Introduction to OSs

- What is an Operating System?
- Architectural Support for Operating Systems
- System Calls
- Basic Organization of an Operating System

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What is an operating system?

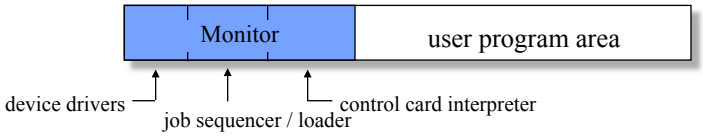
- What an operating system is **not**:
  - An o.s. is **not** a language or a compiler
  - An o.s. is **not** a command interpreter / window system
  - An o.s. is **not** a library of commands
  - An o.s. is **not** a set of utilities

A Short Historical Tour

- **First Generation** Computer Systems (1949-1956):
  - Single user: writes program, operates computer through console or card reader / printer
  - Absolute machine language
  - I/O devices
  - Development of libraries; device drivers
  - Compilers, linkers, loaders
  - Relocatable code

Second-Generation Computers (1956-1963)

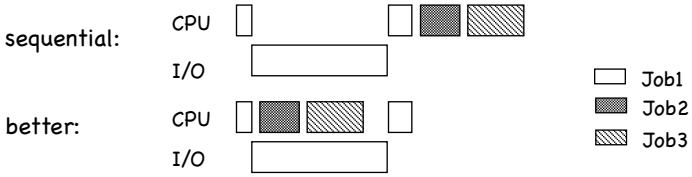
- Problems: scheduling, setup time
- Automation of Load/Translate/Load/Execute
  - Batch systems
  - Monitor programs



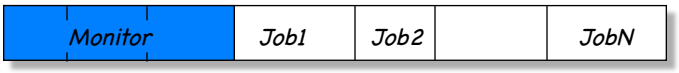
  - Job Control Language
  - Advent of operators: computers as input/output box
- Problem: Resource management and I/O still under control of programmer
  - Memory protection
  - Timers
  - Privileged instructions

Third-Generation Computer Systems (1964-1975)

- Problem with batching: one-job-at-a-time



- Solution: **Multiprogramming**
  - Job pools: have several programs ready to execute
  - Keep several programs in memory



- New issues:
  - Job scheduling
  - Memory management
  - Protection

Time Sharing (mid 1960s on)

- OS interleaves execution of multiple user programs with time quantum
  - CTSS (1961): time quantum 0.2 sec
- User returns to own the machine
- New aspects and issues:
  - On-line file systems
  - resource protection
  - virtual memory
  - sophisticated process scheduling
- Advent of systematic techniques for designing and analyzing OSs.

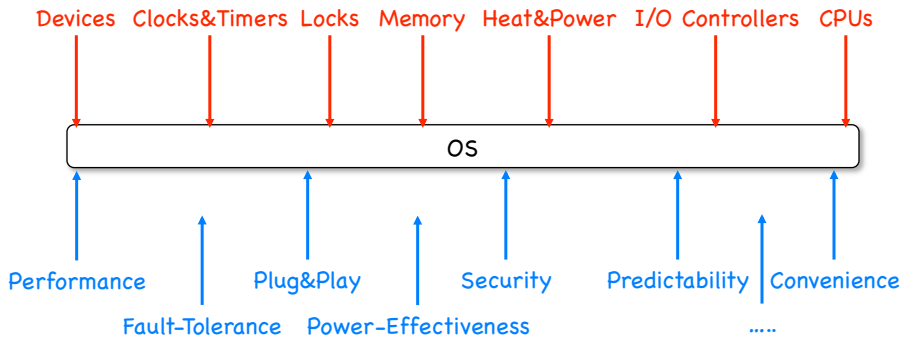
The Recent Past

- Personal computers and Computing as Utility
  - History repeats itself
- Parallel systems
  - Resource management
  - Fault tolerance
- Real-Time Systems
- Distributed Systems
  - Communication
  - Resource sharing
  - Network operating systems
  - Distributed operating systems
- Secure Systems

What, then, is an Operating System?

- Controls and coordinates the use of system resources.
- Primary goal: Provide a convenient environment for a user to access the available resources (CPU, memory, I/O)
  - Provide appropriate abstractions (files, processes, ...)
  - "virtual machine"
- Secondary goal: Efficient operation of the computer system.
- Resource Management
  - Transforming: Create virtual substitutes that are easier to use.
  - Multiplexing: Create the illusion of multiple resources from a single resource
  - Scheduling: "Who gets the resource when?"

The OS as Servant to Two Masters



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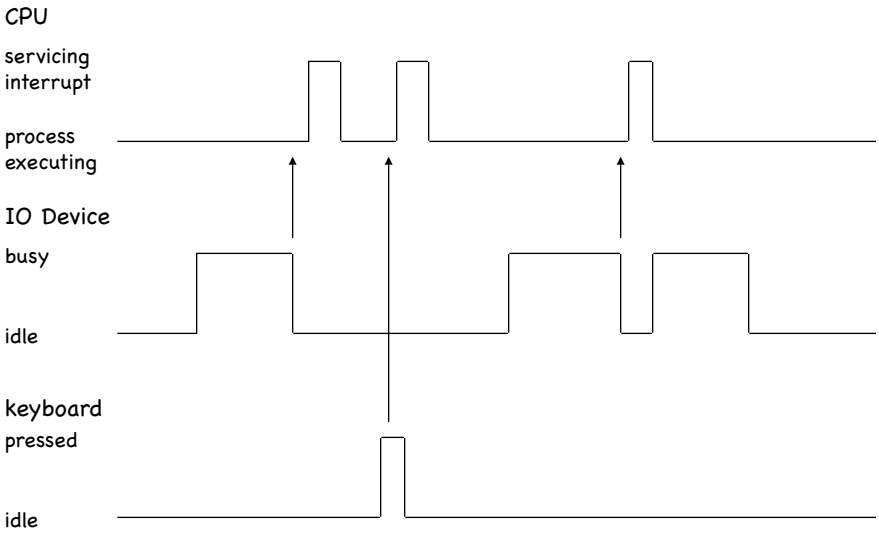
Architectural Support for OS's

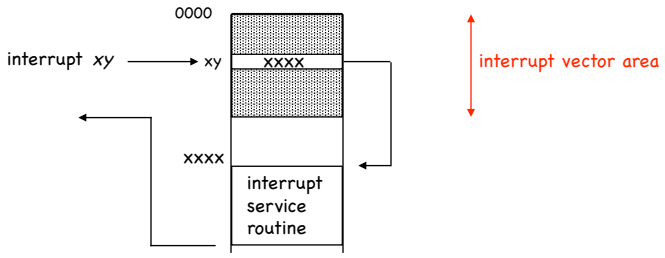
- Dealing with Asynchronous Events: Exceptions, Interrupts
  - Modern OS's are interrupt-driven (some still are not!).
  - Simple interrupt handling vs. exception handling MIPS-style.
- Hardware Protection
  - Privilege Levels (e.g. user/kernel/supervisor, etc.)
  - Priviledged instructions: typically CPU control instructions
  - I/O Protection
  - Memory Protection
- Support for Address Spaces
- Timers

Modern OS's are Interrupt-Driven



Interrupts / Exceptions

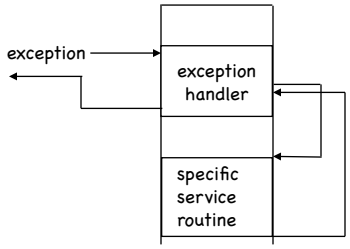
- When an interrupt occurs, CPU stops, saves state, typically changes into supervisor mode, and immediately jumps to predefined location.
- Appropriate interrupt service routine is found through the *interrupt vector*.
- Return-from-interrupt automatically restores state.



- Interrupts/Exceptions can be invoked by *asynchronous events* (I/O devices, timers, various errors) or can be *software-generated* (system calls).

Exceptions, MIPS-Style

- MIPS CPU deals with **exceptions**.
  - Interrupts are just a special case of exceptions.
- The MIPS Architecture has no interrupt-vector table!
  - All exceptions trigger a jump to the same location, and de-multiplexing happens in the exception handler, after looking up the reason for the exception in the `CAUSE` register.



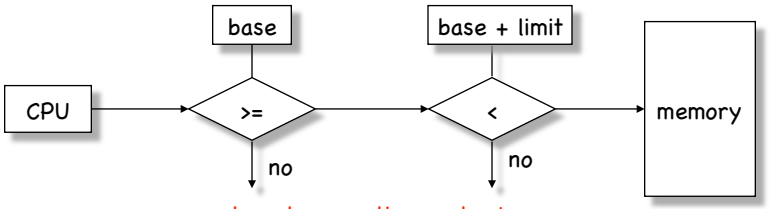
MIPS Exception Handler (low-level)

Hardware Protection

- Originally: User owned the machine, no monitor. No protection necessary.
- Resident monitor, resource sharing: One program can adversely affect the execution of others.
- Examples
  - halt and other instructions
  - modify data or code in other programs or monitor itself
  - access/modify data on storage devices
  - refuse to relinquish processor
- Benign (bug) vs. malicious (virus)

Hardware Protection (2)

- Dual-mode operation
  - *user mode* vs. *supervisor mode*
  - e.g. halt instruction is privileged.
- I/O Protection
  - define all I/O operations to be privileged
- Memory Protection
  - protect interrupt vector, interrupt service routines
  - determine legal address ranges



Timers

- Timers can be set, and a trap occurs when the timer expires. (And OS acquires control over the CPU.)
- Other uses of timers:
  - time sharing
  - time-of-day

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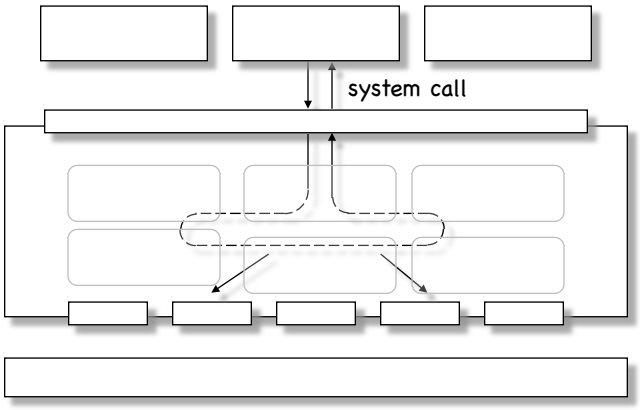
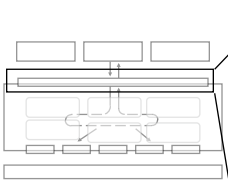
External Structure of an OS

The outsider's view of the OS.



System Calls

Provide the interface between a process and the OS.



Example: vanilla **copy**:

```
int copy(char * fname1, *fname2) {
  FILE *f, *g;
  char c;
  f = fopen(fname1, "r");
  g = fopen(fname2, "w");
  while (read(f, &c, 1) > 0)
      write(g, c, 1);
  fclose(f);
  fclose(g);
}
```

System Call Implementation: Linux on x86

- Example: `_syscall(int, setuid, uid_t, uid)`
- expands to:

```
_setuid:
  subl $4,%exp
  pushl %ebx
  movzwl 12(%esp),%eax
  movl %eax,4(%esp)
  movl $23,%eax   <<<---- System Call number (setuid = 23)
  movl 4(%esp),%ebx
  int $0x80       <<<---- call transfer to kernel entry point _system_call()
  movl %eax,%edx
  testl %edx,%edx
  jge L2
  negl %edx
  movl %edx,_errno
  movl $-1,%eax
  popl %ebx
  addl $4,%esp
retL2:
  movl %edx,%eax
  popl %ebx
  addl $4,%esp
  ret
```

Why Interrupts?

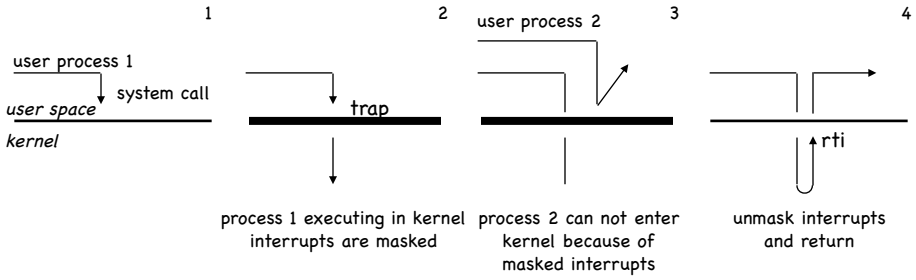
Reason 1: Can load user program into memory without knowing exact address of system procedures

Reason 2: Separation of address space, including stacks: *user stack* and *kernel stack*.

Reason 3: Automatic change to *supervisor mode*.

Reason 4: Can control *access* to kernel by masking interrupts.

Reason 4: Mutual Exclusion in Kernel



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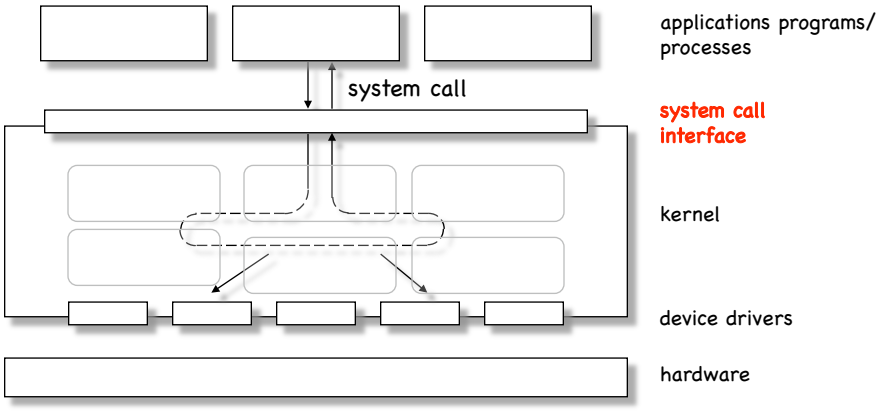
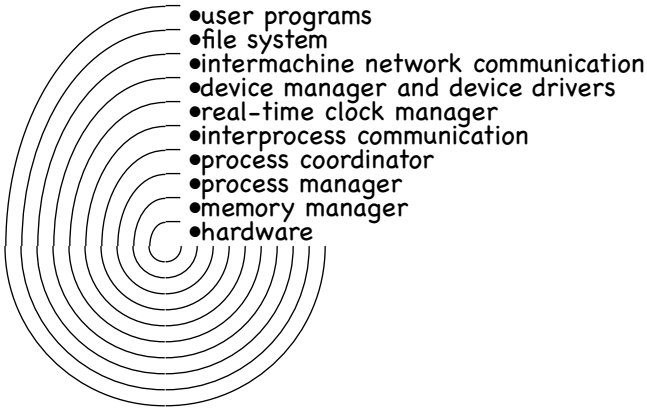


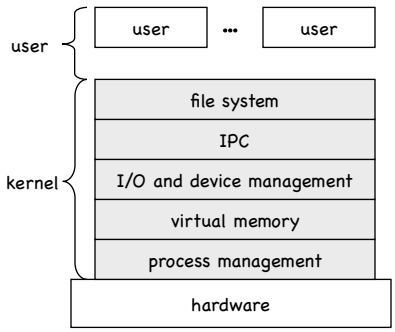
Internal Structure: Layered Services

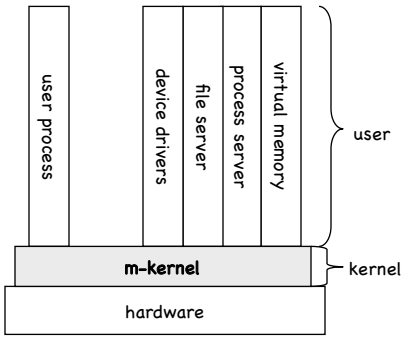
The insider's view of the OS.
Example: XINU [Comer 1984]



Internal Structure: μ-Kernels

- Layered Kernels *vs.* Microkernels





Hierarchical decomposition.
Interaction only between adjacent layers.

Kernel has only core operating system functions (memory management, IPC, I/O, interrupts)
Other functions run in *server processes* in user space.

Operations in a μ-Kernel

- Non-kernel components of the OS are implemented as server processes.
- Communication between user and servers using messages through kernel.
- "client-server architecture within a single computer"
- Examples: Mach, Windows NT, Chorus, L4, ...

Windows 2000 System Structure

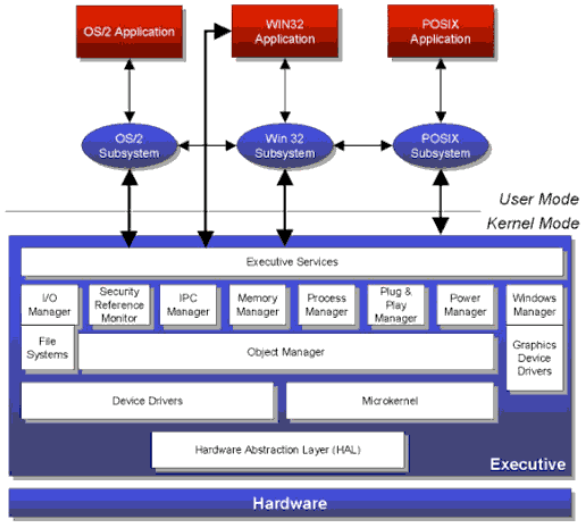


Figure 2.– System architecture