CHAPTER V: PROCESS CONTROL IN UNIX (CHAPTER 8 IN THE BOOK)

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Introduction

$$\text{Context:} \begin{cases} \text{- single computer (single CPU)} \\ \text{- under UNIX operating system} \end{cases}$$

Several simultaneously executing programs → appear as if they are being executed in parallel!

⇒ multiprogramming:

The CPU executes some instructions of one program then switches to another program giving the illusion that any program is continuously executing, this scheme is called *time-slicing*.

Important notion:

an executing program → a *process*

Unix Processes

Every process in Unix has the followings :

- A unique process ID (PID)
- Some code : instructions that are being executed
- Some data : variables
- A stack : a form of memory where it is possible to push and pop.
- An environment : registers' contents, tables of open files,...

Unix starts as a single process, called *init*. The PID of *init* is 1.
The only way to create a new process in Unix, is to duplicate an existing one.
→ the process *init* is the ancestor of all subsequent processes.
In particular, process *init* never dies.

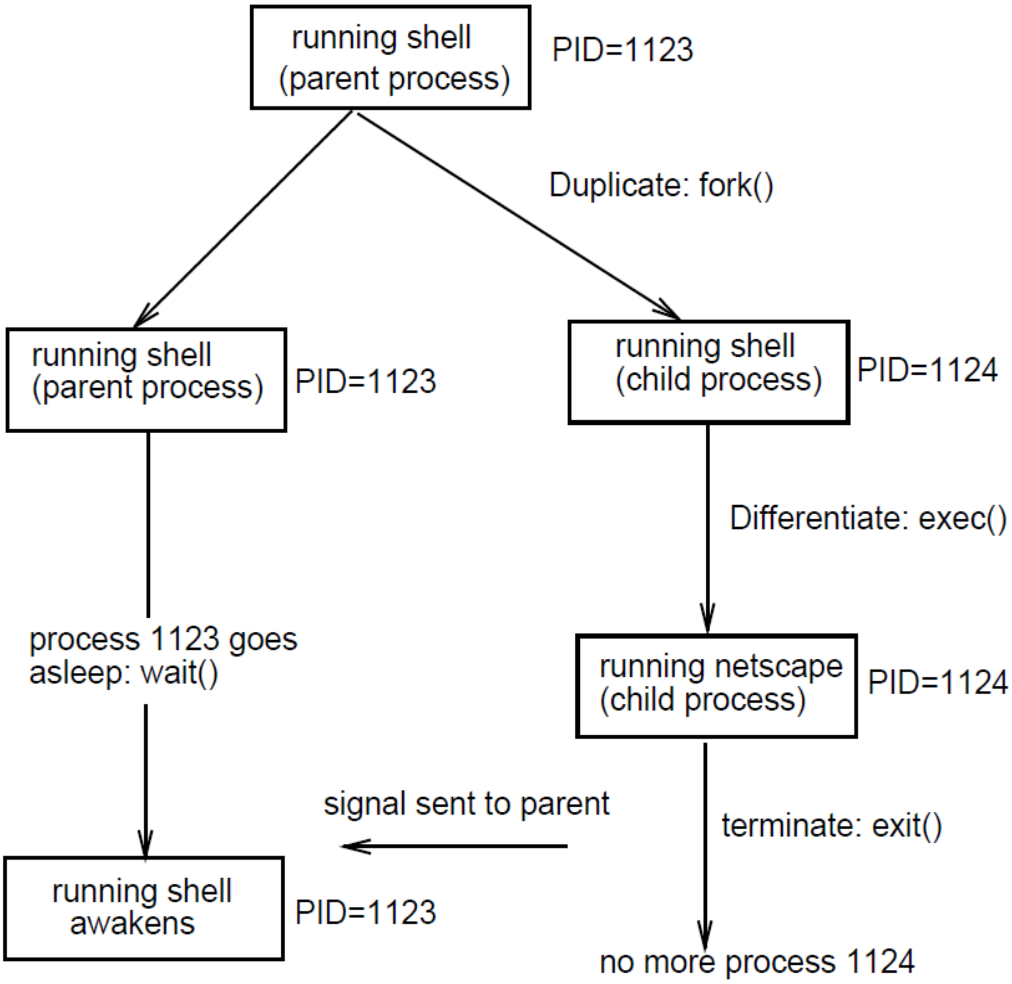
The creation or spawning of new processes is done with two system calls:

- *fork()*: duplicates the caller process
- *exec()*: replaces the caller process by a new one.

Example: Running a utility from a shell(*bash*).

The following steps are necessary

- *bash fork*s a copy of itself.
- the child process *exec*s the utility program.
- the parent process waits for the termination(*exit*) of its child process by going asleep.
- when the child process terminates, a signal is sent to the parent process(the shell program *bash*). The latter wakes-up and becomes ready to accept the next command.


running shell
(parent process)
PID=1123
Duplicate: fork()
running shell
(parent process)
PID=1123
running shell
(child process)
PID=1124
Differentiate: exec()
process 1123 goes
asleep: wait()
running netscape
(child process)
PID=1124
signal sent to parent
terminate: exit()
running shell
awakens
PID=1123
no more process 1124

Creating a new Process: fork()

Synopsis: **pid_t fork(void);**

when succesful, the *fork()* system call :

- creates a copy of the caller (parent) process.
- returns the *PID* of the newly created process to the parent
- returns 0 to the new process (the child).

If not succesful, the *fork()* returns -1.

fork() is a strange system call : called by a single process but returns twice, to two different processes.

In particular, a child process has :

- its own unique *PID*,
- a different *PPID*,
- its own copy of the parent's data segment and file descriptors

fork() is primarily used in two situations :

1. A process wants to execute another program (Shells).
2. A process has a main task and, when necessary, creates a child to handle an operation (Servers).

Here is a simple example :

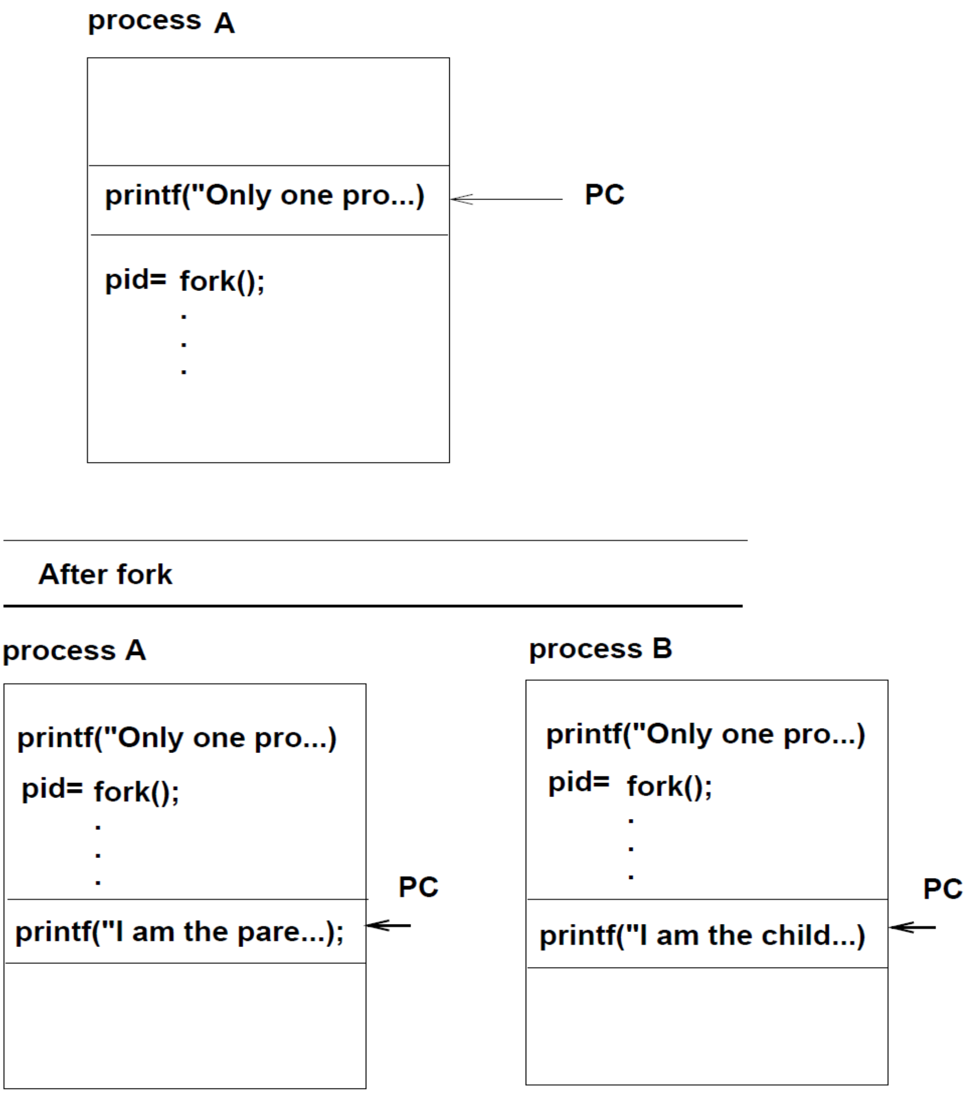
```
#include <unistd.h>

int main(int argc, char *argv[]){
  int pid;

  printf("Only one process\n");
  pid = fork();

  if(pid == -1){
    perror("impossible to fork");
    exit(1);
  }
  if(pid > 0)
    printf("I am the parent, pid=%d\n", getpid());
  else
    if(pid == 0)
      printf("I am the child, pid=%d\n", getpid());

  exit(0);
}
```


process A
printf("Only one pro...)
PC
pid= fork();
After fork
process A
printf("Only one pro...)
pid= fork();
printf("I am the pare...);
PC
process B
printf("Only one pro...)
pid= fork();
printf("I am the child...)
PC

Terminating a process: exit()

Synopsis: **void exit(int status);**
This call terminates a process and never returns
The *status* value is available to the parent process through the *wait()* system call.

When invoked by a process, the *exit()* system call:

- closes all the process's file descriptors
- frees the memory used by its code, data and stack
- sends a **SIGCHLD** signal to its parent and waits for the parent to accept its return code.

Waiting for a process: wait()

Synopsis: **pid_t wait(int *status);**

This call allows a parent process to wait for one of its children to terminate and to accept its child's termination code.

When called, *wait()* can

- block (suspend) the caller process, if all of its children are still running, or
- return immediately with a termination status of a child, if a child has terminated and is waiting for its termination to be accepted, or
- return immediately with an error(-1), if it does not have any child process.

When succesful, *wait()* returns the *pid* of the terminating child process.

The value in *status* is encoded as follow :

- if the rightmost byte of *status* is zero, then the leftmost byte contains the status returned by the child : a value between 0 and 255.
  This represents a normal termination of the child process.
- if the rightmost byte of *status* is nonzero, then the rightmost 7 bits are equal to the *signal number*, that caused the process to terminate. The remaining bit of the rightmost byte is set to 1 if a core dump was produced by the child process.

Some bit-manipulation macros have been defined to deal with the value in the variable *status*.

#include < *sys/wait.h* >)

- *WIFEXITED(status)*: true for normal child termination.
- *WEXITSTATUS(status)*: used only when WIFEXITED(status) is true, it returns the exit status as an integer within the range [0..255].
- *WIFSIGNALED(status)*: true for abnormal child termination
- *WTERMSIG(status)*: used only when WIFSIGNALED(status) is true, it returns the signal number that caused the abnormal child death.
- *WCOREDUMP(status)*: true if a core file was generated.

Orphan and zombie Processes

A process that terminates does not leave the system before its parent accepts its return.

There are 2 interesting situations, when :

1. a parent exits(for example, the parent has been killed prematurely) while its children are still alive.
   → the children become *orphans*.

   Because somebody must accept their return codes, the kerned simply changes their *PPID* to 1.

   → *orphan* processes are systematically adopted by the process *init* (PID of init is 1).
   In particular, *init* accepts all its children returns.

2. a live parent never makes the system call *wait()*.
   the children become *zombies* and remain in the system's process table waiting for the acceptance of their return. However, they loose their ressources (data, code, stack...).

   Because the system's process table has a fixed-size, too many zombie processes can require the intervebtion of the system administrator.

   Example :
   Below is a C program, called zombie.c, to create a zombie.

```
int main(int argc, char *argv[]){
 int pid;

 pid = fork();
 if (pid){  // means pid !=0
   printf("parent process, pid=%d\n", getpid());
   while(1)
    sleep(5);
 }
 printf("child process, pid=%d\n", getpid());
 exit(0);
}
```

1- run in background the program:> ./zombie &
On the screen you will get:
I am the child, pid=12357
I am the parent, pid=12356
2- look for the processes:> ps -ef | grep 12356
On the screen you will get:
boufama 12357 12356 0 0:00 $< defunct >$
boufama 12356 20142 0 20:01:44 pts/7 0:00 ./zombie

Differentiating a process: exec()

The *exec()* family of system calls allows a process to replace its current code, data and stack with those of another program.

Synopsis :

- int execl(const char *path, [const char *arg_i,]$^+$ NULL)
- int execlp(const char *path, [const char *arg_i,]$^+$ NULL)
- int execv(const char *path, const char *argv[])
- int execvp(const char *path, const char *argv[])

where $i = 0, \ldots, n$ and $^+$ means one or more times.
The difference between these 4 system calls has to do with syntax.
execl() and *execv()* require the whole pathname of the executable program to be supplied.
execlp() and *execvp()* use the variable $**PATH** to find the program.

In particular :

- A successful call to *exec()* never returns.
- *exec()* returns -1 if not successful.
- For both *execl()* and *execlp()*, arg_0 must be the name of the program.
- For both *execv()* and *execvp()*, $arg[0]$ must be the name of the program.

Changing directories: chdir()

A child process inherents its current working directory from its parent.
A process can change its working directory using *chdir()*.
Synopsis :
int chdir(const char * pathName);

chdir() returns 0 if successful -1 otherwise.
It fails if the specified path name does not exist or if the process does not have execute permission from the directory.

Changing priorities: nice()

Every process has a system scheduling priority, a value between -20 and 19.
This value affects the amount of CPU time allocated to the process.
The smaller the value the faster the process will be.
A process may change its priority value using *nice()*;

Synopsis : int nice(int delta);

nice() adds *delta* to the process current priority value.
Note that only super-user processes can have a negative priority value.
nice() returns the new priority value if successful and -1 otherwise.

Write a C program, that behaves like a simple shell, to process commands entered by the user. In particular, the program should assemble commands and execute them. The commands/programs location can be anywhere in **PATH** and might have arguments.

```
Algorithm:

While(1)
begin
  get command line from user
  assemble command args
  duplicate current process
  child execs to the new program
  parent process waits for its child to terminate
  When the child terminates, parent prints its pid
  and exit status
end
```