CS350: Operating Systems

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Administrivia

- Class web page: `https://cs.uwaterloo.ca/cs350/`
  - All assignments and handouts
- Textbooks
  - *Operating System Concepts*
  - *Operating Systems: Three Easy Pieces*

Administrivia Continued

- Q&A through Piazza (see class website)
- Quizzes and Final through Waterloo LEARN
- Four projects due throughout term

Course Goals: Introduce you to Systems

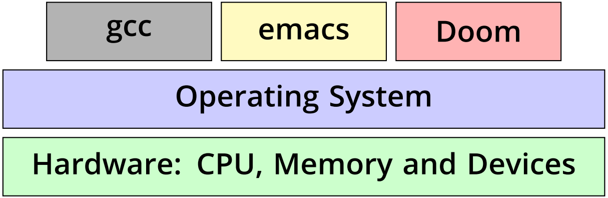
- Operating Systems
- Distributed Systems
- Networking
- Internet of Things
- Computer Architecture
- Embedded Systems
- Database Systems
- Systems and Machine Learning
- ...

Course Goals: Practical Understanding of OSes

- Introduce you to operating systems
  - Every computer, phone and watch runs an OS
  - Makes you a more effective programmer
  - How the OS affects your software
- General systems concepts
  - Concurrency, memory management, and I/O
  - Security and protection
  - Tools for software performance
- Practical skills
  - Learn to work with large code bases
  - My lectures: industry and research experience

What is an operating system?

- Layer between applications and hardware



- Makes hardware useful to the programmer
- Usually: Provides abstractions for applications
  - Manages and hides details of hardware
  - Accesses hardware through low/level interfaces unavailable to applications
- Often: Provides protection
  - Prevents one process/user from clobbering another

Why study operating systems?

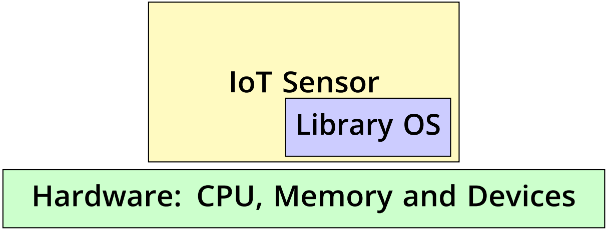
- Operating systems are a maturing field
  - Most people use a handful of mature OSes
  - Hard to get people to switch operating systems
  - Hard to have impact with a new OS
- High-performance servers are an OS issue
  - Face many of the same issues as OSes
- Resource consumption is an OS issue
  - Battery life, radio spectrum, etc.
- Security is an OS issue
  - Security requires a solid foundation
- New “smart” devices need new OSes
- Web browsers, databases, and game engines look like OSes

Course topics

- Threads & Processes
- Concurrency & Synchronization
- Scheduling
- Virtual Memory
- I/O
- Disks, File systems, Network file systems
- Protection & Security
- Virtual machines
- Will often use Unix as the example
  - Most OSes heavily influenced by Unix (e.g. OS161)
  - Windows is a notable exception

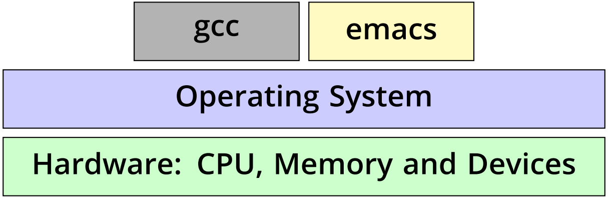
Primitive Operating Systems

- Just a library of standard services (no protection)



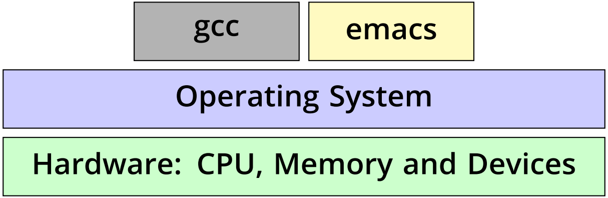
  - Standard interface above hardware-specific drivers, etc.
- Simplifying assumptions
  - System runs one program at a time
  - No bad users or programs (often bad assumption)
- Problem: Poor utilization
  - ...of hardware (e.g., CPU idle while waiting for disk)
  - ...of human user (must wait for each program to finish)

Multitasking



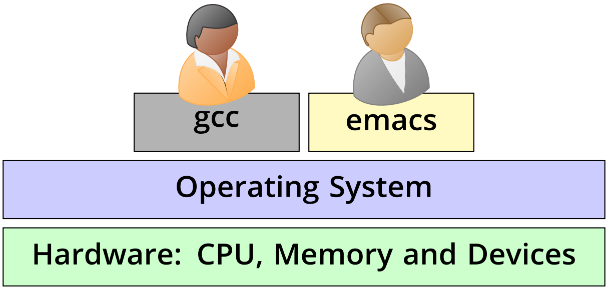
- Idea: Run more than one process at once
  - When one process blocks (waiting for user input, IO, etc.) run another process
- Problem: What can ill-behaved process do?

Multitasking



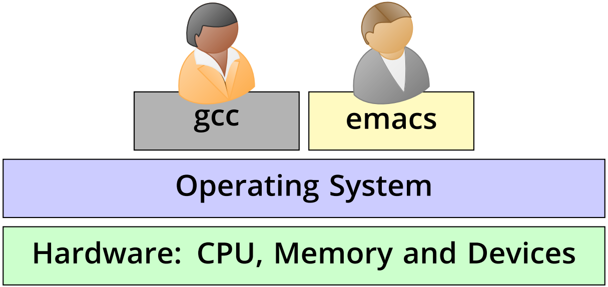
- Idea: Run more than one process at once
  - When one process blocks (waiting for user input, IO, etc.) run another process
- Problem: What can ill-behaved process do?
  - Go into infinite loop and never relinquish CPU
  - Scribble over other processes' memory to make them fail
- OS provides mechanisms to address these problems
  - *Preemption* – take CPU away from looping process
  - *Memory protection* – protect process's memory from one another

Multi-user OSes



- Many OSes use *protection* to serve distrustful users/apps
- Idea: With N users, system not N times slower
  - User demand for CPU is bursty
- What can go wrong?

Multi-user OSes

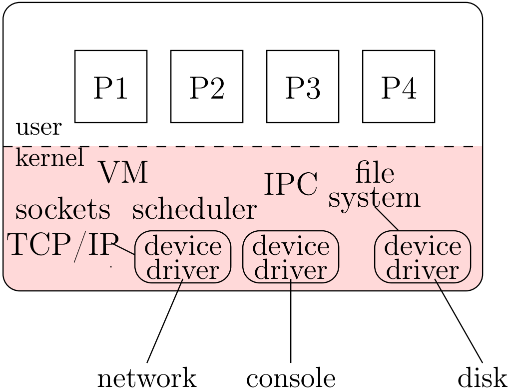


- Many OSes use *protection* to serve distrustful users/apps
- Idea: With N users, system not N times slower
  - User demand for CPU is bursty
- What can go wrong?
  - Users are gluttons, use too much CPU, etc. (need policies)
  - Total memory usage greater than in machine (must virtualize)
  - Super-linear slowdown with increasing demand (thrashing)

Protection

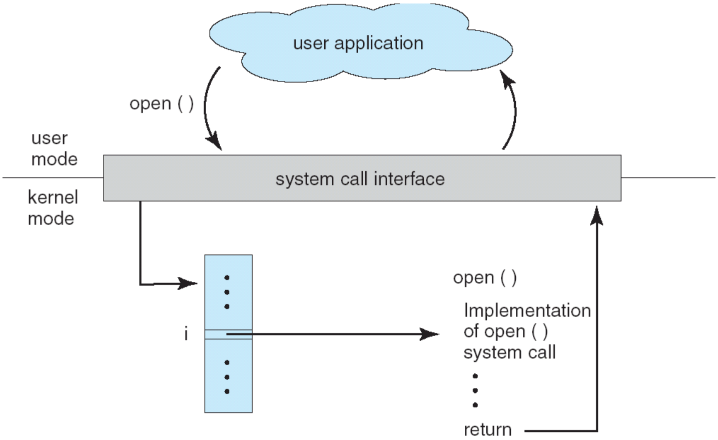
- Mechanisms that isolate bad programs and people
- Pre-emption:
  - Give application a resource, take it away if needed elsewhere
- Interposition/mediation:
  - Place OS between application and "stuff"
  - Track all pieces that application allowed to use (e.g., in table)
  - On every access, look in table to check that access legal
- Privileged & unprivileged modes in CPUs:
  - Applications unprivileged (unprivileged *user* mode)
  - OS privileged (privileged supervisor/*kernel* mode)
  - Protection operations can only be done in privileged mode

Typical OS structure



- **Most software runs as user-level processes (P[1-4])**
- **OS *kernel* runs in *privileged* mode (shaded)**
  - Creates/deletes processes
  - Provides access to hardware

System calls

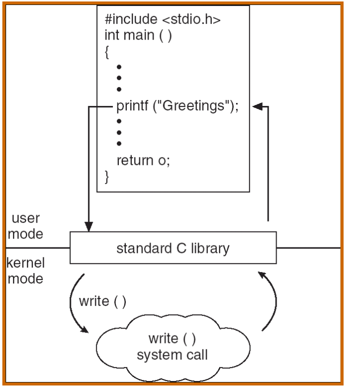


- Applications can invoke kernel through *system calls*
  - Special instruction transfers control to kernel
  - ...which dispatches to one of few hundred syscall handlers

System calls (continued)

- Goal: Do things app. can't do in unprivileged mode
  - Like a library call, but into more privileged kernel code
- Kernel supplies well-defined *system call* interface
  - Applications set up syscall arguments and *trap* to kernel
  - Kernel performs operation and returns result
- Higher-level functions built on syscall interface
  - `printf`, `scanf`, `gets`, etc. all user-level code
- Example: POSIX/UNIX interface
  - `open`, `close`, `read`, `write`, …

System call example



- Standard library implemented in terms of syscalls
  - *printf* – in libc, has same privileges as application
  - calls *write* – in kernel, which can send bits out serial port