System Calls

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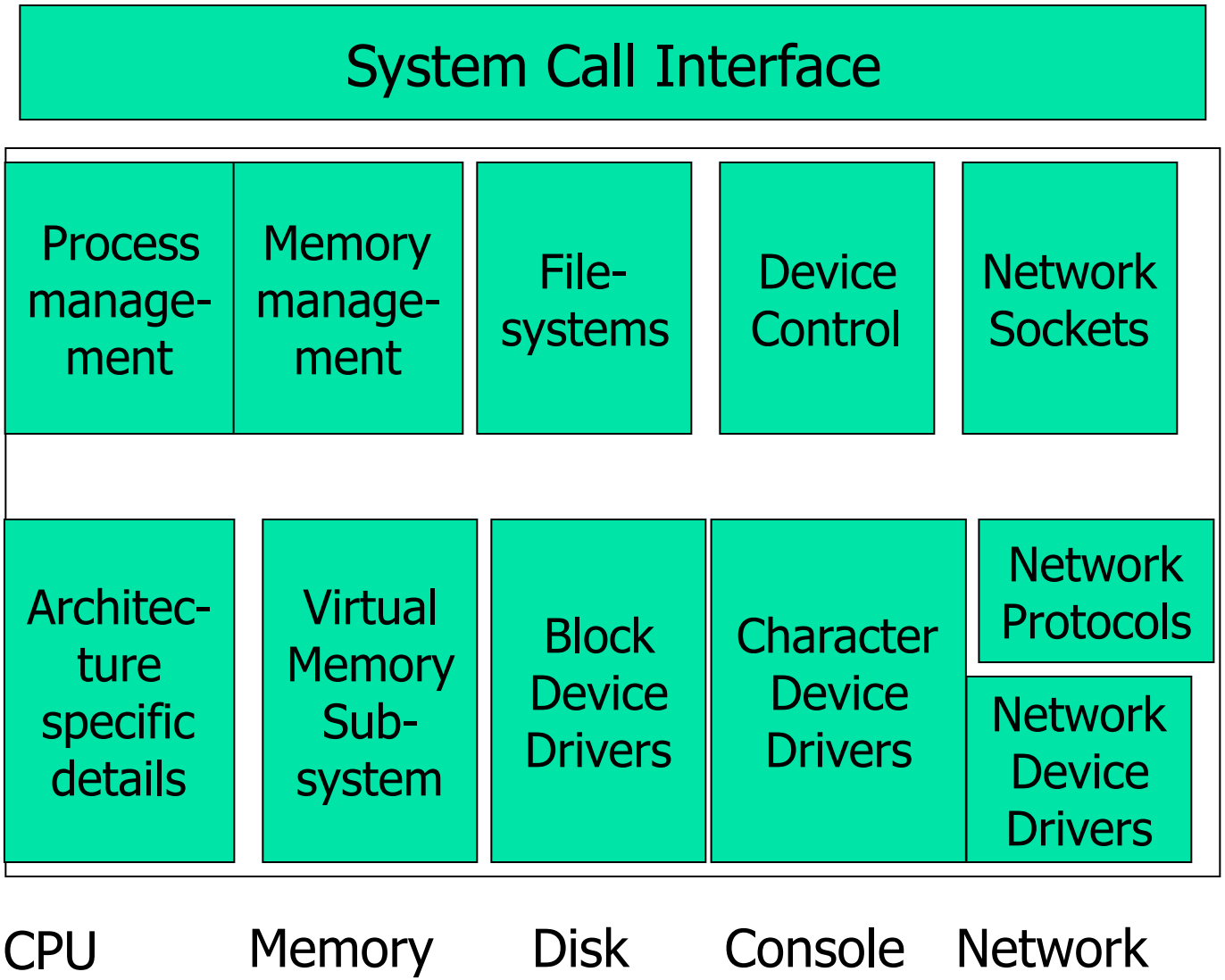
Simplified Organization of Linux Kernel



System Calls

- Operating systems typically support two levels of privileges:
  - User mode – application execute at this level
  - Supervisor mode – OS (kernel) code executes at this level
- Applications need to call OS routines to request privileged operations.
- System calls
  - Safely transfer control from lower privilege level (user mode) to higher privilege level (supervisor mode).
  - Examples: open, read, write, close, wait, exec, fork, kill
- Kernel can tightly control entry points for the application into the OS.
  - Application can’t randomly jump into any part of the OS code.

Syscall Internals

1. Syscall invoked via a special CPU instruction that triggers a software trap
    1. int 0x80/lcall7/lcall27
2. Process making the syscall is interrupted
3. Information needed to continue its execution later is saved
4. Processor switches to higher privileged level
5. Processor determines the service being requested by the user-mode by examining the processor state and/or its stack.
6. Executes the requested system call operation.
7. Process making the syscall may be “put to sleep” if the syscall involved blocking I/O.
8. When syscall completes, process is “woken up” (if needed).
9. Original process state is restored
10. Processor switches back to lower (user) privilege level
11. Process returns from syscall and continues execution.

Syscall Usage

- To make it easier to invoke system calls, OS writers normally provide a library that sits between programs and system call interface.
  - Libc, glibc, etc.
- This library provides wrapper routines
- Wrappers hide the low-level details of
  - Preparing arguments
  - Passing arguments to kernel
  - Switching to supervisor mode
  - Fetching and returning results to application.
- Helps to reduce OS dependency and increase portability of programs.

Implementing System Calls

Steps in writing a system call

- Create an entry for the system call in the kernel's syscall_table
  - User processes trapping to the kernel (through SYS_ENTER or int 0x80) find the syscall function by indexing into this table.

- Write the system call code as a kernel function
  - Be careful when reading/writing to user-space
  - Use *copy_to_user()* or *copy_from_user()* routines.
    - These perform sanity checks.

- Generate/Use a user-level system call stub
  - Hides the complexity of making a system call from user applications.
  - See *man syscall*

Step 1: Create a sys_call_table entry (for 64-bit x86 machines)

- arch/x86/syscalls/syscall_64.tbl

```
#
# 64-bit system call numbers and entry vectors
#
# The format is:
# <number> <abi> <name> <entry point>
#
# The abi is "common", "64" or "x32" for this file.
...
309  common       getcpu                  sys_getcpu
310  64           process_vm_readv        sys_process_vm_readv
311  64           process_vm_writev       sys_process_vm_writev
312  common       kcmp                    sys_kcmp
313  common       foo                     sys_foo
```

Step 2: Write the system call handler

- System call with no arguments and integer return value

```
asmlinkage int sys_foo(void) {
        printk (KERN ALERT "I am foo. UID is %d\n", current->uid);
        return current->uid;
}
```

- Syscall with one primitive argument

```
asmlinkage int sys_foo(int arg) {
        printk (KERN ALERT "This is foo. Argument is %d\n", arg);
        return arg;
}
```

- To see log: dmesg, /var/log/kern.log

Step 2: Write the system call handler (cont...)

- Verifying argument passed by user space

```
asmlinkage long sys_close(unsigned int fd)
{
        struct file * filp;
        struct files_struct *files = current->files;
        struct fdtable *fdt;
        spin_lock(&files->file_lock);
        fdt = files_fdtable(files);
          if (fd >= fdt->max_fds)
                goto out_unlock;
          filp = fdt->fd[fd];
          if (!filp)
                goto out_unlock;
        ...
out_unlock:
        spin_unlock(&files->file_lock);
        return -EBADF;
}
```

- Call-by-reference argument
  - User-space pointer sent as argument.
  - Data to be copied back using the pointer.

```
asmlinkage ssize_t sys_read ( unsigned int fd,
        char __user * buf,  size_t count)
{
        ...

       if( !access_ok( VERIFY_WRITE, buf, count))
                return -EFAULT;

        ...
}
```

Example syscall implementation

```
asmlinkage int sys_foo(void) {
        static int count = 0;
        printk(KERN_ALERT "Hello World! %d\n", count++);
        return -EFAULT; // what happens to this return value?
}

EXPORT_SYMBOL(sys_foo);
```

Step 3: Invoke your new handler with syscall

- Use the **syscall(...) library function**.
  - Do a "man syscall" for details.
- For instance, for a no-argument system call named foo(), you'll call
  - ret = syscall(__NR_sys_foo);
  - Assuming you've defined __NR_sys_foo earlier
- For a 1 argument system call named foo(arg), you call
  - ret = syscall(__NR_sys_foo, arg);
- and so on for 2, 3, 4 arguments etc.
- For this method, check
  - http://www.ibm.com/developerworks/linux/library/l-system-calls/

Step 3: Invoke your new handler with syscall (cont...

```
#include <stdio.h>
#include <errno.h>
#include <unistd.h>
#include <linux/unistd.h>
// define the new syscall number. Standard syscalls are defined in linux/unistd.h
#define __NR_sys_foo 333
int main(void)
{
        int ret;
          while(1) {
         // making the system call
                        ret = syscall(__NR_sys_foo);
                        printf("ret = %d errno = %d\n", ret, errno);
                        sleep(1);
       }
          return 0;
}
```