C shell
(Φροντιστήριο για την 1η σειρά)

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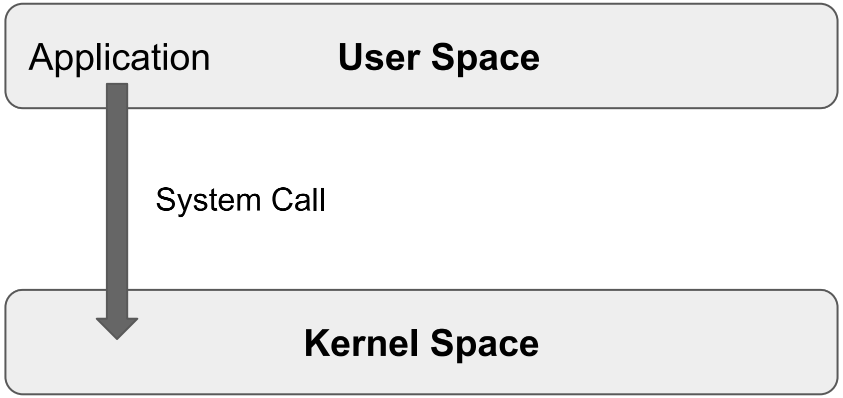
System Calls

- If a **process** is running a user program in user mode and needs a system service, such as reading data from a file, it has to execute a **trap instruction** to transfer control the **operating system**



System Calls

A system call is a request for service that a program makes of the kernel. The service is generally something that only the kernel has the privilege to do, such as doing I/O

System Calls

Process Control	fork(), wait(), exec(), exit(), ...
File Manipulation	open(), close(), read(), write(), ...
Directory Management	mkdir(), rmdir(), mount(), link(), ...
Other	chdir(), chmod(), kill(), time(), ...

fork()

- Fork creates a new process (**child process**).
  - It creates an exact duplicate of the original process, including all the file descriptors, registers etc.

- The fork is called once, but returns twice!
  - After the fork, the original process and the copy (the parent and the child) go at separate ways
  - The fork call returns a value, which is zero in the child and equal to the child's process identifier (**PID**) in the parent.

- Now consider how fork is used by the shell. When a command is typed, the shell forks off a new process. This child process must execute the user command

fork() – PID (Process IDentity)

● **pid < 0**	the creation of a child process was unsuccessful
● **pid == 0**	the newly created child
● **pid > 0**	the process ID of the child process passes to the parent

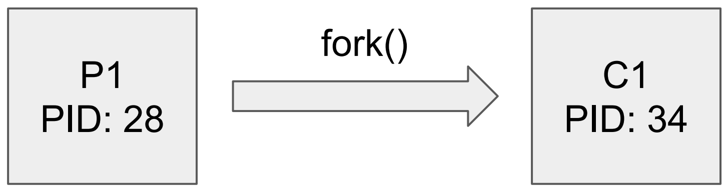
```
#include <unistd.h>
pid_t pid = fork();
printf(“PID:%d\n”,pid);
…
```

The parent will print:

```
PID:34
```

The child will always print:

```
PID:0
```



fork()

```
#define TRUE 1
while (TRUE) {                                  /* repeat forever                   */
    type_prompt();                              /* display prompt on the screen */
    read_command(command, parameters);          /* read input from terminal        */
    if (fork() != 0) {                          /* fork off child process           */
        /* Parent code */
        waitpid(-1, &status, 0);                /* wait for child to exit           */
    } else {
        /* Child code */
        execve(command, parameters, 0);         /* execute command                  */
    }
}
```

exec (binary path)

- The exec() call **replaces/overwrites** a current process image with a new one (i.e. loads a new program within the current process)
- The file descriptor table remains the same as the original process
- Argument passed via exec() appear in the argv[] of the main function
- Upon success, exec() **never** returns to the caller
  - It replaces the current process image, so it cannot return anything to the program that made the call
  - If it does return, it means the call failed

exec("/bin/ls"): overwrites the memory code image with the binary from /bin/ls and executes

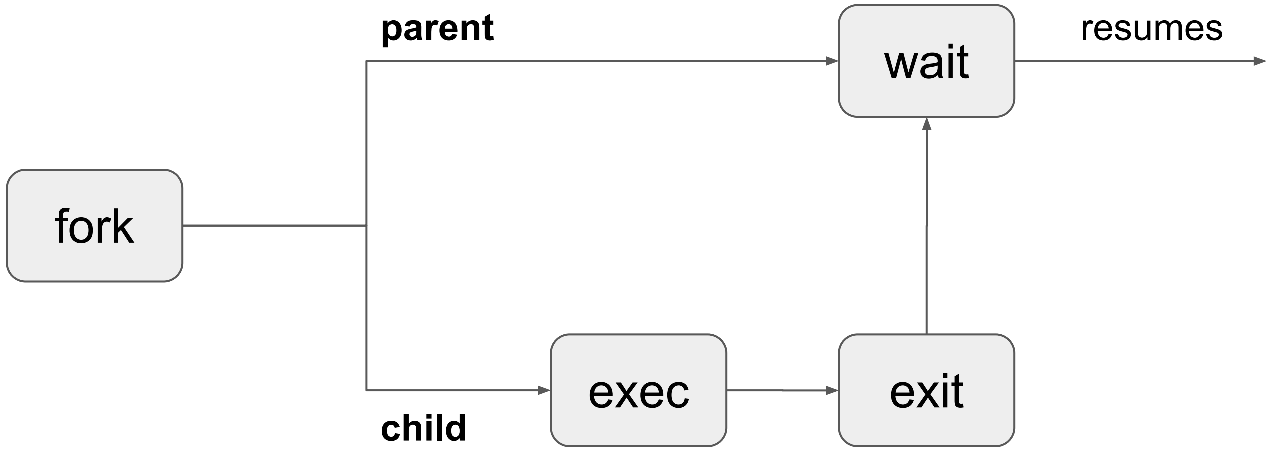
exec (binary path)

- There’s not a single syscall under the same exec()
- By **exec()** we usually refer to a family of calls:
  - int execl(char *path, char *arg, ...);
  - int execv(char *path, char *argv[]);
  - int execle(char *path, char *arg, ..., char *envp[]);
  - int execve(char *path, char *argv[], char *envp[]);
  - int execlp(char *file, char *arg, ...);
  - int execvp(char *file, char *argv[]);

l	argument list
v	argument vector
e	environmental vector
p	search path

fork and exec

- Often after calling fork() we want to load a new program into the child. E.g.: a *shell*



wait()

- Forces the parent to **suspend** execution, i.e. wait for its children or a specific child to die (terminate)

- When the child process dies, it returns an exit status to the operating system, which is then returned to the waiting parent process. The parent process then resumes execution

- A child process that dies but is never waited on by its parent becomes a **zombie process**. Such a process continues to exist as an entry in the system process table even though it is no longer an actively executing program

exit()

- This call gracefully terminates process execution. Gracefully means it does clean up and release of resources, and puts the process into the **zombie state**

- When the child process dies, an exit status is returned to the OS and a signal is sent to the parent process

- The exit status can then be retrieved by the parent process via the wait system call

fork, exec and wait

```
while (1) {                                   /* repeat forever                */
    type_prompt();                            /* display prompt on the screen */
    read_command(command, parameters);        /* read input from terminal      */
    if (fork() != 0) {                        /* fork off child process        */
        /* Parent code */
        waitpid(-1, &status, 0);              /* wait for child to exit        */
    } else {
        /* Child code */
        execve(command, parameters, 0);       /* execute command               */
    }
}
```

Process state

In computing, a process is an instance of a computer program that is being executed. It contains the program code and its current activity

- **Orphan** is a process whose parent process has finished or terminated, though it remains running itself
- **Daemon** runs as a background process rather than being under the direct control of an interactive user
- **Zombie** is a process that has completed execution but still has an entry in the process table

Pipelines

- Pipelines (pipes) provide a unidirectional interprocess communication channel

- “|” (pipe) operator between two commands directs the stdout of the first to the stdin of the second. Any of the commands may have options or arguments

- Examples:
  - command_1| command_2 parameter_1 | command_3 | command_4 ….
  - ls -l | grep key | more
  - ls -al | grep txt | wc -l

```
void main(int argc, char *argv[]) {
        int pipefd[2];
        pid_t cpid;
        char buf;
        if (pipe(pipefd) == -1) {
                perror("pipe");
                exit(EXIT_FAILURE);
        }
        cpid = fork();
        if (cpid == -1) {
                perror("fork");
                exit(EXIT_FAILURE);
        }
        if (cpid == 0) {                                /* Child reads from pipe              */
                close(pipefd[1]);                       /* Close unused write end             */
                while (read(pipefd[0], &buf, 1) > 0)
                write(STDOUT_FILENO, &buf, 1);
                write(STDOUT_FILENO, "\n", 1);
                close(pipefd[0]);
                exit(EXIT_SUCCESS);
        } else {                                        /* Parent writes argv[1] to pipe      */
                close(pipefd[0]);                       /* Close unused read end              */
                write(pipefd[1], argv[1], strlen(argv[1]));
                close(pipefd[1]);                       /* Reader will see EOF                */
                wait(NULL);                             /* Wait for child                     */
                exit(EXIT_SUCCESS);
        }
```

Redirection

- Use dup2()
  - dup2(source_fd, destination_fd)
- Standard Input “<“
  - sort < file_list.txt
- Standard Output “>”,”>>”
  - ls > file_list.txt
  - ls >> file_list.txt (append)
- Use fopen()
  - “r”   for input “<“
  - “w+” for output “>”
  - “a”   for append output

Assignment 1

- Implement a C shell (command interpreter) that reads and executes user commands
- Shell prompt: <user>@cs345sh/<dir>$
- Simple command examples:
    - cd
    - exit
    - ….
- Complex command examples:
    - ls -al
    - cat file.txt
    - sort -r -o log.txt input.txt
    - ....

Assignment 1

- Pipe examples
  - ls -al | wc -l
  - ls -al | sort -r -k 6 | head 5
  - ....

- Redirection examples
  - cat < data.txt
  - ls -al > log.txt   /* overwrite */
  - ls -al >> log.txt   /* append   */

Assignment 1

- Environment Variables
  - Variables that are exported to all processes spawned by the shell
  - Some environment variables affect the shell itself, such as PATH
- setenv
  - setenv VAR [VALUE]
  - E.g   <user>@cs345sh/<dir>$ setenv PATH /home/user/src
- unsetenv
  - unsetenv VAR
  - E.g   <user>@cs345sh/<dir>$ unsetenv PATH
- env
  - Reports all the environment variables in use

Useful links

- https://linux.die.net/man/3/exec
- https://linux.die.net/man/2/fork
- https://linux.die.net/man/2/wait
- https://linux.die.net/man/2/pipe
- https://linux.die.net/man/2/dup2
- https://www.tutorialspoint.com/c_standard_library/c_function_fopen.htm
- http://man7.org/linux/man-pages/man2/pipe.2.html
- http://man7.org/linux/man-pages/man3/termios.3.html
- http://web.eecs.utk.edu/~huangj/cs360/360/notes/Fork/lecture.html
- https://kb.iu.edu/d/acar