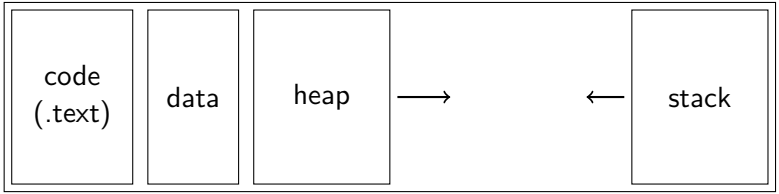
Virtualisation

Johan Montelius

KTH

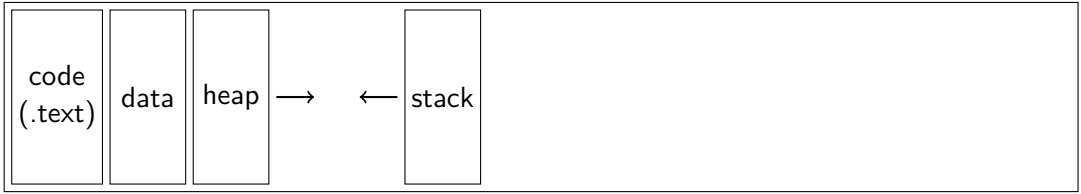
2019

the process

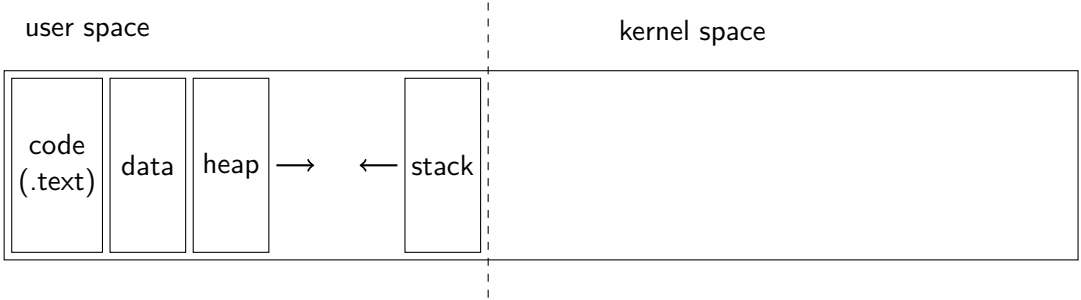


The role of the operating system - provide a virtual environment for a process.

the kernel



the kernel



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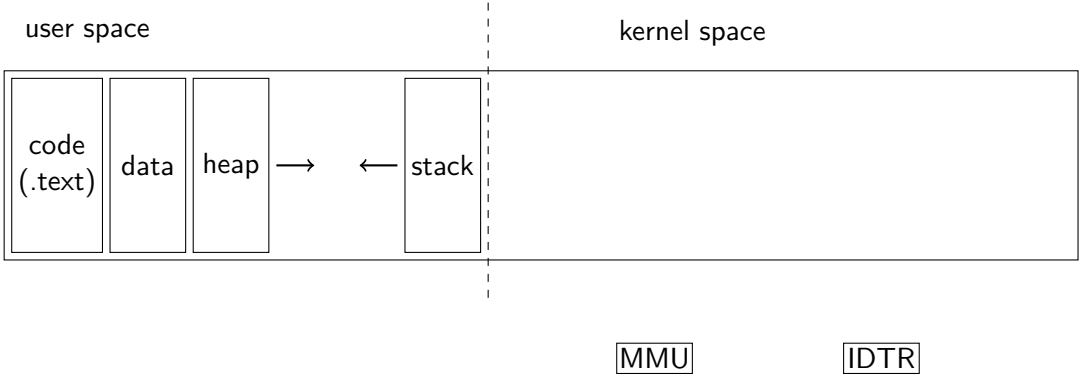

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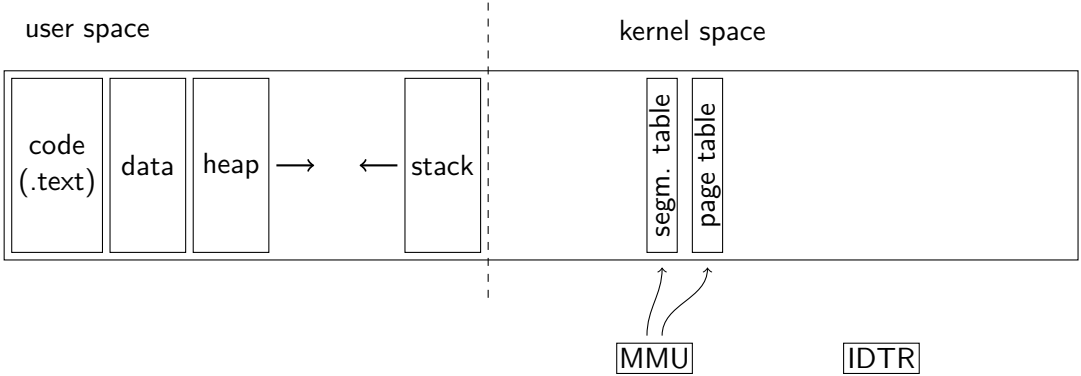
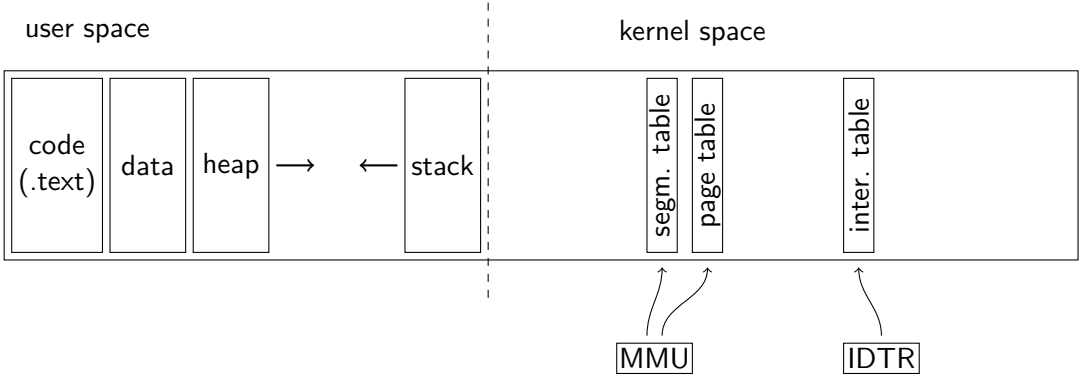

user space
kernel space
code
(.text)
data
heap
stack
segm. table
page table
MMU
IDTR

the kernel


user space
kernel space
code (.text)
data
heap
stack
segm. table
page table
inter. table
MMU
IDTR

indirect execution

Who is in control?

indirect execution

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indirect execution

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Limited direct execution:

- only work with mapped memory in user space,
- only execute non-privileged instructions,
- for a limited amount of time.

Interrupts

Synchronous interrupts - exceptions:

- faults:

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  - page fault
  - privilege violation
  - divide by zero, ...

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The kernel is interrupt driven.

Virtualisation

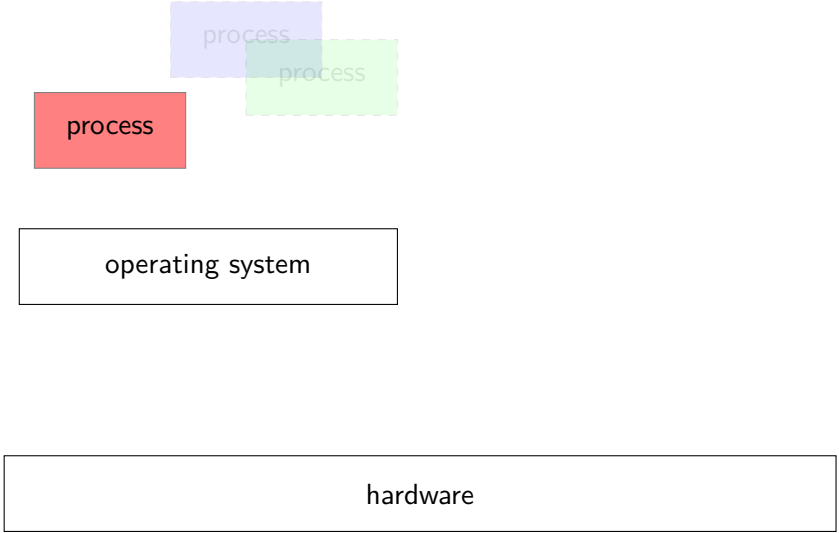
hardware

Virtualisation

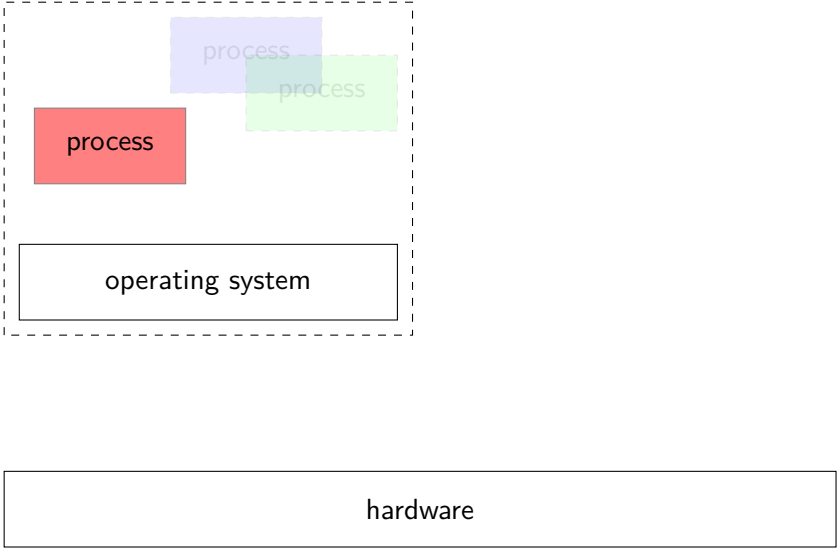
operating system

hardware

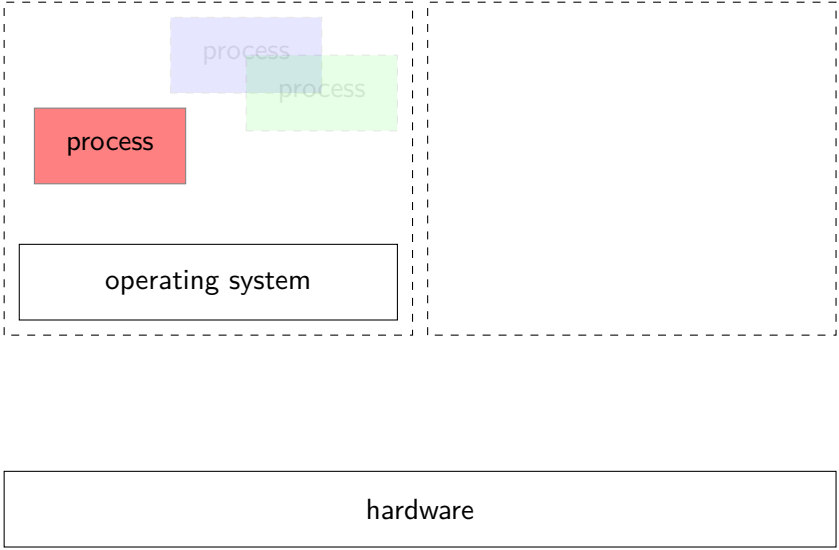
Virtualisation



Virtualisation



Virtualisation



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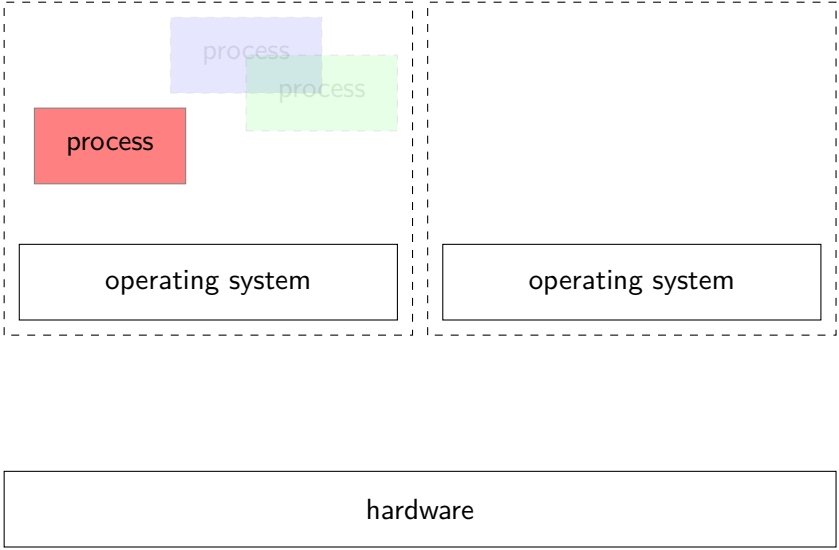

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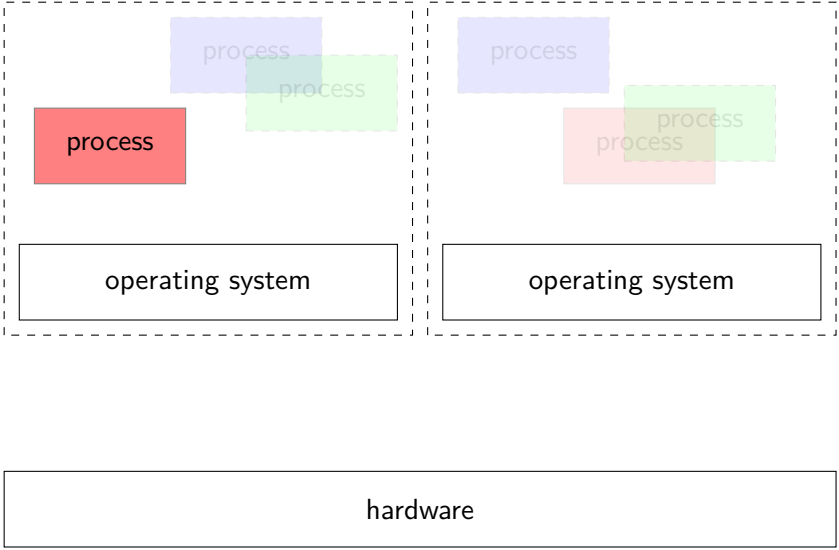

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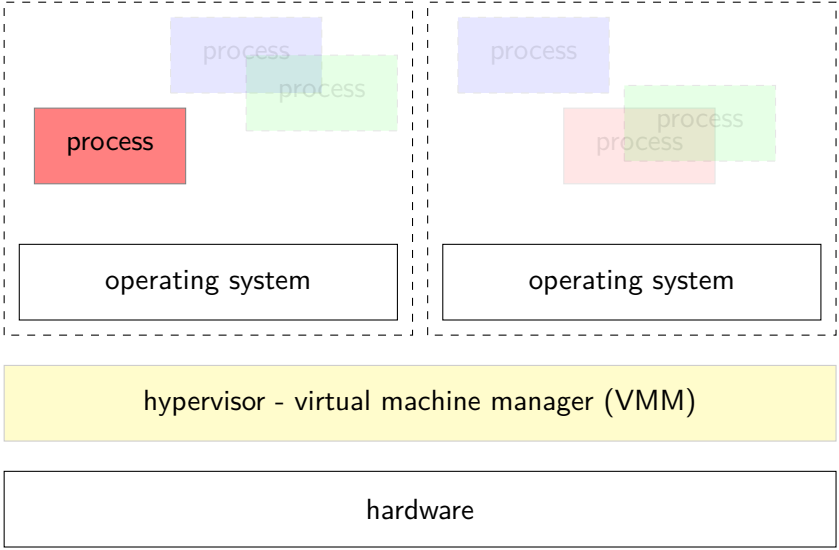

Why?

Why?

Utilisation of hardware.

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Is this important?

the Hypervisor

Provide virtualisaton of the hardware:

- a virtual cpu, part of the processing power

the Hypervisor

Provide virtualisaton of the hardware:

- a virtual cpu, part of the processing power
- a virtual memory, the illusion of physical memory

the Hypervisor

Provide virtualisaton of the hardware:

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I think we have seen this before.

the solution

Provide *limited direct execution* i.e. allow each guest operating system to execute in *user space* and only perform non-privileged operations.

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Provide *limited direct execution* i.e. allow each guest operating system to execute in *user space* and only perform non-privileged operations.

What is the first thing an operating system wants to do?

the virtual IDT

Hypervisor	Guest Operating system
set up IDT	

the virtual IDT

Hypervisor	Guest Operating system
set up IDT	
pass control to OS	

the virtual IDT

Hypervisor	Guest Operating system
set up IDT	
pass control to OS →	
	initialize OS

the virtual IDT

Hypervisor	Guest Operating system
set up IDT pass control to OS →	
	initialize OS set up IDT

the virtual IDT

Hypervisor	Guest Operating system
set up IDT	
pass control to OS $\longrightarrow$	
	initialize OS
	set up IDT
handle interrupt $\longleftarrow$	

the virtual IDT

Hypervisor		Guest Operating system
set up IDT pass control to OS	$\longrightarrow$	
		initialize OS set up IDT
handle interrupt save ref to IDT of OS	$\longleftarrow$	

the virtual IDT

Hypervisor		Guest Operating system
set up IDT pass control to OS	$\longrightarrow$	
		initialize OS set up IDT
handle interrupt	$\longleftarrow$	
save ref to IDT of OS pass control to OS		

the virtual IDT

Hypervisor		Guest Operating system
set up IDT pass control to OS	$\longrightarrow$	
		initialize OS set up IDT
handle interrupt	$\longleftarrow$	
save ref to IDT of OS pass control to OS	$\longrightarrow$	

the virtual IDT

Hypervisor		Guest Operating system
set up IDT pass control to OS	$\longrightarrow$	
		initialize OS set up IDT
handle interrupt	$\longleftarrow$	
save ref to IDT of OS pass control to OS	$\longrightarrow$	
		continue as if nothing happened

The operating system is running in non-privileged mode.

a system call

Hypervisor | Guest operating system | Application

running

a system call

Hypervisor	Guest operating system	Application
		running system call

a system call

Hypervisor	Guest operating system	Application
		running system call `INT 0x80`

a system call

Hypervisor	Guest operating system	Application
		running system call
←		`INT 0x80`

a system call

Hypervisor	Guest operating system	Application
		running system call `INT 0x80`
handle interrupt ←		

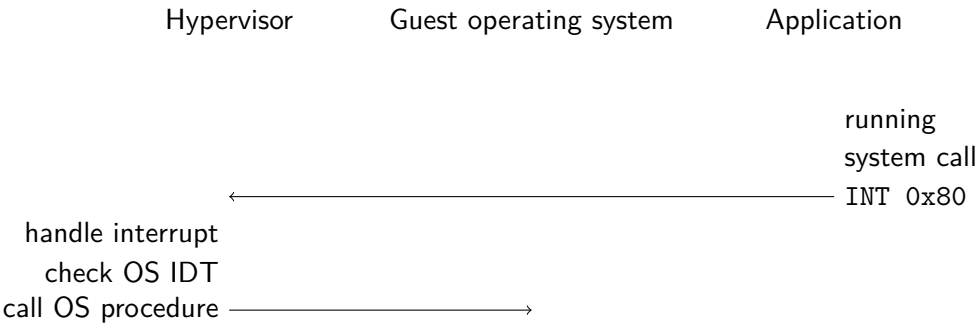
a system call

Hypervisor	Guest operating system	Application
		running system call `INT 0x80`
←		
handle interrupt check OS IDT		

a system call

Hypervisor	Guest operating system	Application
		running system call `INT 0x80`
←		
handle interrupt check OS IDT call OS procedure		

a system call



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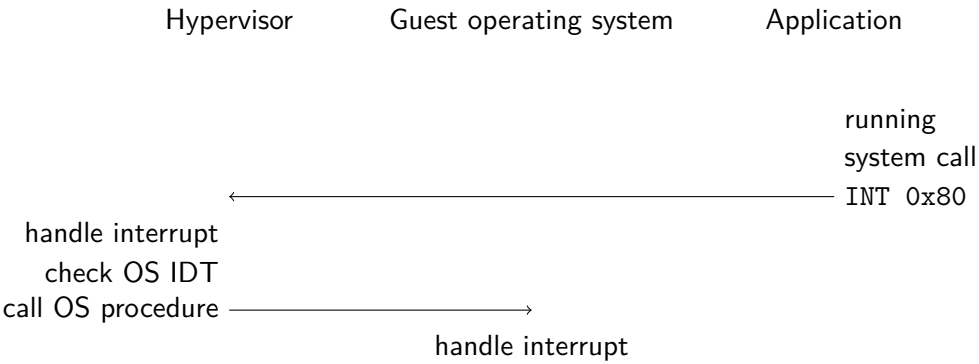

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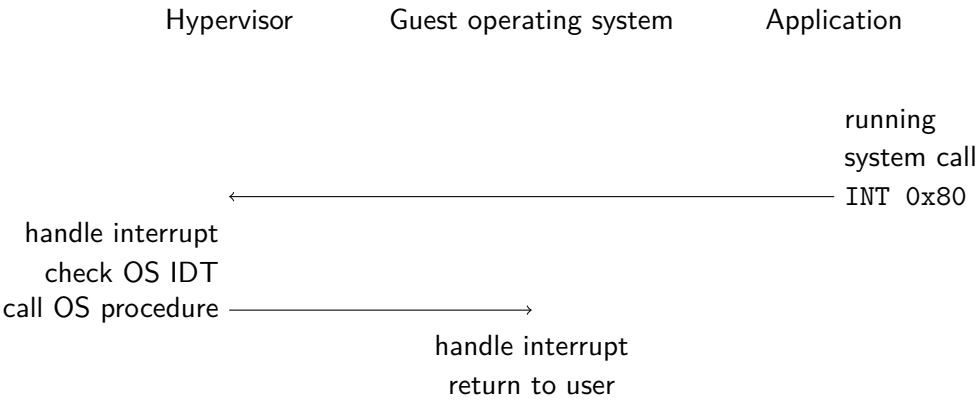
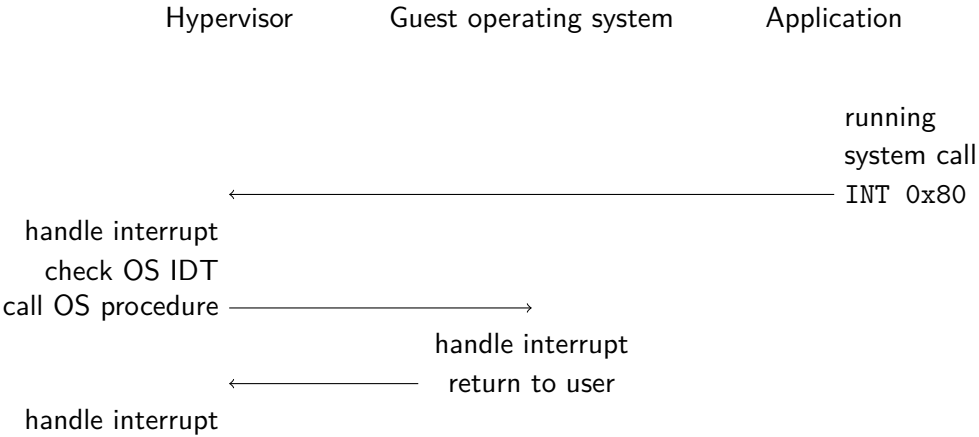


a system call

Hypervisor	Guest operating system	Application
		running system call `INT 0x80`
←		
handle interrupt check OS IDT call OS procedure		
→		
	handle interrupt return to user	
	←	

a system call



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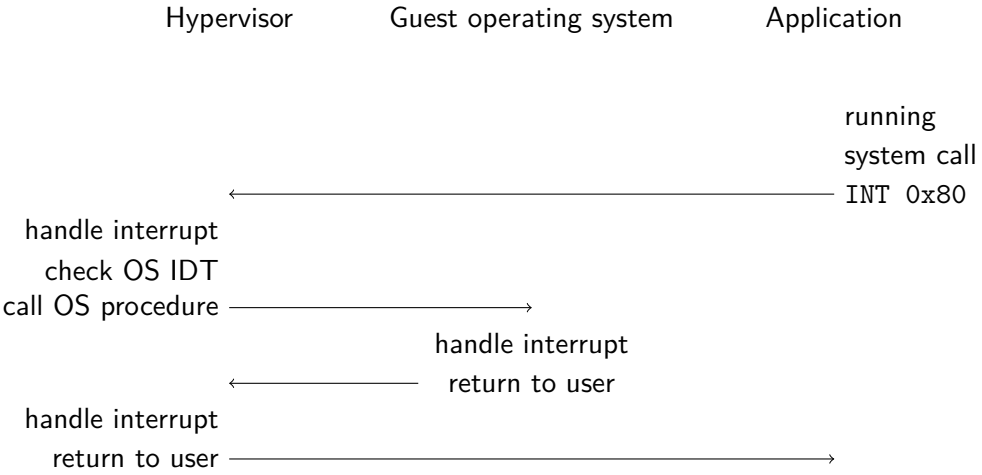

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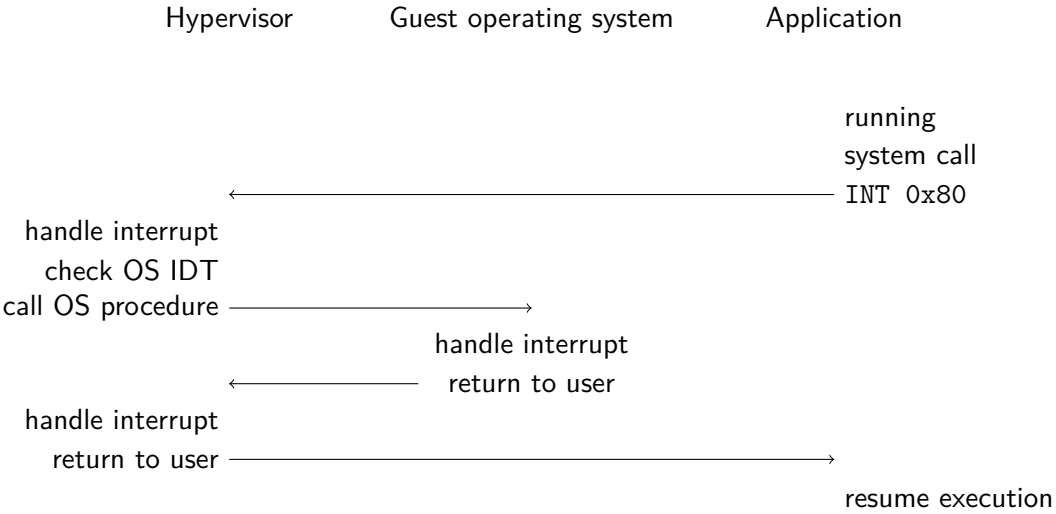
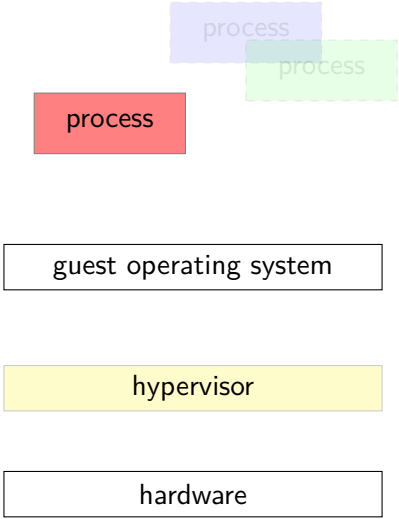


What about virtual memory?



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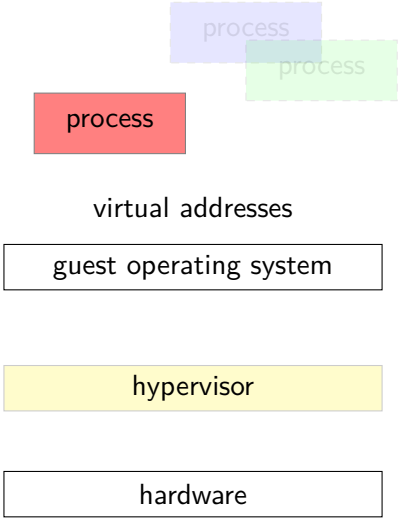

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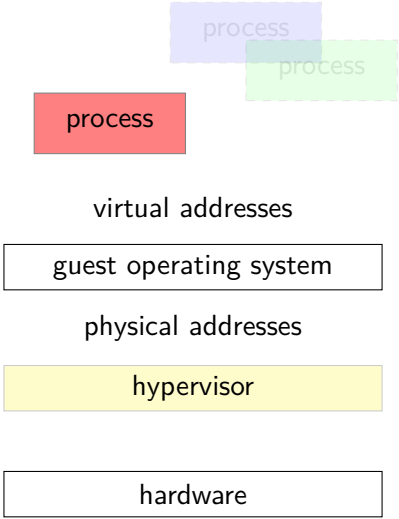
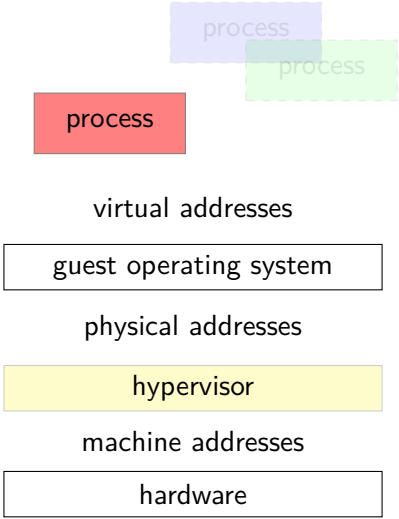


- regular translation tables

What about virtual memory?



- regular translation tables
- second level translation

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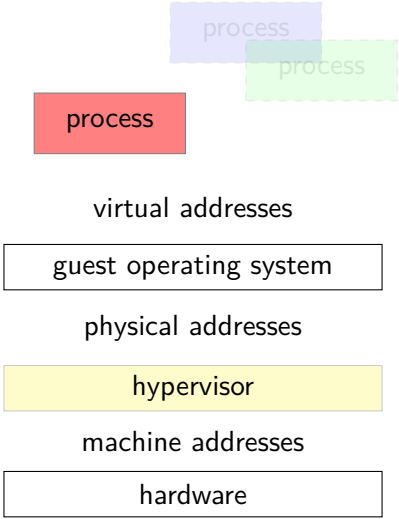

- regular translation tables
- second level translation

This will be expensive!

regular paging

User process uses virtual addresses that are automatic translated by the hardware (using page table and the MMU) to physical addresses.

regular paging

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A *page fault* invokes the kernel that, if allowed, maps a missing page and return to the user process.

second level paging

Hypervisor Guest operating system Application

running

second level paging

Hypervisor	Guest operating system	Application
		running page fault

second level paging

Hypervisor	Guest operating system	Application
		running
←		page fault

second level paging

Hypervisor	Guest operating system	Application
		running
←		page fault
handle interrupt		

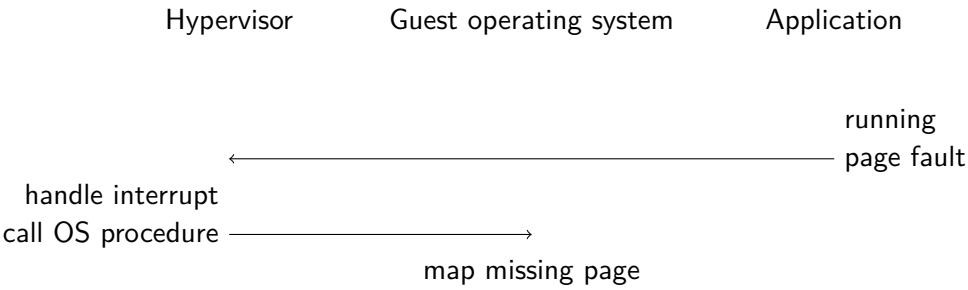
second level paging

Hypervisor	Guest operating system	Application
		running
←		page fault
handle interrupt		
call OS procedure		

second level paging

Hypervisor	Guest operating system	Application
		running
←		page fault
handle interrupt		
call OS procedure →		

second level paging



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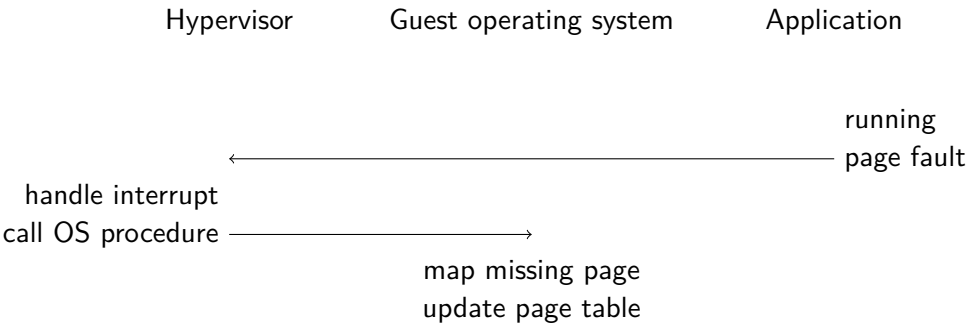

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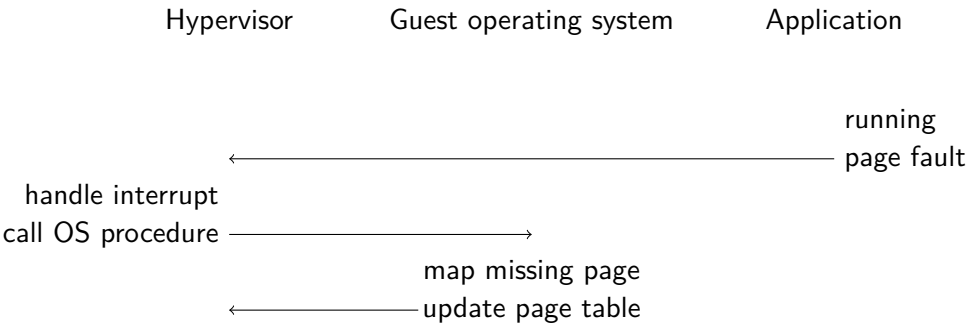

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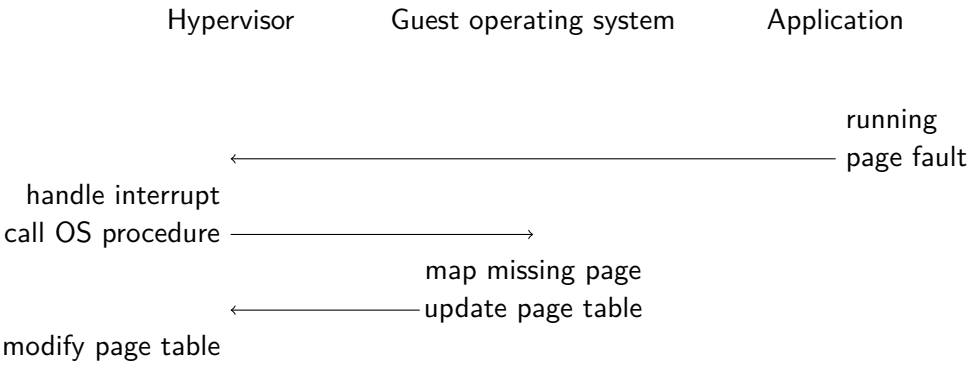

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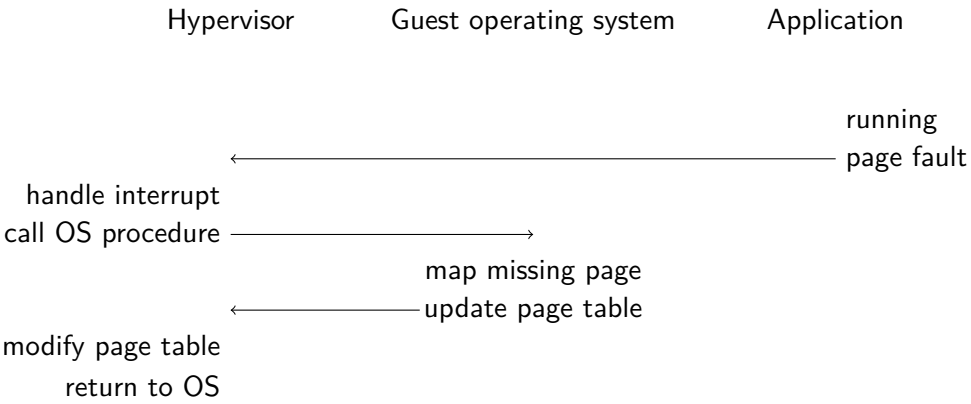

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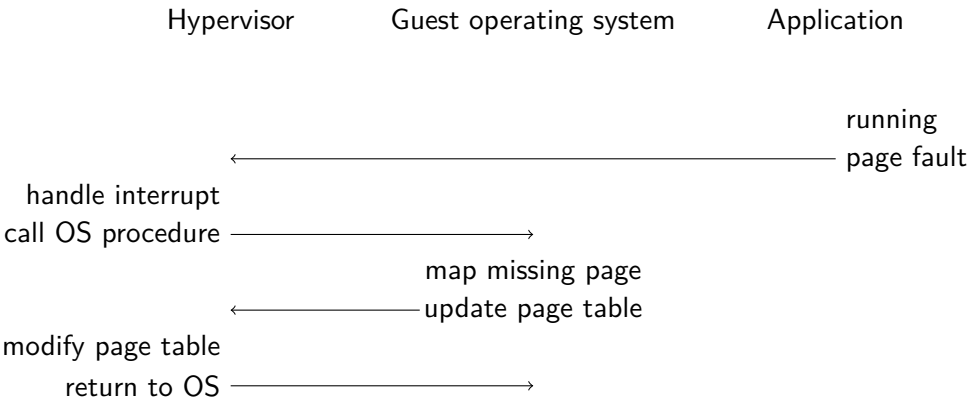

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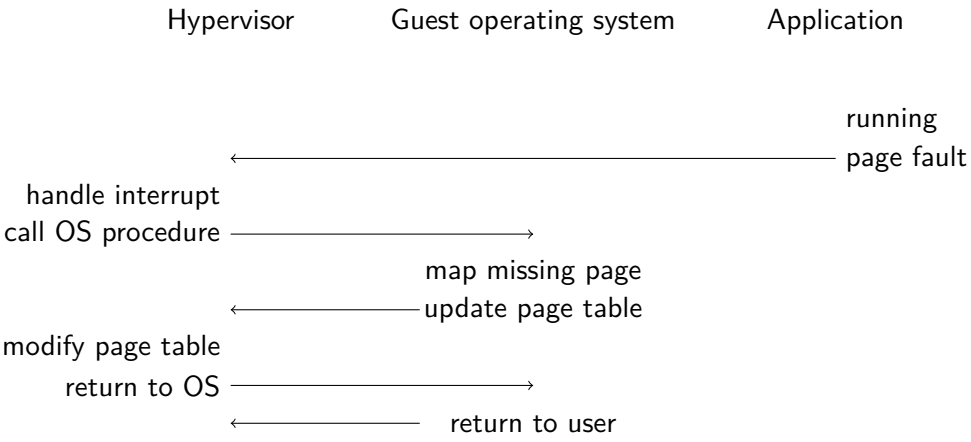

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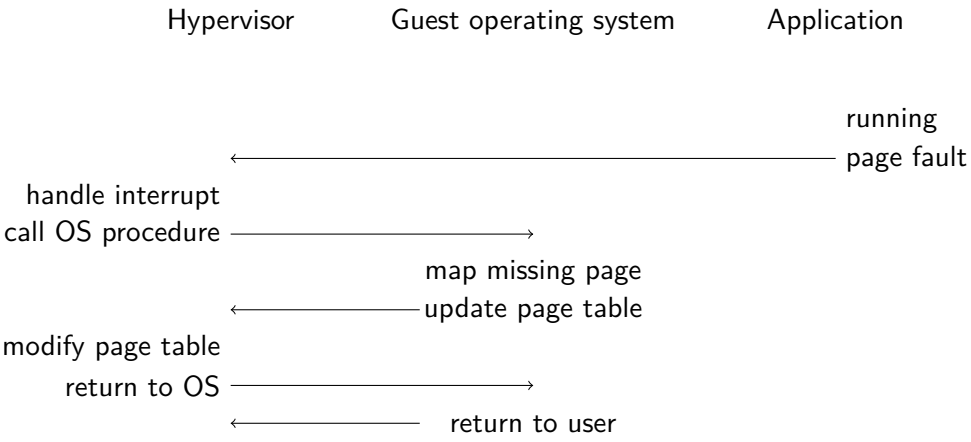

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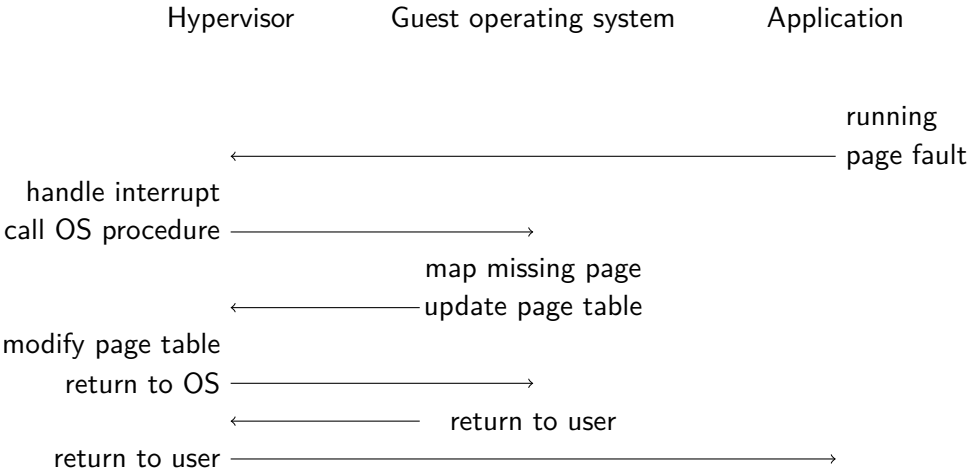

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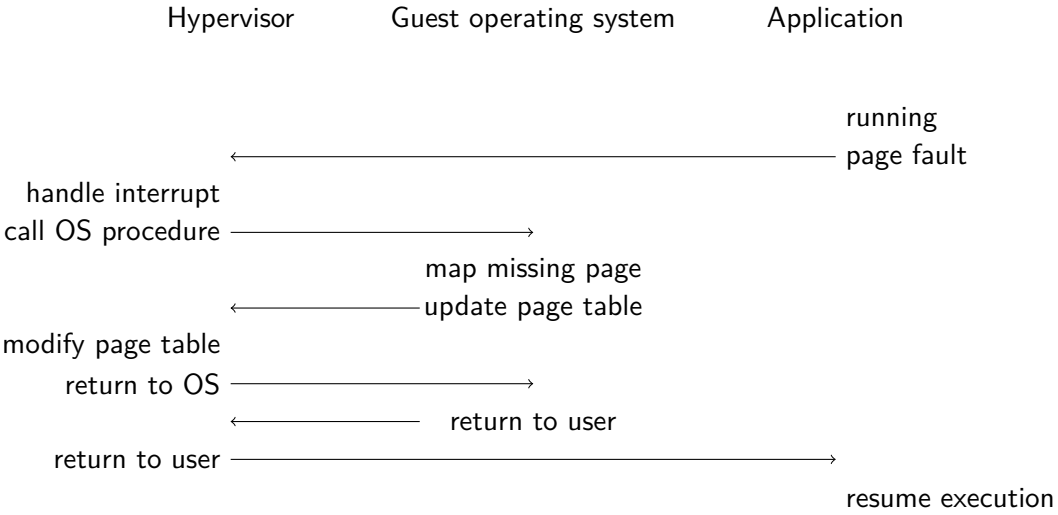

...wait a second

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If the guest operating system is executing in user mode - how does it protect itself from the application process that is also running in user mode?

...wait a second

If the guest operating system is executing in user mode - how does it protect itself from the application process that is also running in user mode?

If we allow the guest operating system to run in kernel mode - then the hypervisor can not protect it self.

system call revisited

Hypervisor

Guest operating system

kernel space

Application

user space

in user mode

system call revisited

Hypervisor

Guest operating system

kernel space

Application

user space

in user mode

system call

system call revisited

Hypervisor

Guest operating system

kernel space

Application

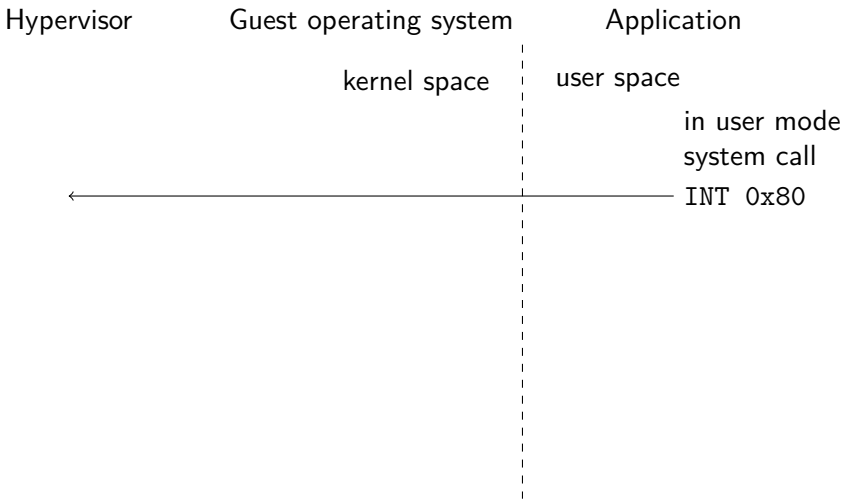
user space

in user mode

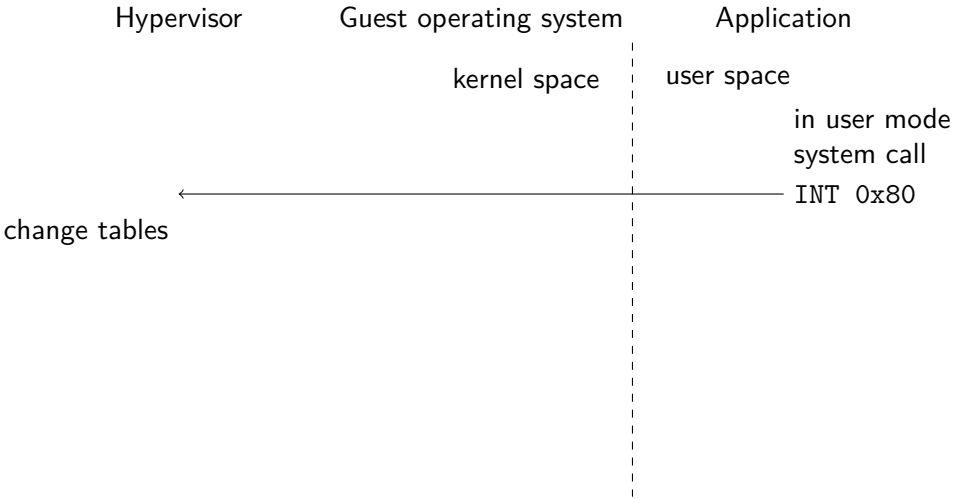
system call

`INT 0x80`

system call revisited



system call revisited



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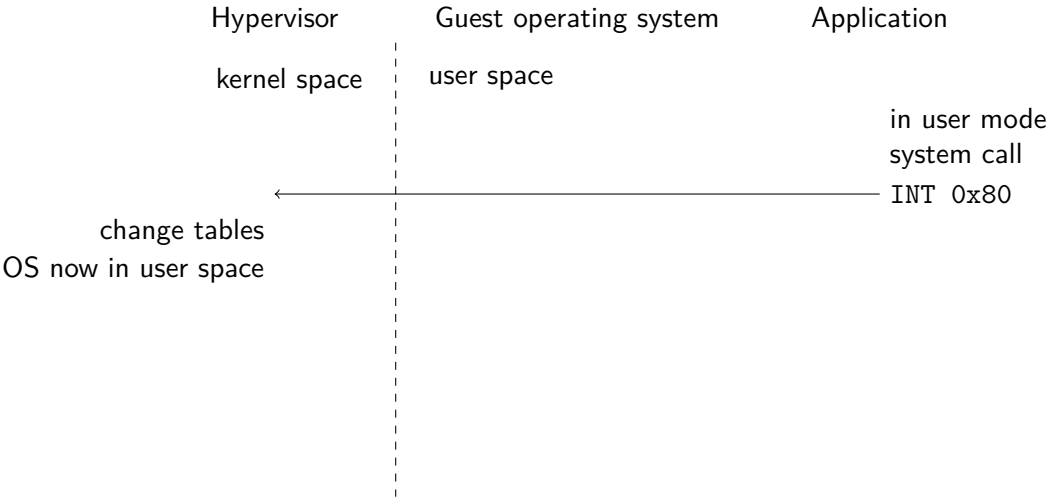

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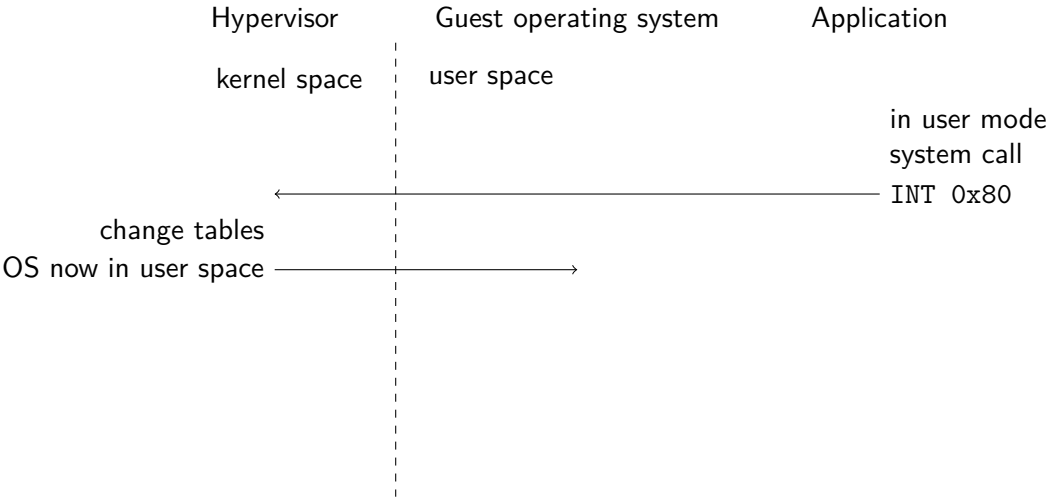

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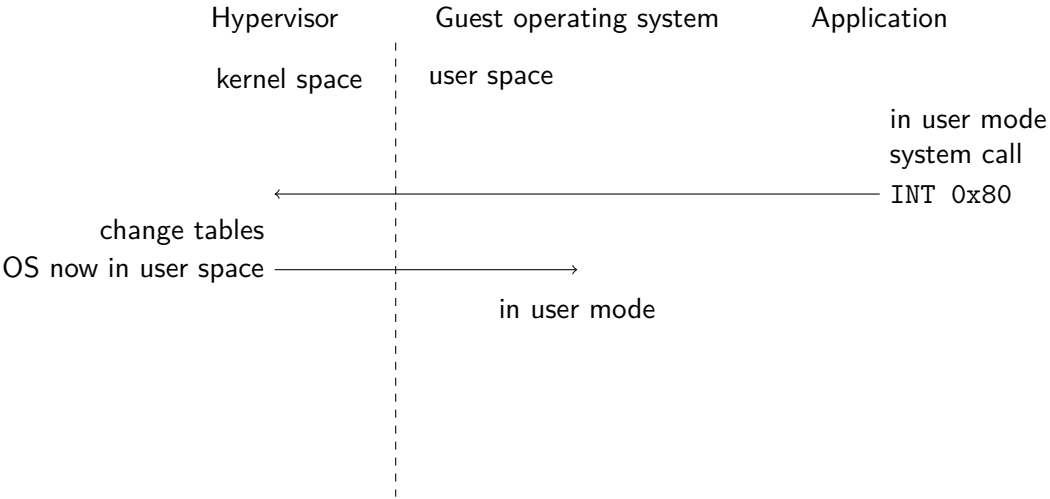

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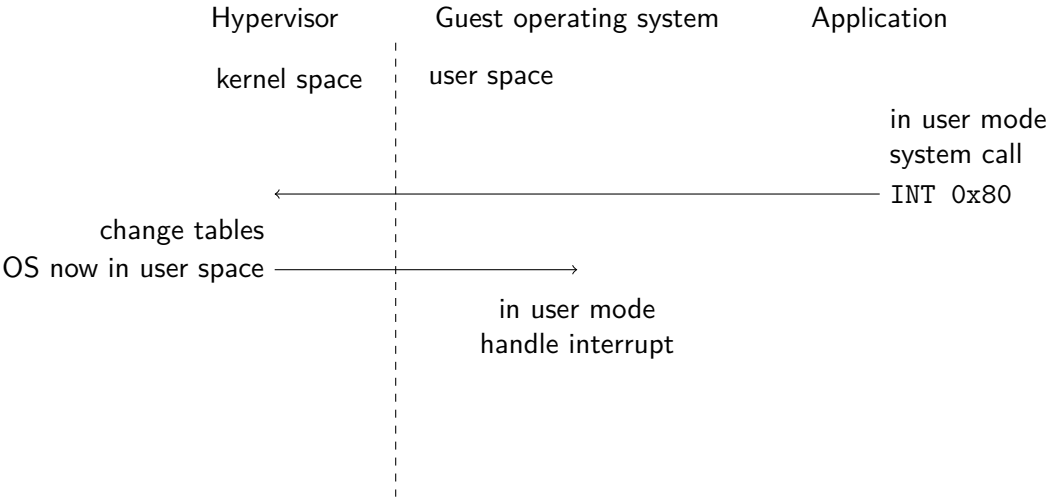
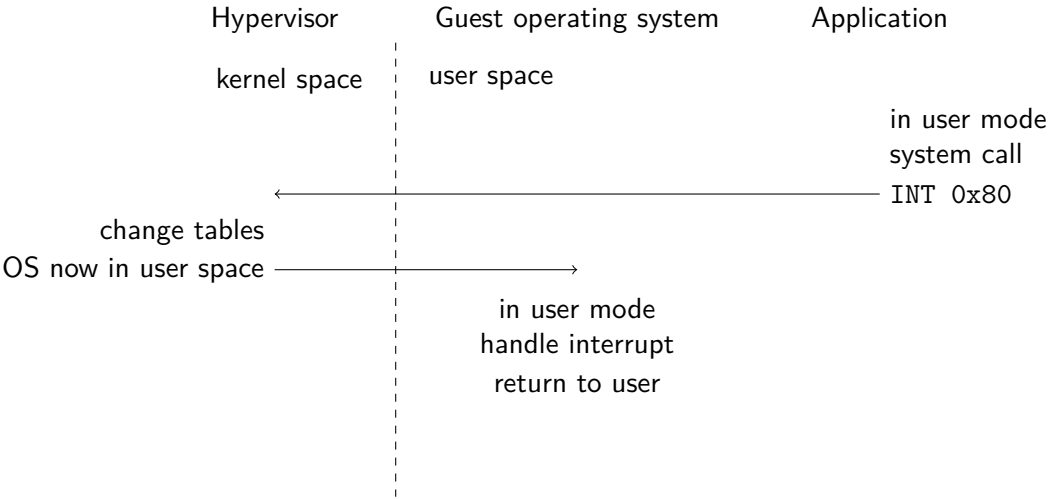


system call revisited



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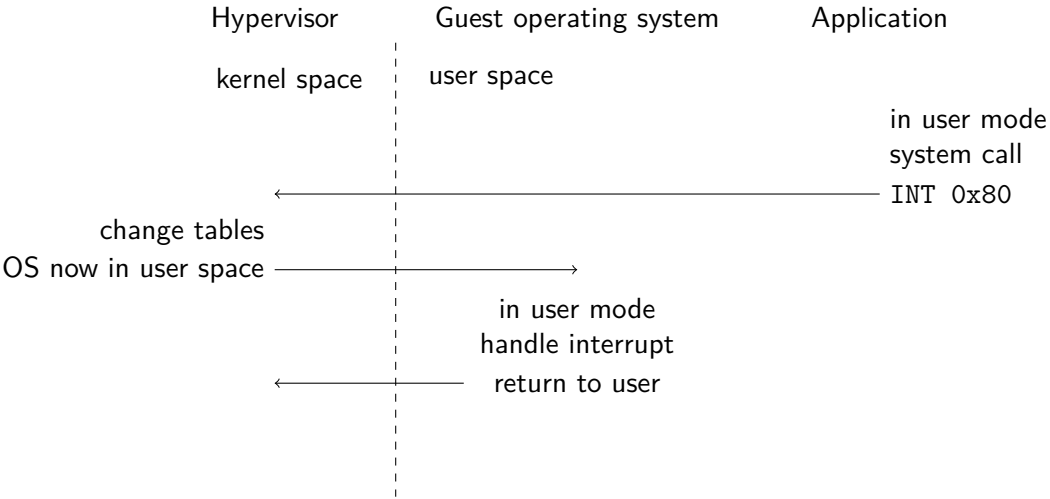

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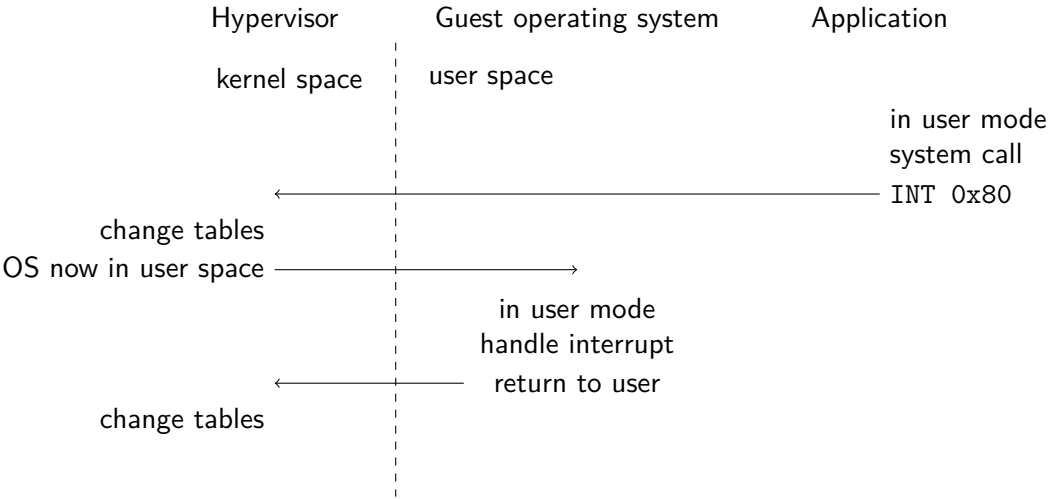

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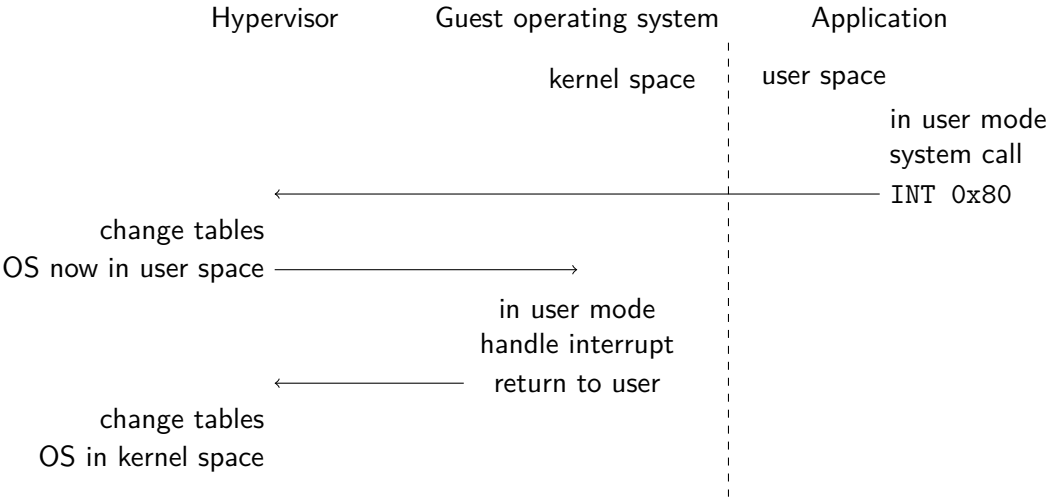

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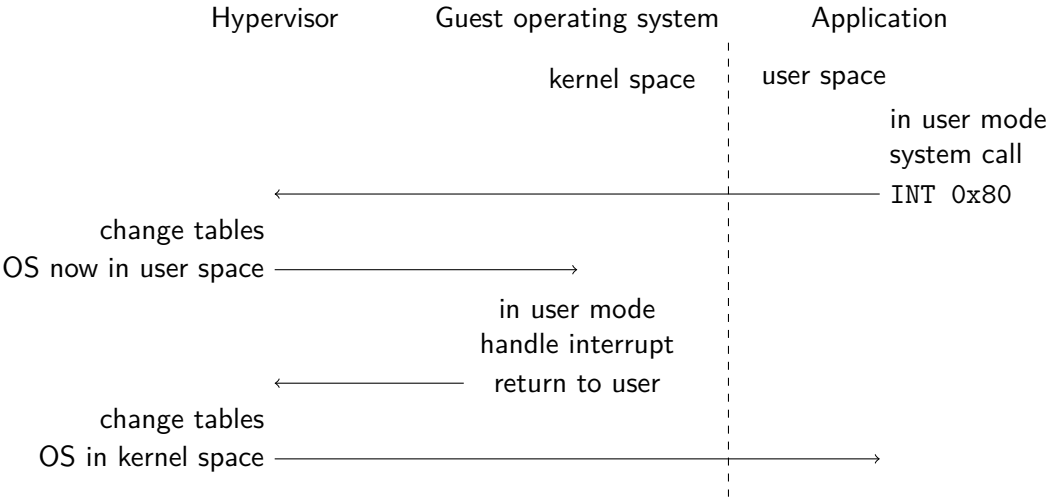

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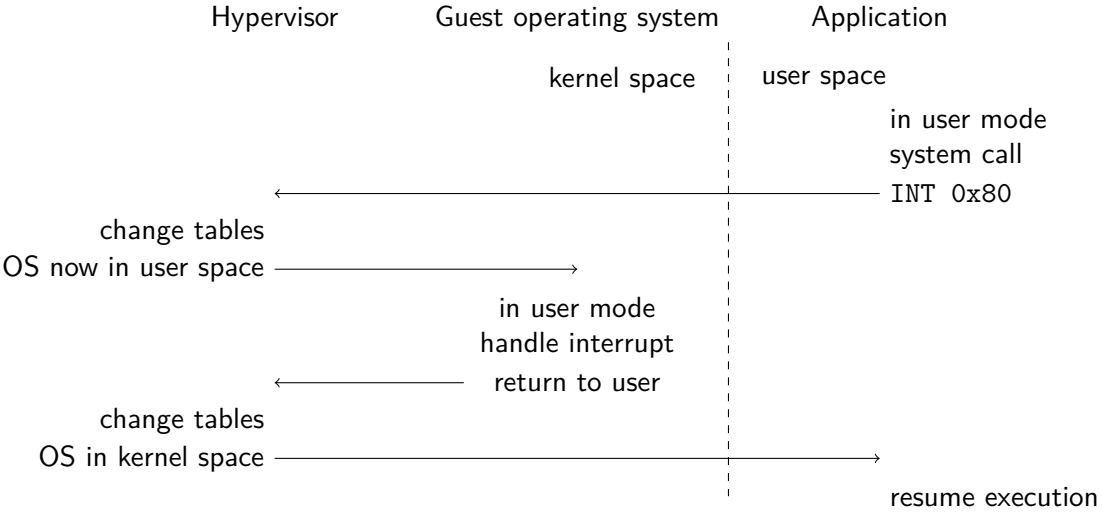

.. thank god for harware

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Hardware support:

.. thank god for harware

Hardware support:

- Available in both AMD an Intel x86 processors

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Hardware support:

- Available in both AMD an Intel x86 processors
- Allows hypervisors to provide near “bare metal” performance.

.. a different approach

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Para-virtualization: change the operating system that you want to virtualize.

.. a different approach

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- Change kernel modules in the operating system.

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- Change kernel modules in the operating system.
- Recompile source code or patch binary code.

The original goal

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Utilisation of hardware.

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Applications are completely separated from each other.

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Applications can use different operating systems.

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What if we skip this.

containers

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An operating system uses several name spaces: memory addresses, file paths, port numbers, device interrupt requests, process id, user id, . . .

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containers

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Provide a *container*, a separate environment with its own name spaces.

Processes in different containers are completely separated from each other ... but they use the same kernel.

containers

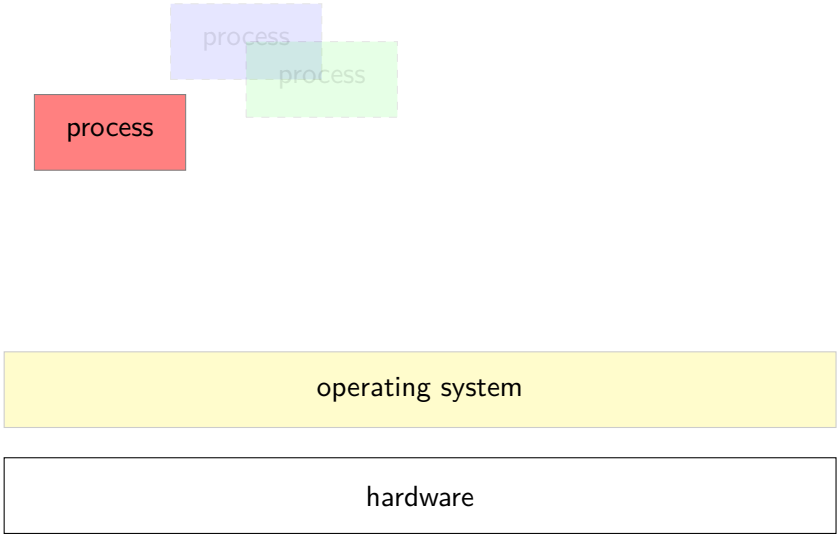
hardware

containers

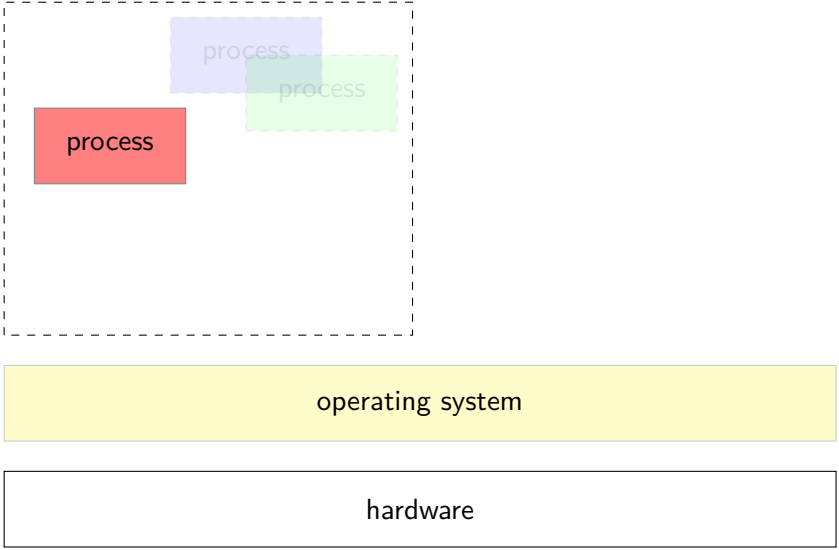
operating system

hardware

containers



containers



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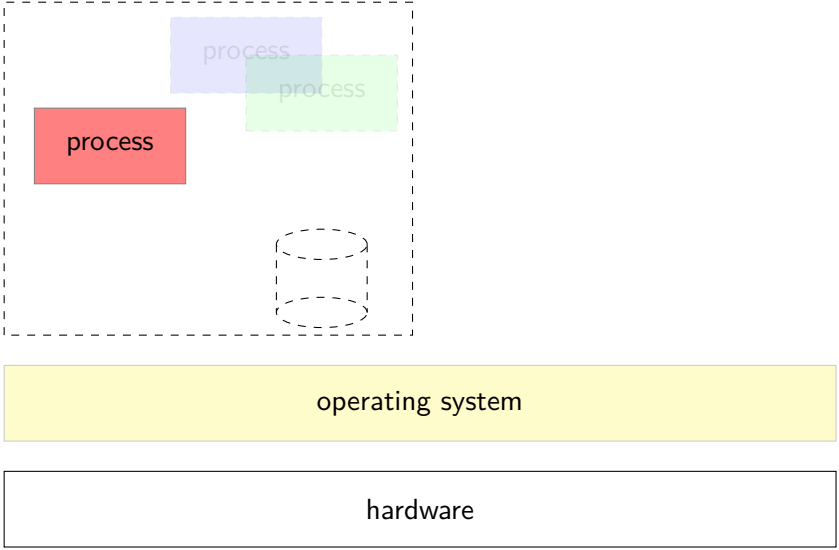

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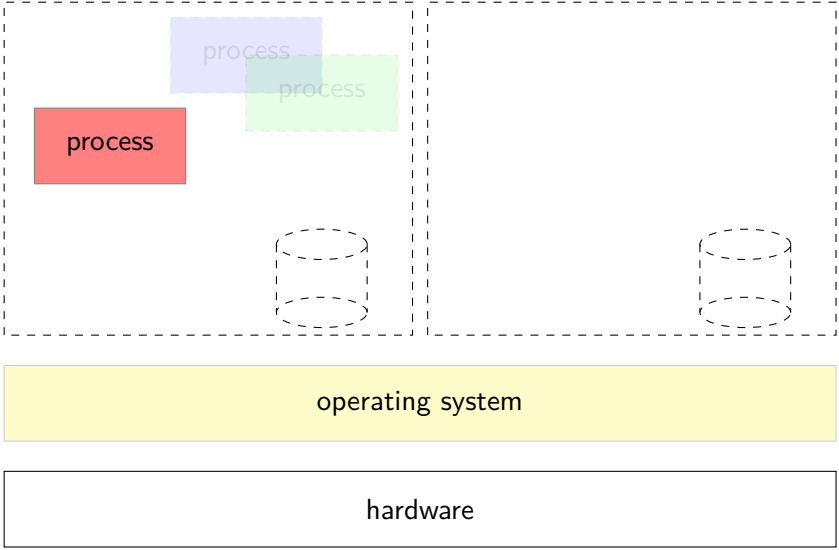

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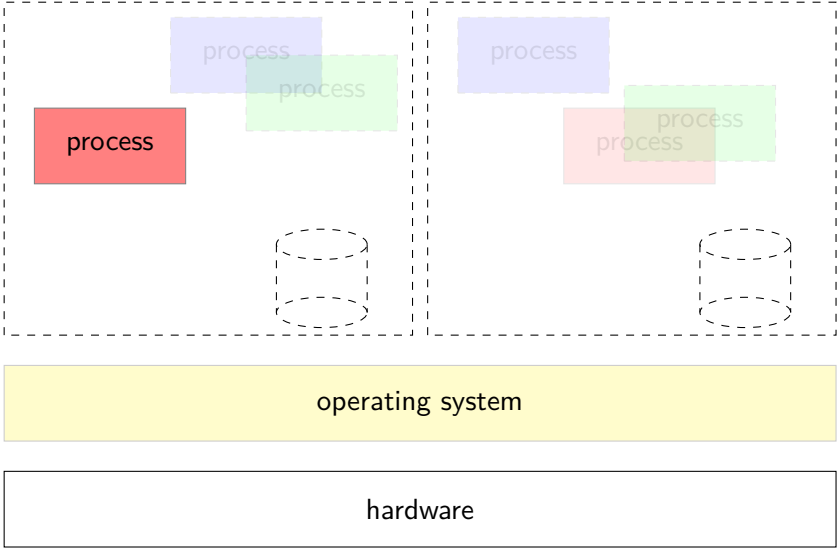
process
process
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process
process
process
operating system
hardware

the original goal

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Why do they have to run on the same hardware?

emulating hardware

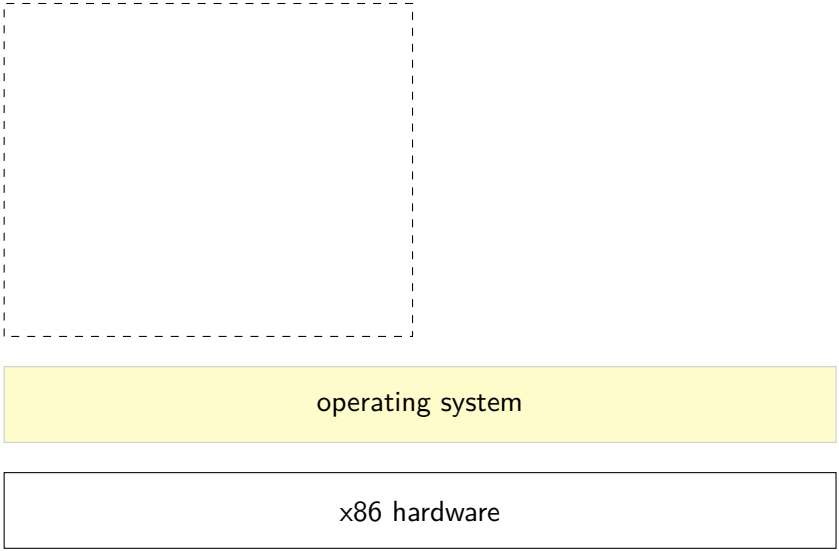
x86 hardware

emulating hardware

operating system

x86 hardware

emulating hardware



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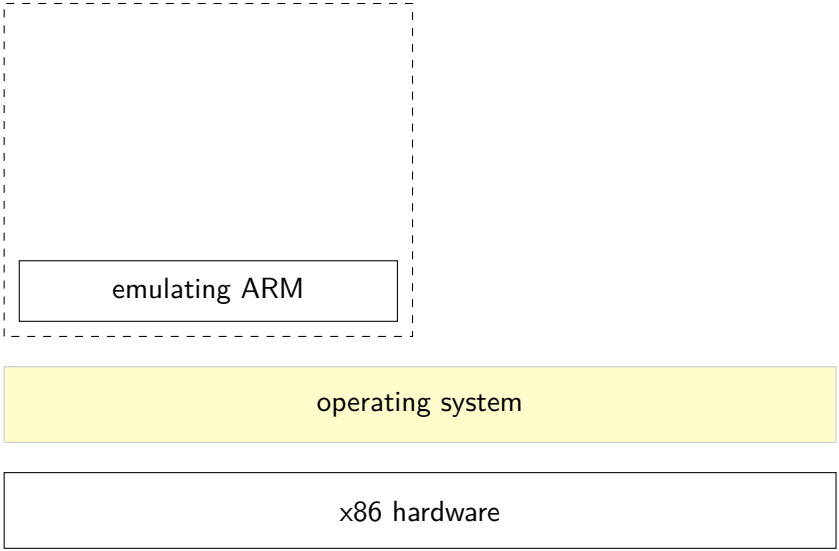

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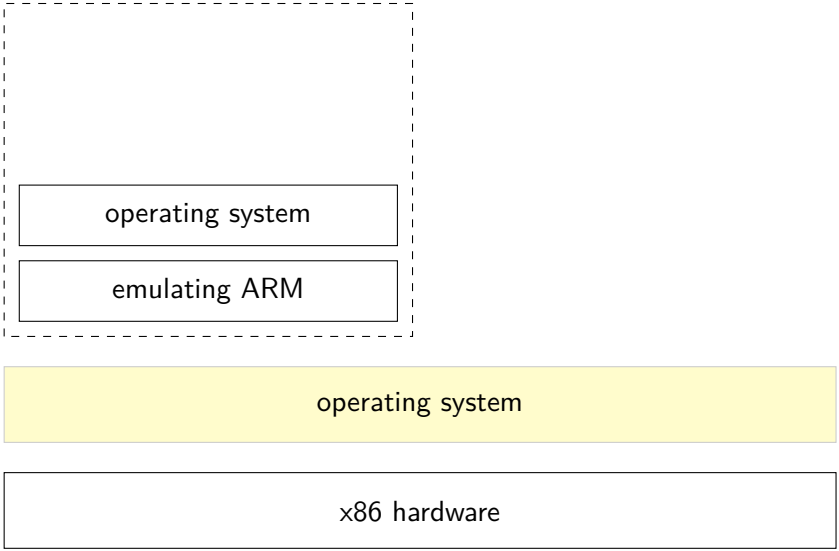

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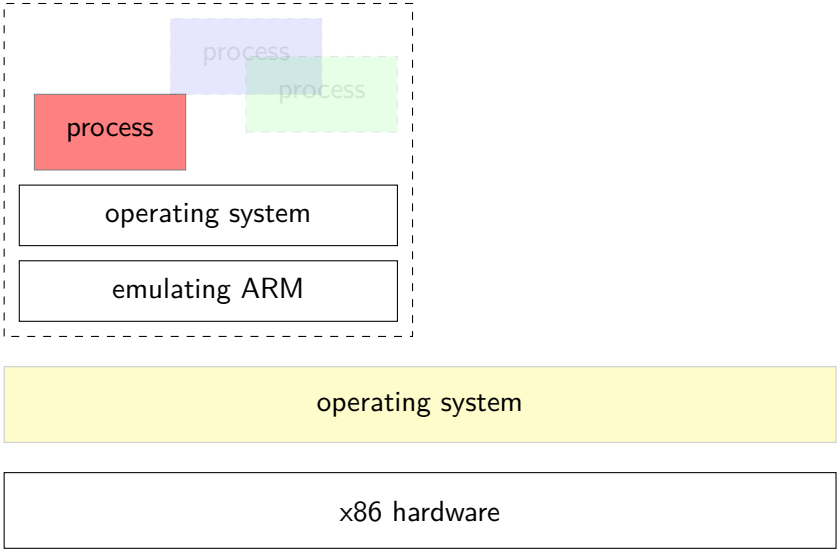

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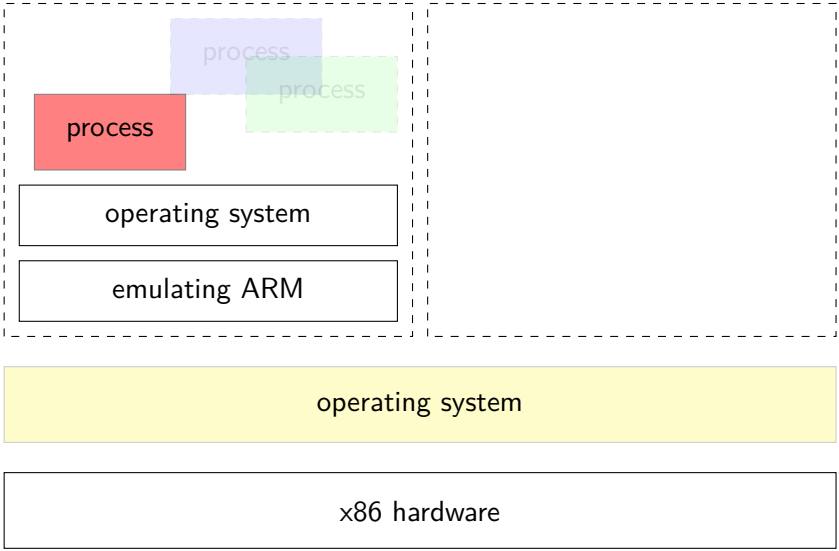

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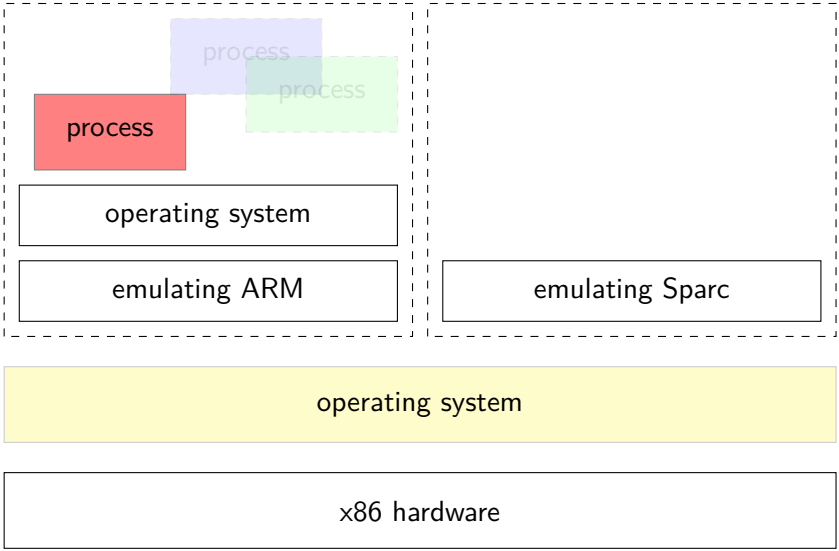

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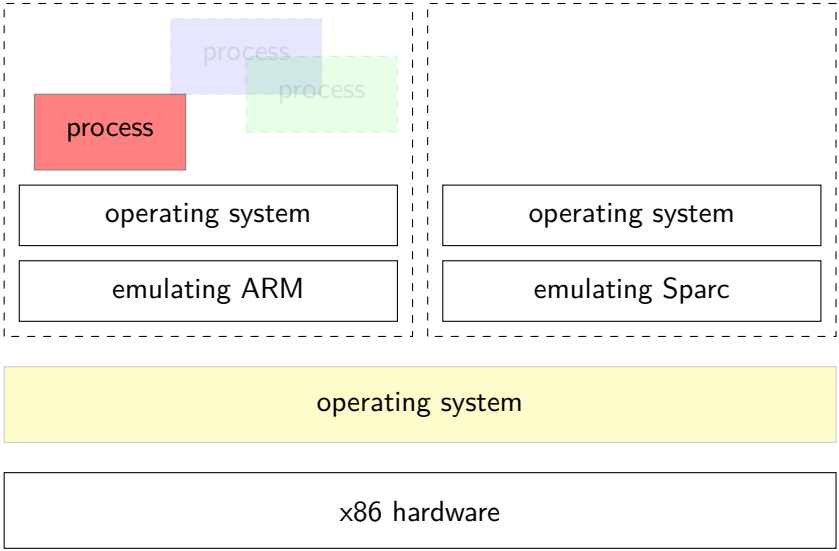

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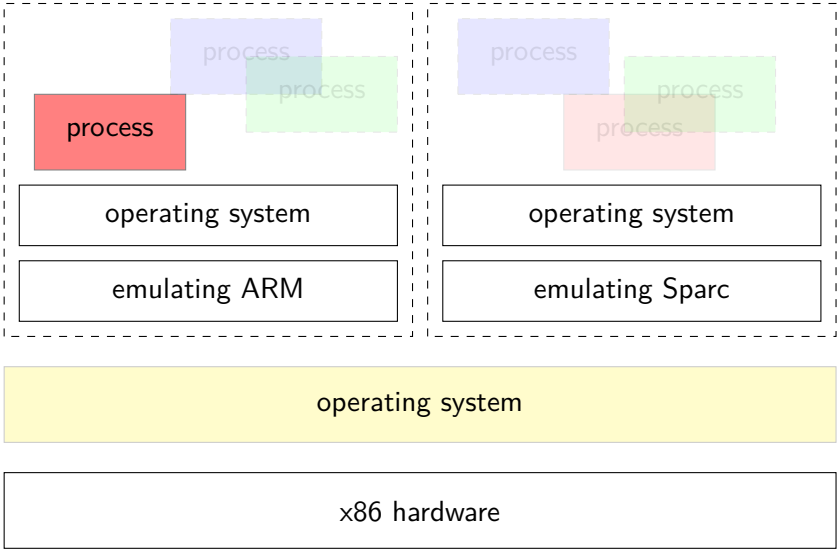

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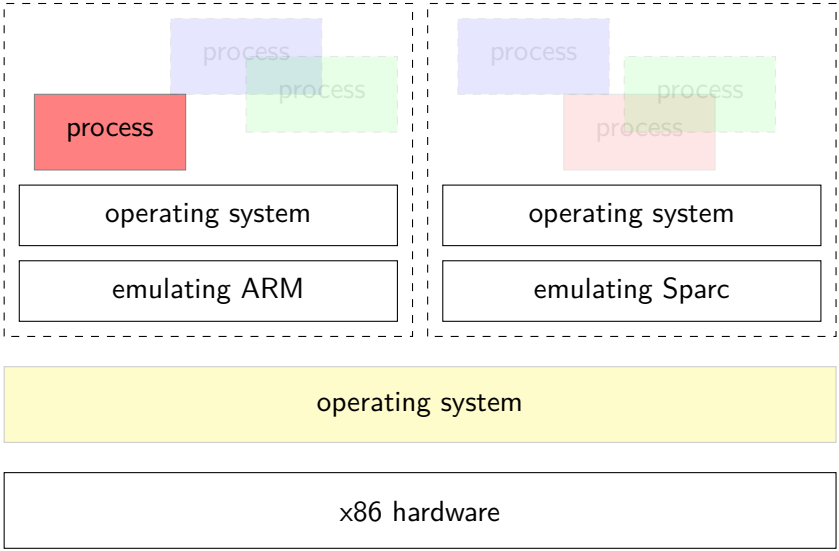

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- Runtime systems
  - Dedicated to a language (JVM, Erlang).

... but I never installed a Hypervisor?

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VirtualBox etc also installs a kernel module that turns your regular operating system into a hypervisor.

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