Virtualization
In Cloud Computing

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Virtualization

Virtualization

- It is a technology to **run multiple same or different OSs on a single physical system** which are **completely isolated from each other** to.
  - Share underlying hardware resources*
    - **Ex:** Run both Windows and Linux on the same machine
- It is defined as **the abstraction over computing resources, such as**
  - storage, processing power, memory, and network, I/O, etc..
- It is the **process** by which **one computer behaves as many computers.**
- Virtualization used to improve ***IT throughput*** and ***costs*** by using physical resources as a pool from which virtual resources can be allocated.

- VMWare white paper, *Virtualization Overview*

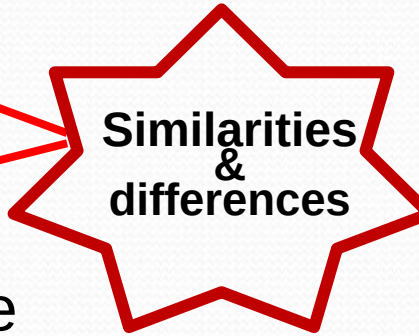
Virtualization

A technology to run multiple same or different isolated OSs on a single physical system by abstracting and partitioning its physical resource (storage, processing power, memory, and network or I/O) into multiple **V**irtual **M**achines (**VM**s) with different workloads to improve ***IT throughput*** and ***cost*** .

Dual Boot and Virtualization

Dual Boot System

- A computer system in which two operating systems are installed on the same hard drive, allowing either operating system to be loaded and given control.

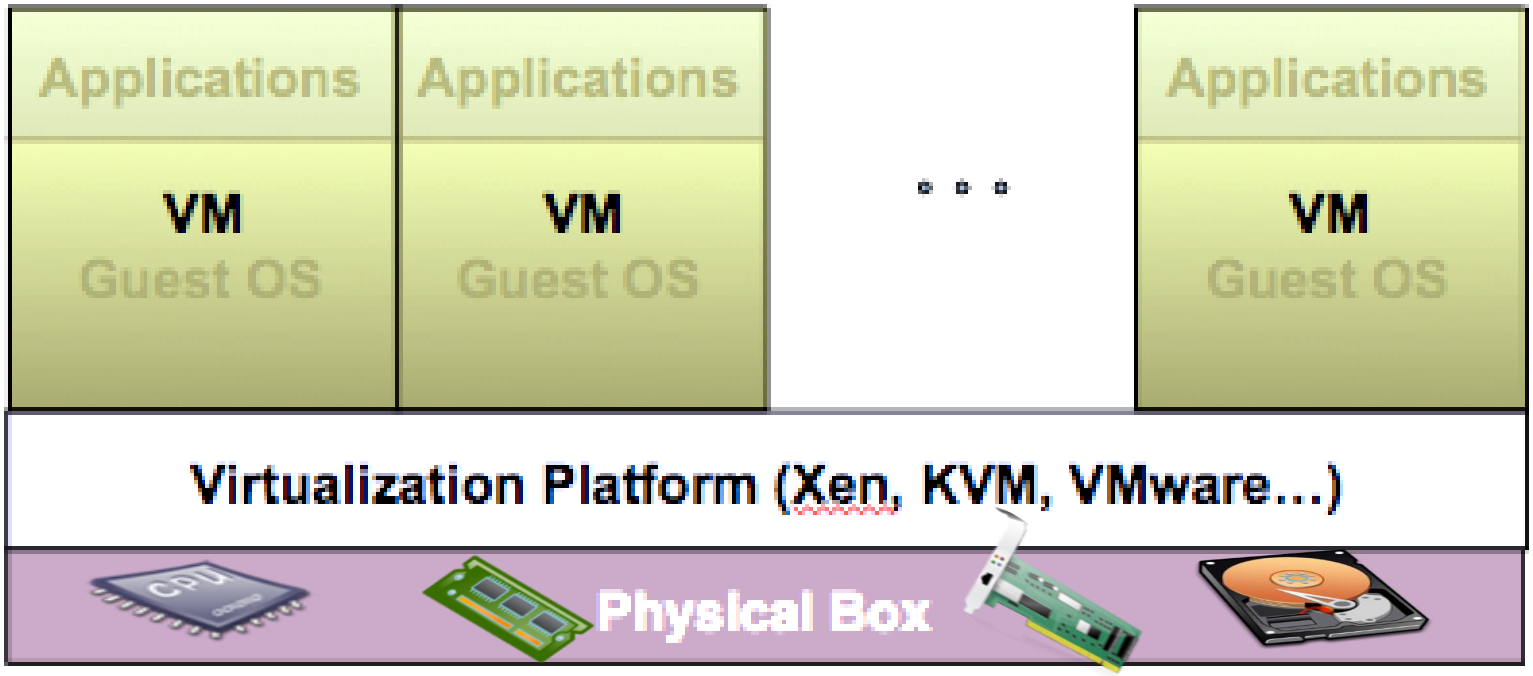


Virtualization System

- A system pretends to be two or more of the same system.
- Virtualization layer partitions physical resource of the underlying physical server into multiple **V**irtual **M**achines (**VM**s) with different workloads.

Virtualization Architecture

- A **V**irtual **M**achine (VM) is an isolated runtime environment (guest OS and applications)
- Multiple VMs can run on a single physical system



Virtualization Overview

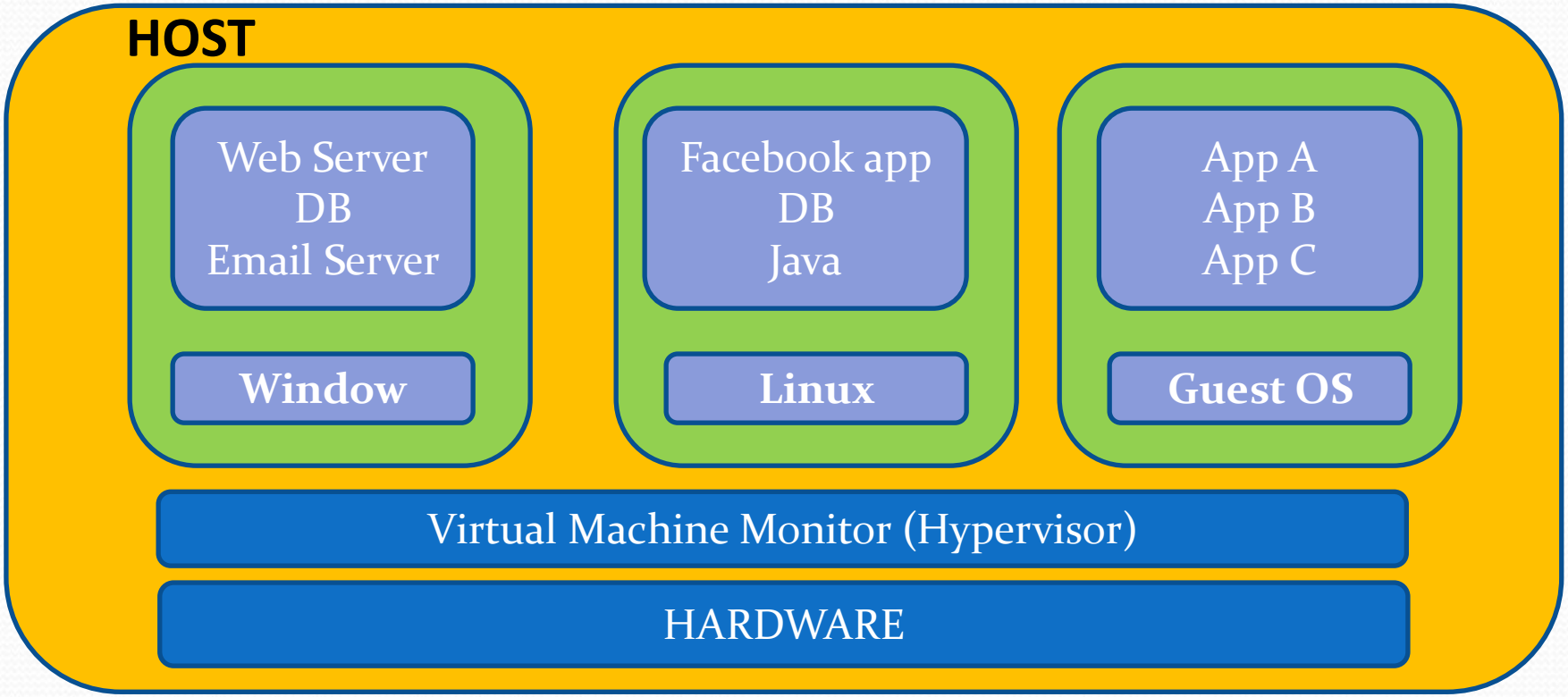
- VMs can be scaled ***up*** and ***down*** on demand with a high level of resources' abstraction.

- Virtualization enables:
  - High reliable, and agile deployment mechanisms, and management of services

- Virtualization provides on-demand ***cloning*** and ***live migration*** services which improve ***reliability***.

Virtualization

VIM: **V**irtualization **I**nfrastructure **M**anagement



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Virtualization Overview

Fundamental Idea :

- Abstract hardware of a single computer into several different execution environments
  - Similar to ***layered approach by*** creating virtual system (**virtual machine**, or **VM**) on which operating systems and/or applications can run
    - i.e., Virtualization creates VMs , and a VM can run both OS and application
- **Several Components**
  - **Host** – underlying hardware system
  - **Virtual Machine Manager (VMM)** or **hypervisor** – creates and runs virtual machines by providing interface that is ***identical*** to the host
  - **Guest** – process provided with virtual copy of the host
    - Usually an operating system
- Single physical machine can run multiple operating systems concurrently, each in its own virtual machine

Virtualization Overview

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  - Creating virtual system (**virtual machine**, or **VM**) on which operating systems and/or applications can run
    - (i.e., Virtualization creates VMs , and a VM can run both OS and application)
- Single physical machine can run ***multiple operating systems concurrently***, each in its ***own virtual machine***

Virtual Machine, Guest Operating System & VMM (Virtual Machine Monitor)

Virtual Machine (VM)

- A representation of a real machine using software that provides an operating environment which can run or **host** a **guest OS**
- A VM provides interface identical to underlying **bare hardware**
  - ✓ i.e. all devices, interrupts, memory, page tables etc.

Guest Operating System

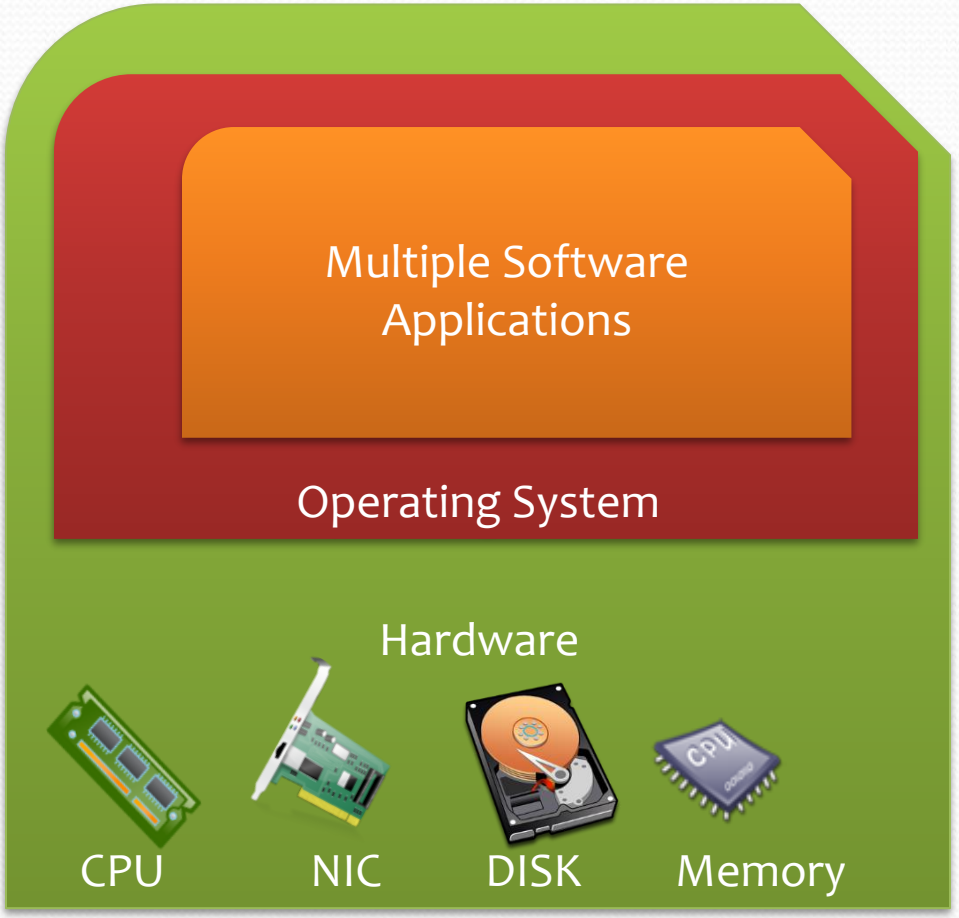
An operating system running in a virtual machine environment that would otherwise run directly on a separate physical system.

Virtualization Layer

Middleware between the underlying hardware and virtual machines represented in the system, also known as ***Vrtual Machine Monitor*** **(VMM)** or ***hypervisor***.

Server without Virtualization

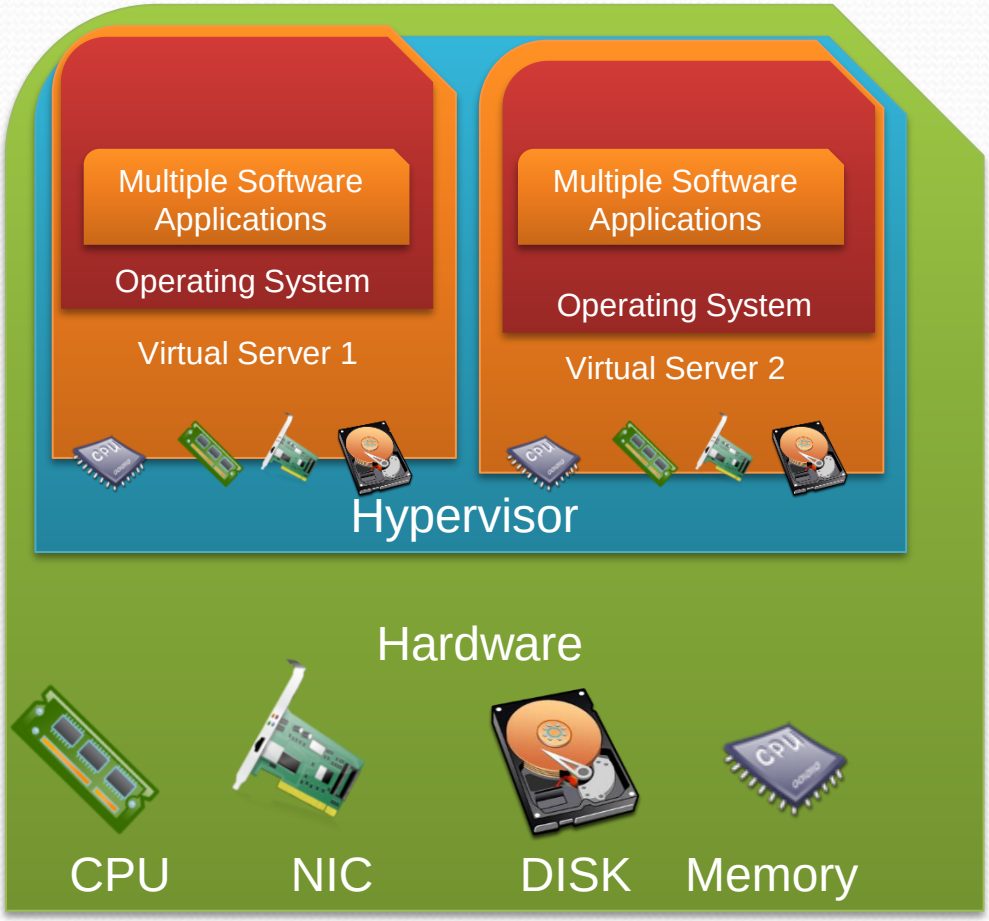
- Single OS can run at a time within a server.
- Software and hardware tightly coupled
  - Running multiple applications on same machine creates conflict
  - Under utilization of resources.
  - Inflexible and costly infrastructure.
  - Hardware changes require manual effort and access to the physical server.



(Courtesy of VMWare, 2008)

Server with Virtualization

- Hardware-independence of OS and applications
- Can run multiple OSs simultaneously.
- Each OS can have different hardware configuration.
  - Efficient utilization of hardware resources.
  - Each virtual machine is independent and can be provisioned any time .
  - Save electricity, initial cost to buy servers, space etc.
  - Easy to manage and monitor virtual machines centrally.



(Courtesy of VMWare, 2008)

Hypervisor

A hypervisor

- **V**irtual **M**achine **M**anager/**M**onitor (VMM), or virtualization manager,
- A software that allows multiple ***OSs*** (guest) to share ***a single hardware host***.
- Each guest OS appears to have the host's processor, memory, and other resources all to itself.
- However, the hypervisor is actually

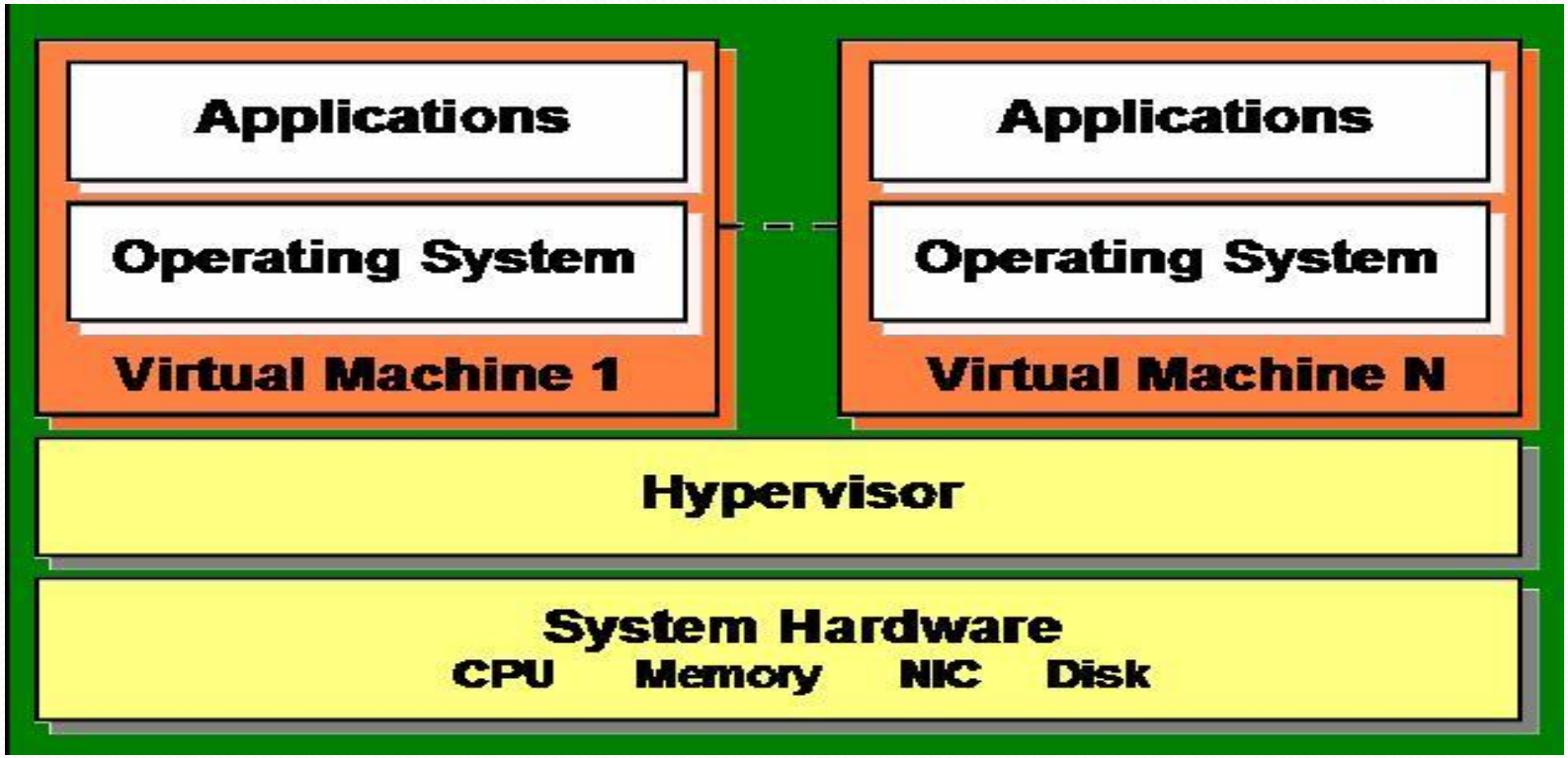
By

- ✓ ***Controlling*** the host processor and resources,
- ✓ ***Allocating*** what is needed to each operating system in turn, and
- ✓ ***Making sure*** that the guest operating systems (called **V**irtual **M**achines(VMs)) cannot disrupt each other.

Hypervisor

- Virtualization Software
  - ✓ VMWare, KVM, Xen, QEMU

The term ***hypervisor*** is a variant of ***supervisor***, a traditional term for the kernel of an operating system: the ***hypervisor*** is the ***supervisor*** of the ***supervisor***, with ***hyper-*** used as a stronger variant of ***super***

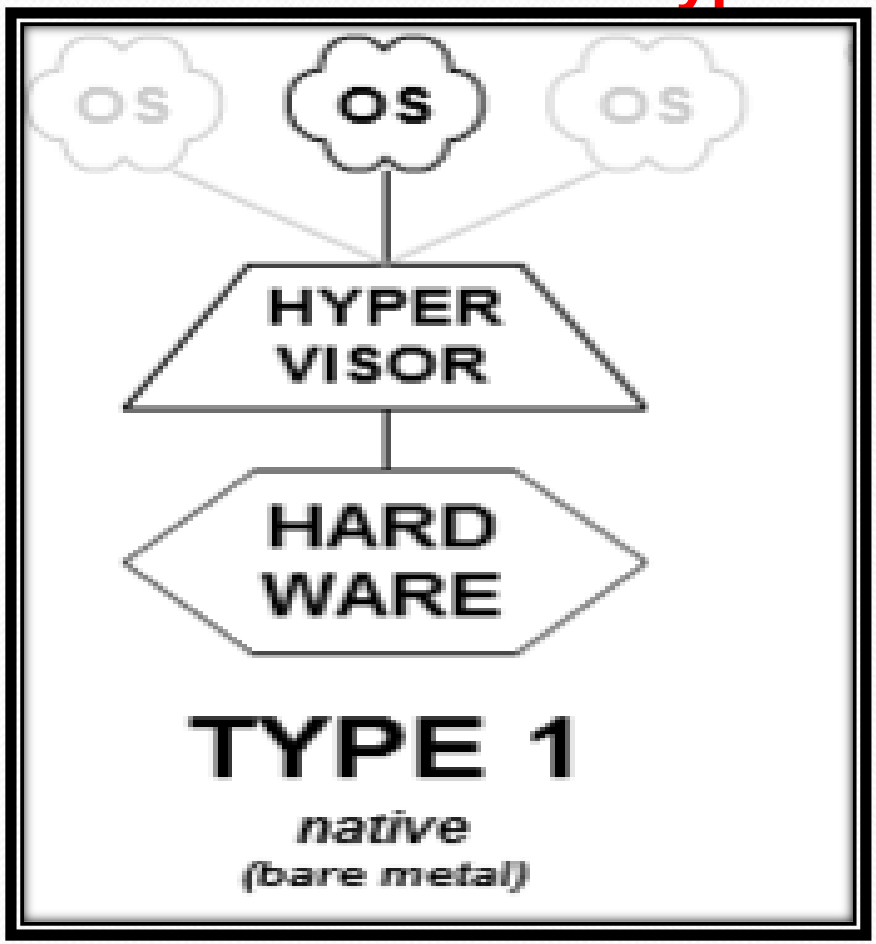


Hypervisor Types

Hypervisor Types

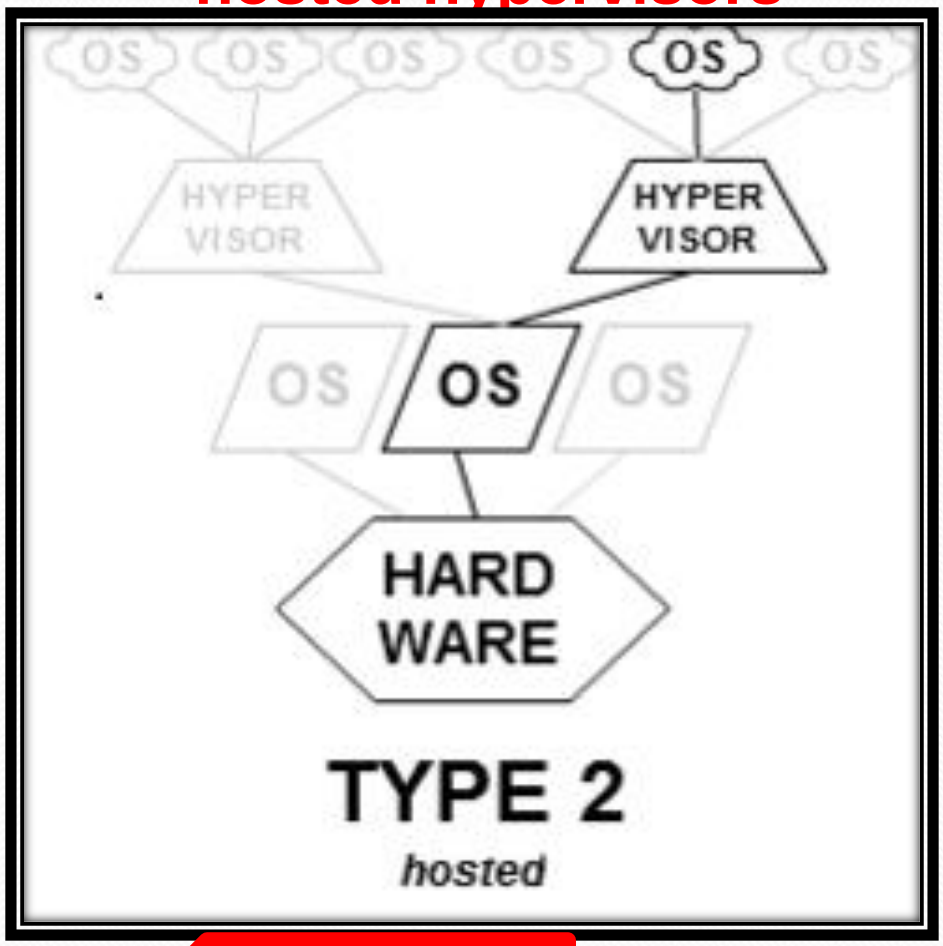
Type-1 (Full Virtualization)

native or bare-metal hypervisors



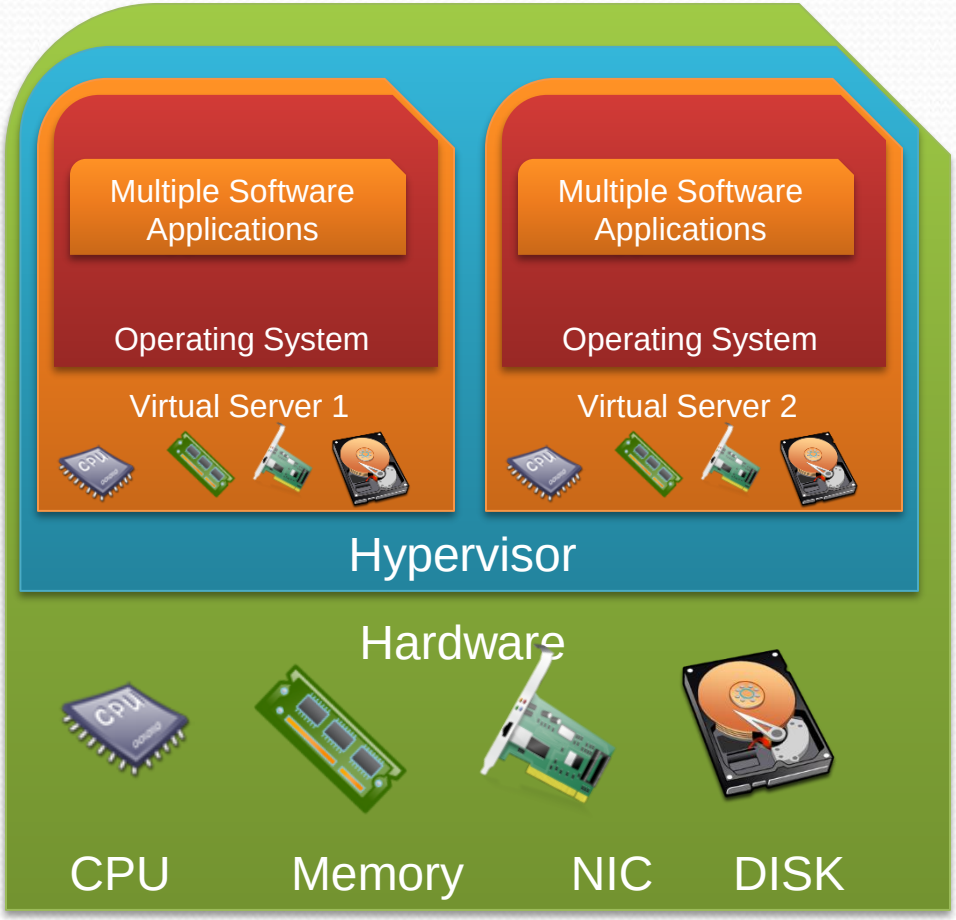
Type-2 (Para Virtualization)

hosted hypervisors



Full Virtualization

- It is called "***native or bare-metal hypervisors***"
- It directly sitting on top of the **bare hardware** devices
- Hypervisors Enable to run multi- unmodified ***guest operating system***
- Guest OS is not aware that it is being virtualized.
- **Note:** No ***host OS*** is used here



e.g.: VMware uses a combination of direct execution and binary translation techniques to achieve full virtualization of server systems.

Full Virtualization Concepts

A ***hypervisor*** is ***a software*** , ***firmware*** or ***hardware virtualization technique*** allowing multiple operating systems, called ***guests*** to run on a host machine. This is also called the ***Virtual Machine Monitor*** (***VMM***).

The Existing Role of the Operating System

Virtualization is Based on Insertion a ***Hypervisor*** *on Top of Hardware*

Full Virtualization

- A certain kind of virtual machine environment that ***provides a complete simulation of the underlying hardware.***
- The result is a system in which ***all software (including all OS's) capable of executing on the raw (bare) hardware***

Full virtualization has proven highly successful

- **Sharing a computer system among multiple users**
- **Isolating users from each other (and from the control program) and**
- **Emulating new hardware to achieve:**
  - ✓ **Improved reliability,**
  - ✓ **Security, and**
  - ✓ **Productivity.**

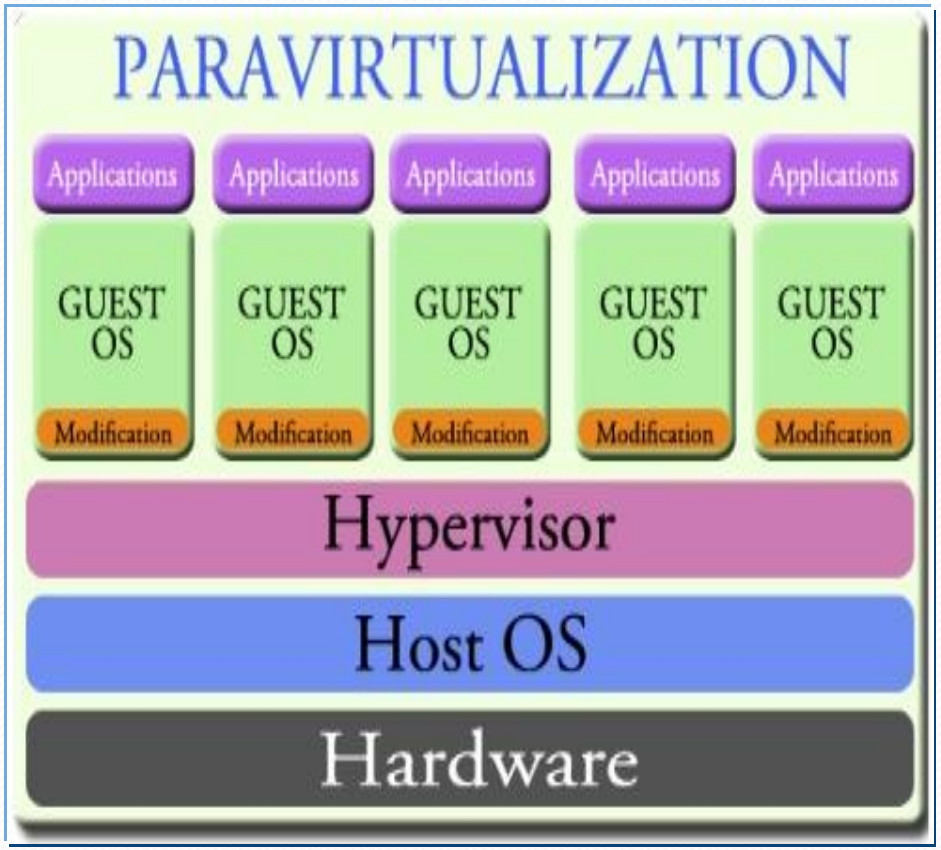
Full Virtualization -- Challenges

1) Security issues -- Interception
2) Simulation of privileged operations -- I/O instructions
3) The effects of every operation performed within a given virtual machine must be kept within that virtual machine – virtual operations cannot be allowed to alter the state of any other virtual machine, the control program, or the hardware (Encapsulation).
4) Some machine instructions of guest virtual machine can be executed directly by the hardware,
   - E.g., memory locations and arithmetic registers.
5) Some instructions of guest virtual machine cannot be allowed to execute directly; instead they must be trapped and simulated.
   - Such instructions either access or affect state information that is outside the virtual machine.
6) Some hardware is not easy to be used for full virtualization, **e.g.**, x86

Para Virtualization

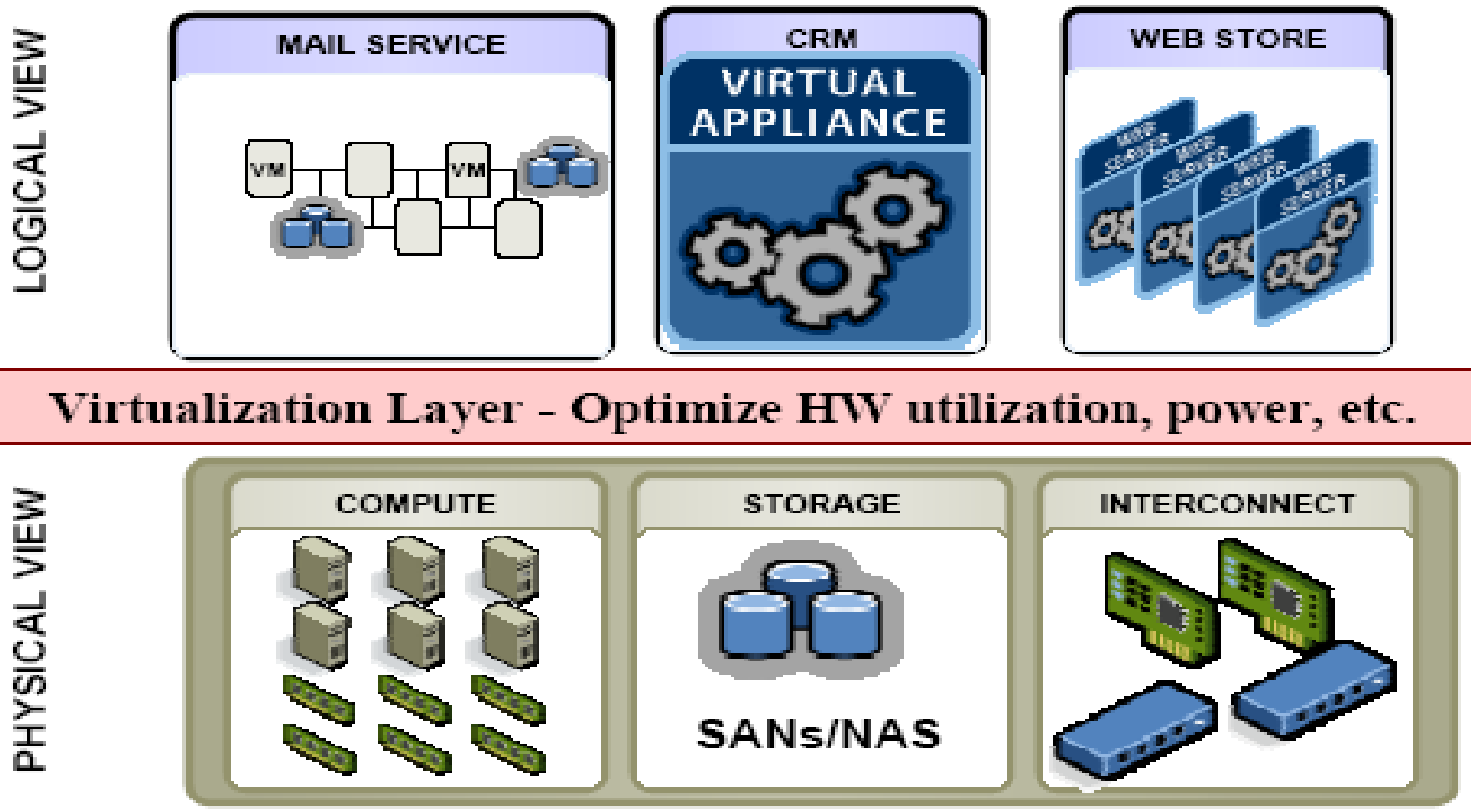
Full Vrs. Para

- These hypervisors run on a conventional operating system (**Host OS**) just as other computer programs do.
- A **Guest OS** runs as a process on the **Host OS**.
- Para hypervisors abstract **Guest OSs** from the **Host OS**.
  - By explicitly ***modifying*** **Guest OS.** So, that it is aware of being virtualized to allow near native performance.
- Improves performance.
- Lower overhead.



Ex: **Xen** -- modified Linux kernel and a version of Windows XP

User's view of virtualization



(Courtesy of VMWare, 2008)

Benefits of Virtualization

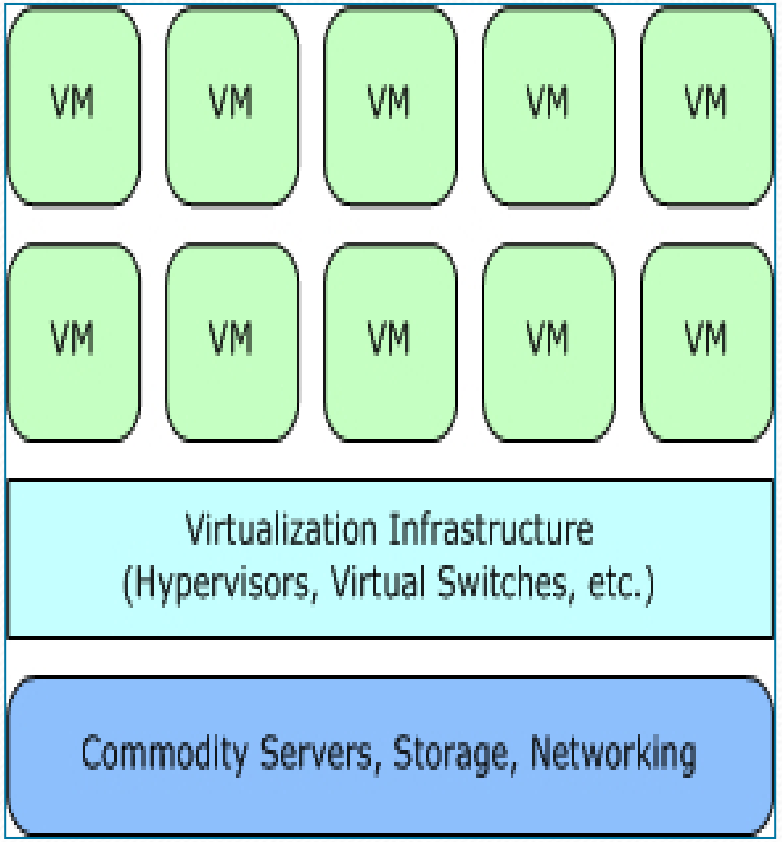
- ***Consolidation*:** Operate different OS's and applications on one single server
- ***Sharing of resources*:** helps cost reduction
- ***Isolation***: Virtual machines are isolated from each other as if they are physically separated
- ***Encapsulation*:** Virtual machines encapsulate a complete computing environment
- ***Hardware Independence*:** Virtual machines run independently of underlying hardware
- ***Portability*:** Virtual machines can be migrated between different hosts.

Virtualization in Cloud Computing

Virtualization in Cloud Computing

Cloud computing takes virtualization one step further:

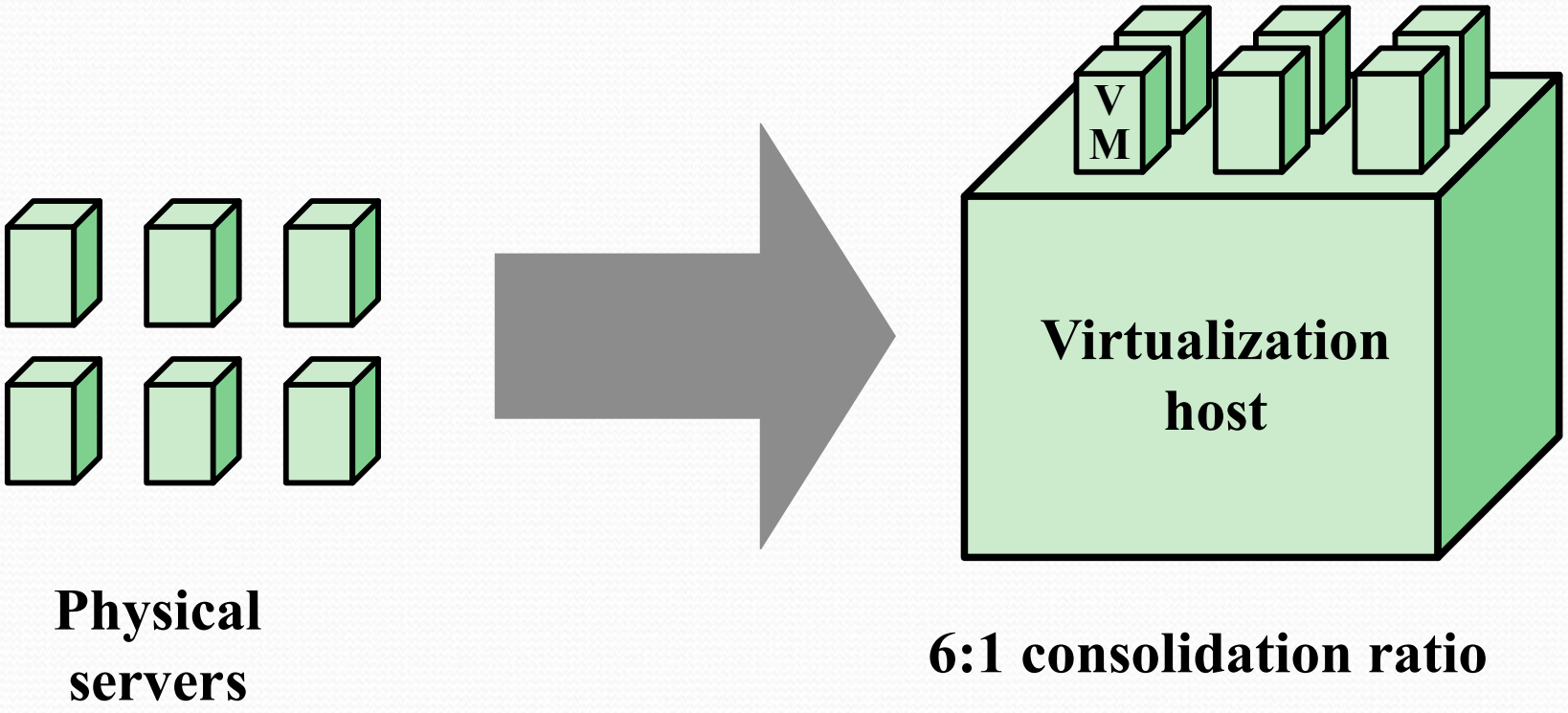
- You don't need to own hardware
- Resources are rented as needed from a cloud
- Various providers allow creating virtual servers:
  - Choose the OS and software each instance will have
  - The chosen OS will run on a large server farm
  - Can instantiate more virtual servers or shut down existing ones within minutes
- You get billed only for what you used



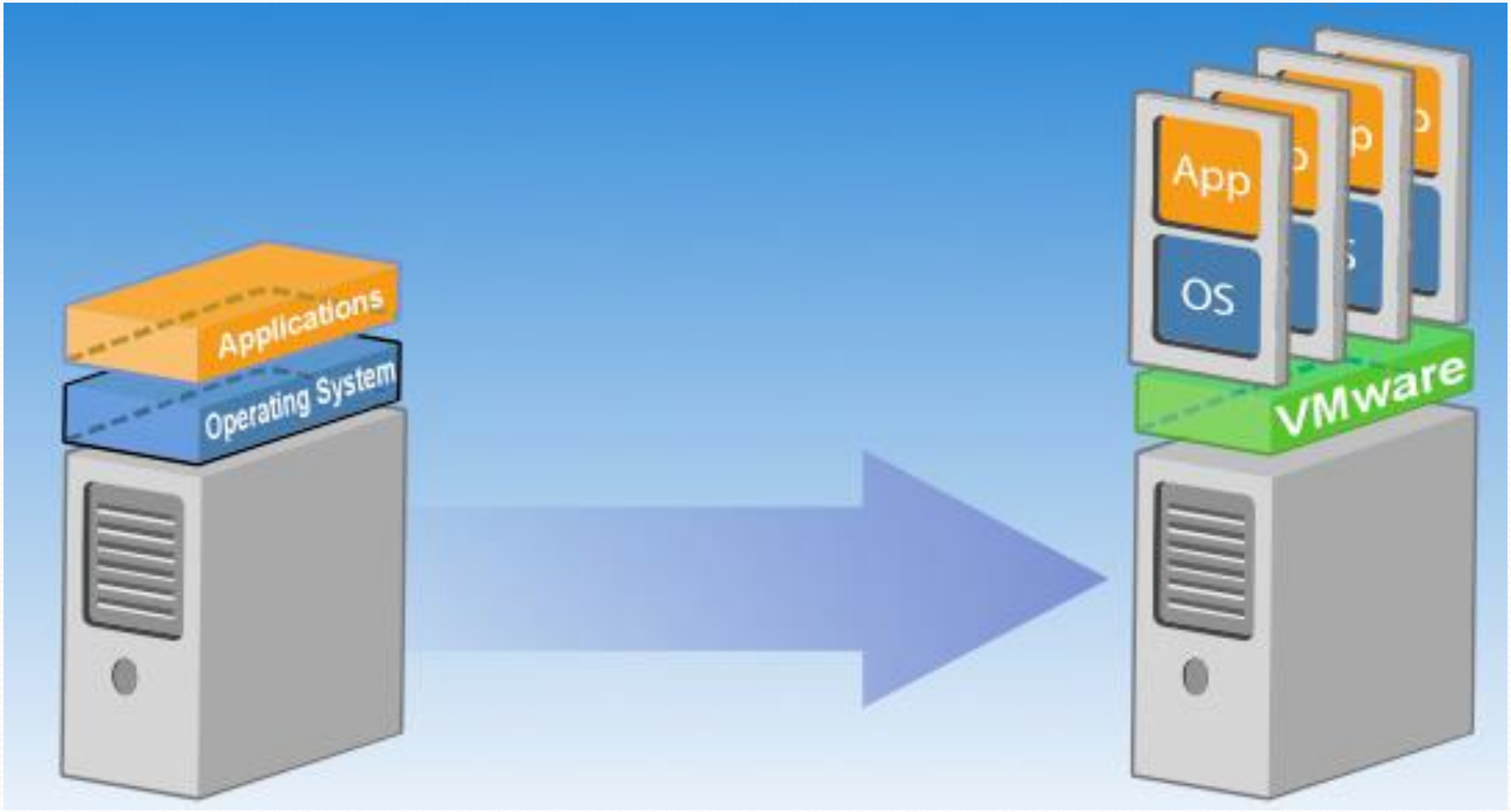
Virtualization Over Cloud Computing

- Benefits of virtualization over cloud computing:
  - ✓ Reduce capital expenses (CAP-EX), and
  - ✓ Reduce maintenance and operation expenses (OP-EX) through server consolidation,
  - ✓ Reduce physical space needed in data centers.
  - ✓ Resource Management, Migration, Maintainability, High availability and Fault tolerance are other benefits.
- Virtualization is implemented using ***hypervisors***.

Virtual Machine Consolidation

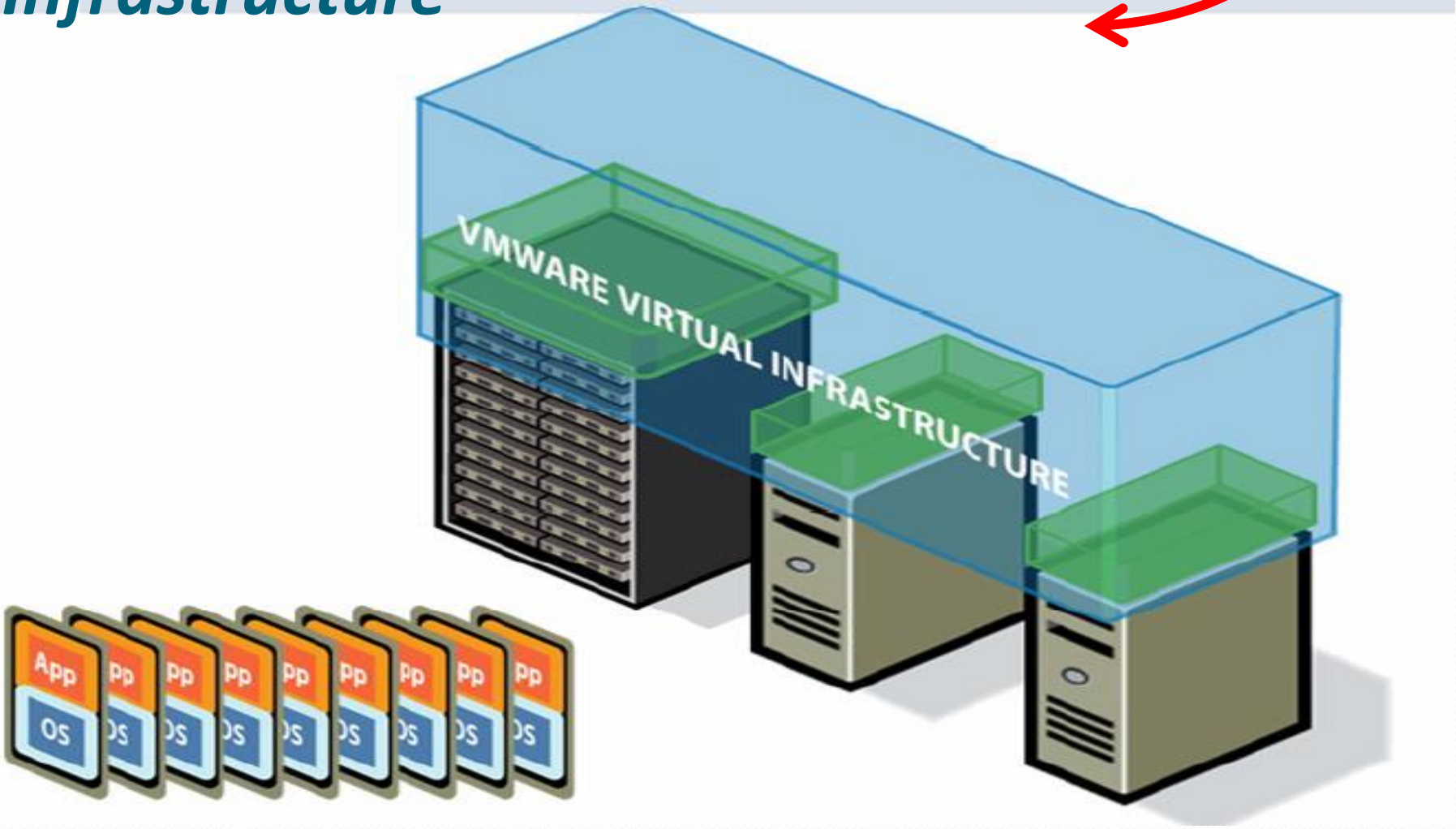


******(cOmmon)Virtualization Allows Transformation of a Server for Multiple Applications/OS

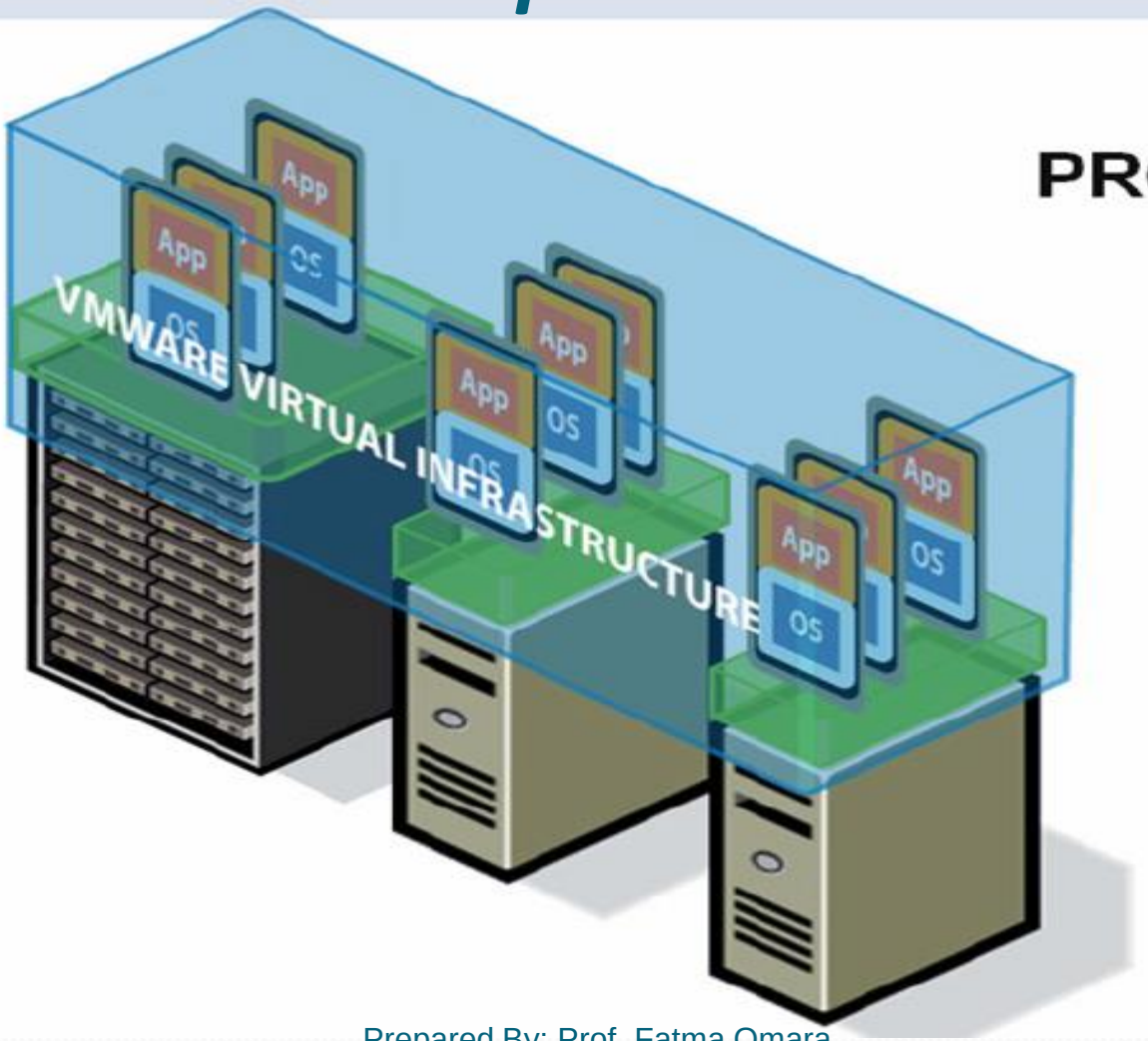


Virtual Machines Run on Any Hardware Configuration

Virtual Machines Can Run on a Shared Infrastructure

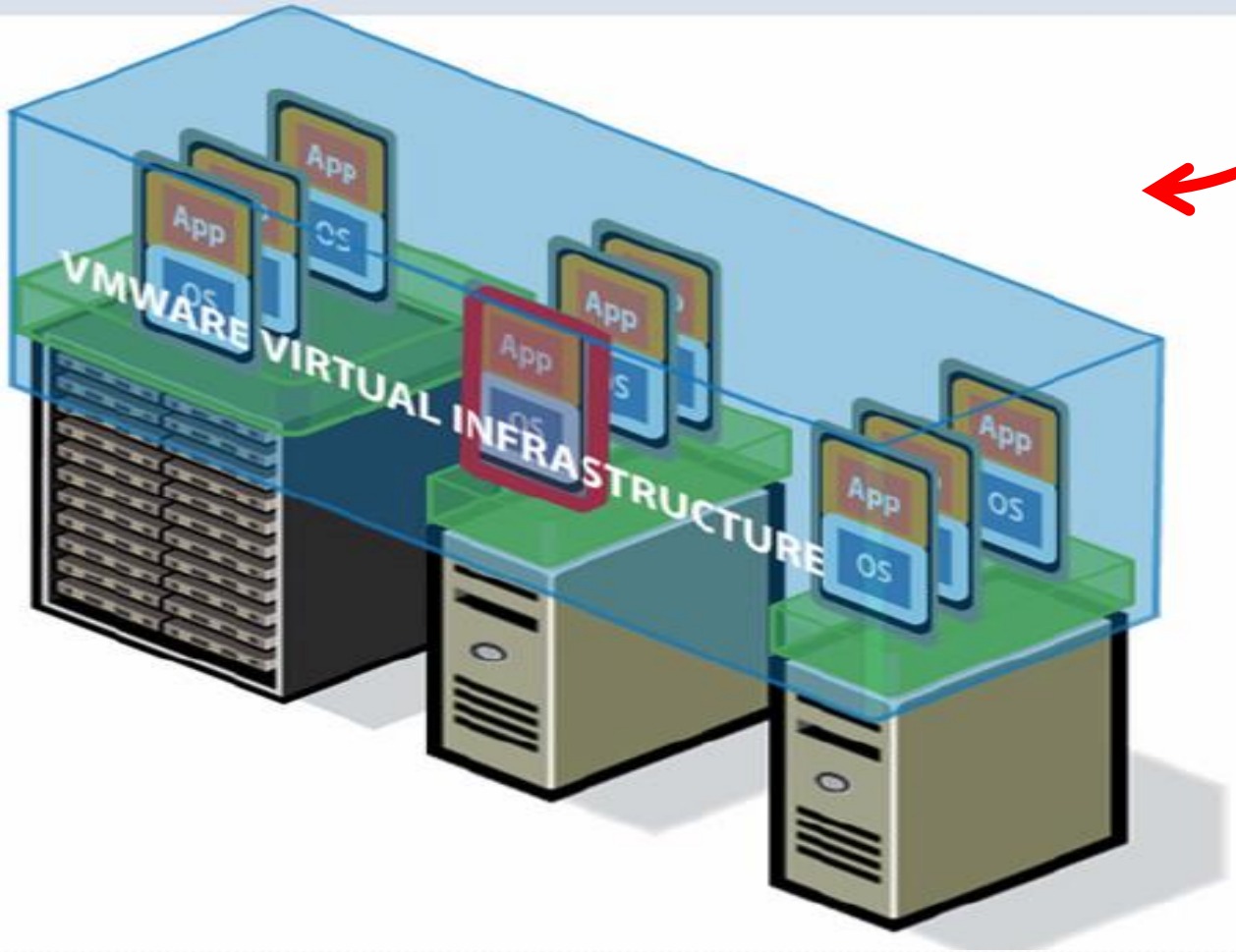


A Single Software Can Span Different Hardware Components

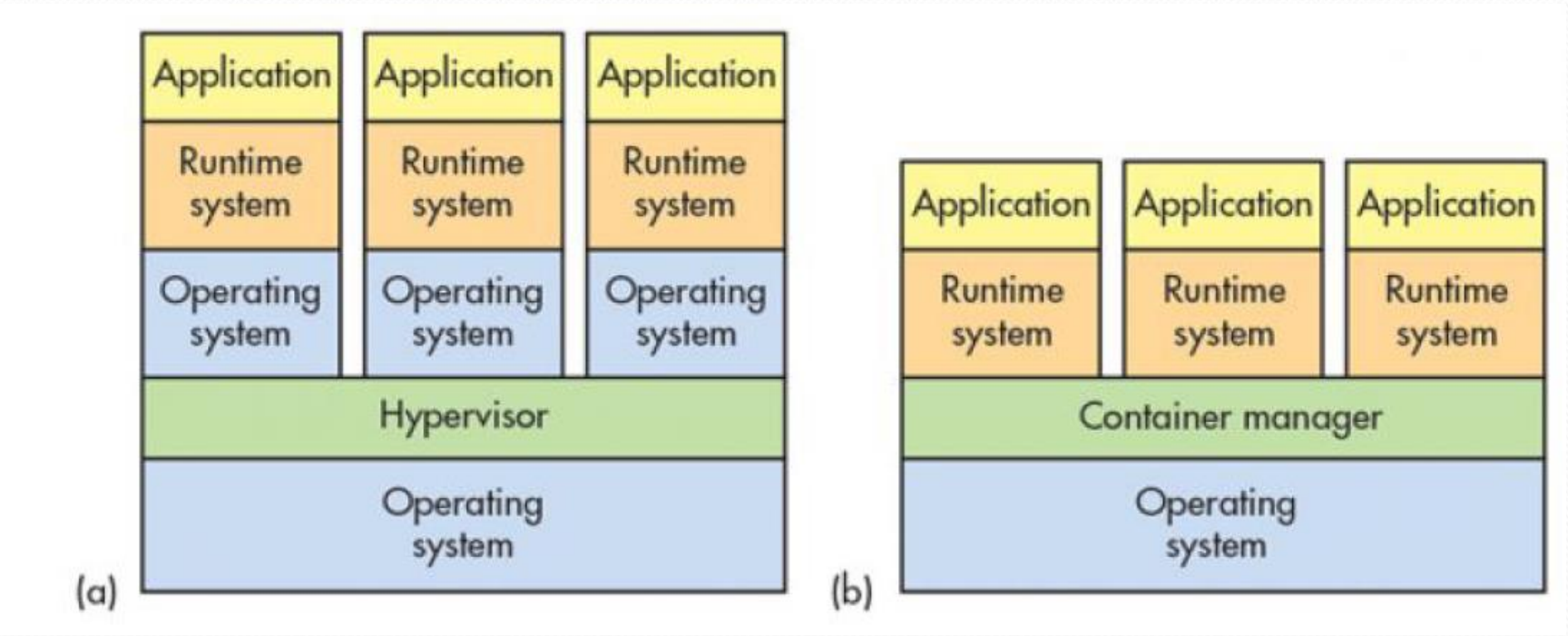


PROVISIONING

Virtualization Allows Moving Applications Without Service Interruption



Virtualization vs Containerization



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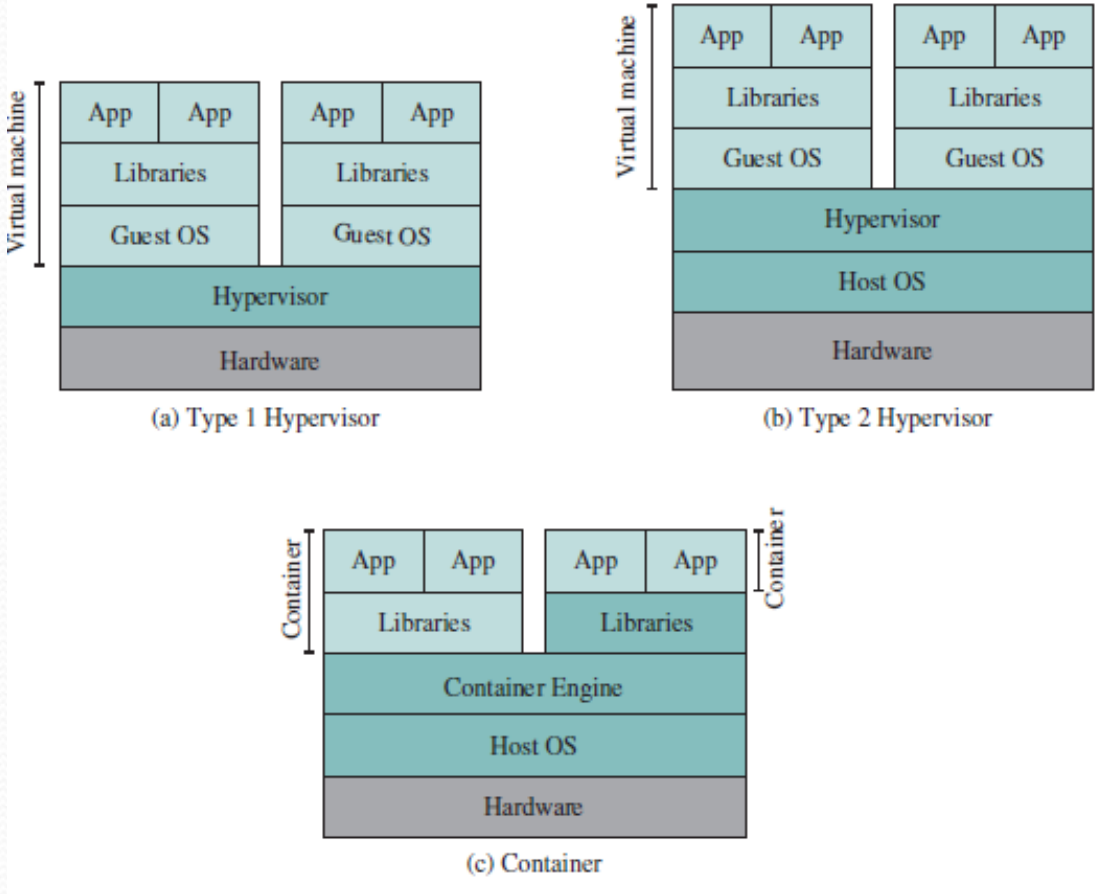
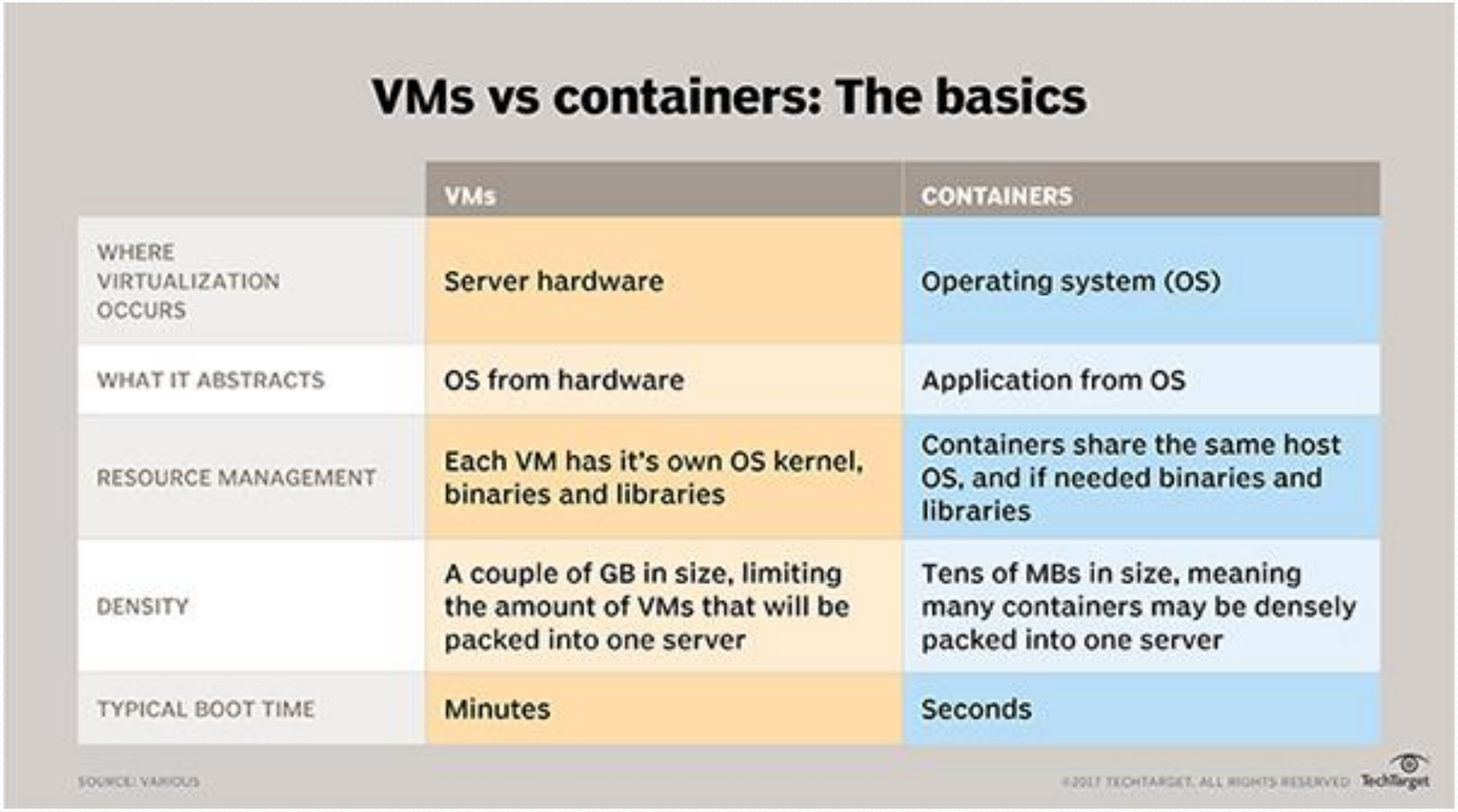


Virtualization vs Containerization

- **Virtual machines** (VMs) are an abstraction of physical hardware turning one server into many servers.
  - The hypervisor allows multiple VMs to run on a single machine.

- **Containers** are an abstraction at the app layer that packages code and dependencies together.
  - Multiple containers can run on the same machine and share the OS kernel with other containers, each running as isolated processes in user space.

Virtualization vs Containerization



VMs vs containers: The basics

	VMs	CONTAINERS
WHERE VIRTUALIZATION OCCURS	Server hardware	Operating system (OS)
WHAT IT ABSTRACTS	OS from hardware	Application from OS
RESOURCE MANAGEMENT	Each VM has it's own OS kernel, binaries and libraries	Containers share the same host OS, and if needed binaries and libraries
DENSITY	A couple of GB in size, limiting the amount of VMs that will be packed into one server	Tens of MBs in size, meaning many containers may be densely packed into one server
TYPICAL BOOT TIME	Minutes	Seconds

SOURCE: VARIOUS

Combining VMs and Containers