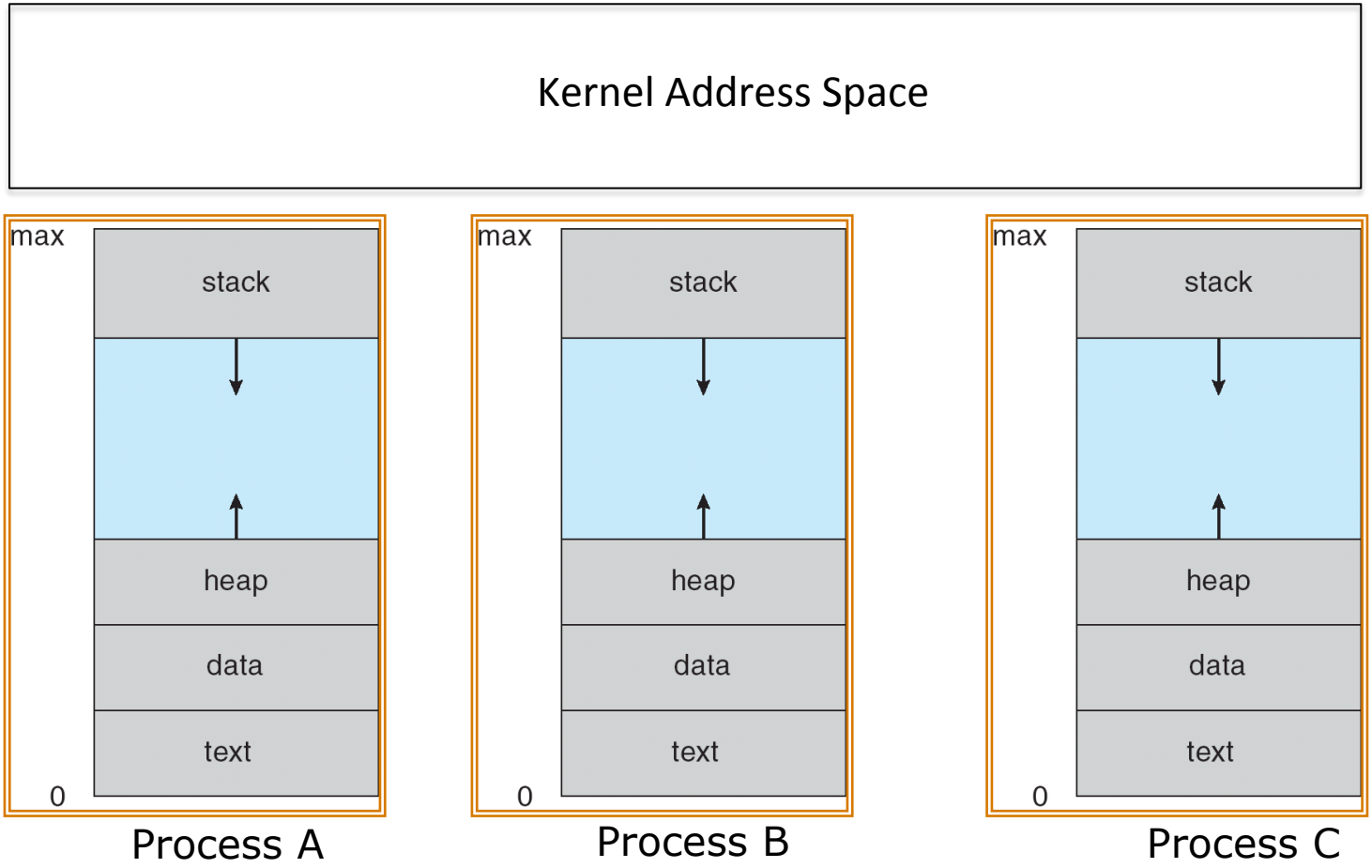
System Calls

COMS W4118

References: Operating Systems Concepts (9e), Linux Kernel Development, previous W4118s

Address Space Overview



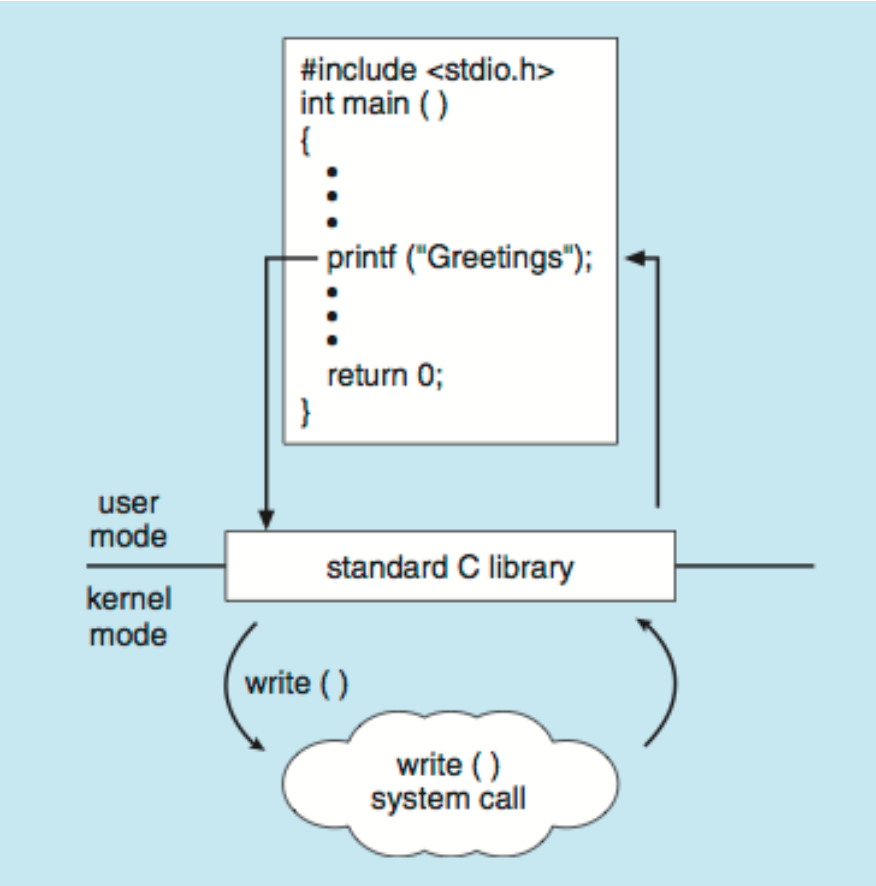
- Processes can't access anything outside address space
- How do they communicate with outside world?

System calls

- User processes cannot perform privileged operations themselves
- Must request OS to do so on their behalf by issuing system calls
- System calls elevate privilege of user process
  - Must ensure kernel is not tricked into doing something a user process should not be doing
  - Must verify every single parameter!

Library vs. System Calls

- C program invoking printf() libc library call, which calls write() system call

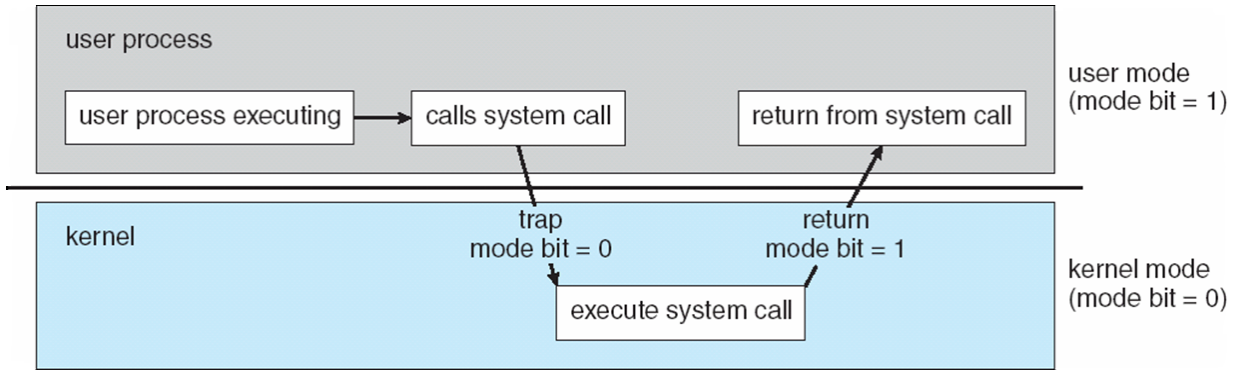


Examples of Windows and Unix System Calls

	Windows	Unix
Process Control	CreateProcess() ExitProcess() WaitForSingleObject()	fork() exit() wait()
File Manipulation	CreateFile() ReadFile() WriteFile() CloseHandle()	open() read() write() close()
Device Manipulation	SetConsoleMode() ReadConsole() WriteConsole()	ioctl() read() write()
Information Maintenance	GetCurrentProcessID() SetTimer() Sleep()	getpid() alarm() sleep()
Communication	CreatePipe() CreateFileMapping() MapViewOfFile()	pipe() shmget() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

System Call Dispatch

- How should actual system call be invoked?
  - Program can't see kernel namespace



- Need hardware support to change privilege level
- Traps
  - Type of interrupt
  - Software interrupts and exceptions
  - Software interrupts initiated by programmer
  - Exceptions occur automatically

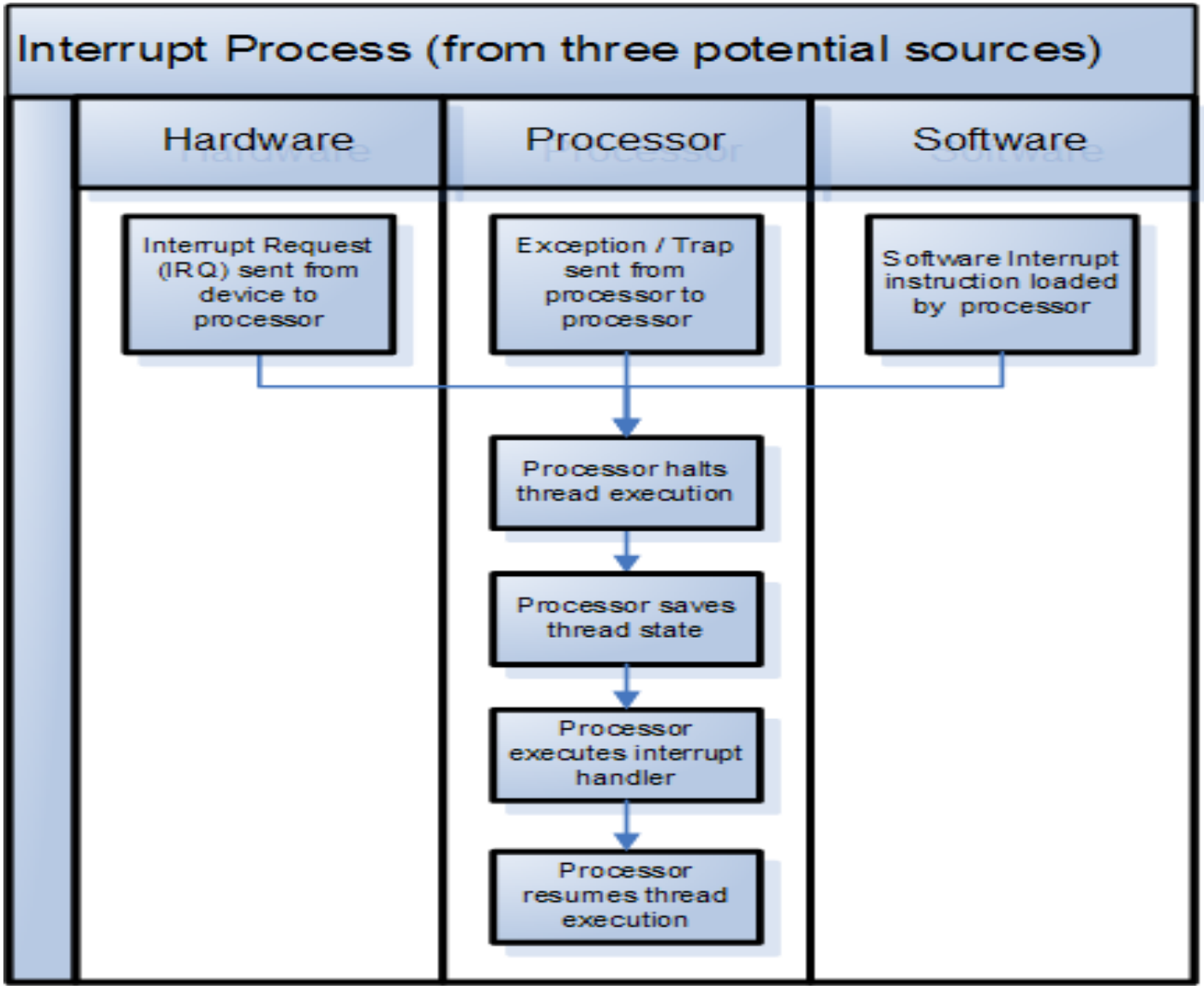
Traps, Interrupts, Exceptions

```
for(;;) {
   if (interrupt) {
      n = get interrupt number
      call interrupt handler n
   }
   fetch next instruction
   run next instruction
}
```

```
for(;;) {
   fetch next instruction
   run next instruction {
      if (instr == "int n")
        call interrupt handler n
   }
   if (error or interrupt) {
      n = get error or interrupt type
      call interrupt handler n
   }
}
```

- On x86, int n (n=0:255) calls interrupts n
- Some interrupts are privileged
- Can't be called by user mode
- Others aren't, e.g., syscalls
- Processor transitions to privileged mode when handling interrupt

Three kinds of interrupts

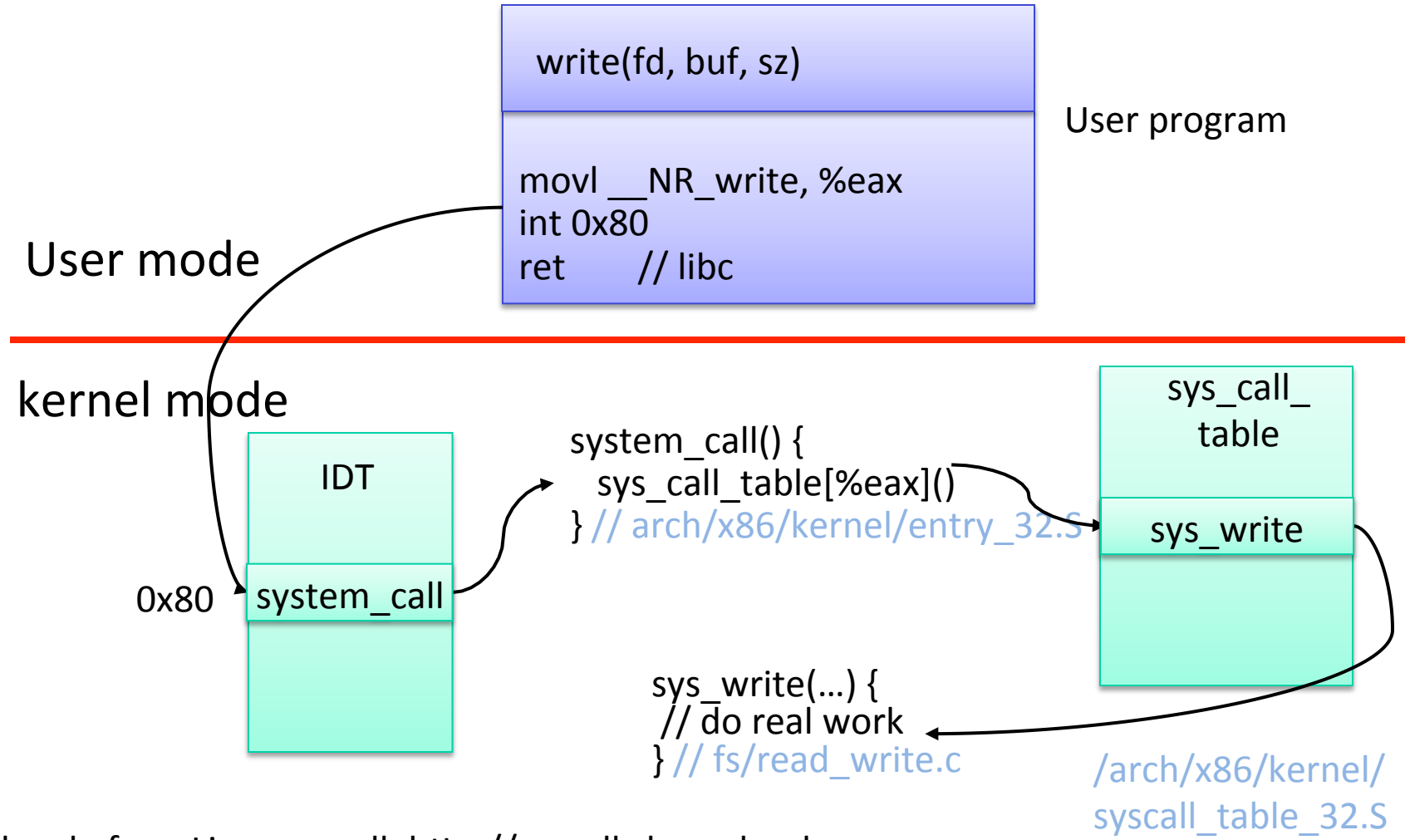


System call dispatch

1. Kernel assigns system call type a system call number
2. Kernel initializes system call table, mapping system call number to functions implementing the system call
   - Also called system call vector

3. User process sets up system call number and arguments
4. User process runs int X (on Linux, X=80h)
5. Hardware switches to kernel mode and invokes kernel's interrupt handler for X (interrupt dispatch)
6. Kernel looks up syscall table using system call number
7. Kernel invokes the corresponding function
8. Kernel returns by running iret (interrupt return)

Linux System Call Dispatch



To find code for a Linux syscall: http://syscalls.kernelgrok.com

System call parameter passing

- Typical methods
  - Pass via registers (e.g., Linux)
    - More parameters than registers?
  - Pass via user-mode stack
    - Complex: user mode and kernel mode stacks
  - Pass via designated memory region
    - Address passed in register

Linux System Call Parameter Passing

- Syscalls with fewer than 6 parameters passed in registers
  - %eax (syscall number), %ebx, %ecx, %esi, %edi, %ebp
- If 6 or more arguments
  - Pass pointer to block structure containing argument list
- Maximum size of argument is register size
  - Larger arguments passed as pointers
  - Stub code copies parameters onto kernel stack before calling syscall code (kernel stack, will study later)
- Use special routines to fetch pointer arguments
  - get_user(), put_user(), copy_to_user(), copy_from_user
  - Include/asm/uaccess.S
  - These functions can block. Why?
  - Why use these functions?
- OS must validate system call parameters

Linux system call naming convention

- Usually the user-mode wrapper foo() traps into kernel, which calls sys_foo()
  - sys_foo is implemented by DEFINEx(foo, …)
  - Expands to “asmlinkage long sys_foo(void)”
  - Where x specifies the number of parameters to syscall
  - Often wrappers to foo() in kernel
- System call number for foo() is __NR_foo
  - arch/x86/include/asm/unistd_32.h
  - Architecture specific
- All system calls begin with sys_

System Call from Userspace

- Generic syscall stub provided in libc
  - _syscalln
  - Where n is the number of parameters
- Example
  - To implement: ssize_t write(int fd, const void *buf, size_t count);
  - Declare:

```
#define __NR_write 4 /* Syscall number */
_syscall3(ssize_t, write, int, fd, const void*, buf, size_t count)
```

- Usually done in libc for standard syscalls

Tracing system calls in Linux

- Use the "strace" command (man strace for info)
- Linux has a powerful mechanism for tracing system call execution for a compiled application
- Output is printed for each system call as it is executed, including parameters and return codes
- ptrace() system call is used to implement strace
  - Also used by debuggers (breakpoint, singlestep, etc)
- Use the "ltrace" command to trace dynamically loaded library calls

System Call Tracing Demo

- pwd
- ltrace pwd
  - Library calls
  - setlocale, getcwd, puts: makes sense
- strace pwd
  - System calls
  - execve, open, fstat, mmap, brk: what are these?
  - getcwd, write

Interesting System Calls

- brk, sbrk: increase size of program data
  - void* sbrk(int bytes)
  - Accessed through malloc
- mmap
  - Another way to allocate memory
  - Maps a file into a process's address space
  - Or just grab memory with MAP_ANONYMOUS
  - MAP_PRIVATE or MAP_SHARED