Design and Analysis of Operating Systems CSCI 3753

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Adding a New Device

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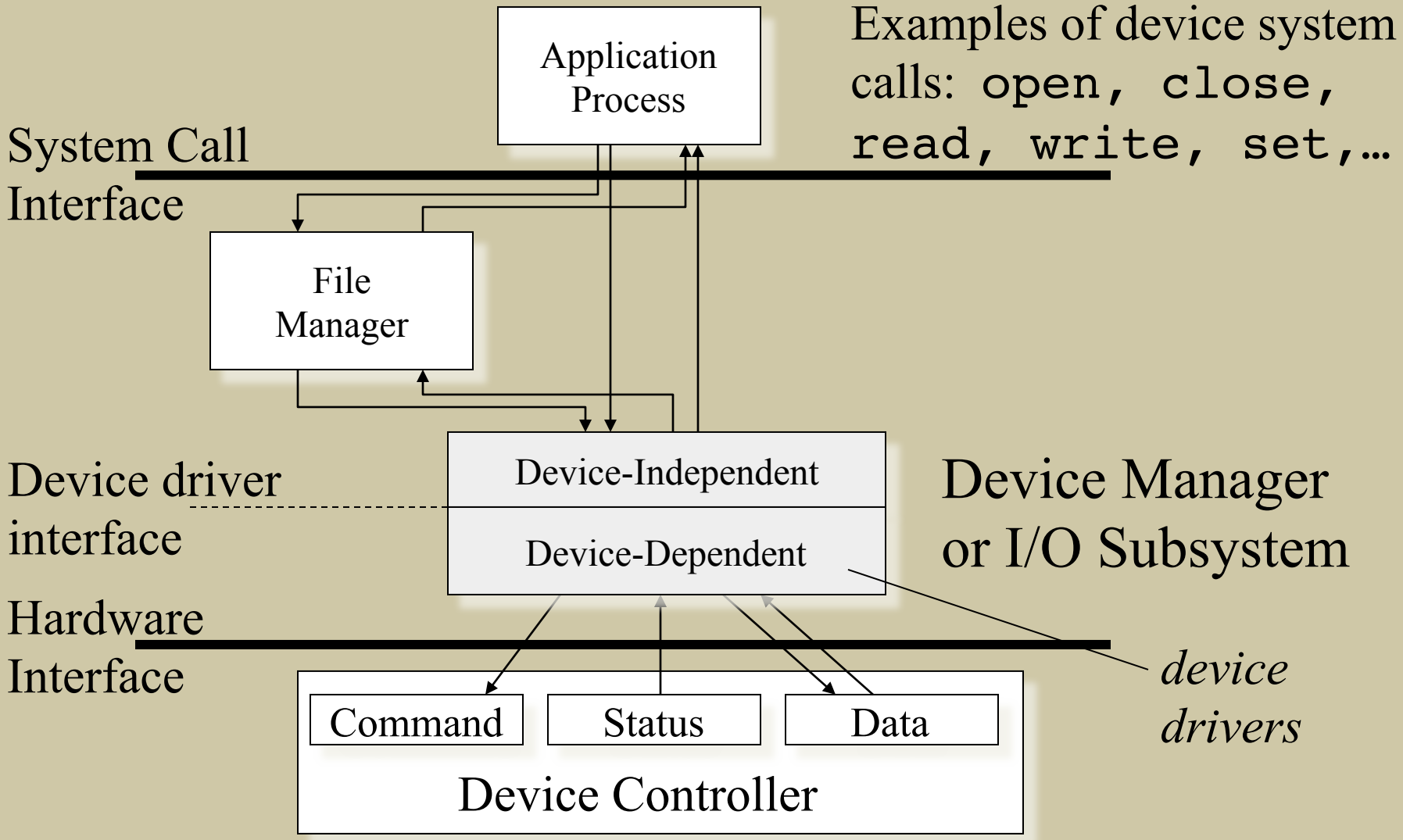
Device Management Organization



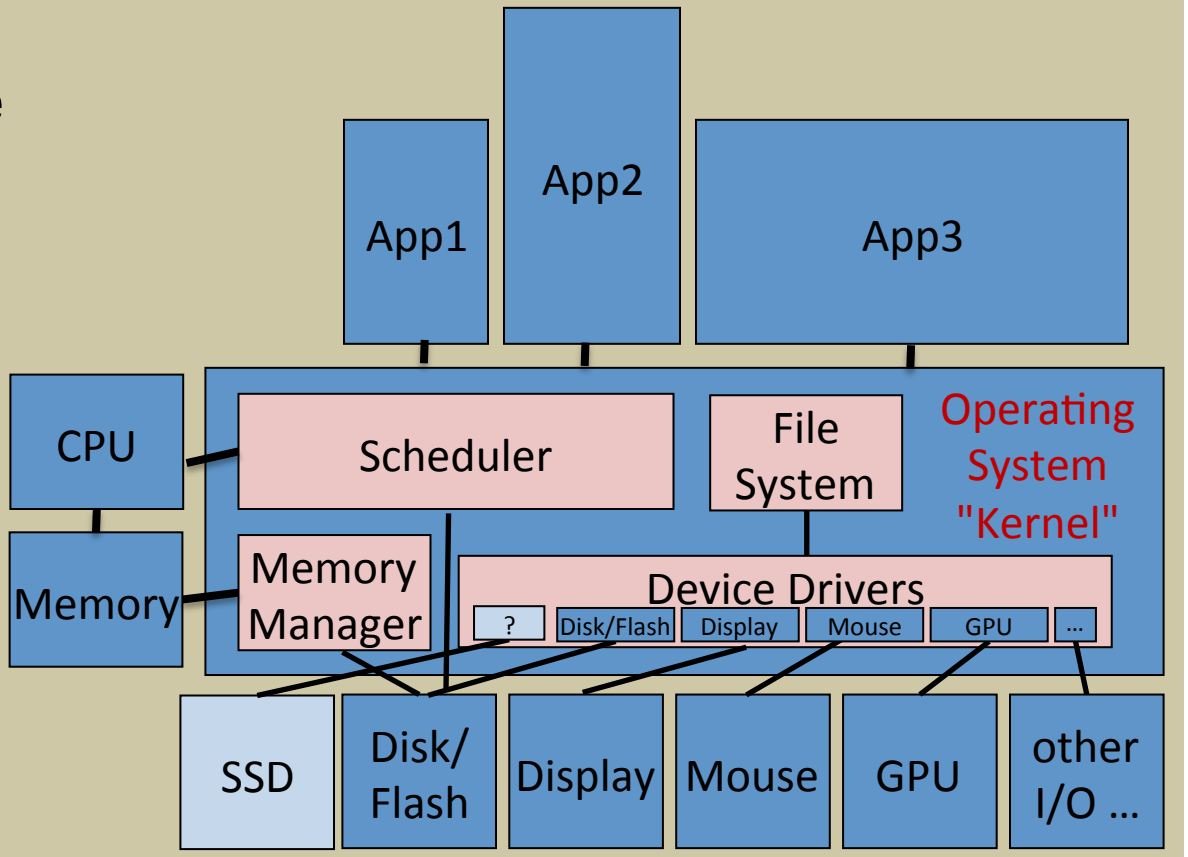
Devices have both device-independent and device-dependent code

There is special device driver code associated with each different device connected to the system

1.Device-Independent API

2.Device-Dependent driver code

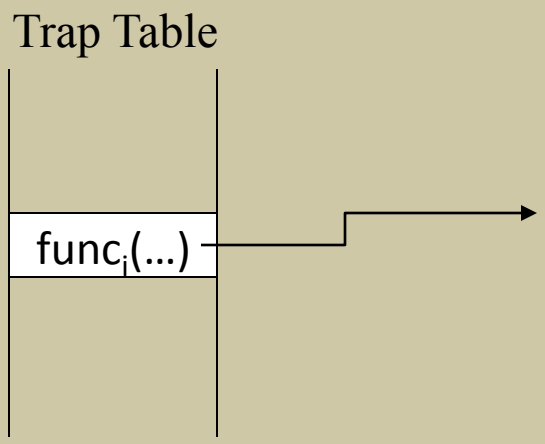
3.Device Controller



Device Independent Part

- A set of system calls that an application program can use to invoke I/O operations
- A particular device will respond to only a subset of these system calls
  - A keyboard does not respond to *write( )* system call
- POSIX set: *open*(), *close*( ), *read*( ), *write*( ), *lseek*( ) and *ioctl*( )

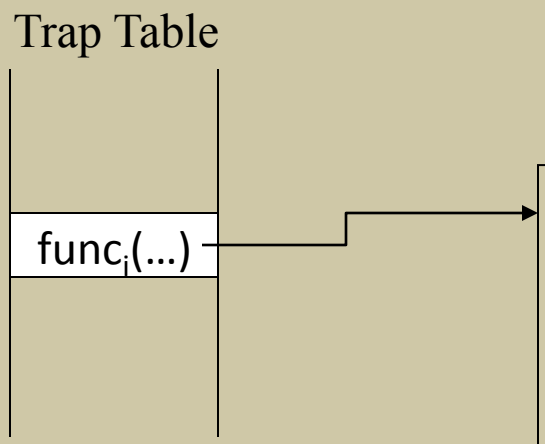
Device Independent Function Call




```
dev_func_i(devID, …) {
// Processing common to all devices
  …
  switch(devID) {
  case dev0: dev0_func_i(…);
       break;
  case dev1: dev1_func_i(…);
       break;
  …
  case devM: devM_func_i(…);
       break;
  };
// Processing common to all devices
  …
}
```

Adding a New Device

- Write device-specific functions for each I/O system call
- For each I/O system call, add a new *case* clause to the *switch* statement in device independent function call




```
dev_func_i(devID, …) {
// Processing common to all devices
  …
  switch(devID) {
  case dev0: dev0_func_i(…);
       break;
  case dev1: dev1_func_i(…);
       break;
  …
  case devM: devM_func_i(…);
       break;
  case devNew: devNew_func_i(…);
       break;
  };
// Processing common to all devices
  …
}
```

Adding a New Device

- After updating all dev_func_*(…) in the kernel, compile the kernel

Problem: Need to recompile the kernel, every time a new device or a new driver is added

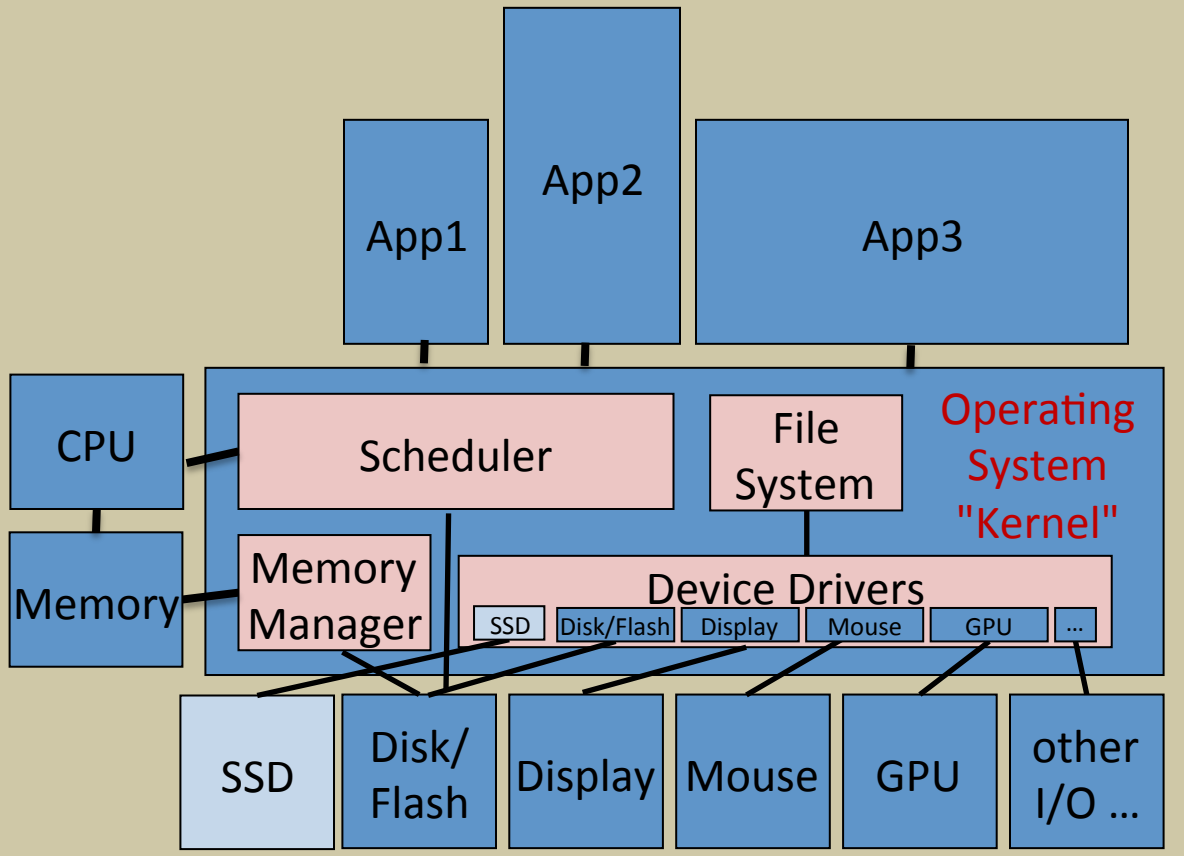
Devices have both device-independent and device-dependent code

We need a way to dynamically add new code into the OS Kernel when a new device needs to be supported.

1. *Load Device-Dependent* driver code into kernel

2. *Only load the device drivers as needed*

3. *Do not want to recompile kernel for changes in the device driver*



Loadable Kernel Modules

- A loadable kernel module (LKM) is an object file that contains code to extend a running kernel
- Windows (kernel-mode driver), Linux (LKM), OS X (Kernel extension: kext)
- Without loadable kernel modules, an OS would have to include all possible anticipated functionality already compiled directly into the base kernel – monolithic kernel
- LKMs can be loaded and unloaded from kernel on demand at runtime

LKMs

- Offer an easy way to extend the functionality of the kernel without having to rebuild or recompile the kernel again
- Simple and efficient way to create programs that reside in the kernel and run in privileged mode
- Most of the drivers today are written as LKMs
- See */lib/modules* for the all the LKMs
- *lsmod*: lists all kernel modules that are already loaded
  - Reads */proc/modules* file

How to write a kernel module

- Kernel Modules are written in the C programming language
- You must have a Linux kernel source tree to build your module
- You must be running the same kernel you built your module with to run it
- Linux kernel object: *.ko* extension

Kernel Module: Basics

- A kernel module file has several typical components:
  - MODULE_AUTHOR("your name")
  - MODULE_LICENSE("GPL")
    - The license must be an open source license (GPL, BSD, etc.) or you will "taint" your kernel.
    - Tainted kernel loses many abilities to run other open source modules and capabilities.

Kernel Module: Key Operations

- int init_module(void)
  - Called when the kernel loads your module.
  - Initialize all your stuff here.
  - Return 0 if all went well, negative if something blew up.

- Typically, init_module( ) either
  - registers a handler for something with the kernel
  - or replaces one of the kernel functions with its own code

  (usually code to do something and then call the original function)

Kernel Module: Key Operations

- void cleanup_module(void)
  - Called when the kernel unloads your module.
  - Free all your resources here.

Hello World Example

```
#include <linux/kernel.h>
#include <linux/module.h>
MODULE_AUTHOR("Shiv Mishra");
MODULE_LICENSE("GPL");


 int init_module(void)
 {
      printk(KERN_ALERT "Hello world: I am the developer
                                          speaking from the Kernel");
      return 0;
 }
```

Hello World Example

```
void cleanup_module(void)
{
    printk(KERN_ALERT “Goodbye from the developer,
                                    I am exiting the Kernel”);
}
```

Building Your Kernel Module

- Accompany your module with a 1-line GNU Makefile:
  - obj-m += hello.o
  - Assumes file name is “hello.c”

- Run the magic make command:
  - make -C <kernel-src> M=`pwd` modules
  - Produces: hello.ko

- Assumes current directory is the module source.

obj-$(CONFIG_FOO) += foo.o

- Good definitions are the main part (heart) of the kbuild Makefile
- The most simple kbuild makefile contains one line:

  obj-$(CONFIG_FOO) += foo.o

- Tell kbuild that there is one object in that directory named foo.o
  - foo.o will be built from foo.c or foo.S
- $(CONFIG_FOO) evaluates to either y (for built-in) or m (for module). If CONFIG_FOO is neither y nor m, then the file will not be compiled nor linked.

Loading Your Kernel Module: *insmod*

- *Use insmod* to manually load your kernel module

  sudo insmod helloworld.ko

- *insmod* makes an *init_module* system call to load the LKM into kernel memory
- *init_module* system call invokes the LKM's initialization routine (also called *init_module*) right after it loads the LKM
- The LKM author sets up the initialization routine to call a kernel function that registers the subroutines that the LKM contains

Where is our Hello World message

- dmesg
- /var/log/system.log

Unloading Your Kernel Module

- Use *rmmod* command

  rmmod hello.ko

- Should print the Goodbye message

Kernel Module Dependencies: *modprobe*

- insmod/rmmod can be cumbersome...
  - You must manually enforce inter-module dependencies.

- *modprobe* automatically manages dependent modules
  - Copy hello.ko into /lib/modules/<version>
  - Run depmod
  - modprobe hello / modprobe -r hello

- Dependent modules are automatically loaded/unloaded.

- *depmod* creates a Makefile-like dependency file, based on the symbols it finds in the set of modules mentioned on the command line or from the directories specified in the configuration file

- This dependency file is later used by *modprobe* to automatically load the correct module or stack of modules

modinfo command

- .ko files contain an additional .modinfo section where additional information about the module is kept
  - Filename, license, dependencies, …

- modinfo command retrieves that information

```
modinfo hello.ko
```

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