Operating Systems Principles
UCLA-CS111-W18

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Contents

1 L3: Arpaci-Dusseau Chapter 5: Interlude: Process API

1.1 The fork() System Call

- Crux: How to create and control processes
- fork()
  - Creates new process; returns child's PID to parent; returns 0 to child;
  - Each has own PC, registers, address space
- Nondeterministic Behavior
  - Scheduler will decide which process to run
  - May lead to problems in multi-threaded programs

1.2 The wait() System Call

- wait()
  - Parent calls wait() to wait for child to finish execution

1.3 The exec() System Call

- exec()
  - Loads code, overwrites code segment, and reinitializes memory space
  - Takes exceutable name and arguments
  - Does not create a new process; transform current process

1.4 Why? Motivating The API

- Separation
  - Separating fork() and exec() allows code to alter the environment of the about-to-run program
- Example
  - Shell forks a process, execs the program, and waits until finished
  - The separation allows for things such as output to be redirected (closes stdout and opens file)

1.5 Other Parts Of The API

- kill()
  - System call sends signal to process to sleep, die, etc

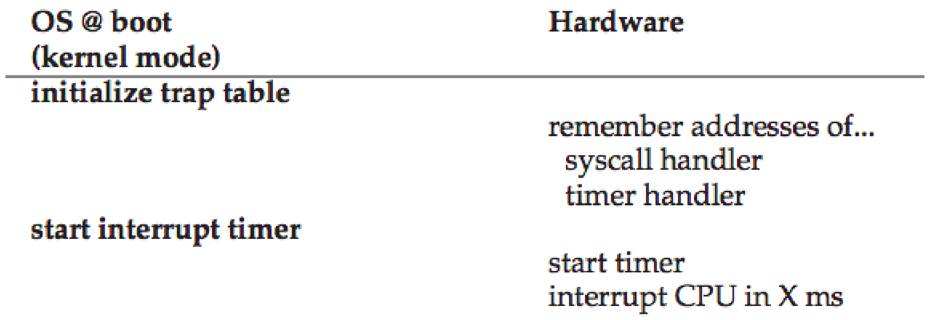
2 L3: Arpaci-Dusseau Chapter 6: Mechanism: Limited Direct Execution

2.1 Basic Technique: Limited Direct Execution

- Crux: How to efficiently virtualize CPU with control
- Limited Direct Execution
  - OS will create entry for process list, allocate memory for program, load program into memory, setup stack with argc/v, clear registers, execute call to main()
  - Program will run main(), execute return
  - OS will free memory, remove from process list
- LDE good bc fast, but
  - Problem of keeping control
  - Problem of time sharing still

2.2 Problem 1: Restricted Operations

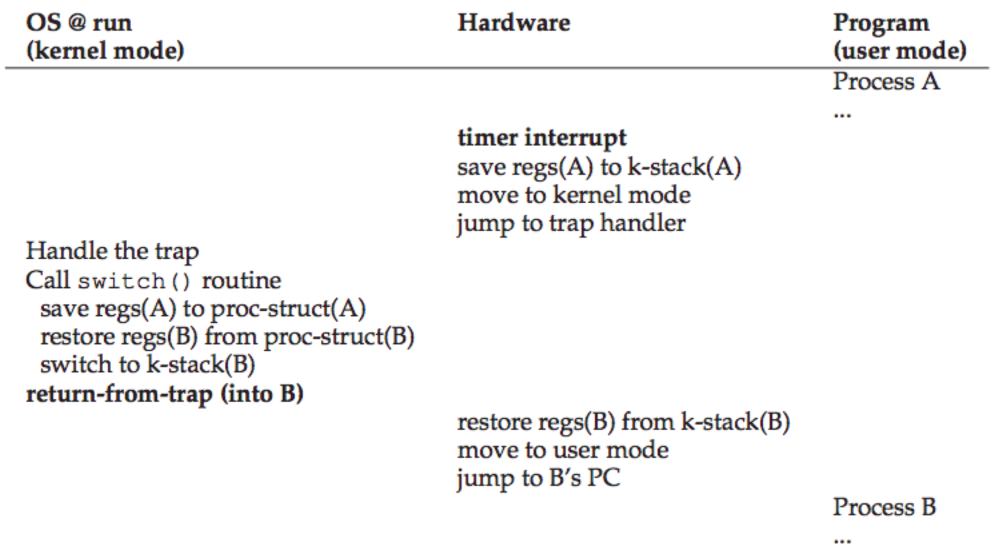
- User mode vs. Kernel mode
  - Restricted mode which needs to ask kernel to perform system calls
  - Calls like open() are actually procedure calls with trap to enter kernel and raise privilege
  - Return-from-trap is used to enter user mode from kernel and drop privilege
  - Push counters, flags, registers onto per-process kernel stack when trapping
- Trap table is used to control what code is executed when trapping
  - Trap handler used by hardware to cause interrupts
  - Telling hardware where trap table is is privileged
  - Trap handler actually uses system-call number, rather than specifying an address (another layer of protection)
- Two phases of LDE
  - At boot, kernel initializes trap table and remembers where it is



OS @ boot (kernel mode)	**Hardware**
initialize trap table	
	remember addresses of... syscall handler timer handler
start interrupt timer	
	start timer interrupt CPU in X ms

2.3 Problem 2: Switching Between Processes

- How can OS regain control?
  - Because process is running, so OS is not running
- Cooperative Approach
  - System calls include explicit yield system call, transfering control back to OS
- Noncooperative Approach
  - Reboot, Timer Interrupt
- Saving and Restoring Context
  - Scheduler will choose when to switch processes



OS @ run (kernel mode)	**Hardware**	**Program (user mode)**
		Process A ...
	timer interrupt save regs(A) to k-stack(A) move to kernel mode jump to trap handler	
Handle the trap Call `switch()` routine save regs(A) to proc-struct(A) restore regs(B) from proc-struct(B) switch to k-stack(B) **return-from-trap (into B)**		
	restore regs(B) from k-stack(B) move to user mode jump to B's PC	
		Process B ...

2.4 Worried About Concurrency?

- Interrupt during interrupt?
  - Many complex things to do
  - Could disable interrupts (but this might lose interrupts), or locking schemes, etc

2.5 Summary

- Reboot
  - Good technique because restores system to well-tested state
  - OS will 'baby-proof' by only allowing processes to run in restricted mode and with interrupt handlers

3 L3: Linking and Libraries: Object Modules, Linkage Editing, Libraries

3.1 Introduction

- Process as fundamental; as executing instance of program
  - Program as one or more files (these are not the executables though)
  - Source must be translated

3.2 The Software Generation Tool Chain

- Source module
  - Editable text in some language like C
- Relocatable object module
  - Sets of compiled instructions; incomplete programs
- Library
  - Collection of object modules
- Load module
  - Complete programs ready to be loaded into memory
- Compiler
  - Parse source modules; usually generates assembly, may generate pseudo-machine
- Assembler
  - Object module with mostly machine code
  - Memory addresses of functions, variables may not be filled in
- Linkage Editor
  - Find all required object modules and resolve all references
- Program Loader
  - Examines load module, creates virtual space, reads instructions, initializes data values
  - Find and map additional shared libraries

3.3 Object Modules

- Code in multiple files
  - Because more understandable if splitting functionality
  - Many functions are reused, so use external libraries
- Relocatable object modules are program fragments
  - Incomplete because make references to code in other modules
  - Even the references to other code are only relative
- ELF format
  - Header section with types, sizes, and location of other sections
  - Code and data section to be loaded contiguously
  - Symbol table of external symbols
  - Relocation entries describing location of field, width/type of field, symbol table entry

3.4 Libraries

- Reusable, standard functions in libraries
  - Libraries not always orthogonal and independent
- Build program by combining object modules and resolving external references

3.5 Linkage Editing

- Resolution
  - Search libraries to find object modules to resolve external references
- Loading
  - Lay text and data in single virtual address space
- Relocation
  - Ensure references correctly reflect chosen address

3.6 Load Modules

- Load module requires no relocation and is complete
- When loading new module
  - Determine required text and data sizes and locations, allocate segments, read contents, create a stack segment with pointer
- Load module has symbol table to help determine where exceptions occurred

3.7 Static vs. Shared Libraries

- Static Linking
  - Many copies, so inefficient; also, permenant copy, so don't receive updates
- Shared Libraries
  - Implementations vary, but one way
    - Reserve address for libraries, linkage edit, map with redirection table, etc, more mapping
  - Efficient, but doesn't work for static data because one copy
  - But can be slow to load many libraries, and must know library name at loadtime

3.8 Dynamically Loaded Libraries

- DLL loaded once needed
  - Choose and load library, binds, use library, unload
  - Resource efficient because can unload
- Implicitly Loaded Dynamically Loadable Libraries
  - Another implementation of DLL with different pros/cons

4 L3:

4.1 Overview