COS 318: Operating Systems

Introduction

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http://www.cs.princeton.edu/courses/archive/fall11/cos318/

Today

- Course staff and logistics
- What is an operating system?
- Evolution of computing and operating systems
- Why study operating systems?

Course Staff and Logistics

Instructor

- Prof. Margaret Martonosi, 204 CS Building,

  mrm@cs.princeton.edu

  Office hours: Tue 3-5pm
- Prof. Vivek Pai, CS322

  vivek@cs.princeton.edu

  Office hours: Thu 3-5pm

Teaching Assistants

- Mark Browning, mrbrowni@princeton.edu
  - Office Hours: Mon 12:30-2:30pm
- Xianmin (Sam) Chen, xianminc@princeton.edu
  - Office Hours: Fri 10am-12pm
- Srinivas Narayana, narayana@princeton.edu
  - Office Hours: Fri 2-4pm.
- All TA Office hours are in the “Fishbowl”: Friend 010

What you will learn

- What an OS does. What services are provided, what functions are performed, what resources are managed, and what interfaces and abstractions are supported.
- How the OS is implemented. How the code is structured. What algorithms are used.
- Techniques, skills, and "systems intuition" (e.g., concurrent programming).
- Peeks at current research topics.

COS318 in Systems Course Sequence

- Prerequisites
  - COS 217: Introduction to Programming Systems
  - COS 226: Algorithms and Data Structures
- 300-400 courses in systems
  - **COS318: Operating Systems**
  - COS320: Compiler Techniques
  - COS333: Advanced Programming Techniques
  - COS425: Database Systems
  - COS471: Computer Architecture
- Courses needing COS318
  - COS 461: Computer Networks
  - COS 518: Advanced Operating Systems
  - COS 561: Advanced Computer Networks

Information & where to get it!

- Website
  - http://www.cs.princeton.edu/courses/archive/fall11/cos318/
  - Materials will go here: projects, schedule, lecture/precept slides…
  - ~0 paper handouts!
- Textbook:
  - *Modern Operating Systems*, 3rd Edition, Andrew S. Tanenbaum
  - Keep up with readings!
- Questions about coursework, logistics, projects, etc: Enroll in Piazza

  http://www.piazza.com/princeton/fall2011/cos318

Besides Lecture

- Regular precept
  - Time: Tuesday 7:30pm – 8:30pm
  - Location: default is this room, CS 105
- First precept: Tues Sep 20
  - Will cover a bit of x86 assembler review in addition to project-specific topics.
- Project 1 Design review
  - Monday Sep. 26, 6pm -- 9pm
  - Sign up online (1 slot per team)
  - Project 1 deadline: Oct 5

Exams, Participation and Grading

- Grading
  - First 5 projects: 45% with extra points
  - Midterm: 15%
  - Final Exam: 15%
  - Final project: 15%
  - Reading & participation: 10%
- Midterm and Final Exam
  - Test lecture materials and projects
  - Midterm: Thursday of midterm week, Oct 27
- Reading and participation
  - Do your reading BEFORE each lecture
  - Occasional quizzes just to check on this.

The Projects

- Projects
  1. Bootup
  2. Non-preemptive kernel
  3. Preemptive kernel
  4. Interprocess communication and driver
  5. Virtual Memory
  6. File Systems
- How
  - Pair up with a partner for projects 1,2,3
  - Different partner for 4,5
  - On your own for #6
  - Each project takes 2-3 weeks
  - Design review at the end of week one
  - All projects due Wednesdays at NOON!
- The Lab aka “The Fishbowl”
  - Linux cluster in 010 Friend Center, a good place to be
  - You can setup your own Linux PC to do projects

Project Grading

- Design Review
  - Signup online for appointments
  - 10 minutes with the TA in charge
  - 0-5 points for each design review
  - 10% deduction for missing the appointment
- Project completion
  - 10 points for each project
- Late policy of grading projects
  - 1 hour: 98.6%, 6 hours: 92%, 1 day: 71.7%
  - 3 days: 36.8%, 7 days: 9.7%

Why Piazza?

- Instructors' Goal: Want to view this course as a learning community, where we all contribute to asking and answering questions.
  - Piazza helps provide a forum for this.
- Easier for students to answer each other's questions
- Easier for one of us (2 profs + 3 TAs) to see and answer questions (or endorse your answers) in a timely manner.
- Please use it instead of email, unless the question is of a personal/private nature.

Ethics and other issues

- **Do not put your code or designs or thoughts on the Web**
  - Other schools are using similar projects
  - Not even on Facebook or the like
- **Follow Honor System**: ask when unsure, cooperation OK but work is your own (or in pairs for projects)

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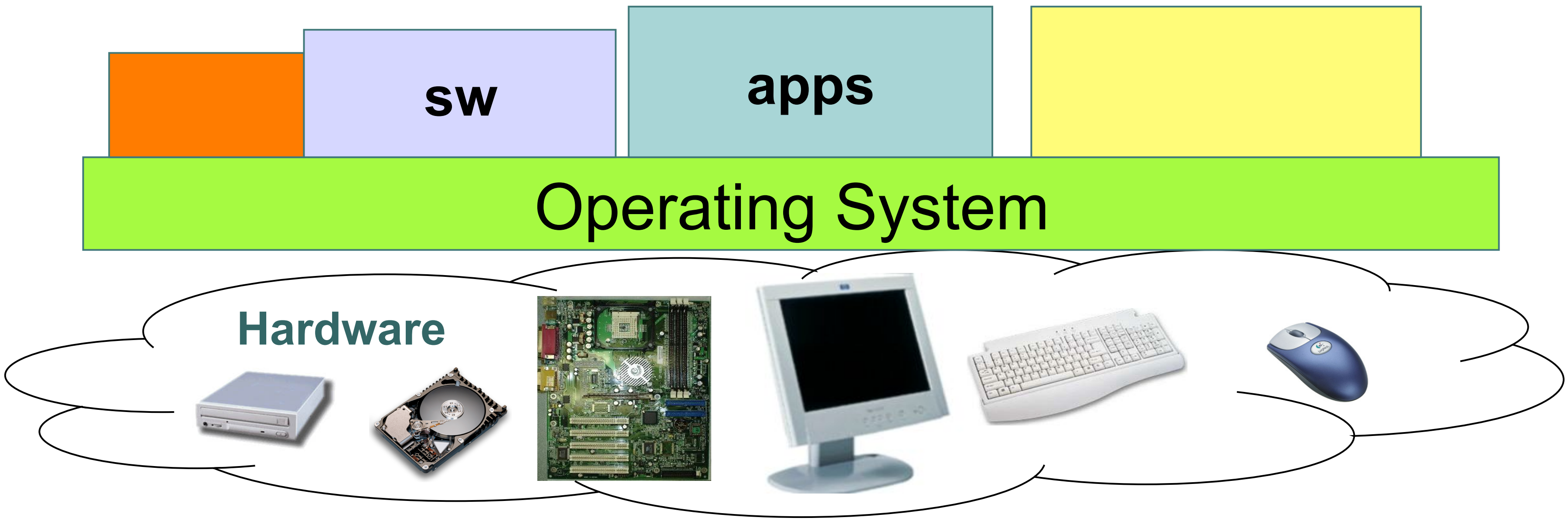
Let's begin at the beginning…

- When you write a program, what happens?

Managing and Abstracting Hardware Resources



- Hardware to manage: CPU, Primary memory, Secondary memory devices (disk, tapes), Networks, Input devices (keyboard, mouse, camera), Output devices (printers, display, speakers)

Resources to manage:

- CPU Cycles
- Network and memory bandwidth
- Energy / battery-life (mobile)
- …

What is an OS?

- Resource Manager of physical (HW) devices ...
- Abstract machine environment. The OS defines a set of logical resources (objects) and operations on those objects (an interface on the use of those objects).
- Allows sharing of resources. Controls interactions among different users.
- Privileged, protected software - the kernel. Different kind of relationship between OS and user code (entry via system calls, interrupts).

- Birthplace of system design principles!
  e.g., Separation of Policy and Mechanism.

What Does an Operating System Do?

- Provides a *layer of abstraction* for hardware resources
  - Allows user programs to deal with higher-level, simpler, and more portable concepts than the raw hardware
    - E.g., files rather than disk blocks
  - Makes finite resources seem “infinite”
- Manages the resources
  - Manage complex resources and their interactions for an application
  - Allow multiple applications to share resources without hurting one another
  - Allow multiple users to share resources without hurting one another

How to Mitigate Complexity? Abstraction!

- Hide underlying details, and provide cleaner, easier-to-use, more elegant concepts and interfaces
  - Also provides standardized interfaces despite diversity of implementation underneath
- Key CS principle
- Key to understanding Operating Systems

Examples

- Threads or Processes (Fork)
- Address spaces (Allocate)
- Files (Open, Close, Read, Write)
- Network Messages (Send, Receive)

One Abstraction Example: Disk

Disk hw and operations are very complex

- Multiple heads, cylinders, sectors, segments
- Wait for physical movement before read or write
- Data stored discontiguously
- Sizes, speeds vary on different computers
- IT WOULD BE HORRIBLE TO WRITE CODE SPECIALIZED FOR EACH DISK!

- OS provides simple read () and write() calls as the API
  - Manages the complexity transparently, in conjunction with the disk controller hardware
  - Such I/O abstractions have outlived several storage technologies!

Resource Management

4 sub-issues:

- Resource Allocation
- Resource Virtualization
- Resource Reclamation
- Resource Protection

Resource Allocation

- Computer has finite resources
- Different applications and users compete for them
- OS dynamically manages which applications get how many resources
- *Multiplex* resources in space and time
  - Time multiplexing: CPU, network
  - Space multiplexing: disk, memory

- E.g., what if an application runs an infinite loop?

```
while (1);
```

Resource Virtualization

- OS gives each program the illusion of effectively infinite, private resources
  - “infinite” memory (by backing up to disk)
  - CPU (by time-sharing)

Resource Reclamation

- The OS giveth, and the OS taketh away
  - Voluntary or involuntary at runtime
  - Implied at program termination
  - Cooperative

Protection

- You can’t hurt me, I can’t hurt you
- OS provides safety and security
- Protects programs and their data from one another, as well as users from one another
- E.g., what if I could modify your data, either on disk or while your program was running?

Mechanism vs. policy

- Mechanisms are tools or vehicles to implement policies
- Examples of policies:
  - All users should be treated equally
  - Preferred users should be treated better

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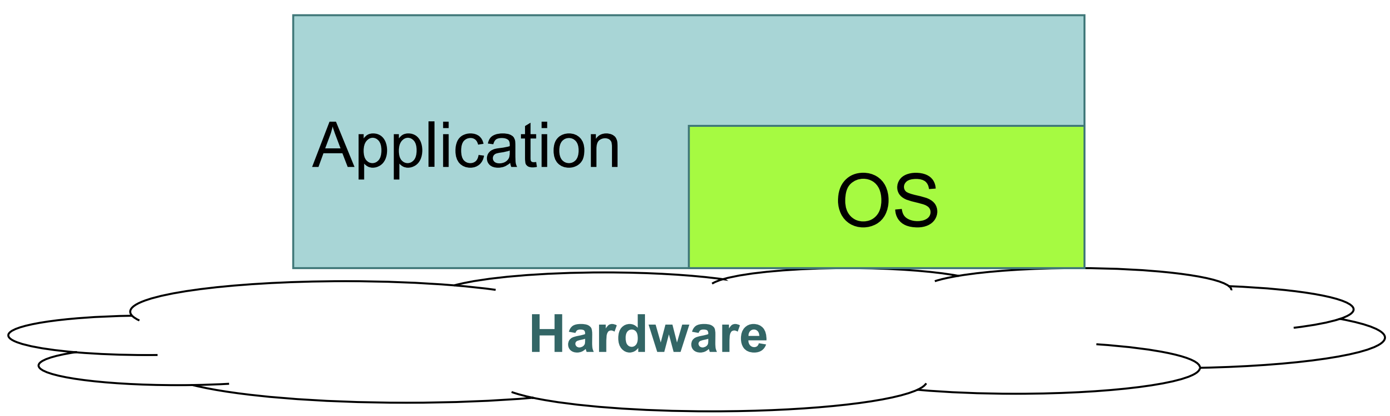
A Typical Academic Computer (1988 vs. 2008)

	1988	2008	Ratio
Intel CPU transistors	0.5M	1.9B	~4000x
Intel CPU core x clock	10Mhz	4×2.66Ghz	~1000x
DRAM	2MB	16GB	8000x
Disk	40MB	1TB	25,000x
Network BW	10Mbits/sec	10GBits/sec	1000x
Address bits	32	64	2x
Users/machine	10s	< 1	>10x
$/machine	$30K	$3K	1/10x
$/Mhz	$30,000/10	$3,000/10,000	1/10,000x

Moore's Law! ++

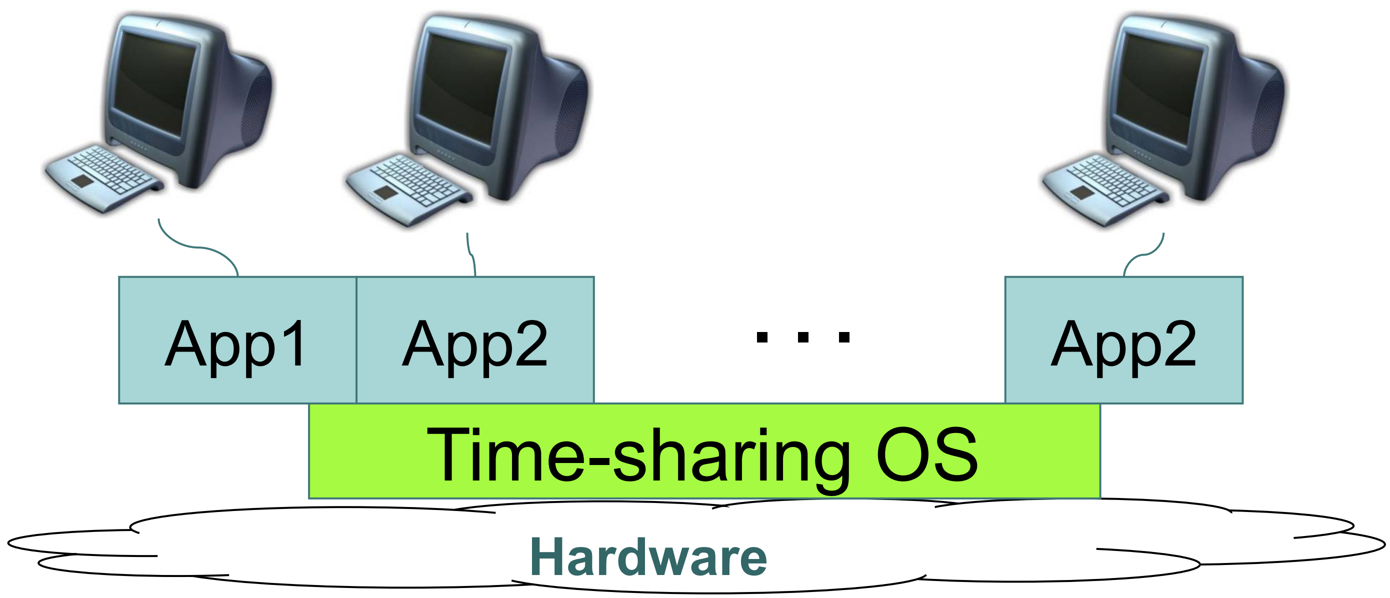
Phase 1: Batch Systems

- Hardware very expensive, only one user at a time
- Batch processing: load, run, print
  - OS linked in as a subroutine library
- Problem: better system utilization
  - System idle when job waiting for I/O
- Development: multiprogramming
  - Multiple jobs resident in computer's memory
  - Hardware switches between them (interrupts)
  - Memory protection: keep bugs to individual programs



Phase 2: Time Sharing

- Problem: batch jobs hard to debug
- Use cheap terminals to share a computer interactively
- MULTICS: designed in 1963, run in 1969
- Shortly after, Unix enters the mainstream
- Issue: thrashing as the number of users increases



Phase 3: Personal Computer

- Personal computer
  - Altos OS, Ethernet, Bitmap display, laser printer
  - Pop-menu window interface, email, publishing SW, spreadsheet, FTP, Telnet
  - Eventually >100M units per year
- PC operating system
  - Memory protection
  - Multiprogramming
  - Networking

Now: > 1 Machines per User

- Pervasive computers
  - Wearable computers
  - Communication devices
  - Entertainment equipment
  - Computerized vehicle
- OS are specialized
  - Embedded OS
  - Specially configured general-purpose OS

Now: Multiple Processors per Machine

- Clusters
  - A network of PCs
  - Commodity OS
- Multicomputers
  - Supercomputer with many CPUs and high-speed communication
  - Specialized OS with special message-passing support
- Multiprocessors
  - SMP: Symmetric MultiProcessor
  - ccNUMA: Cache-Coherent Non-Uniform Memory Access
  - General-purpose, single-image OS with multiproccesor support
- Chip Multiprocessors
  - 2+ cores per chip COMMON

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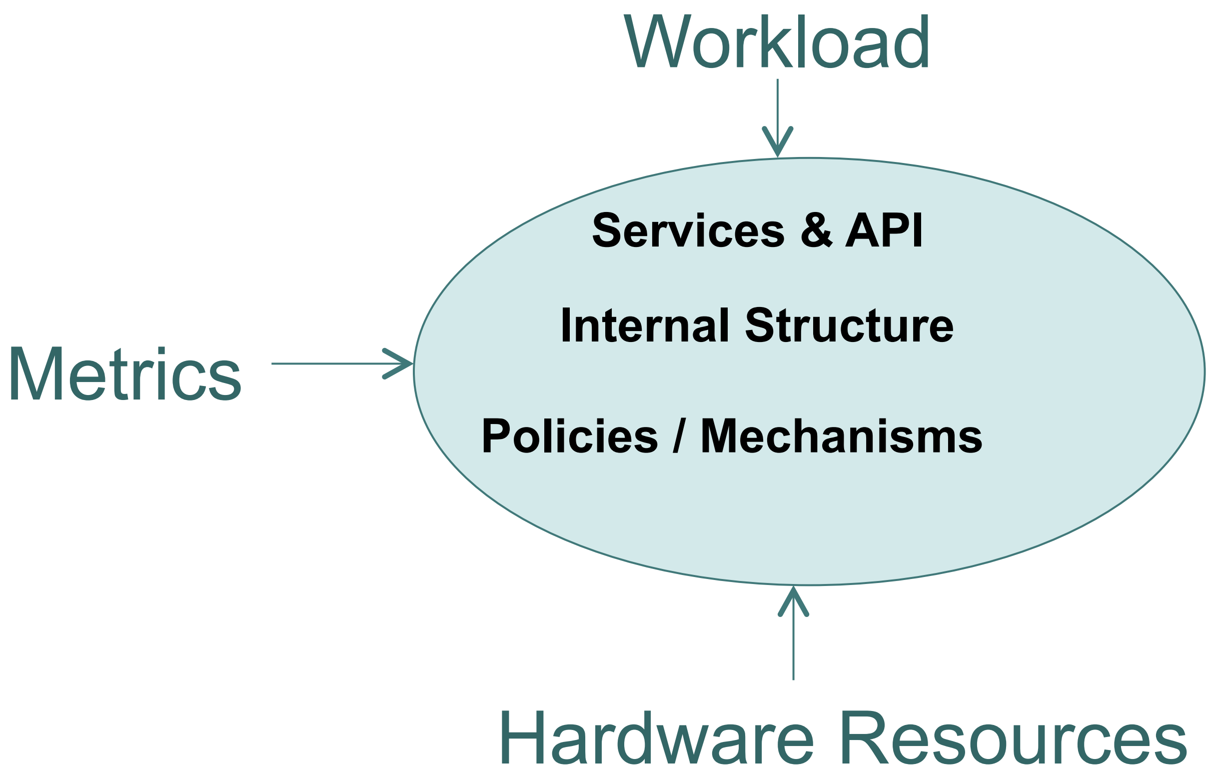
Why Study OS?

- OS is a key part of a computer system
  - It makes our life better (or worse)
  - It is “magic” to realize what we want
  - It gives us “power”
- Learn about concurrency
  - Parallel programs run on OS
  - OS runs on parallel hardware
  - Best way to learn concurrent programming
- Understand how a system works
  - How many procedures does a key stroke invoke?
  - What happens when your application references 0 as a pointer?
  - Building a small OS will go a long way…

Why Study OS?

- Important for studying other areas
  - Networking, distributed systems, …
- Full employment
  - New hardware capabilities and organizations
  - New features
  - New approaches
  - Engineering tradeoffs keep shifting as the hardware changes below and the apps change above

Influences in OS Design



Influences in OS Design

Traditional

Workload

Scientific computations
Database operations
Multi-user

Services & API

Internal Structure

Policies / Mechanisms

Metrics

Performance as
Bandwidth
and Latency.

Hardware Resources

Processor, Memory, Disks, Network,
Keyboard, Display, Multiprocessors

Influences in OS Design

Changing

Workload

Productivity applications
Games, Multimedia, Web
Process control
Personal (PDAs),
Embedded
E-Commerce

Services & API

Internal Structure

Policies / Mechanisms

Metrics

Accessibility,
Reliability,
No-futz-ness
Energy efficiency,
Security

Hardware Resources

Processor, Memory, Disks (?), Wireless & IR,
Keyboard(?), Display(?), Mic & Speaker,
Motors & Sensors, GPS, Camera, Batteries

Things To Do

- For today's material: Read MOS 1.1-1.3
- For next time: Read MOS 1.4-1.5
- Make "tent", leave with me, pick up and use every class.
- Choose a partner for first 3 projects and email vivek/me with your choice.
  - Use Piazza to help find available partners!