Welcome to...

W4118: Operating Systems I

Spring 2023

cs4118.github.io/www/2023-1/

Advanced UNIX Programming

First four weeks of the semester: UNIX from the outside

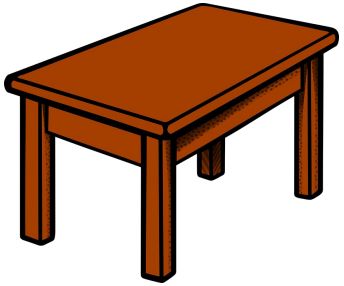
- Advanced systems programming material that comes between cs3157 and OS

Processes, threads, concurrency, signals, networking, non-blocking & async I/O

`hw3-multi-server`:

- add complex functionality to a provided basic web server

Crossing to the Kernel: System Calls



Sometimes a process needs to perform **privileged operations**, e.g.:

- File I/O: `open()`, `read()`, `write()`, `close()`, etc.
- Memory management: Allocate/free memory, protection
- Process management: `fork()`, `exec()`, etc.

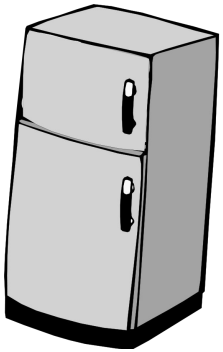
Can't trust (nor expect) userspace processes to do bookkeeping & access control.

OS needs to provide a well-defined **interface** to the kernel!

`hw4-tabletop`:

- add a new system call to Linux and install custom kernel to test it
- inspect a running process's file descriptor table

Synchronization



Many threads of execution can **concurrently** access shared memory.
Race conditions can lead to data corruption and unpredictable behavior.

Need OS support to provide **mutual exclusion** and **synchronization**!

`hw5-fridge`:

- implement an in-kernel hashtable accessible via system calls
- use synchronization primitives to ensure safe data structure access

Scheduling

System may have many processes to execute, but fixed # of CPUs…

OS needs to **virtualize the CPU**! (i.e. provide illusion of infinite CPUs):

- **multiplex** process execution across multiple CPUs
- permit higher **priority** processes to run sooner/for longer

`hw6-freezer`:

- add a new scheduling policy to the Linux scheduler
- replace the default Linux scheduling policy

Memory Management

Processes execute within a **byte-addressable linear virtual address** space.

- Perks: pointers, arrays, stack grows “downwards”, heap grows “upwards”

How is this possible given fixed RAM size and variable # of running processes?

OS needs to **virtualize physical memory** (i.e. provide illusion of linear vaddr spaces)

- map virtual addresses to physical addresses on-the-fly
- protect virtual memory mappings from other processes and illegal access

`hw7-farfetchd`:

- “hack” a process’s address space by writing directly to its physical memory

File System

File access is made straightforward by the file API (syscalls), but there are many implementation details hidden behind the kernel:

- read/write/execute permission enforcement, user access validation
- resolving path names and fetching corresponding data at offset from disk
- persisting metadata and data on disk, keeping metadata synchronized

The OS needs to implement the file API and ensure data persistence

`hw8-pantryfs`:

- implement a simple file system and hook it into Linux VFS

Stuff we skimmed/skipped...

Deadlock theory

I/O systems

Network file system (NFS)

Interrupt handlers and bottom half

Kernel synchronization using RCU

Kernel memory management & block I/O layer

Virtualization

Networking

Final Reminders

Fill out Courseworks evaluation (!!!)

Remember your pledge

- Don’t share class materials with friends
- Don’t post any class-related code to GitHub
- Don’t post any class materials to Chegg, CourseHero, etc.

(it’s almost over!)

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