VIRTUALIZATION TECHNIQUES

UNIT 1

INTRODUCTION TO VIRTUALIZATION

VIRTUALIZATION

*__cost-effective, hardware-reducing, and energy-saving techniques used by cloud providers is Virtualization__. Virtualization allows sharing of a single physical instance of a resource or an application among multiple customers and organizations at one time.

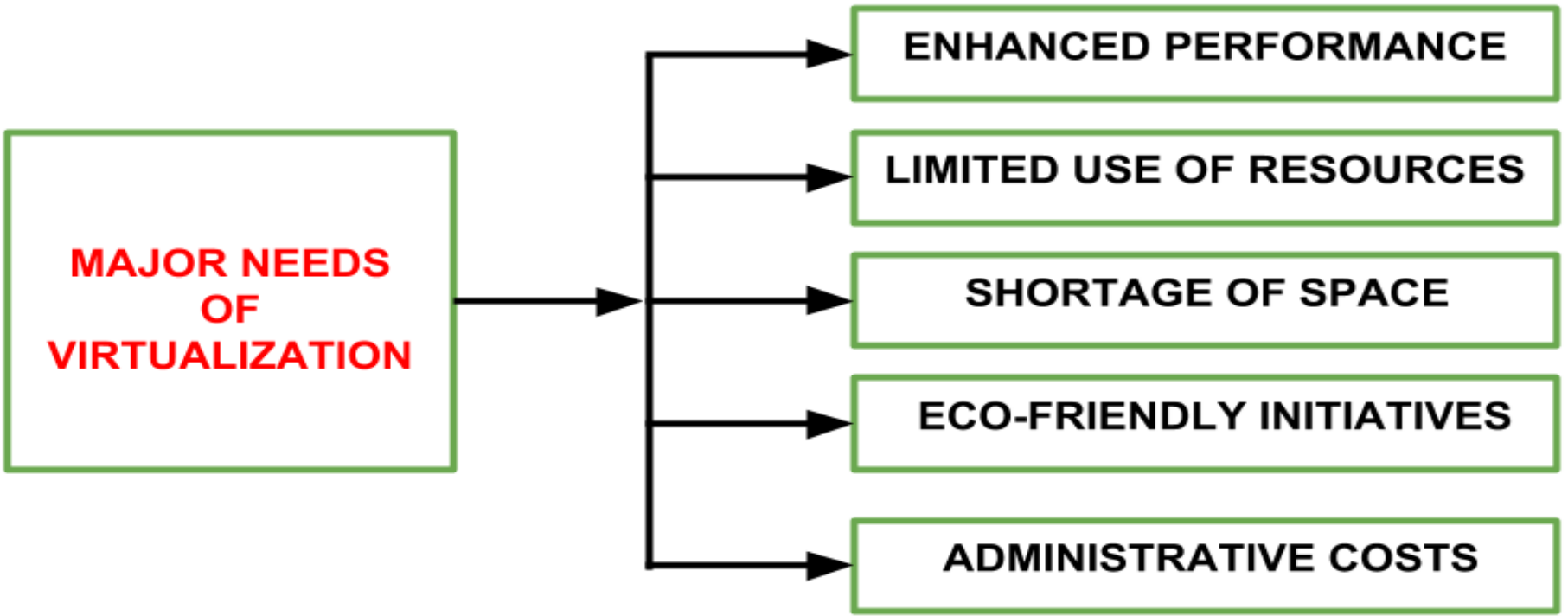
*It does this by assigning a logical name to physical storage and providing a pointer to that physical resource on demand.

*The term virtualization is often synonymous with hardware virtualization, which plays a fundamental role in efficiently delivering Infrastructure-as-a-Service (IaaS) solutions for cloud computing. Moreover, virtualization technologies provide a virtual environment for not only executing applications but also for **storage, memory, and networking.**

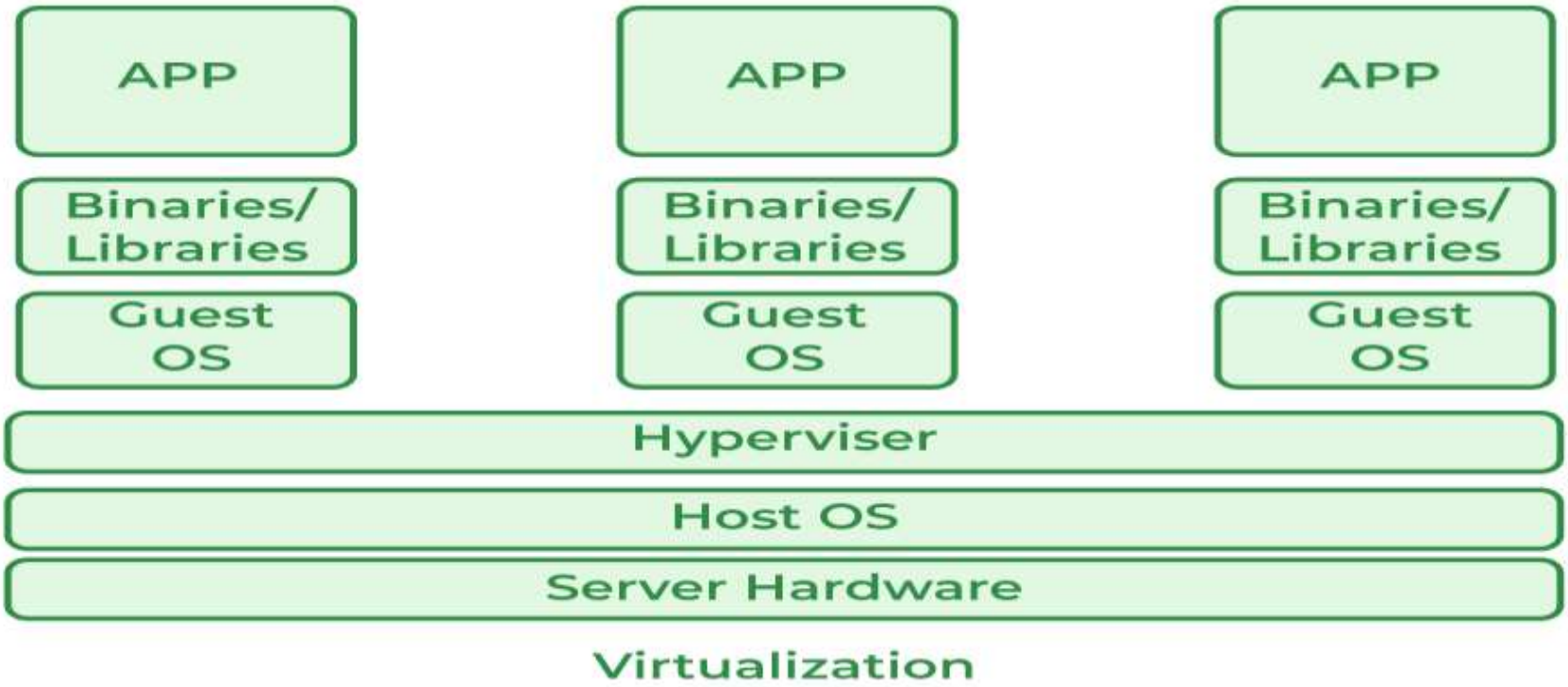
NEED OF VIRTUALIZATION

.Cost Savings

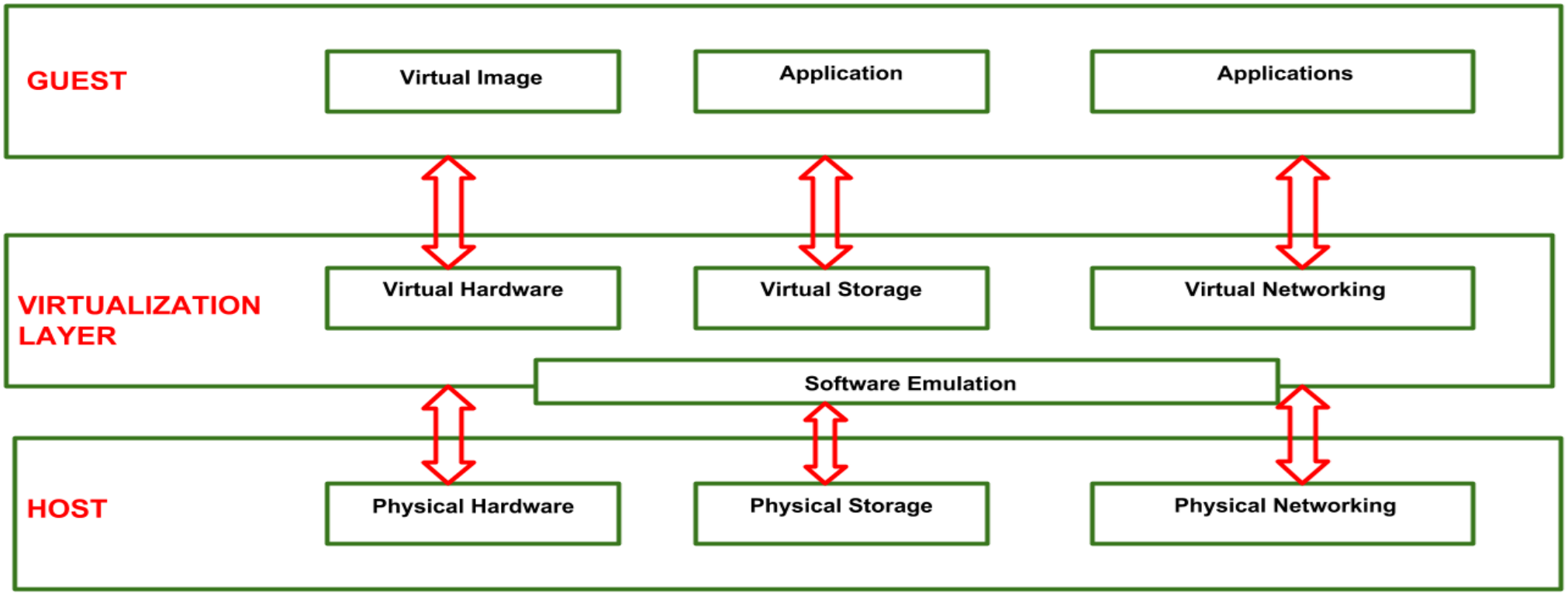
- Resource Utilization
- Scalability
- Isolation
- Improved Management
- Flexibility
- Disaster Management


MAJOR NEEDS OF VIRTUALIZATION
ENHANCED PERFORMANCE
LIMITED USE OF RESOURCES
SHORTAGE OF SPACE
ECO-FRIENDLY INITIATIVES
ADMINISTRATIVE COSTS

VIRTUALIZATION



REFERENCE MODEL



GUEST:

The guest represents the system component that interacts with the virtualization layer rather than with the host, as would normally happ

2. **HOST:**

The host represents the original environment where the guest is supposed to be managed. Each guest runs on the host using shared reso

3. **VIRTUALIZATION LAYER:**

The virtualization layer is responsible for recreating the same or a different environment where the guest will operate. It is an additional

APPLICATION IN CLOUD

*Virtualization has a prominent impact on Cloud Computing. In the case of cloud computing, users store data in the cloud, but with the help of Virtualization, users have the extra benefit of sharing the infrastructure.

*Cloud Vendors take care of the required physical resources, but these cloud providers charge a huge amount for these services which impacts every user or organization.

*Virtualization helps Users or Organisations in maintaining those services which are required by a company through external (third-party) people, which helps in reducing costs to the company. This is the way through which Virtualization works in Cloud Computing.

CHARACTERSTICS

*__Increased Security:__ The ability to control the execution of a guest program in a completely transparent manner opens new possibilities for delivering a secure, controlled execution environment. All the operations of the guest programs are generally performed against the virtual machine, which then translates and applies them to the host programs.

*__Managed Execution__: In particular, sharing, aggregation, emulation, and isolation are the most relevant features.

*__Sharing__: Virtualization allows the creation of a separate computing environment within the same host.

*__Aggregation__: It is possible to share physical resources among several guests, but virtualization also allows aggregation, which is the opposite process.

RESOURCE MANAGEMENT

***Reduced equipment costs :**Virtualization allows multiple virtual machines to run on a single physical server, significantly reducing the need to purchase additional hardware.

For example, you can reduce hardware costs by >70% if you reduce the number of servers from 100 to 25.

***Optimizing energy consumption:** Reducing the number of large and energy-intensive physical servers leads to a significant reduction in energy consumption. This also helps reduce environmental impact.

***Reduced maintenance costs:**Reducing the physical server fleet means reducing the need for regular maintenance and spare parts. Organize a policy of "less hardware - less problems!" .

SCALABILITY AND FLEXIBILITY

***Dynamic resource allocation:**

Virtualization systems, such as VMware vSphere or Microsoft Hyper-V, allow you to dynamically change the allocated resources (CPU, memory, storage) for virtual machines without physical intervention, which helps to quickly scale applications.

***Workload isolation and management:**

For example, if a healthcare company implements desktop virtualization, it will help protect sensitive patient data and simplify employee desktop management.

HYPERVISOR

A hypervisor is a software that you can use to run multiple virtual machines on a single physical machine.

- Every virtual machine has its own operating system and applications. The hypervisor allocates the underlying physical computing resources such as CPU and memory to individual virtual machines as required.
- Thus, it supports the optimal use of physical IT infrastructure.

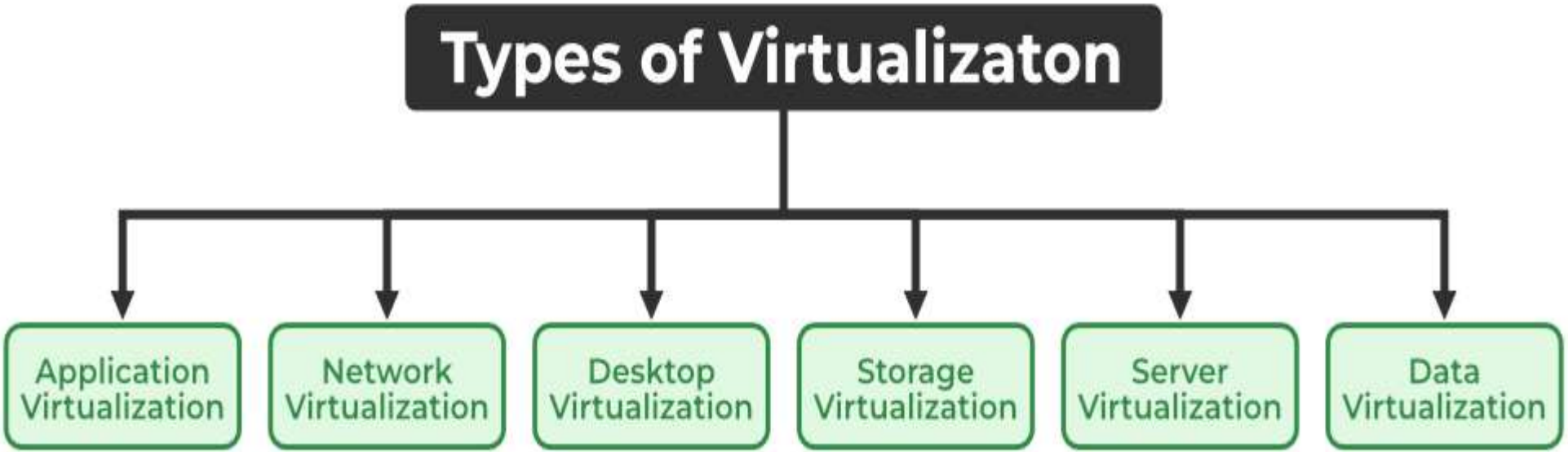
BENEFITS

***Hardware independence:**A hypervisor abstracts the host's hardware from the operating software environment. IT administrators can configure, deploy, and manage software applications without being constrained to a specific hardware setup. For example,one can run macOS on a virtual machine instead of iMac computers.

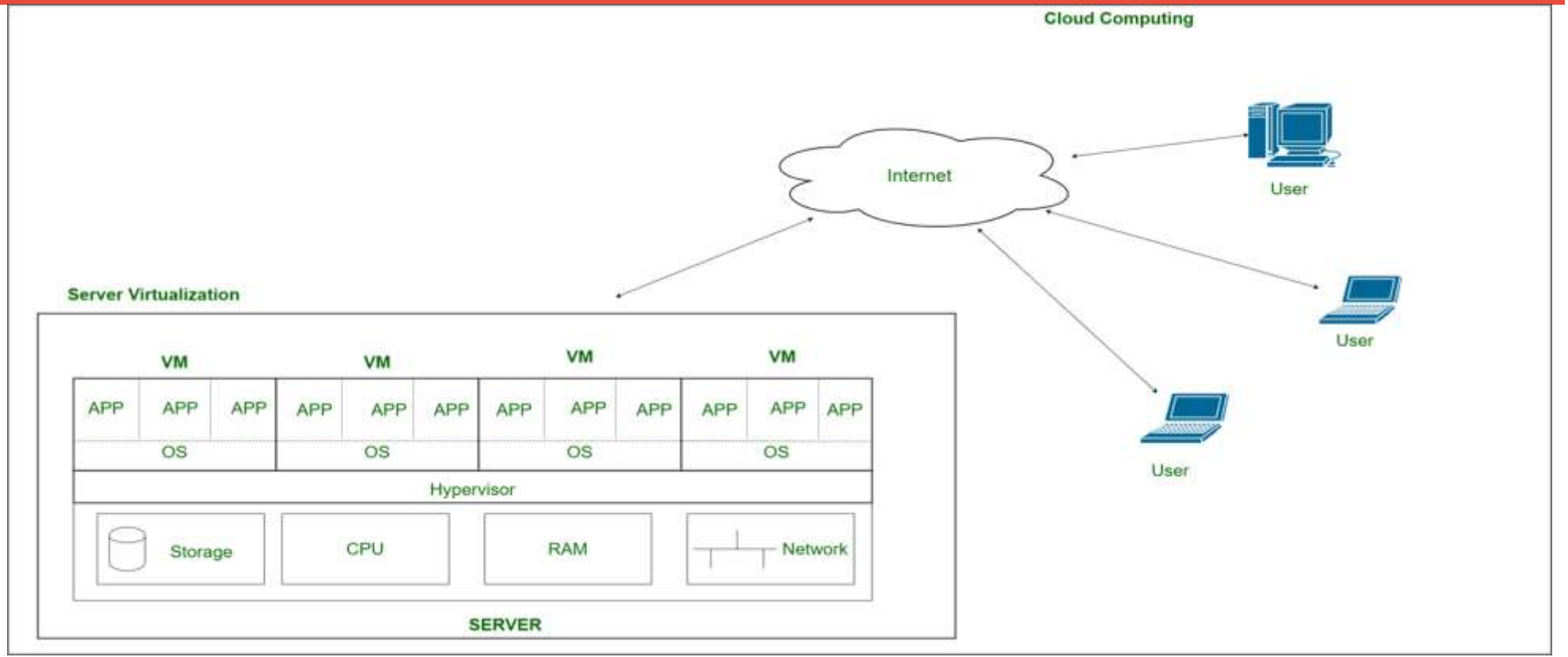
***Efficiency :**Hypervisors make setting up a server operating system more efficient. Manually installing the operating system and related software components is a time-consuming process. Instead,one can configure the hypervisor to immediately create your virtual environment.

***Scalability:**Organizations use hypervisors to maximize resource usage on physical computers. Instead of using separate machines for different workloads, hypervisors create multiple virtual computers to run several workloads on a single machine. This translates to faster scalability and reduced hardware expenditure

TYPES


Types of Virtualizaton
Application Virtualization
Network Virtualization
Desktop Virtualization
Storage Virtualization
Server Virtualization
Data Virtualization

SERVER VIRTUALIZATION



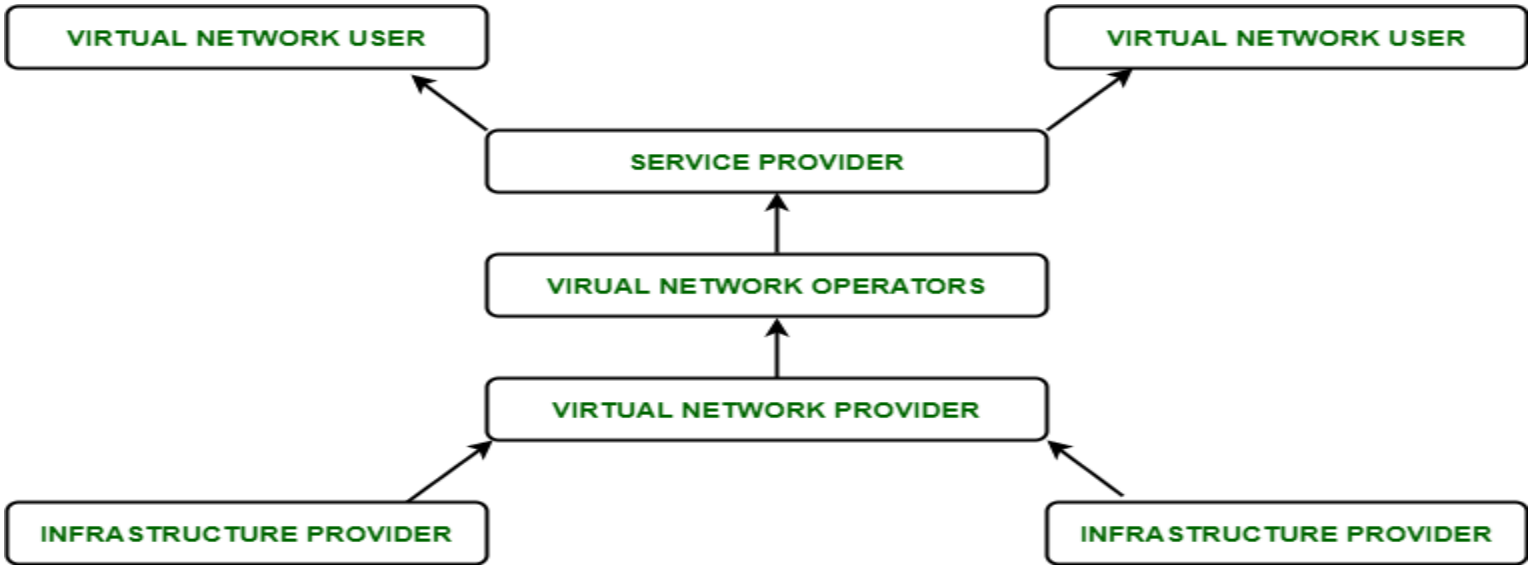
- **Server virtualization:** To implement Server Virtualization, hypervisor is installed on server which manages and allocates host hardware requirements to each virtual machine. This hypervisor sits over server hardware and regulates resources of each VM. A user can increase or decrease resources or can delete entire VM as per his/her need. This servers with VM created on them is called server virtualization and concept of **controlling this VM by users through internet is called Cloud Computing**.

- **Storage virtualization:**Storage virtualization is functional RAID(Redundant array of independent disks) levels and controllers are made desirable, which is an important component of storage servers. Applications and operating systems on the device can directly access the discs for writing.

- Local storage is configured by the controllers in RAID groups, and the operating system sees the storage based on the configuration. The controller, however, is in charge of figuring out how to write or retrieve the data that the operating system requests because the storage is abstracted.

- **Network-based storage virtualization**: The most popular type of virtualization used by

·**Network virtualization**:Network Virtualization is a process of logically grouping physical networks and making them operate as single or multiple independent networks called Virtual Networks.



.Physical switch OS

[redacted]

Data virtualization:

- Modern organizations collect data from several sources and store it in different formats. They might also store data in different places, such as in a cloud infrastructure and an on-premises data center.
- Data virtualization creates a software layer between this data and the applications that need it. Data virtualization tools process an application's data request and return results in a suitable format.
- Thus, organizations use data virtualization solutions to increase flexibility for data integration and support cross-functional data analysis.

OS Virtualization:

- Operating system-based Virtualization refers to an operating system feature in which the kernel enables the existence of various isolated user-space instances.
- The installation of virtualization software also refers to Operating system-based virtualization. It is installed over a pre-existing operating system and that operating system is called the **host operating system.**
- In this virtualization, a user installs the virtualization software in the operating system of his system like any other program and utilizes this application to operate and generate various virtual machines.
- Here, the virtualization software allows direct access to any of the created virtual machines to the user. As the host OS can provide hardware devices with the mandatory support, operating system virtualization may affect compatibility issues of hardware even when the hardware driver is not allocated to the virtualization

CONTAINER

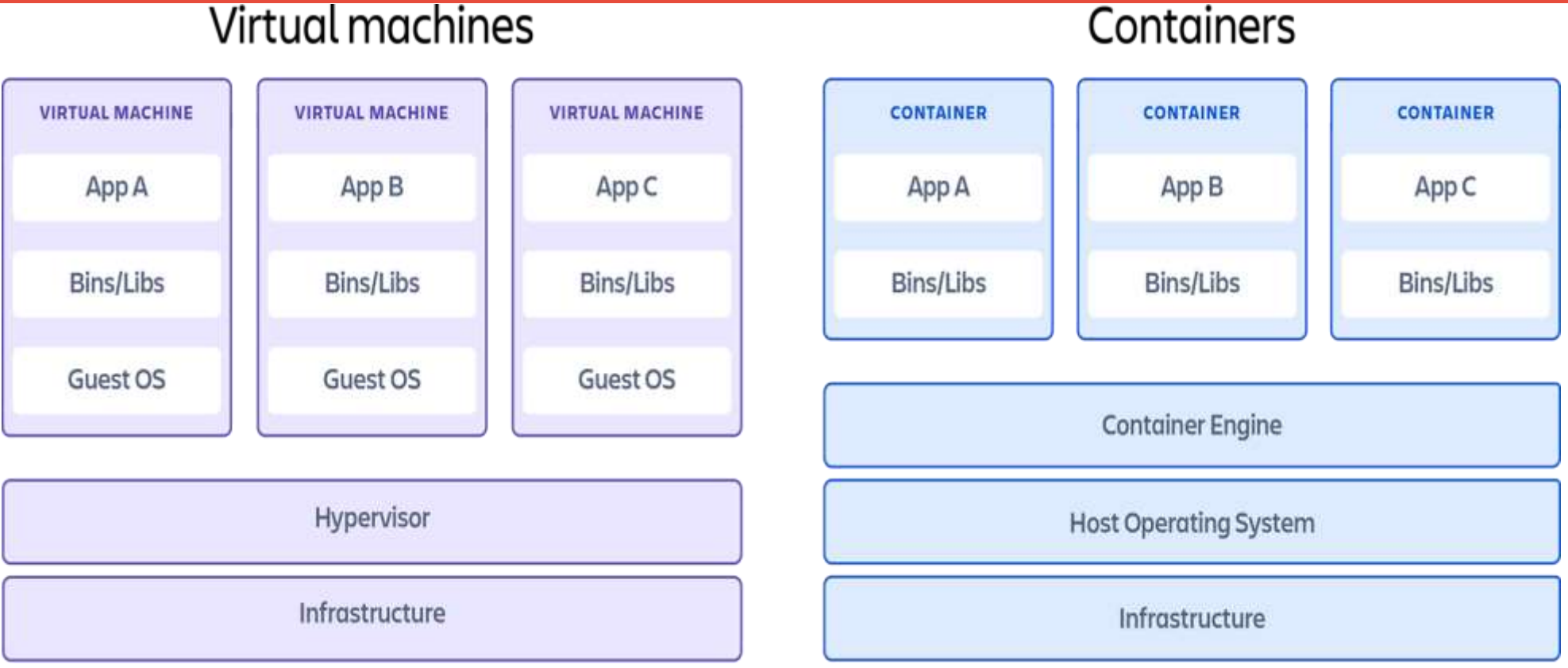
- Containers are lightweight software packages that contain all the dependencies required to execute the contained software application. These dependencies include things like system libraries, external third-party code packages, and other operating system level applications. The dependencies included in a container exist in stack levels that are higher than the operating system.

- **Iteration speed**

- Because containers are lightweight and only include high level software, they are very fast to modify and iterate on.

- **Robust ecosystem**

- Most container runtime systems offer a hosted public repository of pre-made containers. These container repositories contain many popular software applications like databases or messaging systems and can be instantly downloaded and executed, saving time for development teams


Virtual machines
VIRTUAL MACHINE
App A
Bins/Libs
Guest OS
VIRTUAL MACHINE
App B
Bins/Libs
Guest OS
VIRTUAL MACHINE
App C
Bins/Libs
Guest OS
Hypervisor
Infrastructure
Containers
CONTAINER
App A
Bins/Libs
CONTAINER
App B
Bins/Libs
CONTAINER
App C
Bins/Libs
Container Engine
Host Operating System
Infrastructure

Major operating system-based services:

- Backup and Recovery.
- Security Management.
- Integration to Directory Services.
- Hardware capabilities can be employed, such as the network connection and CPU.
- Connected peripherals with which it can interact, such as a webcam, printer, keyboard, or Scanners.
- Data that can be read or written, such as files, folders, and network shares.

- **Resource isolation**: Operating system-based virtualization provides a high level of resource isolation, which allows each container to have its own set of resources, including CPU, memory, and I/O bandwidth

- **Application virtualization:**

- Application virtualization pulls out the functions of applications to run on operating systems other than the operating systems for which they were designed. For example, users can run a Microsoft Windows application on a Linux machine without changing the machine configuration. To achieve application virtualization, follow these practices:

- **Application streaming** – Users stream the application from a remote server, so it runs only on the end user's device when needed.

- **Server-based application virtualization** – Users can access the remote application from their browser or client interface without installing it.

- **Local application virtualization** – The application code is shipped with its own environment to run on all operating systems without changes.

BENEFITS

- Application virtualization allows apps to comply with strict governance and privacy regulations such as the Health Insurance Portability and Accountability Act (HIPAA) and Payment Card Industry Data Security Standards (PCI DSS). This helps keep private information safe from any malware or attempts at compromise.
- Despite legacy apps being developed prior to technological advancements, application virtualization allows them to continue running. This is a major benefit to information systems professionals, as there are many legacy apps that are critical in organizations' operational infrastructure.
- Application virtualization also manages incident resolution. This occurs through the process of the virtualization layer restoring desktop settings to the original settings, which effectively wipes any virtualized images from the desktop and resaves them as a new image. This keeps all data safe and available for continued use and diverts any negative event from corrupting the data.

Desktop virtualization

- Most organizations have nontechnical staff that use desktop operating systems to run common business applications. For instance, you might have the following staff:
- A customer service team that requires a desktop computer with Windows 10 and customer-relationship management software
- A marketing team that requires Windows Vista for sales applications
- One can use desktop virtualization to run these different desktop operating systems on virtual machines, which teams can access remotely. This type of virtualization makes desktop management efficient and secure, saving money on desktop hardware.
- **Virtual desktop infrastructure** :Virtual desktop infrastructure runs virtual desktops on a remote server. Your users can access them by using client devices.

TYPE 1

*The type 1 hypervisor sits on top of the metal server and has direct access to the hardware resources. Because of this, the type 1 hypervisor is also known as a **bare-metal hypervisor**. The host machine does not have an operating system installed in a bare-metal hypervisor setup. **Instead, the hypervisor software acts as a lightweight operating system.**

***Pros and cons:**

Due to its architecture, the type 1 hypervisor is very efficient. It can directly manage and allocate resources for multiple virtual machines without going through the host operating system. These types of hypervisors are also more secure, as the absence of a host operating system reduces the risks of instability. One problem with Type-1

TYPE 2

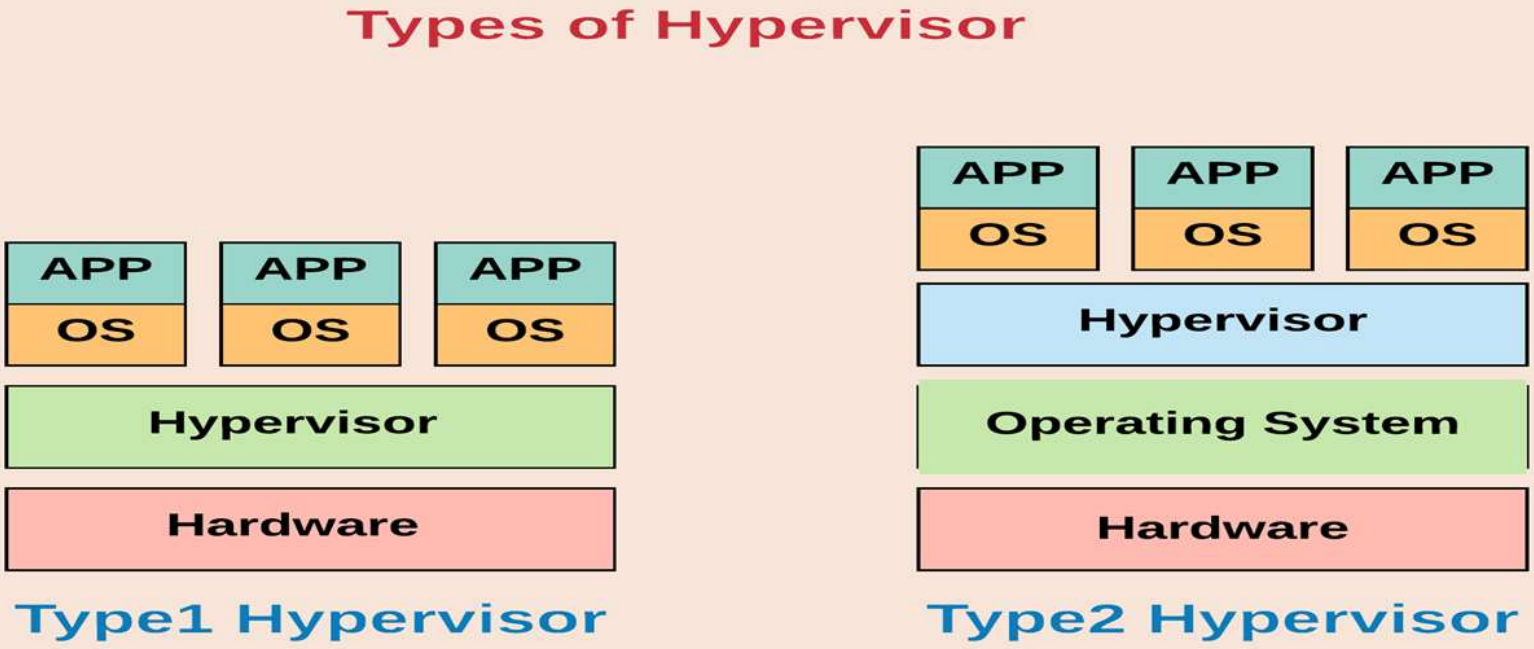
The type 2 hypervisor is a hypervisor program installed on a host operating system. It is also known as a **hosted or embedded hypervisor**. Like other software applications, hosted hypervisors do not have complete control of the computer resources. Instead, the system administrator allocates the resources for the hosted hypervisor, which it distributes to the virtual machines.

***Pros and cons**

·Quick and easy access to a guest Operating System alongside the host machine running. These hypervisors usually come with additional useful features for guest machines. Such tools enhance the coordination between the host machine and the guest machine.

·The presence of the host operating system introduces latency to the virtualized environment. When the virtual machine requests computing resources, the hypervisor cannot directly access the underlying hardware but relays the request to the host operating system. Also, the hypervisor and its hosted virtual machines are dependent on the stability of the host operating system.

TYPES


Types of Hypervisor
APP
OS
APP
OS
APP
OS
Hypervisor
Hardware
Type1 Hypervisor
APP
OS
APP
OS
APP
OS
Hypervisor
Operating System
Hardware
Type2 Hypervisor
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TYPE 1 VS TYPE 2

Criteria	Type 1 hypervisor	Type 2 hypervisor
AKA	Bare-metal or Native	Hosted
Definition	Runs directly on the system with VMs running on them	Runs on a conventional Operating System
Virtualization	Hardware Virtualization	OS Virtualization
Operation	Guest OS and applications run on the hypervisor	Runs as an application on the host OS
Scalability	Better Scalability	Not so much, because of its reliance on the underlying OS.
Setup/Installation	Simple, as long as you have the necessary hardware support	Lot simpler setup, as you already have an Operating System.
System Independence	Has direct access to hardware along with virtual machines it hosts	Are not allowed to directly access the host hardware and its resources
Speed	Faster	Slower because of the system's dependency
Performance	Higher-performance as there's no middle layer	Comparatively has reduced performance rate as it runs with extra overhead
Security	More Secure	Less Secure, as any problem in the base operating system affects the entire system including the protected Hypervisor
Examples	• VMware ESXi • Microsoft Hyper-V • Citrix XenServer	• VMware Workstation Player • Microsoft Virtual PC • Sun's VirtualBox

HYPERVISOR REFERENCE MODEL

*__DISPATCHER:__

·The dispatcher behaves like the entry point of the monitor and reroutes the instructions of the virtual machine instance to one of the other two modules.

·*__ALLOCATOR:__

·The allocator is responsible for deciding the system resources to be provided to the virtual machine instance. It means whenever a virtual machine tries to execute an instruction that results in changing the machine resources associated with the virtual machine, the allocator is invoked by the dispatcher.

*__INTERPRETER:__

BENEFITS

*More flexible and efficient allocation of resources.

*Enhance development productivity.

*It lowers the cost of IT infrastructure.

*Remote access and rapid scalability.

*High availability and disaster recovery.

*Pay peruse of the IT infrastructure on demand.

*Enables running multiple operating systems

HARDWARE VIRTUALIZATION

Hardware virtualization is the method used to create virtual versions of physical desktops and operating systems.

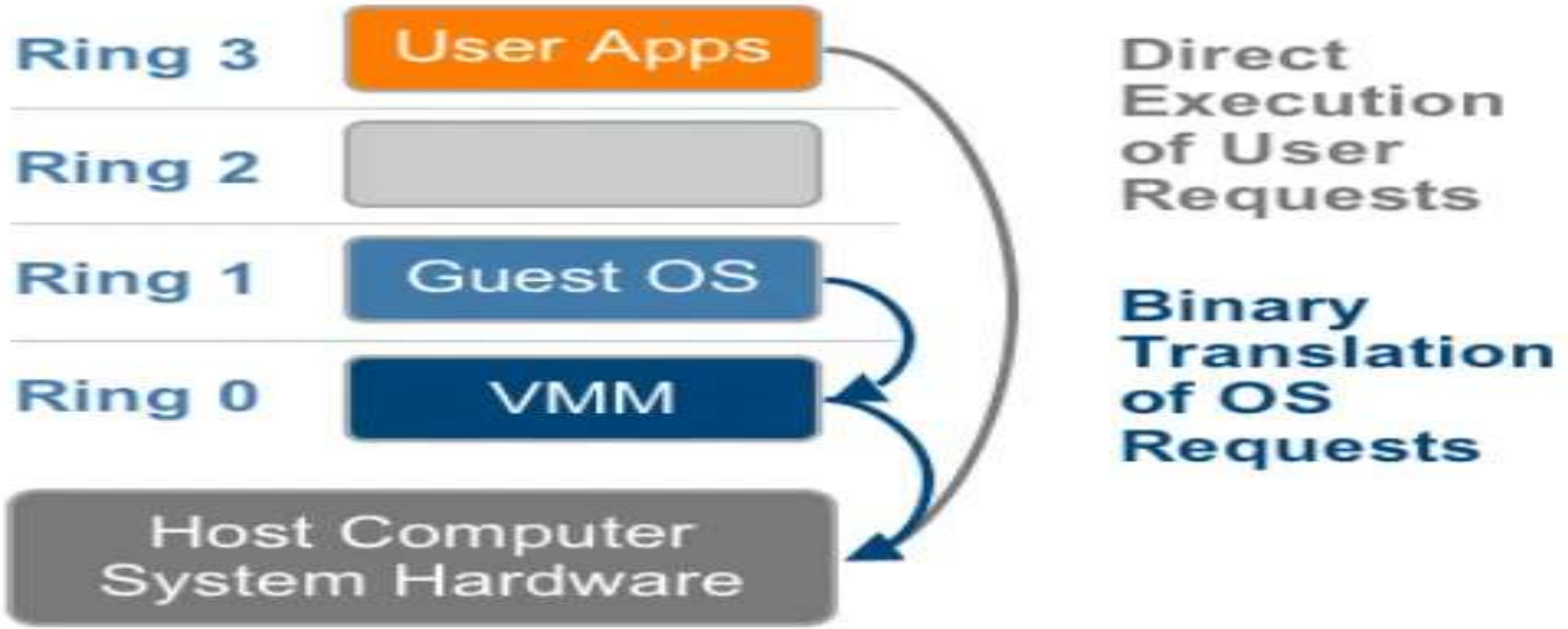
- It uses a **virtual machine manager (VMM) called a hypervisor** to provide abstracted hardware to multiple guest operating systems, which can then share the physical hardware resources more efficiently.
- Hardware virtualization offers many benefits, such as better performance and lower costs.

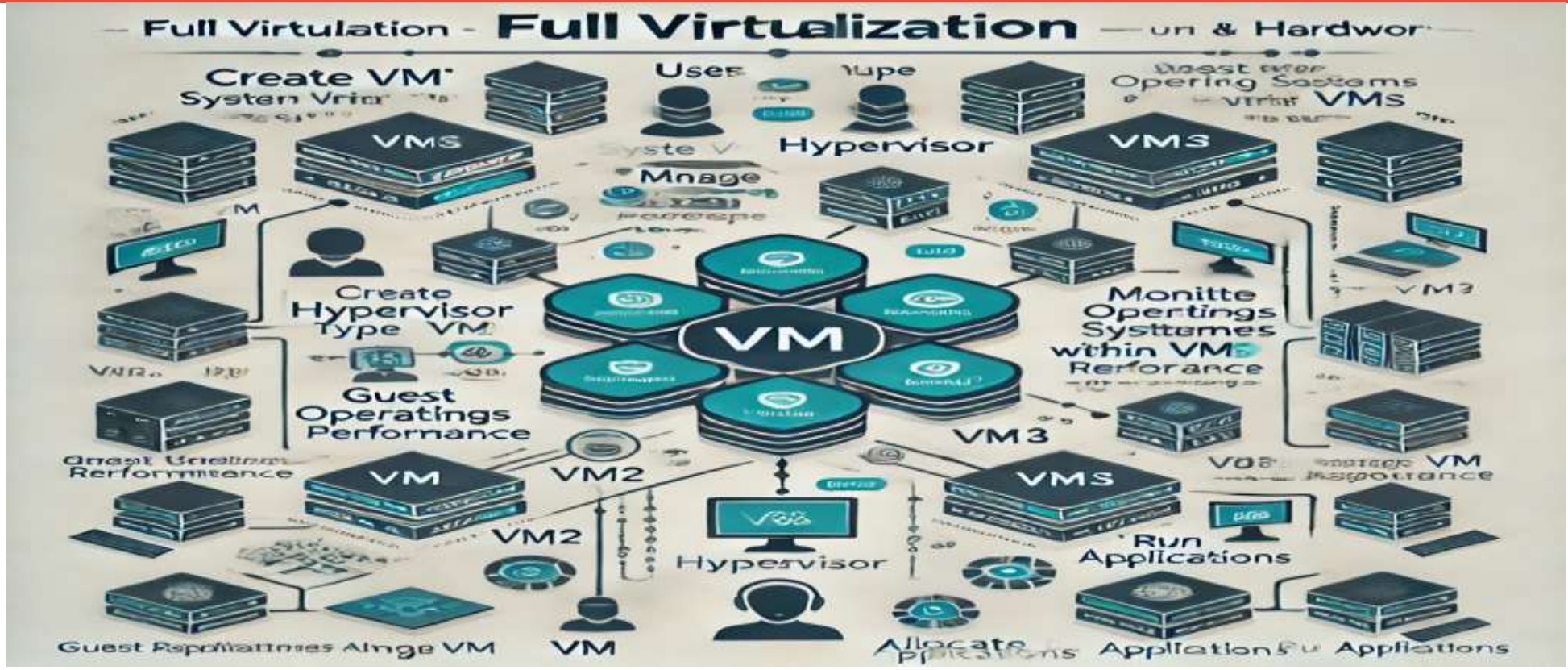
- How does hardware virtualization differ from virtualization?
- What are the components of hardware virtualization?
- How does hardware virtualization work?
- What are the different types of hardware virtualization?
- Solutions for hardware virtualization

- By separating resources or requests for service from the physical delivery of that service, virtualization technology enables administrators to distribute resources across the enterprise and use infrastructure more efficiently.
- Virtualization is the technology that enables cloud computing by allowing different computers to access a shared pool of resources. Virtualization technologies are used in a range of system layers to consolidate workloads and make IT environments more scalable and flexible.
- **Hardware virtualization is a type of virtualization that has made it possible for companies to efficiently employ underused physical hardware.** Full utilization of the physical resources available in powerful servers, for example, reduces the total cost of ownership for server deployment.

- The hardware layer, or virtualization host, contains the physical server components such as CPU, memory, network, and disk drives. This is the physical hardware on which virtualization takes place. It requires an x86-based system with one or more CPUs to run all supported guest operating systems.
- The hypervisor creates a virtualization layer that runs between the OS and the server hardware, allowing many instances of an operating system or different operating systems to run in parallel on a single machine. Hypervisors isolate operating systems and applications from the underlying computer hardware, or the host machine, from the virtual machines that use its resources.
- Virtual machines are software emulations of a computing hardware environment and provide the functionalities of a physical computer. Virtual machines themselves consist of virtual hardware, a guest operating system, and guest software or applications.

FULL VIRTUALIZATION




Full Virtulation - Full Virtualization
Create VM
Hypervisor
VMS
VM
Create Hypervisor Type VM
Guest Operatings Performance
Monitte Opertings Systemes within VM Reforance
VM2
VM3
Run Applications
Allocate
Application
Applications


System Castor
VMS
Hypervisor
'Create VM
'Crnage VM
CREATE VM
HYPERVISOR
Manage VM
'Monitate VM
VM Performance
Hypervisor
Hypervisor
Hypervisor
Mange VM
VM Performriance
SYSTEM ADMINSTRATOR
Monitate
VM
Rerformance
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'Manage
Matory
VULL VIRTUALATION
Moniage
M
Monitate
VM Performance
Network
'Alocate VM
Resources

KEY CONCEPTS

CPU Virtualization:

.The hypervisor intercepts and manages privileged CPU instructions that the guest OS tries to execute. It ensures that these instructions do not interfere with the host OS or other VMs.

.Modern CPUs include hardware-assisted virtualization features (e.g., Intel VT-x, AMD-V) to improve performance by reducing the overhead of intercepting and managing privileged instructions.

.**Memory Virtualization:**

.The hypervisor allocates physical memory to each VM and manages a mapping between the virtual memory addresses used by the VM

ADVANTAGES

- **Isolation:** VMs are isolated from each other and the host OS, improving security and stability. Failures or security breaches in one VM do not affect others.
- **Compatibility**: Since the guest OS runs unmodified, it can be any operating system that would normally run on the physical hardware.
- **Resource Utilization**: Multiple VMs can share the same physical hardware, leading to better resource utilization and cost savings.
- **Flexibility and Scalability:** New VMs can be easily created, cloned, and migrated across physical hosts, providing flexibility in managing workloads and scaling infrastructure.

CHALLENGES & CONSIDERATIONS

- **Performance Overhead:** Full virtualization can introduce performance overhead due to the additional layer of abstraction. Hardware-assisted virtualization features in modern CPUs help mitigate this overhead.

- **Complexity**: Managing and maintaining a virtualized environment can be complex, requiring specialized knowledge and tools.

- **Resource Contention:** VMs share the same physical resources, which can lead to contention and performance degradation if not managed properly.

PARA VIRTUALIZATION

- Para-virtualization is a virtualization technique where the guest operating system is modified to work in a virtualized environment.
- Unlike full virtualization, where the guest OS runs unmodified, para-virtualization requires the OS to be aware of the hypervisor and make explicit calls to it for certain operations.
- This results in improved performance and efficiency, as the guest OS and hypervisor can cooperate more closely.

- **Hypervisor (Virtual Machine Monitor - VMM):**
- Manages and allocates resources to the guest OS.
- Provides an API for the guest OS to interact with the hardware efficiently.

- **Guest Operating System:**
- Modified to include hypercalls, which are explicit calls to the hypervisor for operations that would normally require privileged access to hardware.
- Examples of hypercalls include memory management, scheduling, and I/O operations.

- **Hypercalls:**
- Replace certain hardware instructions with calls to the hypervisor

- **CPU Virtualization:**
- The guest OS uses hypercalls to request CPU resources from the hypervisor.
- The hypervisor schedules and allocates CPU time to each VM, ensuring efficient use of the physical CPU.

- **Memory Virtualization:**
- The guest OS and hypervisor cooperate in managing memory.
- The guest OS uses hypercalls to request memory allocation and to manage page tables, reducing the overhead of memory

ADVANTAGES

- **Improved Performance:** By eliminating the need for trapping and emulating privileged instructions, para-virtualization reduces overhead and improves performance compared to full virtualization.
- **Efficient Resource Utilization**: The cooperation between the guest OS and the hypervisor leads to more efficient use of CPU, memory, and I/O resources.
- **Simpler Hypervisor Design:** The hypervisor can be simpler and more efficient, as it does not need to fully emulate hardware.

CHALLENGES & CONSIDERATIONS

- **Guest OS Modification:** The guest OS must be modified to support para-virtualization, which can limit the choice of operating systems that can be used.

- **Compatibility:** Not all operating systems support para-virtualization, which can be a limitation in heterogeneous environments.

- **Complexity:** Modifying the guest OS and maintaining compatibility with the hypervisor can add complexity to the virtualization setup.

DRAWBACK

*__High Initial Investment:__ Clouds have a very high initial investment, but it is also true that it will help in reducing the cost of companies.

*__Learning New Infrastructure:__ As the companies shifted from Servers to Cloud, it requires highly skilled staff who have skills to work with the cloud easily, and for this, you have to hire new staff or provide training to current staff.

__*Risk of Data:__ Hosting data on third-party resources can lead to putting the data at risk, it has the chance of getting attacked by any hacker or cracker very easily.