Operating Systems
ECE344

Lecture 15: Final Review

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Announcements

- Piazza bonus points
  - Will keep "endorsing" students' answers and questions until April 29th

- Additional office hours
  - Will hold office hours during the normal lecture time on Monday/Thursday
  - You can also send me emails for appointments

- Please keep checking Piazza for important announcements

Course Plugs

- If you like ECE 344 topics and you like programming, you might find some other courses interesting next year

- ECE454: Computer System Programming

- ECE419: Distributed Systems

- ECE552: Computer Architecture

Overview

- Final mechanics

- What we have learnt
  - Scheduling and deadlock
  - Memory management
  - Paging
  - Page replacement
  - Disk I/O
  - File systems
  - Advanced topics (won't appear in the final exam)

- The End

Final Exam

- April 30th, 9:30 AM
    - GB-404: Student A-MAL
    - GB-405: Student MAN-Z

- Closed book
    - Sorry, no past sample exams
    - But questions in the textbook can be good exercise

Final Mechanics

- Bulk of the final covers material after midterm
  - Scheduling, deadlock, memory management (paging and replacement), file systems

- Some material on concurrency, synchronization
  - Synch primitives, synch problems

- Based upon lecture material and project

- Again, please, do not cheat

Scheduling

- When does scheduling happen?
  - Job changes state (e.g., waiting to running)
  - Interrupt, exception
  - Job creation, termination

Scheduling Goals

- Goals
  - Maximize CPU utilization
  - Maximize job throughput
  - Minimize turnaround time
  - Minimize waiting time
  - Minimize response time

- Different systems have different goals

- What is the goal of a batch system?

- What is the goal of an interactive system?

Starvation

- Starvation
  - Indefinite denial of a resource (CPU, lock)

- Causes
  - Side effect of scheduling
  - Side effect of synchronization

- Operating systems try to prevent starvation

Scheduling Algorithms

- What are the properties, advantages and disadvantages of the following scheduling algorithms?
  - First Come First Serve (FCFS)/First In First Out (FIFO)
  - Shortest Job First (SJF)
  - Priority
  - Round Robin
  - Multilevel feedback queues

- What scheduling algorithm does Unix use? Why?

Deadlock

- Deadlock happens when processes are waiting on each other and cannot make progress

- What are the conditions for deadlock?
  - Mutual exclusion
  - Hold and wait
  - No preemption
  - Circular wait

- How to visualize, represent abstractly?
  - Resource allocation graph (RAG)

Deadlock Approaches

- Dealing with deadlock
  - Ignore it (Ostrich algorithm)
  - Prevent it (prevent one of the four conditions)
  - Avoid it (have tight control over resource allocation)
  - Detect and recover from it

- What is the Banker's algorithm?
  - Which of the four approaches above does it implement?

Memory Management

- Why is memory management useful?
  - Why do we have virtual memory if it is so complex?

- What are the mechanisms for implementing MM?
  - Physical and virtual addressing
  - Partitioning, paging, and segmentation
  - Page tables, TLB

- What are the policies related to MM?
  - Page replacement

- What are the overheads related to providing memory management?

Virtualizing Memory

- What is the difference between a physical and virtual address?

- What is the difference between fixed and variable partitioning?
  - How do base and limit registers work?

- What is internal fragmentation?

- What is external fragmentation?

- What is a protection fault?

Paging

- How is paging different from partitioning?

- What are the advantages/disadvantages of paging?

- What are page tables?

- What are page table entries (PTE)?

- Know these terms
  - Virtual page number (VPN), page frame number (PFN), offset

- Know how to break down virtual addresses into page numbers, offset

- How have you implemented paging in OS161?

Page Table Entries

- What is a page table entry?

- What are all of the PTE bits used for?
  - Modify
  - Reference
  - Valid
  - Protection

Segmentation

- What is segmentation?

- How does it compare/contrast with paging?

- What are its advantages/disadvantages with respect to partitioning, paging?

- What is a segment table?

- How can paging and segmentation be combined?

Page Tables

- Page tables introduce overhead
  - Space for storing them
  - Time to use them for translation

- What techniques can be used to reduce their overhead?

- How do two-level (multi-level) page tables work?

TLBs

- What problem does the TLB solve?

- How do TLBs work?

- Why are TLBs effective?

- How are TLBs managed?
  - What happens on a TLB miss fault?

- What is the difference between a hardware and software managed TLB?

Page Faults

- What is a page fault?

- How is it used to implement demand paged virtual memory?

- What is the complete sequence of steps, from a TLB miss to paging in from disk, for translating a virtual address to a physical address?

Advanced Mem Management

- What is shared memory?

- What is copy on write?

- What are memory mapped files?

Page Replacement

- What is the purpose of the page replacement algorithm?

- What application behavior does page replacement try to exploit?

- When is the page replacement algorithm used?

- Understand
  - Belady's (optimal), FIFO, LRU, Approximate LRU, LRU Clock, Working Set

- What is thrashing?

Disk

- Understand the memory hierarchy concept, locality

- Physical disk structure
  - Platters, surfaces, tracks, sectors, cylinders, arms, heads

- Disk interface
  - How does the OS make requests to the disk?

- Disk performance
  - What steps determine disk request performance?
  - What are seek, rotation, transfer?

File Systems

- Topics
  - Files
  - Directories
  - Sharing
  - Protection
  - Layouts
  - Buffer Cache

- What is a file system?

- Why are file systems useful (why do we have them)?

Files and Directories

- What is a file?
  - What operations are supported?
  - What characteristics do they have?
  - What are file access methods?

- What is a directory?
  - What are they used for?
  - How are the implemented?
  - What is a directory entry?

- How are directories used to do path name translation?

File System Layouts

- What are file system layouts used for?

- What are the general strategies?
  - Contiguous, linked, indexed?

- What are the tradeoffs for those strategies?

- How do those strategies reflect file access methods?

- What is an inode?
  - How are inodes different from directories?
  - How are inodes and directories used to do path resolution, find files?

File Buffer Cache

- What is the file buffer cache, and why do operating systems use one?

- What is the difference between caching reads and caching writes?

- What are the tradeoffs of using memory for a file buffer cache vs. VM?

Final words on the lab

- One of the hardest lab you do in your undergraduate years
  - But if you survived it, your programming & hacking capabilities have significant improvements
  - OS: one of the hardest program to write & debug
  - Debug concurrent programs, user- AND kernel space, low-level hardware, interrupts and exceptions, assembly, etc.
  - Hack into a large, unfamiliar code base and implement additional features
  - Work as a team
  - Using version control systems
  - etc.

- I am very very proud of you!

Summary

- Now you understand how a computer works internally
  - More importantly, you had your hands dirty and implemented one
  - If you found such 'hand-dirty' experience interesting:
    - Take my ECE 454 course in Fall
    - Consider doing a Master with me

- Any remaining questions?

The End

- Congratulations on surviving ECE 344!
  - It's a very challenging course, but I hope you found it worthwhile

- Final take-away:
  - Facing a hard problem, analyze it, design and implement the most appropriate solution

- Good luck, and thanks for a great class!
  - It's my first teaching experience and thanks for making it so enjoyable!