Kernel Assignments

CS 256/456
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Introduction to Nachos: Our Objective

- Provide a basic understanding of the structure of Nachos
  - not a replacement of your own practice and learning
- Learn design rationale for Nachos
  - you are welcome to suggest improvements to the assignments
- Jump start you on Programming Assignment #3

Motivation for Nachos

- Motivation: need good projects for teaching operating systems
- Assignments so far are all at user level
  - OK with understanding OS concepts
  - Not real OS development experience
- Develop an OS from scratch on a real hardware (e.g., Intel IA32)
  - Real hardware is too complex to work with
  - Very hard to support even the most basic user programs
- Making enhancement/adjustment of an existing OS (e.g., Linux)
  - Modern OSes are too complex to understand
  - Not complete view about OS development
- Nachos is a toolkit for teaching operating systems; not an operating system itself

Overall Nachos Structure
Nachos Kernel and User Programs

- The Nachos kernel runs directly as a user program on the host machine.
  - Kernel code written in C++.
- User programs run on the Nachos kernel and the simulated hardware (with a MIPS CPU).
- User programs access simulated I/O devices through Nachos syscalls.
- User programs written in a stripped-down C, compiled into MIPS executables.

Simulated Nachos Hardware

- Simulated MIPS CPU
  - A MIPS instruction interpreter
- Simulated memory
  - Basically an array of words
- Simulated I/O devices
  - Console terminal
  - Disk
  - Timer
  - Network interface

Nachos as An Instructional Tool

- The Nachos toolkit contains:
  - The simulated hardware (MIPS CPU, memory, I/O devices)
  - A cross-compiler/linker that compiles your C user programs into Nachos executables
    - instructions are in MIPS
    - the segment layout and header format can be recognized by the Nachos kernel
  - A skeleton OS kernel supporting
    - a single system call: halt
    - limited synchronization primitives
    - running a single user program at a time
    - no inter-process communication
- Your job is to augment the OS step by step
  - don’t touch the simulated hardware
  - shouldn’t need to touch the compiler

The Most Common Confusion

- Nachos kernel and Nachos user programs do not run on the same machine (real or virtual)
- Implications:
  - they don’t run on the same CPU (real or virtual)
  - they don’t share the same memory (real or virtual)
- This is a big weakness
  - why not let Nachos kernel run on the simulated hardware?
  - the projects become too challenging
  - a pain to develop code on the simulated hardware, e.g., can’t run gdb
Nachos Assignments

Start from a given skeleton OS, filling the missing pieces step by step
- Assignment #3: threads and synchronization
- Assignment #4: supporting multiple user programs
- Assignment #5: virtual memory
- Assignment #6: file system and disk scheduling

Assignment #3: Threads and Synchronization

- Become familiar with Nachos and the behavior of a working (but incomplete) thread system
- Use what is supplied to study concurrent programming
- Threads you use for this assignment are:
  - Nachos threads in kernel
  - user-level threads from the host machine's perspective
- Synchronization primitives are used for synchronization between Nachos threads in kernel

Learning about Nachos

- You cannot learn all about software systems from textbooks
  - read the source code for systems that other people have written
- For Nachos:
  - it is not sufficient to just read the textbook, lectures, and information on the assignment Web pages
  - read over the Nachos source code
  - try to understand where the various pieces of the system live, and how they fit together
- It will take a while to develop an understanding. Start early and be patient!

Traversing the Nachos Files

- starting from the Makefiles
  - threads/
    - support threads and synchronization
    - the threads support is fully functional, though some of the synchronization primitives have not been implemented.
  - userprog/
    - support the loading and execution of user programs
    - basic memory management
  - vm/
    - virtual memory subsystem
Traversing the Nachos Files

- `test/`
  - some simple Nachos user programs
  - `Makefile` for compiling these programs and converting them to NOFF
- `machine/`
  - support machine simulation.
  - You need to read some header files to know how to access the simulated machine.
  - It might also be instructive to look at the implementation of the machine simulation.
  - But you shouldn’t have to modify anything here.

Administrative Issues

- `group assignments`
  - group of two
  - don’t form the same group for all four assignments
- `C/C++ programming`
  - high-level languages (e.g., Java, perl) are not suitable for operating system development
- `recommendations:`
  - start early
  - take full advantage of TA’s office hours (TA is Jonathan Pearson)

An Alternative Assignment Track

- Nachos-based assignments:
  - Nachos is specifically designed for OS course projects.
  - The kernels you develop on it are not “real”.
- Xen-based assignments
  - Xen, on the other hand, is a “true” virtual machine.
  - You will be working with slightly modified Linux on it.

- Why not choose Xen assignments?
  - More realistic, but much more challenging (the Nachos assignments will be challenging enough).
  - Not able to develop a whole-system understanding as you might for Nachos assignments.
  - We are the first to introduce the Xen assignments so there might be problems and you need to be very patient with us.

Xen: An “True” Virtual Machine

- Real operating systems (with slight modifications) can run on Xen.
  - we use a modified Linux 2.6.10
- For Xen assignments:
  - you will spend most of your time reading, understanding the Linux code.
  - and you will also spend a lot of time on Linux administration.
  - even debugging becomes very challenging.
  - you will get help from us, but you are expected to figure out lots of things on your own.
Xen Assignments

Make adjustment to a fully functional kernel
- Assignment #3: write a system call
- Assignment #4: threads and synchronization
- Assignment #5: CPU scheduling
- Assignment #6: memory management

Administrative Issues

- group assignments
  - group of two
  - don’t form the same group for all four assignments
- C programming
  - you program the same way that the Linux kernel does
- TA is Pin Lu
- approval ahead of time for choosing Xen assignments
  - email the TA and me today or tomorrow
  - we need to set up accounts, assign IP addresses, …, for you
- grading is done through interview with the TA

What Are Other Schools Doing?

- Most do Nachos-based assignments
  - Berkeley, Washington, Duke, …

- Improved Nachos where the kernel runs (along with user programs) on the instructional virtual machine
  - Harvard

- Some have assignments through modifying the Linux kernel on real virtual machines (mostly VMware)
  - Columbia, Washington

- The most challenging is to develop a workable OS (not as complete as Linux) from scratch
  - Princeton