Software systems and issues

- **operating systems**
  - controlling the computer
- **file systems and databases**
  - storing information
- **applications**
  - programs that do things
- **cloud computing, virtual machines, platforms**
  - where boundaries become even less clear

- **intellectual property**
  - copyrights, patents, licenses
- **interfaces, standards, antitrust**
  - agreements on how to communicate and inter-operate
- **open source software**
  - freely available software

Operating system

- **a program that controls the resources of a computer**
  - interface between hardware and all other software
  - examples: DOS, Windows 3.0/3.1/95/98/NT/ME/2000/XP/Vista/7/8
    Unix/Linux, Mac OS X, iOS, ...

- **runs other programs ("applications", your programs)**
- **manages information on disk (file system)**
- **controls peripheral devices, communicates with outside**

- **provides a level of abstraction above the raw hardware**
  - makes the hardware appear to provide higher-level services than it really does
  - makes programming much easier

History of general-purpose operating systems

- **1950's: signup sheets**
- **1960's: batch operating systems**
  - operators running batches of jobs
  - OS/360 (IBM)
- **1970's: time-sharing**
  - simultaneous access for multiple users
  - Unix (Bell Labs; Ken Thompson & Dennis Ritchie)
- **1980's: personal computers, single user systems**
  - DOS, Windows, MacOS
  - Unix
- **1990's: personal computers, PDA's, …**
  - PalmOS, Windows CE, …
  - Unix / Linux
- **2000's: Windows vs. Unix/Linux?**
  - MacOSX is a Unix system
- **2010's: Apple vs. Google**
  - iOS, Android, Chrome-OS, … (Unix/Linux-based)
- **not all computers have general-purpose operating systems**
  - "embedded systems": small, specialized, but increasingly general

Unix operating system

- **developed ~1971 at Bell Labs**
  - by Ken Thompson and Dennis Ritchie
- **clean, elegant design**
  - at least in the early days
- **efficient, robust, easy to adapt, fun**
  - widely adopted in universities, spread from there
- **written in C, so easily ported to new machines**
  - runs on everything (not just PC's)

- **influence**
  - languages, tools, de facto standard environment
  - enabled workstation hardware business (e.g., Sun Microsystems)
  - supports a lot of Internet services and infrastructure
    often Linux

Linux

- **a version of Unix written from scratch**
  - by Linus Torvalds, Finnish student (started 1991)

- **source code freely available (kernel.org)**
  - large group of volunteers making contributions
  - anyone can modify it, fix bugs, add features
  - Torvalds approves, sets standard
  - commercial versions make money by packaging and support, not by selling the code itself

- **used by major sites, including**
  - Google, Amazon, Facebook, Twitter, YouTube, ABC, CBS, CNN, ...

What an operating system does

- **manages CPUs, schedules and coordinates running programs**
  - switches CPU among programs that are actually computing
  - suspends programs that are waiting for something (e.g., disk, network)
  - keeps individual programs from hogging resources
- **manages memory (RAM)**
  - loads programs in memory so they can run
  - swaps them to disk and back if there isn't enough RAM (virtual memory)
  - keeps separate programs from interfering with each other
  - and with the operating system itself (protection)
- **manages and coordinates input/output to devices**
  - disks, display, keyboard, mouse, network, ...
  - keeps separate uses of shared devices from interfering with each other
  - provides uniform interface to disparate devices
- **manages files on disk (file system)**
  - provides hierarchy of directories and files for storing information

To run programs, the operating system must

- **fetch program to be run (usually from disk)**
- **load it into RAM**
  - maybe only part, with more loaded as it runs (dynamic libraries)
- **transfer control to it**
- **provide services to it while it runs**
  - reading and writing info on disk
  - communications with other devices
- **regain control and recover resources when program is finished**
- **protect itself from errant program behavior**
- **share memory & other resources among multiple programs running "at the same time"**
  - manage memory, disks, network, ...
  - protect programs from each other
  - manage allocation of CPUs among multiple activities

Memory management

- **what's in memory? over-simplified pictures:**

Unix:

Windows:

- **reality is more complicated**
  - pieces of programs are partly in RAM, partly on disk
    can only execute instructions that are in RAM
- **memory protection:**
  - making sure that one program can't damage another or the OS
- **virtual memory:**
  - making it look like there is more RAM than there really is

Operating system controls devices

- **operating system hides physical properties of devices**
  - device has specific capabilities, parameters, etc.
  - hardware and software in device and OS present these at higher level
  - e.g., printer

    logical view: put characters out in 66 lines of 80 characters

    physical view: paint individual bits of characters in raster across page
  - e.g., CD-ROM

    logical view: file system just like the one on the hard drive

    physical view: long spiral of individual bits read by a laser
- **OS uses device drivers to control physical devices**
  - driver code has detailed knowledge of how to operate a particular device
  - implemented as functions that provide interface between specific capabilities of a device and what the operating system expects
  - loaded as part of OS as needed, e.g., when a device is plugged in

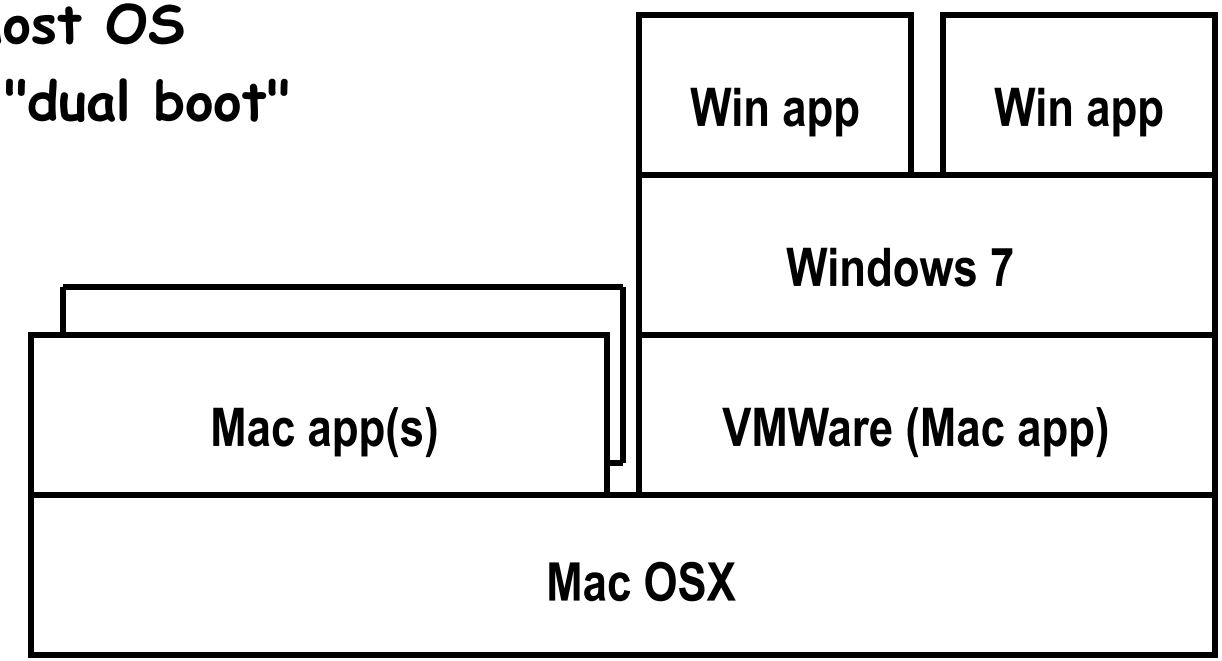
    ("Windows has found new hardware")
- **drivers insulate OS and application programs from specific properties of devices**

How does an operating system work?

- **loaded into RAM & started when machine is turned on ("boot")**
  - so it starts out being in charge / running on the bare hardware
- **gives control in turn to each program that is ready to run**
- **responds to external events / devices / …**
  - does actions, relays events to programs, …
- **programs (applications) request services by "making a system call"**
  - execute a particular instruction that transfers control to specific part of operating system
  - parameters say what task to do
- **OS does operation, returns control (and result) to application**

Virtual machines

- **running other OS's on top of an OS**
  - e.g., VMWare, VirtualBox, Parallels, Xen, HyperV, ...
- **system calls from applications to "guest" OS are intercepted by "host" OS**
  - e.g., guest == Windows 7 or Linux, host == MacOSX
- **passed to guest OS, which handles them by converting into system calls to host OS**
- **not the same as "dual boot"**



Bootstrapping: how does it all get started

- **CPU begins executing at specific memory location when turned on**
  - location is defined by the hardware: part of the machine's design
  - often in ROM (read-only memory) so not volatile but changeable

- **"bootstrap" instructions placed there read more instructions**
  - CPU tries to read first block from disk as bootstrap to copy more of the operating system
  - if that fails, tries to read bootstrap from somewhere else
    e.g., CD-ROM, USB, network, ...