COS 318: Operating Systems

Introduction

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http://www.cs.princeton.edu/courses/archive/fall16/cos318/

Today

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

Information and Staff

- Website
  - http://www.cs.princeton.edu/courses/archive/fall16/cos318/
- Textbooks
  - Modern Operating Systems, 4th Edition, Tanenbaum and Bos
- Instructors
  - Jaswinder Pal Singh, Office: 423 CS, Hours: Mon 1:30 – 3 pm
- Teaching assistants (offices and hours to be posted on web site)
  - Qizhe Cai,
  - Ghassan Jerfel
  - Pranjit Kalita
  - Huilian (Sophie) Qiu

Grading

◆ Projects	60%
◆ Final project	20%
◆ Exam	20%

- No final exam after break

Projects

- Projects
  - Bootloader (150-300 lines)
  - Non-preemptive kernel (200-250 lines)
  - Preemptive kernel (100-150 lines)
  - Inter-process communication and device driver (300-350 lines)
  - Virtual memory (300-450 lines)
  - File system (500+ lines)
- How
  - Pair with a partner for project 1, 2 and 3
  - Pair with a different partner for project 4 and 5
  - Do the final project yourself (no partners)
  - Design review at the end of week one
  - All projects due Sundays at 11:55pm
- Where to do the projects
  - Develop on courselab machines, via remote login from your computer
  - Create bootable image on USB drive
  - Test using bochs, final test on lab machines in Friend 010

Project Grading

- Design Review
  - Requirements will be specified for each project
  - Sign up online for making appointments
  - 10 minutes with the TA in charge
  - 0-5 points for each design review
  - 10% deduction for missing an appointment
- Project completion
  - Assigned project points plus possible extra points
- Late policy for grading projects
  - 1 hour: 98.6%, 6 hours: 92%, 1 day: 71.7%
  - 3 days: 36.8%, 7 days: 9.7%

Logistics

- Precepts
  - Time: Mon 7:30pm – 8:20pm in CS 105
  - No second session
- For project 1
  - A tutorial on assembly programming and kernel debugging
    - Mon 9/19: 7:30-8:20pm in CS 105
  - Precept
    - 9/26: 7:30-8:20pm in CS 105
  - Design review
    - 9/26 (Monday) 1:30pm – evening (Friend 010)
    - Sign up online (1 slot per team)
  - Due: 10/2 (Sunday) 11:55pm

Piazza for Discussions

- Piazza is convenient
  - Most of you love it (?)
- Search, ask and answer questions
  - Students are encouraged to answer questions
  - Staff will try to answer in a timely manner
- Only use email if your question is personal/private
  - Project grading questions: send email to the TA in charge

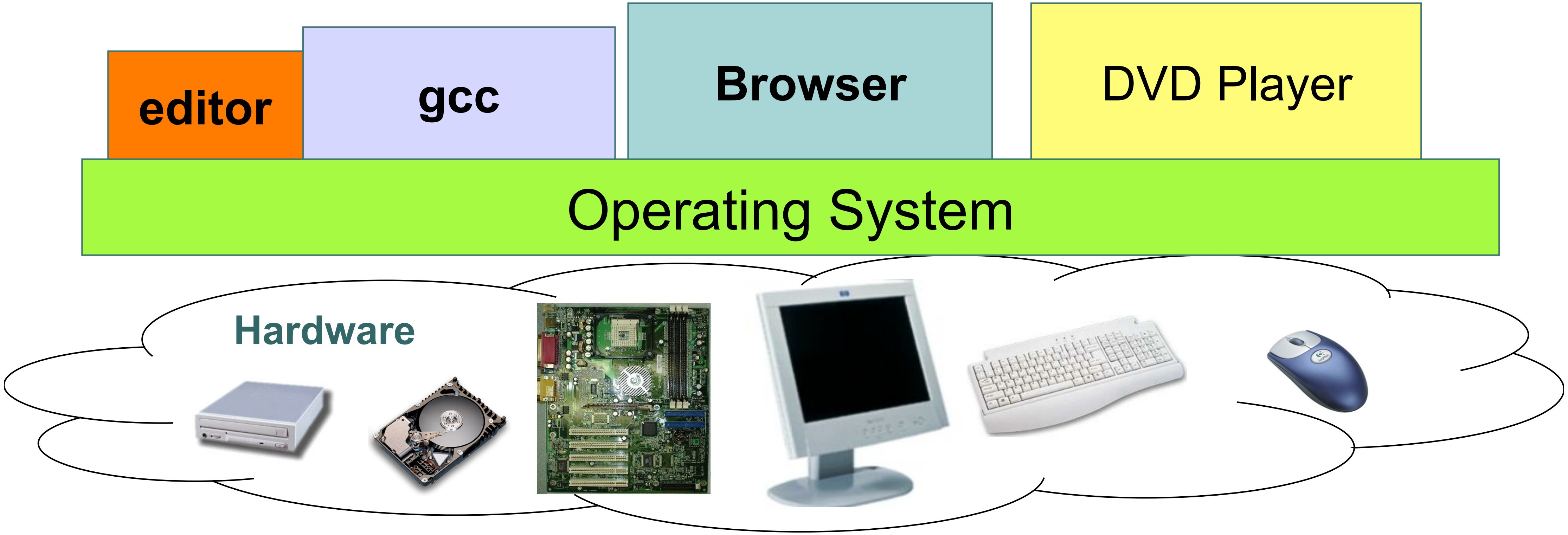
Ethics and Other Issues

- Follow Honor System
  - Ask teaching staff if you are not sure
  - Asking each other questions is okay
  - **Work must be your own (or your team's)**
- If you discover any solutions online
  - Tell teaching staff
- Do not put your code or design on the web, in social media, or anywhere public or available to others …

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
  - COS432: Information Security
  - COS475: Computer Architecture
- Courses needing COS318
  - COS 461: Computer Networks
  - COS 518: Advanced Operating Systems
  - COS 561: Advanced Computer Networks

What Is Operating System?



- Software between applications and hardware
- Provide abstractions to layers above
- Implement abstractions for and manage resources below
- What about the UI?

Consider reading from disks

- Different types of disks, with very different structures
  - Floppy, various kinds of hard drives, Flash, IDE, …
- Different hardware mechanisms to read, different layouts of data on disk, different mechanics

- Floppy disk has ~20 commands to interact with it
- Read/write have 13 parameters; controller returns 23 codes
- Motor may be on or off, don't read when motor off, etc.
- And this is only one disk tyhpe

- Rather, a simple abstraction: data are in files, you read from and write to files using simple interfaces
- OS manages all the rest

What Do Operating Systems Do?

- Provides abstractions to user-level software above
  - User programs can deal with simpler, high-level concepts
  - Hide complex and unreliable hardware, and the variety of hardware
  - Provide illusions like "sole application running" or "infinite memory"

- Implement the abstractions: manage resources
  - Manage application interaction with hardware resources
  - Allow multiple applications and multiple users to share resources effectively without hurting one another
  - Protect application software from crashing a system

Some Examples

- System example
  - What if a user tries to access disk blocks directly?
- Protection example
  - What if a user program can access all RAM memory?
  - What if a user runs the following code:

```
int main() {
    while(1)
        fork();
}
```

- Resource management example
  - What if many programs are running infinite loops?

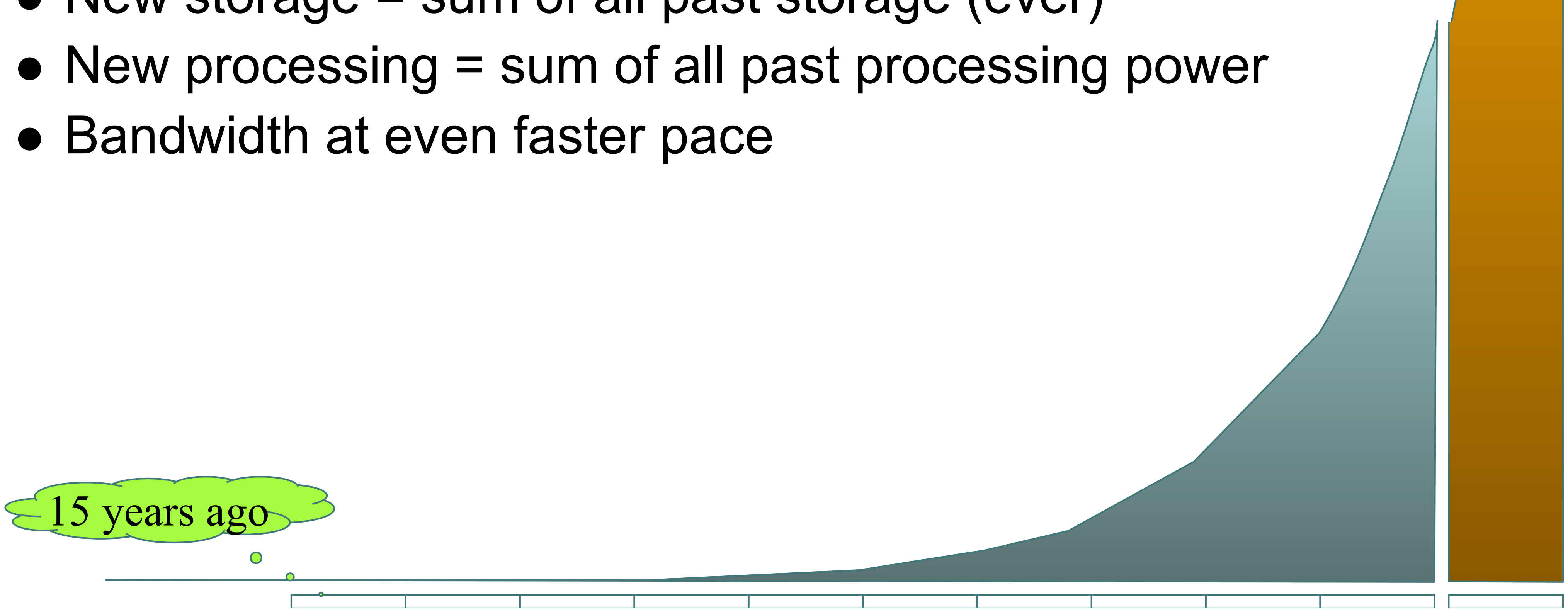
```
while (1);
```

A Typical Academic Computer (1981 vs. 2011)

	1981	2011	Ratio
Intel CPU transistors	0.1M	1.9B	~20000x
Intel CPU core x clock	10Mhz	10×2.4Ghz	~2,400x
DRAM	1MB	64GB	64,000x
Disk	5MB	1TB	200,000x
Network BW	10Mbits/sec	10GBits/sec	1000x
Address bits	32	64	2x
Users/machine	10s	< 1	>10x
$/machine	$30K	$1.5K	1/20x
$/Mhz	$30,000	$1,500/24,000	1/4,800x

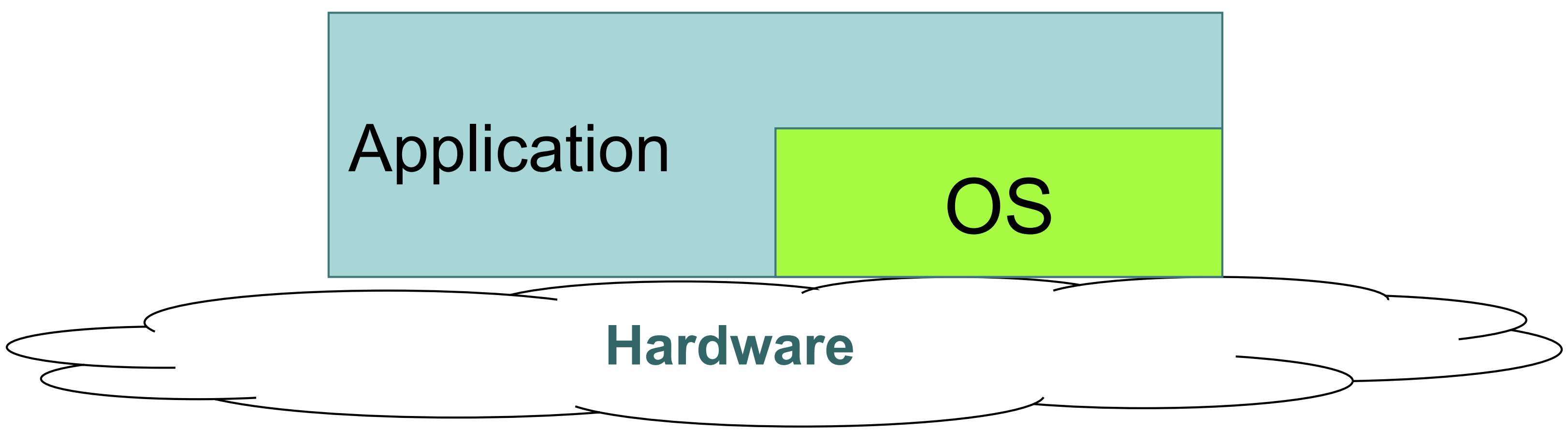
Exponential Growth in Computing and Communications (Courtesy Jim Gray)

- #transistors on chip doubles every 18 months
- 100x per decade
- Progress in next 18 months
  = ALL previous progress
  - New storage = sum of all past storage (ever)
  - New processing = sum of all past processing power
  - Bandwidth at even faster pace



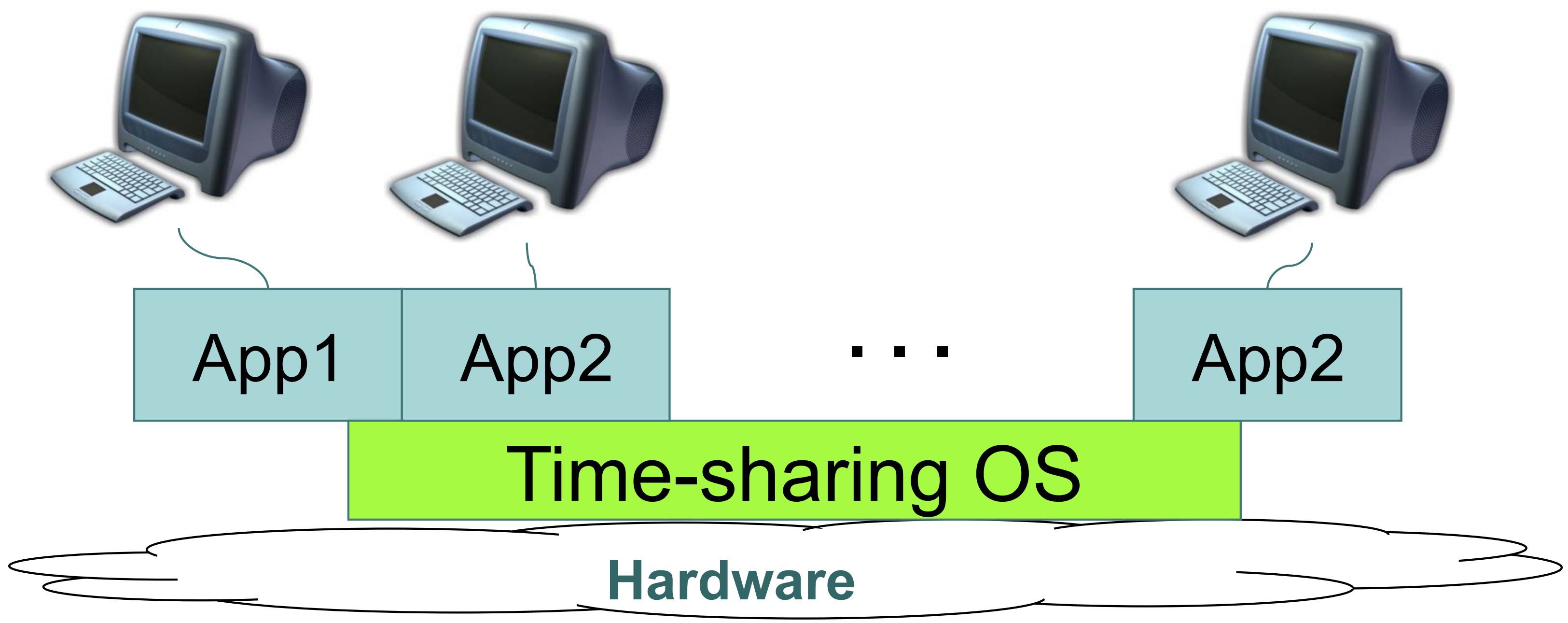
Phase 1: Hardware Expensive, Human Cheap

- User at console, OS as subroutine library
- Batch monitor (no protection): load, run, print
- A lot of the (expensive) hardware sits idle a lot. Developments:
  - Interrupts; overlap I/O and CPU
  - Direct Memory Access (DMA)
  - Memory protection: keep bugs to individual programs
  - Multics: designed in 1963 and run in 1969; multiprogramming
- Assumption: No bad people. No bad programs. Minimum interactions



Phase 2: Hardware Cheap, Human Expensive

- Use cheap terminals to share a computer
- Time-sharing OS
- Unix enters the mainstream as hardware got cheaper
- Problems: thrashing as the number of users increases



Phase 3: HW Cheaper, Human More Expensive

- Personal computer
  - Altos OS, Ethernet, Bitmap display, laser printer (79)
  - Pop-menu window interface, email, publishing SW, spreadsheet, FTP, Telnet
  - Became >200M units per year
- PC operating system
  - Memory protection
  - Multiprogramming
  - Networking

First PC at Xerox PARC

Now: > 1 Machines per User

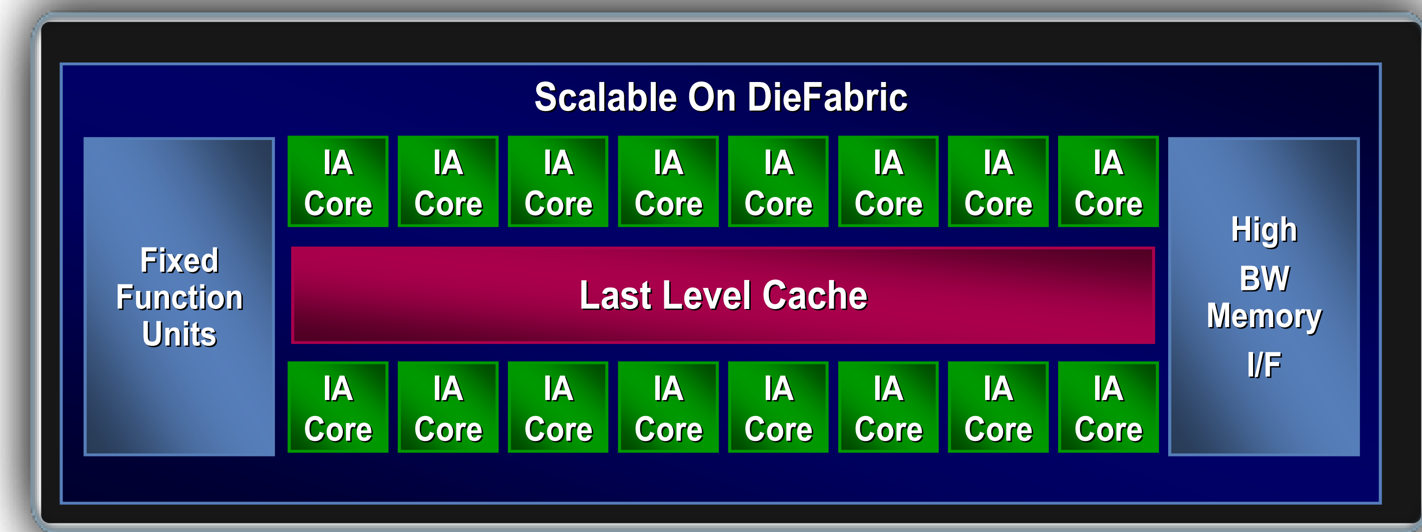
- Pervasive computers
  - Wearable computers
  - Communication devices
  - Entertainment equipment
  - Computerized vehicle
  - Phones ~2B units /year
- OS are specialized
  - Embedded OS
  - Specially general-purpose OS (e.g. iOS, Android)

Now: Multiple Processors per "Machine"

- Multiprocessors
  - SMP: Symmetric MultiProcessor
  - ccNUMA: Cache-Coherent Non-Uniform Memory Access
  - General-purpose, single-image OS with multiproccesor support
- Multicomputers
  - Supercomputer with many CPUs and high-speed communication
  - Specialized OS with special message-passing support
- Clusters
  - A network of PCs
  - Server OS w/ cluster abstraction (e.g. MapReduce)

Now: Multiple "Cores" per Processor

- Multicore or Manycore transition
  - Intel Xeon processor has 10 cores / 20 threads
  - New Intel Xeon Phi has 60 cores
  - nVidia GPUs has 3000 FPUs
- Accelerated need for software support
  - OS support for manycores
  - Parallel programming of applications



Now: Datacenter as A Computer

- Cloud computing
  - Hosting data in the cloud
  - Software as services
  - Examples:
    - Google, Microsoft, Salesforce, Yahoo, …

- Utility computing
  - Pay as you go for computing resources
  - Outsourced warehouse-scale hardware and software
  - Examples:
    - Amazon, Google, Micros

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" (reduce fear factor)
- Learn how computer systems really work, who does what, how
- Learn key CS concepts: abstraction, layering, virtualization, indirection
- 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?

Why Study OS?

- Basic knowledge for many areas
  - Networking, distributed systems, security, …
- Build an OS
  - Real OS is huge, but building a small OS will go a long way
- More employable
  - Become someone who understand “systems”
  - Become the top group of “athletes”
  - Ability to build things from ground up

- Question:
  - Why shouldn’t you study OS?

Does COS318 Require A Lot of Time?

- Yes
  - But less than a couple of years ago, and we're trying to make it even less
  - Part of that is measuring where time goes (see later)
- To become a top athlete, you want to know the entire HW/SW stack, and spend 10,000 hours programming
  - "Practice isn't the thing you do once you're good. It's the thing you do that makes you good."
  - "In fact, researchers have settled on what they believe is the magic number for true expertise: **ten thousand hours**."
    — Malcolm Gladwell, *Outliers: The Story of Success*

Things to Do

- Today's material
  - Read *MOS 1.1-1.3*
  - Lecture available online
- Next lecture
  - Read MOS 1.4-1.5
- Make "tent" with your name
  - Use next time
- Use piazza to find a partner
  - Find a partner before the end of next lecture for projects 1, 2 and 3