Cloud Resource Virtualization

ARADHANA BEHURA

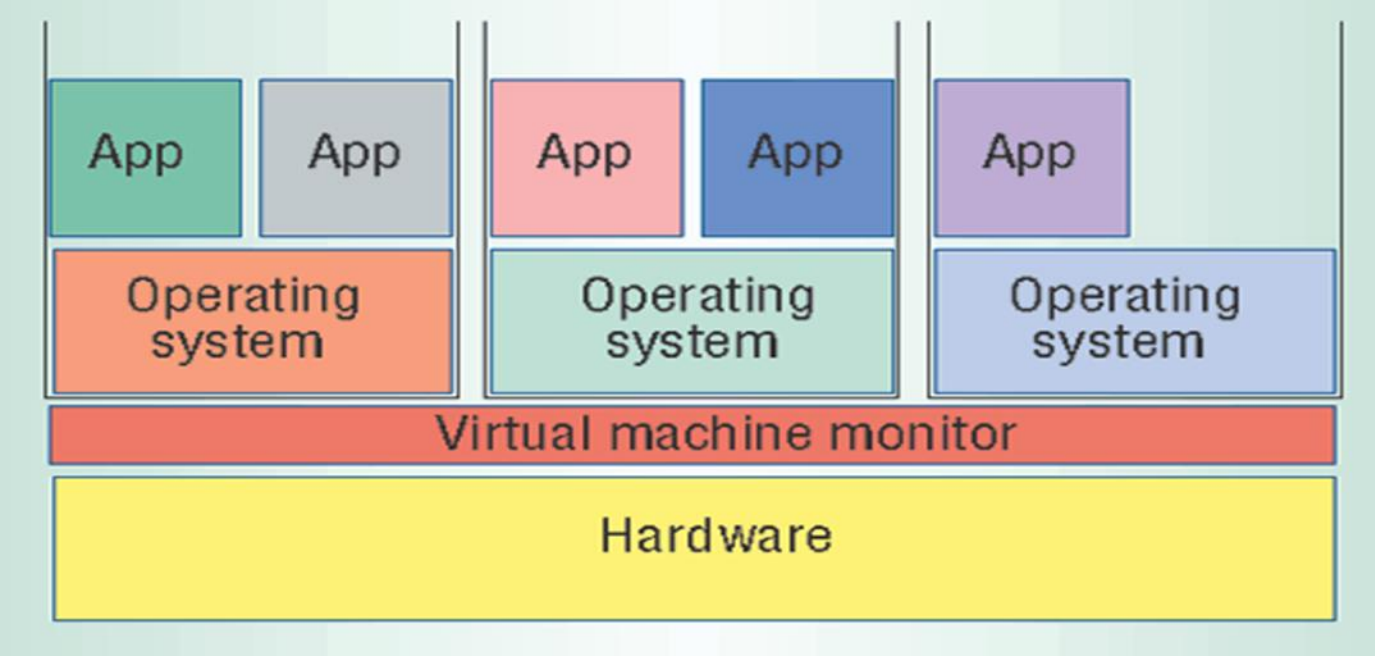
Communication & Computing Group

Department of CSE

Email: 921CS5007@nitrkl.ac.in, 7787821733

Virtualization in Cloud Computing

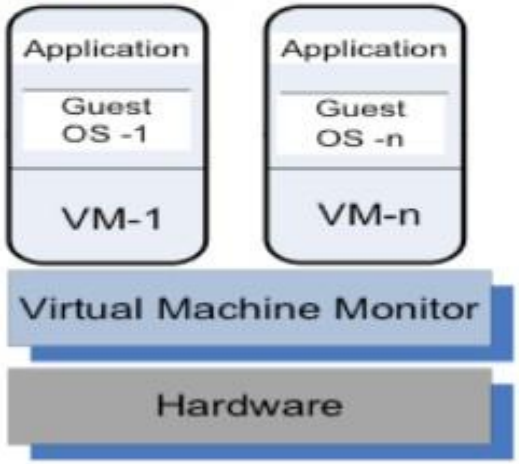
- **Virtualization** is the creation of virtual servers, infrastructures, devices and **computing** resources.
- **Virtualization** changes the **hardware-software relations** and is one of the foundational elements of **cloud computing** technology that helps utilize the capabilities of **cloud computing** to the full.



Cloud Resource Virtualization

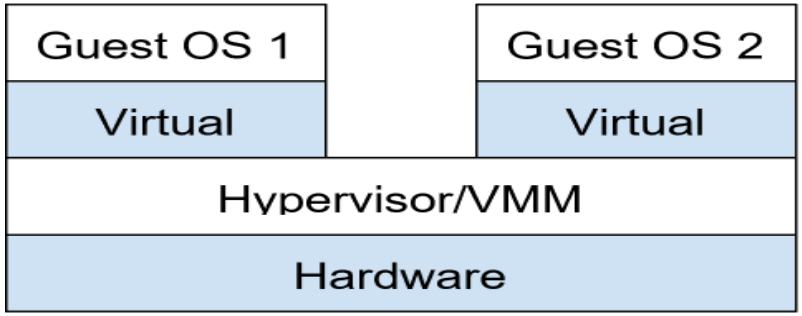
Virtual Machine Monitor (VMM / Hypervisor)

- A **virtual machine monitor (VMM/hypervisor)** partitions the resources of computer system into one or more **virtual machines (VMs)**. Allows several operating systems to run concurrently on a single hardware platform
- A VM is an execution environment that runs an OS
- VM – an isolated environment that appears to be a whole computer, but actually only has access to a portion of the computer resources
- A VMM allows:
  - Multiple services to share the same platform
  - Live migration - the movement of a server from one platform to another
  - System modification while maintaining backward compatibility with the original system
  - Enforces isolation among the systems, thus security

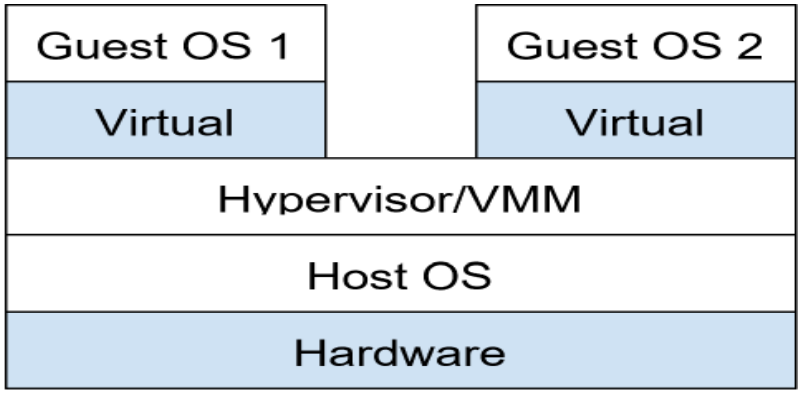


- A **guest operating system** is an OS that runs in a VM under the control of the VMM.

Hypervisors



Type 1/Bare-metal

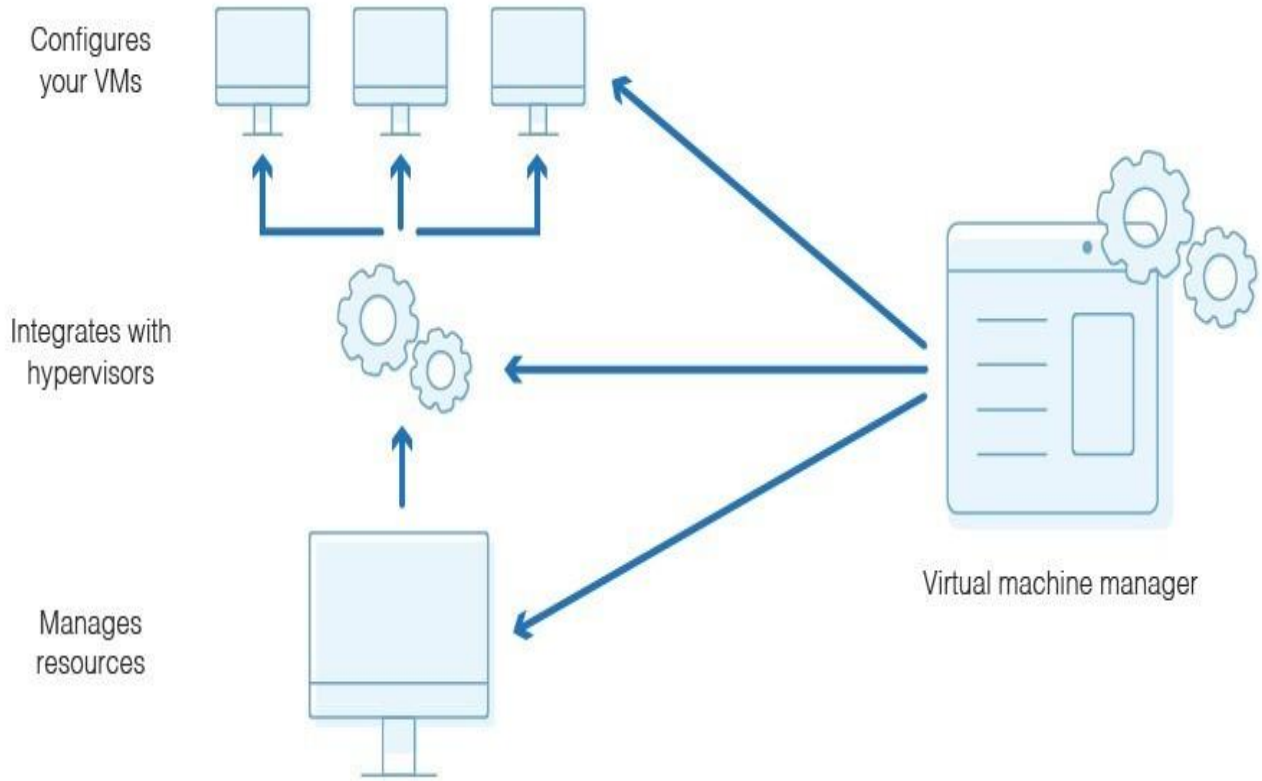


Type 2/Hosted

CONTD.

- A bare-metal **hypervisor** (**Type 1**) is a layer of software we install directly on top of a physical server and its underlying hardware.
- There is no software or any operating system in between, hence the name bare-metal **hypervisor**. **Type 1 hypervisors** are mainly found in enterprise environments
- A **Type 2 hypervisor**, also called a hosted **hypervisor**, is a virtual machine manager that is installed as a software application on an existing operating system (OS).
- **Type-2 hypervisors** abstract guest operating systems from the host operating system.
- Parallels Desktop for Mac, QEMU, VirtualBox, **VMware** Player and **VMware** Workstation are examples of **type-2 hypervisors**.

What Does a Virtual Machine Manager Do?



Cloud Virtualization

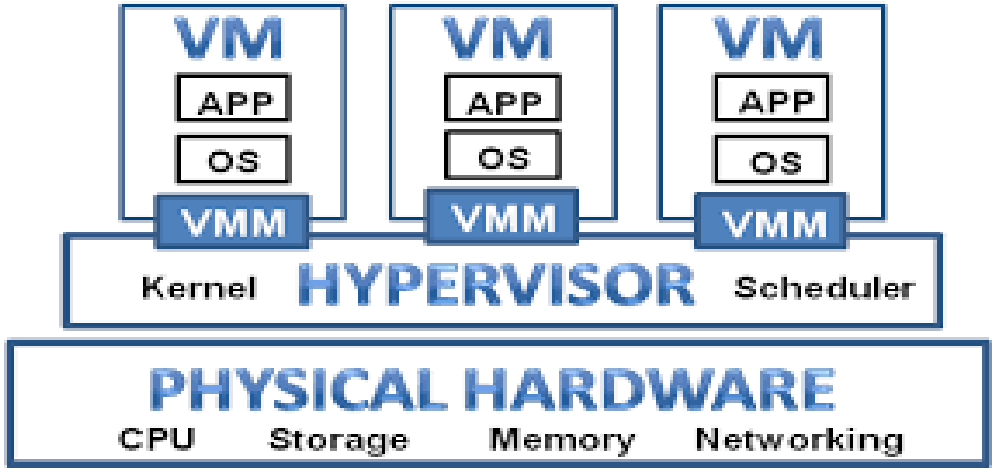
Chapter 3

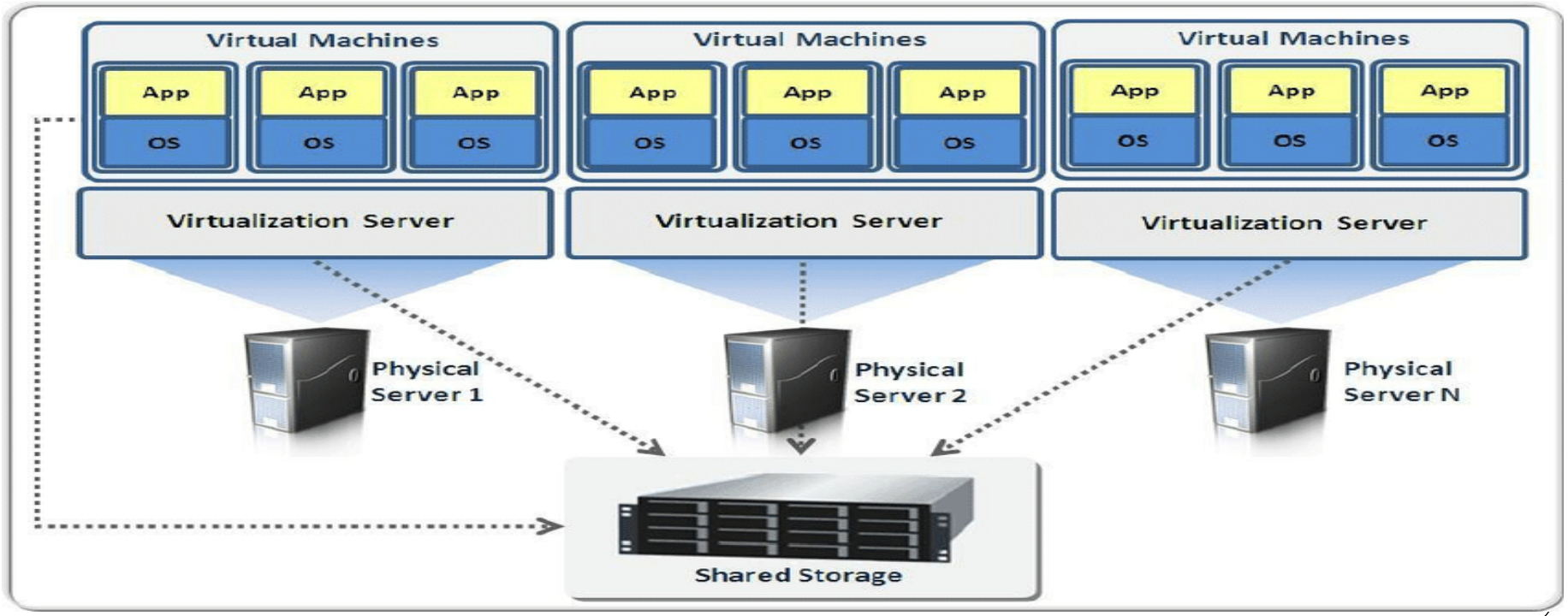
Virtualization is the creation of a virtual (rather than actual) version of something, such as an operating system, a server, a storage device or network resources.

Virtualization

- In computing, virtualization means to create a virtual version of a device or resource, such as a server, storage device, network or even an operating system where the framework divides the resource into one or more execution environments.
- Even something as simple as partitioning a hard drive is considered virtualization because you take one drive and partition it to create two separate hard drives.
- Devices, applications and human users are able to interact with the virtual resource as if it were a real single logical resource.

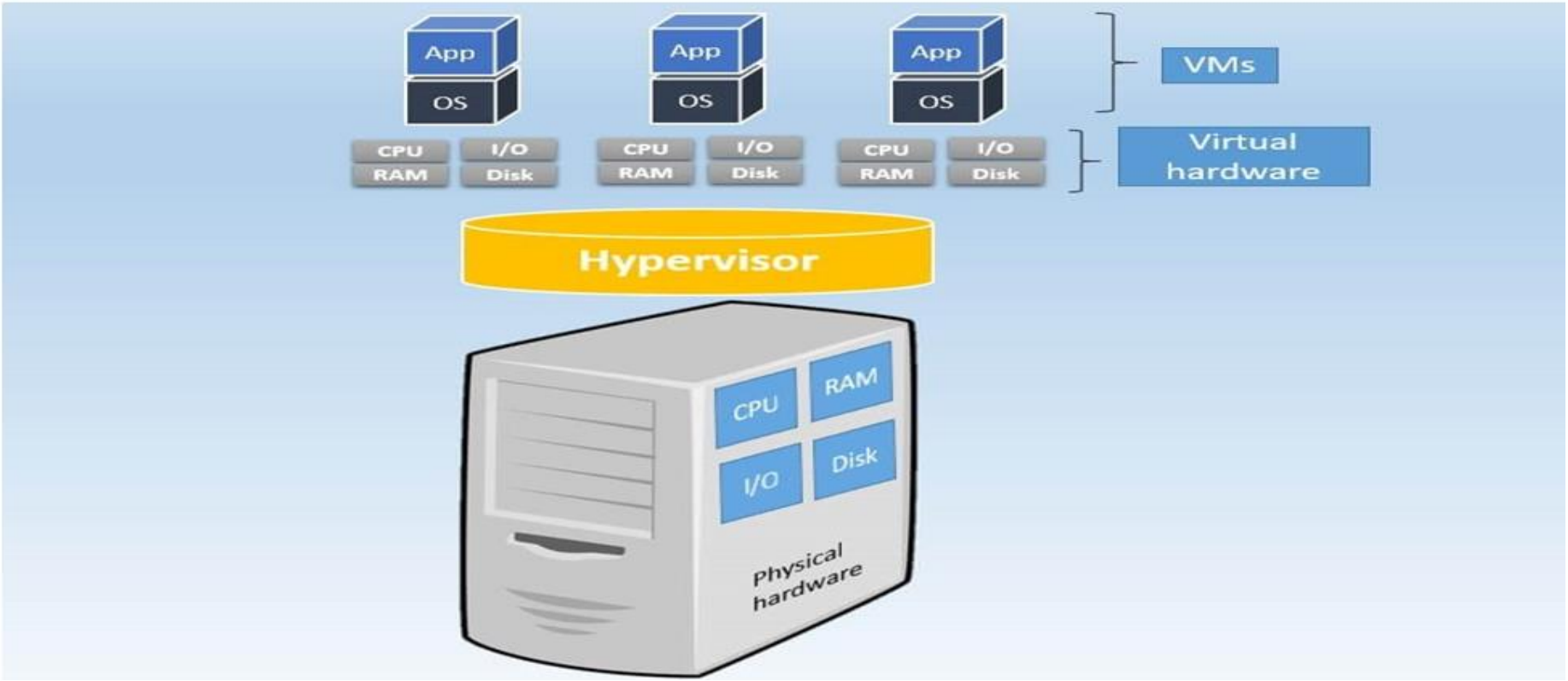
Virtual machine environment





Virtual Machine (VM)

- A **Virtual Machine** (VM) is a compute resource that uses software instead of a physical computer to run programs and deploy applications



The two types of virtual machines

- [1] **A process virtual machine** allows a single process to run as an application on a host machine, providing a platform-independent programming environment by masking the information of the underlying hardware or operating system.
- An example of a process VM is the Java Virtual Machine, which enables any operating system to run Java applications as if they were native to that system.
- [2] **A system virtual machine** is fully virtualized to substitute for a physical machine.
- A system platform supports the sharing of a host computer's physical resources between multiple virtual machines, each running its own copy of the operating system. This virtualization process relies on a hypervisor, which can run on bare hardware, such as VMware ESXi, or on top of an operating system.

Virtualization : An Introduction

- Virtualization can be viewed as part of an overall trend in enterprise IT that includes **autonomic computing**, a scenario in which the IT environment will be able to manage itself based on perceived activity, and **utility computing**, in which computer processing power is seen as a utility that clients can pay for only as needed.
- The usual goal of virtualization is to centralize administrative tasks while improving **scalability** and work loads.
- Virtualization is a basic tenet of cloud computing, it simplifies some of the resource management tasks; for example, the **state of a virtual machine (VM)** running under a **virtual machine monitor (VMM)** can de saved and migrated to another server to balance the load.

Virtualization : An Introduction

- Resource sharing in a virtual machine environment requires ample hardware support such as powerful processors, and architectural support for multilevel control.
- In practice resources, such as CPU cycles, memory, secondary storage, and I/O and communication bandwidth, are shared among several virtual machines; for each virtual machine resources must be shared among **multiple instances of an application.**
- Virtualization abstracts the underlaying resources and simplifies their use, isolates users from one another, and supports replication which, in turn, increases the elasticity of the system.

Virtualization : An Introduction

- Traditional processor architectures were conceived for one level of control as they support **two execution modes**, the **kernel** and the **user mode.**
- In a virtualized environment all resources are under the control of a **virtual machine monitor** (VMM) and a second level of control is exercised by the **guest operating system**.
- A two-level scheduling for sharing CPU cycles can be implemented, sharing of resources such as cache, memory, and I/O bandwidth is more intricate.
- The system functions critical for the performance of a virtual machine environment are cache and memory management, handling of privileged instructions, and I/O handling

Virtualization

- **Virtualization simulates** the interface to a physical object by any one of four means:

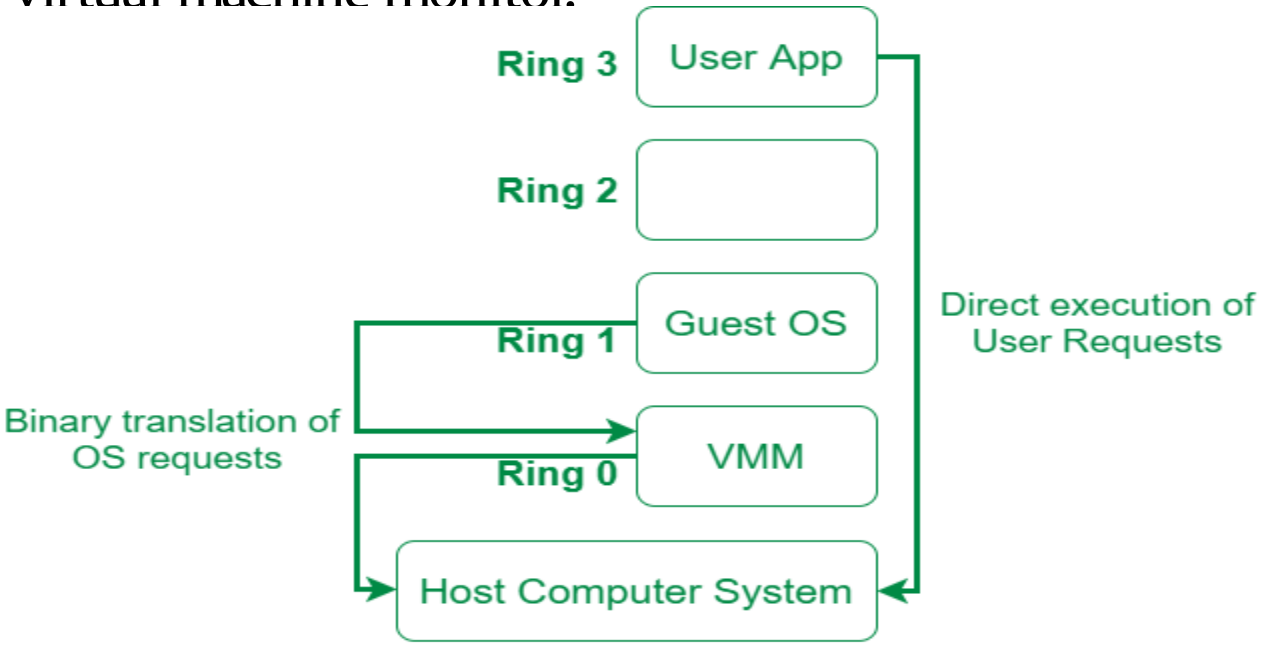
1. **Multiplexing:** create multiple virtual objects from one instance of a physical object. For example, a processor is multiplexed among a number of processes or threads.
2. **Aggregation:** create one **virtual object** from multiple physical objects. For example, a number of physical disks are aggregated into a RAID disk.
3. **Emulation:** construct a virtual object from a different type of a physical object. Example, a physical disk emulates a Random Access Memory.
4. **Multiplexing and emulation**.

   Examples: virtual memory with paging multiplexes real memory and disk and a virtual address emulates a real address;

   The TCP protocol emulates a reliable bit pipe and multiplexes a physical communication channel and a processor.

Two distinct approaches for virtualization

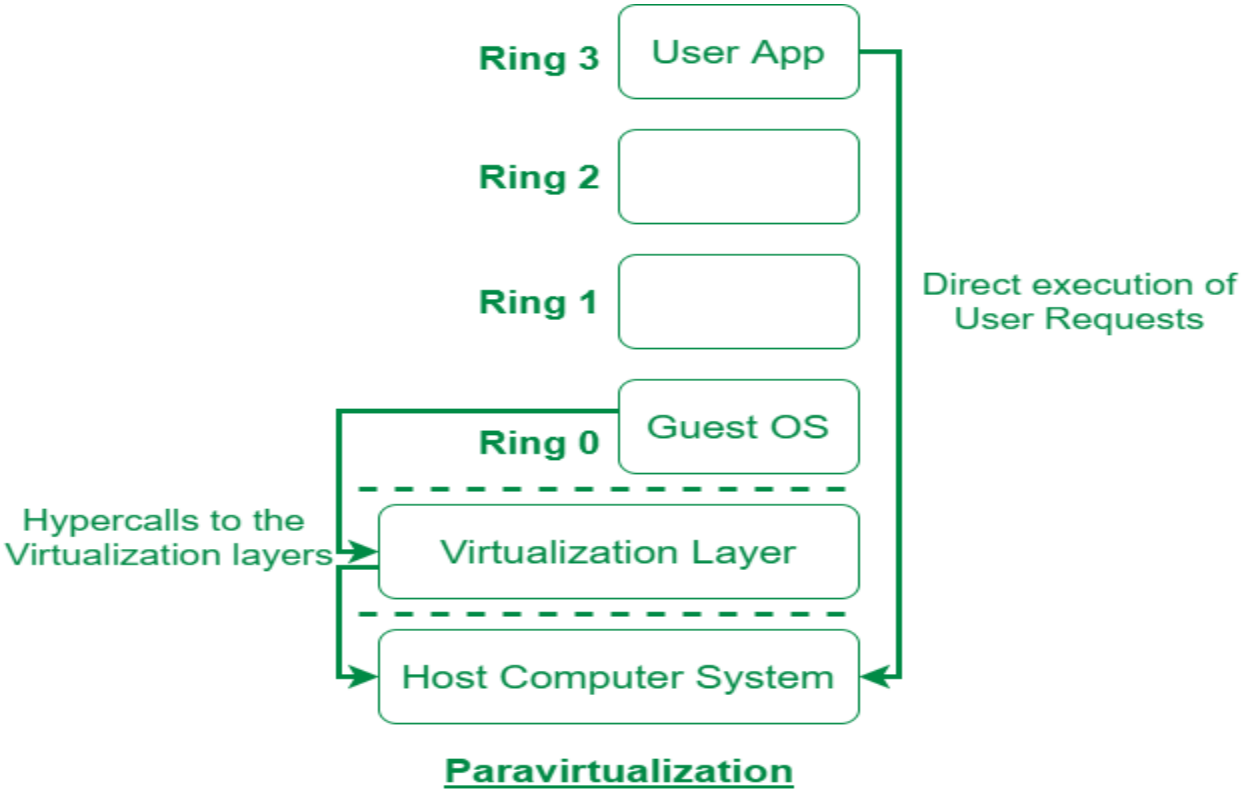
- **Full virtualization**: Full virtualization is feasible when the hardware abstraction provided by the virtual machine monitor is an exact replica of the physical hardware; in this case any operating system running on the hardware will run without modifications under the virtual machine monitor.



Full Virtualization

Two distinct approaches for virtualization

- **Para-virtualization:** Para-virtualization require some modifications of the guest operating systems, as the hardware abstraction provided by the VMM does not support all the functions the hardware does.



Paravirtualization

Features	Full Virtualization	ParaVirtualization
Definition	It is the first generation of software solutions for server virtualization.	The interaction of the guest operating system with the hypervisor to improve performance and productivity is known as paravirtualization.
Security	It is less secure than para-virtualization.	It is more secure than full virtualization.
Performance	Its performance is slow than para-virtualization.	Its performance is high than full virtualization.
Guest OS Modification	It supports all the Guest OS without any change.	The Guest OS has to be modified in para-virtualization, and only a few OS support it.
Guest OS hypervisor independent	It enables the Guest OS to run independently.	It enables the Guest OS to interact with the hypervisor.
Potable and Compatible	It is more portable and compatible.	It is less portable and compatible.
Isolation	It offers optimum isolation.	It offers less isolation.
Efficient	It is less efficient than paravirtualization.	It is more simplified than full virtualization.
Characteristic	It is software based.	It is cooperative virtualization.
Examples	It is used in Microsoft, VMware, ESXi and Parallels systems.	It is mainly used in VMware and Xen systems.

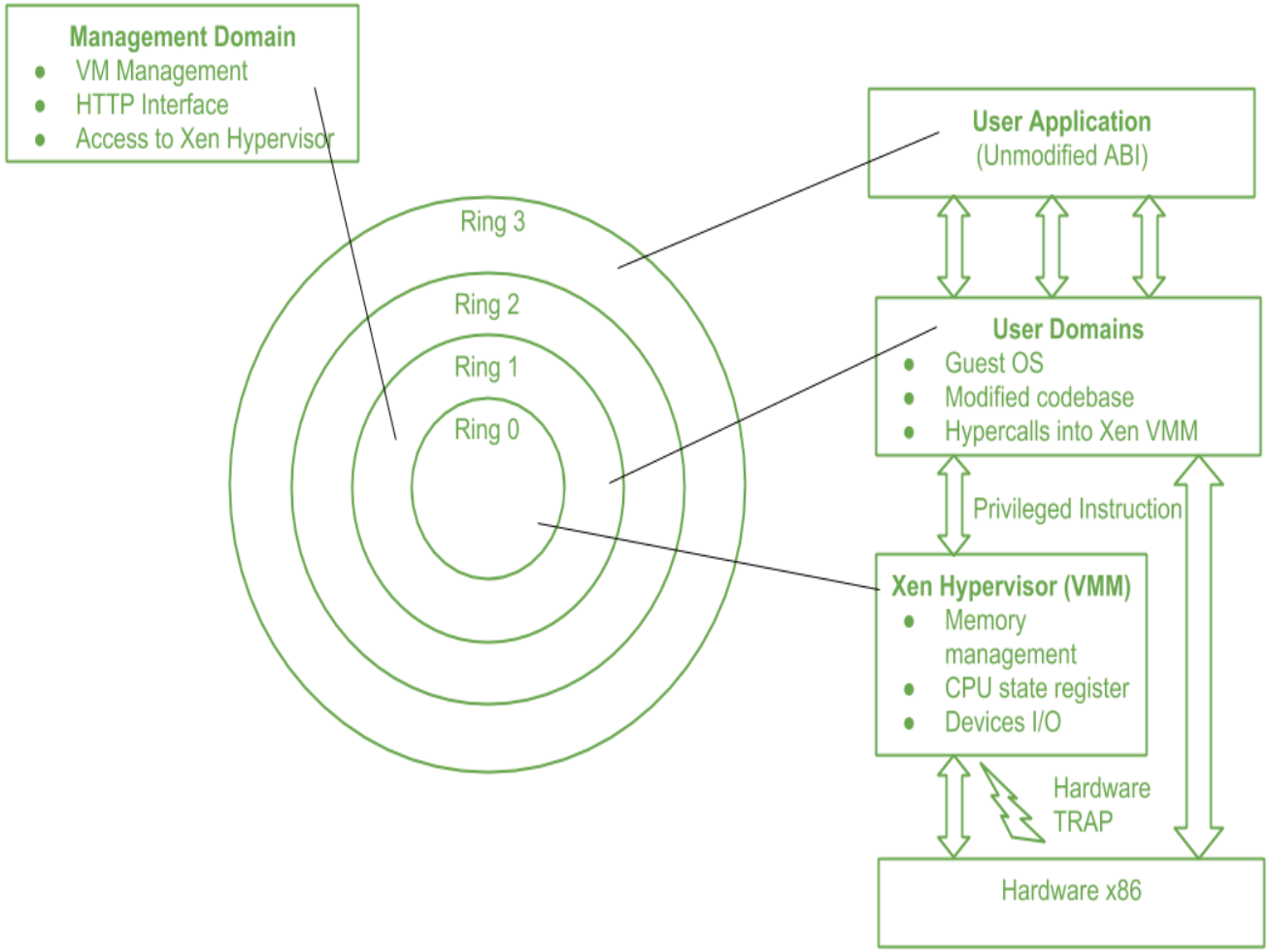
Types

- Full virtualization enables the Guest operating system to run independently. In contrast, paravirtualization enables the Guest OS to interact with the hypervisor.
- Binary translation and a direct approach are used in full virtualization. On the other hand, paravirtualization operates through hypercalls.

- **Full Virtualization:** It is the first software solution for server virtualization and uses binary translation and direct approach techniques. In full virtualization, guest OS is completely isolated by the virtual machine from the virtualization layer and hardware.
- **Paravirtualization:** Paravirtualization is the category of CPU virtualization which uses hypercalls for operations to handle instructions at compile time. In paravirtualization, guest OS is not completely isolated but it is partially isolated by the virtual machine from the virtualization layer and hardware.

Virtualization | Xen: Paravirtualization

- **Xen** is an open source hypervisor based on paravirtualization. It is the most popular application of paravirtualization.
- Xen has been extended to compatible with full virtualization using hardware-assisted virtualization. It enables high performance to execute guest operating system.
- This is probably done by removing the performance loss while executing the instructions requiring significant handling and by modifying portion of the guest operating system executed by Xen, with reference to the execution of such instructions.
- Hence this especially support x86, which is the most used architecture on commodity machines and servers.


Management Domain
VM Management
HTTP Interface
Access to Xen Hypervisor
Ring 3
Ring 2
Ring 1
Ring 0
User Application
(Unmodified ABI)
User Domains
Guest OS
Modified codebase
Hypercalls into Xen VMM
Privileged Instruction
Xen Hypervisor (VMM)
Memory management
CPU state register
Devices I/O
Hardware TRAP
Hardware x86

- Above figure describes the Xen Architecture and its mapping onto a classic x86 privilege model.
- A Xen based system is handled by Xen hypervisor, which is executed in the most privileged mode and maintains the access of guest operating system to the basic hardware. Guest operating system are run between domains, which represents virtual machine instances.
- In addition, particular control software, which has privileged access to the host and handles all other guest OS, runs in a special domain called Domain 0.
- This the only one loaded once the virtual machine manager has fully booted, and hosts an HTTP server that delivers requests for virtual machine creation, configuration, and termination.
- This component establishes the primary version of a shared virtual machine manager (VMM), which is a necessary part of Cloud computing system delivering Infrastructure-as-a-Service (IaaS) solution.

Various x86 implementation support four distinct security levels, termed as rings, i.e.,

- Ring 0,
- Ring 1,
- Ring 2,
- Ring 3

Pros:

•**a)** Xen server is developed over open-source Xen hypervisor and it uses a combination of hardware-based virtualization and paravirtualization. This tightly coupled collaboration between the operating system and virtualized platform enables the system to develop lighter and flexible hypervisor that delivers their functionalities in an optimized manner.

•**b)** Xen supports balancing of large workload efficiently that capture CPU, Memory, disk input-output and network input-output of data. It offers two modes to handle this workload: Performance enhancement, and For handling data density.

•**c)** It also comes equipped with a special storage feature that we call Citrix storage link. Which allows a system administrator to uses the features of arrays from Giant companies- Hp, Netapp, Dell Equal logic etc.

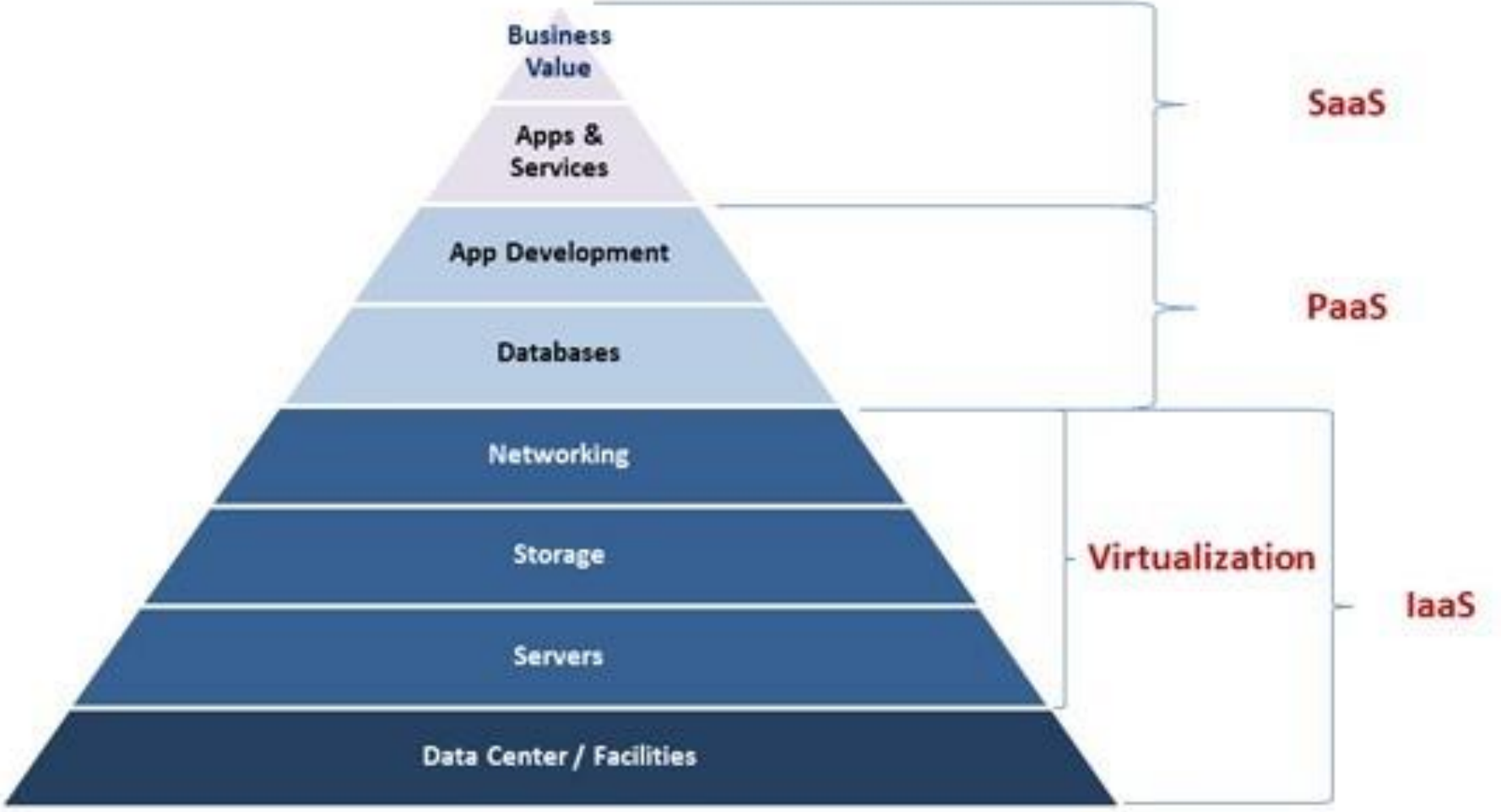
•**d)** It also supports multiple processor, Iive migration one machine to another, physical server to virtual machine or virtual server to virtual machine conversion tools, centralized multiserver management, real time performance monitoring over window and linux.

CONS:

•**e)** Xen relies on 3rd-party component to manage the resources like drivers, storage, backup, recovery & fault tolerance.

•**f)** Xen sometimes may cause increase in load on your resources by high input-output rate and and may cause starvation of other Vm's.

Information Technology stack showing technology layers addressed by virtualization and by cloud computing.



Motivation

- Three fundamental abstractions are necessary to describe the operation of a computing systems: (1) interpreters/processors, (2) memory, (3) communications links
- As the scale of a system and the size of its users grows, it becomes very challenging to manage its recourses
- **Resource management issues**: (1) provision for peak demands à overprovisioning , (2) heterogeneity of hardware and software , (3) machine failures
- Virtualization is a basic enabler of Cloud Computing, it simplifies the management of physical resources for the three abstractions
- For example, the state of a virtual machine (VM) running under a virtual machine monitor (VMM) can de saved and migrated to another server to balance the load
- § For example, virtualization allows users to operate in environments they are familiar with, rather than forcing them to specific ones

Motivation

- Virtualization abstracts the underlying resources; simplifies their use; isolates users from one another; and supports replication which increases the elasticity of a system.

Cloud resource virtualization is important for:

§ Performance isolation

- as we can dynamically assign and account for resources across different applications

§ **System security:**

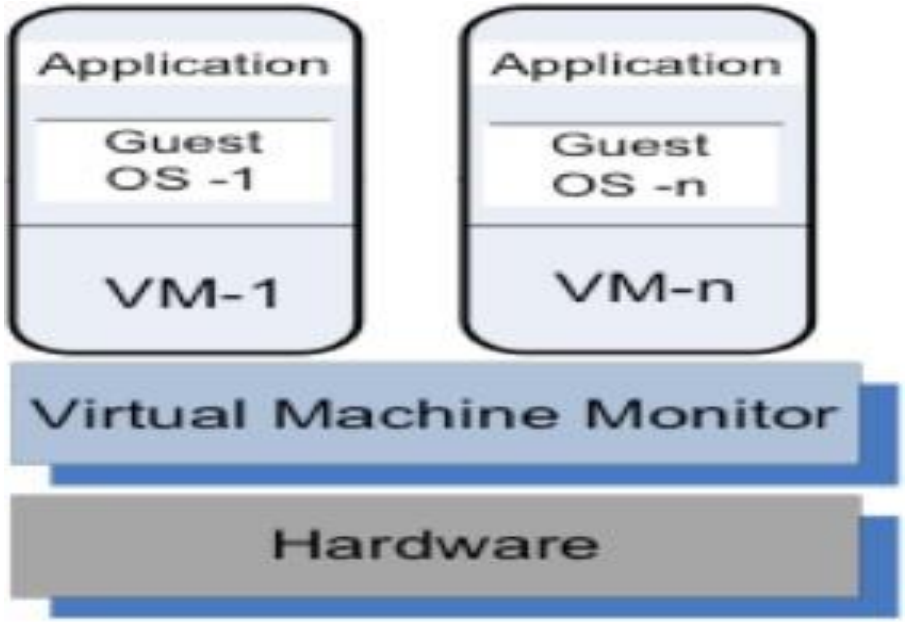
- as it allows isolation of services running on the same hardware

§ **Performance and reliability**:

- as it allows applications to migrate from one platform to another
- The development and management of services offered by a provider

Definations

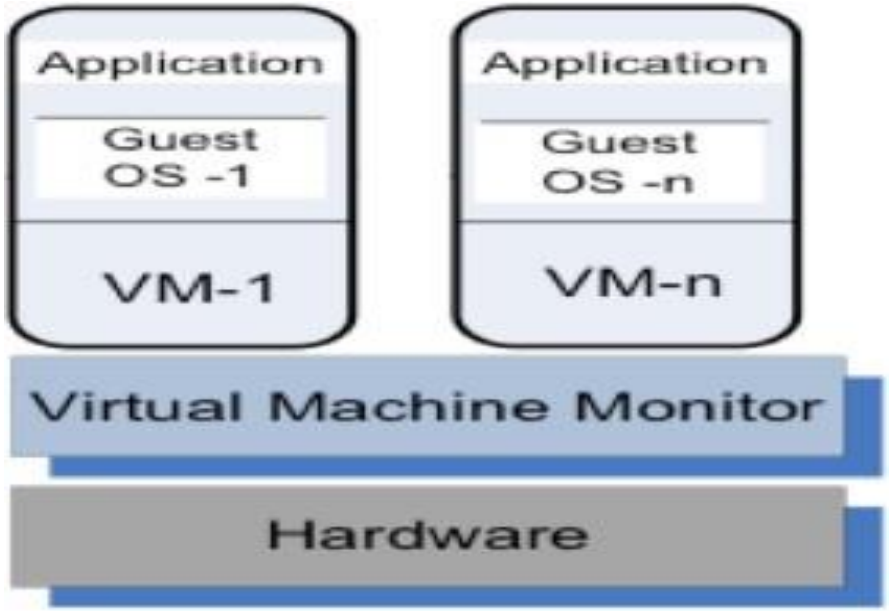
- *Virtual Machine (VM): An instance of an* operating system running on a virtualized system. Also known as a *virtual or guest OS*
- *hypervisor: The underlying virtualization system* sitting between the guest OSes and the hardware. Also known as a *Virtual Machine Monitor (VMM)*.



Requirements of a VMM

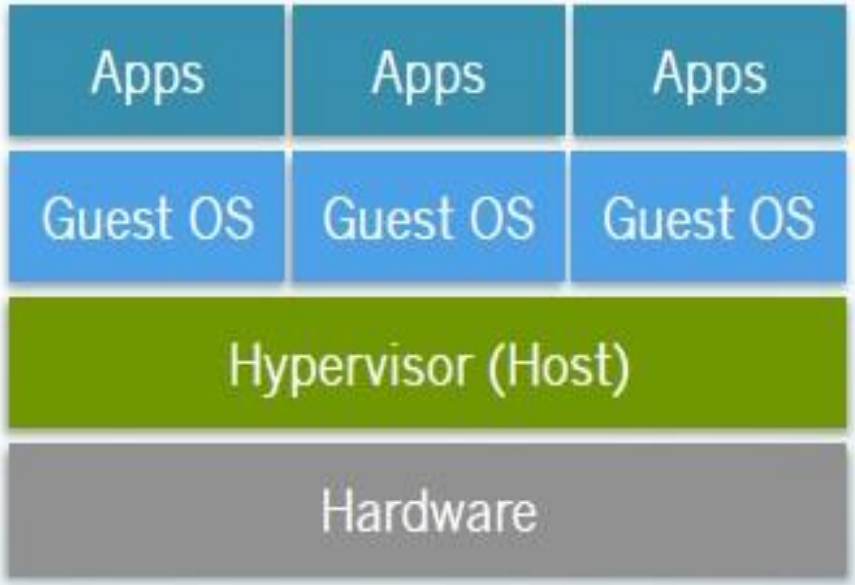
- **Developed by Popek & Goldberg in 1974 :**

1. Provides environment identical to underlying hardware.
2. Most of the instructions coming from the guest OS are executed by the hardware without being modified by the VMM.
3. Resource management is handled by the VMM (this all non-CPU hardware such as memory and peripherals).



Guest OS model

- Hypervisor exists as a layer between the operating systems and the hardware.
- Performs memory management and scheduling required to coordinate multiple operating systems.
- May also have a separate controlling interface.



Virtualization Challenges

- **Privileged Instructions**
  - Handling architecture-imposed instruction privilege levels.
- **Performance Requirements**
  - Holding down the cost of VMM activities.
- **Memory Management**
  - Managing multiple address spaces efficiently.
- **I/OVirtualization**
  - Handling I/O requests from multiple operating systems.

Virtualization

Virtualization simulates the interface to a physical object by:

- **Multiplexing**: creates multiple virtual objects from one instance of a physical object. Many virtual objects to one physical. Example – a processor is multiplexed among a number of processes or threads.
- **Aggregation:** creates one virtual object from multiple physical objects. One virtual object to many physical objects. Example – a number of physical disks are aggregated into a RAID disk.
- **Emulation:** constructs a virtual object of a certain type from a different type of a physical object. Example - a physical disk emulates a Random Access Memory (RAM).
- **Multiplexing and emulation:** Examples - virtual memory with paging multiplexes real memory and disk; a virtual address emulates a real address.

Layering and virtualization

Section 5.2

Layering and Virtualization

Layering – a common approach to manage system complexity:

- Simplifies the description of the subsystems; each subsystem is abstracted through its interfaces with the other subsystems
- Minimises the interactions among the subsystems of a complex system
- With layering we are able to design, implement, and modify the individual subsystems independently

Layering in a computer system:

- **Hardware**
- **Software**
  - § Operating system
  - § Libraries
  - § Applications

Interfaces

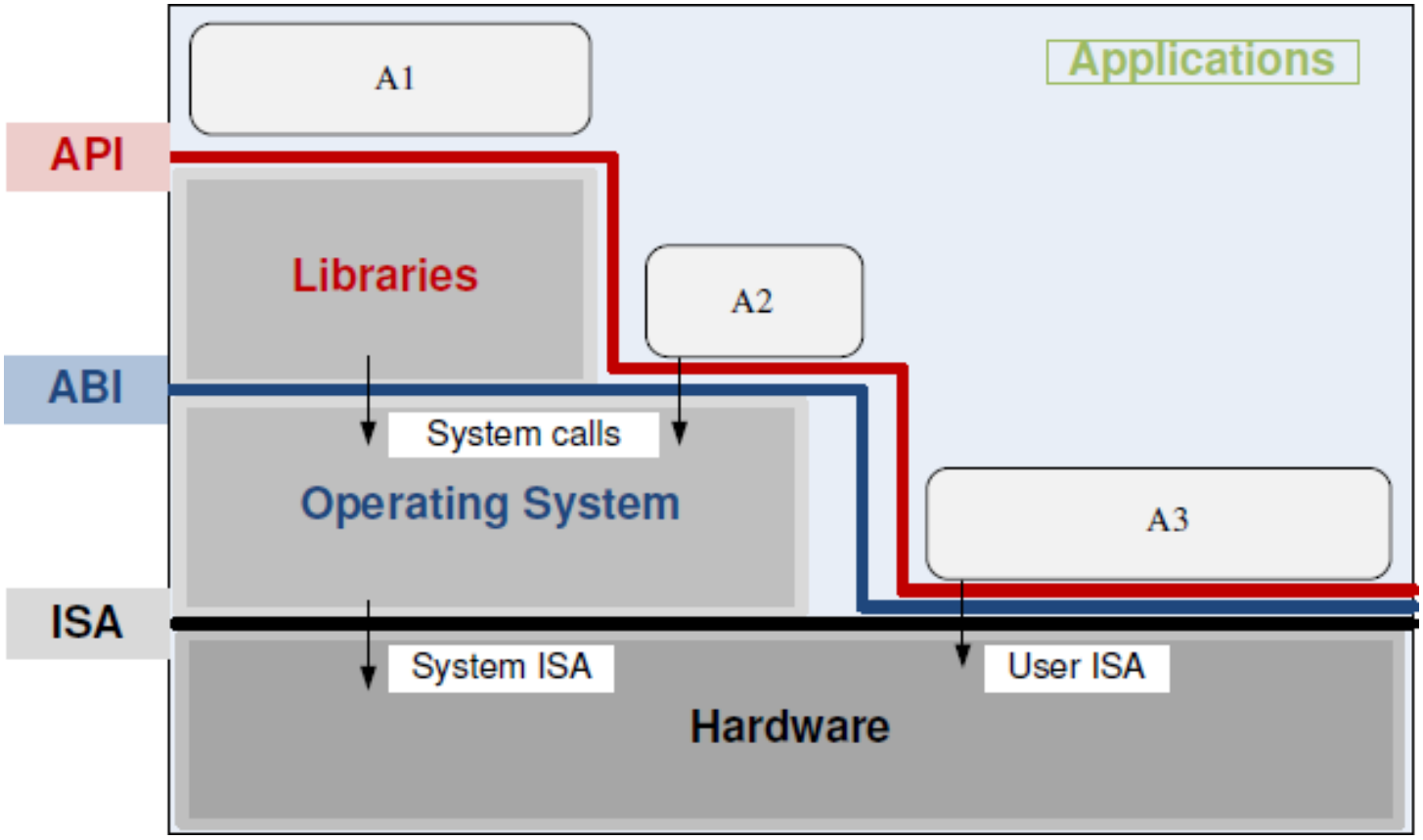
- **Instruction Set Architecture** (ISA) – at the boundary between hardware and software.
- **Application Binary Interface** (ABI) – allows the ensemble consisting of the application and the library modules to access the hardware; the ABI does not include privileged system instructions, instead it invokes system calls.

An application binary interface (ABI) is a set of rules that **dictate how two pieces of software communicate with each other**. It is a low-level interface that defines how software components interact with each other, and it is used to ensure that different software components can work together.

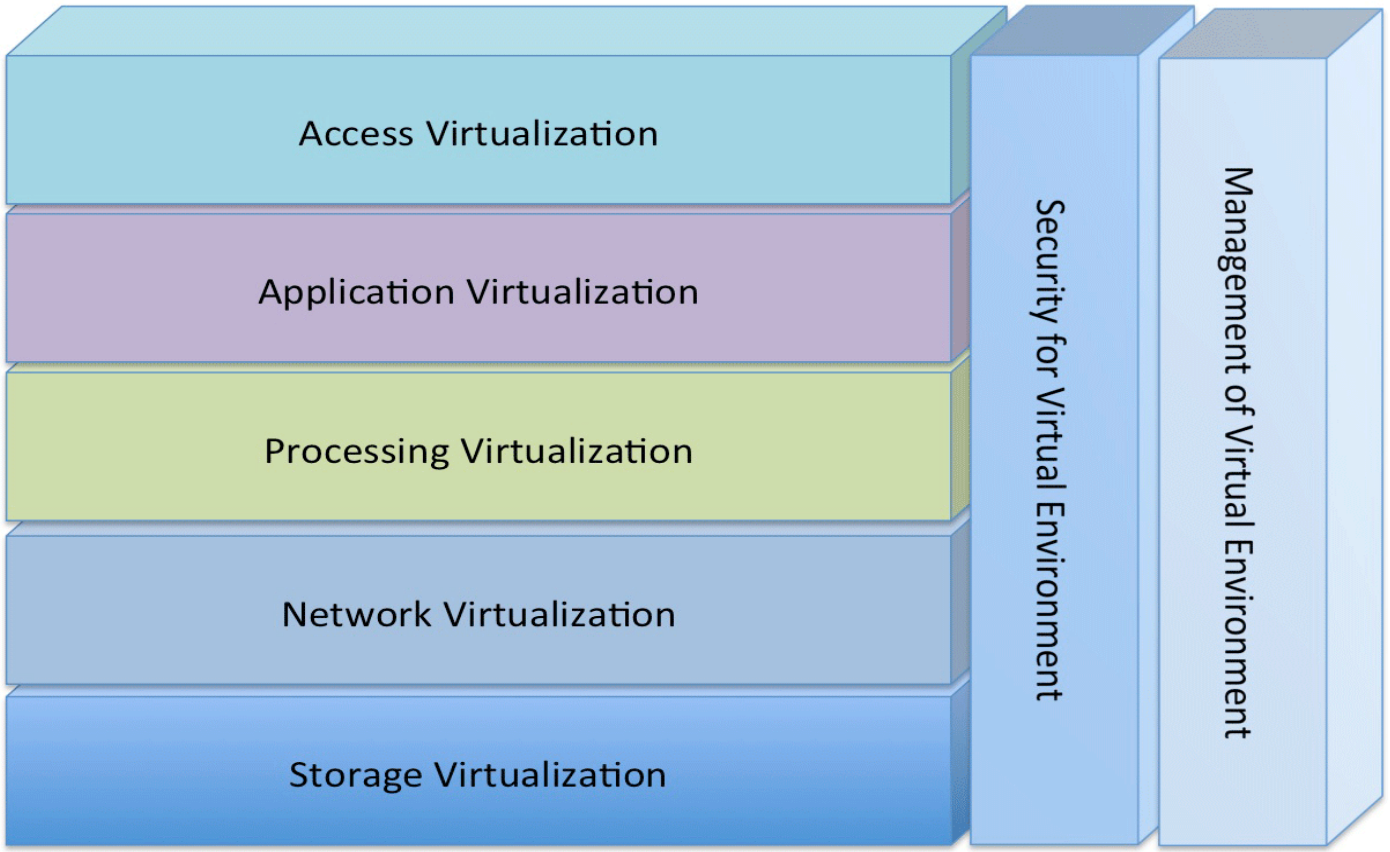
System Call: It provides an interface between user programs and operating systems.

- **Application Program Interface** (API) - defines the set of instructions the hardware was designed to execute and gives the application access to the ISA; it includes HLL library calls which often invoke system calls.

Layering and virtualization

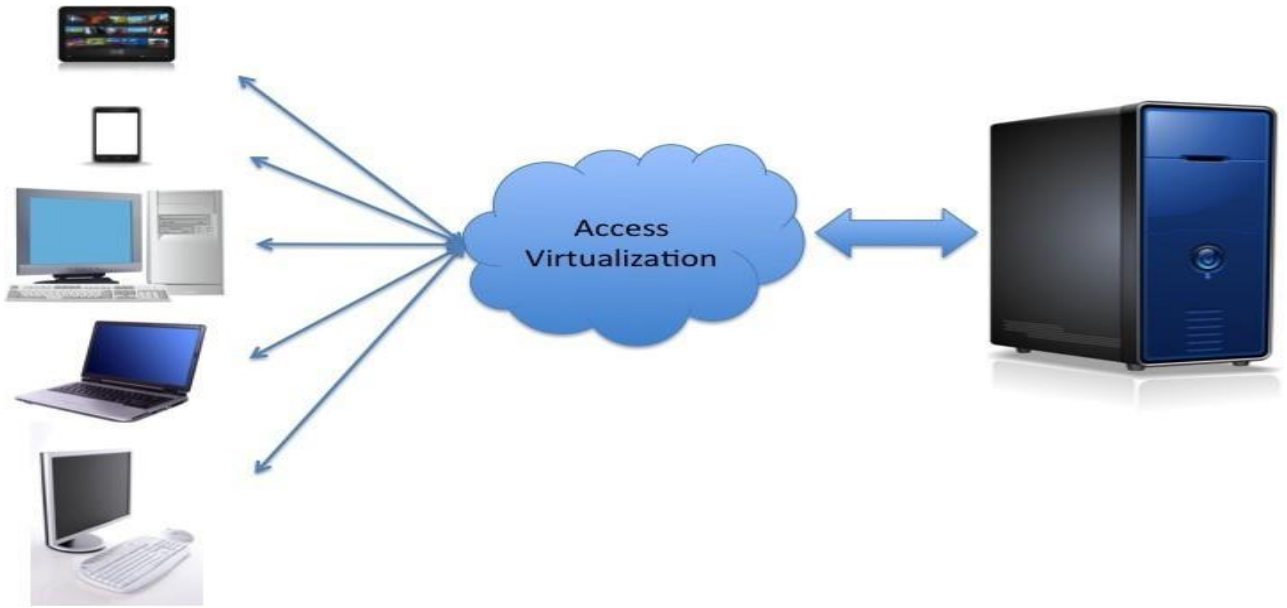


The 7-Layer Virtualization Model



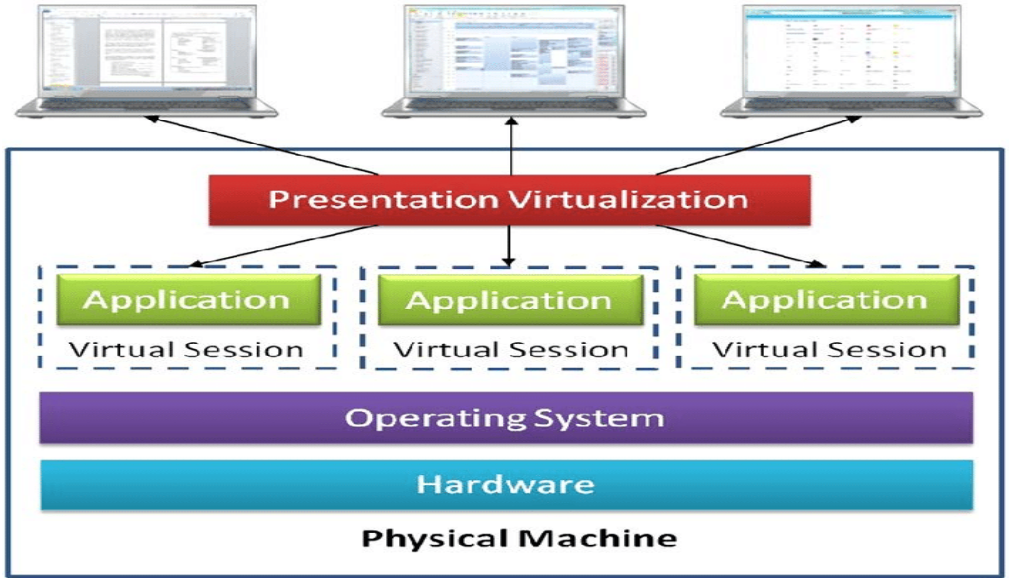
Virtualization Layer 1: access virtualization

- **Virtualization Layer 1:** Allows applications to work with remote client devices without change, even though those remote devices were never been thought of or available when the application was written. This is called *access virtualization*.
- XenDesktop from Citrix is an example of products that work in this layer of virtualization.



Virtualization Layer 2: application virtualization

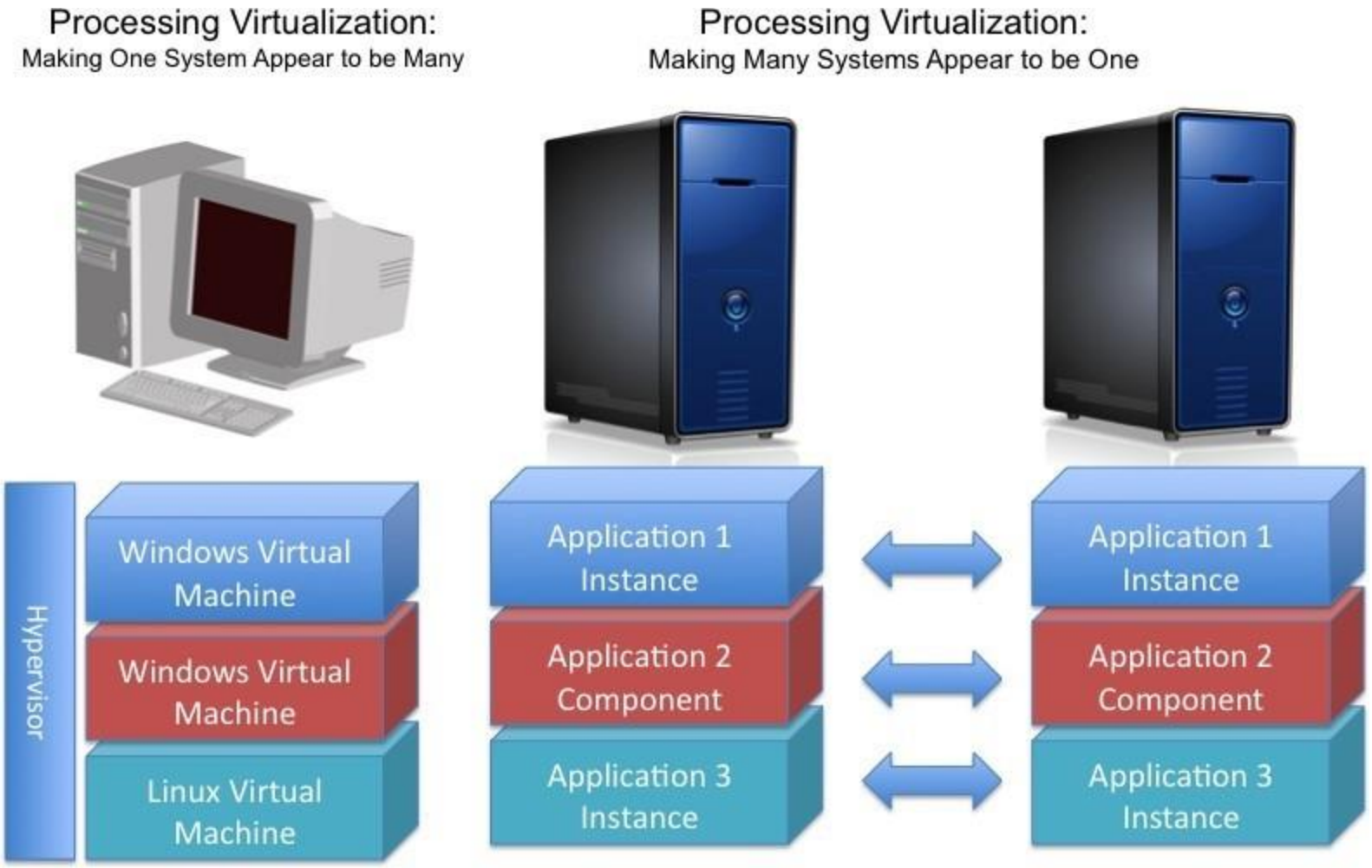
- Allows applications written for one OS version or OS to happily execute in another environment; this environment can be a new OS version or an entirely different OS. This is called *application virtualization*.
- This type of software would make it possible for an application written for Windows XP to work just fine on Windows 7 or Windows 8. AppZero fits into this layer of virtualization, as does XenApp from Citrix, App-V from Microsoft and VMware ThinApp



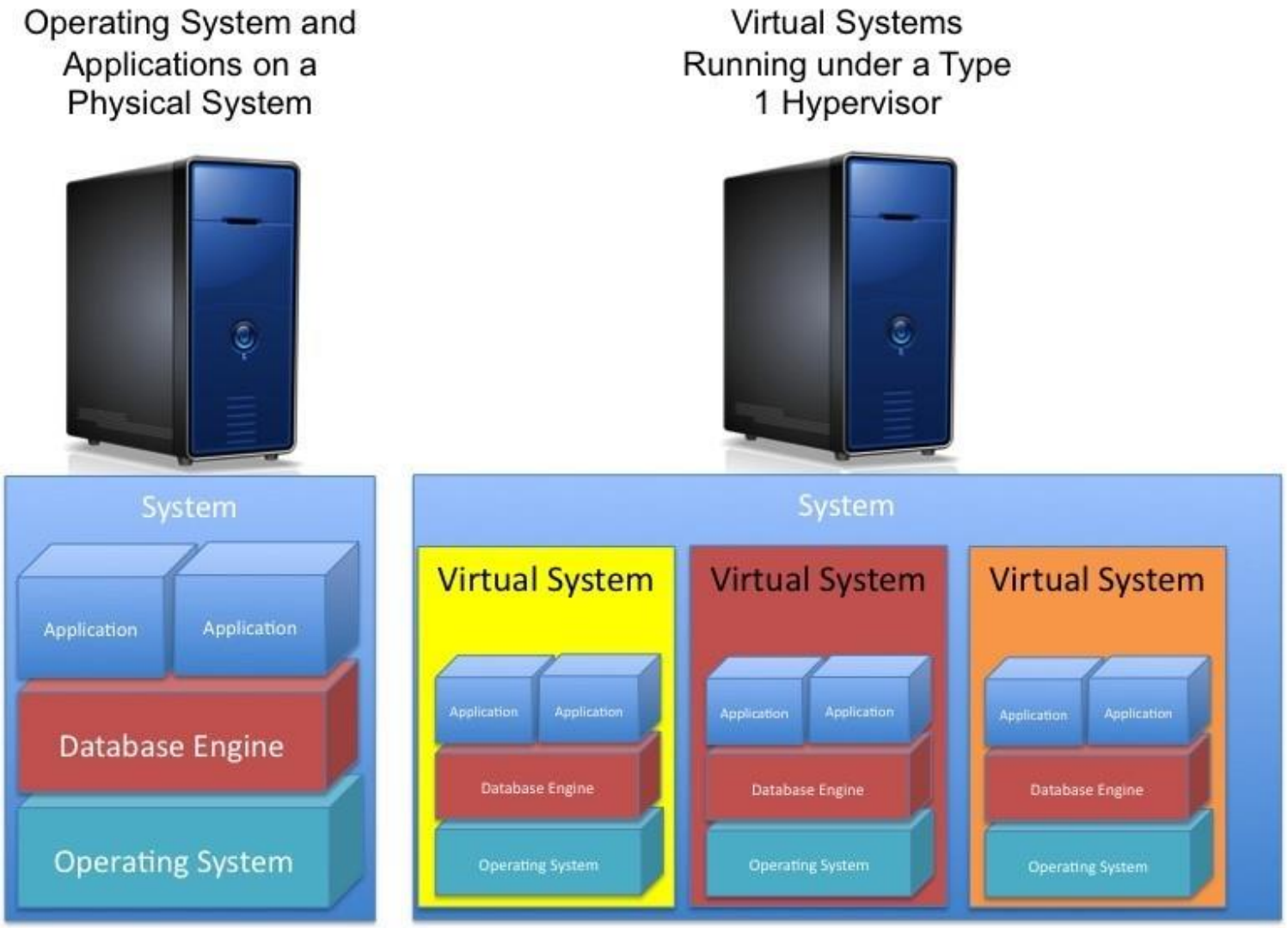
Virtualization Layer 3: processing virtualization

- Allows one system to support workloads as if it was many systems, or allows one workload to run across many systems as if it was a single computing resource.This is called *processing virtualization* .
- VM software is one of five different types of software that live at this layer. One of today's hottest catch phrases, software-defined datacenter (SDDC), is basically the use of this type of software, combined with a couple of other virtualization layers.
- Citrix XenServer, Microsoft Hyper-V and VMware vServer are all examples of VM software that lives in this layer of virtualization. Adaptive Computing Moab and IBM Platform Computing LSF are both examples of cluster managers that also live at this layer of virtualization.

Virtualization Layer 3 : processing virtualization



Virtualization Layer 3 : processing virtualization



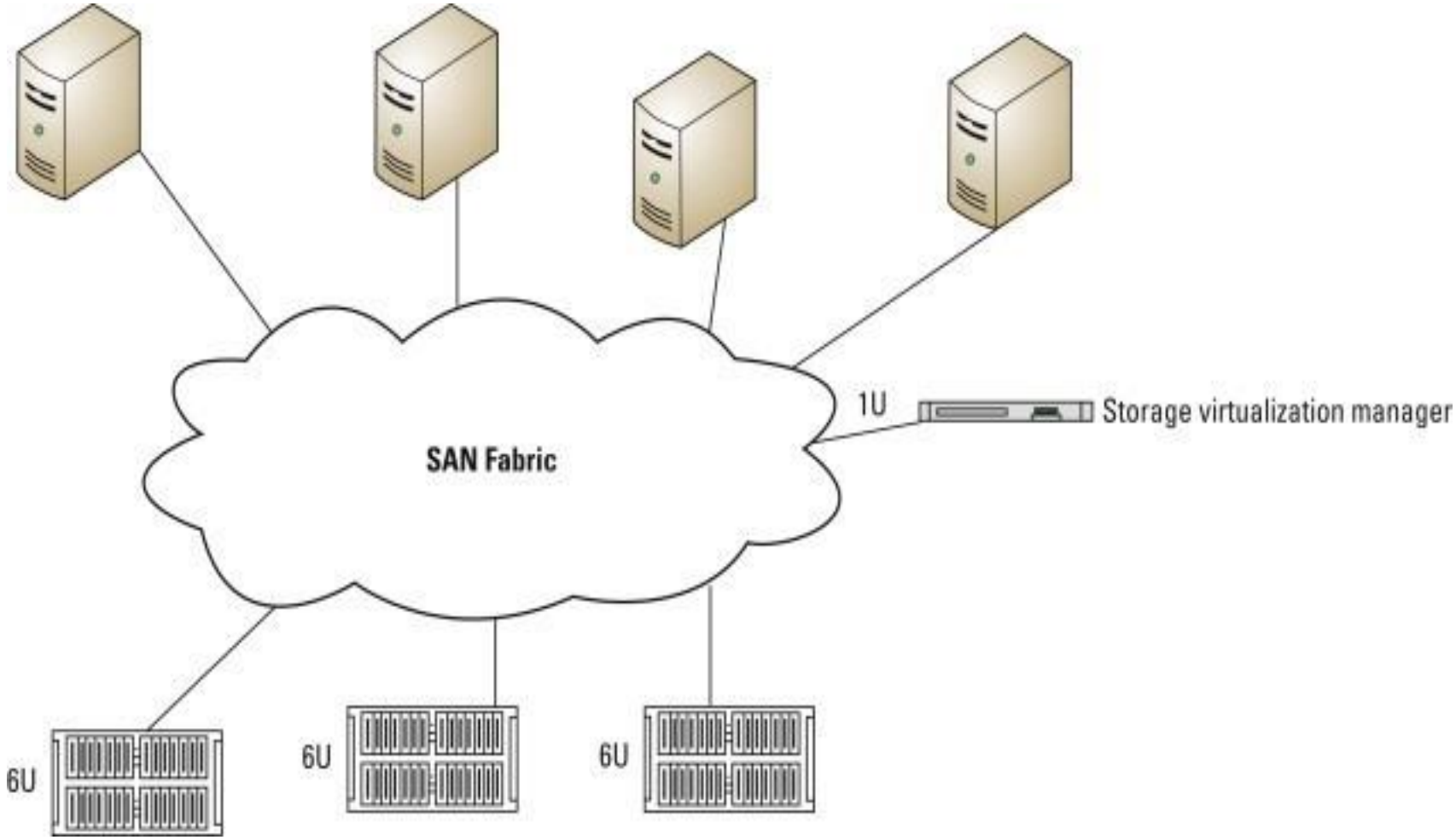
Virtualization Layer 4: storage virtualization

- Allows workloads to access storage without having to know where the data is stored, what type of device is storing the data, or whether the storage is attached directly to the system hosting the workload, to a storage server just down the LAN, or to storage in the cloud. This is called *storage virtualization*.
- Another one of today's most talked-about catch phrases, software-defined storage (SDS), is an example of this technology. Open-E DSS(data storage software), Sanbolic clustered storage, DataCore SANsymphony-V and VMware VSAN are examples of storage virtualization technology

What is vSAN in virtualization?

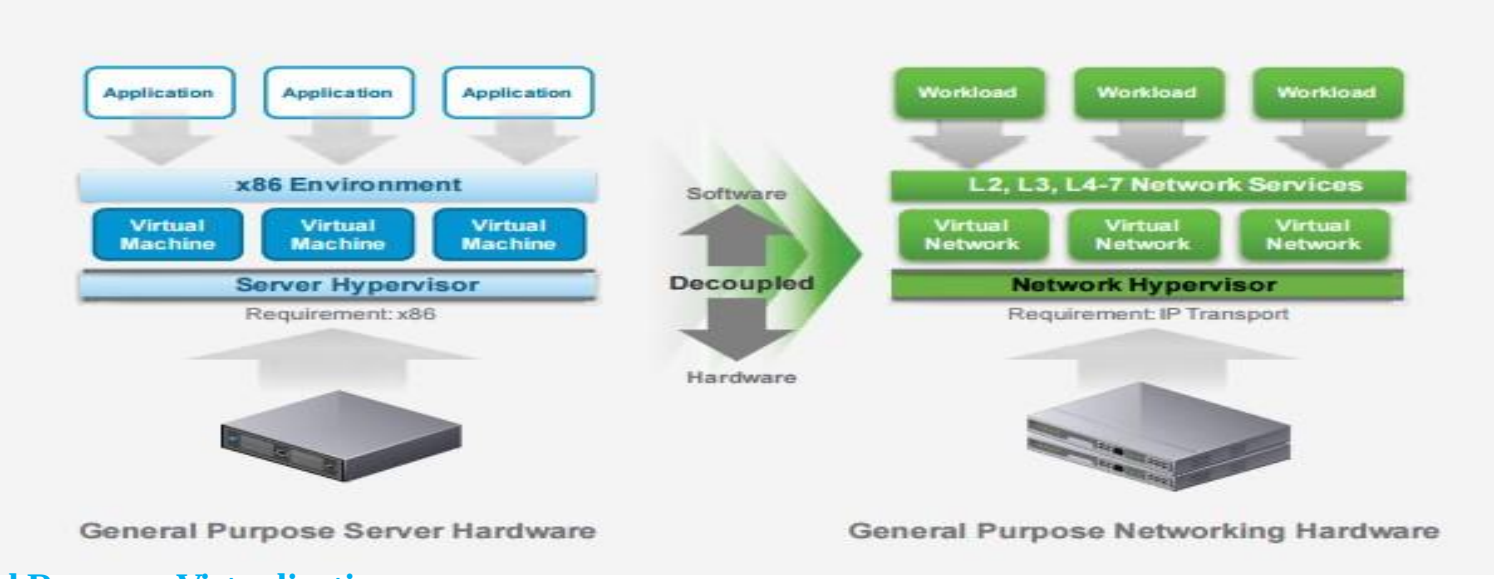
A virtual storage area network (VSAN) is **a logical partition in a physical storage area network (SAN)**. VSANs enable traffic to be isolated within specific portions of a storage area network, so if a problem occurs in one logical partition, it can be handled with a minimum of disruption to the rest of the network

Virtualization Layer 4: storage virtualization



Virtualization Layer 5: network virtualization

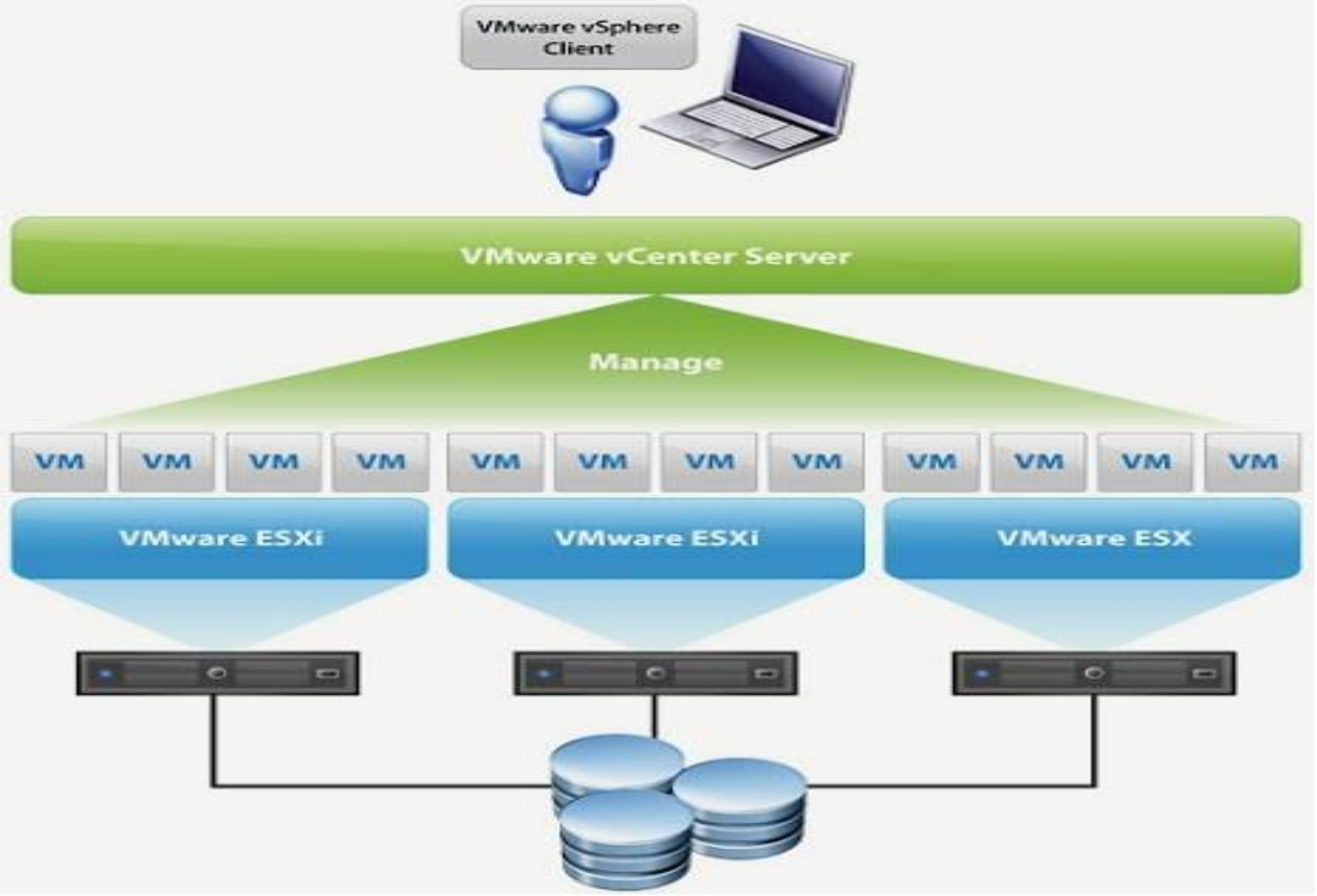
- Allows systems to work with other systems safely and securely, without having to care too much about the details of the underlying network.This is called *network virtualization* .
- Yet another current catchphrase, software-defined networking (SDN), is an implementation of network virtualization.
- Products that offer network virtualization include the Cisco Extensible Network Controller (XNC) and Juniper Contrail



Virtualization Layer 6: management of virtualized environments

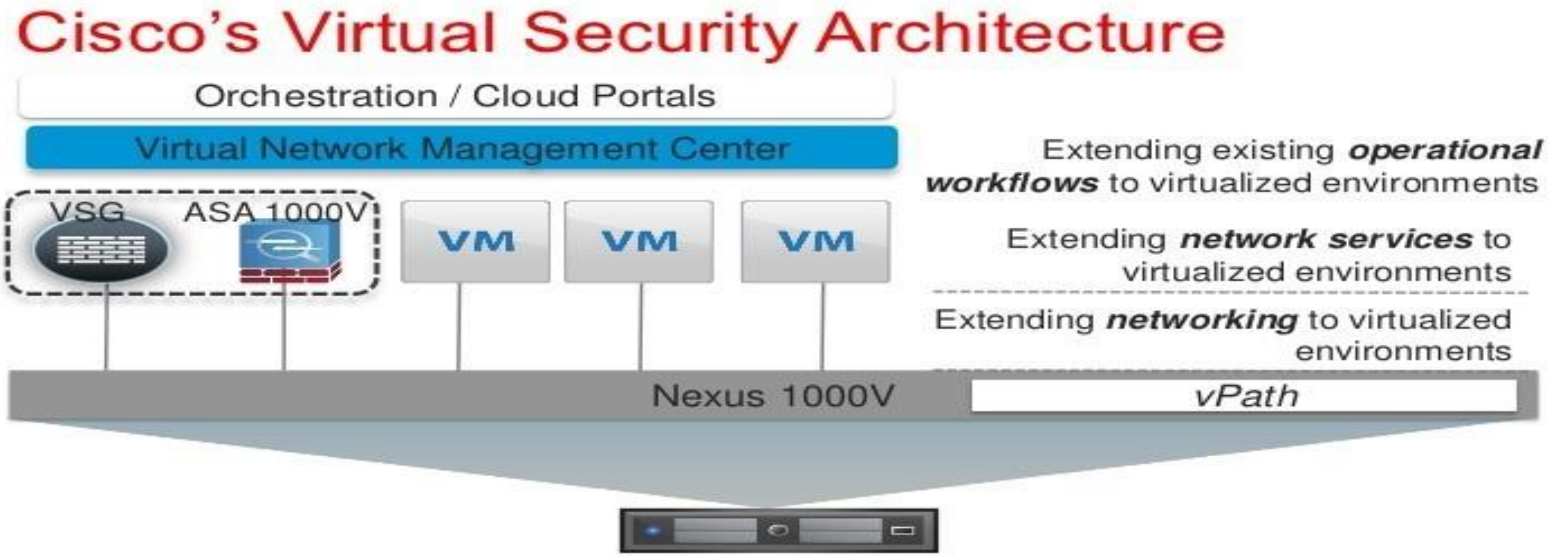
- Allows IT administrators and operators to easily monitor and manage virtual environments across boundaries.
- The boundaries can include the physical location of systems; OSes in use; applications or workloads in use; network topology; storage implementation; and how client systems connect to the applications. This is called *management of virtualized environments* in the model.
- This, by the way, is an important part of SDN, SDS and SDDC. A whole host of companies, including AppNeta, BMC, CA, HP and IBM, offer management and monitoring software.

Virtualization Layer 6: management of virtualized environments

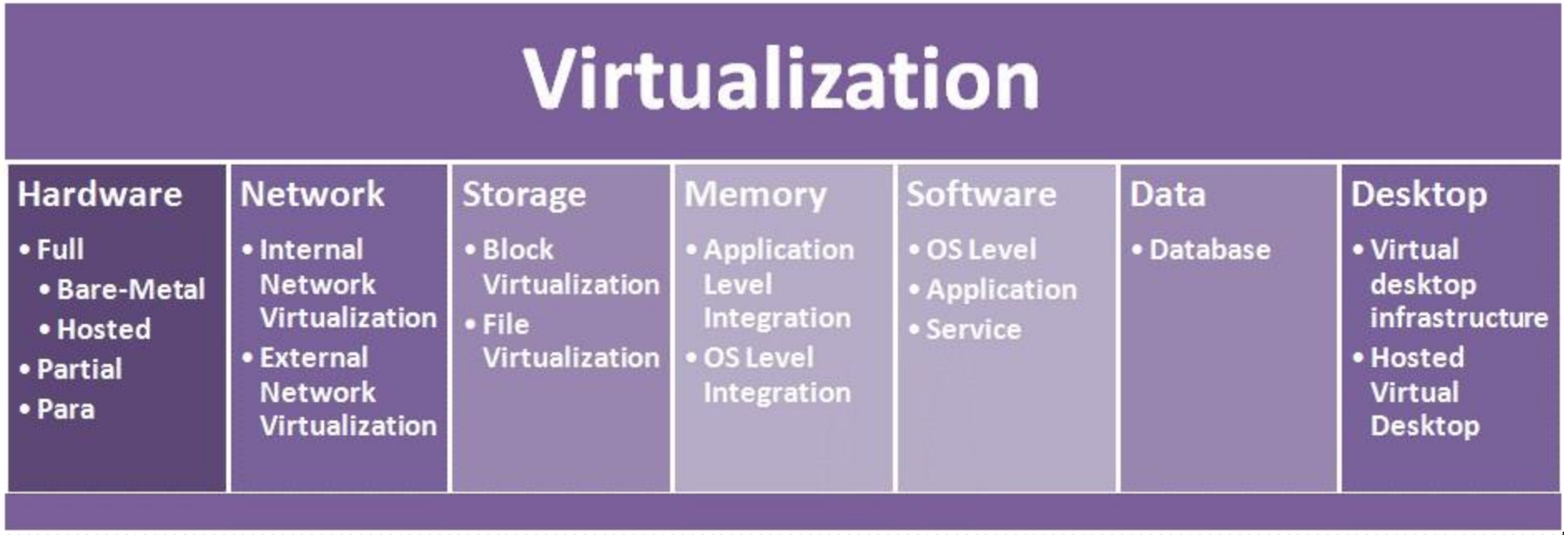


Virtualization Layer 7: security for virtualized environments

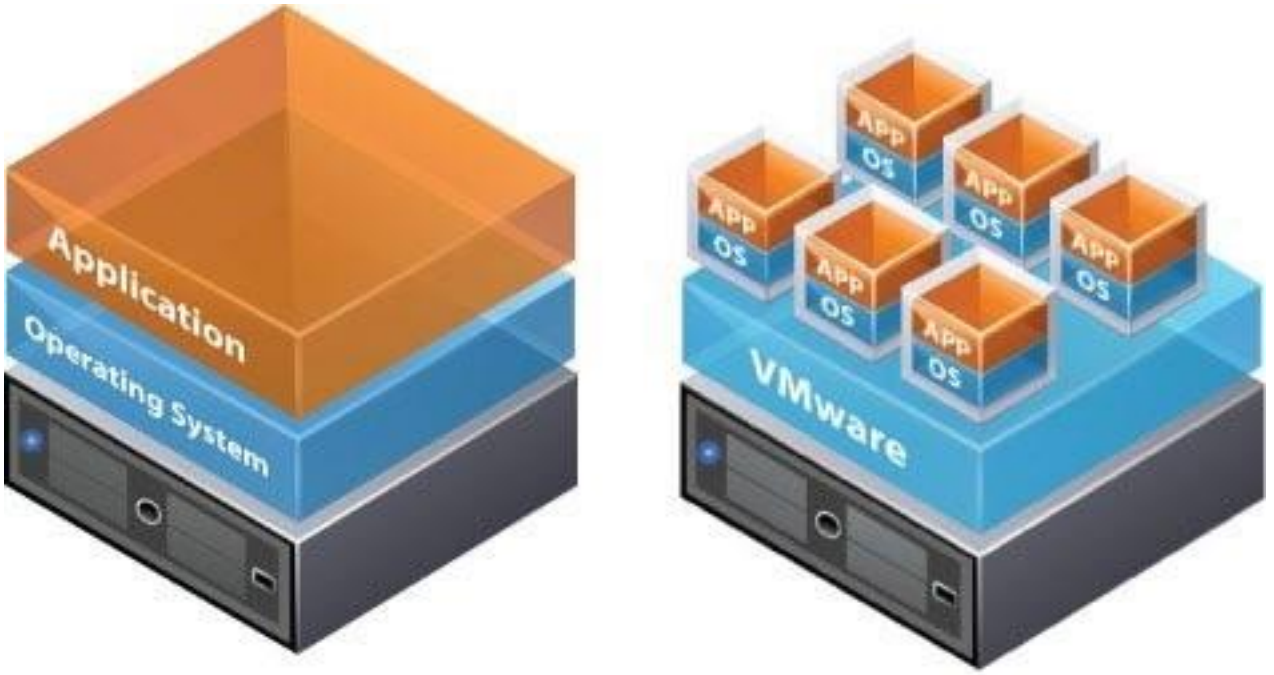
- Monitors and protects all of the other layers of virtualization so that only authorized use can be made of the resources. Yes, this is called *security for virtualized environments* in the model. As with management of virtualized environments, this layer is an important part of SDN, SDS and SDDC.
- Bitdefender, Kaspersky, TrendMicro, McAfee and many others play in this area of the virtualization market.



Types of Virtualization in Cloud Computing



Virtualization in Cloud Computing



Traditional Architecture

Virtual Architecture

Virtualization associated with computing technologies

1. **Hardware virtualization or Server virtualization**: the partitioning a physical server into smaller virtual servers.
2. **Network virtualization**: using network resources through a logical segmentation of a single physical network.
3. **Storage virtualization**: the amalgamation of multiple network storage devices into what appears to be a single storage unit.
4. **Memory Virtualization :**

Virtualization associated with computing technologies

5. **Software Virtualization:**

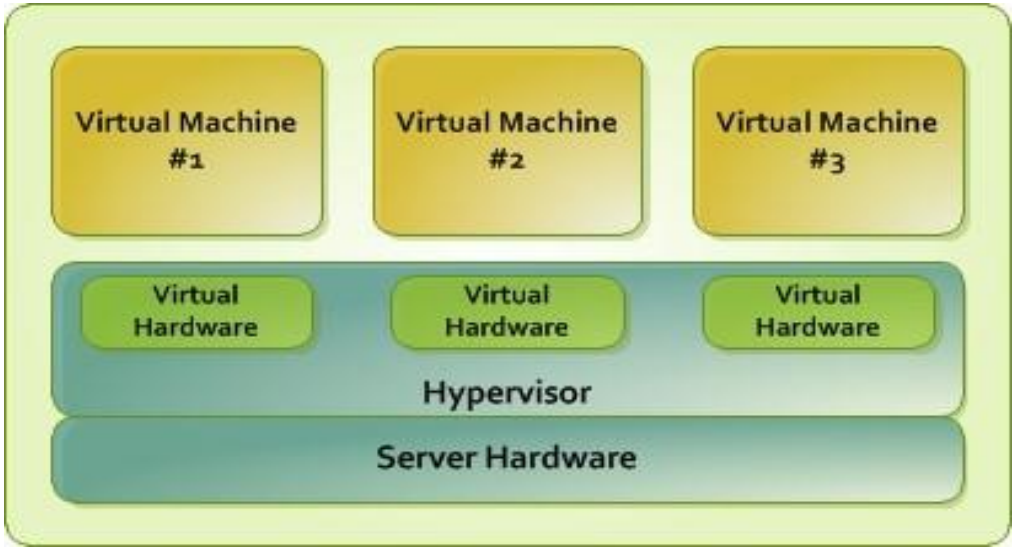
5. **Data Virtualization:**

5. **Desk Top Virtualization**

1: Hardware virtualization

1: Hardware virtualization

- Hardware virtualization, which is also known as *server virtualization* or simply **virtualization**, is the abstraction of computing resources from the software that uses those resources.
- The basic logic behind **hardware virtualization** is to integrate many small services into a large physical server so that it can **use** more effectively and providing the service efficiently. Here, the operating system which runs on the physical server convert into an operating system which works inside the virtual machine.



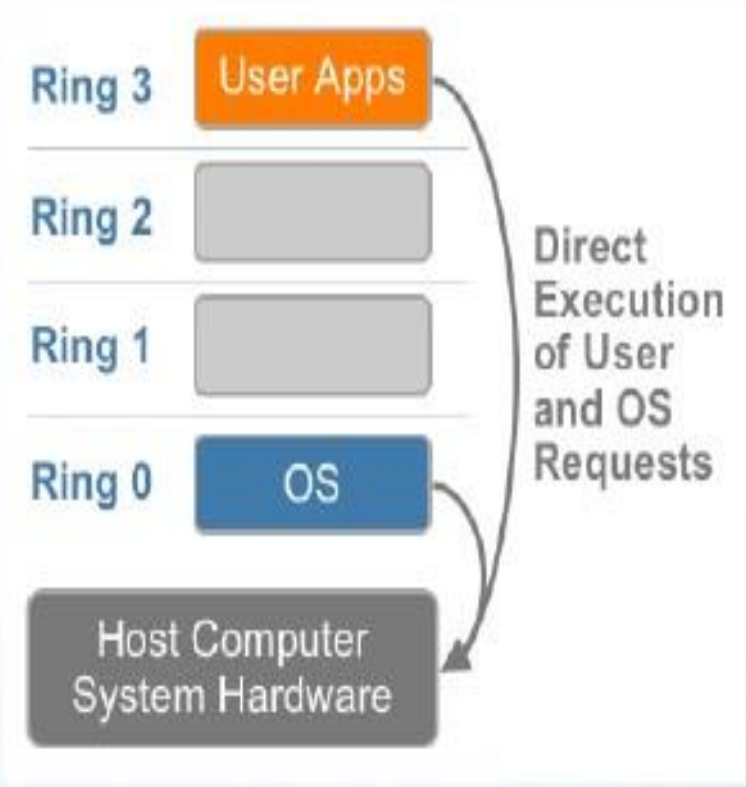
1: Hardware virtualization

- **Types of Hardware Virtualization**

1. Full Virtualization: Here the hardware architecture is completely simulated. …
2. **Emulation** Virtualization: Here the virtual machine simulates the hardware & is independent. …
3. Para-Virtualization: Here, the hardware is not simulated; instead the guest software runs its isolated system.

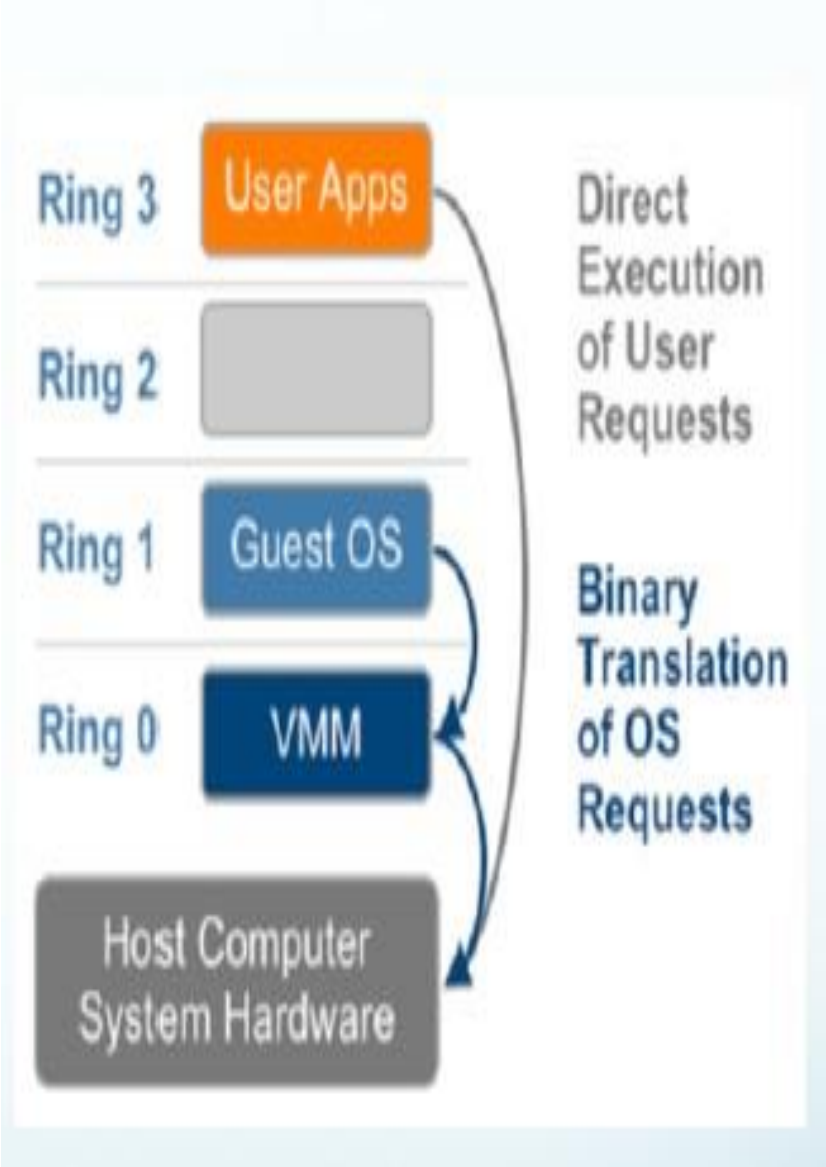
Virtualizing privileged instruction

- x86 architecture has four privilege levels (rings).
- The OS assumes it will be executing in Ring 0.
- Many system calls require 0-level privileges to execute.
- Any virtualization strategy must find a way to circumvent this.



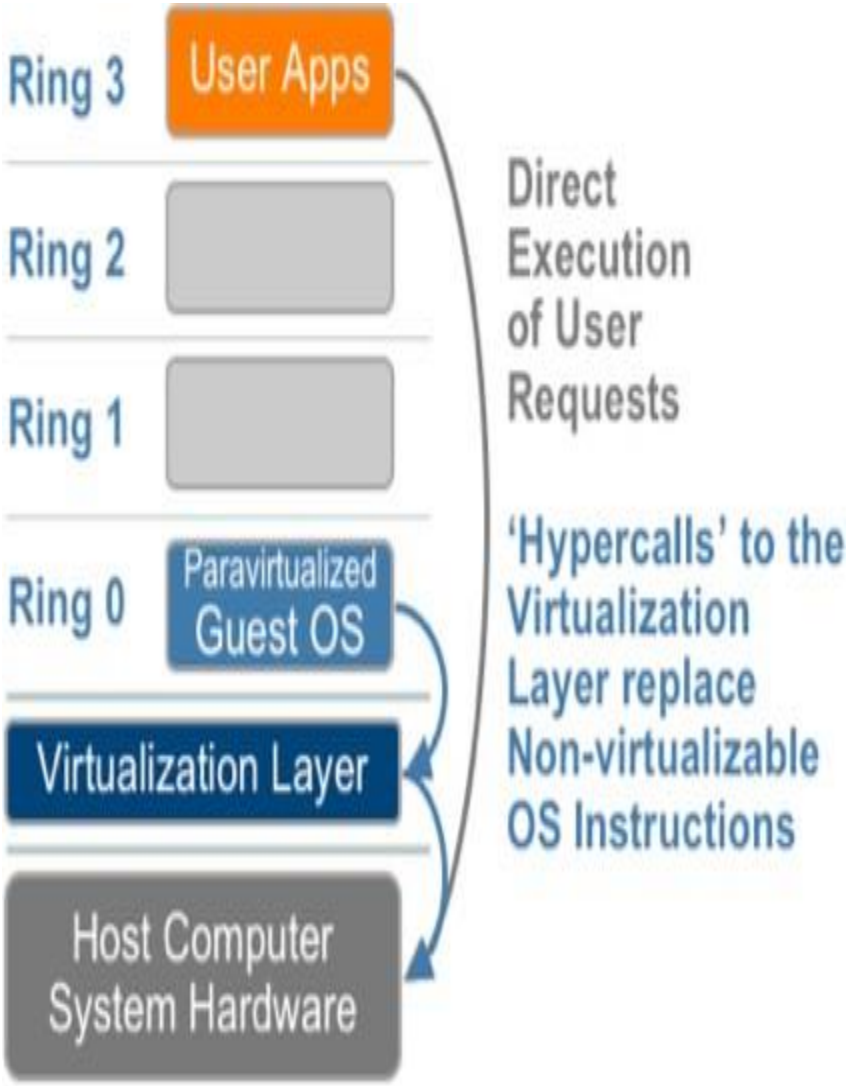
Full Virtualization

- "Hardware is functionally identical to underlying architecture."
- Typically accomplished through interpretation or binary translation.
- **Advantage:** Guest OS will run without any changes to source code.
- **Disadvantage:** Complex, usually slower than paravirtualization.



Paravirtualization

- Replace certain unvirtualized sections of OS code with virtualization-friendly code.
- Virtual architecture "similar but not identical to the underlying architecture."
- Advantages: easier, lower virtualization overhead
- Disadvantages: requires **modifications to guest OS**



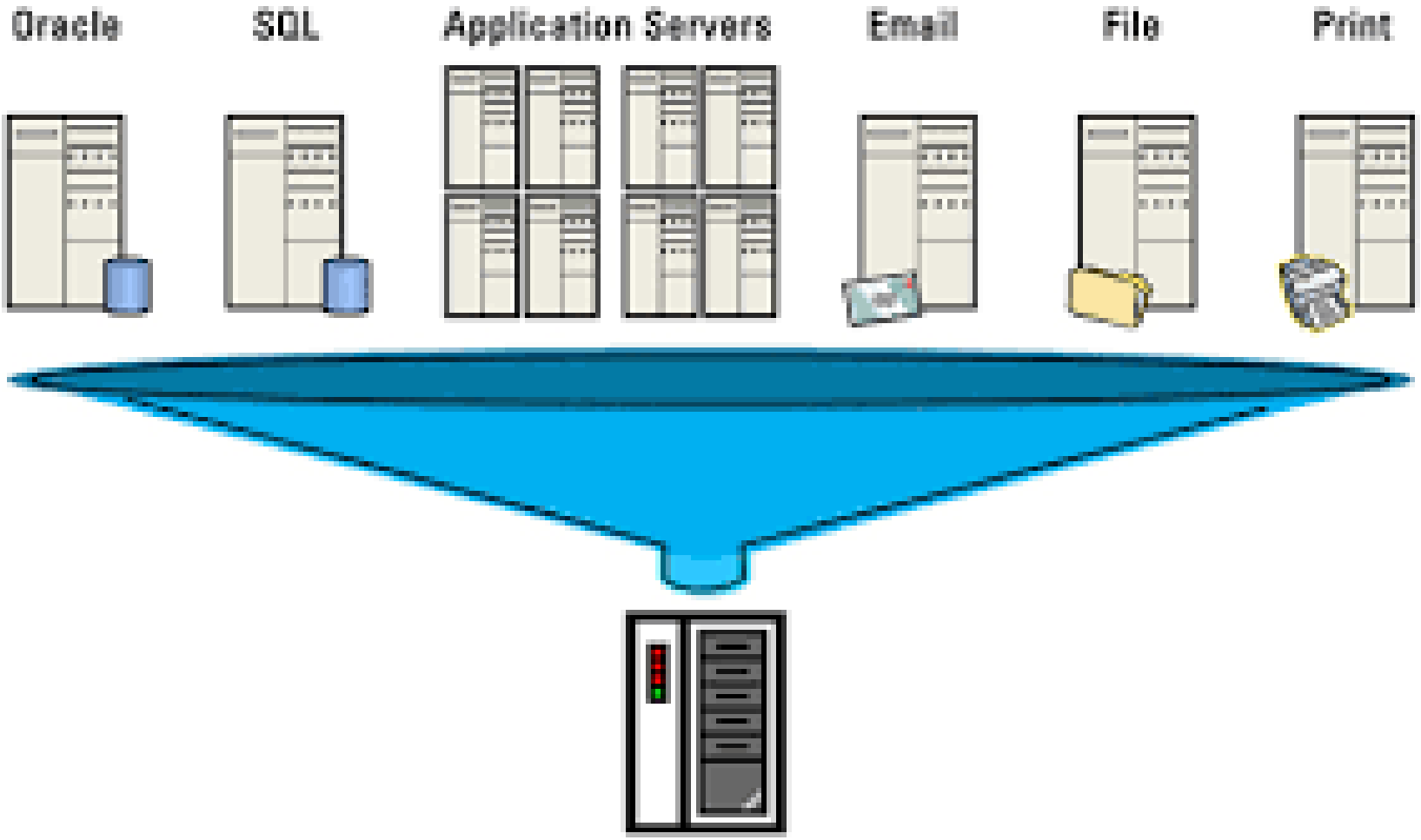
The benefits of hardware virtualization

- **Lower Cost**: Because of server consolidation, the cost decreases; now it is possible for multiple OS to exist together in a single hardware. This minimizes the quantity of rack space, reduces the number of servers and eventually drops the power consumption.
- **Efficient resource utilization**: Physical resources can be shared among virtual machines. The unused resources allocated by one virtual machine can be used by another virtual machine in case of any need.
- **Increase IT flexibility**: The quick development of hardware resources became possible became possible using virtualization, and the resources can be managed consistently also.
- **Advanced Hardware Virtualization features:** With the advancement of modern hypervisors highly complex operations maximize the abstraction of hardware & ensure maximum uptime, and this technique helps to migrate an ongoing virtual machine from one host to another host dynamically.

1: Server virtualization

- Server virtualization is the masking of server resources (including the number and identity of individual physical servers, processors, and operating systems) from server users.
- The intention is to spare the user from having to understand and manage complicated details of server resources while increasing resource sharing and utilization and maintaining the capacity to expand later.
- The **server** administrator uses a software application to divide one physical **server** into multiple isolated virtual environments.

1: Server virtualization



1: Hardware virtualization

Hardware virtualization vendors and products

- **VMware ESXi** is a hypervisor designed for hardware virtualization. ESXi installs directly onto a server and has direct control over a machine's underlying resources. ESXi will run without an OS and includes its own kernel. ESXi is the compact, and now preferred, version of VMware's ESX. ESXi is smaller and doesn't contain the ESX service console.
- **Microsoft Hyper-V** is a hypervisor designed for hardware virtualization on an x86 architecture. Hyper-V isolates VMs in partitions, where each guest OS will execute a partition. Partitions operate in the manner of parent and child partitions. Parent partitions have direct access to the hardware, while child partitions have a virtual view of system resources. Parent partitions create child partitions using a hypercall API. Hyper-V is available for 64-bit versions of Windows 8 Professional, Enterprise, Education and later.
- **Xen** is an open source hypervisor. Xen is included in the Linux kernel and is managed by the Linux Foundation. However, Xen is only supported by a small amount of Linux distributions, such as SUSE Linux Enterprise Server. The software supports full virtualization, paravirtualization and hardware-assisted virtualization. XenServer is another open source Xen product to deploy, host and manage VMs.

2 :Network virtualization

2 : Network virtualization

- Ne**twork virtualization** is the process of combining hardware and software **network** resources and **network** functionality into a single, software-based administrative entity, a virtual **network**.
- **Network virtualization** involves platform **virtualization**, often combined with resource **virtualization**.
- **Network virtualization** is a method of combining the available resources in a **network** by splitting up the available bandwidth into channels, each of which is independent from the others, and each of which can be assigned (or reassigned) to a particular server or device in real time.

2 : Network virtualization

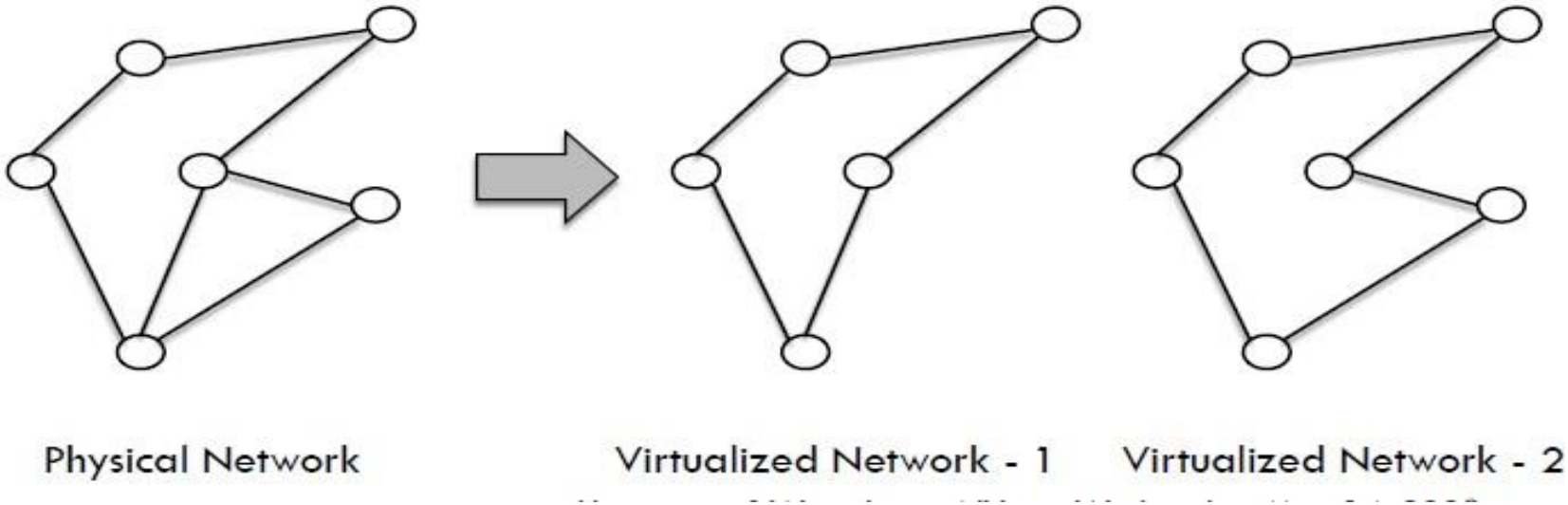
- In network virtualization, multiple sub-networks can be created on the same physical network, which may or may not is authorized to communicate with each other.
- This enables restriction of file movement across networks and enhances security, and allows better monitoring and identification of data usage which lets the network administrator's scale up the network appropriately.
- It also increases reliability as a disruption in one network doesn't affect other networks, and the diagnosis is easier.

Subtypes:

- Internal network: Enables a single system to function like a network
- External network: Consolidation of multiple networks into a single one, or segregation of a single network into multiple ones

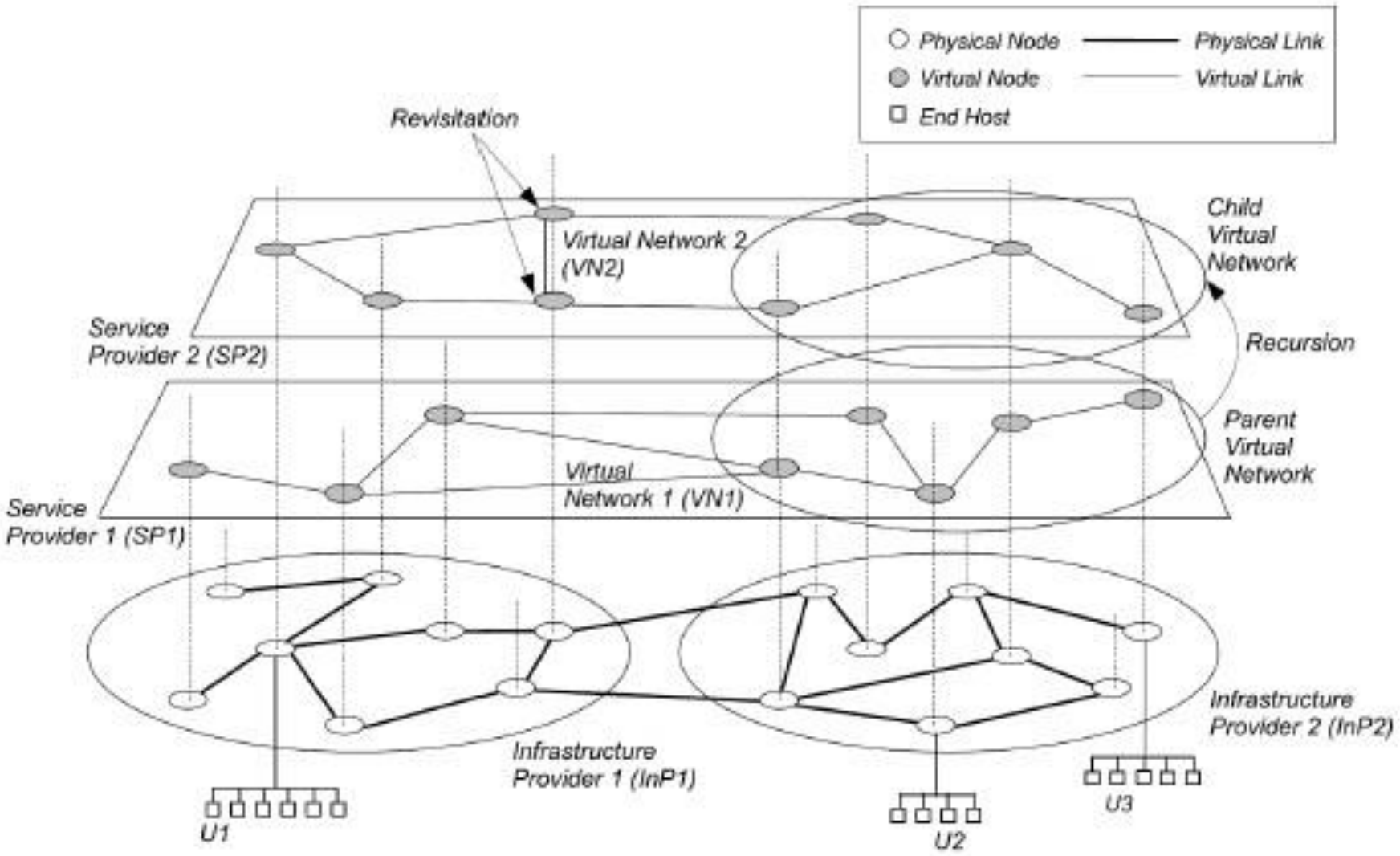
2: Network virtualization

Making a physical network appear as multiple logical ones



- The idea is that virtualization disguises the true complexity of the network by separating it into manageable parts, much like your partitioned hard drive makes it easier to manage your files.

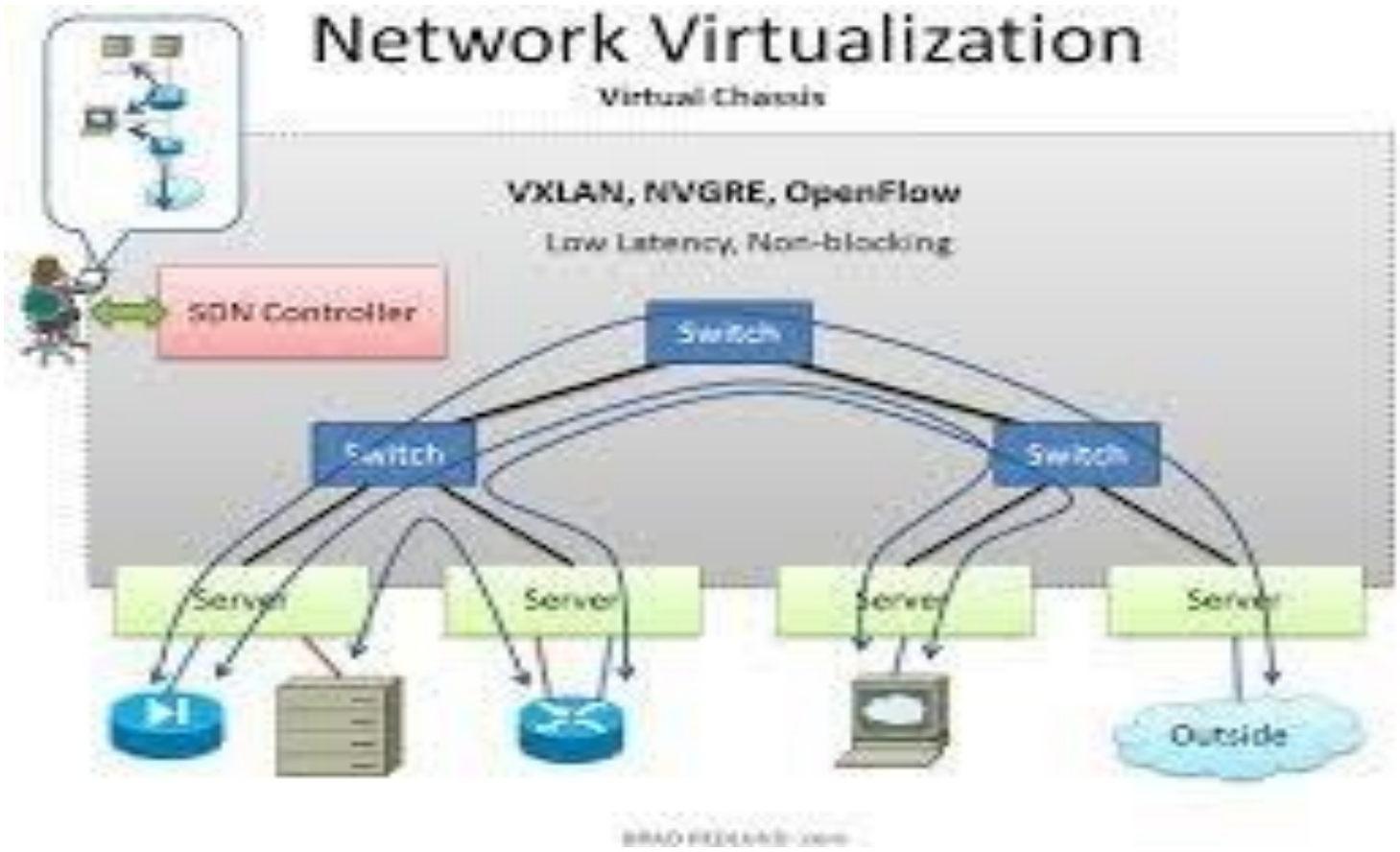
2: Network virtualization



2 : Network virtualization

- Network virtualization in cloud computing is a method of combining the available resources in a network by splitting up the available bandwidth into different channels, each being separate and distinguished.
- They can be either assigned to a particular server or device or stay unassigned completely — all in real time.
- The idea is that the technology disguises the true complexity of the network by separating it into parts that are easy to manage, much like your segmented hard drive makes it easier for you to manage files.
- Network virtualization refers to the management and monitoring of a computer network as a single managerial entity from a single software-based administrator's console.

2: Network virtualization



3: Storage virtualization

3: Storage virtualization

- Storage virtualization is the pooling of physical storage from multiple network storage devices into what appears to be a single storage device that is managed from a central console.
- Storage virtualization is commonly used in storage area networks (SANs)
- A **Storage area network**, or SAN, is a high-speed **network** of **storage** devices that also connects those **storage** devices with servers.
- It provides block-level **storage** that can be accessed by the applications running on any networked servers.

3: Storage virtualization

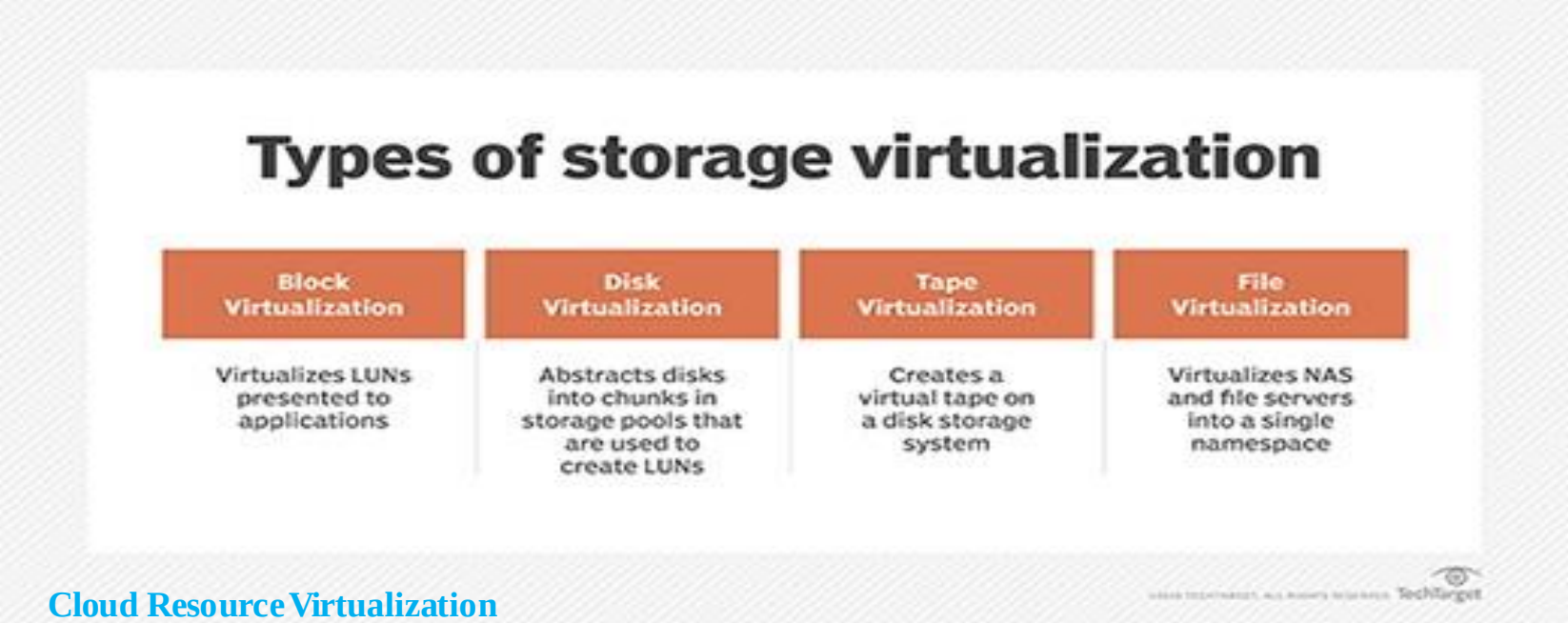
- Multiple physical storage devices are grouped together, which then appear as a single storage device. This provides various advantages such as homogenization of storage across storage devices of multiple capacity and speeds, reduced downtime, load balancing and better optimization of performance and speed.
- Partitioning your hard drive into multiple partitions is an example of this virtualization.

Subtypes:

- **Block Virtualization** – Multiple storage devices are consolidated into one
- **File Virtualization** – Storage system grants access to files that are stored over multiple hosts

3: Storage virtualization

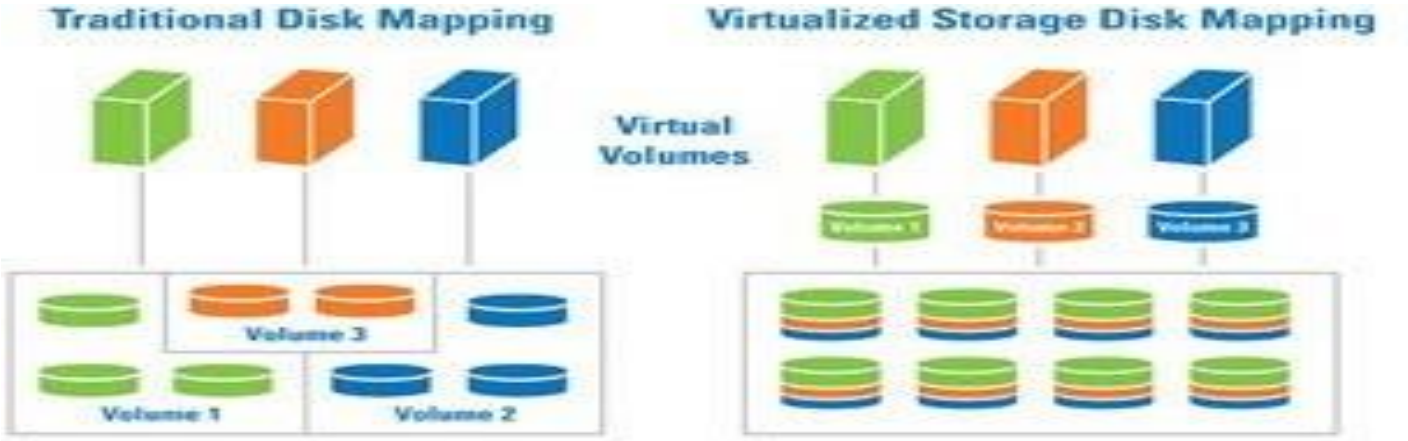
- **Storage virtualization** creates a **layer of abstraction between the operating system** and the physical disks used for data **storage**.
- For example, the **storage virtualization** software or device creates a logical space, and then manages metadata that establishes a map between the logical space and the physical disk space.



Cloud Resource Virtualization

3: Storage virtualization

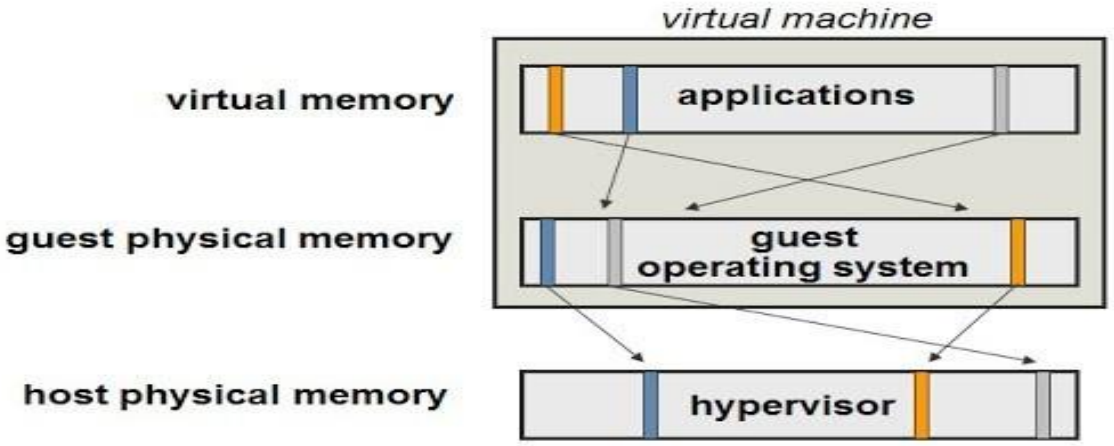
- Storage Virtualization is the concept of virtualizing enterprise storage at the disk level, creating a dynamic pool of shared storage resources available to all servers, all the time. With read/write operations spread across all drives, multiple requests can be processed in parallel, boosting system performance. This allows users to create hundreds of virtual volumes in seconds to support any virtual server platform and



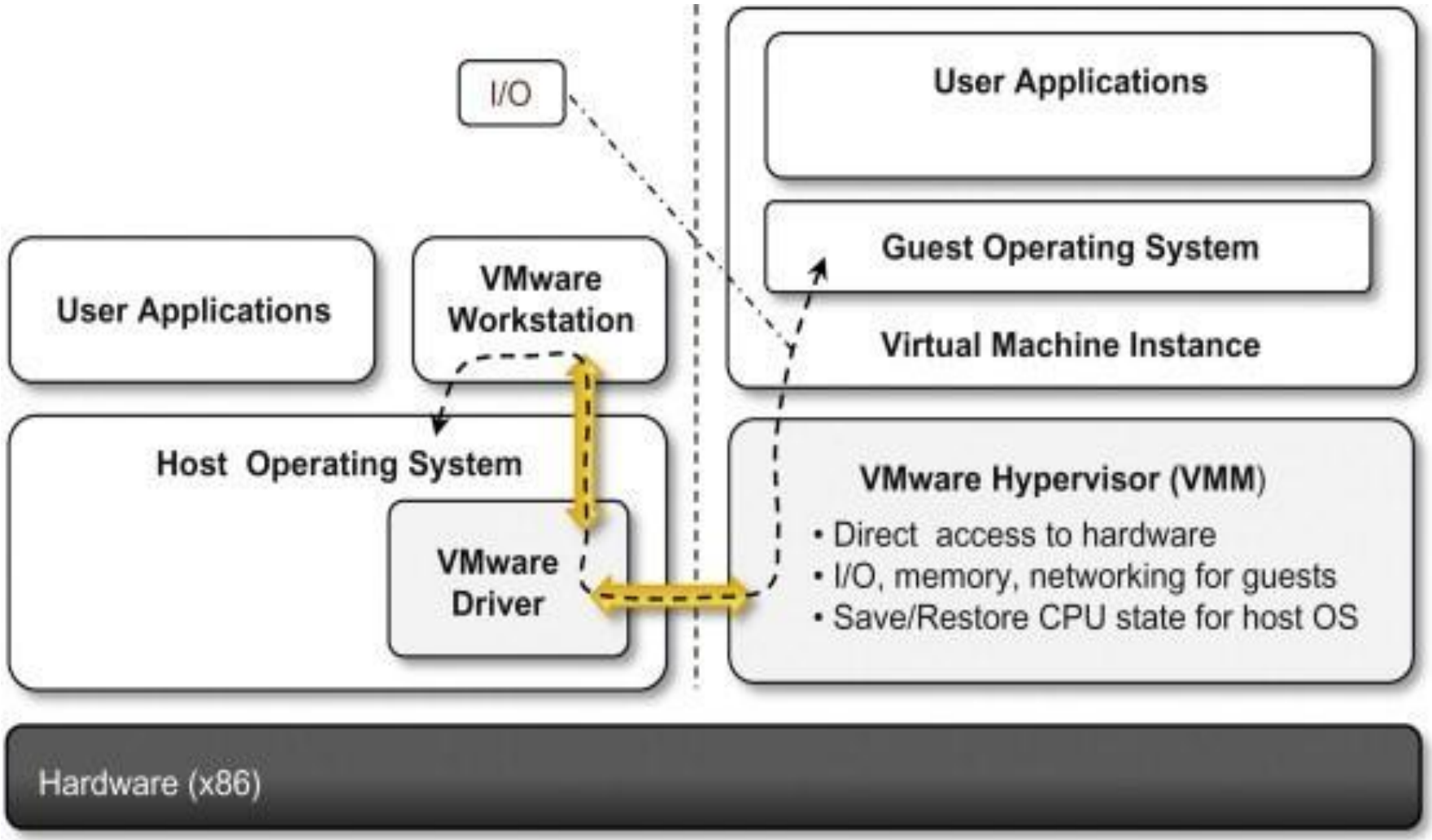
4: Memory Virtualization

4: Memory virtualization

- In computer science, memory virtualization decouples volatile random access memory resources from individual systems in the Data Centre, and then aggregates those resources into a virtualized memory pool available to any computer in the cluster.
- It introduces a way to decouple memory from the server to provide a shared, distributed or networked function.
- It enhances performance by providing greater memory capacity without any addition to the main memory. That's why a portion of the disk drive serves as an extension of the main memory.



4: Memory virtualization



4: Memory Virtualization

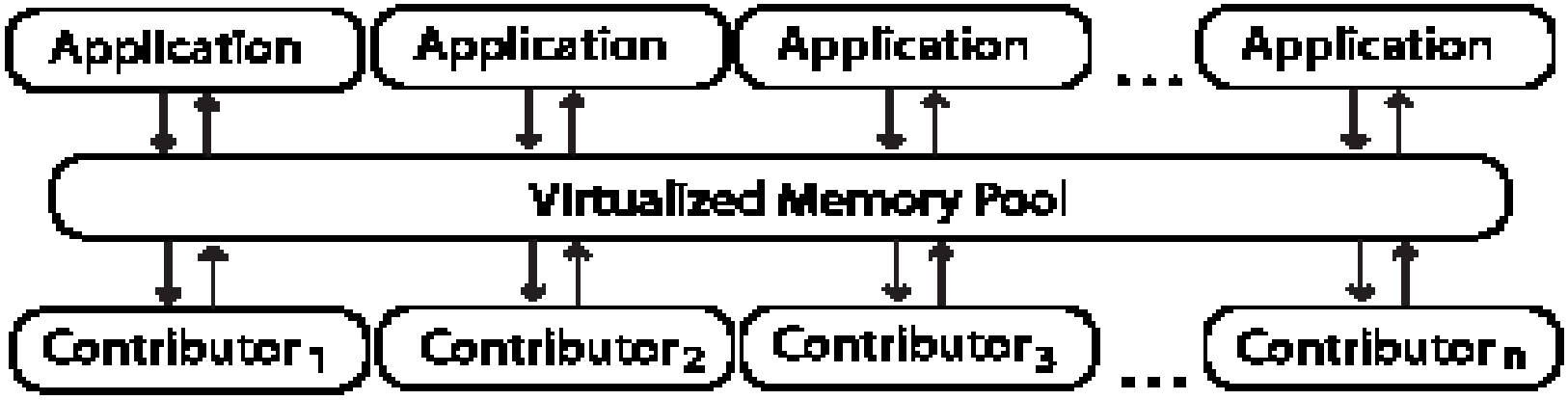
- Physical memory across different servers is aggregated into a single virtualized memory pool.
- It provides the benefit of an enlarged contiguous working memory. You may already be familiar with this, as some OS such as Microsoft Windows OS allows a portion of your storage disk to serve as an extension of your RAM.

Subtypes:

- **Application-level control** – Applications access the memory pool directly
- **Operating system level control** – Access to the memory pool is provided through an operating system

4: Memory virtualization: Implementation

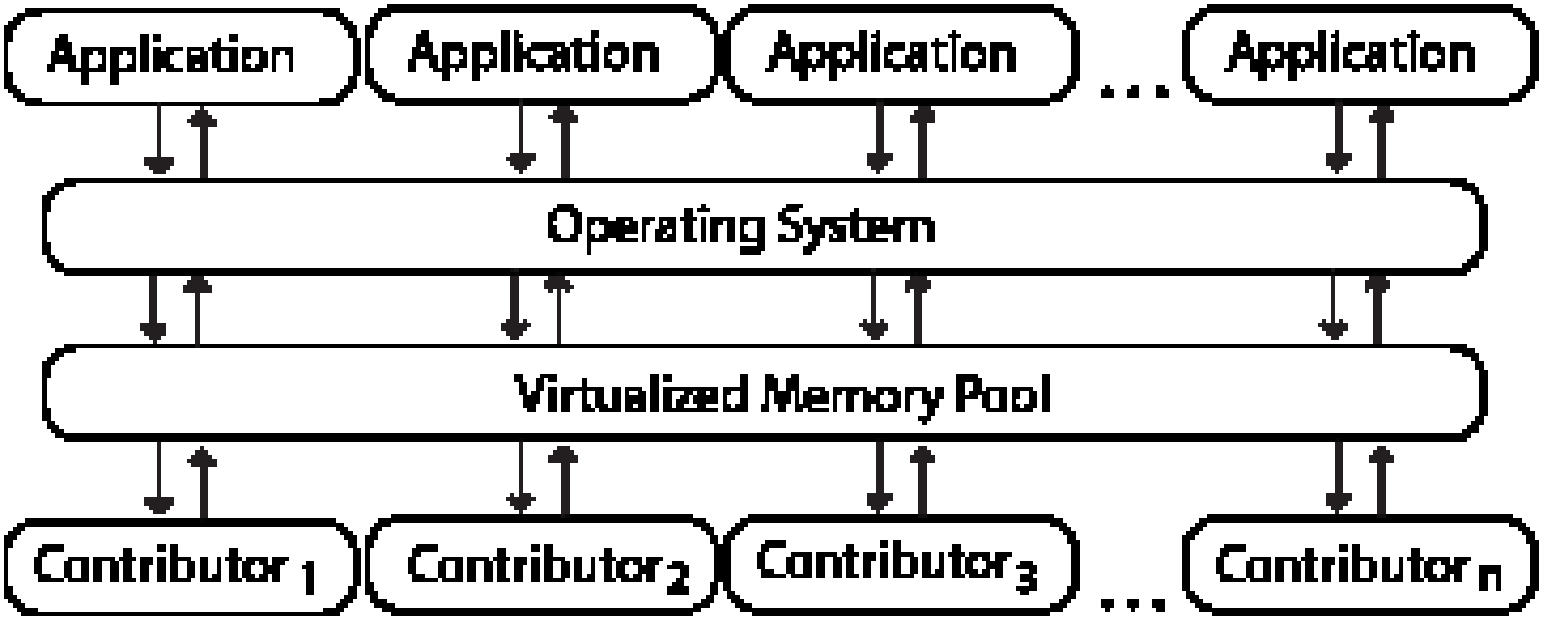
- **Application-level integration –** Applications running on connected computers directly connect to the memory pool through an API or the file system.



Memory Virtualization: Application Level Implementation

4: Memory virtualization: Implementation

- **Operating System-Level Integration –** The operating system first connects to the memory pool and makes that pooled memory available to applications



Memory Virtualization: Addressable Memory Implementation

5: Software virtualization

5: Software virtualization

- Software **Visualization in Cloud Computing** allows the single computer server to run one or more virtual environments. It is quite similar to virtualizations but here it abstracts the software installation procedure and creates a virtual software out of it.
- In software virtualizations, an application will be installed which will perform the further task. One software is physical while others are virtual as it allows 2 or more operating system using only one computer.
- Software virtualization is similar to that of **virtualization** except that it is capable to abstract the **software** installation procedure and create virtual **software** installation.
- It is also called **application virtualization** is the practice of running **software** from a remote server.

5: Software virtualization

It creates a computer system complete with hardware that lets the guest operating system to run. For example, it lets you run **Android** OS on a host machine natively using a Microsoft Windows OS, utilizing the same hardware as the host machine does

Benefits of Software Virtualization

Testing

- It is easier to test the new operating system and software on VMs as it does not require any additional hardware and the testing can do within the same software. After the testing, the VM can move or delete for the further testing.

Utilization

- In software virtualization, there is higher efficiency in resource utilization if it tunes correctly. The VM can modify as per the requirement such as the user can modify ram, drive space, etc. It requires very less amount of hardware as compared to the equivalent number of physical machines.

Efficient

- It is efficient in a way such that it can run 12 virtual machines and eliminates the use of 12 physical boxes. This is the power cost as well as the cost of maintaining the server.

Benefits of Software Virtualization

Less Downtime

- The software is upgrading and the upgrade in the VMs can do when the VM is working. VM can modify when it is working or it is not working which means that the downtime of it is very less.

Flexible

- It provides flexibility to the user so that the user can modify the software as per their demand. The modification can do within minutes and can adjust easily when the workload changes.

Secure

- It can protect with many hantaviruses. Moreover, there are several firewalls which prevent hacking and virus. The data in the software virtualization is safe as it stores in several different places so if the disaster takes place the data can retrieve easily.

How Software Virtualization in Cloud Computing Works?

- **Backup:** With the help of software virtualization, the entire **operating system** or server installation can be backed up. This also benefits in a way that if the new server hack just restoring the previous version will allow running the server.
- **Run multiple operating systems:** The different operating system can use in a single computer with the partition in the hard drive. The only thing to keep in mind is to keep a snapshot of everything. If the data drowns, it can retrieve from some other place.
- **Running a different version of applications**: With the help of software virtualization new as well as the old operating system can use. So a program, if it is not working on a particular operating system, we can check it on another one.
- **Templates:** After the configuration of VM as per the demand, it can convert into a template and this template can use to make multiple copies of the original one.

5: Type of Software virtualization

i. Operating System Virtualization

ii. Application Virtualization

iii. Service Virtualization

i. Operating System Virtualization

- In operating system virtualization, the hardware is used which consists of software on which different operating systems work. Here, the operating system does not interfere with each other so that each one of them works efficiently.

ii. Application Virtualization

- Application virtualization is a technology, encapsulates the computer program within the operating system. It can say that application virtualizations refer to running an application on a thin client. This thin client runs an environment, which is different from what refer to as encapsulating from the operating system which is the location of it.

5: Type of Software virtualization

Service Virtualization

- In the service virtualization, the DevOps team can use the virtual servers rather than the physical one. It emulates the behaviour of essential components which will be present in the final production environment.
- With the help of service virtualization, the complex application can go through testing much earlier in the development process. It can say that service visualization is a technique to simulate the behaviour of some components in a mixture of component-based applications

5.1: Operating system virtualization

- Operating system virtualization is the use of software to allow a piece of hardware to run multiple operating system images at the same time.
- The technology got its start on mainframes decades ago, allowing administrators to avoid wasting expensive processing power.
- Operating system virtualization (OS virtualization) is a server virtualization technology that involves tailoring a standard operating system so that it can run different applications handled by multiple users on a single computer at a time.

5.2: Application virtualization

- **Application virtualization** is software technology that encapsulates **computer programs** from the underlying **operating system** on which it is executed.
- A fully **virtualized application** is not installed in the traditional sense, although it is still executed as if it were.
- The application behaves at runtime like it is directly interfacing with the original operating system and all the resources managed by it, but can be isolated or **sandboxed** to varying degrees.
- Application virtualization fools the computer into working as if the application is running on the local machine, while in fact it is running on a virtual machine (such as a server) in another location, using its operating system (OS), and being accessed by the local machine.

Application virtualization

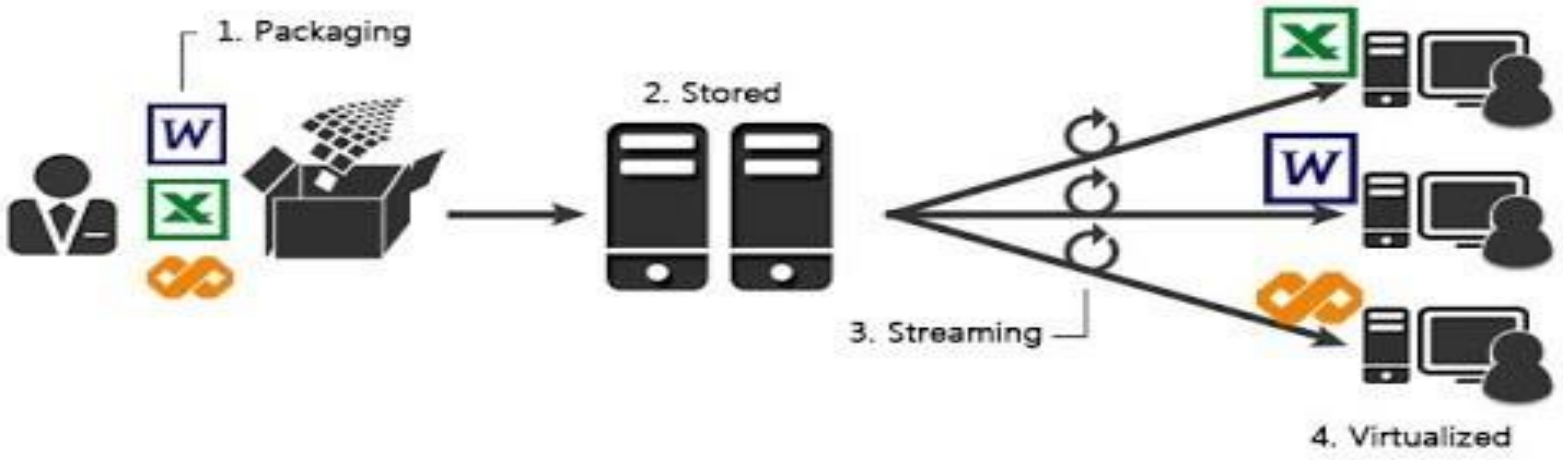
- Application virtualization, also called **application service virtualization**, is a term under the larger umbrella of virtualization.
- It refers to running an application on a thin client; a terminal or a network workstation with few resident programs and accessing most programs residing on a connected server.
- The thin client runs in an environment separate from, sometimes referred to as being encapsulated from, the operating system where the application is located.
- App virtualization (application virtualization) is the separation of an installation of an application from the client computer that is accessing it. There are two types of application virtualization: **remote** and **streaming**.

Application virtualization

- **Application virtualization** is a process that deceives a standard app into believing that it interfaces directly with an operating system's capacities when, in fact, it does not.
- This use requires a virtualization layer inserted between the app and the OS. This layer, or framework, must run an app's subsets virtually and without impacting the subjacent OS.
- The virtualization layer replaces a portion of the runtime environment typically supplied by the OS, transparently diverting files and registry log changes to a single executable file.
- By diverting the app's processes into one file instead of many dispersed across the OS, the app easily operates on a different device, and formerly incompatible apps can now run adjacently.
- Used in conjunction with application virtualization is **desktop virtualization**—the abstraction of the physical desktop environment and its related app software from the end-user device that accesses it.

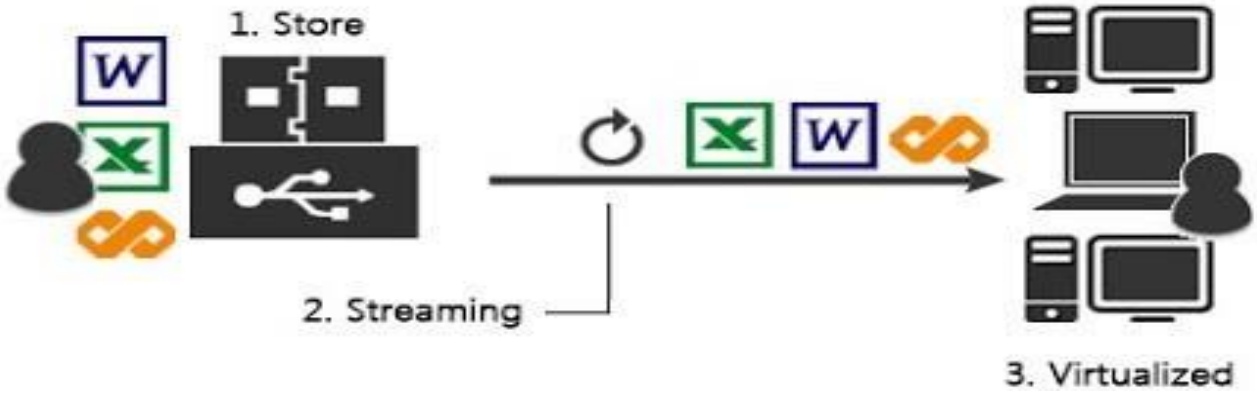
Application Virtualization from Servers

- Software pack is made by the pack builder, or it can be provided by service provider.
- The administrator uploads software packs on the server
- When the users launches the application, server streams it to the users in realtime.
- As the streaming process begins, the application is virtualized as if it is installled in the local machine.



Application Virtualization from a Portable Device

- Store the software pack on the device storage.
- When the user launches the application, the application gets streamed.
- As the streaming process begins, the user can use the software as if it is locally installed.



The advantages of application virtualization

- **No installation required:** Installing an application on hundreds or thousands of computers is prone to error. Application virtualization simplifies software deployment.
- **Application retirement simplified:** Getting rid of an app in your whole network is much easier as well. Since virtual apps just have to be deleted, uninstalling them is usually not required.
- **No more application conflicts:** Sometimes installing an app corrupts another app. Application virtualization helps reduce the risks of application conflicts.
- **No registry and system bloat:** The more apps you install on a desktop, the more bloated its registry and system folder will get. This makes the computer slower and increases the risk of failures. Application virtualization lets the registry and the system folder untouched.
- **End users require only minimal privileges:** Legacy apps that require admin rights usually work in environments where end-users only have standard rights.

The advantages of application virtualization

- **Multiple runtime environments:** You can deploy the runtime environment together with the application. This enables you to run different versions of a runtime environment on a desktop. For example, you can run different Java versions simultaneously without messing around with environment variables.
- **Multiple versions of the same application:** For instance, end users can run Word 2003 and Word 2007 at the same time.
- **Deploy apps on unmanaged computers:** If clients or partners have to use an app to access the services of your organization, you can just send them an executable where you have already configured everything for them.
- **Application updates:** You can update the virtualized application at a central location on your servers. This means you have to update an app only once and not on all of your desktops.

The advantages of application virtualization

- **Rollback:** If an app no longer works properly on a user's desktop because he or she changed too many settings or installed incompatible add-ons, you can just reset the app to its original state.
- **Simplified roaming:** Some products allow you to store settings and data belonging to the app in the virtual environment on a server or a memory stick. This way, end users can access their apps with their own settings regardless on which desktop they logon. This is also possible if you are not working with roaming user profiles.
- **Simplified OS deployment:** Deploying a new OS in your network doesn't affect the applications. Also, if you have to reinstall an image on a desktop, you don't have to worry about the apps running on this machine because end users can just access them on the server.
- **Integration with desktop virtualization:** Software virtualization and desktop virtualization perfectly harmonize because these technologies allow you to separate the OS deployment process from software distribution.

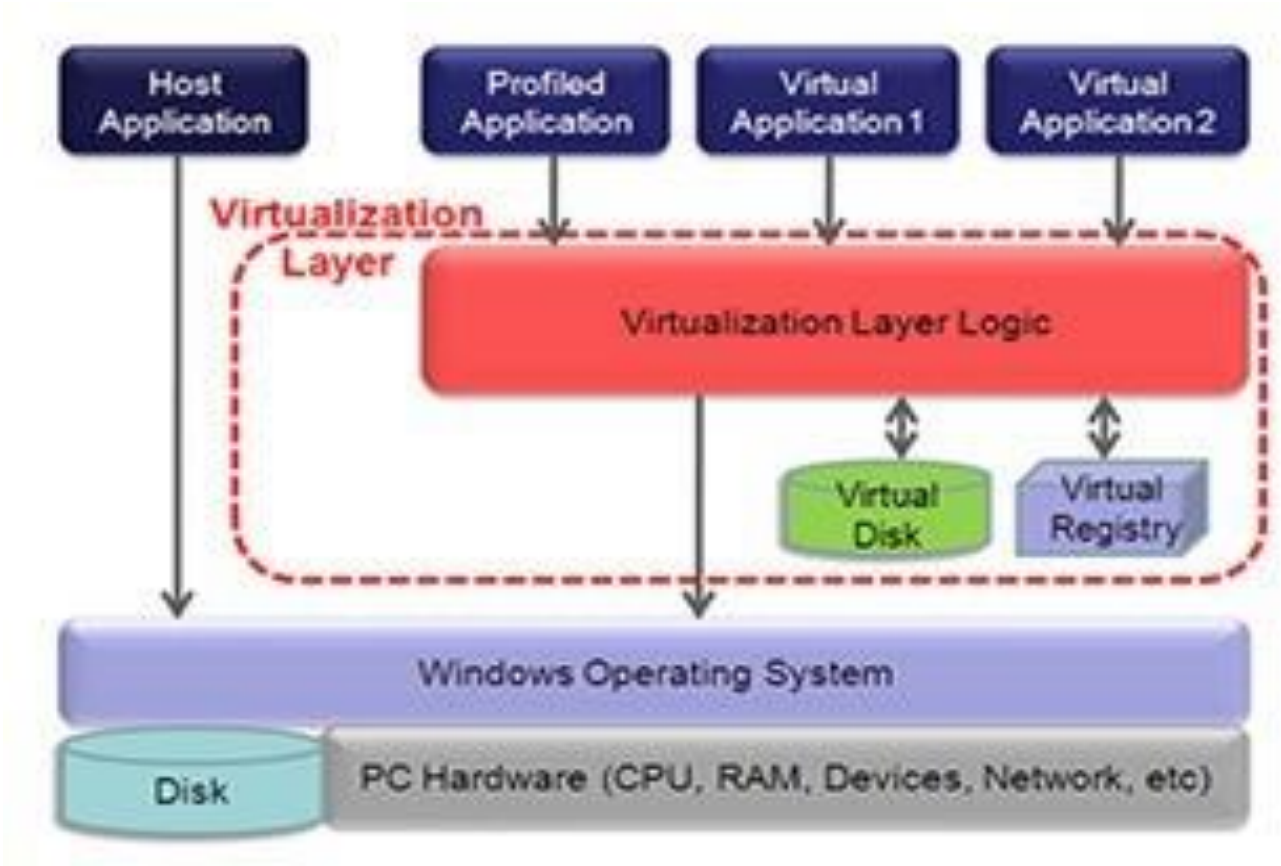
The advantages of application virtualization

- **Reduced regression testing:** Once you know that your app works in the virtual environment, you don't have to make sure that it works on all of the different desktop variations in your network. Changes on desktops usually don't have an effect on the virtualized apps.
- **Improved security:** Virtualized apps are isolated from the operating system and from each other. This way, malware can't infect other parts of the system, easily .
- **Helpdesk support:** Helpdesk personnel can easily access all available apps in your organization and can run the app in the same environment as end users.
- **Operating system independent:** Virtualized apps are often OS independent. If you have apps that are Vista incompatible, then application virtualization might be your solution. Application virtualization also paves the way for Vista x64. Legacy apps that wouldn't work on a 64-bit-system might run without problems on Vista x64 in a virtual environment. Together with Wine and Crossover, you can also run complex Windows apps on Linux and OS X.

How Server Virtualization and Application Virtualization Differ

- Although the two processes share key features—such as lowering costs, bolstering data security, and central control—they fulfill separate functions.
- Server virtualization refers to the use of one or several servers clustered into multiple server groups. Should a data center have 20 physical servers, they can be virtualized into two groups of 10, for example, or two groups with one of 5 servers and the other with 15. There's no difference between a virtual server(s) and a group of 5, 10, or 15 physical servers operating as individual servers.
- Conversely, one physical server can be partitioned into separate multiple virtual servers, helping to maximize organizational resources and facilitating recovery from unexpected server outages. With virtual servers, further cost reductions are realized by reducing organizational needs for multiple servers, which leads to lower maintenance and lower environmental and power expenditures
- Virtualizing apps means that they run without any dependencies through another operating system or browser. An example would be virtualizing Microsoft PowerPoint to run on Ubuntu over an Opera browser.
- The implementation of both environments differs, as well. Desktop virtualization impacts network architecture, transmission protocol, and the data center while server virtualization only affects changes to the server.

Application Virtualization



Remote applications

- Remote applications run on a server. End users view and interact with their applications over a network via a remote display protocol.
- The remote applications can be completely integrated with the user's desktop so that they appear and behave the same as local applications, through technology known as seamless windows.
- The server-based operating system instances that run remote applications can be shared with other users (a terminal services desktop), or the application can be running on its own OS instance on the server (**Virtual Desktop Infrastructure (**VDI) desktop).
- A constant network connection must be maintained in order for a remote application to function.

Streaming applications

- With **streaming applications**, the virtualized application is executed on the end user's local computer.
- When an application is requested, components are downloaded to the local computer on demand.
- Only certain parts of an application are required in order to launch; the remainder can be downloaded in the background as needed.
- Once completely downloaded, a streamed application can function without a network connection.
- Various models and degrees of isolation ensure that streaming applications will not interfere with other applications, and that they can be cleanly removed when closed.

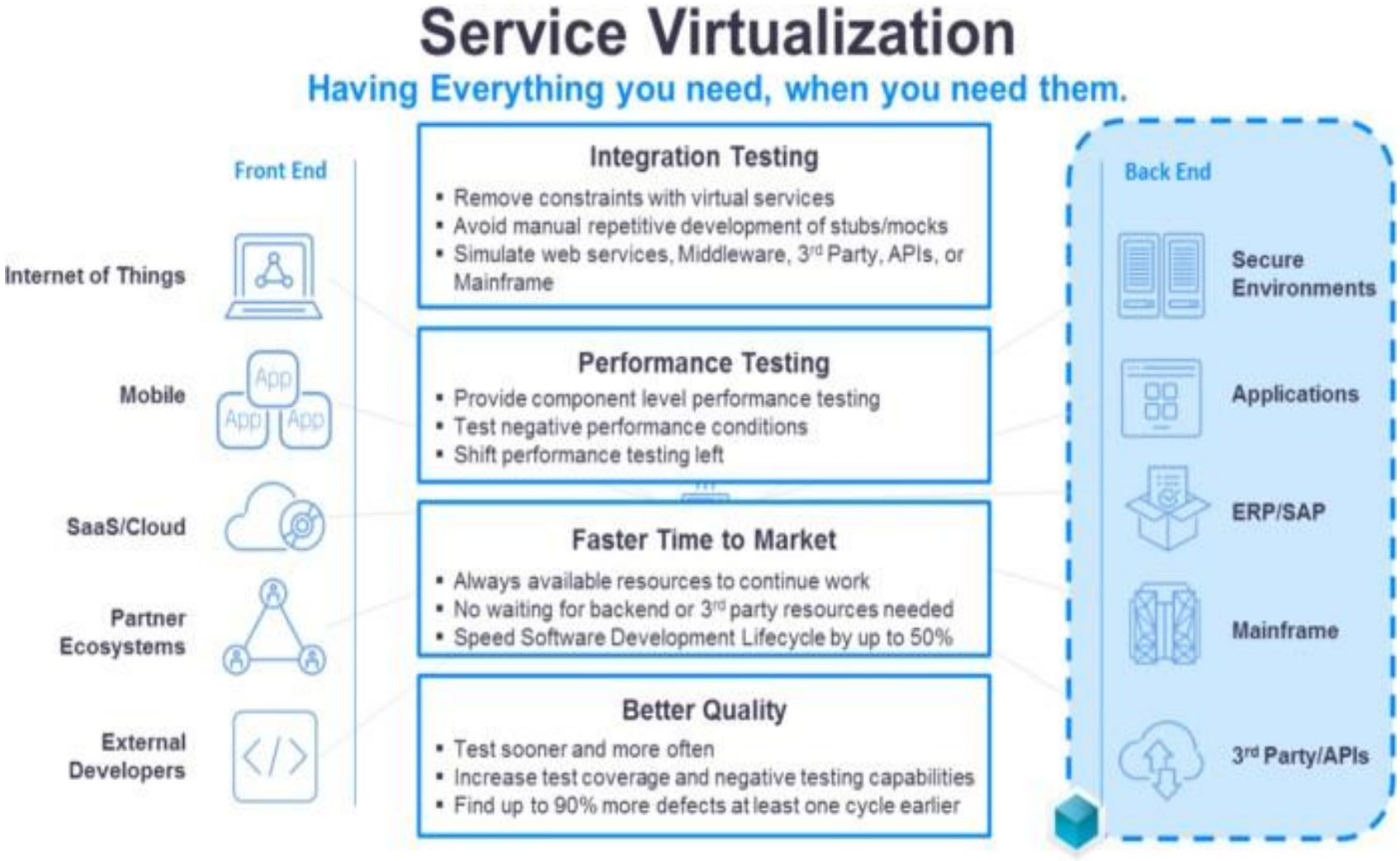
5.3 : Service virtualization

- In software engineering, service virtualization or service virtualization is a method to emulate the behavior of specific components in heterogeneous component-based applications such as API-driven applications, cloud-based applications and service-oriented architectures.
- **Service Virtualization** is implemented to emulate the **required** database, network settings, and even system configurations for testing the application. This helps in cutting down the time, efforts, and costs.
- It involves constant testing and releases across multiple testing environments

Why Service virtualization ? (Software testing)

- Service Virtualization is a method that helps you to emulate (virtual services) the behaviors of the component in a Service Oriented Architecture (Microservice).
- Practically the software development, testing, and operations teams do not work in synch, and each team has to wait for others to have components ready. This causes delays in workflows and may deliver an inferior product.
- With Service Virtualization, DevOps teams use virtual services instead of production services, so they can test the system even when key components are not ready.
- With Service Virtualization, integrating of applications takes place early in the development cycle thereby reducing time and cost to fix errors.

Testing as service



Why Service Virtualization?

- Helps you to accelerate Application Delivery while mitigating business risks
- It helps you to simulates the behavior of select components within an application to enable end-to-end testing of the application as a whole.
- Allows the teams to work in parallel
- Allows you to Test Early and often which expose defect when they are faster, easiest and least costly to resolve
- Facilitates better test coverage
- Virtual services offer rich tools for editing and managing which help you improve productivity, cut down on maintenance time and development costs.
- It is useful for anyone involved in developing and delivering software applications.
- Access to more systems and services
- It supports test-driven development.
- Gives you an isolated environment for testing

Example: Service Virtualization

- For example, say you are developing an e-commerce mobile app that lets you browse items and make a payment in this scenario, the mobile app likely integrates with several systems, including databases and web-services (APIs).
- These integrations allow you to get items, make the payment, and ultimately place the order.
- Many of these resources are in your control – but many others are not, because they're owned by other teams. Such resources are called **third-party dependencies**.
- A typical list of third-party dependencies for this example may look like the following:

Example: A typical list of third-party dependencies

Resource	Owner	Availability
Database	Yourself	Always Available
User Profile API	CRM team	Still Under Development
Inventory API	ERP Team	Only in Production
Payment API	Payment Gateway	Needs a Credit Card
Ordering API	Order Management Team	Available, but with Rate Limits

Example: Service Virtualization

- As you can see in the above table, not all the dependencies are under your control. Often while developing code you will reach a point when you must use these third- party dependencies and interact with them. One example might involve getting data for a customer profile screen. If these dependencies are not ready and responsive, you will have to stop working on the code that call them.
- Often, to work around this, developers will write functions or methods that return a hard-coded API response. This is not ideal, as the hard-coded values are valid for just one scenario and not reusable, this also encourages bad code writing practices. Similarly, a tester testing functionality that depends on other unavailable resources will be forced to skip testing until that resource is available, adversely impacting test coverage.
- Unavailable dependencies create issues for developers and testers as they limit the amount of development and testing that can be done. Without full availability of dependent resources and services, all possible use cases do not get covered.
- This results in limited unit testing and many of the test cases do not get executed at all. Often these dependencies cause bottlenecks. Teams have to pause their work because they've come to a point where they absolutely need the actual third part services.Without them, it's not possible to get any work done at all.

API Virtualization: The Perfect Solution to Challenges with API Mocking

- Mocking provides a way to emulate the missing resource, especially APIs, while testing or developing a software.
- Mocks are very basic setups that are created on code or on tools that can mimic, for example, a few API calls. This allows the development and testing teams to do a very basic level of testing using these emulated calls.
- API virtualization is often compared with mocking, but they're not the same thing. Mocks are imitation software components that are used by developers to emulate real software components for testing purposes, which initially sounds a lot like virtualization.

API Virtualization: The Perfect Solution to Challenges with API Mocking

- However, one of the biggest distinctions between mocking services and virtual APIs is that mocking functions tend to be very context-specific, simulating a specific behavioral response to fulfill a certain development need at a certain time (i.e., injecting a missing dependency in order to bypass its absence, or temporarily test its presence, perhaps in isolation from the rest of the application under test).
- API virtualization, on the other hand, delivers—for all development intents and testing purposes—the same behavior and functionality for any developer or tester who wants to use the API, at any time.
- Thus, once they're created and exist as part of a projectwide test environment, virtual components eliminate the need for individual developers to write and rewrite their own mocks, saving time and effort for all concerned.

Mocking

- Mocking provides a way to emulate the missing resource, especially APIs, while testing or developing a software. Mocks are very basic setups that are created on code or on tools that can mimic, for example, a few API calls. This allows the development and testing teams to do a very basic level of testing using these emulated calls.
- Generally, mocks are created by development teams in code, and run for their own development and testing. Mock creation for users who are non-developers is difficult: testers often use open source tools for creating mocks – and if they don't have strong coding skills, they'll find this very hard to do. There are not many 'easy to use' open-source tools available for mocking.
- A good example of a tool that allows testers to create mocks is the open source version of SoapUI. However, as it is an all-purpose API testing tool (rather than one focused solely on mocking or virtualization), it doesn't make it easy for testers to scale and adapt mocks to multiple testing scenarios.

10 Best Service Virtualization Tools in 2020: Microservices and Mocking

1. **Traffic Parrot:** makes it easy for developers and testers to do service virtualization, mocking, and simulation. It helps create tests faster and with less effort by providing simulators and mocks of backend APIs and third-party systems.
2. UP9: provides an out-of-the-box test automation for microservices, kubernetes and cloud-native, replacing the need for developers to constantly build and maintain tests, while providing comprehensive service test-coverage.
3. WireMock is simulator tool for HTTP based API. It allows you stay test even when an API does not exist or is incomplete. It allows checking of an edge case and failure modes that the real API may not able to produce.
4. Mountebank is an open source tool which can execute multi-protocol tests.The codebase is Node JS. It is easy to create stubs and mocks.

10 Best Service Virtualization Tools in 2020: Microservices and Mocking

5. Hoverfly cloud is an integrated service virtualization solution. It is designed from the ground up for integration, automation, and performance.You can optimize virtualized services to efficiently handle the load from the system under test.
6. MicroFocus Data simulation software allows developers and QA testers to virtualize micro service's behavior.The tool does not delay delivery regardless of access to production systems.
7. CA Service Virtualization tool simulates unavailable systems across the software development lifecycle.The tool helps developers, QA testing team to work together for faster delivery and higher application quality and reliability.
8. Mocklab is service virtualization tool with user-friendly UI. It allows easy copy, paste or record stubbed HTTP responses. It helps for easy sharing among the team.

10 Best Service Virtualization Tools in 2020: Microservices and Mocking

9. IBM Rational Test Virtualization offers fast and quick testing in the development lifecycle. It helps to reduce dependencies by simulating part or an entire application.This helps software testing teams as they need not wait for the availability of those applications to begin their work.
10. Tricentis Tosca allows steady access to dependent systems so that tests can be execute reliably, and continuously. It simulates the dependent component behavior need to run your tests

Benefits to application virtualization

- Requiring fewer resources compared to using a separate virtual machine.
- Allowing incompatible applications to run on a local machine simultaneously.
- Maintaining a standard, more efficient, and cost-effective OS configuration across multiple machines in a given organization, independent of the applications being used.
- Facilitating more rapid application deployment.
- Facilitating security by isolating applications from the local OS.
- Easier tracking of license usage, which may save on license costs.
- Allowing applications to be copied to portable media and used by other client computers, with no need for local installation.
- Increasing ability to handle high and diverse/variable work volume.

What is Microsoft Application Virtualization ?

- Microsoft Application Virtualization (App-V) can make applications available to end user computers without having to install the applications directly on those computers.
- This is made possible through a process known as sequencing the application, which enables each application to run in its own self-contained virtual environment on the client computer.
- The sequenced applications are isolated from each other. This eliminates application conflicts, but the applications can still interact with the client computer.
- Applications are no longer installed on the client—and there is minimal impact on the host operating system or other applications.

Microsoft Application Virtualization

- Applications are rapidly delivered, when needed, to laptops, desktops, and Remote Desktop Servers. In most cases only a small percentage of the application is needed to launch the application.
- Microsoft App-V components include the **App-V Sequencer**, used to virtualize an application, the **App-V client**, installed on end points where App-V applications will execute, and the **App-V Management Server** and the App-V Streaming Server, used to deliver and stream applications to the App-V clients

6: Data Virtualization

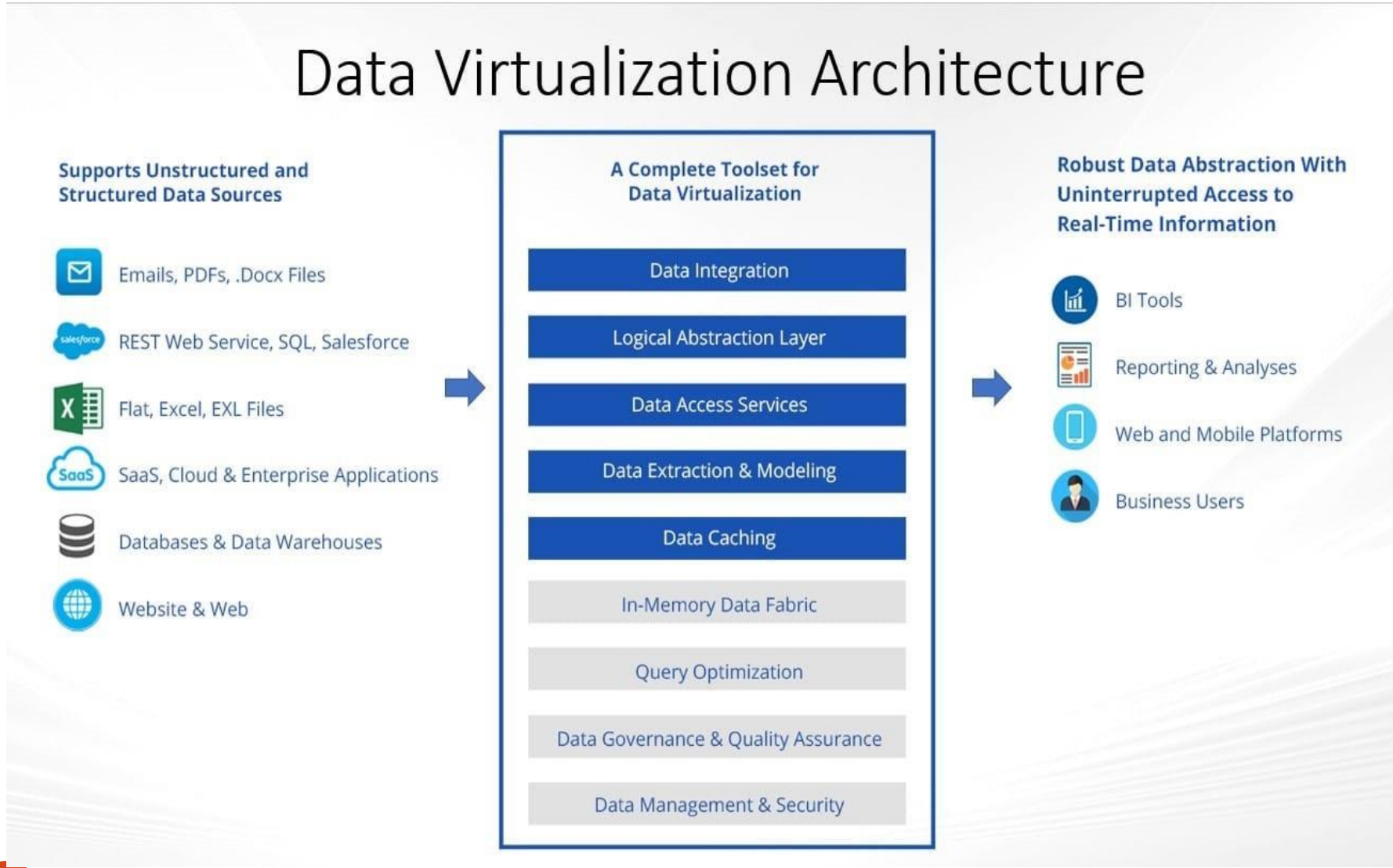
6: Data Virtualization

- **Data Virtualization** lets you easily manipulate data, as the data is presented as an abstract layer completely independent of data structure and database systems.
- Data virtualization creates an abstraction layer that brings in data from different sources without performing the entire Extract-Transform-Load (ETL) process or creating a separate, integrated platform for viewing data.
- Instead, it virtually connects to different databases, integrates all the information to provide virtual views, and publishes them as a data service, like REST. This enhances data accessibility, making specific bits of information readily available for reporting, analysis, and decision making
- Decreases data input and formatting errors.

What is Data Virtualization Layer?

- Data virtualization is a logical data layer to integrate enterprise data available across disparate data sources.
- It consolidates data to a single centralized layer by creating a replicated image. This allows the user to alter the source data without accessing it, allowing real-time data access for business operations, while keeping source data secure.
- Businesses nowadays make data virtualization software an integral part of their approach to data management, as it allows complementing processes like data warehousing, **data preparation**, data quality management, and data integration.

Data Virtualization Architecture



Applications of Data Virtualization

Businesses can leverage virtualization technology to optimize their systems and operations in several ways, such as:

- **Data Delivery:** It enables you to publish datasets (requested by users or generated through client application) as data services or business data views.
- **Data Federation:** It works in unison with data federation software to provide integrated views of data sources from disparate databases.
- **Data Transformation:** It allows users to apply transformation logics on the presentation layer, thus improving the overall quality of data.
- **Data Movement and Replication:** Data virtualization tools don't copy or move data from the primary system or storage location, saving users from performing extraction processes and keeping multiple copies of inconsistent, outdated data.
- **Virtualized Data Access:** It allows you to break down data stores by establishing a logical data access point to disparate sources.
- **Abstraction:** It creates an abstraction layer that hides away the technical aspects, such as storage technology, system language, APIs, storage structure, and location, of the data

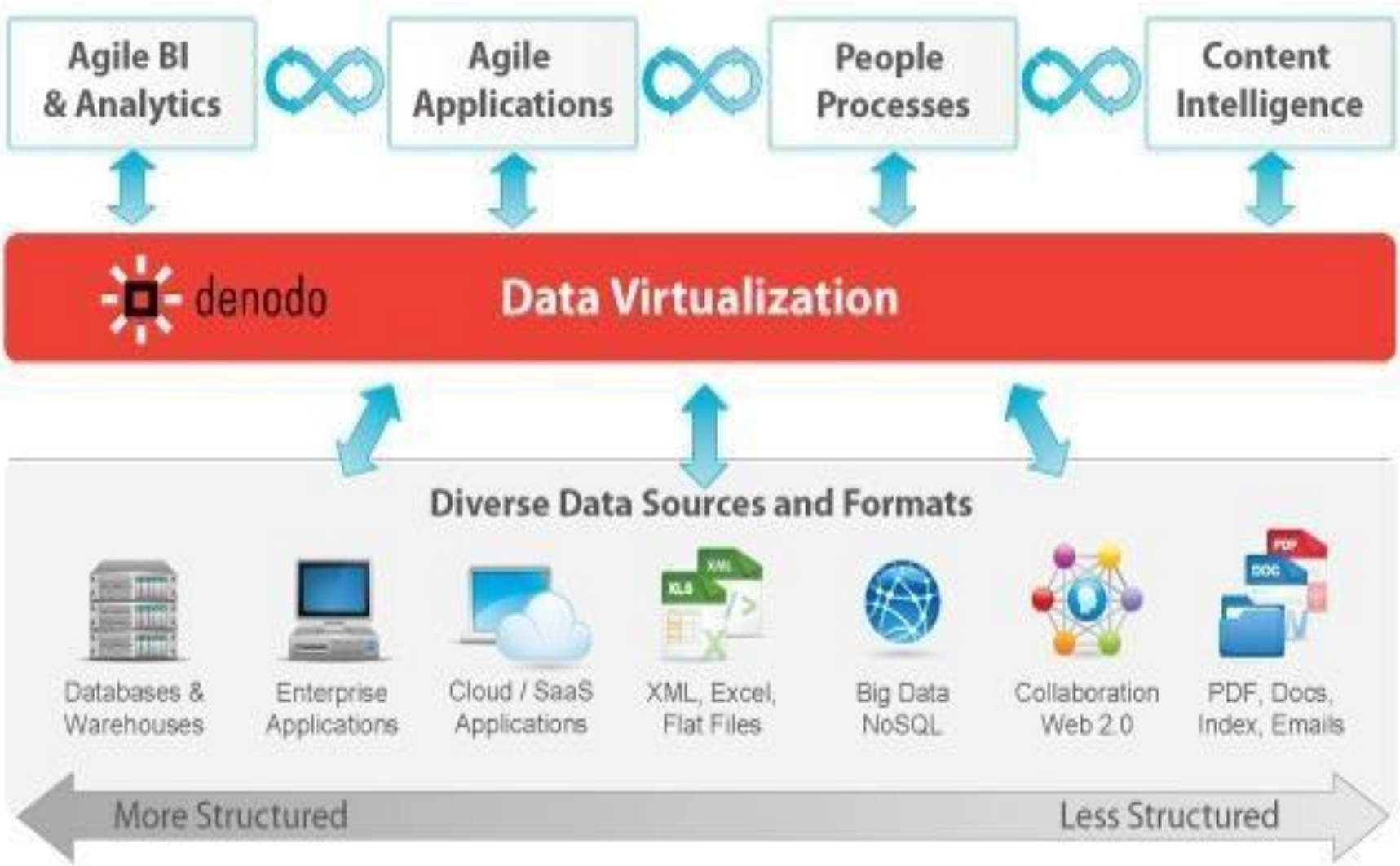
Benefits of Data Virtualization

- According to Gartner, by 2020, about 35 percent of enterprises will make data virtualization a part of their data integration strategy. Here is why enterprises are increasingly opting for tools offering data virtualization platform:
- **Multi-mode and multi-source data access**, making it easy for users at different levels to use data as per their requirements
- **Enhanced security and data governance** for keeping critical data safe from unauthorized users
- **Hiding away the complexity of underlying data sources**, while presenting the data as if it is from a single database or system
- **Information agility**, which is integral in business environments, as data is readily available for swift decision making

Benefits of Data Virtualization

- **Infrastructure agnostic platform**, as it enables data from a variety of databases and systems to be easily integrated, leading to reduced operational costs and data redundancy
- **Simplified table structure**, which can streamline application development and reduce the need for application maintenance
- **Easy integration of new cloud sources to existing IT systems easily,** allowing users to have a complete picture of external and internal information
- **Hybrid query optimization,** enabling you to streamline queries for a scheduled push, demand pull, and other types of data requests
- **Increased speed-to-market,** as it cuts down the time needed to obtain data for improving new or existing products or services to meet consumer demands

Data Virtualization



7: Desktop Virtualization

Desktop virtualization is often referred to as VDI

7: Desktop Virtualization

- **Desktop Virtualization is** perhaps the most common form of virtualization for any regular IT employee.
- The user's desktop is stored on a remote server, allowing the user to access his desktop from any device or location.
- Employees can work conveniently from the comfort of their home. Since the data transfer takes place over secure protocols, any risk of data theft is minimized.

Virtual Desktop Infrastructure (VDI) Software

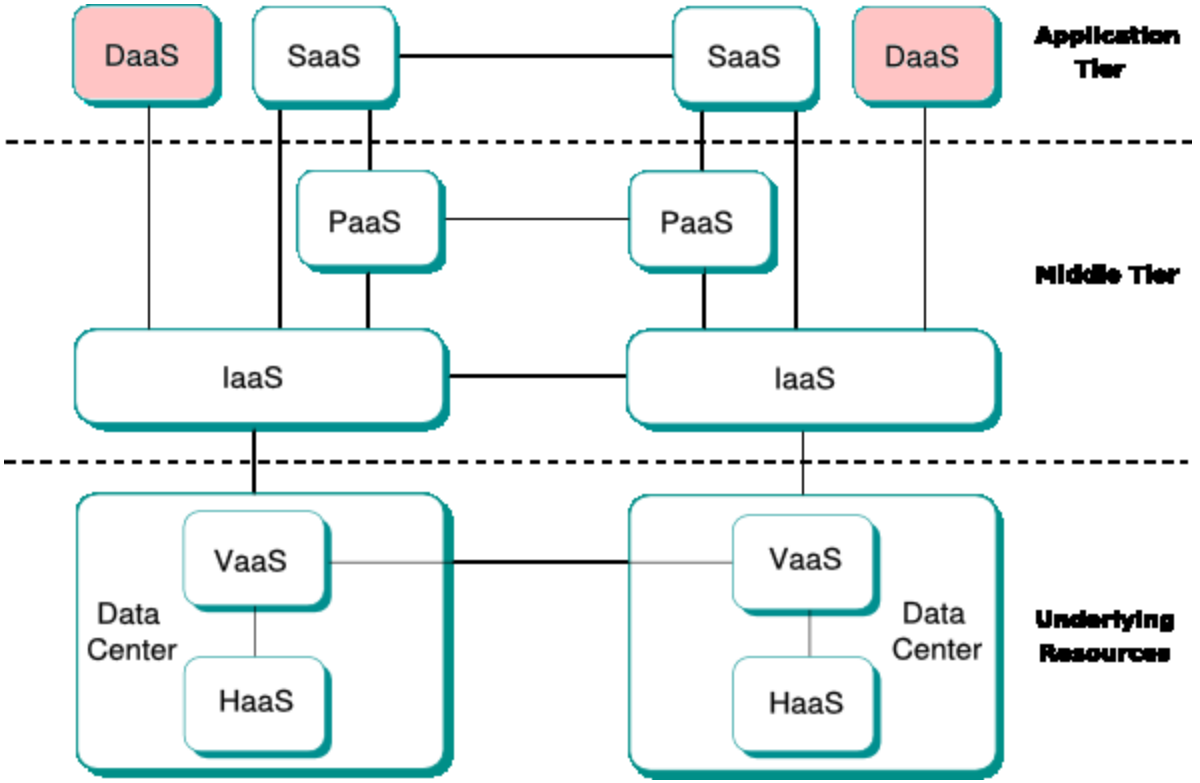
- Virtual Desktop Infrastructure (VDI) is, simply put, desktop virtualization. Desktop (or client) virtualization is like server virtualization but for end-user machines.
- The end user's desktop environment is separated by virtualization from the physical machine where it appears.
- Desktop virtualization is an instance of client-server computing. This is because the virtualized desktop is stored on a central server and not on the machine being virtualized.

Virtual Desktop Infrastructure (VDI) Software

- This enables desktop users to log into their desktop from any machine, like a laptop or home computer.
- In addition to providing flexibility, there are security advantages to client virtualization. For example, if a user's machine is lost or stolen it's a simpler matter for IT to erase company data from the device.
- The biggest difference between server and desktop virtualization is network resource usage.
  - **Server virtualization** achieves better server utilization by making it possible to run multiple virtual machines on a single server.Thus it does not add additional load to a network.
  - **Desktop virtualization,** however, operates entirely on the network. And as client resources are served to client machines across a network, the network's performance can be slower.

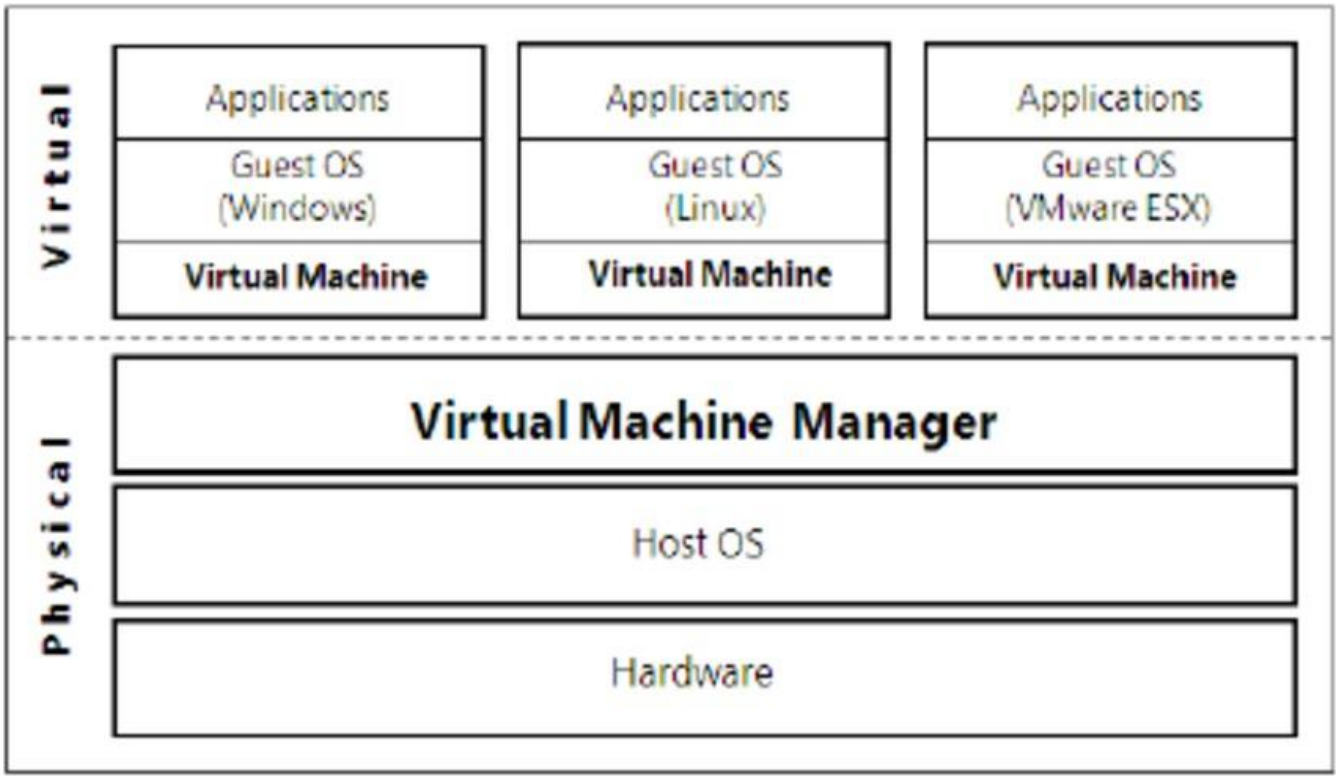
7: Desktop Virtualization

- **Desktop virtualization** is technology that lets users simulate a workstation load to access a **desktop** from a connected device remotely or locally. This separates the **desktop** environment and its applications from the physical client device used to access it.



7: Desktop Virtualization

- Desktop *virtualization* abstracts the desktop environment available on a personal computer in order to provide access to it using a client/server approach. Desktop virtualization provides the same outcome of **hardware virtualization** but serves a different purpose.



7: Desktop and application virtualization

- Desktop **virtualization** is an approach that provides a centralized infrastructure that hosts a desktop image that the workforce can leverage remotely.
- Desktop virtualization is often referred to as VDI, which, depending on the vendor in question, stands for either **virtual desktop** infrastructure or virtual desktop interface.
- As opposed to providing a full **desktop environment**, an organization can simply virtualize key applications that are centrally served.
- Like desktop virtualization, the centralized control associated with **application virtualization** allows the organization to employ strict access control and perhaps more quickly patch the application.
- Additionally, application virtualization can run legacy applications that would otherwise be unable to run on the systems employed by the workforce.

Amazon WorkSpaces

- **Amazon** WorkSpaces is a managed, secure **Desktop-as-a-Service (DaaS)** solution.
- Amazon WorkSpaces having provision for either Windows or Linux desktops in just a few minutes and quickly scale to provide thousands of desktops to workers across the globe.
- You can pay either monthly or hourly, just for the WorkSpaces you launch, which helps you save money when compared to traditional desktops and on-premises VDI solutions.
- Amazon WorkSpaces helps you eliminate the complexity in managing hardware inventory, OS versions and patches, and Virtual Desktop Infrastructure (VDI), which helps simplify your desktop delivery strategy.
- With Amazon WorkSpaces, your users get a fast, responsive desktop of their choice that they can access anywhere, anytime, from any supported device.

Virtual Desktop Infrastructure Software Features & Capabilities

- Management tools for creation, management, and deployment of virtual clients
- Support for a variety of hardware peripherals such as printer, monitors, etc.
- User profile management (e.g credentials & access)
- User environment management (e.g performance monitoring, cloning)
- Dynamic automated allocation of virtual resources
- Support persistent desktop (i.e. user settings personalized or can be retained)
- Support non-persistent desktop (retain pristine settings, easy to update)
- Optimization for mobile platform deployment
- Optimization of storage and memory allocation
- Network monitoring

Virtual Desktop Infrastructure Advantages & Disadvantages

Advantages

- Maintaining a single OS image will minimize costs towards administration and support.
- Administrative tasks decrease as all operating system and application updates are handled at once.
- Security is a major plus with VDI as all licensing and program downloads are centralized.

Disadvantages

- Increased network requirements depending on the nature of your business (simple word processing tools versus more graphics and memory intense environments).
- Changing from decentralized to centralized licensing does take quite a bit of time to adjust to, and while cost savings may come down the road, startup costs can be high.
- A lack of end-user privacy. Not all users or employees will be thrilled to have some of their privacy taken away due to the nature of VDI.

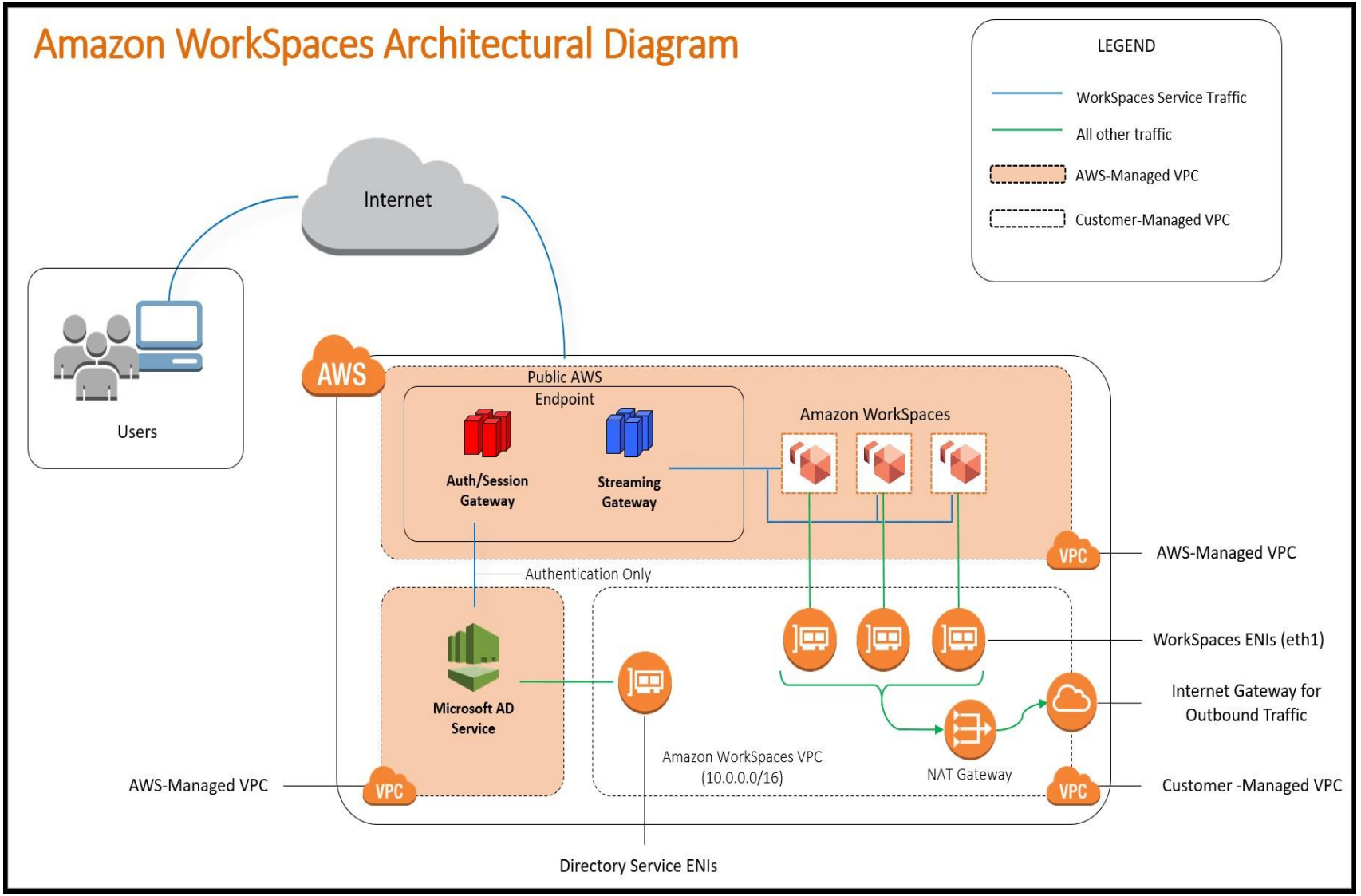
20 Best Virtual Desktop Infrastructure Software Solutions in 2020

- Amazon WorkSpaces
- IBM Cloud
- Cisco VXI
- VMware Horizon Cloud
- Red Hat Virtualization
- Citrix Virtual Apps & Desktops
- SolarWinds Virtualization Manager
- Parallels RAS
- Nutanix VDI
- Vagrant
- Paperspace
- Nvidia Virtual GPU
- Evolve IPVDI
- Xen Project
- Neverfail Workspaces
- Nerdio Private Cloud
- Teradici
- IGEL UDC
- Virtuozzo
- Liquidware FlexApp

Example: Amazon Workspaces

- **Amazon WorkSpaces**, a managed, secure cloud desktop service, heads the giant names in our top 20 best virtual desktop infrastructure software.
- One can use Amazon WorkSpaces to provision either Windows or Linux desktops in just a few minutes and quickly scale to provide thousands of desktops to workers across the globe.
- One can pay either monthly or hourly just for the WorkSpaces you launch. This helps you save money when compared to traditional desktops and on-premise VDI solutions.
- Among its most prominent features is the elimination of many administrative tasks associated with managing your desktop lifecycle, including provisioning, deployment, maintenance, and recycling of desktops.
- There is less hardware inventory to manage and no need for complex virtual desktop infrastructure deployments that don't scale.

Example: Amazon Workspaces



The difference between virtualization and cloud computing

- The difference between virtualization and cloud computing is to say that the former is a technology, while the latter is a service whose foundation is formed by said technology.
- Virtualization can exist without the cloud, but cloud computing cannot exist without virtualization – at least, not in its current format.
- The term cloud computing then is best used to refer to a situation in which "shared computing resources, software, or data are delivered as a service and on-demand through the Internet."
- *Example:* ***A server environment which lacks any of these features, is not cloud computing.***

The side effects of virtualization

Seven disadvantages of server virtualization

- David Coyle, research vice president at Gartner, detailed the seven side effects at the research firm's Infrastructure, Operations and Management Summit, which drew nearly 900 attendees.

- Virtualization promises to solve issues such as underutilization, high hardware costs and poor system availability, the benefits come only when the technology is applied with proper care and consistently monitored for change.

7 side effects of sloppy virtualization

1. Magnified physical failures
2. Degraded performance
3. New skills
4. Complex root cause analysis
5. New management tools
6. Virtual machine sprawl
7. Virtual habits

The side effects of virtualization

- There are side effects of virtualization, notably the ***performance penalty*** *and* ***the hardware costs.*** *As we shall see shortly, all privileged operations of a virtual machine must* be trapped and validated by the Virtual Machine Monitor which, ultimately, controls the system behavior; the increased overhead has a negative impact on the performance.
- The cost of the hardware for a virtual machine is higher than the cost for a system running a traditional operating system because the physical hardware is shared among a set of guest operating systems and it is typically configured with faster and/or multi-core processors, more memory, larger disks, and additional network interfaces as compared with a system running a traditional operating system

Thanks for Your Attention!

References

- http://www.vfrank.org/2013/09/18/understanding-vmware-ballooning/
- https://www.vmware.com/cloud-solutions.html
- https://www.vmware.com/topics/glossary/content/application-virtualization
- https://smartbear.com/learn/software-testing/what-is-service-virtualization/
- https://www.guru99.com/service-virtualization-tools.html
- https://www.soapui.org/learn/mocking/what-is-api-virtualization/
- https://dzone.com/articles/making-mainframe-agile-in-continuous-testing-with-1
- https://financesonline.com/virtual-desktop-infrastructure/

Exercises

Exercises and Problems

1. Virtualization simplifies the use of resources, isolates users from one another, supports replication and mobility, but exacts a price in terms of performance and cost. Analyze each one of these aspects for: (i) memory virtualization, (ii) processor virtualization, and (iii) virtualization of a communication channel.
2. Virtualization of the processor combined with virtual memory management pose multiple challenges; analyze the interaction of interrupt handling and paging
3. What are the different types of Virtualization in Cloud Computing? What is the necessity of data virtualization? What is Data Virtualization Layer? Discuss the benefits of Data Virtualization?
4. Discuss the 7-Layer virtualization model in the context of cloud computing? What is software virtualization? What are the benefits of software virtualization?