HY345 - Assignment 3 Tutorial

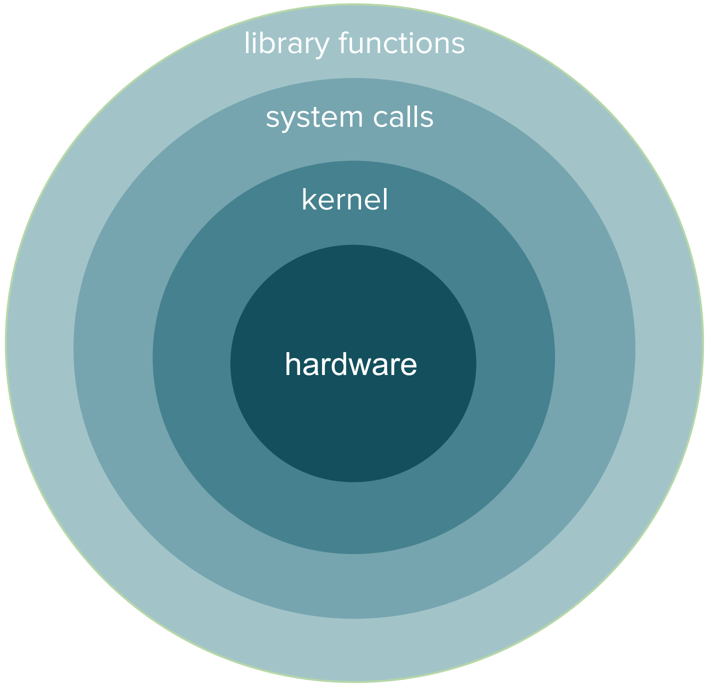
System calls

Outline

- Linux kernel
- System calls
- Emulator
- Implementing a new system call
- Notes

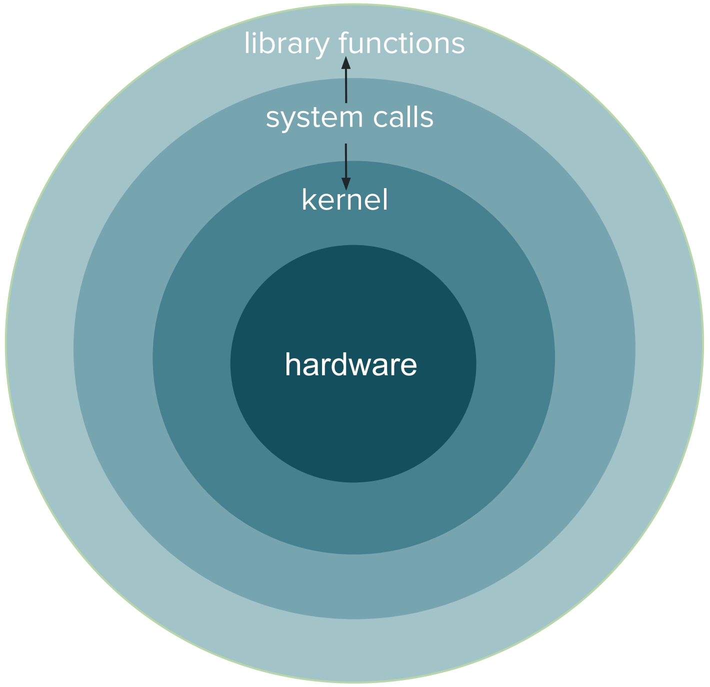
Kernel

- core of the operating system
- interface between **resources** and **user processes**
- what the kernel does:
  - memory management
  - process management
  - device drivers
  - **system calls**



System calls

- the interface between a process and the operating system
- how a program **requests a service from the kernel**



System calls - Examples

- Process control: fork, exit, wait
- File manipulation: open, read, close
- Device manipulation: ioctl, release
- Information: getpid, gettid
- Communication: pipe, socket
- Security: chmod, chown

System calls

- How do we make a system call in a C program?

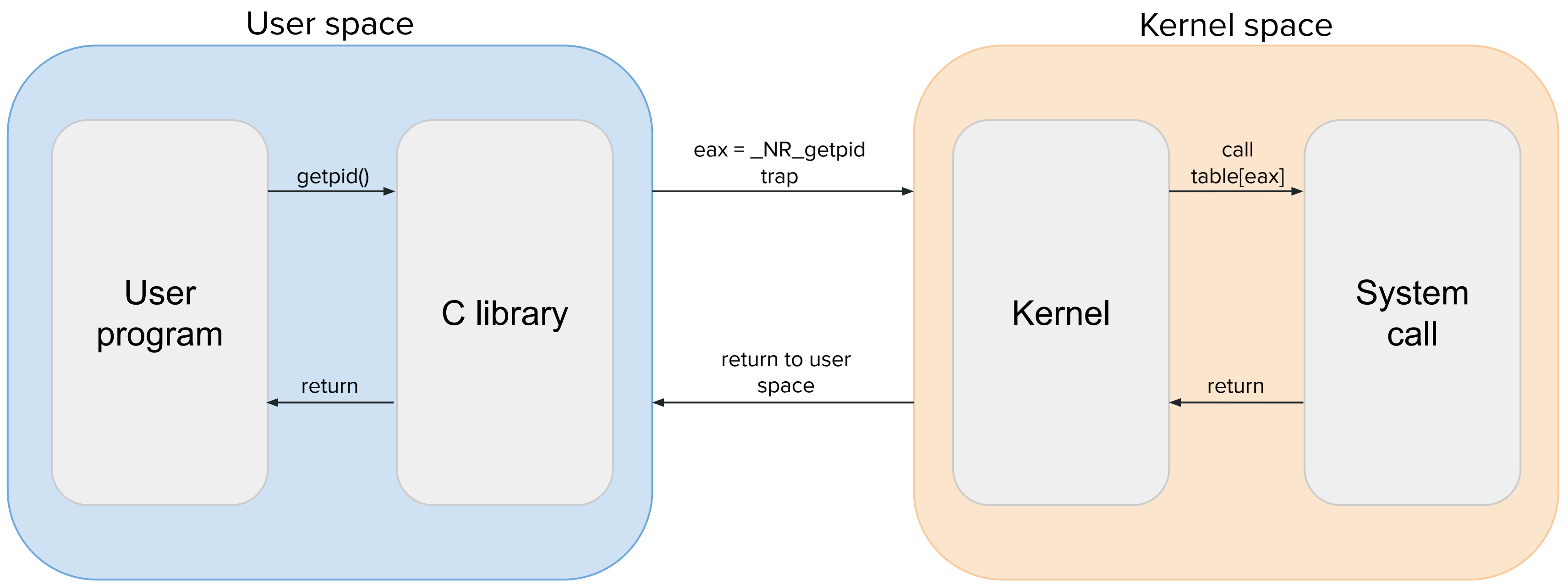
  ```
  syscall(long number, ...);
  ```

  - number: the number that corresponds to the system call
  - '...' : the arguments we want to pass to the system call

- System call numbers can be found in `<sys/syscall.h>`

System calls

```
printf( “The process ID is %d\n”, getpid() );
```



Assignment 3

- Introduce 2 new fields for each process:
    - **group_name**: the name of the group
    - **member_id:** the id inside the group

- Implement 2 new system calls
    - `set_task_params(...)`
    - `get_task_params(...)`

- Support for a new scheduling policy
    - Shortest Task First (will be implemented in Assignment 4)

Linux Kernel

Getting the source code:

```
$ cd spare
$ mkdir <username>
$ chmod 700 <username>
$ cd <username>
$ cp ~hy345/qemu-linux/linux-2.6.38.1-patched.tar.bz2 .
$ tar -jxvf linux-2.6.38.1-patched.tar.bz2
```

Linux Kernel

Compiling it:

```
$ cd linux-2.6.38.1
$ cp ~hy345/qemu-linux/.config .

<Implement additional functionality>



$export PATH="/home/misc/courses/hy345/gcc-4.9.2-standalone/bin/:$PATH"
$export
PATH="/home/misc/courses/hy345/gcc-4.9.2-standalone/libexec/gcc/x86_64-unknown
-linux-gnu/4.9.2/:$PATH"

$ make ARCH=i386 bzImage
```

Emulator

- Load the image and start the guest OS

```
$ cp ~hy345/qemu-linux/hy345-linux.img .
$ qemu-system-i386 -hda hy345-linux.img -curses
```

- Load the image and start the guest OS **with the new kernel**

```
$ qemu-system-i386 -hda hy345-linux.img -append "root=/dev/hda"
-kernel linux-2.6.38.1/arch/x86/boot/bzImage -curses
```

Implementing a new system call

1. Define a system call number
2. Define a function pointer
3. Define a function
4. Implement the system call

Example: Implement the system call **dummy_sys**. Takes one integer as an argument, prints something and returns the integer multiplied by 2.

1. Define a system call number

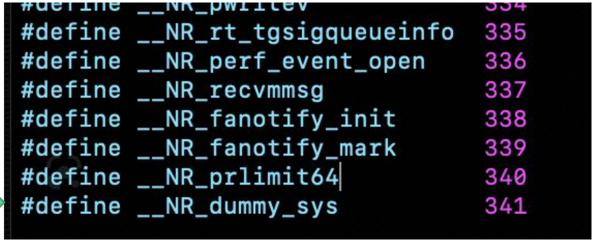
- Each system call has an invocation number

- Edit *linux-2.6.38.1/arch/x86/include/asm/unistd_32.h*
  - Define a new system call number

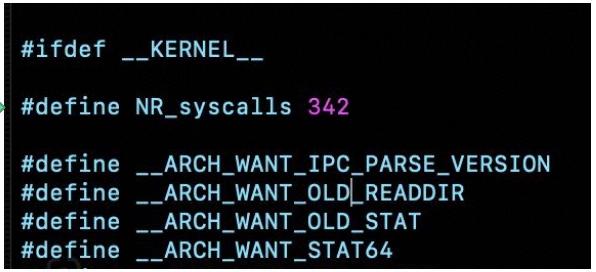
    `#define __NR_dummy_sys 341`

  - Increase the number of system calls by 1

    `#define NR_syscalls 342`



```
#define __NR_pwritev            334
#define __NR_rt_tgsigqueueinfo  335
#define __NR_perf_event_open    336
#define __NR_recvmmsg           337
#define __NR_fanotify_init      338
#define __NR_fanotify_mark      339
#define __NR_prlimit64          340
#define __NR_dummy_sys          341
```



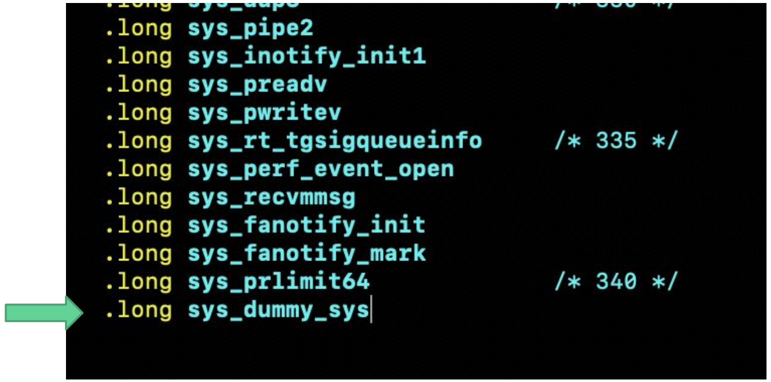
```
#ifdef __KERNEL__

#define NR_syscalls 342

#define __ARCH_WANT_IPC_PARSE_VERSION
#define __ARCH_WANT_OLD_READDIR
#define __ARCH_WANT_OLD_STAT
#define __ARCH_WANT_STAT64
```

2. Define a function pointer

- The kernel needs to have a function pointer pointing to the new system call

- Edit *linux-2.6.38.1/arch/x86/kernel/syscall_table_32.S*
  - Add an entry at the bottom of the list

    `.long sys_dummy_sys`



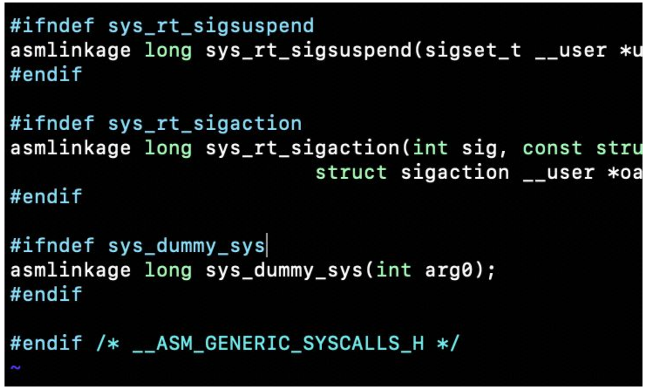
```
    .long sys_pipe2
    .long sys_inotify_init1
    .long sys_preadv
    .long sys_pwritev
    .long sys_rt_tgsigqueueinfo      /* 335 */
    .long sys_perf_event_open
    .long sys_recvmmsg
    .long sys_fanotify_init
    .long sys_fanotify_mark
    .long sys_prlimit64              /* 340 */
    .long sys_dummy_sys
```

3. Define a function

- We need to define a function signature

- Edit *linux-2.6.38.1/include/asm-generic/syscalls.h*
  - At the bottom of the file add

```
#ifndef sys_dummy_sys
    asmlinkage long sys_dummy_sys(int arg0);
#endif
```



```
#ifndef sys_rt_sigsuspend
asmlinkage long sys_rt_sigsuspend(sigset_t __user *u
#endif

#ifndef sys_rt_sigaction
asmlinkage long sys_rt_sigaction(int sig, const stru
                                 struct sigaction __user *oa
#endif

#ifndef sys_dummy_sys
asmlinkage long sys_dummy_sys(int arg0);
#endif

#endif /* __ASM_GENERIC_SYSCALLS_H */
~
```

4. Implement the system call

- Create *linux-2.6.38.1/kernel/dummy_sys.c*

```
#include <linux/kernel.h>


asmlinkage long sys_dummy_sys(int arg0){
     printk(“Called dummy_sys\n”);
     return ((long) arg0*2);
}
```

- Add to *linux-2.6.38.1/kernel/Makefile*:

```
    obj-y += dummy_sys.o
```

Simple demo application

```c
#include <stdio.h>

#include <unistd.h>

#include <errno.h>


#define __NR_dummy_sys 341


int main(void){

      printf("Trap to kernel level\n");

      syscall(__NR_dummy_sys, 42); /* you should check return value for errors */

      printf("Back to user level\n");

      return 0;

}
```

Test the new system call

- Start the VM with the new kernel

  -
    ```
    $ qemu-system-i386 -hda hy345-linux.img -append "root=/dev/hda" -kernel
    linux-2.6.38.1/arch/x86/boot/bzImage -curses
    ```
- Write a test application

  -
    ```
    $ vi test.c
    ```
- Compile the test application

  -
    ```
    $ gcc -o demo.out test.c
    ```
- Run the test

  -
    ```
    $ ./demo.out
    ```
- Check the kernel log

  -
    ```
    $ dmesg | tail
    ```

Wrapper function

- Macro

```
#define dummy_sys(arg1) syscall(341, arg1)
```

- Wrapper function

```
long dummy_sys(int arg1){
    return syscall(341, arg1);
}
```

Notes

Process Data

- Edit *linux-2.6.38.1/include/linux/sched.h*
  - Find the task_struct structure
  - Introduce the 2 new fields

- Your system calls will interact with those fields

Faster Compiling Using ccache

Στο directory που δουλεύετε για την άσκηση φτιάχνετε ένα subdirectory:

```
mkdir -p /spare/csdXXXX/ccache
```

Κάνετε export το path:

```
export PATH="/home/misc/courses/hy345/ccache-4.7.4-linux-x86_64/:$PATH"
```

Πλέον για να κάνετε build τον kernel χρησιμοποιείτε την εντολή:

```
CCACHE_DIR=/spare/csdXXXX/ccache/ make CC="ccache gcc" ARCH=i386
bzImage
```

Printk()

- Prints messages to the kernel log
- Every time one of your system calls is executed, you should print a message
  - Your name, A.M. and the name of the system call
- You can view these messages from the user level
  - dmesg
  - cat /var/log/messages
- Very useful for debugging

Hints

Useful kernel functions:

- for_each_process()
- get_current()
- access_ok()
- copy_to_user()
- copy_from_user()

Turnin

What to submit:

- bzImage
- Modified or created source files
- Test programs and headers in Guest OS
- README

START COMPILING LINUX KERNEL
WAITING FOR IT TO FINISH
memegenerator.net

Good luck!