server.c*. Do not forget to click on the submit button after (and only after) you have uploaded the file.
5. A word of caution, for debugging the programs, if you wish to write messages to the terminal, you should write to the standard error using the following library call: `fprintf(stderr,”message string\n”)` as the standard input and standard output are to be modified.
6. See point 4 in “Background Information” for hints on how to observe processes/threads and pipes to help debug your programs.
7. When `user` is run, the following output should appear on your screen (Note that PIDs shall be specific to your execution).

```
[test1@sitedev assign1]$ user
Simulation starting
Server Connected  (2147)
Server Connected (2149)
Need to recharge. (2145)
Select one option
1) Mobile (2146)
2) Wireless (29786) (2146)
     Selected : 1) Mobile (29785) (2145)
1) Credit (2146)
2) Debit (2146)
     Selected : 2) Debit (2145)
1) Confirm (2146)
2) Cancel (2146)
     Selected : 1) Confirm (2145)
Successful (2146)
Link severed (2149)
Link severed (2147)
Simulation Complete
```

Bot Server PID
User Server PID
Bot PID
User PID

Background information:

1. An open file descriptor is an integer, used as a handle to identify an open file. Such descriptors are used in library functions or system calls such as `read()` and `write()` to perform I/O operations.

2. In Unix/Linux, each process has by default three open file descriptors:
   a. Standard input (file descriptor 0, i.e. read(0,buf, 4) reads 4 characters from the standard input to the buffer buf). Typically, the standard input for a program launched from the command line is the keyboard input.
   b. Standard output (file descriptor 1).
   c. Standard error (file descriptor 2).
   d. When a command is run from the shell, the standard input, standard output and standard error are connected to the shell tty (terminal). So reading the standard input reads from the keyboard and writing to the standard output or standard error writes to the display.
   e. Note that many library functions used these file descriptors by default. For example *printf("String")* writes "String" to the standard output.
   f. From the shell it is possible to connect the standard output from one process to the standard output to another process using the pipe character "|". For example, the command "who | wc" connects the standard output from the who process to the standard input of the wc process such that any data written to the standard output by the who process is written (via a pipe) to the standard input of the wc process.

3. You will need the following C library functions:
   a. fork() – should be familiar from lectures
   b. pthread_create() – should be familiar from lectures
   c. pipe()
      - should be familiar from lectures
      - note that multiple process can be attached to each end of the pipes, which means that a pipe is maintained until no processes are connected at either end of the pipe
   d. execvp(const char * program, const char *args[]) (or execlp)
      - replaces the current process with the program from the file specified in the first argument
      - the second argument is a NULL terminated array of strings representing the command line arguments
      - by convention, args[0] is the file name of the file to be executed
   e. execlp(const char * program, const char *arg1, const char *arg2, … NULL)
      - replaces the current process with the program from the file specified in the first argument
      - the second argument subsequent arguments are strings representing the command line arguments.
      - by convention, arg1 is the file name of the file to be executed

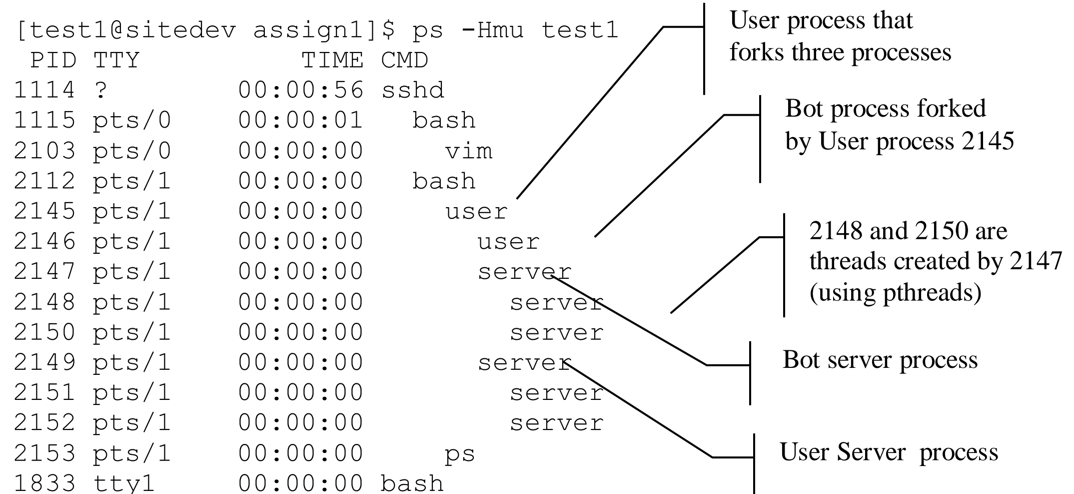
f. dup2(int newfd, int oldfd) – duplicates the oldfd by the newfd and closes the oldfd. See http://mkssoftware.com/docs/man3/dup2.3.asp for more information. For example, the following program:

```
int main(int argc, char *argv[]) {
    int fd;
    printf("Hello, world!")
    fd = open("outFile.dat", "w");
    if (fd != -1) dup2(fd, 1);
        printf("Hello, world!");
      close(fd);
}
```

   will redirect the standard output of the program into the file outFile.dat, i.e. the first "Hello, world!" will go into the console, the second into the file "outFile.dat".

g. read(int fd, char *buff, int bufSize) – read from the file (or pipe) identified by the file descriptor fd bufSize characters into the buffer buff. Returns the number of bytes read, or -1 if error or 0 if the end of file has been reached (or the write end of the pipe has been closed and all data read).
h. write(int fd, char *buff, int bufSize) – write into the file/pipe bufSize characters from the buffer buff
i. close(int fd) – closes an open file descriptor
j. printf(): You may want to use the printf() function to format output. This function writes to the standard output (fd 1). But be careful since this function buffers output and does not write immediately to the standard output. To force and immediate write, used fflush(stdout). Alternatively, you may used sprintf(), to format the an output into a buffer and use write() to write to the standard output.
k. fprintf(): this is a version of *printf()* that provides the means to specify where output should be send. Use it to write to the standard error with *fprintf(stderr,"a message", arg, arg,…)*. This function is useful for debugging as it will write to the terminal in processes where the standard output has been redirected to a pipe.
l. getpid(): this function returns the PID of the current process. It is useful in creating messages printed on the screen to identify the source of the message.
m. Consult the manual pages (by typing 'man function_name', i.e. 'man fork') and/or web resources for more information.

4. Here is a hint at how you can observe the connection of processes to pipes
    a. Insert long delays using the standard library function `sleep` (e.g. `sleep(300)`) to allow observation of processes, threads and pipes at different points in the execution of the programs (particularly in `user.c`).
    b. To see the processes and threads created using the command "`ps -Hmu test1`" (replace test1 with your user name if you are using one of the SITE Linux platforms). The option H has `ps` print out a tree of processes/threads and the option m includes all threads. In fact, Linux treats all processes and threads as tasks assigning each a PID. See below for expected output.



See the next page for a hint on observing file descriptors and pipes.

c. To see how pipes and standard input, standard output, and standard error are set up for the various processes, use the command "`ls -l /proc/xxx/fd`" where `xxx` is replaced with the PID of a process. This will display how the various file descriptors of the identified process are connected. See below for expected output from the programs of this assignment.

```
[test1@sitedev]$ ls -l /proc/2145/fd /proc/2149/fd /proc/2147/fd /proc/2146/fd

/proc/2145/fd:
total 0
lrwx------    1 test1    test1          64 Feb  3 12:03 0 -> /dev/pts/1
l-wx------    1 test1    test1          64 Feb  3 12:03 1 -> pipe:[11096]
lrwx------    1 test1    test1          64 Feb  3 12:03 2 -> /dev/pts/1

/proc/2146/fd:
total 0
lrwx------    1 test1    test1          64 Feb  3 12:03 0 -> /dev/pts/1
l-wx------    1 test1    test1          64 Feb  3 12:03 1 -> pipe:[11093]
lrwx------    1 test1    test1          64 Feb  3 12:03 2 -> /dev/pts/1

/proc/2147/fd:
total 0
lr-x------    1 test1    test1          64 Feb  3 12:03 0 -> pipe:[11093]
lrwx------    1 test1    test1          64 Feb  3 12:03 1 -> /dev/pts/1
lrwx------    1 test1    test1          64 Feb  3 12:03 2 -> /dev/pts/1
lr-x------    1 test1    test1          64 Feb  3 12:03 4 -> pipe:[11094]
l-wx------    1 test1    test1          64 Feb  3 12:03 7 -> pipe:[11095]

/proc/2149/fd:
total 0
lr-x------    1 test1    test1          64 Feb  3 12:03 0 -> pipe:[11096]
lrwx------    1 test1    test1          64 Feb  3 12:03 1 -> /dev/pts/1
lrwx------    1 test1    test1          64 Feb  3 12:03 2 -> /dev/pts/1
l-wx------    1 test1    test1          64 Feb  3 12:03 5 -> pipe:[11094]
lr-x------    1 test1    test1          64 Feb  3 12:03 6 -> pipe:[11095]
```


Notice that the User process messages written to the standard output traverses pipe 11096 to the User server process where the message is sent to the Bot server process who then writes the message to its standard output. A similar path with different pipes is taken by messages leaving the Bot process. Notice that both servers have their standard output attached to /dev/pts/1 that corresponds to a terminal (actually a pseudo-terminal connected to an ssh client). So messages written to the standard output by the Servers processes shall appear on the terminal.

Grading criteria;
Compiles and runs correctly by fulfilling the conditions below [100pts].
If any of the points below fail to be implemented; 5 points will be deducted for each non-implemented part.
If does not compile and/or run correctly; the conditions below will be checked individually:

- Setting up user and bot [15]
- Setting both the severs correctly [15]
- Connection between the user server and user (bot server and bot)[25]
- Generating threads and in order execution of threads[15]

TA office hours and contacts for questions about the assignment:
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Wednesday: 10:30 - 12:00, **Room:** STE5000J
Wednesday: 18:00 - 19:30, **Room:** STE5000J