Fundamentos de los Sistemas Operativos (FSO)

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Part 2: Process Management

Seminar 3

UNIX system calls for processes

fSO

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DISCA

Llamadas al sistema UNIX para procesos

- Goals:
  - To know the **services** provided by UNIX **to create processes**
  - To analyse **C language examples** with process related system calls
  - To know the **signal concept**
- Bibliografía:
  - "UNIX System Programming ", Kay A. Robbins, Steven Robbins. Prentice Hall. ISBN 0-13-042411-0

Content

- Identification
- Creation
- Waiting
- Ending
- Signals

UNIX process related system calls

	Processes
fork	Create a child process
exit	End process
wait	Wait for a process ending
exec	Execute a program
getpid	Get process ID attribute
getppid	Get parent ID attribute

	Signals
kill	Send signals
alarm	Generate an alarm (clock signal)
sigemptyset	Init a mask with no signals set
sigfillset	Init a mask with signals set
sigaddset	Append a signal to a signal set
sigdelset	Delete a signals in a signal set
sigismember	Check if a signals belongs to a signal set
sigprocmask	Check/Modify/Set a signal mask
sigaction	Capture/Manage a signal
sigsuspend	Wait signals capture

- **Identification**
- Creation
- Waiting
- Ending
- Signals

Identification

- Every process must have an ID
- The creator process is the *parent* while the created process is the *child*. To know them we use:
  - Process ID (PID)
  - Parent process ID (PPID)

```
pid_t getpid(void);
```

```
pid_t getppid(void);
```

```
/*** ej1_getpid.c *****/
#include <stdio.h>

int main(void)
{
   printf("\nProcess ID: %ld\n", (long)getpid());

   printf("Parent process ID: %ld\n", (long)getppid());

   while(1);

   return 0;
}
```

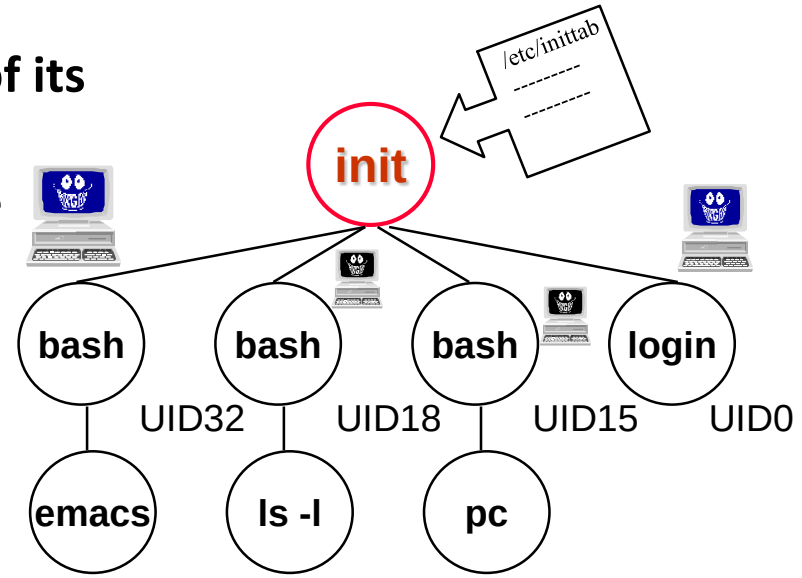
```
$ gcc -o ej1 ej1_getpid.c
$ ./ej1 &
[1] 2959
$
Process ID: 2959
Parent process ID: 1060
$ ps -l
  UID  PID   PPID F    CPU PRI NI SZ      RSS  WCHAN S ADDR             TTY     TIME    CMD
  501  1060  1059 4006 0   31  0  2435548 1088 -     S ffffff80136e3d50 ttys000 0:00.06 bash
  501  2959  1060 4006 0   31  0  2434832  340 -     R ffffff80140d8300 ttys000 0:04.65 ./a.out
```

- Identification
- **Creation**
- Waiting
- Ending
- Signals

Creation

```
pid_t fork(void);
```

- Unix uses a copying mechanism for process creation
  - The **child process is an exact replica of its parent** process
  - The **child process inherits** most of the attributes **from its parent**:
    - Memory image
    - UID, GID
    - Current directory
    - Opened file descriptors
  - Unix assigns an **identifier to every process called PID** at the time of its creation
  - Every process knows the **identifier of its parent process, PPID**
  - The child execution is concurrent with the parent and independent
  - Processes are organized into a **hierarchical tree**



- **fork:** process creation

```
#include <sys/types.h>
#include <unistd.h>

pid_t fork(void)
```

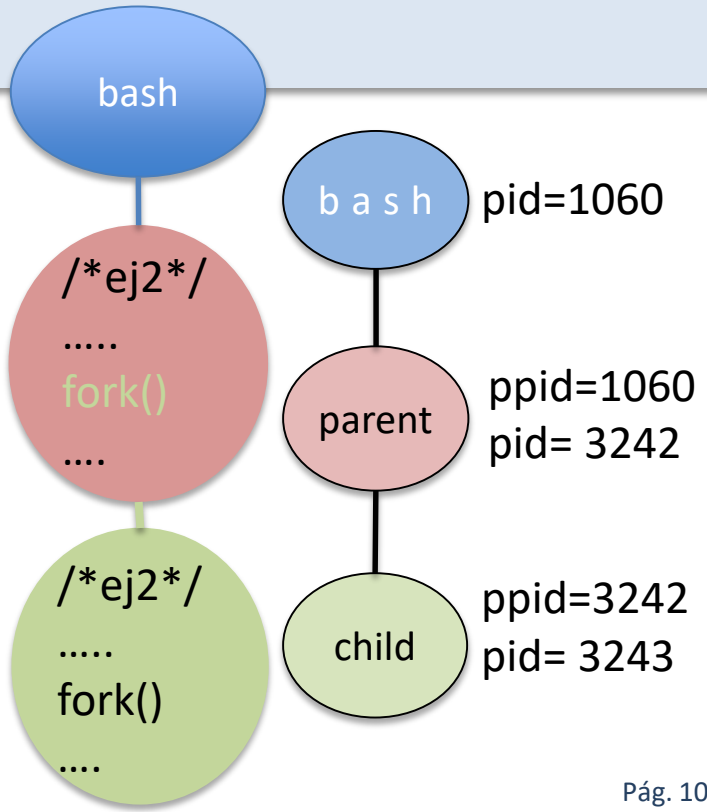
  - **Description**
    - It creates a child process which is a “clon” from the parent: the child process inherits the most part of the parent attributes.
    - NON Inherited attributes: PID, PPID, pendant signals, file locks and time/accounting.
  - **Returning value**
    - 0 to the child
    - Child PID to the parent
    - -1 to the parent if an error happens
  - **Errors**
    - Not enough resources to create the process

Creation

Parent and child resume execution with the instruction following `fork()`

```
/**ej2_fork.c **/
#include <stdio.h>
#include <sys/types.h>

int main(void)
{ printf("Process %ld creates another process\n", (long)getpid());
  fork();
  printf("Process %ld with parent %ld\n",(long)getpid(),(long)getppid());
  sleep(5);
  return 0;
}
```

```
$ ps
  PID TTY           TIME CMD
 1060 ttys000    0:00.07 -bash
$ gcc -o ej2 ej2_fork.c
$ ./ej2
Process 3242 creates another process
Process 3242 with parent 1060
Process 3243 with parant 3242
$
```



- Parent and child execute diferent code

```
// ej3_fork.c
#include <sys/types.h>
#include <unistd.h>

int main() {
    pid_t val;
    int var = 0;
    printf("PID before fork(): %d\n", (long) getpid());
    val = fork();
    if (val > 0) {
      printf(“Parent PID: %d\n", (long) getpid());
      var++;
    } else {
      printf("Child PID: %d\n", (long) getpid());
    }
    printf("Process [%d]-> var=%d\n", (long) getpid(), var);
    return 0;
}
```

How many processes print this message?

What value(s) of “var” are shown?

- Example

```
// ej4_fork.c

#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>

int main(void)
{
    pid_t pid=fork();

    switch (pid) {
    case -1:
        printf("Could not create child process \n");
        break;
    case 0:
        printf("I am the child with PID %ld and my parent is %ld \n",
                (long)getpid(), (long)getppid());
        break;
    default:
        printf("I am the parent with PID %ld and my child is %ld \n",
                (long)getpid(), pid);
    }
    sleep(5);
    return 0;
}
```

```
$ gcc –o ej3 ej3_fork.c
$ ./ej3
I am the parent with PID 3702 and my child is 3704
I am the child with PID 3704 and my parent is 3702
```

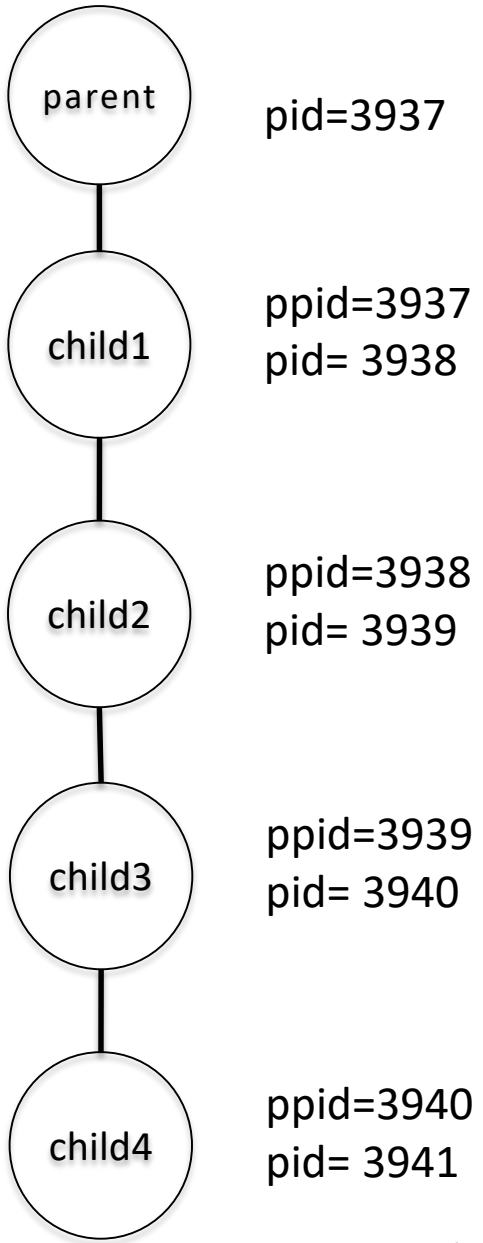
- Creating processes in chain

```
// ej5_proc_chain.c
#include <stdio.h>
#include <sys/types.h>

#define NPROCESSES 4

int main(void)
{
     pid_t pid;
     int i;

     for (i=0; i<NPROCESSES; i++) {
          pid=fork();
          if (pid!=0)
               break;
          printf("I am the child with PID %ld
                  my parent is %ld\n",
                  (long)getpid(), (long)getppid());
     }
     sleep(5);
     return 0;
}
```

Variants

if (pid > 0)
if (pid==0)
if (pid<0)

```
$ ./a.out
I am the child with PID 3938 my parent is 3937
I am the child with PID 3939 my parent is 3938
I am the child with PID 3940 my parent is 3939
I am the child with PID 3941 my parent is 3940
```



- **exec()**
  - The call to fork () creates a child who is a copy of the calling process
  - What if we want to run a different program? Use **exec()** call
  - There are different versions **exec** depending on the parameters specified:

```
#include <unistd.h>
int execl(const char *path, const char *arg0, ...,
          const char *argn, char * /*NULL*/);
int execlp(const char *file, const char *arg, ... ,
           const char *argn, char * /*NULL*/);
int execle(const char *path, const char *arg, ...,
           const char *argn, char * /*NULL*/, char * const envp[]);

int execv(const char *path, char *const argv[] );
int execvp(const char *file, char *const argv[]);
int execve(const char *path, char *const argv[], char *const envp[]);
```

  - Variant **l**: arguments are provided separately
  - Variant **v**: arguments are provided through a pointer to a vector
  - Variant **p**: the location of **file** is searched on the PATH
  - Variant **e**: the environment is provided to the child through **envp**, it is not inherited from the parent

- **exec () features**
  - It changes the process memory image by the one defined in the new executable file.
  - The executable file in specified by its name or its absolute path.
  - Some process attributes remain:
    - **Signal handlers, exept the ones captured and treated by the default action.**
    - **PID and PPID**
    - **Time accounting**
    - **File descriptors**
    - **Working directory, root directory and file creation mode mask**
  - If the SETUID bit of the executable file is set then EXEC sets as efective UID the UID of the executable file owner
    - The same happens with the SETGID bit
  - Errors
    - Executable file doesn't exist or it is not recognized as executable
    - Permissions
    - Incorrect arguments
    - Not enough meory or resources
  - Returning value
    - If EXEC returns to the calling program it is because an error happened, the returning value is -1

- Exec() example: the child process lists the current directory

```
// ej6_exec.c
#include <stdio.h>
#include <sys/types.h>

int main(void)
{
     int status;
     pid_t pid=fork();

     char* arguments [] = { "ls", "-l", 0 };

     switch (pid) {
     case -1:
          printf("The child  process could not be created \n");
          break;
     case 0:
          printf("I am the child with PID %ld, the current directory content is: \n",
                  (long)getpid());
          if (execvp("ls",arguments)==-1){
               printf("Error in exec\n");
               exit(0);
          }
          break;
     default:
          printf("I am the parent process with PID %ld and my child is %d.\n",
                  (long)getpid(), pid)
     }
     return 0;

}
```

Another way:

```
execl("/bin/ls", "ls","-l",NULL)
```

- Identification
- Creation
- **Waiting**
- Ending
- Signals

- The parent has to wait for its child to finish:

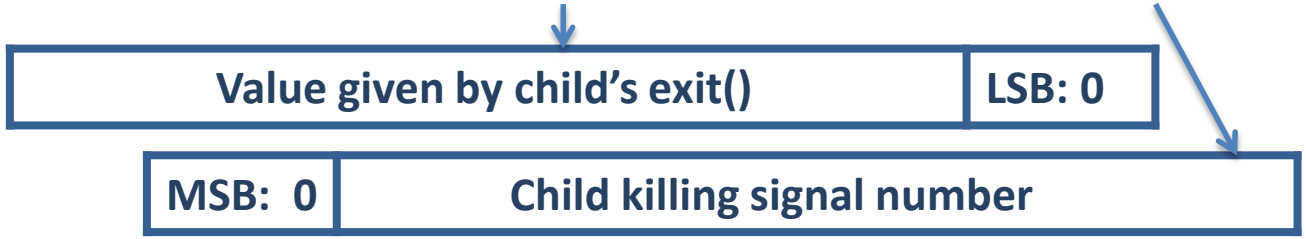
```
#include <sys/types.h>
#include <sys/wait.h>
pid_t wait(int *status);
pid_t waitpid(pid_t pid, int *status, int options);
```

  - `wait` and `waitpid` stop the calling process execution until a child ends, or until the calling process receives a signal

- `wait()` call

```
pid_t wait(int *status);
```

  - It suspends the execution of the calling process until any of its children finishes
    - If there is any zombie child then wait returns immediately
  - **status:** is not a NULL pointer, it contains information about child termination:
    - Child finished with **exit** or child finished by a **signal**



  - **Returning value:**
    - -1 if error or no children
    - Otherwise the finished child PID

- Wait() example:

```
// ej7_wait.c
#include <stdio.h>
#include <sys/types.h>
#include <errno.h>

int main(void)
{
     int status;
     pid_t pid=fork();

     switch (pid) {
     case -1:
          printf(" The child  process could not be created \n");
          break;
     case 0:
          printf("I am the child process with PID %ld and my parent is %ld\n",
                  (long)getpid(), (long)getppid());
          sleep(20);
          printf("I have finished \n");
          break;
     default:
          printf("I am the parent process with PID %ld and my child is %d.
                  Waiting ...\n", (long)getpid(), pid);
          if (wait(&status) != -1)
               printf("My child has ended ok \n");
     }
     return 0;
}
```

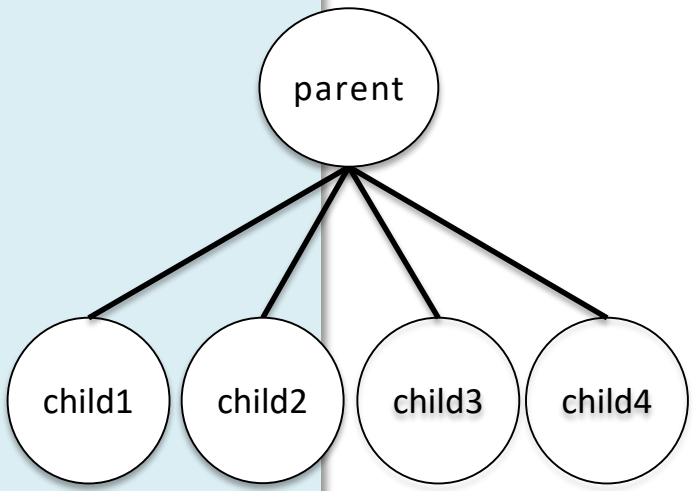
- `waitpid() call`

```
pid_t  waitpid(pid_t pid, int *status, int options);
```

  - It waits for a particular child
  - Parameters:
    - **pid**: PID of the child to wait for. If its value is -1 it waits until the first child ends (like **wait**)
    - **status**: like wait()
    - **options**:
      - Value 0: blocking (common value)
      - WNOHANG: non blocking
    - **Returning value**:
      - **0** : no child ended (non-blocking version),
      - **-1** : error
      - **> 0** : pid of the returning child

- `waitpid()` example: fan process creation

```
// ej8_waitpid.c
#include <stdio.h>
#include <sys/types.h>

#define NPROCESSES 4

int main(void)
{
     pid_t pid[NPROCESSES];
     int i, status;

     for (i=0; i<NPROCESSES; i++) {
          pid[i]=fork();
          if (pid[i]==0){
               printf("I am the child %ld my parent is %ld\n",
                         (long)getpid(), (long)getppid());
               sleep(10);
               exit(0);
          }
     }
     // Now wait for the third child
     if (waitpid(pid[2],&status,0)==pid[2])
          printf(" My third child has finished  \n");
     return 0;
}
```




```
$gcc –o ej8 ej8_waitpid.c
```

- Identification
- Creation
- Waiting
- **Ending**
- Signals

Ending

- A process ends completely when:
  - The process itself ends (normally or abnormally) AND
  - Its parent process does a wait call
- The normal termination is done by calling to **exit**

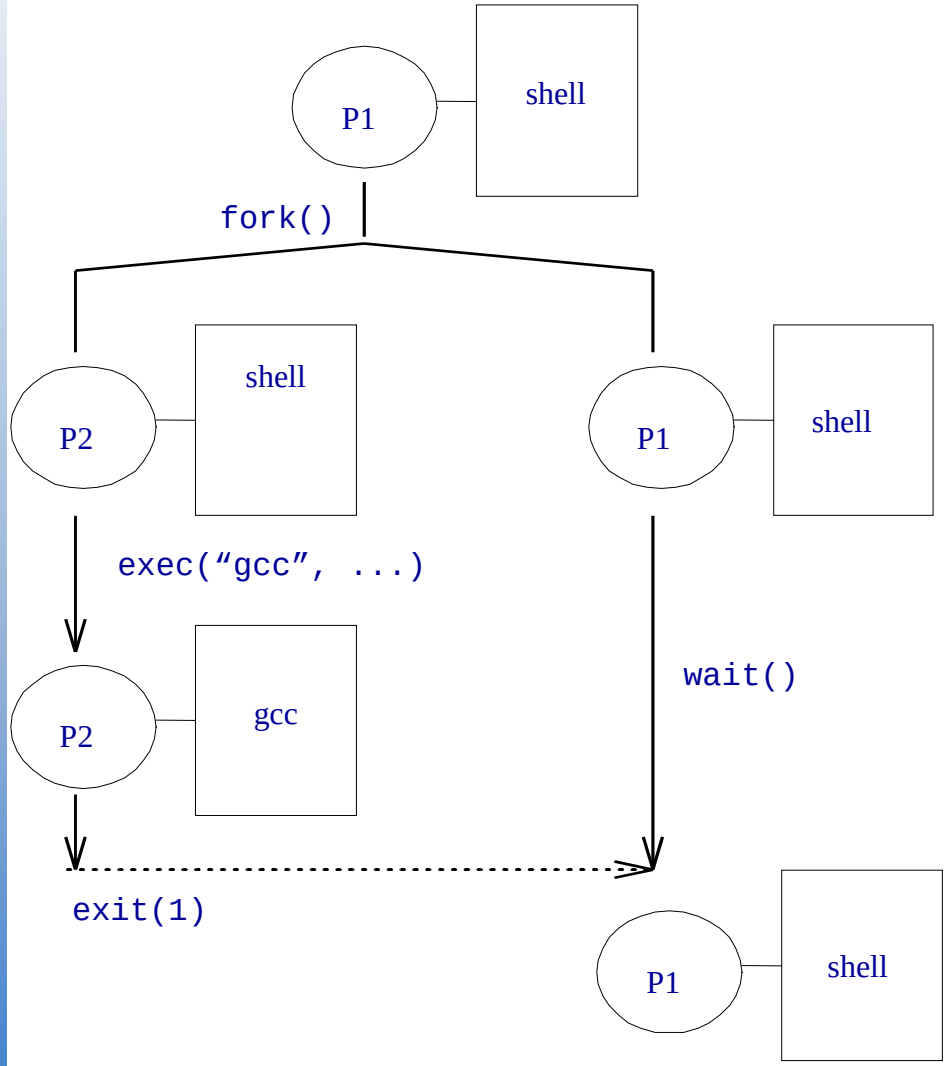
```
void exit (int status)
```

  - The status parameter is used to communicate to the parent how the child process ends
  - By convention, this value is typically 0 if the process ends normally and any other value means abnormal termination
  - The parent process can obtain this value through the system call **wait**

Ending

- **Abnormal ending**:
  - The process is ended by the operating system because of an error condition (memory boundary violation, arithmetic errors) or by some other process initiative
    - Signals
- **Zombie**: If the process ends before his parent calls `wait()`:
- **Orphan**: If the parent process terminates before the child:
  - An orphan process is adopted by process root **init**

- Simplified structure of UNIX shell

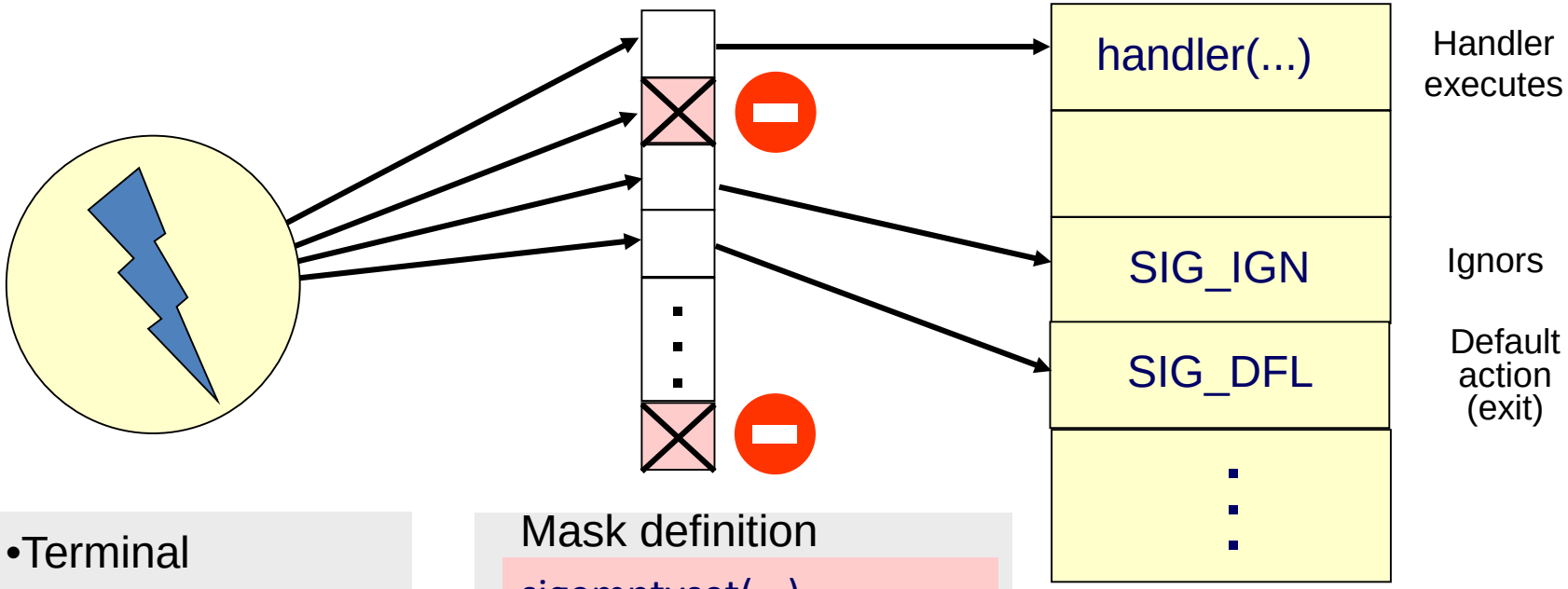



```
while(TRUE) {
 print_prompt();
 read_command(command, parameters);

 p=fork();          /* creates a child */

 if (p != 0) {      /* parent code */
  waitpid(-1, &status, 0); /* waiting for
                              the child */

 } else {           /* child code */
  exec(command, params, 0); /* memory image
                               change */
  error("Command cannot be executed");
  exit(1);
 }
}
```

Content

- Identification
- Creation
- Waiting
- Ending
- **Signals**

Signals



- Terminal
- Errors
- Software

kill(...)
alarm(..)

Mask definition

sigemptyset(...)
sigfillset(..)
sigaddset(..)
sigdelset(..)
sigismemeber(...)

Mask setting

sigprocmask(...)

Handler setting

sigaction(...)

Signal waiting

pause(...)
sigsuspend(...)

- A signal is the **mechanism used by the OS to inform processes about certain events**
- They all follow the same pattern:
  - It is generated due to the occurrence of an event
  - It is supplied to the process
  - It should be treated by the default handling routine or by the one defined by a specific process
- A signal can:
  - Be handled: a handling routine must be installed
  - Be masked: its handling is delayed
  - Be ignored: its occurrence if not informed