CS35L – Spring 2019

Slide set:	5.1
Slide topics:	System Call Programming
Assignment:	5

Assignment 10 Rubric

Presentation (50%):

- Organization / Time Management
- Relevance to topic
- Technical Details and Subject Knowledge
- Presentation abilities / Creativity
- Content of slides (not dull/boring)
- Ability to answer questions and interactivity with audience

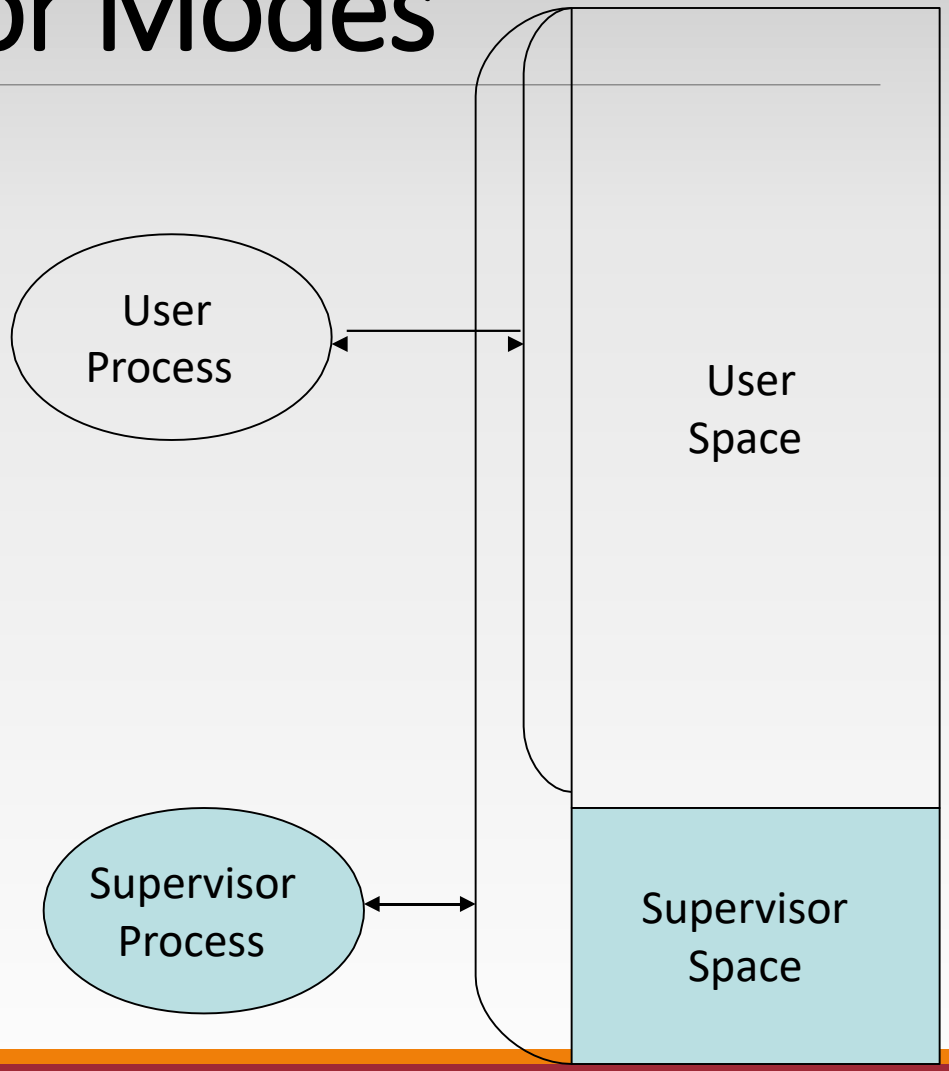
Report (50%)

System Call Programming

Processor Modes

Operating modes that place restrictions on the type of operations that can be performed by running processes

- User mode: restricted access to system resources
- Kernel/Supervisor mode: unrestricted access



User Mode vs. Kernel Mode

Hardware contains a mode-bit
E.g. 0 ➔ kernel mode, 1 ➔ user mode

User mode

- CPU **restricted** to unprivileged instructions and a specified area of memory

Supervisor/kernel mode

- CPU is **unrestricted**, can use all instructions, access all areas of memory and take over the CPU anytime

Why Dual-Mode Operation?

System resources are shared among processes

OS must ensure:

- **Protection**
  - an incorrect/malicious program cannot cause damage to other processes or the system as a whole
- **Fairness**
  - Make sure processes have a fair use of devices and the CPU

Goals for Protection and Fairness

Goals:

- **I/O Protection**
  - Prevent processes from performing illegal I/O operations
- **Memory Protection**
  - Prevent processes from accessing illegal memory and modifying kernel code and data structures
- **CPU Protection**
  - Prevent a process from using the CPU for too long

=> instructions that might affect goals are privileged and can only be executed by *trusted code*

Which Code is Trusted?
=> The Kernel's *ONLY*

- Core of OS software **executing in supervisor** state
- **Trusted software:**
  - Manages hardware resources (CPU, Memory and I/O)
  - Implements protection mechanisms that could not be changed through actions of untrusted software in user space
- **System call interface** is a **safe way** to expose privileged functionality and services of the processor

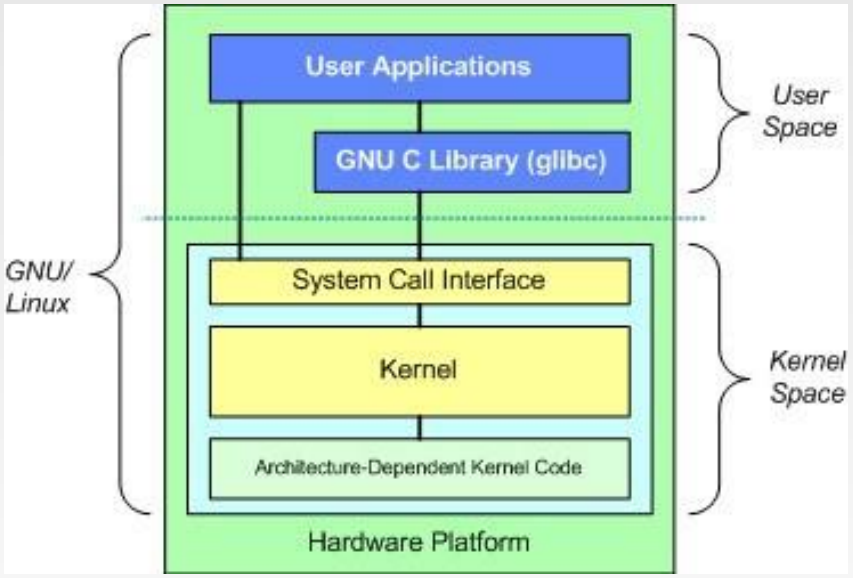
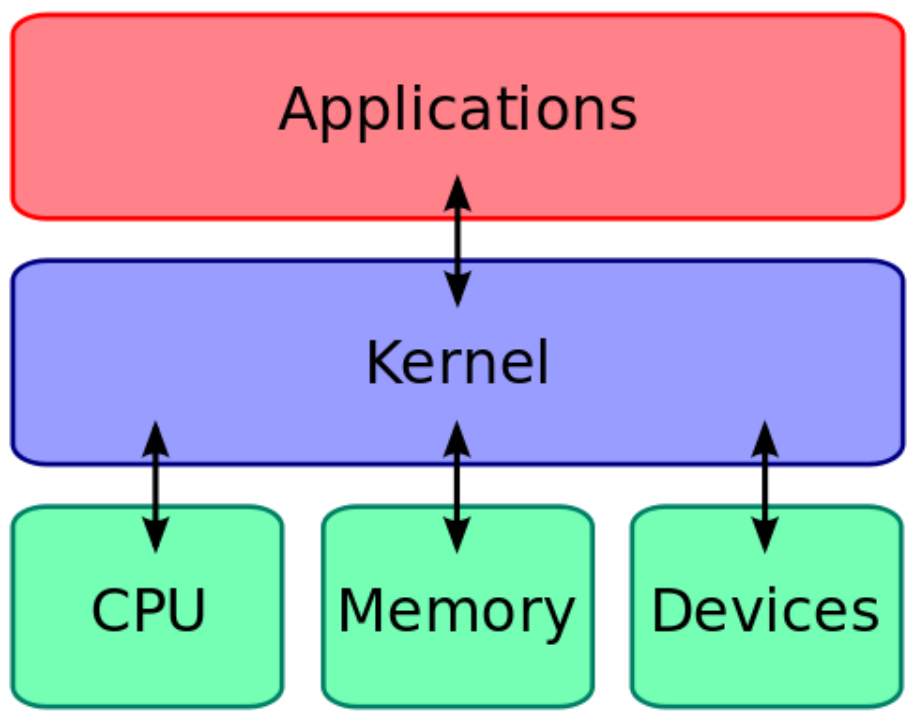


Image by: Tim Jones (IBM)

What About User Processes?

The kernel executes privileged operations on behalf of untrusted user processes



System Calls

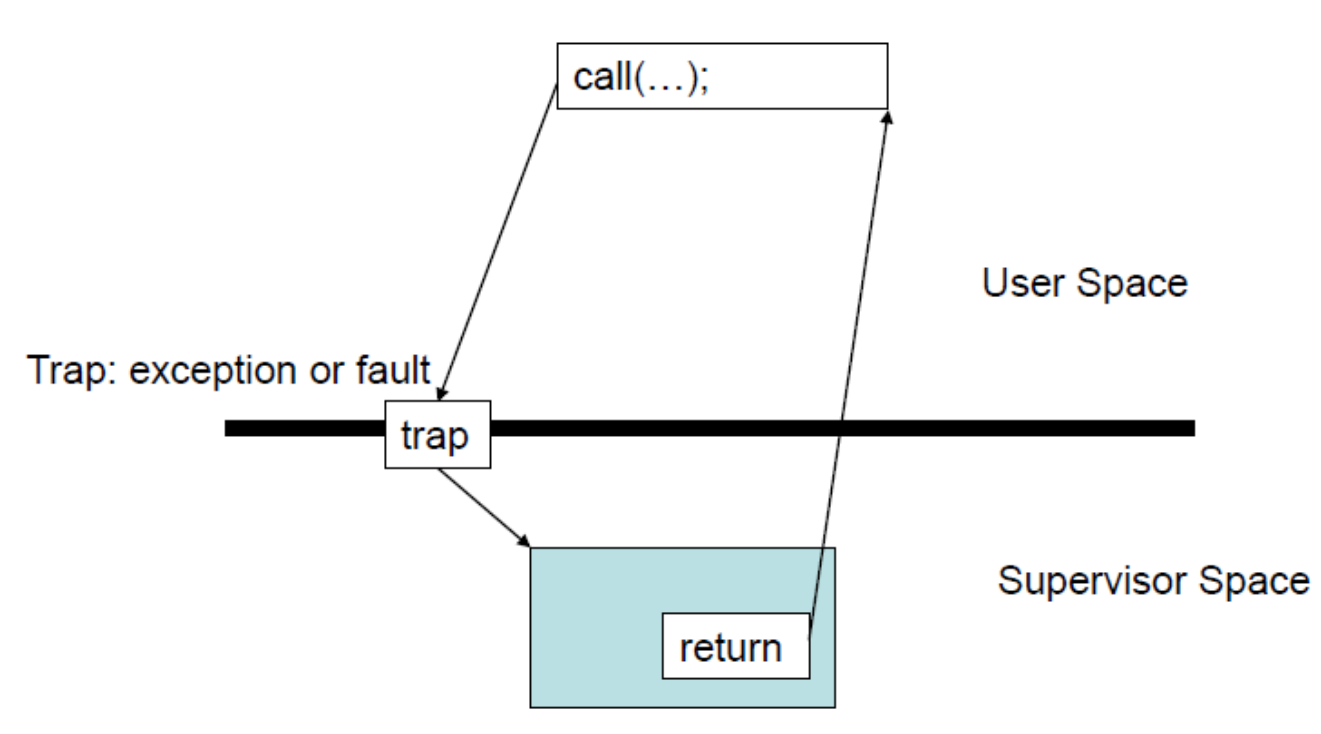
Special type of function that:

- Used by user-level processes to request a service from the kernel
- Changes the CPU's mode from user mode to kernel mode to enable more capabilities
- Is part of the kernel of the OS
- Verifies that the user should be allowed to do the requested action and then does the action (kernel performs the operation on behalf of the user)
- Is the ***only way*** a user program can perform privileged operations

System Calls

When a system call is made, the program being executed is interrupted and control is passed to the kernel

If operation is valid the kernel performs it



System Call Overhead

System calls are expensive and can hurt performance

The system must do many things

- Process is interrupted & computer saves its state
- OS takes control of CPU & verifies validity of the operation
- **OS performs requested action**
- OS restores saved context, switches to user mode
- OS gives control of the CPU back to user process

Example System Calls

- `#include<unistd.h>`

  `ssize_t` **`read`**`(int fildes, void *buf, size_t nbyte)`
  - fildes: file descriptor
  - buf: buffer to write to
  - nbyte: number of bytes to read
- `ssize_t` **`write`**`(int` *`fildes`*`, const void *`*`buf`*`, size_t` *`nbyte`*`);`
  - fildes: file descriptor
  - buf: buffer to write from
  - nbyte: number of bytes to write
- `int` **`open`**`(const char *pathname, int flags, mode_t mode);`
- `int` **`close`**`(int fd);`
- File descriptors
  - 0 stdin
  - 1 stdout
  - 2 stderr

Example System Calls

- `pid_t` **`getpid`**`(void)`
  - Returns the process ID of the calling process
- `int` **`dup`**`(int fd)`
  - Duplicates a file descriptor fd. Returns a second file descriptor that points to the same file table entry as fd does.
- `int` **`fstat`**`(int filedes, struct stat *buf)`
  - Returns information about the file with the descriptor filedes into buf

```
struct stat {
    dev_t     st_dev;     /* ID of device containing file */
    ino_t     st_ino;     /* inode number */
    mode_t    st_mode;    /* protection */
    nlink_t   st_nlink;   /* number of hard links */
    uid_t     st_uid;     /* user ID of owner */
    gid_t     st_gid;     /* group ID of owner */
    dev_t     st_rdev;    /* device ID (if special file) */
    off_t     st_size;    /* total size, in bytes */
    blksize_t st_blksize; /* blocksize for file system I/O */
    blkcnt_t  st_blocks;  /* number of 512B blocks allocated */
    time_t    st_atime;   /* time of last access */
    time_t    st_mtime;   /* time of last modification */
    time_t    st_ctime;   /* time of last status change */
};
```

Library Functions

Functions that are a part of standard C library

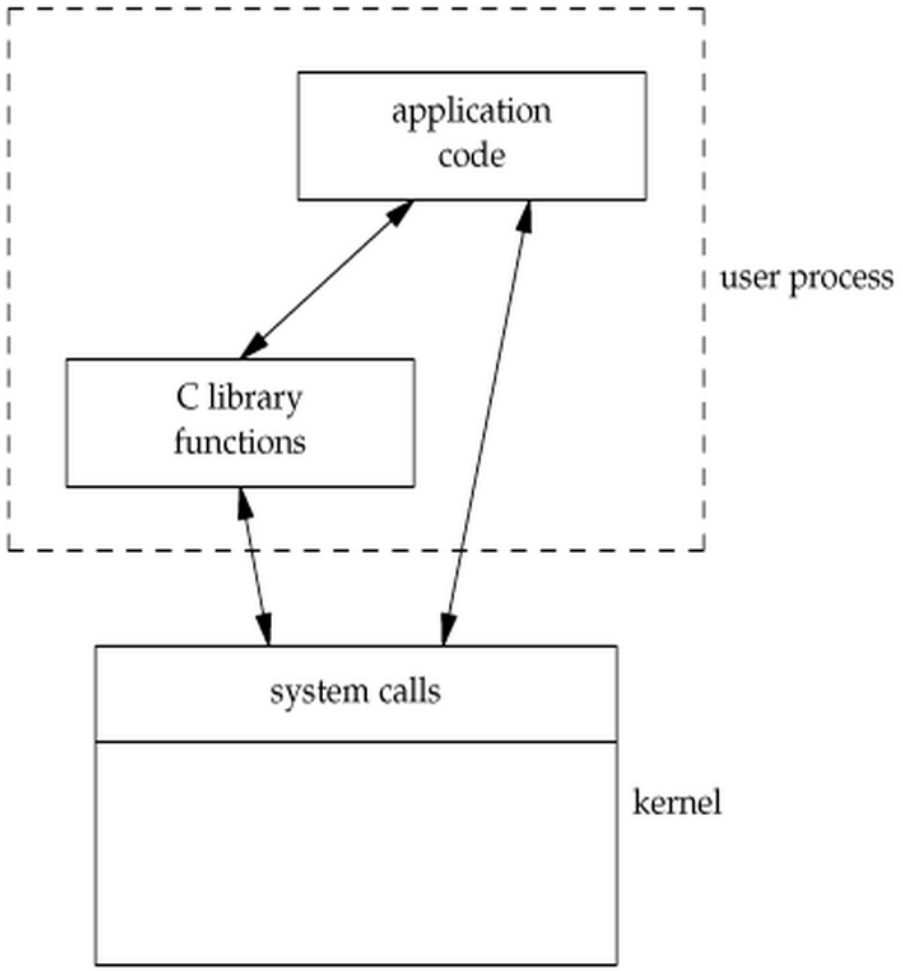
To avoid system call overhead use equivalent library functions

- getchar, putchar vs. read, write (for standard I/O)
- fopen, fclose vs. open, close (for file I/O), etc.

How do these functions perform privileged operations?

- They make system calls

So What's the Point?



- Many library functions invoke system calls indirectly
- So why use library calls?
- Usually equivalent library functions make fewer system calls
- non-frequent switches from user mode to kernel mode
  ➔ less overhead