CSE 451: Operating Systems
Autumn 2009

Module 1
Course Introduction

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Today's agenda

- Administrivia
  - course overview
    - course staff
    - general structure
    - the text
    - policies
    - your to-do list
  - course registration
- OS overview
  - functional
    - resource management, etc.
  - historical
    - batch systems, multiprogramming, timeshared OS's, PCs, networked computers, p2p, embedded systems

Course overview

- Everything you need to know is on the course web page:

http://www.cs.washington.edu/451/

- But to tide you over for the next hour …
  - course staff
    - Ed Lazowska
    - Slava Chernyak
    - Owen Kim
  - general structure
    - read the text prior to class
    - class will supplement rather than regurgitate the text
    - homework exercises provide added impetus to keep up with the reading
    - sections will focus on the project (several separate components)
    - we really want to encourage *discussion*, both in class and in section

- the text
  - Silberschatz, Galvin & Gagne, *Operating System Concepts*, **eighth edition**
    - if using an earlier edition, watch chapter numbering, exercise numbering
- other resources
  - many online
    - some required
    - some optional
    - some prohibited (!)
- policies
  - collaboration vs. cheating
  - homework exercises
  - late policy

- your to-do list …
  - please read the entire course web thoroughly, *today*
  - please get yourself on the cse451 email list, *today*, and check your email *daily*
  - keep up with the reading
  - homework 1 (reading + problems) is posted on the web now
    - reading due Friday
    - problems due at **the start of class** next Wednesday
  - project 0 is posted on the web now
    - will be discussed in section on Thursday
    - due next Friday (but if you don't get started this weekend you'll be in trouble)

Course registration

- If you're going to drop this course
  - please do it soon!
- If you want to get into this course
  - plan for the worst case (we're at our limit currently)
  - but, make sure you've filed a petition with the advisors
    - they run the show!
  - give things a few days to settle down

More about 451

- This is really (at least!) two classes:
  - A classroom/textbook part (mainly run by me)
  - A project part (mainly run by the TAs)
- In a perfect world, we would do this as a two-quarter sequence
- The world isn't perfect ☺
- Sometimes the projects and the lectures will mesh, sometimes they won't
- But in any case, you will have to keep up with both the classroom and the projects
- There will be a lot of work
- But you will learn a lot
- In the end, you'll understand much more deeply how computers work
- **"There is no magic"**

What is an Operating System?

- The text:
  - "an intermediary between the user of a computer and the computer hardware"
  - "manages the computer hardware"
  - "each [piece] should be … well delineated …, with carefully defined inputs, outputs, and functions"
  - "an amazing aspect of operating systems is how varied they are in accomplishing these tasks … mainframe operating systems … personal computer operating systems … operating systems for handheld computers …"
  - "in 1998, the United States Department of Justice filed suit against Microsoft, in essence claiming that Microsoft included too much functionality in its operating system … for example, a web browser was an integral part of the operating system"

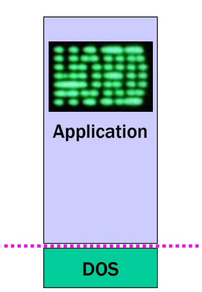
What is an Operating System?

- An operating system (OS) is:
  - a software layer to abstract away and manage details of hardware resources
  - a set of utilities to simplify application development

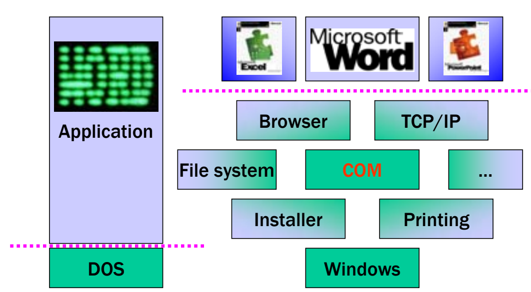
Applications
OS
Hardware

  - "all the code you didn't write" in order to implement your application
  - Key idea: *virtualization* or *abstraction* of resources

What is Windows?

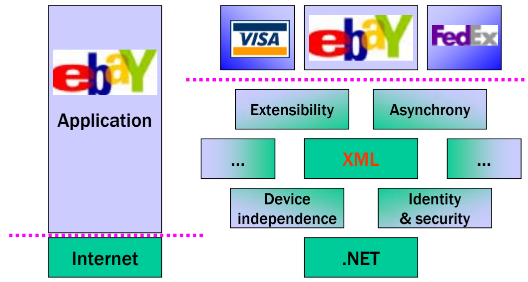


What is Windows?



What is .NET?

What is .NET?



The OS and hardware

- An OS mediates programs' access to hardware resources (*sharing* and *protection*)
  – computation (CPU)
  – volatile storage (memory) and persistent storage (disk, etc.)
  – network communications (TCP/IP stacks, Ethernet cards, etc.)
  – input/output devices (keyboard, display, sound card, etc.)
- The OS abstracts hardware into logical resources and well-defined interfaces to those resources (*ease of use*)
  – processes (CPU, memory)
  – files (disk)
  – programs (sequences of instructions)
  – sockets (network)

Why bother with an OS?

- Application benefits
  – programming simplicity
    - see high-level abstractions (files) instead of low-level hardware details (device registers)
    - abstractions are reusable across many programs
  – portability (across machine configurations or architectures)
    - device independence: 3com card or Intel card?
- User benefits
  – safety
    - program "sees" own virtual machine, thinks it owns computer
    - OS protects programs from each other
    - OS fairly multiplexes resources across programs
  – efficiency (cost and speed)
    - share one computer across many users
    - concurrent execution of multiple programs

The major OS issues

- **structure**: how is the OS organized?
- **sharing**: how are resources shared across users?
- **naming**: how are resources named (by users or programs)?
- **security**: how is the integrity of the OS and its resources ensured?
- **protection**: how is one user/program protected from another?
- **performance**: how do we make it all go fast?
- **reliability**: what happens if something goes wrong (either with hardware or with a program)?
- **extensibility**: can we add new features?
- **communication**: how do programs exchange information, including across a network?

More OS issues…

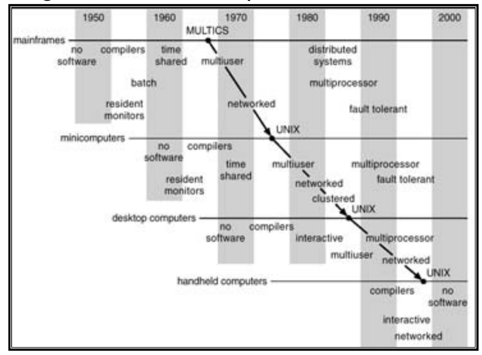
- **concurrency**: how are parallel activities (computation and I/O) created and controlled?
- **scale**: what happens as demands or resources increase?
- **persistence**: how do you make data last longer than program executions?
- **distribution**: how do multiple computers interact with each other?
- **accounting**: how do we keep track of resource usage, and perhaps charge for it?

There are tradeoffs, not right and wrong!

Hardware/Software Changes with Time

- 1960s: mainframe computers (IBM)
- 1970s: minicomputers (DEC)
- 1980s: microprocessors and workstations (SUN)
- 1990s: PCs (rise of Microsoft, Intel, then Dell)
- 2000s:
  - Internet Services / Clusters (Amazon)
  - General Cloud Computing (Google, Amazon)
  - Mobile/ubiquitous/embedded computing
- …..
- 2020: it's up to you!!

Progression of concepts and form factors



Multiple trends at work

- "Ontogeny recapitulates phylogeny"
  - Ernst Haeckel (1834-1919)
    - ("always quotable, even when wrong")
- "Those who cannot remember the past are condemned to repeat it"
  - George Santayana (1863-1952)

Has it all been discovered?

- New challenges constantly arise
  - embedded computing (e.g., iPod)
  - sensor networks (very low power, memory, etc.)
  - peer-to-peer systems
  - ad hoc networking
  - scalable server farm design and management (e.g., Google)
  - software for utilizing huge clusters (e.g., MapReduce, Bigtable)
  - overlay networks (e.g., PlanetLab)
  - worm fingerprinting
  - finding bugs in system code (e.g., model checking)
- Old problems constantly re-define themselves
  - the evolution of PCs recapitulated the evolution of minicomputers, which had recapitulated the evolution of mainframes
  - but the ubiquity of PCs re-defined the issues in protection and security

Protection and security as an example

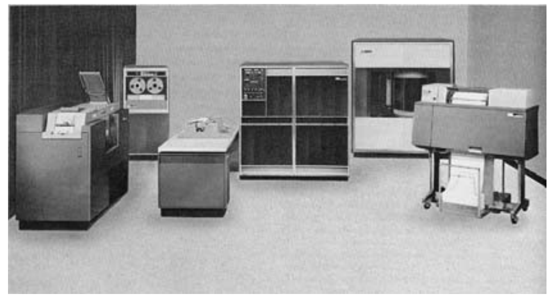
- none
- OS from my program
- your program from my program
- my program from my program
- access by intruding individuals
- access by intruding programs
- denial of service
- distributed denial of service
- spoofing
- spam
- worms
- viruses
- stuff you download and run knowingly (bugs, trojan horses)
- stuff you download and run obliviously (cookies, spyware)

OS history

- In the very beginning…
  - OS was just a library of code that you linked into your program; programs were loaded in their entirety into memory, and executed
  - interfaces were literally switches and blinking lights
- And then came **batch systems**
  - OS was stored in a portion of primary memory
  - OS loaded the next job into memory from the card reader
    - job gets executed
    - output is printed, including a dump of memory
    - repeat…
  - card readers and line printers were very slow
    - so CPU was idle much of the time (wastes $$)

Spooling

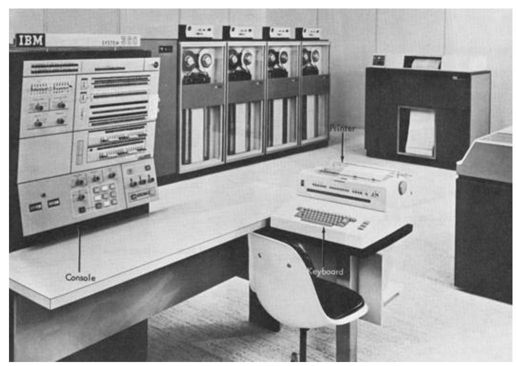
- Disks were much faster than card readers and printers
- Spool (Simultaneous Peripheral Operations On-Line)
  - while one job is executing, spool next job from card reader onto disk
    - slow card reader I/O is overlapped with CPU
  - can even spool multiple programs onto disk
    - OS must choose which to run next
    - job scheduling
  - but, CPU still idle when a program interacts with a peripheral during execution
  - buffering, double-buffering



IBM 1401

Multiprogramming

- To increase system utilization, multiprogramming OSs were invented
  - keeps multiple runnable jobs loaded in memory at once
  - overlaps I/O of a job with computing of another
    - while one job waits for I/O completion, OS runs instructions from another job
  - to benefit, need asynchronous I/O devices
    - need some way to know when devices are done
      - interrupts
      - polling
  - goal: <u>optimize system throughput</u>
    - perhaps at the cost of response time…



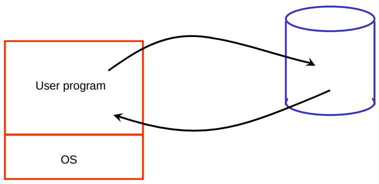
IBM System 360

Timesharing

- To support interactive use, create a timesharing OS:
  - multiple terminals into one machine
  - each user has illusion of entire machine to him/herself
  - <u>optimize response time</u>, perhaps at the cost of throughput
- Timeslicing
  - divide CPU equally among the users
  - if job is truly interactive (e.g., editor), then can jump between programs and users faster than users can generate load
  - permits users to interactively view, edit, debug running programs (why does this matter?)

- MIT CTSS system (operational 1961) was among the first timesharing systems
  - only one user memory-resident at a time (32KB memory!)
- MIT Multics system (operational 1968) was the first large timeshared system
  - nearly all OS concepts can be traced back to Multics!
  - “second system syndrome”

- CTSS as an illustration of architectural and OS functionality requirements



- In early 1980s, a *single* timeshared VAX/780 (like the one in the Allen Center atrium) ran computing for the *entire* CSE department.
- A typical VAX/780 was 1 MIPS (1 MHz) and had 1MB of RAM and 100MB of disk.
- An iPhone is 400 MIPS, has 128MB of RAM (way too little though) and 8GB of disk.

Parallel systems

- Some applications can be written as multiple parallel threads or processes
  - can speed up the execution by running multiple threads/processes simultaneously on multiple CPUs [Burroughs D825, 1962]
  - need OS and language primitives for dividing program into multiple parallel activities
  - need OS primitives for fast communication among activities
    - degree of speedup dictated by communication/computation ratio
  - many flavors of parallel computers today
    - SMPs (symmetric multi-processors)
    - MPPs (massively parallel processors)
    - NOWs (networks of workstations)
    - computational grid (SETI @home)

Personal computing

- Primary goal was to enable new kinds of applications
- Bit mapped display [Xerox Alto,1973]
  - new classes of applications
  - new input device (the mouse)
- Move computing near the display
  - why?
- Window systems
  - the display as a managed resource
- Local area networks [Ethernet]
  - why?
- Effect on OS?

Distributed OS

- Distributed systems to facilitate use of geographically distributed resources
  - workstations on a LAN
  - servers across the Internet
- Supports communications between programs
  - interprocess communication
    - message passing, shared memory
  - networking stacks
- Sharing of distributed resources (hardware, software)
  - load balancing, authentication and access control, …
- Speedup isn't the issue
  - access to diversity of resources is goal

Client/server computing

- Mail server/service
- File server/service
- Print server/service
- Compute server/service
- Game server/service
- Music server/service
- Web server/service
- etc.

Peer-to-peer (p2p) systems

- Napster
- Gnutella
  - example technical challenge: self-organizing overlay network
  - technical advantage of Gnutella?
  - er … legal advantage of Gnutella?

Embedded/mobile/pervasive computing

- Pervasive computing
  - cheap processors embedded everywhere
  - how many are on your body now? in your car?
  - cell phones, PDAs, network computers, …
- Typically very constrained hardware resources
  - slow processors
  - very small amount of memory (e.g., 8 MB)
  - no disk
  - typically only one dedicated application
  - limited power
- But this is changing rapidly!






Ad hoc networking


CSE 451

- In this class we will learn:
  - what are the major components of most OS's?
  - how are the components structured?
  - what are the most important (common?) interfaces?
  - what policies are typically used in an OS?
  - what algorithms are used to implement policies?
- Philosophy
  - you may not ever build an OS
  - but as a computer scientist or computer engineer you need to understand the foundations
  - most importantly, operating systems exemplify the sorts of engineering design tradeoffs that you'll need to make throughout your careers – compromises among and within cost, performance, functionality, complexity, schedule …
  - you will love this course!

