

15-410

“Way easier than when we were students”

Operating System Overview

Aug. 31, 2007

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Synchronization

Syllabus!

- Please read the syllabus!
- It contains answers to questions you haven't asked yet!

Project 0

- AFS volumes aren't created yet (we know)
 - But you still need to get cross-realm tickets (see web)
- Questions?
- Please don't forget about the bboards

Outline

What is an OS?

- “A home for a process”
- Brief history
 - Illustrating some kinds of OS
- Special topics for special hardware
 - Illustrating some OS structural issues
- Things larger/smaller than “just an OS”
 - Motivating “distributed systems”
 - Being faster and smaller and cooler

What is an OS?

PalmOS

- 1 user, 1 task

IBM VM/CMS

- 1000 users, 1 (DOS box) task apiece

Capability-based OS

- “User”? What do you mean by “user”?

What is an OS?

Q: Size

- A1: 16 kilobytes!
- A2: 16 megabytes!

Q: Portable?

- A1: “Of course!!!”
- A2: “Why would you want portability???”

Consensus elusive

- “The stuff between the hardware and the application”

Common Features

Abstraction layer

- People want files, not sectors
- People want I/O, not interrupts
- People want date & time, not "ticks since boot"
- Or: *Obstruction* layer
 - See: Exokernel

Common Features

Virtualization

- Give everybody “their own” machine
- IBM's VM/SP pioneered “strong” virtualization
 - Your own 3081!
 - PC-XT/370!
- Virtualization is hot again
 - VMware, Xen
 - Upcoming lecture (expected, near end of semester)
- Unix process is like a virtual machine too
 - Upcoming lecture (next week)

Common Features

Protected Sharing (*Controlled* Interference)

- Shared disk
 - space-sliced
- Shared CPU
 - time-sliced
- Shared keyboard/display
 - Hmm...
- Shared memory
 - Hmm...
- N levels of shared cache
 - Hmm... shh...

Single-process OS

Examples

- DEC's RT-11
 - moment of silence
- CP/M (and its clone, MS-DOS)
- Apple DOS
- UCSD p-system (1978)
- (Early MacOS; PalmOS)

Single-process OS

Typical features

- One active program
- Some memory management
- A "file system"
- A command interpreter
 - “Built-in” commands
 - DIR, SET, ^C
 - “External” commands
 - compiler, editor

Mainframe “Batch” OS

Examples

- IBM HASP?

Typical features

- One active program
- I/O library
 - Card reader, tape drive, printer
- Load next program
 - (completion or “abend”)

Wasteful

- Usually much of machine is idle

Multiprogramming Batch OS

Key insight

- Sometimes *two* programs fit in memory
- Each program is often waiting for I/O
- Two for the price of one!

Multiprogramming Batch OS

Typical features

- **Job scheduling**
 - Semi-ordered entry to memory
 - No longer a hot research topic
- **Processor scheduling**
 - Multiplexing CPU somehow
- **Input/Output stream abstraction**
 - Virtual card reader/punch
 - JCL!

Multiprogramming Batch OS

Typical features

- Memory mapping or linkage discipline
- (Hopefully) crash isolation

Examples

- IBM MVT, MVS

Timesharing

Key Insight

- (none)

Timesharing = *Interactive* Multiprogramming

- Memory cheap enough for lots of processes
- Terminals cheap enough for lots of users

Timesharing

Examples

- CTS, ITS, TENEX
- MVS/TSO
- VM/CMS
- Multics
- Unix

Timesharing

Typical features

- Swapping processes out of memory to disk
 - A good idea: lots of them are idle!
- Virtual memory
- Fancy process scheduling (priorities, ...)

Inter-user/inter-process *communication!*

- Why not? You're all logged in all day...

Other Visions

Multics

- What if computing were a utility like the telephone?
- What if one mainframe supported everybody in a whole city?
- What would the OS be like?
 - Timesharing on a grand scale
 - Secure, hopefully!
- Invented many “modern” OS technologies

Other Visions

The Humane Interface

- Jef Raskin (designer of Mac UI)
- Design user interface according to cognitive psych
- Then design all other software in system
- User should never see “operating system”
 - Nor “applications” either!

Other Visions

“Just say no”

- An operating system is a collection of things that don't fit into a language. There shouldn't be one.
 - Dan Ingalls (OO/UI pioneer), Byte Magazine, 1981

Shared-memory Multiprocessors

Requirements

- cheap processors
- shared memory with some coherence

Advantages

- Throughput
 - linear if you're lucky
- Resource sharing efficiency (one box, one net port)
 - but maybe: resource hot-spot inefficiency
- Machine can keep running if one processor dies

Asymmetric Multiprocessing

Or “master-slave” multi-processing

Typical

- One processor runs the OS kernel
- Other processors run user tasks

Cheap hack

- Easy to adapt a 1-processor OS

Downside

- Kernel is a “hot spot”
 - Eventually that processor is 100% busy
 - Then more processors can't increase user throughput

Symmetric Multiprocessing

“Ideal” multiprocessing

Re-entrant multi-threaded kernel

Fascinating problems

- **TLB shoot-downs**

Distributed Applications

Concept

- The world is large, so communication is hard
 - Yodeling from one mountain peak to another
 - Standage, Victorian Internet

Client-server

- WWW
- File service

Distributed Applications

Message passing / “Peer-to-peer”

- e-mail
- USENET
- Music/movie “sharing”
- “Ad-hoc networking”
- “Sensor” nets

Loosely-Coupled Distributed Applications

Sample Challenges

- Time delays may be large
 - Vinge, Fire Upon the Deep
 - Clarke, Songs of Distant Earth
- Group membership generally un-knowable
- Temporal coherence often very weak
- Messages must be somewhat self-contained
- No authority to trust

Loosely-Coupled Distributed Applications

Advantages

- Large systems can grow with minimal central planning
- Large, *useful* systems
 - e-mail, USENET, WWW
- Aggregate throughput can be enormous
- Systems can keep working despite damage
 - “The Net interprets censorship as damage and routes around it” –John Gilmore

Distributed File Systems

Typical features

- **Single global namespace**
 - Everybody agrees on mapping between files & names
- **Many servers, but invisible**
 - Server name not part of file name
 - File motion among servers is transparent
- **Authentication across administrative boundaries**
- **Some client autonomy**
 - Avoid server hot spots

Distributed File Systems

Examples

- AFS
- OpenAFS
- Arla
- Coda

“Storage” is hot

- NAS, SAN
- So maybe the time has come

“Cluster” file systems

- Lots of boxes, usually one administrative domain

Distributed Operating Systems

Intuition

- Mixture of remote and local resources

Interactive process

- Local memory, processor, display, keyboard, mouse
- Remote file system

Server process

- Local memory, processor (maybe disk)

Distributed Operating Systems

Examples

- Hydra
- Locus
- V
- Amoeba
- Sprite
- Plan 9
- (Mach, sometimes, in the lab)

Distributed Operating Systems

Common emphases

- “Capabilities” for objects
 - Same format, behavior for remote or local objects
 - (non-forgable handles require cryptography)
- User-centric namespaces
 - My “/tmp” is *mine*

One kind of namespace:

- Unifying files, processes, memory, devices

Real-time Systems

Sometimes time matters

- Music
 - “small” glitches sound *bad*
- Gaming
 - must match hand/eye coordination
- Factory process control
- Avionics

Real-time Systems

Hard real-time

- Glitch means something goes *boom*
- Avoid things with unpredictable timing
 - Virtual memory, disks
- Seriously over-engineer

Soft real-time

- Ok to do it right “most of the time”
- Minor changes to existing OS help a lot
- Fancy scheduler, fancy mutexes, memory locking

Mobile Computing

Examples

- PDAs
- Laptops
- “Sensor” networks

Standard resources are tight

- Memory
- Processor speed
- Screen size
- Power

Mobile $\Rightarrow$ “Pervasive”

Not just “portable” –tiny!

- Size of a...
 - ...candy bar?
 - ...battery?
 - ...dime?
 - ...grain of salt?

New worries

- Intermittent connectivity
- Self-organization
- Power concerns become *pervasive*

Summary - 1

Resource abstraction

- Packets $\Rightarrow$ reliable byte streams
- Disk sectors $\Rightarrow$ files
- Resource naming

Summary - 2

Resource sharing/protection

- CPU time slicing
- Memory swapping/paging
- Disk quotas

Summary - 3

Communication & Synchronization

- Messaging
- Synchronizing & coherence

Closing

Upcoming

- Hardware (in one easy lecture!)
- The Process