PROSO-Project 2

FIB 2009-20010

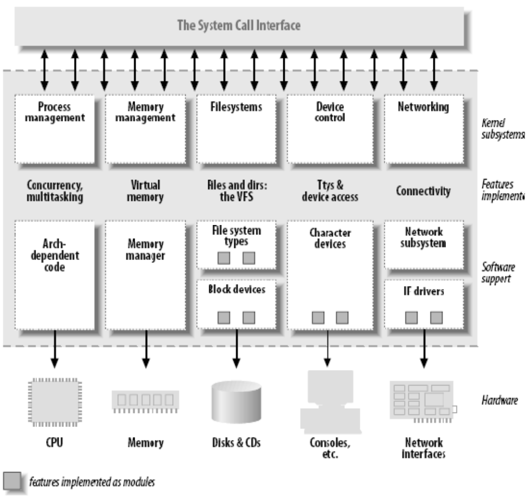
Objectives

- Put into practice in a real operating system, the concepts learn so far with ZeOS
  - System calls
  - Kernel data structures
  - Device drivers
- Get familiar with the development of Linux Kernel
  - Programming tools
  - Restrictions

Basic Concepts

- Modules
  - Means to add new functionalities to the Linux Kernel
  - Dynamically added/removed
- Device Drivers
  - Uniform APIs
    - Kernel <--> driver
    - User programs <--> drivers
  - Generic mechanism to access "devices"
    - Real devices (disk, keyboards, etc.)
    - Virtual devices (e.g. ram disk)
    - Information form kernel components

Kernel Modules and Device Drivers



Linux modules

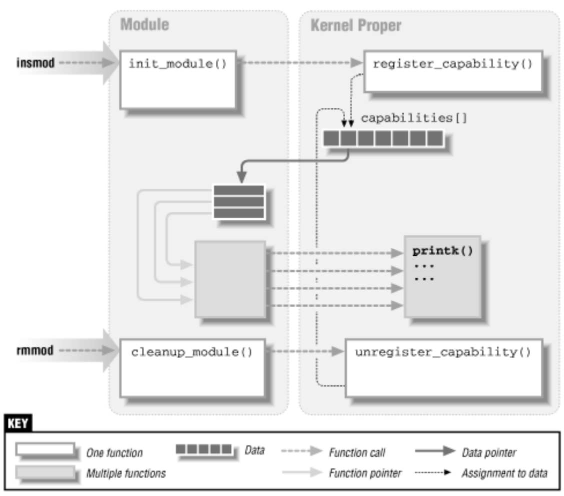
Modules

- Mechanism for adding dynamically functions to the kernel
  - Alternative is adding new sys_calls, but this requires rebuilding the kernel
- Same development limitations than other kernel components
  - Only kernel exported symbols can be accessed/modified
  - No access to libc!
  - Limited debugging tools (e.g. printk)

Kernel module development

- Program files that implement the module
  - Provide initialization and termination functions
  - Register functions to the kernel
  - export functions to other modules
- Compile them
  - Produce object file (.ko = kernel object)
  - Requires kernel sources
- Insert in the kernel
  - Load module & dependencies
  - Pass initialization parameters
- Use it
  - maintain reference count

Modules and Linux Kernel



Module definition: example

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

/*
* Module initialization.
*/
static int __init Mymodule_init(void)
{
 . . .
}

/*
* Finalization module.
*/
static void __exit Mymodule_exit(void)
{
 . . .
}
module_init(Mymodule_init);
module_exit(Mymodule_exit);
```


Module definition : Macros

- **module_param** (parameter name and type)
  - int pid=1;
  - module_param (pid, int, 0);
- **MODULE_PARM_DESC** (parameter description)
  - MODULE_PARM_DESC (pid, "Process ID to monitor (default 1)");
- **MODULE_AUTHOR** (author list)
- **MODULE_DESCRIPTION**
- **MODULE_LICENSE** (GPL, BSD, ...)

Module management

- Install a module

    #insmod mymodule.ko param=value, param=value

    initialization parameters

- Remove a module

    #rmmod mymodule.ko

- Install a module and resolve dependencies

    /lib/modules/version/modules.dep

    ```
    /path_complet/modulA.ko:path_complet/modulB.ko
    /path_complet/modulB.ko:
    ```

    #modprobe modulA.ko

- List information about a module
    - #modinfo mymodule.ko
    - #cat /proc/modules

Managing references to modules

- A module should be removed only when nobody is accessing the functions it provides
- Maintain internal counter of references
    - try_module_get (THIS_MODULE): Inc counter
    - module_put (THIS_MODULE): Dec counter
- For device driver related modules, the kernel can manage this automatically

Using the Linux kernel

- Lots of functions available for data structure management
  - find_task_by_pid
  - for_each_process
  - …
  - Don't repeat existing functionality!
- Access symbols
  - only exported symbols are available
    - Look at /proc/ksyms or execute "ksyms –a" command
  - If not currently exported
    - modify kernel/ksyms.c
    - EXPORT_SYMBOL (variable)
    - Kernel recompilation is needed

Using the Linux kernel

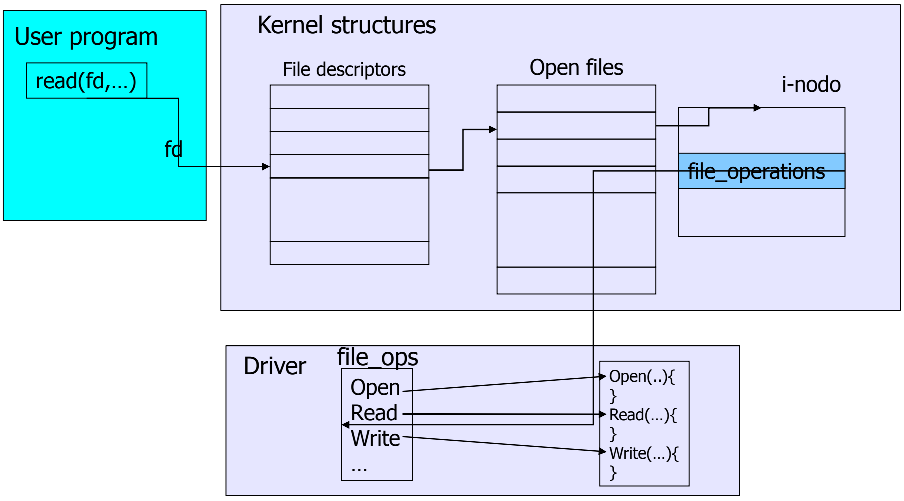
- Accessing to/from user address space
  - unsigned long copy_from_user(void *to, const void *from, unsigned long count);
  - unsigned long copy_to_user(void *to, const void *from, unsigned long count);
  - Validate return values
    - Different than ZeOS!!!

Printing messages

- Print message in the kernel using *printk*
  - *printk(KERN_<level> "message", param, param, . .);*
  - *Different levels of messages*
    - *KERN_EMERG*
    - *KERN_ALERT*
    - *KERN_CRIT*
    - *KERN_ERR*
    - *KERN_WARNING*
    - *KERN_NOTICE*
    - *KERN_INFO*
    - *KERN_DEBUG*
- *Output goes to /var/log/message*

Device Drivers

Device independence



Device drivers

- Set of variables and functions that manages a device (logical or physical)
- Device driver definition: API standard
    - Internal API (not user-level)
    - based on the struct file_operations
- We have to provide only the functions required by the device (e.g. open, read)
- How to include a device driver in the kernel?
    - Statically: recompile the kernel
    - Dynamically: implement as a module

Device's operations

- Device driver definition: API standard

```
struct file_operations my_operations = {
  owner: THIS_MODULE,
  read: my_read,
  ioctl: my_ioctl,
  open: my_open,
  release: my_release,
};
```

maintain reference counter automatically

- Look into <linux/fs.h> for types, etc.

Device drivers API

- Executed at open/close
  - int my_open (struct inode * i, struct file * f);
  - int my_release (struct inode * i, struct file * f);
- ssize t my_read (struct file * f, char * buffer, size t_size, loff_t * offset);
  - Use copy_to_user for accessing the buffer
  - Offset is input/output parameter. Current position in "file"
- int my_ioctl(struct inode * i, struct file * f, unsigned int request, unsigned long argp);
  - Used for control operations

Device identification

- Identified by a major and a minor
  – major: identifies a class of device (e.g. a printer)
  – minor: identifies different devices of the same class (i.e. two different printers)
- Allows the kernel to know which driver handles a device
- Match device's file major and minor

```
crw-rw-rw-   1 root    root     1,   3 Apr 11  2002 null
crw-------   1 root    root    10,   1 Apr 11  2002 psaux
crw-------   1 root    root     4,   1 Oct 28 03:04 tty1
crw-rw-rw-   1 root    tty      4,  64 Apr 11  2002 ttys0
crw-rw----   1 root    uucp     4,  65 Apr 11  2002 ttyS1
crw--w----   1 vcsa    tty      7,   1 Apr 11  2002 vcs1
crw--w----   1 vcsa    tty      7, 129 Apr 11  2002 vcsa1
crw-rw-rw-   1 root    root     1,   5 Apr 11  2002 zero
```


Device registration

- Device identifier must be registered inside the kernel:

  int register_chrdev_region (dev_t first, unsigned int count, const char *name);
- To unregister:

  void unregister_chrdev_region (dev_t first, unsigned int count);

Assign operations to devices

- First, create a new cdev structure:

  struct cdev * cdev_alloc()

- Second, initialize the structure fields
  - owner: with *THIS_MODULE*
  - ops: with the *file_operations*
- Finally, assign this structure to the devices:

  int cdev_add (struct cdev *dev, dev_t num, unsigned int count);

- To delete it:

  void cdev_del (struct cdev *dev);

FIB

UPC

Inserting a new device driver dynamically

- Create a module with:
  - Device driver functions
  - New struct file_operations variable
  - New device dev_t
  - New structure cdev
  - At init_module module
    - Register the device into the kernel:
      - Allocate the device identifier and associate the file_operations
  - At cleanup
    - Unregister the device + Delete the cdev

FIB

UPC

How to use a new device?

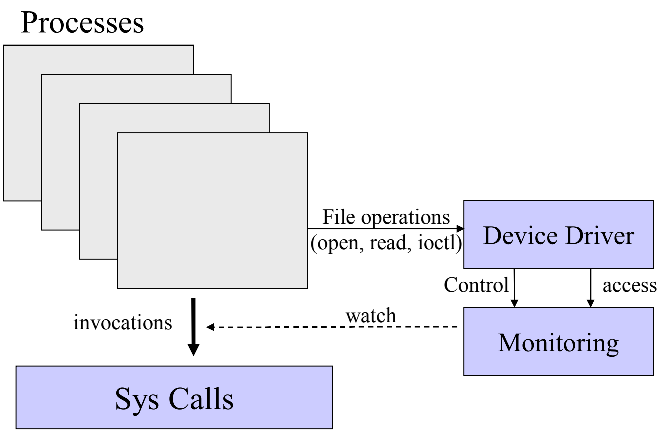
- Create a file with the mknod command usint the new device's identification
  - *mknod* <type> <major> <minor>
  - e.g. mknod mydriver c 255 1
- Access the new file with standard I/O API
  - Open, read, write, close, etc

Description of work

Overview

- Develop a monitoring mechanism to measure the invocation of selected system calls
  - number of invocations
  - execution time
- Activate/deactivate dynamically this monitoring
- All processes are monitored (including those created after monitoring has started)
- Read monitoring information for a given running process

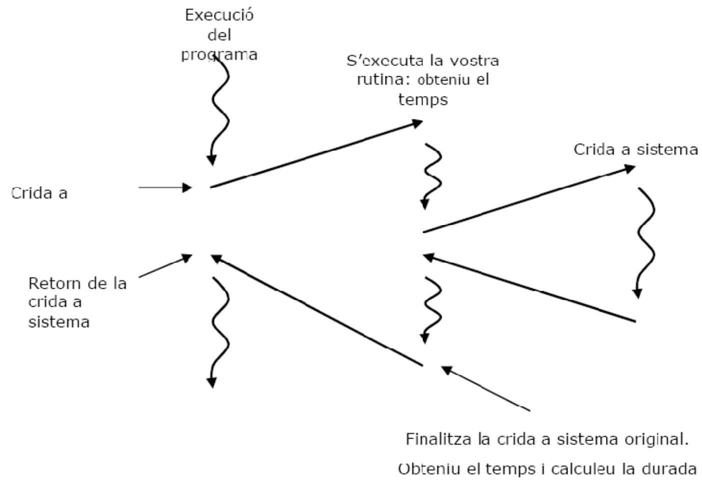
Monitoring processes



Module 1

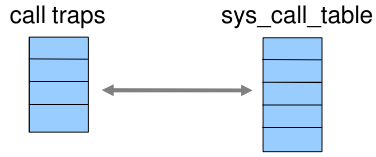
- Get per process information about *open, write, clone, close and lseek* system calls
  - How many times each call is executed
  - How many times they success
  - How many times they fail
  - Total time spent in each system call

Intercepting system calls



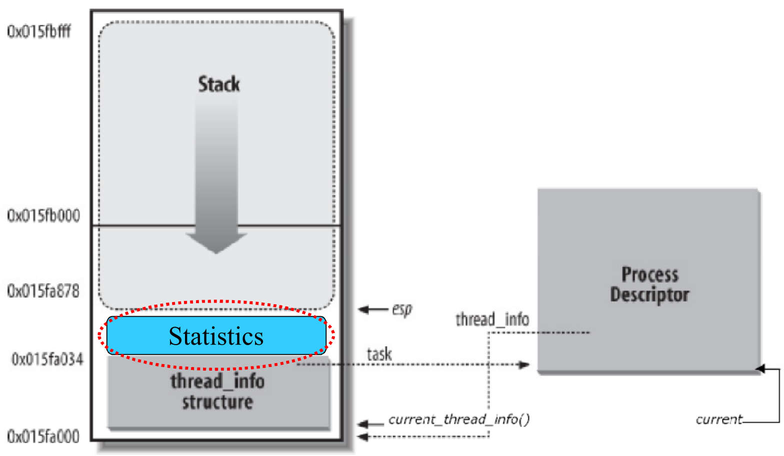
How to get the information?

- Instrument the kernel by substituting original entries in sys_call_table by new ones



- On each call, the trap must:
  - Get initial time→ see the documentation
  - Execute original system call
  - Calculate execution time
  - check call's return code
  - Save information

Where to save information



Module 2: Access to information

- Open → Open the device
  - Only root and only 1 open
  - Defines selected_process=current, selected_call=open
- Read → Return statistics for the selected_process and selected_call
- Ioctl → Set the behaviour of the device
  - CHANGE_PROCESS == Change selected process
  - CHANGE_SYSCALL == Change selected syscall
  - RESET_VALUES == Reset statistics of selected_process
  - RESET_VALUES_ALL_PROCESSES == Reset statistics of all processes
- Release → Close the device

Improvements

- Module 1
  - Two new functions to enable/disable the instrumentation of one of the system_calls (*open, write, clone, close and lseek*)
  - It is mandatory to use a table to store original_syscalls addresses
- Module 2
  - Two new options in *ioctl* to enable/disable the instrumentation of one of the system_calls (*open, write, clone, close and lseek*)
    - » ACTIVAR_SYS_CALL == enable
    - » DESACTIVAR_SYS_CALL == disable
    - » Use functions implemented in Module 1

What to do?

- Module 1 and Module 2 → 80%
- Improvements → 20%

- You have to include exhaustive user tests to validate your modules:
    - Errors
    - Returns values
    - Expected functionality
    - …
  - It is mandatory to provide some .h where data structures and constants required by user codes will be declared