Betriebssysteme

Tutorium 5

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1 Process switching

Process switching — PCB

What does the kernel need to do when switching processes?

- Adjust Instruction, Base and Frame Pointer – okay

The process shouldn't notice it was interrupted! What else do you need to adjust?

- General purpose register
- Address space
- And a bit of housekeeping: Open files, scheduling priorities, ...

⇒ These things make up the PCB - The Process Control Block

Where are the PCBs stored? In user or kernel space?

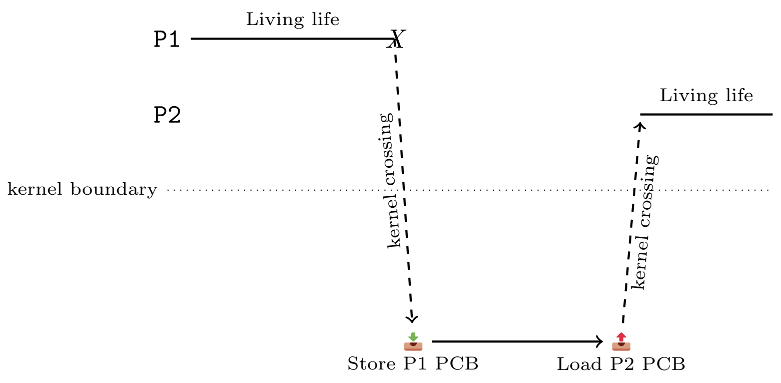
- Kernel space! Users shouldn't be able to modify them

Process switching — PCB

Are the PCBs always valid?
No! Some parts (registers, PC, etc) only when the process is not running. Why? They are saved when it is switched out.

Process switching

In pictures



Process switching

As text

1. Transition to the kernel (How? Interrupt, Exception, Syscall)
2. Save the context of the process. What was that again? Registers, Program counter, Stack pointer, etc.
3. Where do you save it to? A per-process kernel stack typically (as it is often moved there automatically) and then move it to the PCB.
4. Restore the context of the next process
5. Leave kernel mode and transfer control to the PC of the next process

2 Threads

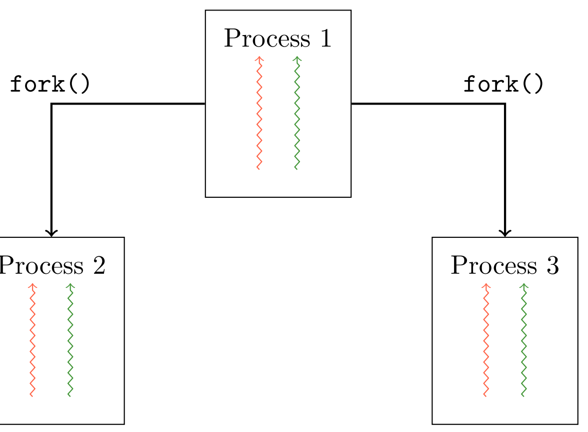
Threads

What are processes, address spaces and threads? How do they relate to each other?

- A thread is an *entity of execution*, the personification of control flow
- A thread lives in an address space, i.e. all the addresses that it can can access and the data that is stored there
- Thread + Address Space = Process

Threads — Forking

Should a fork do this?



Threads — Forking

Who is aware of the fork?

- The thread that executed the fork and the child
- Who else? Nobody!

Can you foresee any problems?

- If you copy the thread it might do weird things
- Locks are memory and will be copied as well! What if a thread holds a critical lock when it is forked?

Do you need thread duplication for our shell example?
No, we `exec` anyways.

Summary
`fork` is not as simple as it once was. Is it still a good abstraction?

Kernel Mode Threads — Kernel Level Threads

What is the difference?

- Kernel Level Thread: The kernel knows about and manages the thread
- Kernel Mode Thread: The thread runs in *kernel mode*

Why would you need kernel *mode* threads?

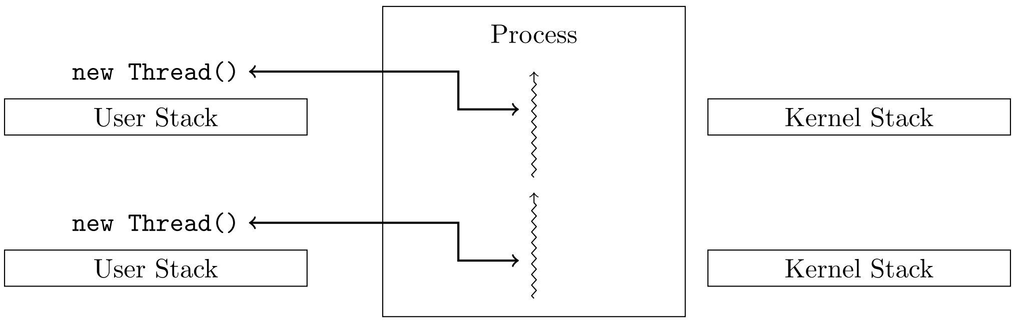
- Sometimes the OS needs to do some housekeeping that doesn't belong in a system call
- Free some pages, swap something in and out of memory
- Flush pages from the disk cache to the hard disk
- Perform VFS Checkpointing
- ...

Thread-Programming

Spawn a few threads using pthreads!
Write a small program that creates five threads using the pthread library. Each thread should print its number (e.g., `Hello, I am 4`) and the main program should wait for each thread to exit.

Thread models — One To One

One To One



Problems?

Thread models - One To One

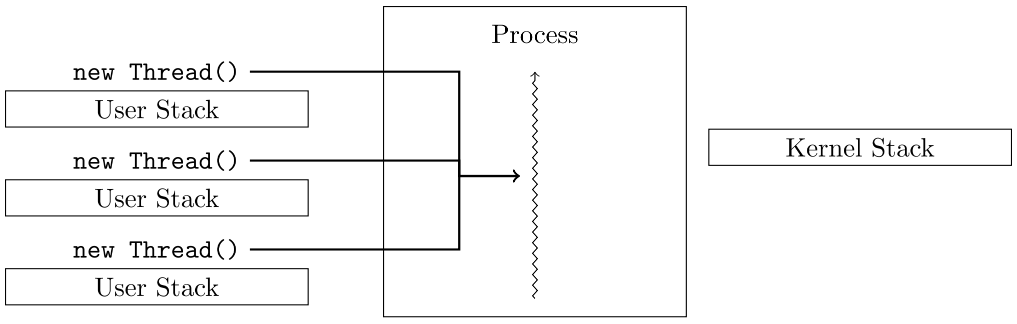
Problems and benefits of *One To One*?

+ Scales with core count
+ Conceptually easy — the OS does the hard stuff
+ Blocking does not affect other threads
+ Can piggy-back onto the OS scheduler

- *Must* piggy-back onto the OS scheduler
- Relatively high overhead due to context switches
- Relatively high overhead *when creating one!!*

Thread models

Many to One



Thread models - Many To One

Problems and benefits of *Many To One*?

Do they improve anything?

- Dummy

+ **Scales with core count?**

− Can only use one core

+ **Conceptually easy — the OS does the hard stuff?**

− Harder to implement — the OS doesn't help you much

+ **Blocking does not affect other threads?**

− Blocking *does* affect other threads

+ **Can piggy-back onto the OS scheduler?**

− Can *not* piggy-back onto the OS scheduler

− ***Must* piggy-back onto the OS scheduler?**

+ Can implement its *own* scheduler

− **Relatively high overhead due to context switches?**

+ Low overhead during context switches

− **Relatively high overhead *when creating one*?**

+ Low overhead when creating one

Thread models - Many To One

Do you know a programming language / runtime using that?

E.g. `nodejs` using its „event loop"

A small excursion - Structured Programming

Control flow should fall into one of four patterns:

- Sequence: One block is executed after another
- Selection: One or more are executed (i.e. an `if`-statement)
- Iteration: A block is executed more than once (i.e. a loop)
- Recursion: A block calls itself until an exit condition is met (i.e. recursion!)

Do you know any keyword in C which *doesn't* quite adhere to that but can instead totally spaghettify your control flow? *`goto`*

Famous paper by a proponent of Structured Programming: *„Go To Statement Considered Harmful"* by Edsger W. Dijkstra

Thread models - Many To One

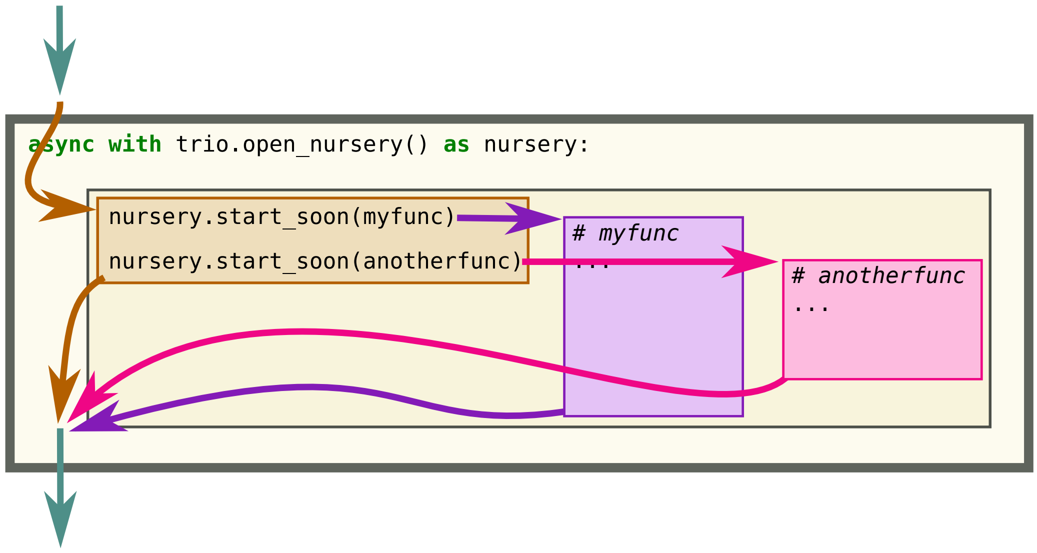
And what about threads?

- Can outlive the methods they were spawned in
- Can use variables and fields after they went out of scope in a method
- Can split up or transfer their control flow arbitrarily

So that might sound familiar…

Thread models - Many To One

Structured Concurrency



async with trio.open_nursery() as nursery:
nursery.start_soon(myfunc)
nursery.start_soon(anotherfunc)
# myfunc
...
# anotherfunc
...

Taken from vorpus.org

Thread models - Many To One

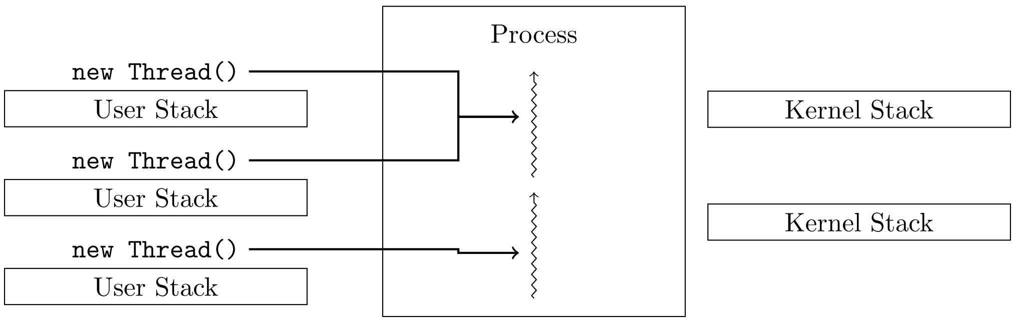
Nice, but what does this have to do with ULTs?

- Spawning lots of threads for small operations *is too slow otherwise*

Further reading: Notes on Structured Concurrency ULTs and Structured concurrency in Java - Project Loom

Thread models - Many To Many

Many To Many



Thread models - Many To Many

Problems and benefits of *Many To Many*?
Important: The kernel *knows about the user level scheduler*

- Dummy

+ **Scales with core count?**

+ Scales with core count

+ **Conceptually easy — the OS does the hard stuff?**

– Harder to implement — the OS doesn't help you much

+ **Blocking does not affect other threads?**

+ Blocking does not affect other threads as the kernel informs the user scheduler (`upcalls`) and does *not* pause the whole kernel level thread

+ **Can piggy-back onto the OS scheduler?**

– Can *not* piggy-back onto the OS scheduler

– ***Must* piggy-back onto the OS scheduler?**

+ Can implement its *own* scheduler

– **Relatively high overhead due to context switches?**

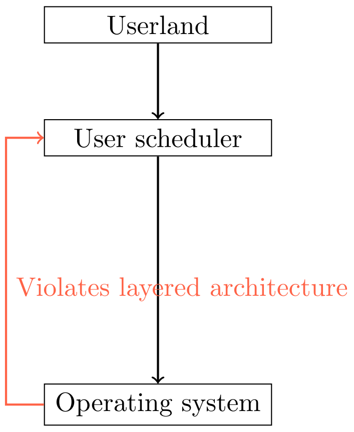
+ Low overhead during context switches (unless you need to interact with the kernel threads, e.g. to schedule between them)

– **Relatively high overhead *when creating one*?**

+ Low overhead when creating one

Thread models - Many To Many

Problems the second
You have all attended SWT 1! So let's have a look.



And preemption is now possible, which might complicate user code.

Thread models - One To One

What events can trigger a context switch?

- Voluntary: yield, blocking system call
- Involuntary:
  - interrupts, exceptions, syscalls
  - end of time-slice
  - high priority thread becoming ready

Thread models - Many To One

What events can trigger a context switch?

- Most libraries only support *cooperative scheduling*
- Why is switching with preemption, interrupts, blocking system calls hard? Kernel is not aware of the ULTs and will return where it came from — *but not call out to the scheduler and carry on*
- The benefit of platforms: How can `Java` (using Project Loom) or `Node.js` switch on most of the above? You can not execute syscalls directly, but need to call library methods! Suspension points can be inserted there.

Thread models - Many To One

„Jobs are either I/O-bound or compute-bound. In neither case would user-level threads be a win. Why would one go for pure user-level threads at all?“

- Program structure (e.g. Structured Concurrency, channels or just easier pipelines)
- The same or higher I/O throughput if on an abstracted platform