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Accelerated AI

Introduction to Operating Systems, Virtualization, Cloud

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System software

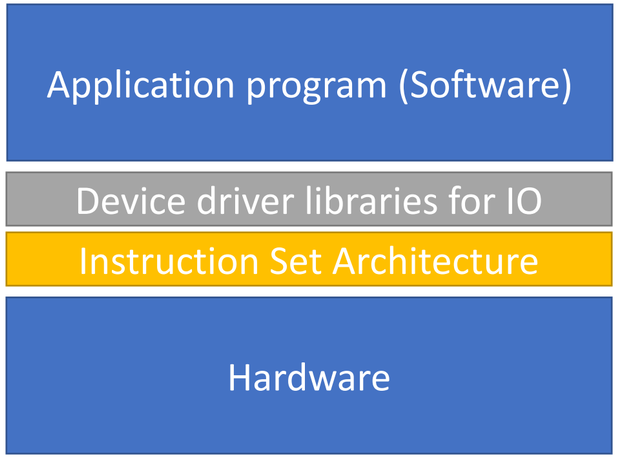
- operating system
- Utilities
- device drivers
- language translators

What is an operating system

- A bunch of software and data residing somewhere in memory.
  - But its not just any software.
- OS is the most privileged software in a computer.
  - Privileged means that OS can do special things, like write to disk, talk over the network, control memory and CPU usage, etc.
- OS manages all system resources
  - CPU, Memory, and I/O devices

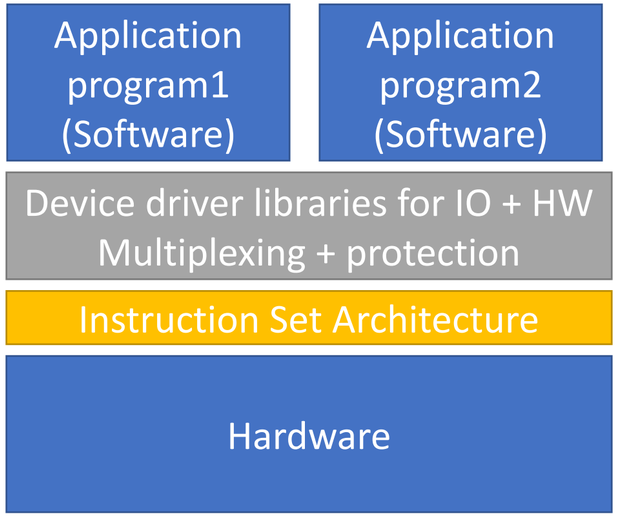
Why there is a need for OS

- Programs do not know how to access system I/O



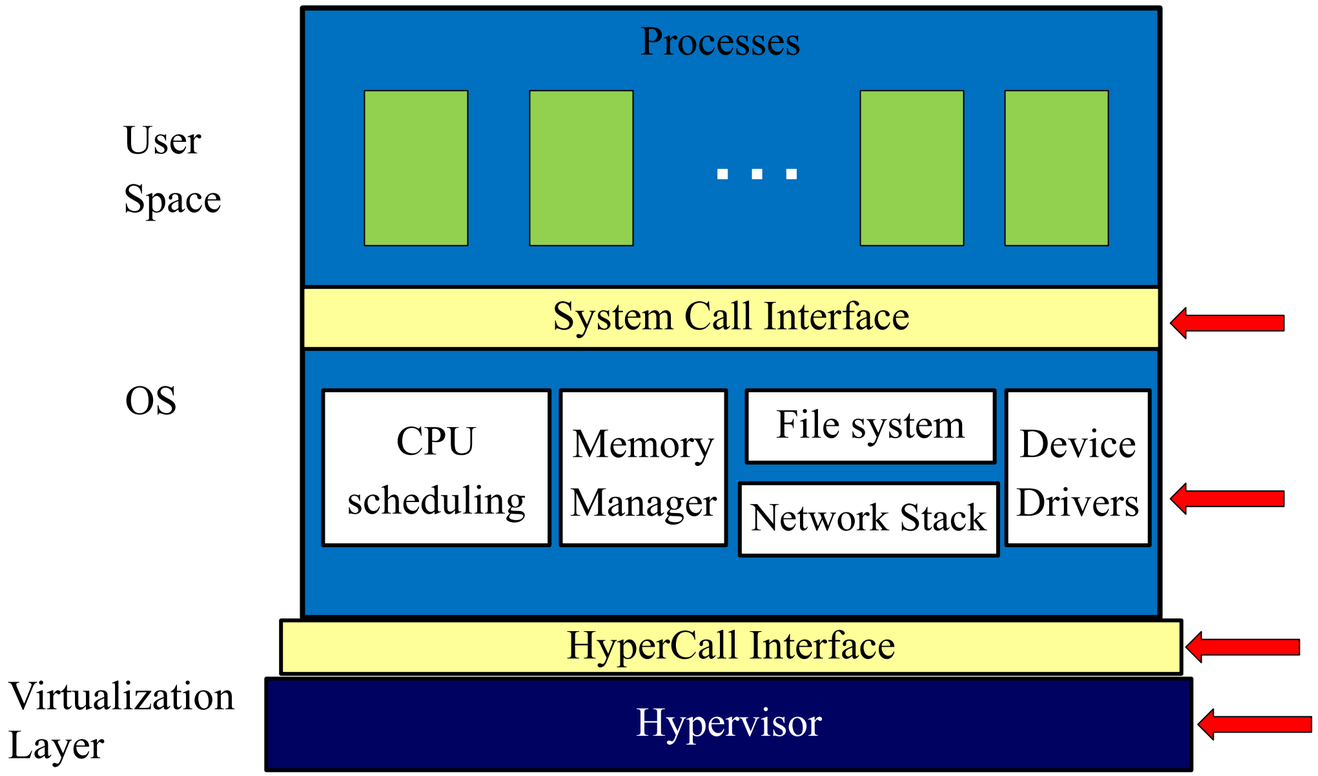
Why there is a need for OS

- What happens when multiple program needs to share the HW



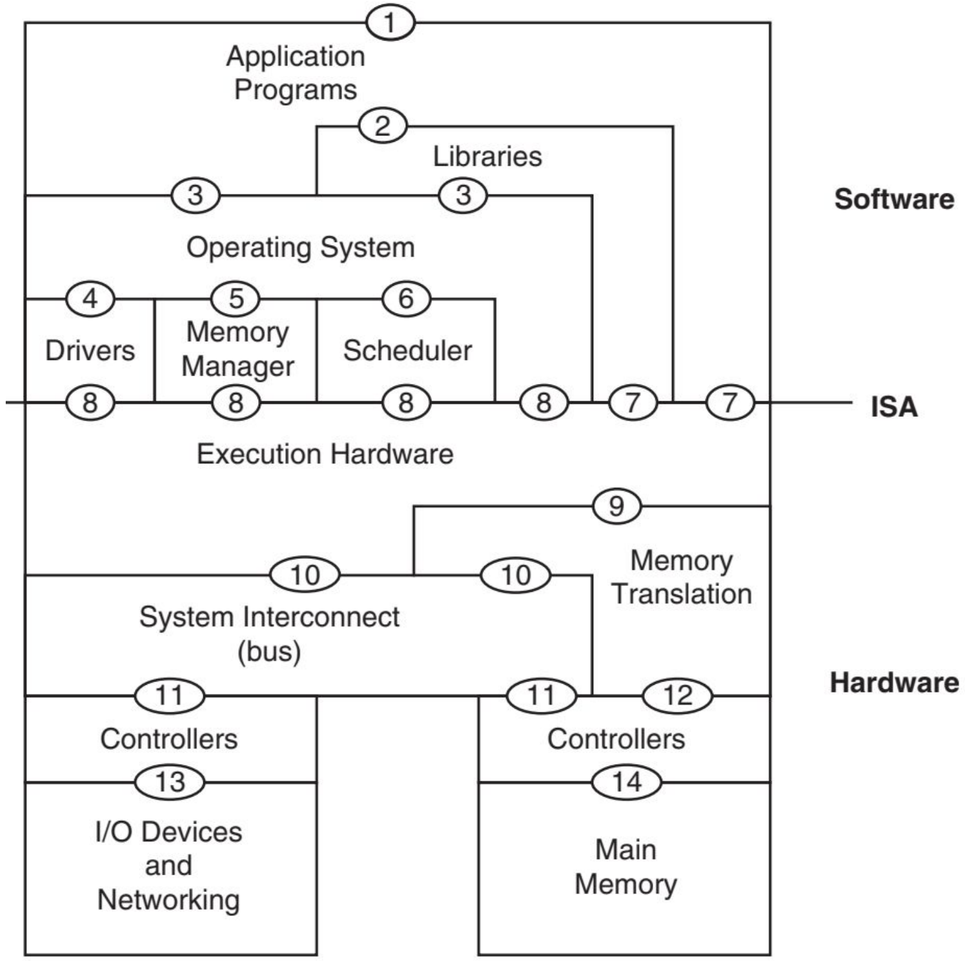
- Two programs does not trust each other
- OS does not trust programs
- HW does not trust programs

Software layers



Credit: Karthik Gopalan

Interfaces available in a computing system



User ISA : 7
System ISA : 8
Syscalls : 3
ABI : 3, 7
API : 2,7

ISA = Instruction Set Architecture
ABI = Application Binary Interface
API = Application Programming Interface

[credit: Smith and Nair]

Virtualization

- Makes a real system appear to be a set of virtual systems

- One-to-many virtualization
  - E.g. one physical machine may appear as multiple virtual machines
  - one physical disk may look like multiple virtual disk
  - one physical network may look like multiple virtual networks

- Many-to-one virtualization
  - Many physical machines/disks/networks may appear to look like one virtual machine/disk/network etc

- Many-to-many virtualization

Credit: Karthik Gopalan

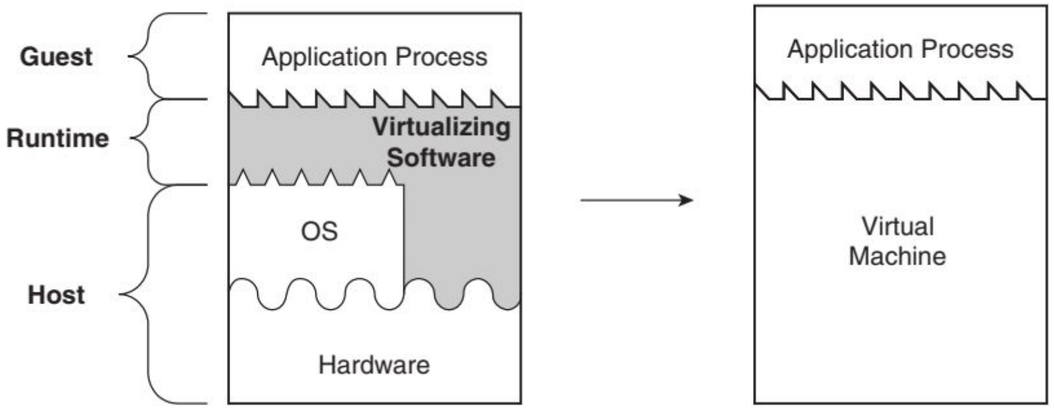
Virtual Machine (VM)

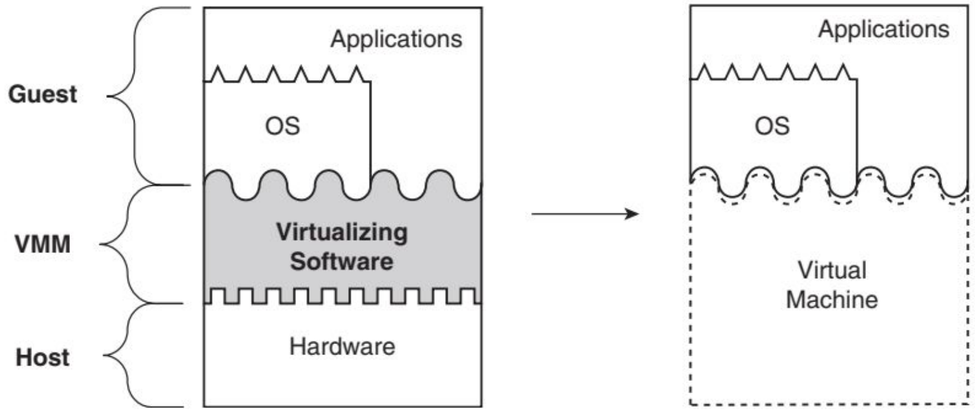
- Logical/Emulated representations of full computing system environment
  - CPU + memory + I/O
  - Implemented by adding layers of software to the real machine to support the desired VM architecture.
- Uses:
  - Multiple OSes on one machine, including legacy OSes
  - Isolation
  - Enhanced security
  - Live migration of servers
  - Virtual environment for testing and development
  - Platform emulation
  - On-the-fly optimization
  - Realizing ISAs not found in physical machines

Credit: Karthik Gopalan

Different types of VMs

- Process VM
  - Virtualizes the ABI
  - Virtualization software => Runtime
  - Runs in non-privileged mode (user space)
  - Performs binary translation.
  - Terminates when guest process terminates.
- System VM
  - Virtualizes the ISA
  - Virtualization software => Hypervisor
  - Runs in privileged mode
  - Traps and emulates privileged instructions



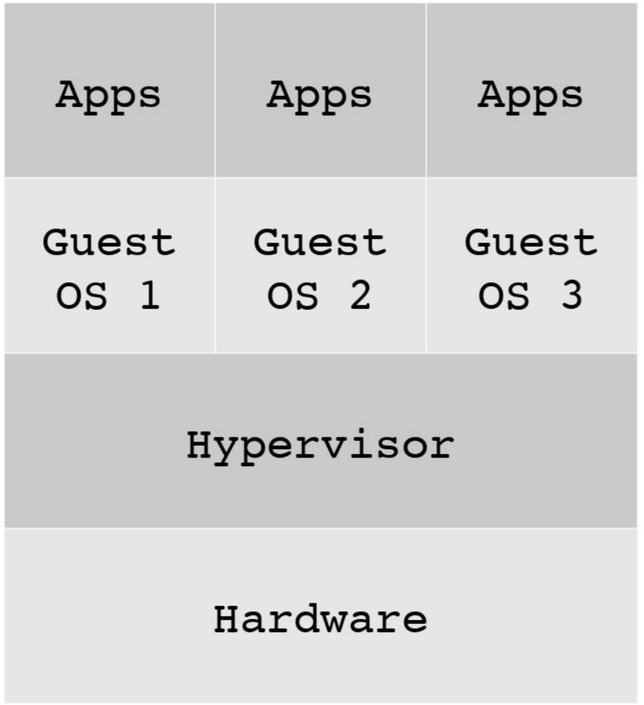


[credit: Smith and Nair]

System VM

Hypervisors

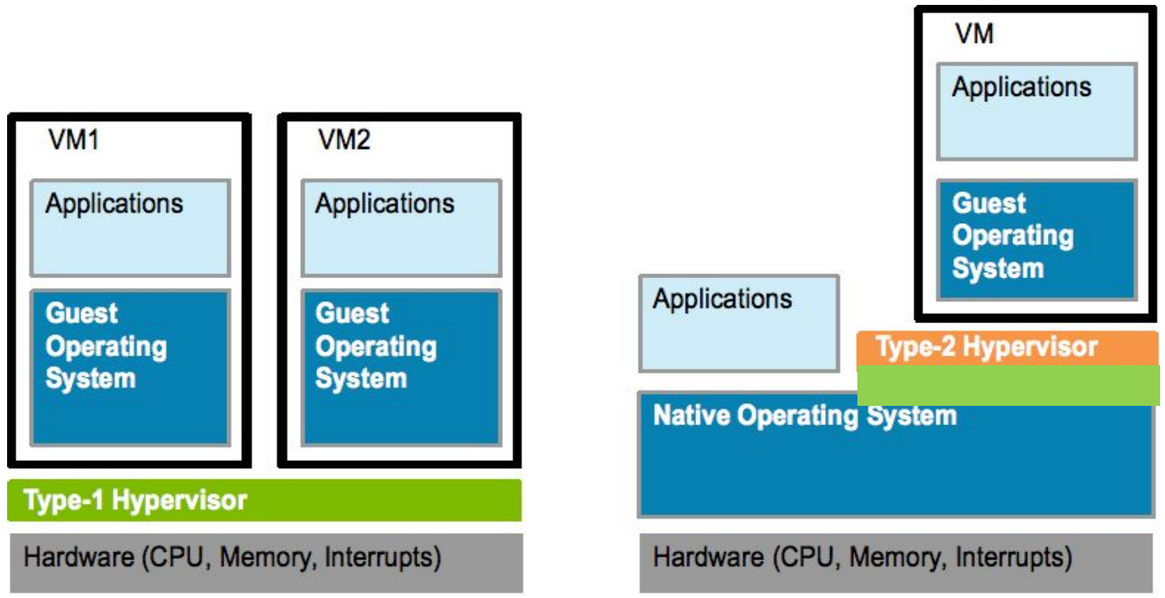
- Also called Virtual Machine Monitor (VMM)
- A hypervisor is an operating system for operating systems
  - Provides a virtual execution environment for an entire OS and its applications
  - Controls access to hardware resources
  - When guest OS executes a privileged instruction, Hypervisor intercepts the instruction, checks for correctness and emulates the instruction.



Credit: Karthik Gopalan

Type of Hypervisors

- Type 1 Hypervisor (bare metal, native): supports multiple virtual machines and runs directly on the hardware (e.g., VMware ESX , Xen, Denali)
- Type 2 Hypervisor (hosted) VM - runs under a host operating system (e.g., user-mode Linux)



https://microkerneldude.files.wordpress.com/2012/01/type1-vs-2.png

Para-virtualized VMs

- Modify guest OS for better performance
- Traditional Hypervisors provide full-virtualization
  - They expose to VMs virtual hardware that is functionally identical to the underlying physical hardware.
  - Advantage : allows unmodified guest OS to execute
  - Disadvantage: Sensitive instructions must be trapped and emulated by Hypervisor.
  - E.g. KVM and VMWare ESX provide full virtualization
- Para-virtualized VM
  - Sees a virtual hardware abstraction that is similar, but not identical to the real hardware.
  - Guest OS is modified to replace sensitive instructions with “hypercalls” to the Hypervisor.
  - Advantage: Results in lower performance overhead
  - Disadvantage: Needs modification to the guest OS.
  - Xen provides both para-virtual as well as full-virtualization
- Often traditional Hypervisors are partially para-virtualizated
  - Device drivers in guest OS may be para-virtualized whereas CPU and Memory may be fully virtualized.

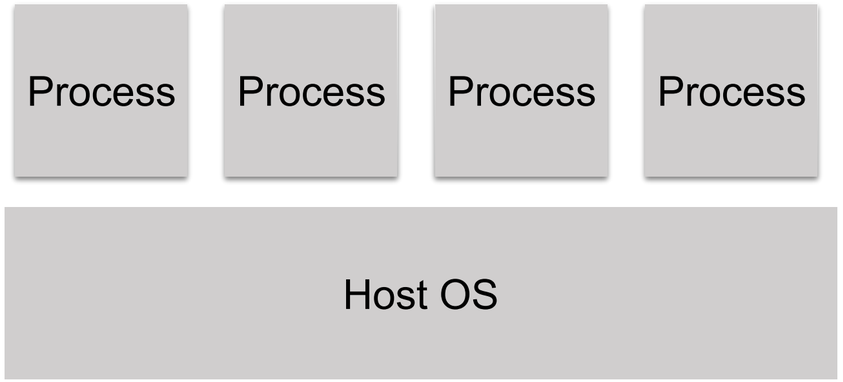
Credit: Karthik Gopalan

Examples of hypervisors

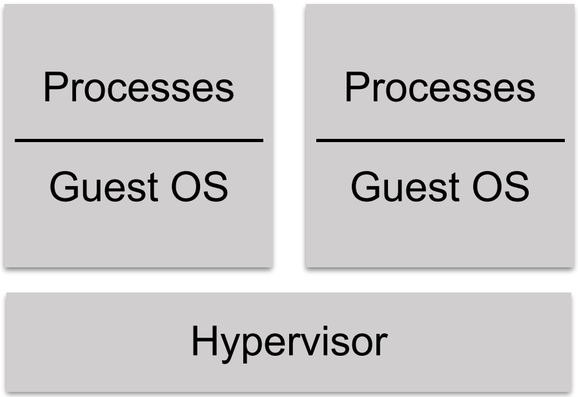
Name	Host ISA	Guest ISA	Host OS	guest OS	Company
Integrity VM	*x86*-64	*x86*-64	HP-Unix	Linux,Windows HP Unix	HP
Power VM	Power	Power	No host OS	Linux, AIX	IBM
z/VM	z-ISA	z-ISA	No host OS	Linux on z-ISA	IBM
Lynx Secure	*x86*	*x86*	No host OS	Linux, Windows	LinuxWorks
Hyper-V Server	*x86*-64	*x86*-64	Windows	Windows	Microsoft
Oracle VM	*x86*, *x86*-64	*x86*, *x86*-64	No host OS	Linux, Windows	Oracle
RTS Hypervisor	*x86*	*x86*	No host OS	Linux, Windows	Real Time Systems
SUN xVM	*x86*, SPARC	same as host	No host OS	Linux, Windows	SUN
VMware EX Server	*x86*, *x86*-64	*x86*, *x86*-64	No host OS	Linux, Windows Solaris, FreeBSD	VMware
VMware Fusion	*x86*, *x86*-64	*x86*, *x86*-64	MAC OS *x86*	Linux, Windows Solaris, FreeBSD	VMware
VMware Server	*x86*, *x86*-64	*x86*, *x86*-64	Linux, Windows	Linux, Windows Solaris, FreeBSD	VMware
VMware Workstation	*x86*, *x86*-64	*x86*, *x86*-64	Linux, Windows	Linux, Windows Solaris, FreeBSD	VMware
VMware Player	*x86*, *x86*-64	*x86*, *x86*-64	Linux Windows	Linux, Windows Solaris, FreeBSD	VMware
Denali	*x86*	*x86*	Denali	ILVACO, NetBSD	University of Washington
Xen	*x86*, *x86*-64	*x86*, *x86*-64	Linux Solaris	Linux, Solaris NetBSD	University of Cambridge

Credit: Anil Madhavapeddy

Traditional Process vs traditional VMs



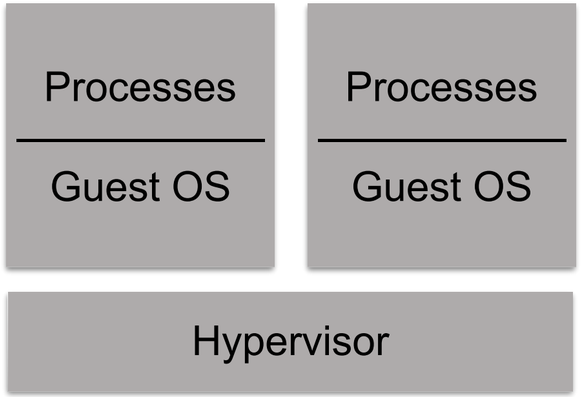
Traditional Processes



Traditional VMs

System VMs

- Each VM has its own
  - Guest OS
  - Guest physical memory (“virtualized” view of memory seen by guest OS)
  - One or more virtual CPUs
  - Virtual I/O devices: virtual disk, virtual network
- Ideally: Co-located VMs don’t see/share ANYTHING

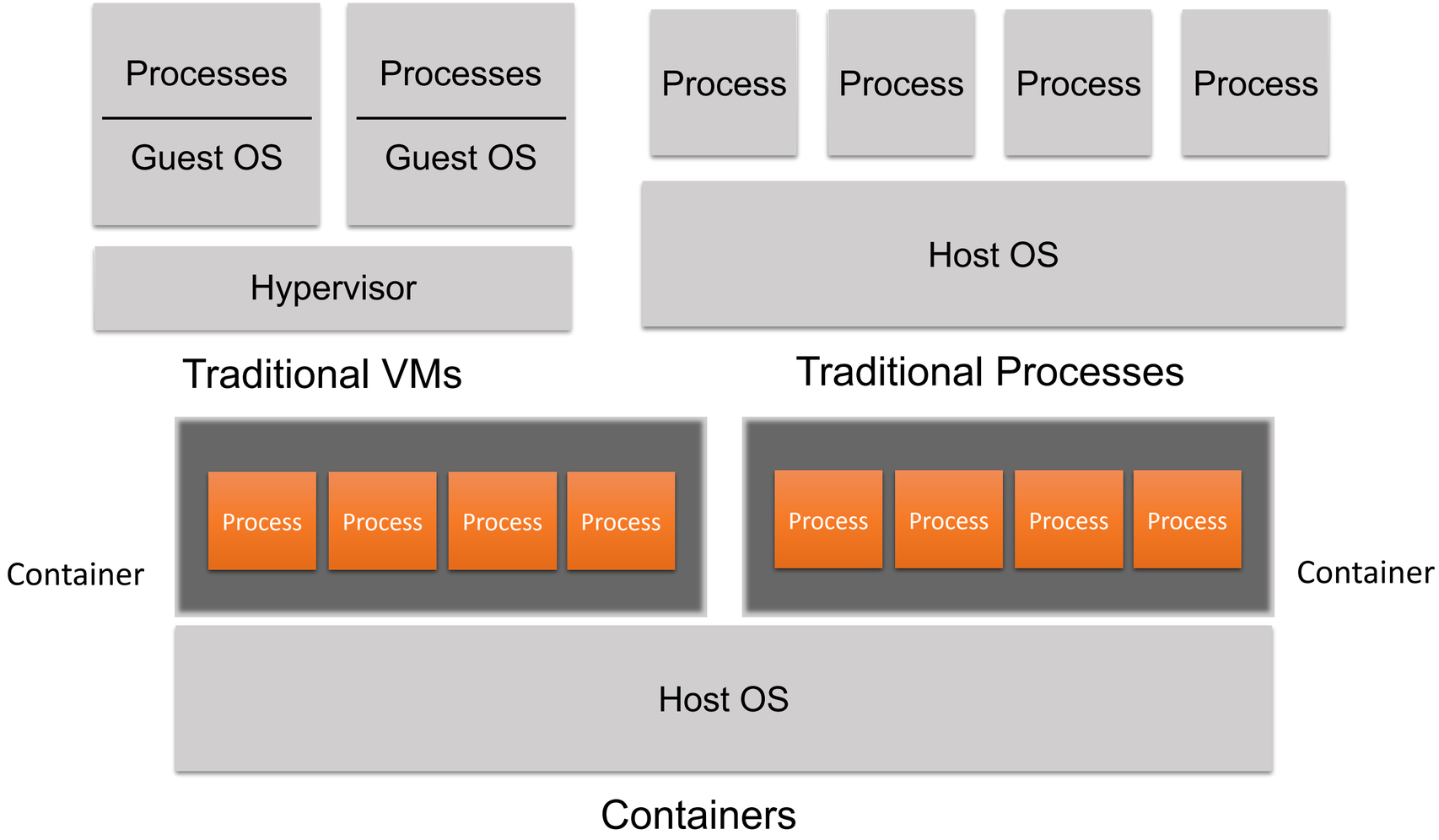


Isolation is important

- Limiting what/who a process/application can see.
- Limiting who can see a process/application

- Processes share too much
  - Great performance but not isolated enough
  - System VMs are too heavy
- Great Isolation but too heavy due to separate guest OS per VM
  Operating-system-level virtualization
  - Multiple isolated user-spaces
  - Share one kernel
  - Native performance

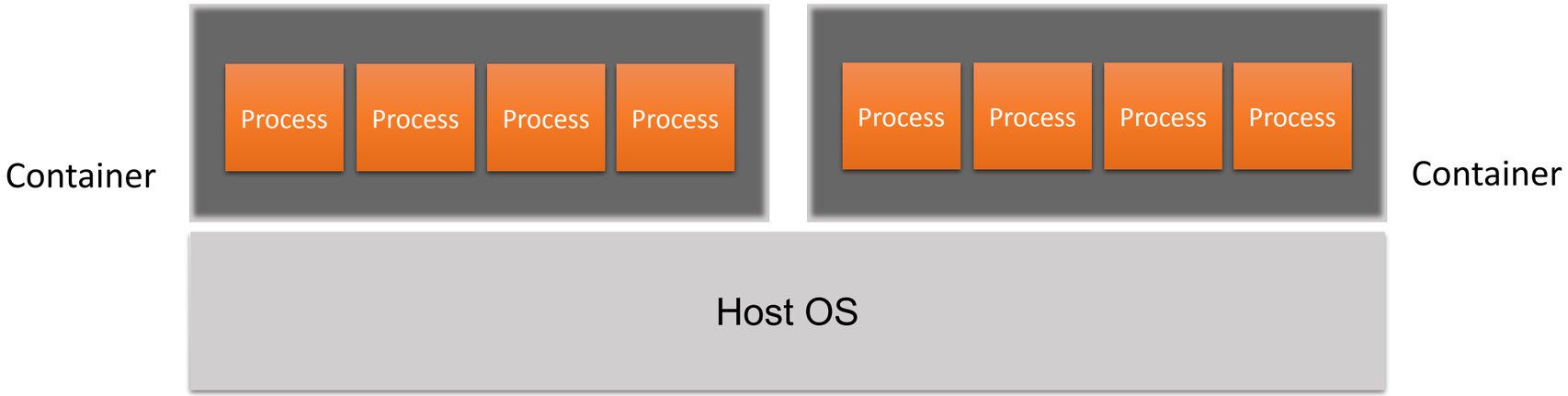
Process VMs and Containers



Credit: Karthik Gopalan

Containers

- Containers
  - group traditional processes together and
  - restrict what resources they can see/access.
- In Linux, containers consist of
  - Namespaces
  - Control Groups (cgroups)



Containers

Cloud Computing

- Virtualized distributed processing, storage, and software resources and a service.

- Delivering computing as a on-demand, pay-as-you-go service.

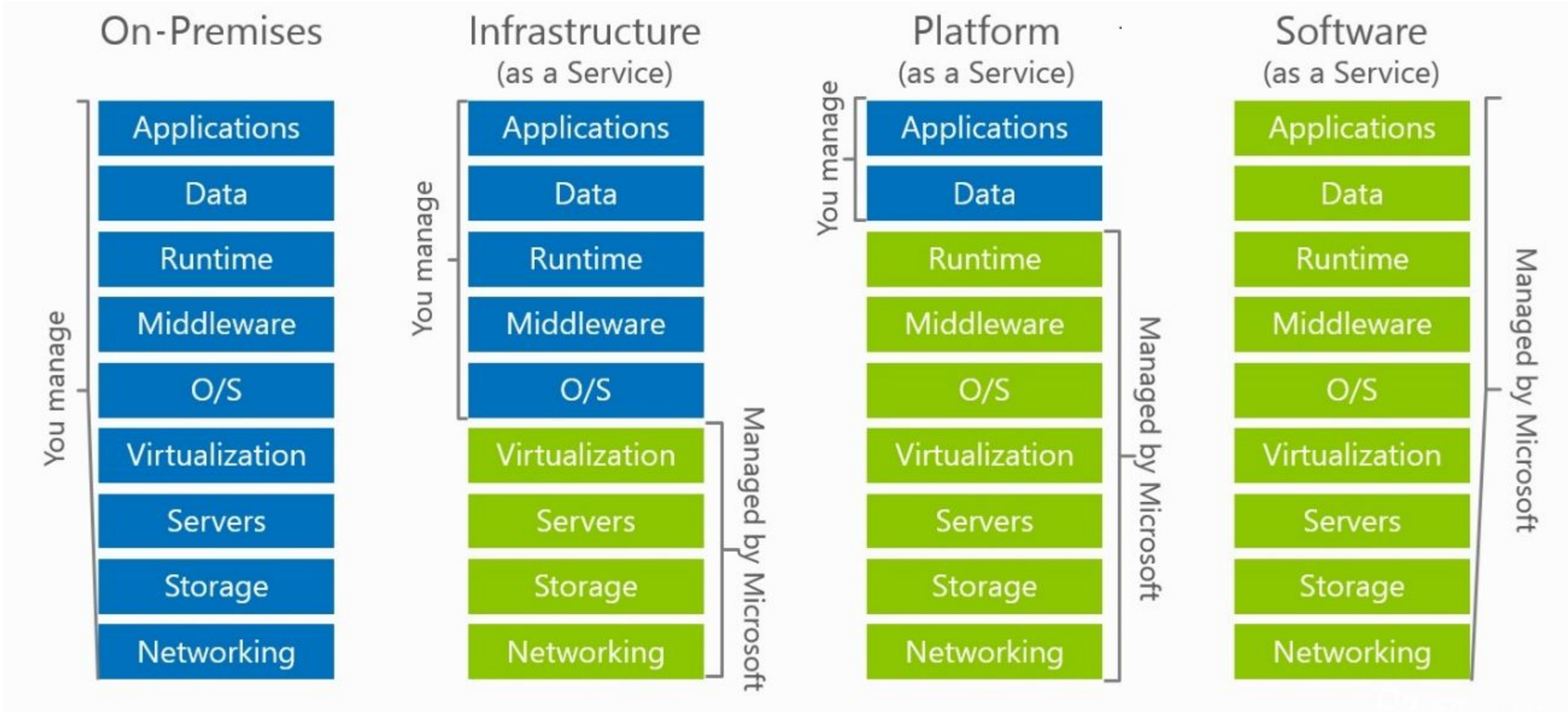
- “A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” – NIST definition

Service models

- IaaS: Infrastructure as a Service
  - Consumer can provision computing resources within provider's infrastructure upon which they can deploy and run arbitrary software, including OS and applications
- PaaS: Platform as a Service
  - Consumer can create custom applications using programming tools supported by the provider and deploy them onto the provider's cloud infrastructure
- SaaS: Software as a Service
  - Consumer uses provider’s applications running on provider's cloud infrastructure

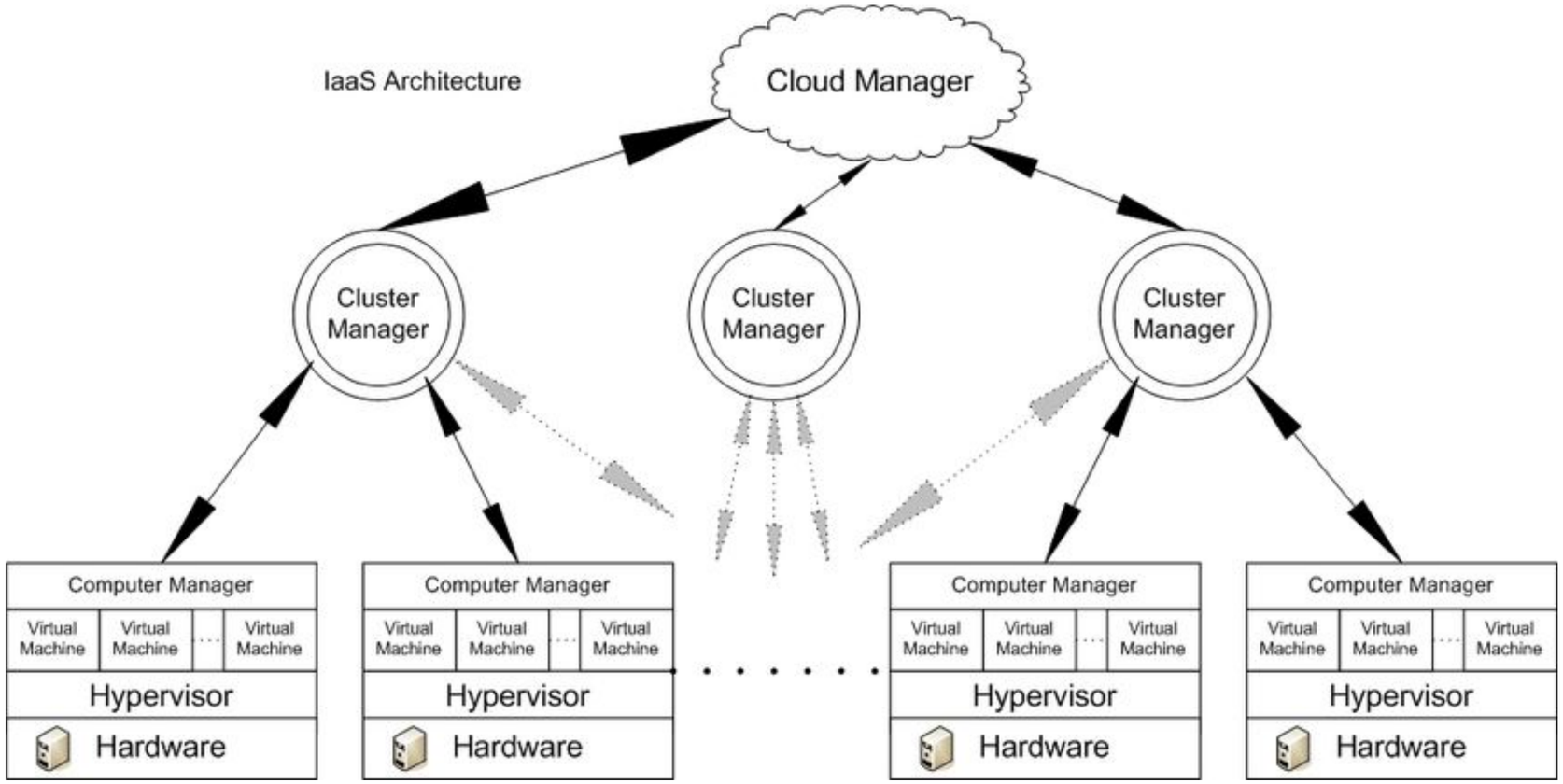
IaaS	PaaS	SaaS
• Virtual Machines • Virtual Networks	• Auto Elastic • Continuous Integration	• Built for Cloud • Uses PaaS

Service models

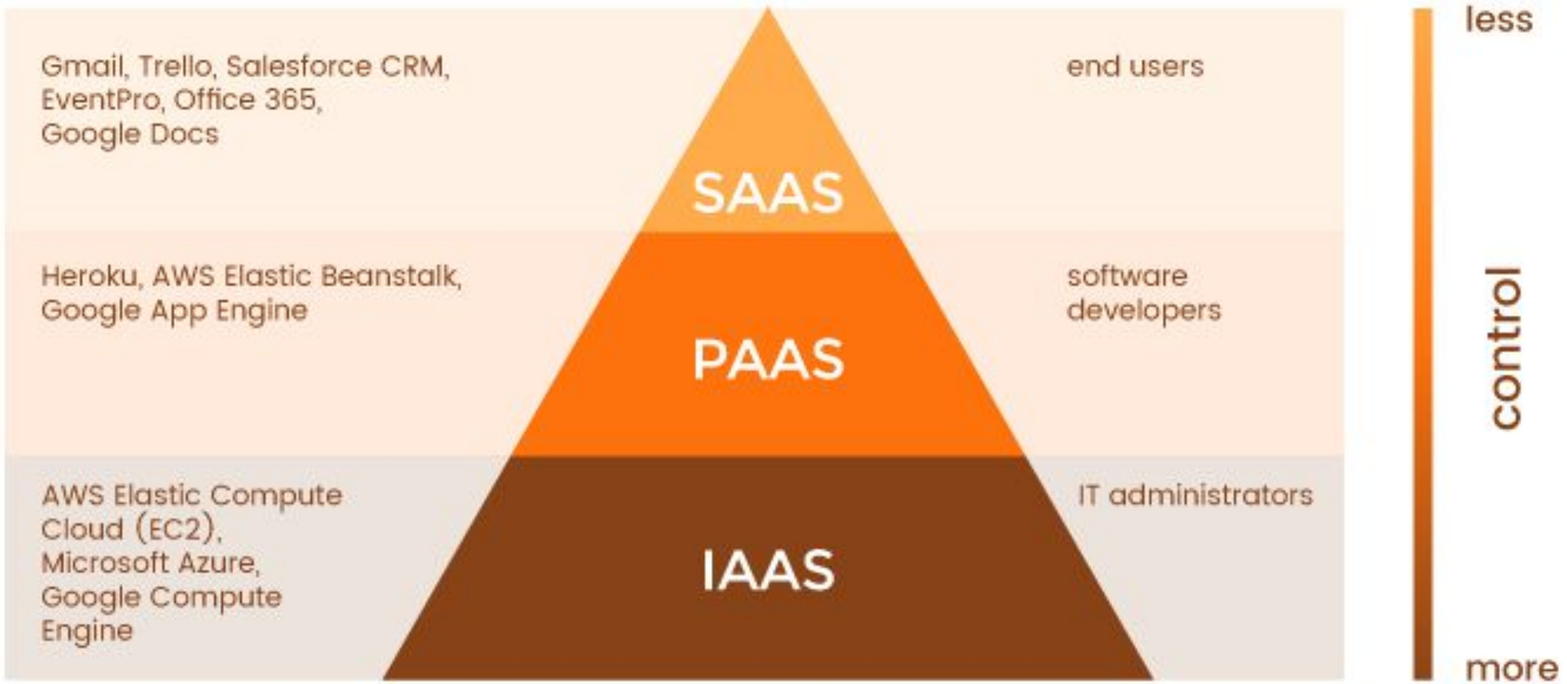


Credit: Microsoft Azure

IAAS cloud acrhitecture



Cloud providers



Credit: rubygarage

Further reading

- The Architecture of Virtual Machines

Thank You