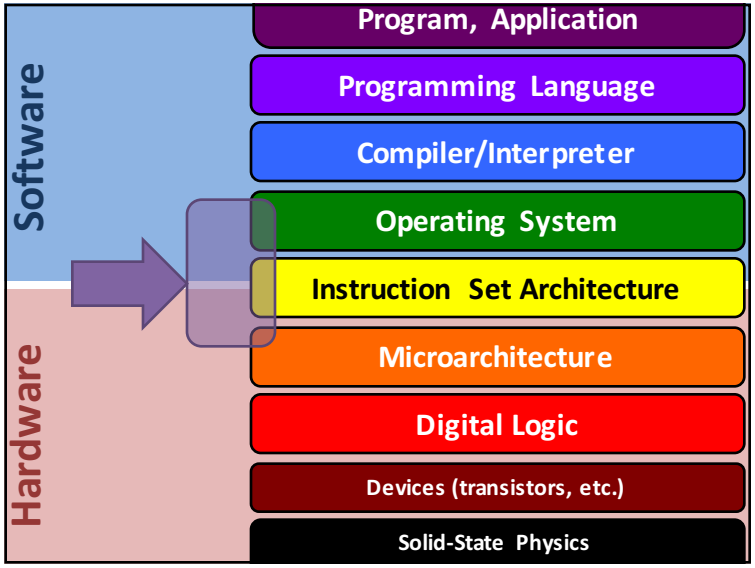


Operating Systems

Problem: unwieldy hardware resources

complex and **varied**
- storage, networks, displays, user interfaces…
- many different implementations

limited
- one/few processors, fixed-size memory

Solution: operating system

Manage, abstract, and virtualize hardware resources
- **Simpler, common interface** to varied hardware
- **Share** limited resources among multiple processes, users
- **Protect** co-resident processes and users from each other

A (brief) 240 tour of Operating Systems

Focus: key abstractions provided by *kernel*
- *barely scraping surface of kernel – take a full OS course*
- *"OS" often used to refer to much more than the kernel*

Abstractions:
- process
- virtual memory
- virtual devices, I/O

Virtualization mechanisms and **hardware support:**
- context-switching
- exceptional control flow
- address translation, paging, TLBs

Processes

Program **= code (static)**

Process **= a running program instance (dynamic)**
- code + state (all registers, memory, other resources)

Key illusions:

Logical control flow — Today
- Each process seems to have exclusive use of the CPU

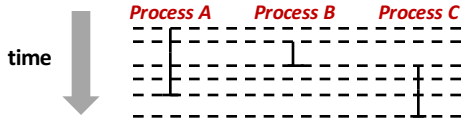
Private address space — Next Week
- Each process seems to have exclusive use of full memory

Why are these abstractions important?

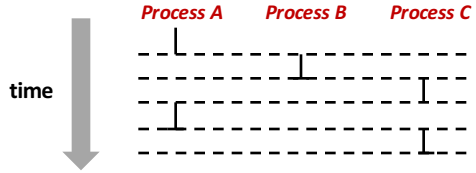
How are these abstractions implemented?

Implementing logical control flow

Abstraction: every process has full control over the CPU



Implementation: time-sharing



Context Switching

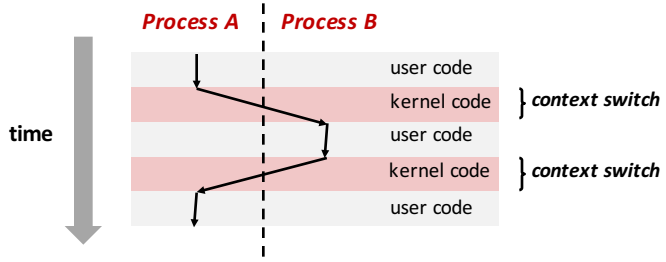
Kernel **(shared OS code) switches between processes**

Kernel code runs as part of every process (NOT its own separate process)

Controls *scheduling*: which process to run next, and when.

Control flow passes between processes via *context switch.*

(how?) context = state = all registers (including PC) + memory



6

Control Flow

Processor: read instruction, execute it, go to next instruction, repeat

Physical control flow

time

<startup>
$inst_1$
$inst_2$
$inst_3$
...
$inst_n$
<shutdown>

Explicit changes:

Jumps (conditional, unconditional)

Call, return

Exceptional changes:

user input

data arrives from disk or network

unexpected errors

transfer control between processes/OS

Exceptions

Synchronous: caused by instruction

Traps: like procedure call to OS

Intentional: transfer control to OS to perform some function

system calls (syscall), breakpoints, ...

Returns control to "next" instruction

Faults: unintentional, maybe recoverable

page faults, segment protection faults, divide by zero

Fix and re-execute faulting instruction or abort process.

Aborts: unintentional, unrecoverable

hardware failure detected

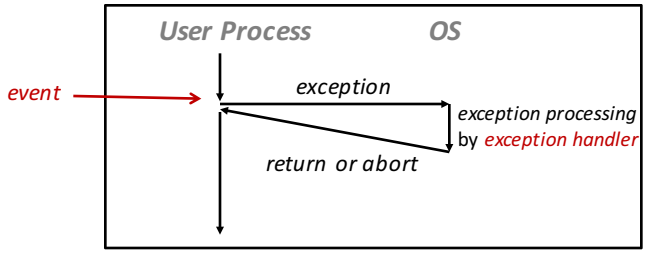
Asynchronous (Interrupts): caused by external events

incoming I/O activity, reset button, timers

Exceptions: hardware support for OS

transfer control to OS in response to *event*

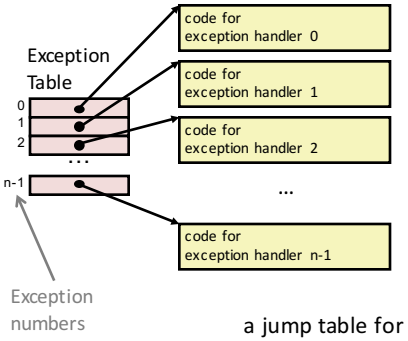
What code should the OS run to handle the event?



9

Interrupt Vector

stored in memory
special register holds base address



Unique ID per type of event

ID = index into exception table
(a.k.a. interrupt vector)

Handler *i* is called each time exception *i* occurs

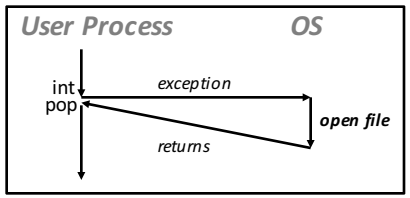
a jump table for exceptions…

10

Open a file (trap/system call)

User process calls: **`open(filename, options)`**
`open` executes system call instruction **`int`**

```
0804d070 <__libc_open>:
 . . .
 804d082:  cd 80                 int    $0x80
 804d084:  5b                    pop    %ebx
 . . .
```



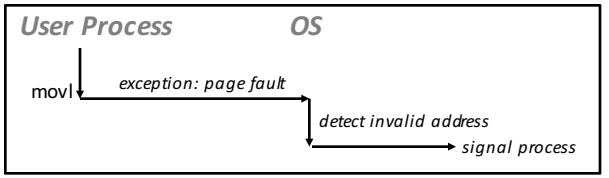
12

Segmentation Fault

```
int a[1000];
void bad () {
    a[5000] = 13;
}
```

Write to invalid memory location.

```
80483b7:  c7 05 60 e3 04 08 0d   movl   $0xd,0x804e360
```



aborts process with SIGSEGV signal

13

Page Fault

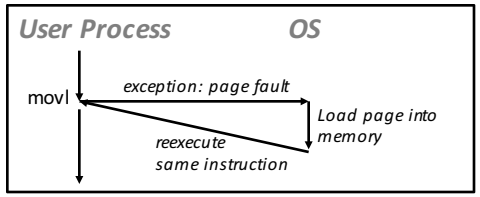
```
int a[1000];
main () {
    a[500] = 13;
}
```

Write to valid memory location

... but contents currently on disk instead

(more later: virtual memory)

```
80483b7:  c7 05 10 9d 04 08 0d  movl   $0xd,0x8049d10
```



14