Week 2

Hardware and Virtualization

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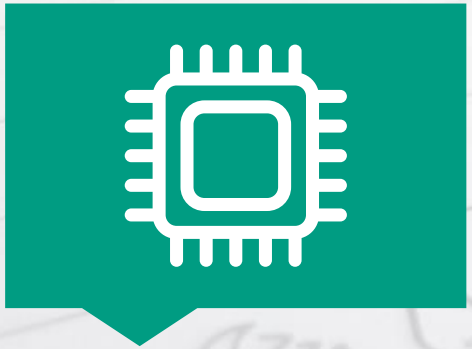
Agenda



Hardware

- How does a computer work?
- CPU, Memory, Disk, Network

Virtualization

- What is it?
- What are the advantages and disadvantages?

VMware workstation

Working on the case

Hardware

How does a computer work?

CPU Clock speed max +/- 4 GHz

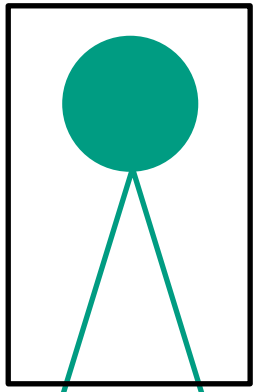
Registers and L1, L2, L3 Cache: ~MB
Super fast. Instruction takes **4 ns**

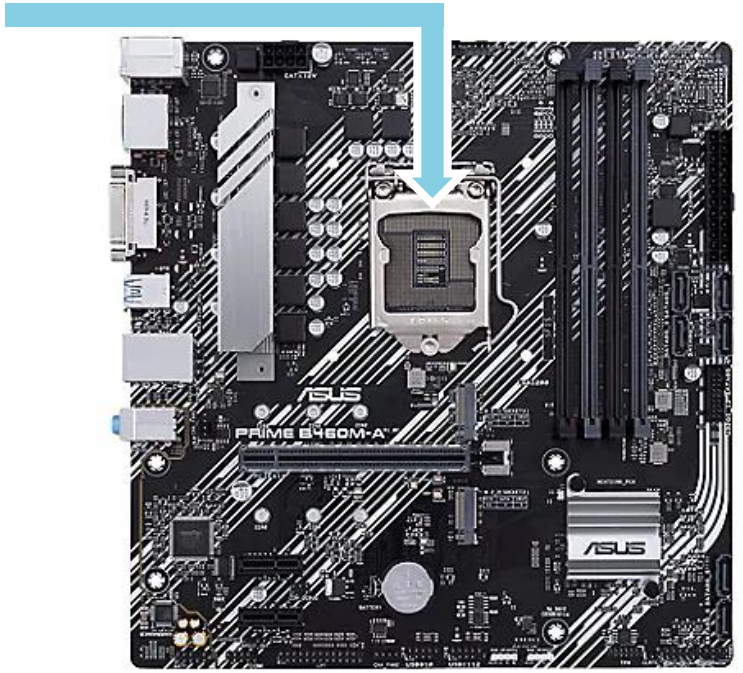
Main memory: ~GB
Very fast. Instruction takes **10 ns**

SSD: ~GB
Quickly. Instruction takes **10 µs**

HDD: ~TB
Less fast. Instruction takes **10 ms**

Network storage: ~TB
Less fast. Instruction takes **10 ms**





motherboard

TB, GB, MB, do you remember?

- 1 Byte is 1 character (letter or number)
- 1 Kilobyte = 1 KB = 1000 Bytes
- 1 Megabyte = 1 MB = 1000,000 Bytes (1 million)
- 1 Gigabyte = 1 GB = 1000,000,000 Bytes (1 billion)
- 1 Terabyte = 1 TB = 1000,000,000,000 Bytes (1000 billion)
- ??
- ??

Decimal			Binary				
Value	Metric		Value	IEC		Legacy	
1000	kB	kilobyte	1024	KiB	kibibyte	KB	kilobyte
1000^2	MB	megabyte	1024^2	MiB	mebibyte	MB	megabyte
1000^3	GB	gigabyte	1024^3	GiB	gibibyte	GB	gigabyte
1000^4	TB	terabyte	1024^4	TiB	tebibyte	TB	terabyte
1000^5	PB	petabyte	1024^5	PiB	pebibyte		–
1000^6	EB	exabyte	1024^6	EiB	exbibyte		–
1000^7	ZB	zettabyte	1024^7	ZiB	zebibyte		–
1000^8	YB	yottabyte	1024^8	YiB	yobibyte		–

https://en.wikipedia.org/wiki/Byte#Multiple-byte_units

How much is 1 GB, TB, PB?

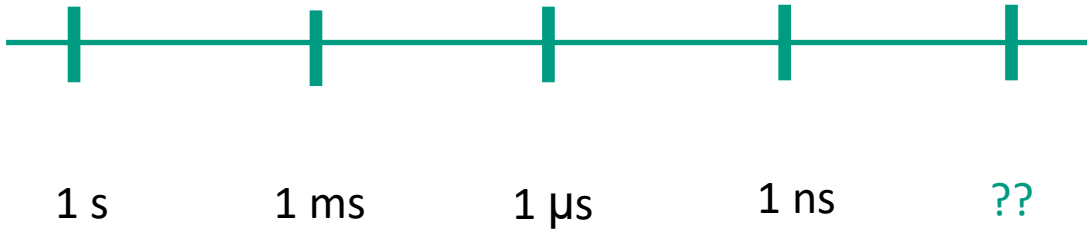
- Internal memory in PC is 4GB to 32GB
- Harddisk in PC is 100GB to 2 TB in size
- Daily upload to Youtube: 4 PB
- Daily upload to Facebook: 1 PB

Video: https://www.youtube.com/watch?v=OQgVrh871hs

Millisecond, microsecond, nanosecond?

- 1 s (second) = 1000 **ms** (millisecond)
- 1 ms = 1000 **µs** (microsecond)
- 1 µs = 1000 **ns** (nanosecond)

- Latency is often expressed in one of these units.



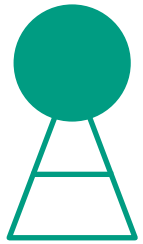
Activity

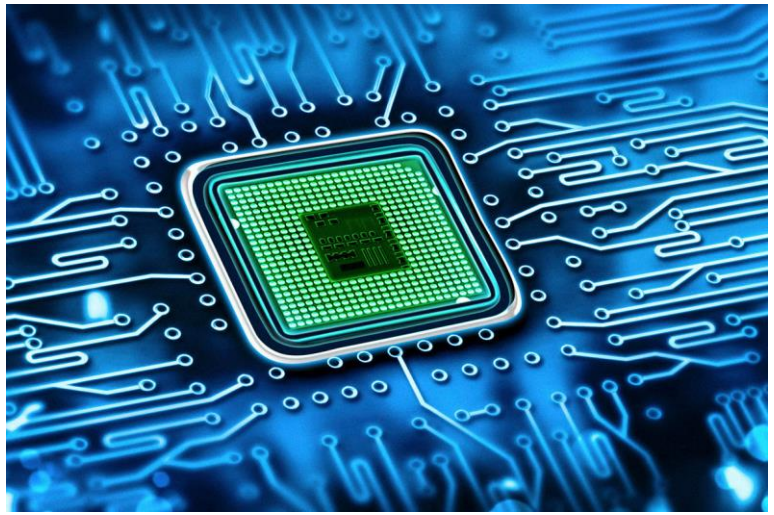
On the previous slides fill in the places with the question marks:

- What comes after PB?
- What comes after ns?
- How much faster is the internal memory compared to a hard disk?
- Youtube receives 4 PB of data every day. How many harddisks of 1TB (as in a PC) are needed to store that?

The processor

- Contains:
  - The CPU
  - Registers
  - L1, L2, L3 cache





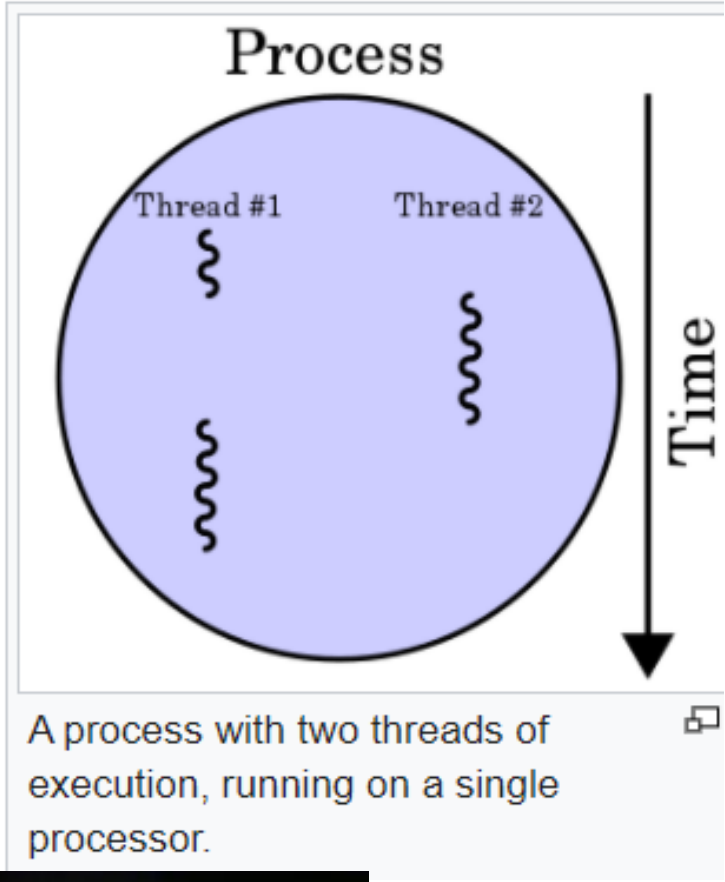
- The clock speed has reached its physical limits:
  - **Max 5 to 6 GHZ**.
- This is why each **processor** now has multiple **cores (each core is a CPU)**.

- Xeon processor: up to 58 cores, L3 cache 70 MB
- In PC often a processor with 4 cores.
- Each core is a CPU.

- Major processor manufacturers are **Intel** and **AMD.**

Hyperthreading

- Within a core, there was still a wait.
- **Hyperthreading** gives more efficient CPU usage.
- If the processor supports it:
  - First turn on hyperthreading in the BIOS (can be reached directly after booting by pressing F10 key).
  - Then double the number of cores.
  - In reality the performance gain not factor 2 but factor 1.6.



A process with two threads of execution, running on a single processor.

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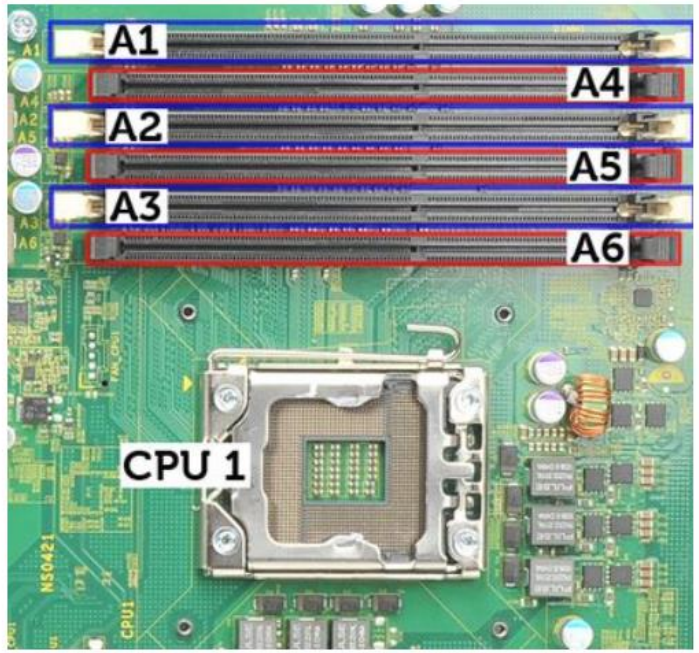
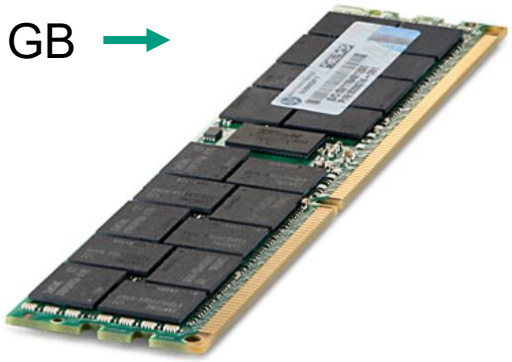
Main memory

- The computer's internal memory.
- Order of size 1GB to 32GB for a PC, 32GB to 1TB for a server.
- Is not permanent memory: computer powered down → internal memory empty

Memory slots →



Memory card 32 GB →

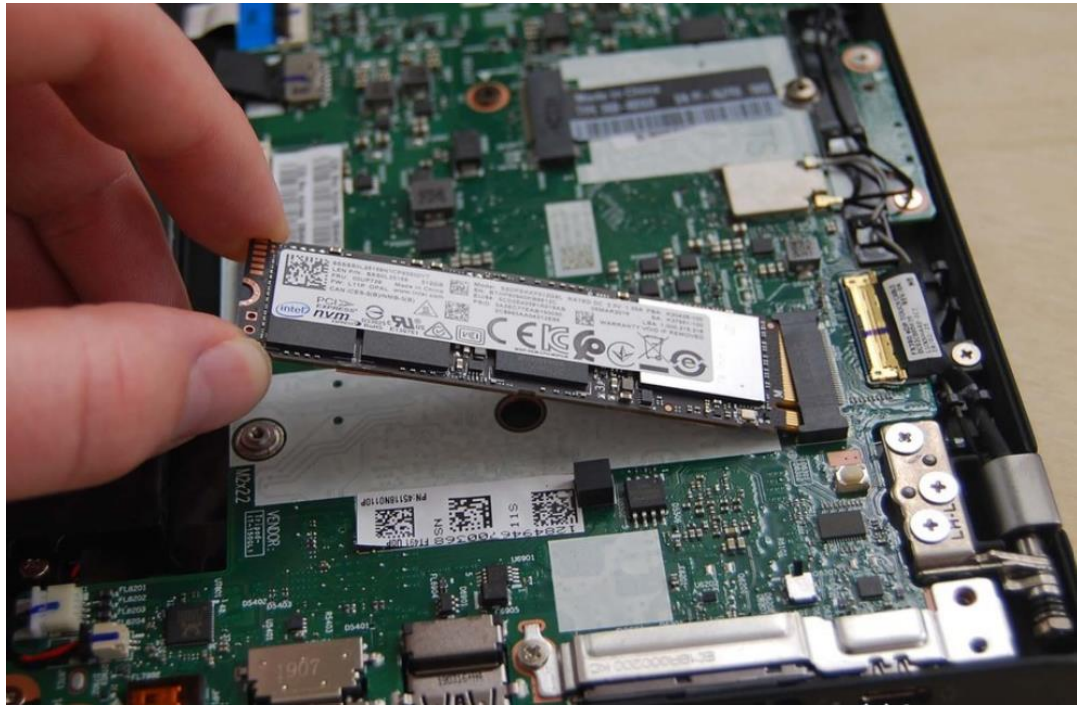


SSD (Solid State Drive)

- Permanent memory (computer powered down → data remains)
- Does not contain a rotating disk (storage in chips (semiconductor material)).
- Cheaper than main memory but also slower (factor 1000).
- Faster than rotating hard disk (factor 1000).
- In PC SSD often 100 - 500 GB.

Used:

- Also used in servers for low latency
- Laptops for size benefit
- Quick booting



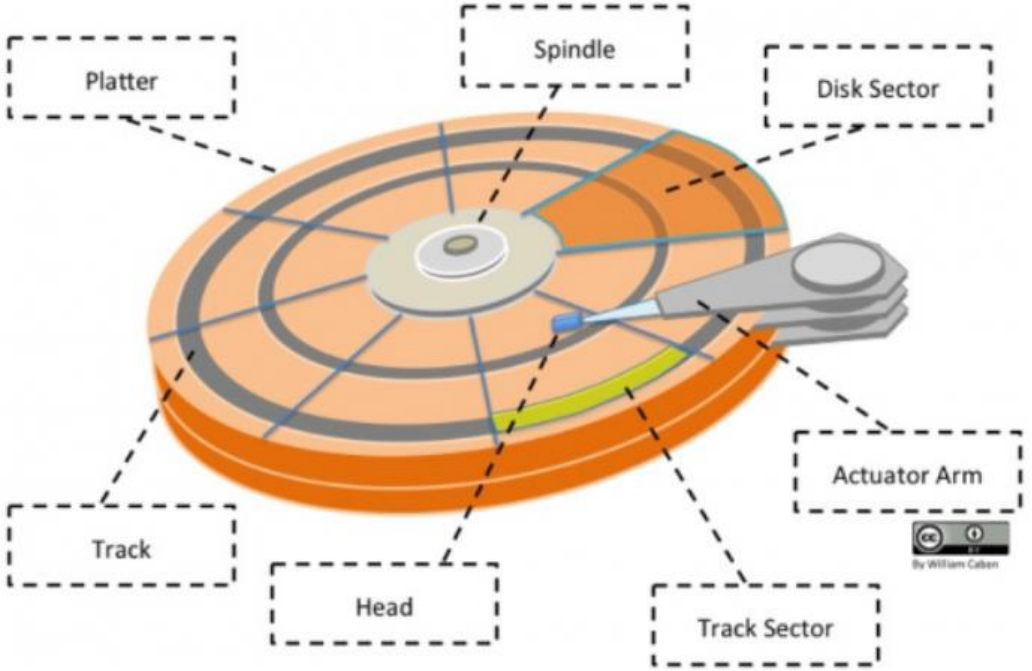
HDD (Hard Disk Drive)

- Permanent memory (computer powered down → data remains)
- Rotating disc
- Maximum speed 15000 rpm (rotations per minute)
- In PC often 7200 rpm

- In PC size often 100 GB - 1 TB
- In storage device 1 TB - 1 PB
- Hard disk latency:

Typical HDD figures

HDD spindle speed [rpm]	Average rotational latency [ms]
4,200	7.14
5,400	5.56
7,200	4.17
10,000	3.00
15,000	2.00



Network

- Computer has 1 or more network cards.
- Speeds:
  - PC: often 1 Gbps
  - Server: 10 Gbps or greater.

There is also wifi in a PC.

SMART Requirements

S	pecific
M	easurable
A	chievable
R	ealistic
T	imely

SMART Examples

Bad	Machine needs to be fast
Good	Must be portable with at least 2-hour normal usage battery life.
?	Can render videos.
?	Meets recommended requirements for Office 365.

Difference PC and Server

PC vs Server

PC

- CPU: intel or AMD, 1 to 4 cores
- Memory: 4GB to 32GB
- SSD: 500 GB to 1 TB
- Hard disk: 500 GB to 2 TB
- Mouse, keyboard and monitor
- Types: Desktop or laptop.

Server

- CPU: 1 or 2 sockets with each socket 4 to 50 cores
- Memory: 32 GB to 1 TB
- SSD: 20 GB to 1 TB
- Hard disk: 20 GB to 1 TB
- 1 keyboard, mouse and monitor for multiple servers
- Types: Tower, Rack or Blade

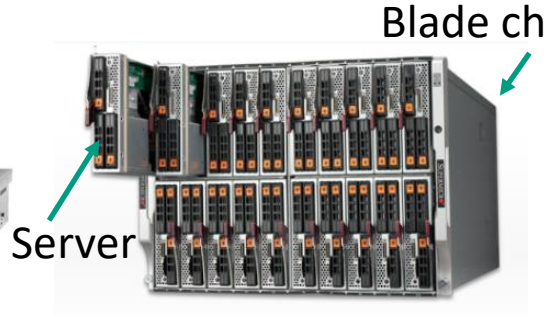
Server often has external storage (on the network)

Laptop model

Desktop model

Tower

Rack



Blade

Activity

Research your own PC

- What CPU is in there with how many cores?
- How much main memory
- SSD yes or no, if so what size?
- Harddisk yes or no. If yes what size and what is the speed?

Watch the following video that shows what goes into a server:

https://youtu.be/F-x_0TRdNS0

You may want to watch this at home.

Virtualization

Introduction

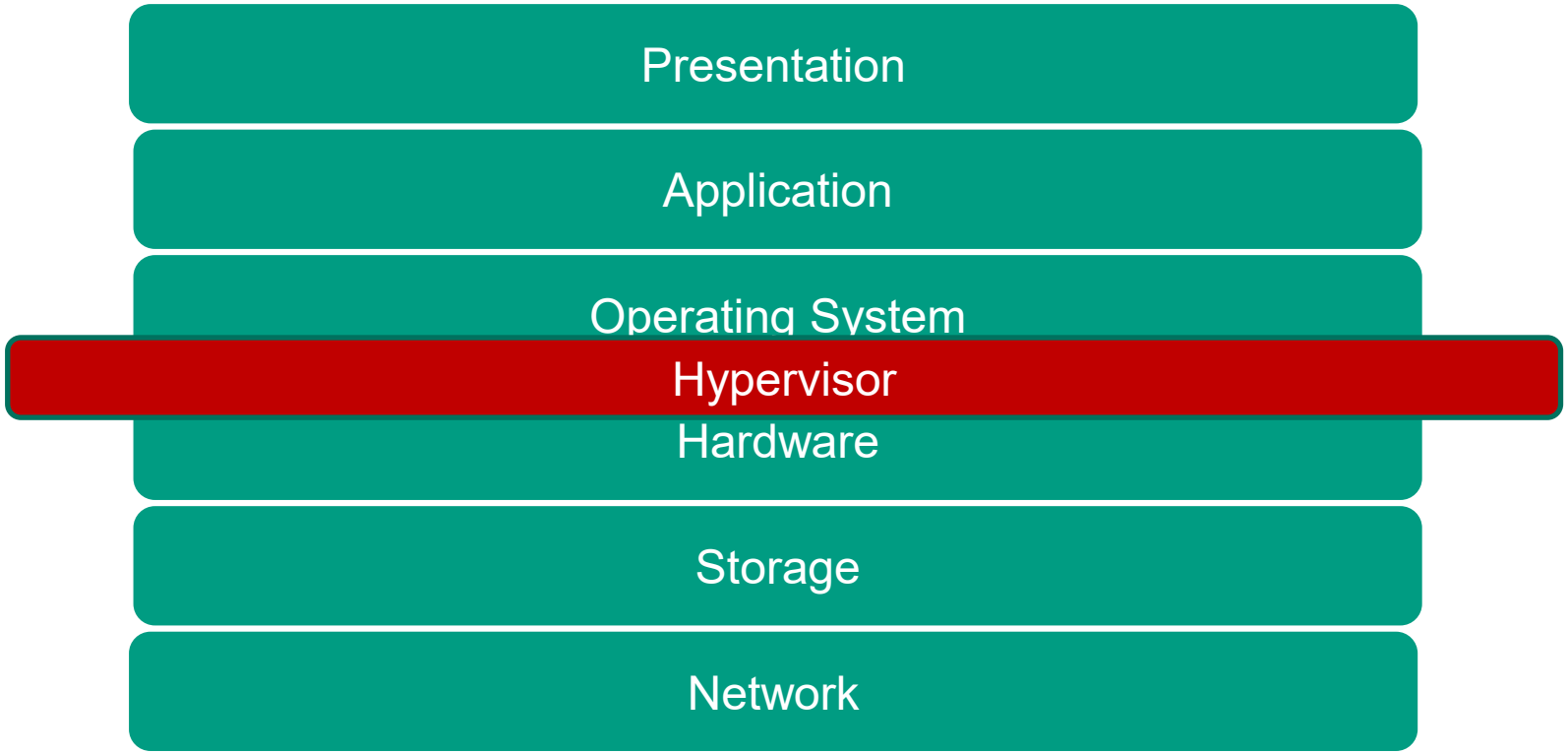
- Normal situation:

- On hardware we install an **Operating System** (e.g. Windows 10 or Linux). And the applications on top of it.

- OS and hardware are then directly linked. Disadvantages:
  - **Hard to replace hardware** (requires reinstalling everything).
  - **Each OS on its own computer** (applications for different OS cannot run together on 1 computer).
  - **Difficult to manage** (many different hardware).
  - **Poor resource usage** (per computer, CPU is only used 10%; just look at your own PC).
  - …

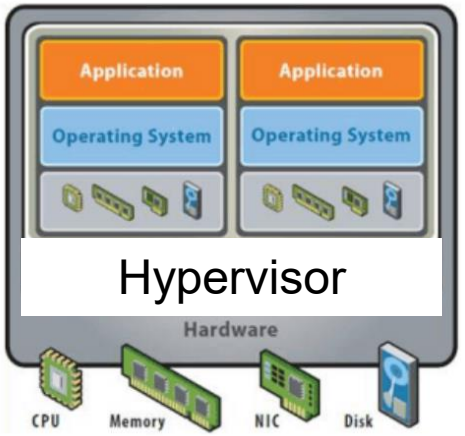
Server virtualization

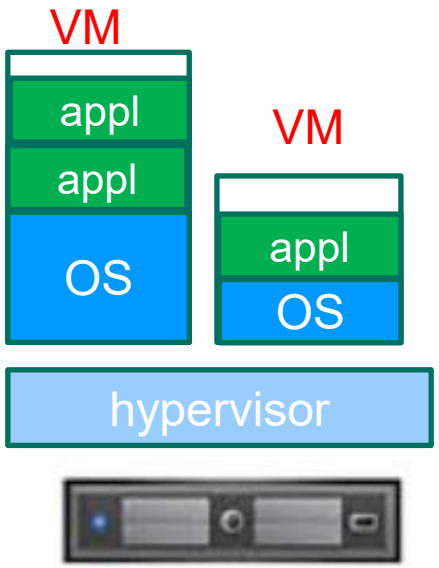
- Separation between hardware and OS.
- Hypervisor applies separation:



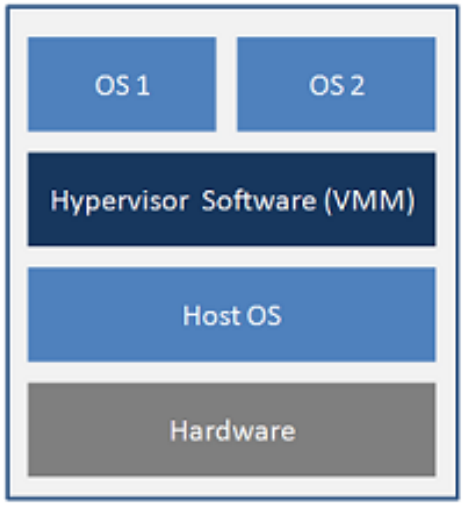
After virtualization

- Installing OS in VM (virtual machine) on hypervisor
- Multiple VMs on 1 machine
- Hardware host is shared with VMs
- VMs are independent of each other
- Virtual machine is software (as a file)

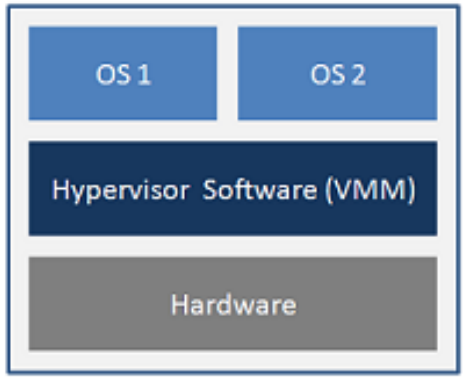




In these lessons we use



Hosted Architecture



Bare-Metal Architecture

Host based

VMware workstation pro 17 on Windows 10/11
or Fusion 13 on Apple macOS

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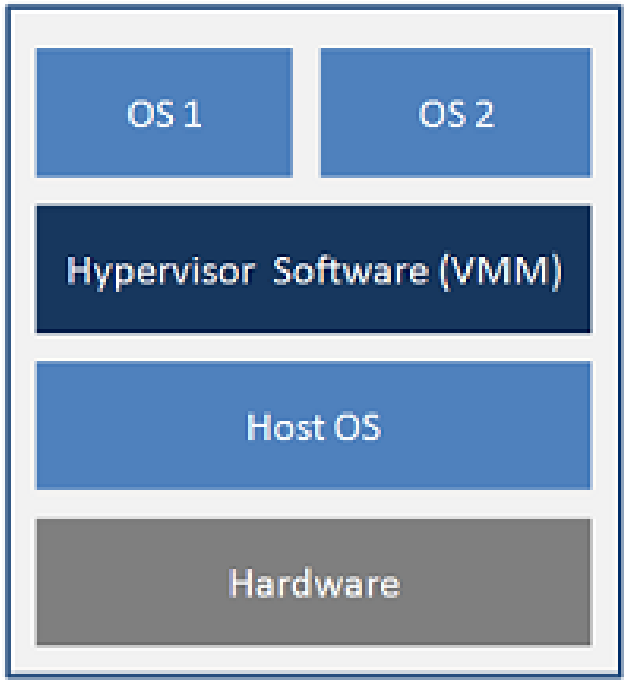
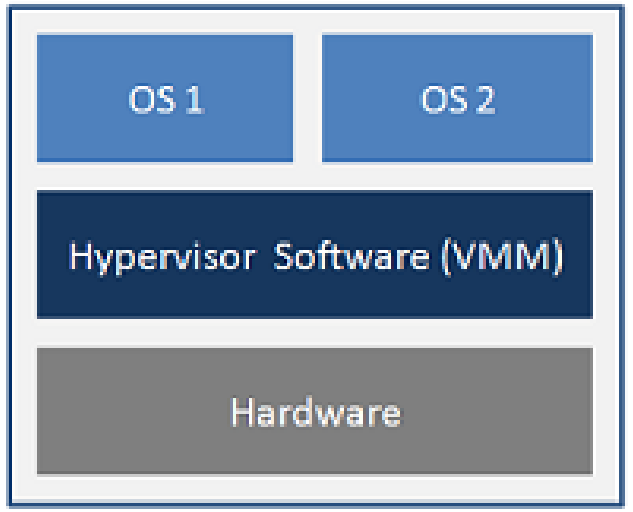
Types of hypervisors

Host based
Used by e.g. developers or small test environments

Hypervisor on underlying OS



Hosted Architecture



Bare-Metal Architecture

Products for Virtualization

Examples Hostbased:

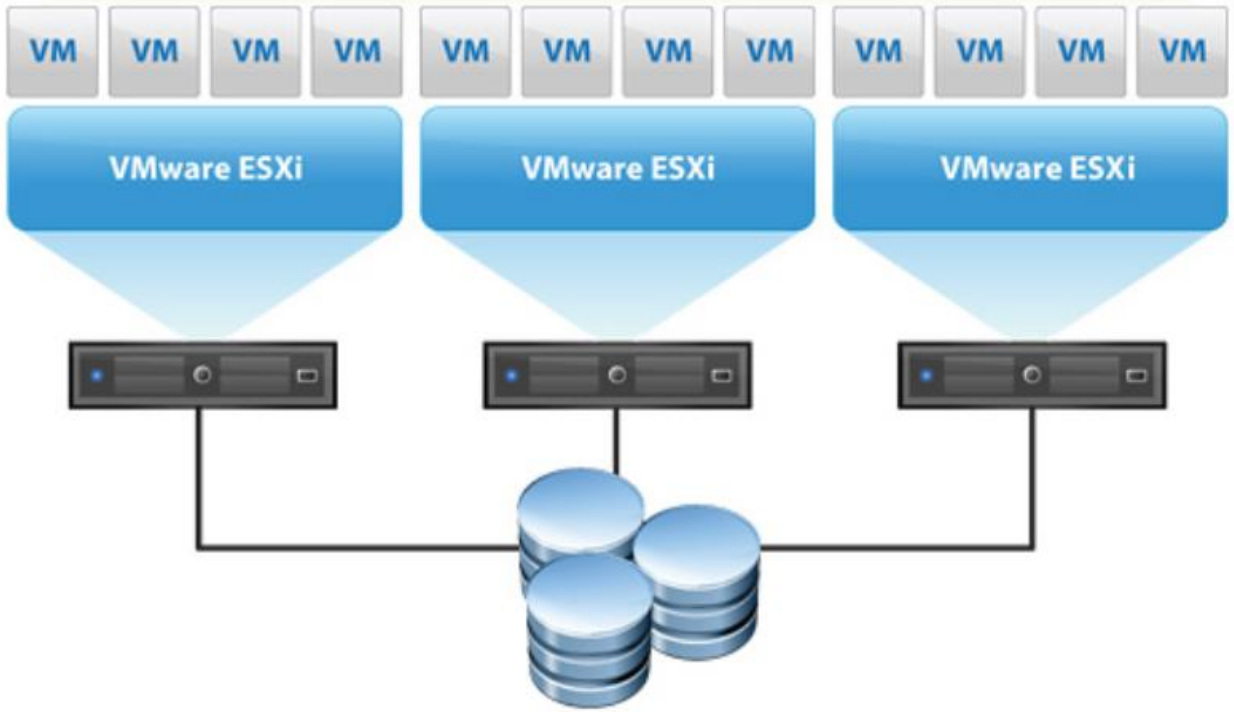
- Virtual Box
- VMware Workstation (on e.g. windows 11)

Examples Bare metal Virtualisation:

- VMware ESXi
- Microsoft Hyper V
- KVM
- Proxmox

In production environments

- Baremetal
- Hypervisor installed directly on hardware (server).
- Hypervisors: HyperV, KVM (open source), VMware ESXi.
- Typical layout:



- Multiple hosts
- Multiple VMs per host
- Shared Storage attached to each host

Benefits of virtualization

- More efficient use of hardware
  (CPU and memory used up to 80%)
- Central management (central access to all VMs)
- Less hardware to maintain
- Smaller data center (so cooling etc.)
- Easier hardware replacement (independent of VM; VMs can be moved to different host)
- If a host fails, the VMs can be restarted elsewhere (automatically)
- Virtual machine has become software (file). Therefore, easy to copy, backup etc.
- …..

Activity

- Examine which quality requirements of the previous lesson virtualization can contribute to.

Working on the case

Case

- Do the assignments of week 2

Please consult the assignments document and the template report for more details.

Any questions?