15-410

"...process_switch(P2) 'takes a while'..."

Yield
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Outline

Project 2 Q&A

Context switch

- Motivated by yield()
- This is a *core idea* of this class

Mysterious yield()

```
process1() {
   while (1)

yield(P2);
}
```

```
process2() {
   while (1)

yield(P1);
}
```

User-space Yield

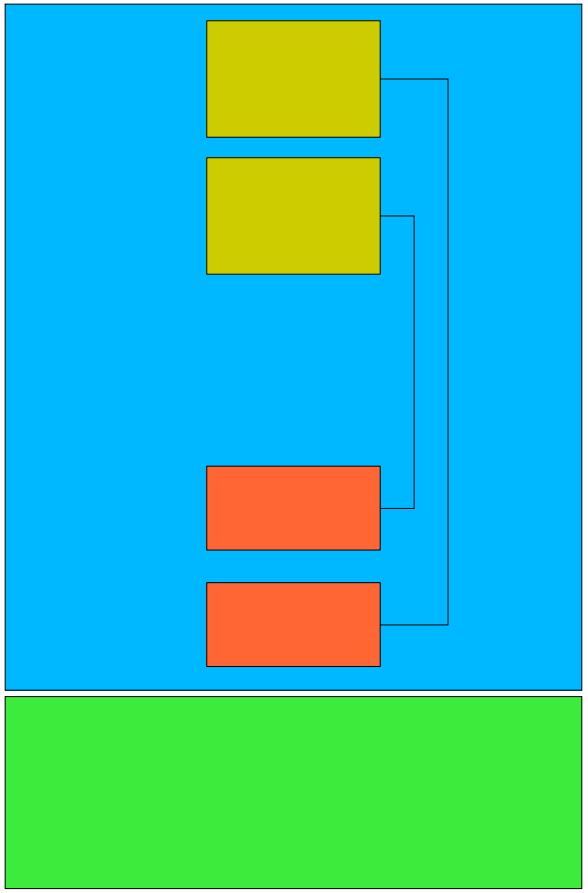
Consider *pure user-space threads*

- **The opposite of Project 2**

What is a thread?

- **A stack**
- **"Thread control block" (TCB)**
  - **Locator for register-save area**
  - **Housekeeping information**

Big Picture

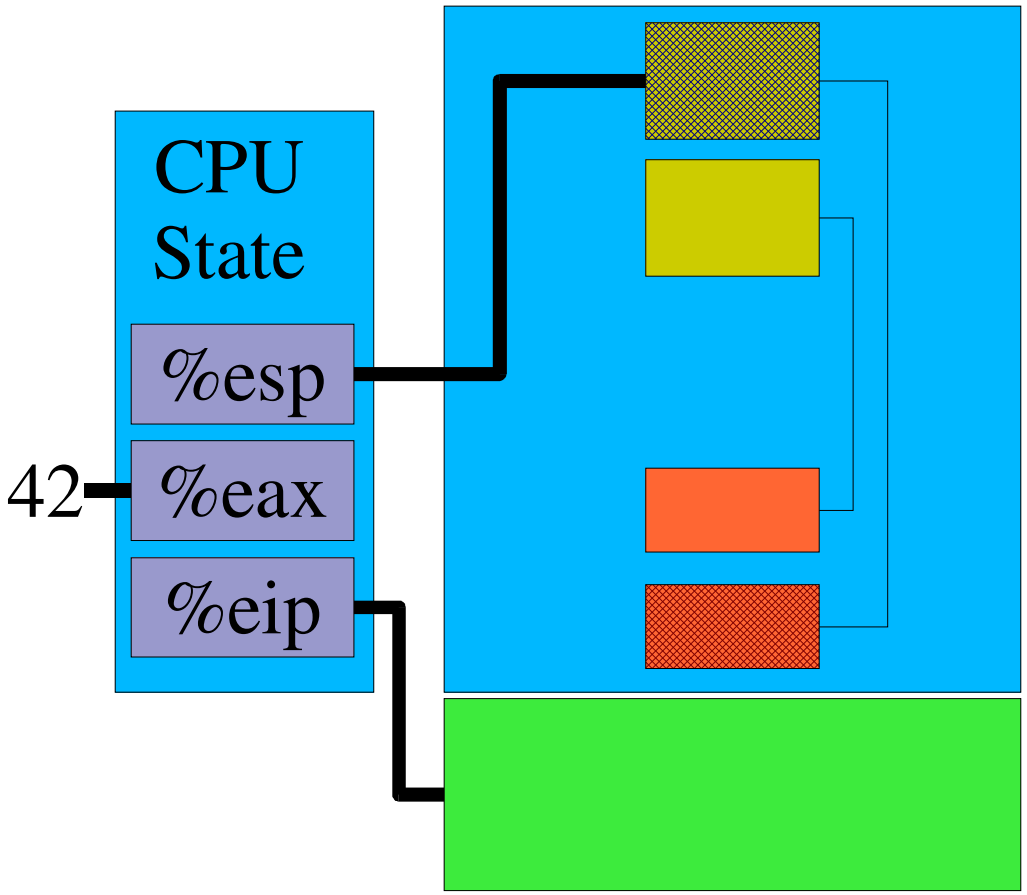


Thread stacks

Thread blocks

Code, Data

Big Picture

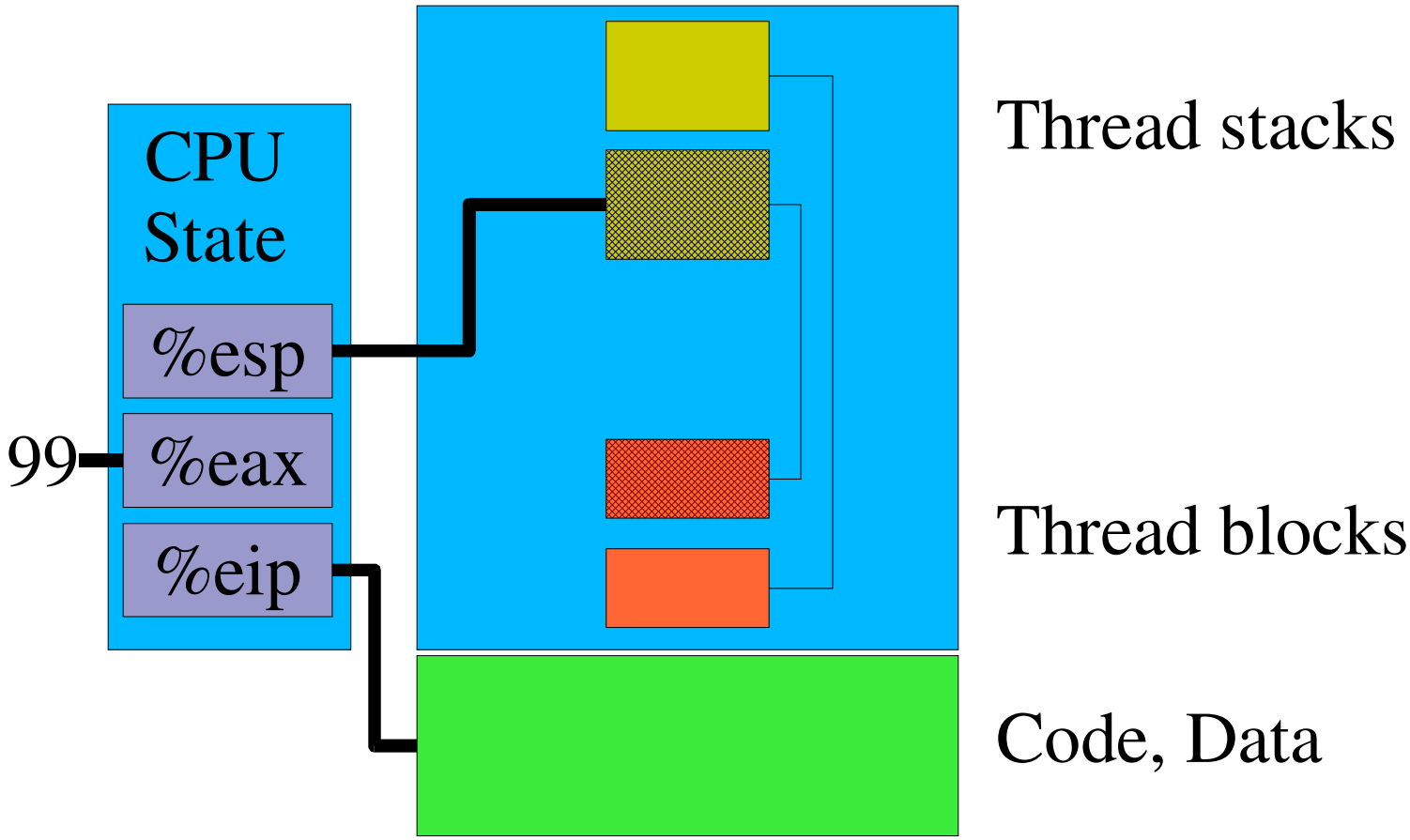


Thread stacks

Thread blocks

Code, Data

Running the Other Thread



User-space Yield

yield(user-thread-3)

- save my registers on stack
- */* magic happens here */*
- restore thread 3's registers from thread 3's stack
- return */* to thread 3! */*

Todo List

General-purpose registers

Stack pointer

Program counter

No magic!

yield(user-thread-3)

```
save registers on stack    /* asm(...) */
tcb->sp = get_esp();       /* asm(...) */
tcb->pc = &there;
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp;    /* asm(...) */
jump(tcb->pc);             /* asm(...) */
there:
restore registers from stack /* asm() */
return
```

The Program Counter

What values can the PC (%eip) contain?

- **Thread switch happens *only in yield***
- **Yield sets saved PC to start of "restore registers"**

All **non-running threads have the *same* saved PC**

- **Please make sure this makes sense to you**

Remove Unnecessary Code

yield(user-thread-3)

```
save registers on stack
tcb->sp = get_esp();
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp;
jump(there);
there:
restore registers from stack
return
```

Remove Unnecessary Code

yield(user-thread-3)

```
save registers on stack
tcb->sp = get_esp();
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp;
restore registers from stack
return
```

User Threads vs. Kernel Processes

User threads

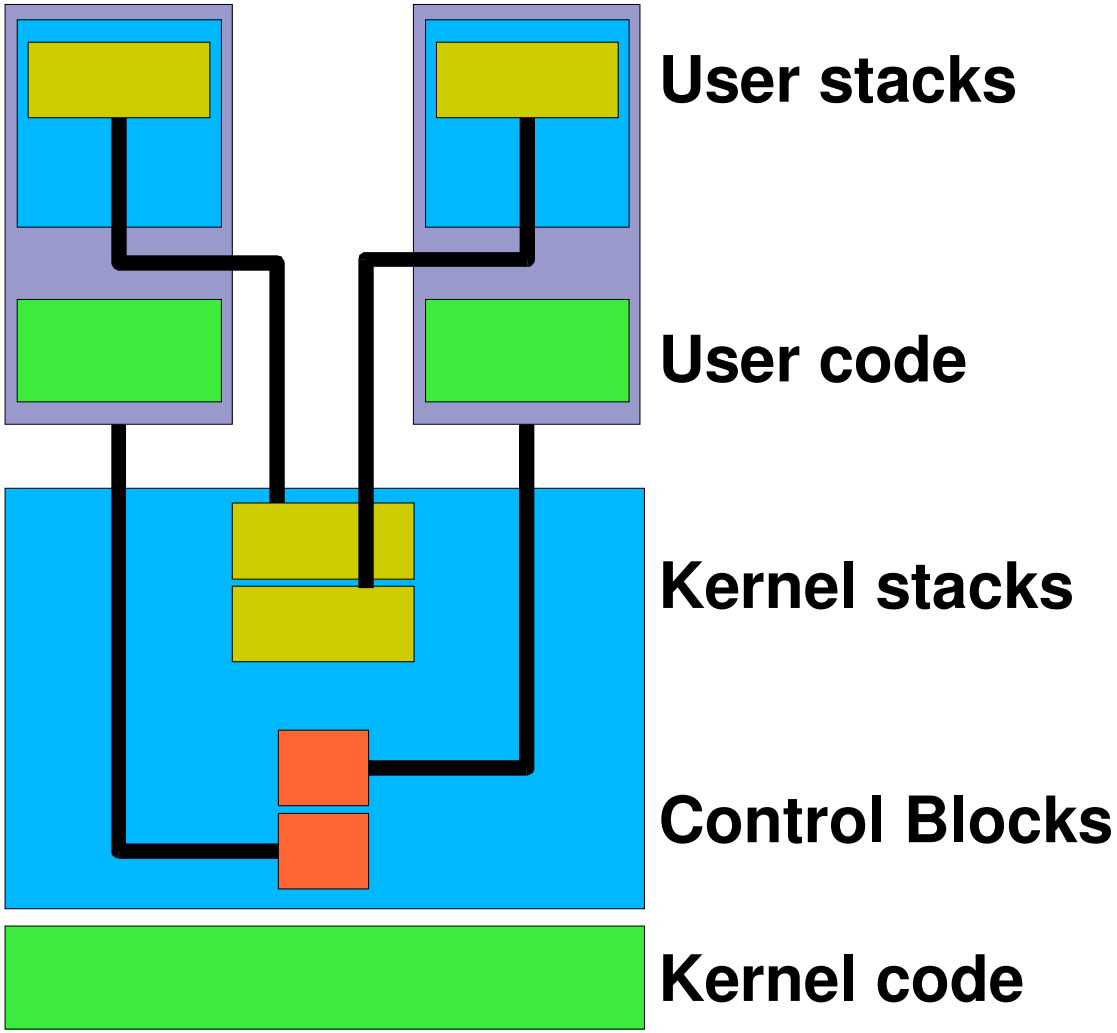
- Share memory
- Threads not protected from each other

Processes

- Do *not* generally share memory
- P1 must *not* modify P2's saved registers

Where are process save areas and control blocks?

Kernel Memory Picture



Yield steps

P1 calls yield(P2)

INT 50 ⇒ *boom!*

Processor trap protocol

- Saves some registers on P1's kernel stack
  - This is a *stack switch* (user ⇒ kernel), intel-sys.pdf 5.10
  - Top-of-kernel-stack specified by %esp0
  - %ss & %esp, %eflags, %cs & %eip

Assembly-language stub

- Saves more registers
- Starts C trap handler

Yield steps

handle_yield()

- return(process_switch(P2))

Assembly-language stub

- Restores registers from P1's kernel stack

Processor return-from-trap protocol (aka IRET)

- Restores %ss & %esp, %eflags, %cs & %eip

INT 50 instruction "completes"

- Back in user-space

P1 yield() library routine returns

What happened to P2??

process_switch(P2) “takes a while”

- When P1 calls it, it “returns” to P2
- When P2 calls it, it “returns” to P1 (eventually)

Inside process_switch()

ATOMICALLY

```
enqueue_tail(runqueue, cur_pcb);
cur_pcb = dequeue(runqueue, P2);
save registers    /* P1's stack */
stackpointer = cur_pcb->sp;
restore registers /* P2's stack */
return
```

User vs. Kernel

Kernel context switches happen for more reasons

- yield()
- Message passing from P1 to P2
- P1 sleeping on disk I/O, so run P2
- *CPU preemption by clock interrupt*

Clock interrupts

P1 doesn't "ask for" clock interrupt

- Clock handler *forces* P1 into kernel
  - Kernel stack looks like a "system call"
  - But it was involuntary

P1 doesn't say who to yield to

- (it didn't make the "system call")
- *Scheduler* chooses next process

I/O completion Example

P1 calls read()

In kernel

- read() starts disk read
- read() calls condition_wait(&buffer);
- condition_wait() calls process_switch()
- process_switch() returns *to P2*

I/O Completion Example

While P2 is running

- Disk completes read, interrupts P2 into kernel
- Interrupt handler calls condition_signal(&buffer);

Option 1

- condition_signal() marks P1 as runnable, returns
- Interrupt handler returns to P2

Option 2

- condition_signal() calls process_switch(P1) (only fair...)
- P2 will finish the interrupt handler *much later*
  - Rembmer to confront implications of this in P3!

Summary

Similar steps for user space, kernel space

Primary differences

- Kernel has open-ended competitive scheduler
- Kernel more interrupt-driven

Implications for 410 projects

- P2: firmly understand thread stacks
  - thread_create() stack setup
  - cleanup
  - race conditions
- P3: firmly understand kernel context switch
  - ...