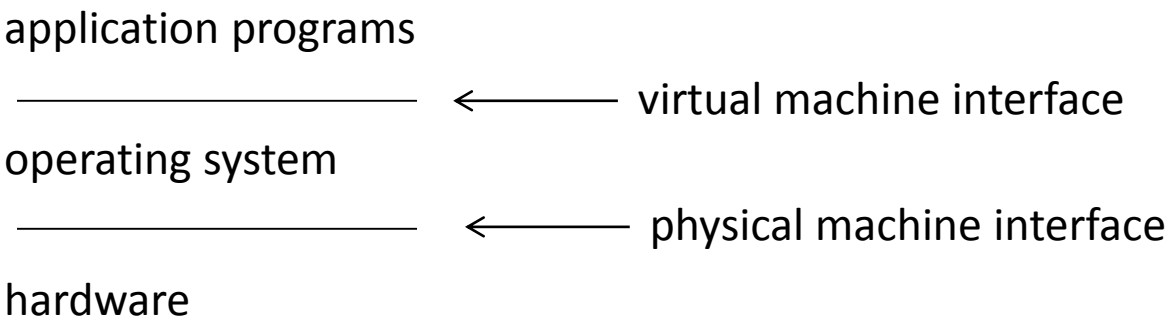
Case studies

- EECS 482: Introduction to operating systems **principles**
  - Abstraction
  - Management of shared resources
  - Indirection
  - Concurrency
  - Atomicity
  - Protection
  - Naming
  - Security
  - Reliability
  - Scheduling
  - Fairness
  - Performance

Two case studies

- Virtual machines (e.g., VMware)
  - Software layer below the operating system
- Web browsers (e.g., Google Chrome)
  - Software layer above the operating system

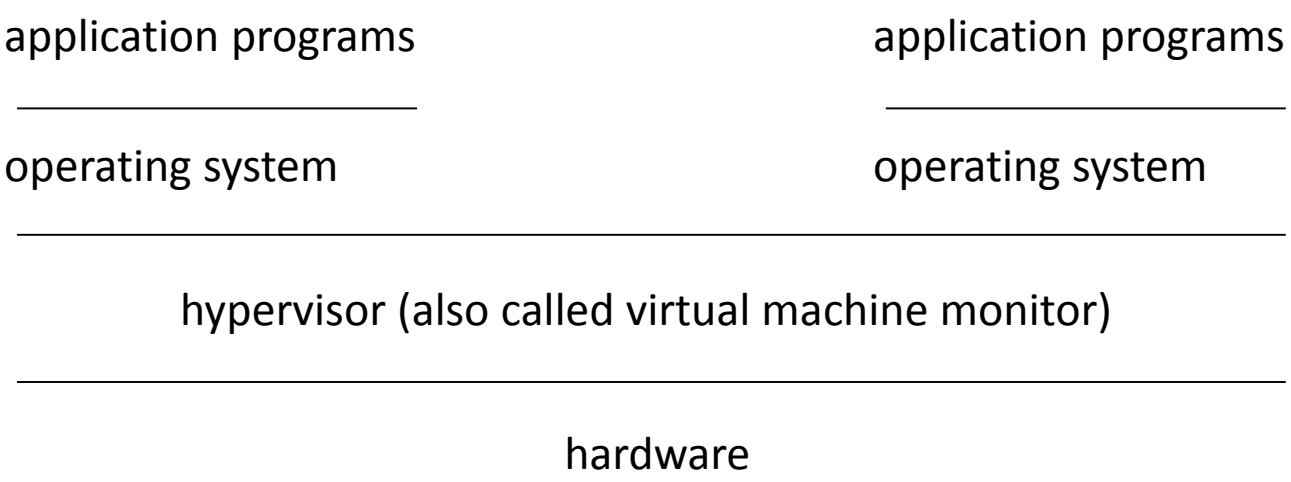
Virtual machines (e.g., VMware)



- Operating systems manage the computer and provide abstractions for application programs
- But who manages the computer and provides abstractions for the operating system?

What type of management or abstractions does an operating system need?

System structure with virtual machines



- How does this work?

Operating system virtualizes the computer for applications

- OS could intercept and simulate each instruction
  - E.g., simulate each load/store, translate virtual address to physical address (similar to vm_syslog)
  - Slow
- Instead, OS allows most instructions to run directly on the hardware
  - Requires hardware support (MMU)
- Not all instructions can run directly on the hardware
  - Some instructions are privileged (e.g., I/O instructions)
  - Privileged instructions should trap to the OS. OS can then kill the (usually misbehaving) application.

Hypervisor virtualizes the computer for operating systems

- Hypervisor could do this by intercepting and simulating each instruction
  - E.g., hypervisor wants to partition 2 GB physical memory into two 1 GB partitions
  - OS #2 issues what it thinks is a physical memory address. Hypervisor intercepts and translates by adding 1 GB to address
  - Slow
- Instead, hypervisor lets most instructions pass through and run directly on the hardware
- How should hypervisor handle privileged instructions issued by OS?

OS virtualization vs. hypervisor virtualization

- Compatibility
  - Hypervisor tries to provide backward compatibility for operating systems that normally run directly on hardware
  - OS doesn't need to support applications that run directly on hardware

- Abstractions
  - Hypervisor is trying to provide the illusion (to operating systems) of running directly on the hardware
  - OS is trying to provide the illusion of running on a different (nicer) computer
    - E.g., threads are nicer than processors
    - E.g., file systems are nicer than disks

Complication #1: x86 is not classically virtualizable

- Run OS in user mode, but make it look (to the OS) like it's running in kernel mode, directly on the hardware
- All instructions that behave differently in user mode and kernel mode should fault to the hypervisor, so the hypervisor can simulate running directly on the hardware

- Unfortunately, some x86 instructions behave differently in user and kernel mode, but do NOT fault when run in kernel mode
- How to handle this?

Complication #2: need multiple levels of memory translation

- Operating system uses MMU to translate from virtual address to "physical" memory
- Hypervisor would like to use MMU to translate from the OS's "physical memory" to the real physical memory (sometimes called "machine memory")
- Would like two levels of translation: virtual -> physical -> machine
- How to provide multiple levels of translation?

Do we need both hypervisors and operating systems?

- Hypervisor does partitioning; OS handles abstractions?

Google Chrome

- http://www.google.com/googlebooks/chrome
- What's a web browser?
  - An important application
  - An environment for displaying and running web pages
- A browser hosts web pages, just like an operating system hosts applications
- Important properties for browsers
  - Stability
  - Speed
  - Security

Concurrency

- Early browsers were single threaded
  - Asynchronous ➔ inconvenient
  - Blocking ➔ unsafe
- Using multiple threads allows the browser to be convenient (use blocking interface) and safe (single thread can't hang the system)
- Multi-threaded versus multi-process
  - What's the difference?

  - What are the implications of each window having its own address space?

Chrome processes

- Chrome process manager
  - Process manager == operating system
- Process isolation
  - Separate processes ➔ separate threads
  - One thread can block without blocking other threads
  - Can kill one tab without killing other tabs
  - What kind of bugs are they worried about?
  - Do they survive all bugs?

Memory management

- Creating a new process costs more than creating a new thread
  - But Google claims that using processes leads to less memory bloat
- One address space for entire browser
  - Ideally, closing a tab frees all memory for that tab
  - But not all memory is cleaned up when a tab closes ➔ fragmentation
  - Why is this a problem?

- One address space per browser window
  - Destroying entire process guarantees that you free all memory for that process
  - Takes advantage of the fact that windows are relatively independent
- Memory manager == operating system

Security

- Assume browser will be compromised. How to limit damage?
- Sandboxing
  - Principle of least privilege
  - Browser process can do only a few things, e.g., display to screen, respond to user communication
- Google writes browser to work with low privilege. But not all browser code is written by Google.
  - Similarly, operating systems must support third-party software (extensions), e.g., device drivers
  - Plugins run at same privilege level as main Chrome process
  - Main Chrome process is like the operating system
  - Renderer processes are like application processes
- How to protect against bad plugins
  - Rewrite to work with low privilege
  - Separate plugin process from renderer process. Similar to microkernel with multiple server processes

Phishing

- Google Chrome monitors web pages for URLs that are known to be bad
  - Similar to virus scanning

Google Gears

- Browser plugin that provides an API (application programming interface) for web pages
- Similarly, operating systems provide an API (system calls) for application programs

Testing

- Chrome Bot (Google's autograder)
- Test early; test often
- Test case design
  - Prioritize testing of popular web pages
  - Unit tests (micro test cases)
  - Macro test cases, e.g., random input (fuzz testing)

- Other topics
  - Dynamic code generation for Javascript. Not an issue for operating systems, since they usually don't virtualize the instruction set (the compiler does that)