Virtualisation

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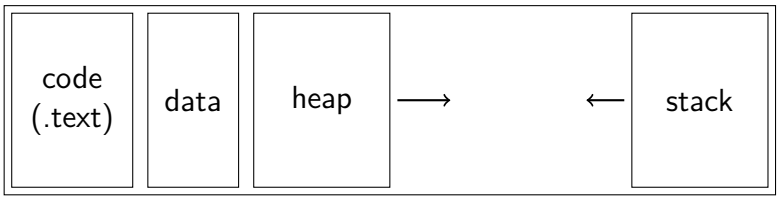
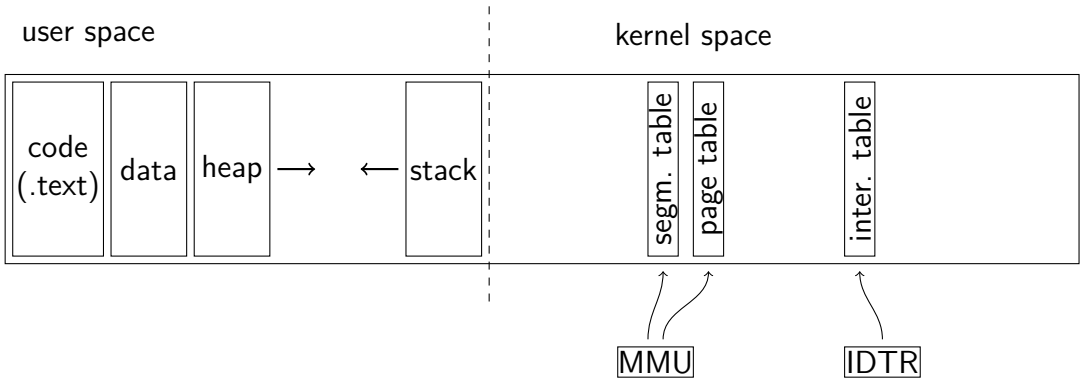
the process



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

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?

- control the registers of the MMU and you control the virtual address space
- control the IDTR and you control what will happen when we have an interrupt
- instructions to set MMU or IDT registers are privileged instructions

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:

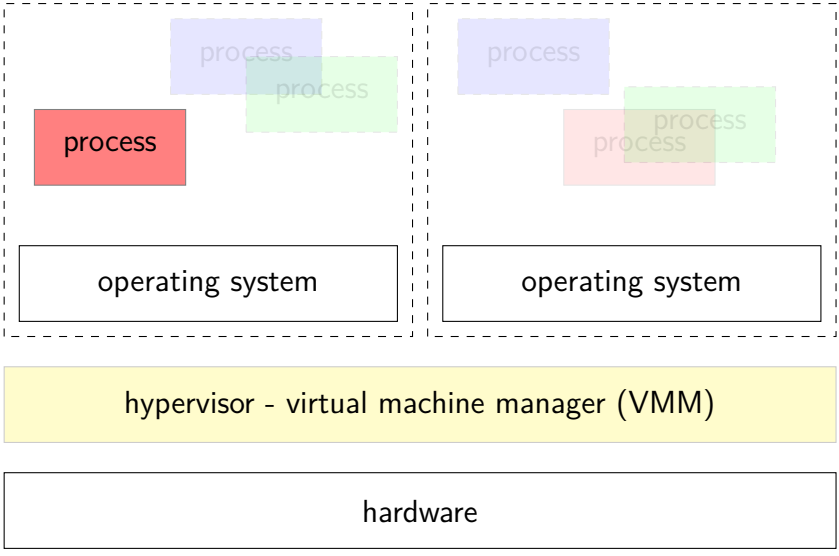
- faults:
  - page fault
  - privilege violation
  - divide by zero, ...
- programmed exceptions:
  - system call (`INT 0x80`)
  - debug instructions

Asynchronous interrupts:

- timer interrupt
- hardware interrupt: I/O complete, ...

The kernel is interrupt driven.

Virtualisation



Why?

Utilisation of hardware.

Also provided by a multi-task operating system, what is new?

Applications are completely separated from each other.

What do two processes in an operating system share?

Applications can use different operating systems.

Is this important?

the Hypervisor

Provide virtualisaton of the hardware:

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

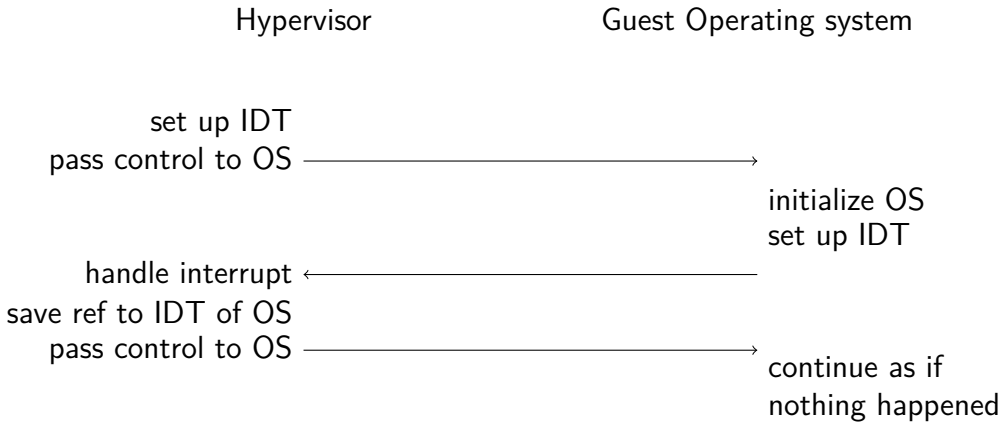
I think we have seen this before.

the solution

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

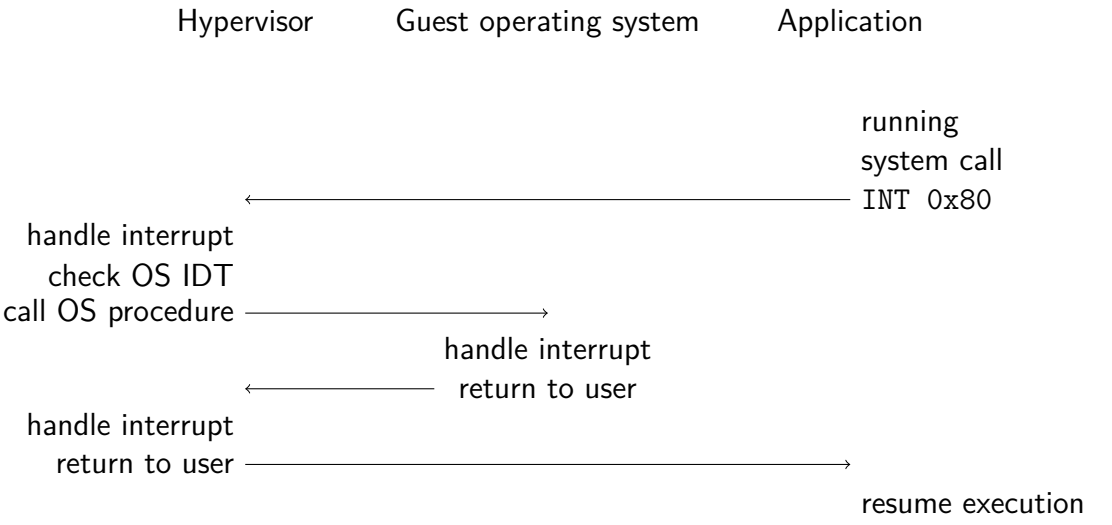
What is the first thing an operating system wants to do?

the virtual IDT

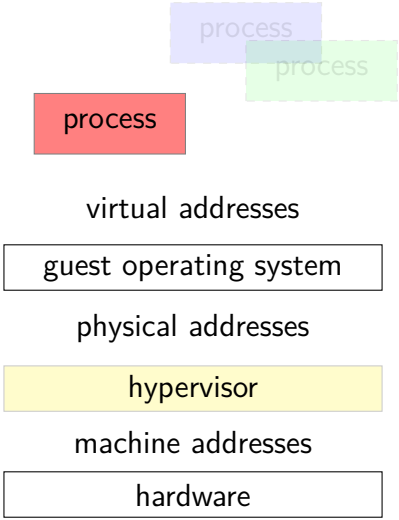


The operating system is running in non-privileged mode.

a system call



What about virtual memory?



- regular translation tables
- second level translation

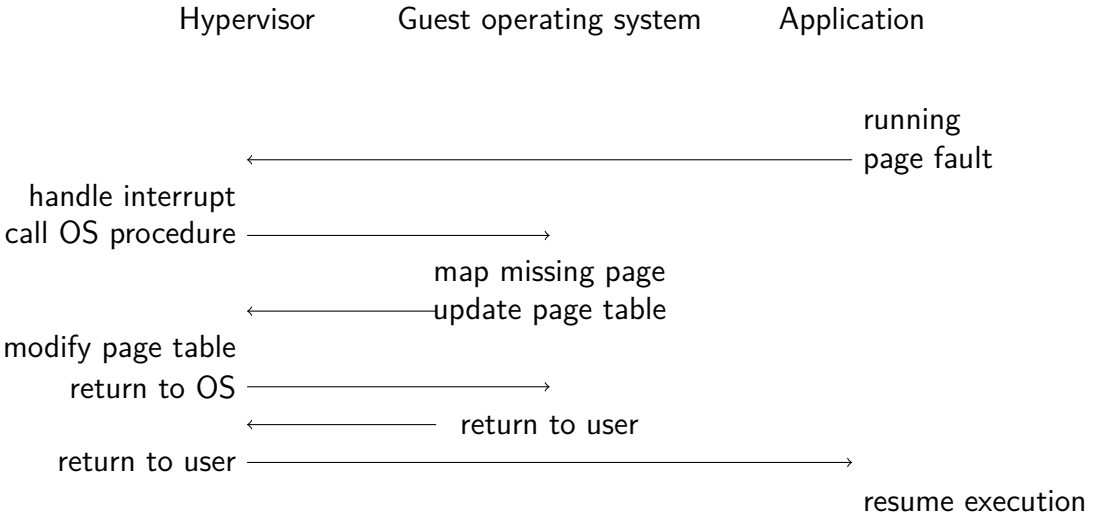
This will be expensive!

regular paging

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

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

second level paging

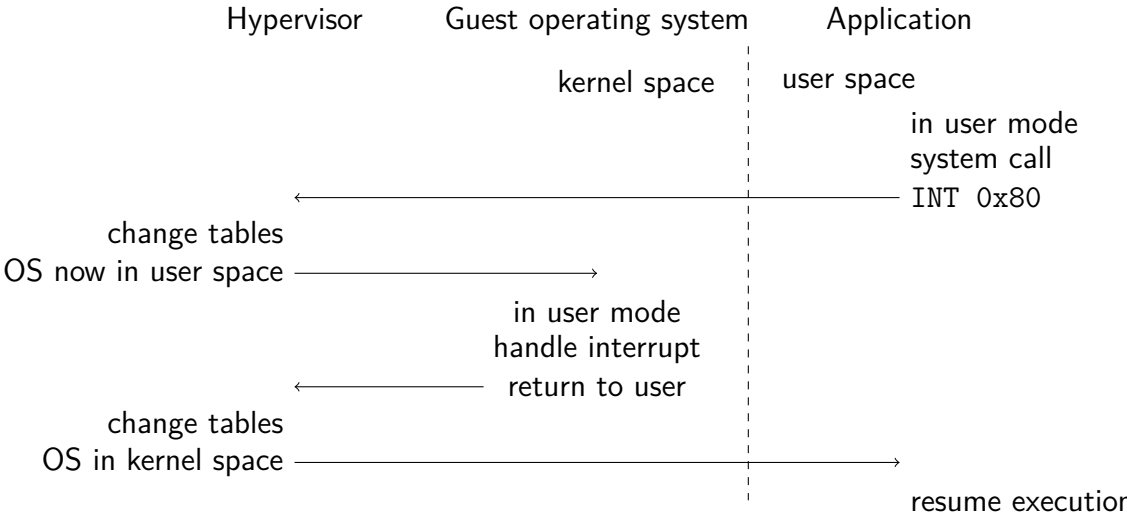


...wait a second

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



.. thank god for harware

Hardware support:

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

.. a different approach

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

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

The original goal

Utilisation of hardware.

Applications are completely separated from each other.

Applications can use different operating systems.

What if we skip this.

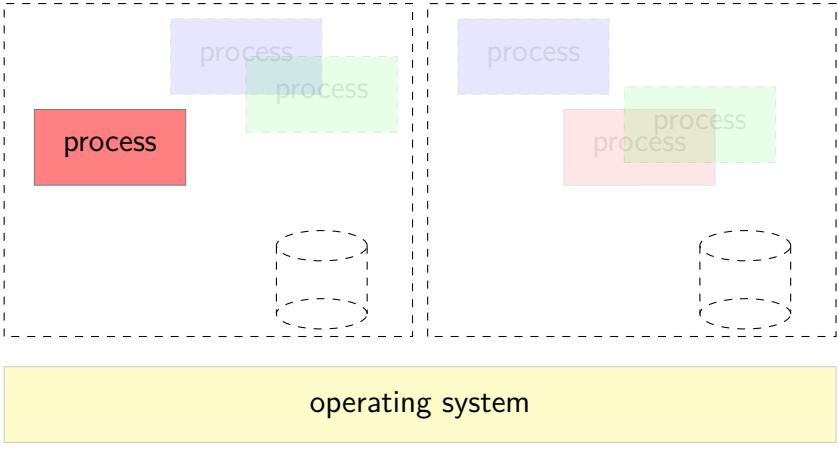
containers

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

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


process
process
process
process
process
process
operating system
hardware

the original goal

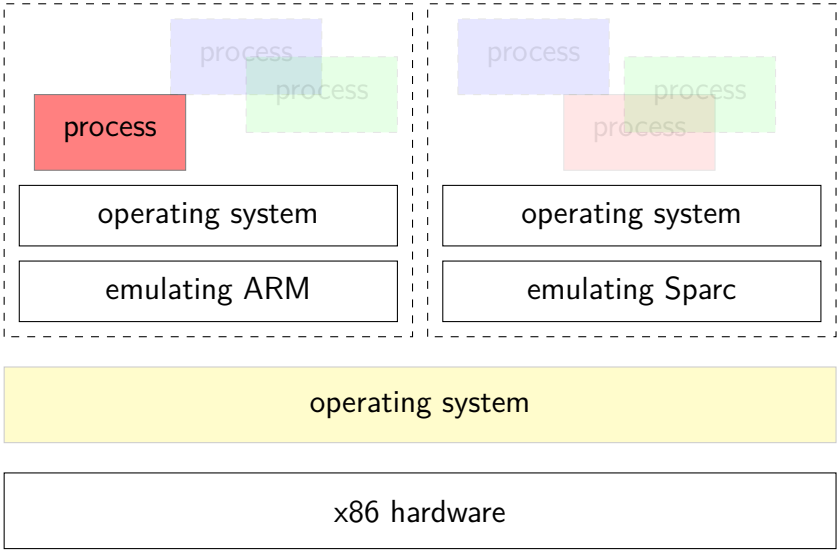
Utilisation of hardware.

Applications are completely separated from each other.

Applications can use different operating systems.

Why do they have to run on the same hardware?

emulating hardware



Types of virtual machines

- Emulators
  - Can emulate a different hardware than the host machine (QEMU, Simics).
- Virtual machines
  - Choose operating system but hardware is set (Xen, KVM, VirtualBox, VMware).
- Containers
  - Separated name spaces in the same operating system (Dockers, Linux Containers).
- Runtime systems
  - Dedicated to a language (JVM, Erlang).

... but I never installed a Hypervisor?

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

Summary

- Multiple operating systems running on the same machine.
- Each operating system provided a virtual hardware.
- With hardware support, near bare metal execution speed can be obtained.
- Other types: emulators, containers, runtime environments.