CSE 451: Operating Systems
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Module 1
Course Introduction

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Course Details

• But first, a word about Health and Safety
• Information portals
  • Course webpage, Canvas, Class discussion board
• Class Prerequisites:
  • CSE332: Data Structures and Parallelism
  • CSE333: Systems Programming
  • CSE351: The Hardware/Software Interface
• Lectures and Sections (will be recorded on zoom or panopto, and lecture slides/notes posted)
• Projects – Led by the TAs
  • 4 labs using xk (brush up on programming in C). Due about every two weeks. Check the class website for the actual schedule.
• Grading (subject to change)
  • Projects 70%, Final 30%
The Projects

- Start them early
- Four of them
- **Teams of two.** You’re likely to be happier if you form a team on your own than if we randomly assign them.
- Debugging is a skill best learned through experience
- Speaking of developing new skills, working in teams remotely presents some challenges. TAs are aware of this and are working on materials that could help.
- Do not believe that passing the test cases means your code works...
  - Sorry
Course Objectives

1. (One thing that I hope you learn from this class) How an OS is designed and built. To better know how to use the OS

2. Debugging large programs, adding new features to an existing (incomplete codebase)

3. Quote in the Cutler lab
   “Bugs: if you don’t put them in, you don’t have to take them out.”

4. A lot of material to cover in the first few weeks, before it all makes sense

5. Textbook: academic head knowledge.
   OSPP will be our main textbook
   OSTEP (the supplemental reading ) is available online for free

6. Lectures: enhance and supplement the textbook and do deep dives into some specific implementation issues.

7. Projects: get hand dirty, learn by doing
Course Roadmap (subject to change)

1. Chapter 2 Kernel Abstraction
2. Chapter 3 Programming Interface
3. Chapter 4 Concurrency
4. Chapter 5 and 6 Synchronization
5. Chapter 8, 9, 10 Memory Management
6. Chapter 7 Scheduling
7. Chapter 11, 12, 13, 14 Storage
8. Wrap up loose ends
An important underlying concept
Policy vs. Mechanism

- **Policy**: is what you are trying to achieve
  - All the programs running on a computer get equal access to the CPU

- **Mechanism**: is how you achieve it
  - Use timers and context switching to share the CPU

- The lectures and textbook is mostly about policy, the projects deal with mechanism
Operating System Mission Statement

• Class exercise, write an OS mission statement (e.g., The mission statement for the UW CSE School might be to prepare students in the art of computer usage for the coming century.)

One possible mission of the OS: provide a means for programs to effortlessly utilize the capability of the computer system
What is an operating system?

- Software to manage a computer’s resources for its users and applications
Operating System Roles

• **Referee:**
  – Ensures that everyone plays by the rules
  – Resource allocation among users, applications
  – Isolation of different users, applications from each other
  – Communication between users, applications

• **Illusionist:**
  – Each application appears to have the entire machine to itself
  – Infinite number of processors, (near) infinite amount of memory, reliable storage, reliable network transport

• **Glue:**
  – Libraries, user interface widgets, ...

Also viewed as Virtualization, Concurrency, and Persistence
Example: File Systems

• **Referee:**
  – Prevent users from accessing each other’s files without permission
  – Even after a file is deleting and its space re-used

• **Illusionist:**
  – Files can grow (nearly) arbitrarily large
  – Files persist even when the machine crashes in the middle of a save

• **Glue:**
  – Named directories, printf, ...
OS Challenges

- Portability
  - For programs:
    - Application programming interface (API)
    - Abstract virtual machine (AVM)
  - For the operating system
    - Hardware abstraction layer
More OS Challenges

• Reliability
  – Does the system do what it was designed to do?

• Availability
  – What portion of the time is the system working?
  – Mean Time To Failure (MTTF), Mean Time to Repair

• Security
  – Can the system be compromised by an attacker?

• Privacy
  – Data is accessible only to authorized users
Even more OS Challenges

• **Performance**
  – Latency/response time
    • How long does an operation take to complete?
  – Throughput
    • How many operations can be done per unit of time?
  – Overhead
    • How much extra work is done by the OS?
  – Fairness
    • How equal is the performance received by different users?
  – Predictability
    • How consistent is the performance over time?

• **Backward and Forward Compatibility**
  – Can it run legacy apps?
  – How to accommodate growing or advancing Hardware. e.g., word size, or memory size.
Operating System History

• **Batch** to **timeshare**

• **Single User** to **multiuser** to **single user** (PC) to **multiuser** (servers, etc.)

• Cost of **computer time** compared to **people time**

• **Single processor** to **multiple processors** to **distributed systems**
Early Operating Systems:
Computers Very Expensive

• One application at a time
  – Had complete control of hardware
  – OS was runtime library
  – Users would stand in line to use the computer

• Batch systems
  – Keep CPU busy by having a queue of jobs
  – OS would load next job while current one runs
  – Users would submit jobs, and wait, and wait, and wait, and
IBM 360 Mainframe
Time-Sharing Operating Systems: Computers and People Expensive

• Multiple users on computer at same time
  – Multiprogramming: run multiple programs at same time
  – Interactive performance: try to complete everyone’s tasks quickly
  – As computers became cheaper, more important to optimize for user time, not computer time
DEC PDP 11 (mini-computer)
(Tape Drive, Removable Hard Drive, Control Panel, Operator Console)
More PDP 11
Today’s Operating Systems:
Computers Cheap

- Smartphones
- Embedded systems
- Internet of Things
- Laptops
- Tablets
- Virtual machines
- Data center servers
Tomorrow’s Operating Systems:
Everything gets Bigger*

• Giant-scale data centers
• Increasing numbers of processors per computer
• Increasing numbers of computers per user
• Very large scale storage

*And more compact
Computer Performance Over Time

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<tr>
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<td>1</td>
<td>200</td>
<td>2500</td>
<td>2.5K</td>
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<tr>
<td>CPUs per computer</td>
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<td>1</td>
<td>10+</td>
<td>10+</td>
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<td>500K</td>
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<td>DRAM Capacity (MiB)/$</td>
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<td>1K</td>
<td>500K</td>
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<td>25K</td>
<td>10M</td>
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<td>Home Internet</td>
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<td>256 Kbps</td>
<td>20 Mbps</td>
<td>100K</td>
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<td>Machine room network</td>
<td>10 Mbps (shared)</td>
<td>100 Mbps (switched)</td>
<td>10 Gbps (switched)</td>
<td>1000</td>
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<td>Ratio of users to computers</td>
<td>100:1</td>
<td>1:1</td>
<td>1:several</td>
<td>100+</td>
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</tbody>
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• But what hasn’t increased over time?
• Have we reached certain limits?
Next Up (Chapter 2 & 3) Kernel Abstractions

Roadmap for next few days

• Hardware modes
• Interrupts, exceptions, and syscalls (traps)
• Memory layout
• Booting the OS
• Processes and Process Management
Attack on Windows NTFS!

A snippet of code used by hackers to try to disable Ukrainian government computers. Cybersecurity and Infrastructure Security Agency