CS 6210: Advanced Operating Systems

(Fall 2013)

- Instructor: Prof.Karsten Schwan(schwan@cc.gatech.edu)
- Office Hours: TBD
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- TA Office Hours: TBD

Prerequisites

- CS2200 or equivalent undergraduate OS course. It should have covered much of *Operating Systems Concepts,* Silberschatz and Galvin (or equivalent).
- Good knowledge of Unix and C programming.
- CS3210 a strongly suggested, though currently not required, prerequisite.
- **Students without adequate background should consider first taking CS 3210.**

Grading

- 10% class participation 35% projects 25% midterm 30% final.
- A passing grade is required in each of the above components in order to pass the class.

Projects

This course is project intensive and will have a sequence of four or five projects. Strong C programming skills are absolutely essential for completing these projects (Java skills are insufficient). Students can either do the entire sequence of assigned projects or they can choose to define a project that fits more closely with their individual research goals as a replacement of the regular class projects after the first one. Projects are designed for groups of 2 students, but the first project is to be completed individually by everyone.

Facilities

Each student in the class will have access to virtual machines on our instructional machine cluster, with additional facilities access made available to special projects, as needed (please talk with the instructor). Additional information regarding project resources will be provided on the class mailing list and with individual project assignments. It is useful to subscribe to the cercs-seminar mailing list, where students can find out about invited lectures in the systems area, and about internship and other opportunities. Finally, if you do not have a CoC account, please apply as soon as possible, as you will need it for class projects!

Collaboration

Plagiarism: In most cases we expect all code that you submit was written by you. All source code, images and write ups you provide should have been created by you alone.

What is allowed: Meeting with other students to discuss implementation issues. You should talk about solutions at the pseudo code level. Sharing snippets of code to solve specific (small) problems. In this case the shared code should be no more than 5 lines. Searching the web for other solution outlines that you may draw on (but not copy directly). If you are inspired by a solution on the web, you MUST cite that code with comments in your code.

What is not allowed: Copying sections of code longer than 5 lines. Note that merely changing variable names does not suffice. Copying code from the web. Use of ideas from the web that are not cited in comments.

Syllabus

Optional supplementary reference texts include the following:

- *Operating Systems Concepts* , Silberschatz and Galvin. 'Dinosaur Book'.
- *OS: Advanced Concepts*, Maekawa, Oldehoeft. Addison-Wesley.
- *Distributed Systems*, Sape Mullender, Addison-Wesley.
- *Distributed Operating Systems* , Andrew S. Tanenbaum, Prentice Hall.
- *An Introduction to Programming with Threads* , Andrew Burrell.
- *Multithreaded Programming with Pthreads* , Chapter 4, Bil Lewis, Daniel J. Berg.

The Class Reading List

Click the title if you want to download the paper.

OS Structures

1. Dawson R. Engler, Frans Kaashoek and James O'Toole, "Exokernel: An Operating System Architecture for Application-Level Resource Management ", Proceedings of the 15th ACM Symposium on Operating System Principles, ACM, December 1995.
2. Brian Bershad et al., " Extensibility, Safety and Performance in the SPIN Operating System ", Proceedings of the 15th ACM Symposium on Operating System Principles, December 1995.
3. J. Liedtke, " On Micro-Kernel Construction ", Proceedings of the 15th ACM Symposium on Operating System Principles, ACM, December 1995.
4. Paul Barham, Boris Dragovic, Keir Fraser, Steven Hand, Tim Harris, Alex Ho, Rolf Neugebauer, Ian Pratt, Andrew Warfield, "Xen and the Art of Virtualization", SOSP 2003.

5. Carl Waldspurger, "Memory Resource Management in VMware ESX Server", OSDI, 2002.

Shared Memory/Server Platforms:

1. Mellor-Crummey, J. M. and Scott, M., "Algorithms for Scalable Synchronization on Shared-Memory Multiprocessors ", ACM Transactions on Computer Systems, Feb. 1991.
2. *Partial reading*: Paul E. Mckenney and John D. Slingwine. "Read-Copy Update: Using Execution History to Solve Concurrency Problems", Parallel and Distributed Computing and Systems, Oct 1998.
3. Ben Gamsa, Orran Krieger, Jonathan Appavoo, and Michael Stumm, "Tornado: Maximizing Locality and Concurrency in a Shared Memory Multiprocessor Operating System" , 1999 Symposium on Operating System Design and Implementation (OSDI).
4. Kinshuk Govil, Dan Teodosiu, Yongqiang Huang, and Mendel Rosenblum. "Cellular Disco: resource management using virtual clusters on shared-memory multiprocessors",17th Symposium on Operating Systems Principles (SOSP), 1999.
5. *Partial reading*: M.S. Squillante and E.D. Lazowska, " Using Processor-Cache Affinity Information in Shared Memory Multiprocessor Scheduling ", IEEE Transactions on Parallel and Distributed Systems, Feb. 1993, pgs. 131-143.
6. Alexandra Fedorova, Margo Seltzer, Christopher Small and Daniel Nussbaum. "Performance of Multithreaded Chip Multiprocessors and Implications for Operating System Design", Usenix Annual Technical Conference, 2005.
7. Ripal Nathuji and Karsten Schwan. "Virtual Power: Coordinated Power Management in Virtualized Enterprise Systems ", Symposium on Operating Systems Principles (SOSP), Oct. 2007.

Communication Mechanisms, Interfaces, and Protocols

Partial reading : Schroeder, M., and Burrows, M., " Performance of the Firefly RPC", Proceedings of the Twelfth ACM Symposium on Operating Systems Principles (SOSP), December 1989.

1. B. N. Bershad, T. E. Anderson, E. D. Lazowska, and H. M. Levy, "Lightweight Remote Procedure Call ", ACM Transactions on Computer Systems, 8(1):37--55, Feb. 1990.
2. C.A. Thekkath and H.M. Levy, "Limits to Low-Latency Communications on High-Speed Networks ", ACM Transactions on Computer Systems, May 1993.
3. Hutchinson N.C., Peterson, L.L., " The x-Kernel: An Architecture for Implementing Network Protocols ", IEEE Transactions on Software Engineering, 17, 1, pgs. 64-76, January 1991.
4. David Wetherall, "Active Networks: Vision and Reality: Lessons from a Capsule-based System ", 17th ACM Symposium on Operating System Principles (SOSP), OS Review, Volume 33, Number 5, Dec. 1999.
5. Liu, Kreitz, van Renesse, Hickey, Hayden, Birman, Constable, "Building Reliable High Performance Communication Systems from Components ", 17th

ACM Symposium on Operating System Principles, OS Review, Volume 33, Number 5, Dec. 1999.

Distributed Platforms:

Concepts

1. Lamport, L., " Time, Clocks, and the Ordering of Events in a Distributed System ", Communications of the ACM, 21, 7, pgs. 558-565, July 1978.

File Systems and Distributed Shared Memory

1. *Partial reading:* Mahadev Satyanarayanan, "Coda: A Highly Available File System for a Distributed Workstation Environment", IEEE Trans. Computers, vol 39, no 4, Apr 1990
2. Anderson, T. et all., " Serverless Network File System ", ACM Transactions on Computer Systems, February 1996.
3. Feeley, Morgan, Pighin, Karlin, Levy, Thekkath,, "Implementing Global Memory Management in a Workstation Cluster ", Fifteenth ACM Symposium on Operating System Principles (SOSP), Dec. 1995.
4. C. Amza, A. Cox, S Dwarkadas, P Keleher, H Lu, R. Rajamony, W. Yu and W. Zwaenepoel, " TreadMarks: Shared Memory Computing on Networks of Workstations " IEEE Computer, February, 1996.

Failures, Consistency, and Recovery

1. R. Haskin et. al., "Recovery Management in QuickSilver ", ACM Transactions on Computer Systems, February 1988.(**skipped**)
2. Satyanarayanan, M., et al., "Lightweight Recoverable Virtual Memory ", The Proceedings of Fourteenth ACM Symposium on Operating System Principles (SOSP), pgs. 146-160, December 1993.
3. J. N. Gray, P. McJones, M. W. Blasgen, R. A. Lorie, T. G. Price, G. R. Putzolu, and I. L. Traiger. " The Recovery Manager of a Data Management System ", ACM Computing Surveys, Vol. 13, No. 2, June 1981, pp. 223-242.
4. D. Porter, O. Hofmann, C. Rossbach, A. Benn, E. Witchel, "Operating System Transactions", SOSP'09.

Object-based Distributed Systems and Protection

1. Mitchell, J. G., et al., " An Overview of the Spring System ", Proceedings of CompCon, Feb. 1994.
2. Hamilton, G., Powell, M.L., and Mitchell, J.J., "Subcontract: A Flexible Base for Distributed Programming ", Proceedings of the Fourteenth ACM SOSP, pgs. 69-79, December 1993.
3. Wollrath, A., Riggs, R., and Waldo, J., "A Distributed Object Model for the Java System ", Usenix Conference on Object Oriented Technologies and Systems, May 1996.
4. Emmanuel Cecchet, Julie Marguerite, Willy Zwaenepoel, "Performance and Scalability of EJB Applications", Proceedings of the 17th ACM SIGPLAN

conference on Object-oriented programming, systems, languages, and applications.

5. Nov. 24 Cohen, E., and Jefferson, D., "Protection in the HYDRA Operating System ", Proceedings of Fifth ACM Symposium on Operating System Principles, pgs. 141-160, 1975.
6. S. Tang, H. Mai, S. King, "Trust and Protection in the Illinois Browser Operating System", OSDI'10.
7. *Reference:* Helen J. Wang, Xiaofeng Fan, Jon Howell, Collin Jackson, " Protection and Communication Abstractions for Web Browsers in MashupOS ", ACM Symposium on Operating System Principles, 2007.

Real-time and Multimedia Systems

1. Shahabi, Zimmermann, Fu, and Yao. "Yima: A Second-Generation Continuous Media Server ", IEEE Computer Magazine, June 2002.
2. Ashvin Goel, Luca Abeni, Charles Krasic, Jim Snow, Jonathan Walpole, "Supporting Time-Sensitive Applications on a Commodity OS", OSDI 2002.
3. T. Broomhead, L. Cremean, J. Ridoux, D. Veitch, "Virtualize Everything but Time", OSDI'10.

Web Services and their Properties

1. *Reference:* Luis Andre Barroso, Jeffrey Dean, Urs Holzle, "Web Search for a Planet: The Google Cluster Architecture", IEEE Micro.
2. Armando Fox, Steven Gribble, Yatin Chawathe, Eric Brewer, and Paul Gauthier, "Cluster-based Scalable Network Services", Sixteenth ACM Symposium on Operating System Principles, Oct. 1997.
3. Saito, Bershad, Levy, "Manageability, Availability, and Performance in Porcupine: A Highly Scalable Cluster-based Mail Service", 17th ACM Symposium on Operating System Principles, OS Review, Volume 33, Number 5, Dec. 1999.
4. *Partial reading:* Eric A. Brewer, "Lessons from Giant-Scale Services ", IEEE Internet Computing.
5. G. DeCandia, D. Hastorun, et. al., "Dynamo: Amazon's Highly Available Key-value Store", SOSP'07.
6. M. Zaharia, A. Konwinski, A. Joseph, R. Katz, I. Stoica, "Improving MapReduce Performance in Heterogeneous Environments", OSDI'08.
7. D. Beaver, S. Kumar, H. C. Li, J. Sobel, P. Vajgel, "Finding a Needle in Haystack: Facebook's Photo Storage", OSDI'10.
8. D. Peng, F. Dabek, "Large-scale Incremental Processing Using Distributed Transactions and Notifications", OSDI'10

New Directions

1. A. Baumann, P. Barham, et al., "The Multikernel: A new OS architecture for scalable multicore systems", SOSP'09.
2. S. Boyd-Wickizer, H. Chen, R. Chen, Y. Mao, F. Kaashoek, et. al, "Corey: An Operating System for Many Cores", OSDI 2008.

Learning Outcomes

After mastering this class, students should have acquired solid knowledge about the principles and practice of operating systems, their development, and their implementation. This includes knowledge about OS structures, multicore and multi-process operating systems, distributed operating systems, middleware like that realized by Java virtual machines, datacenter systems like those run by large web companies, and distributed systems, as when multiple datacenters are used to satisfy world-wide customer demand. The class also touches upon real-time and multi-media systems, but leaves details of those concepts to another course. The class teaches about protection and isolation, but leaves more advanced security concepts to other classes. Finally, more advanced and theoretical concepts in distributed systems are taught in a follow-up course.