## Jaipur Engineering College & Research Centre, Jaipur

# Notes

# Cloud Computing

# [6CS4-06]

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## VISION AND MISSION OF INSTITUTE

### VISION

To become renowned centre of outcome based learning and work towards academic, professional, cultural and social enrichments of the lives of individual and communities"

### MISSION

M1. Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.

M2. Identify areas of focus and provide platform to gain knowledge and solutions based on informed perception of Indian, regional and global needs.

M3. Offer opportunities for interaction between academia and industry.

M4. Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

## VISION AND MISSION OF DEPARTMENT

### VISION

To become renowned Centre of excellence in computer science and engineering and make competent engineers & professionals with high ethical values prepared for lifelong learning.

### MISSION

**M1:** To impart outcome based education for emerging technologies in the field of computer science and engineering.

**M2:** To provide opportunities for interaction between academia and industry.

**M3:** To provide platform for lifelong learning by accepting the change in technologies

**M4:** To develop aptitude of fulfilling social responsibilities.

## COURSE OUTCOMES

**CO1:** Implement the cloud computing architecture i.e, the model, types of clouds, various service models and programming concepts.

**CO2:** Acquire knowledge about the recent trends in area of cloud computing like Hadoop, programming of Google app engine and virtualization technology and resource management.

**CO3:** Identify the various threats related to cloud and as well as disaster recovery related to same.

**CO4:**Analyze the cloud platforms in IT industry and various case studies on the industries providing cloud services.

**Program Outcomes (PO)**

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## Program Educational Objectives (PEO)

1. To provide students with the fundamentals of Engineering Sciences with more emphasis in Computer Science & Engineering by way of analyzing and exploiting Engineering challenge

2. To train students with good scientific and engineering knowledge so as to comprehend, analyze, design, and create novel products and solutions for the real life problems.

3. To inculcate professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach, entrepreneurial thinking and an ability to relate engineering issues with social issues.

4. To provide students with an academic environment aware of excellence, leadership, written ethical codes and guidelines, and the self-motivated life-long learning needed for a successful professional career.

5. To prepare students to excel in Industry and Higher education by Educating Students along with High moral values and Knowledge.

**MAPPING CO-PO**

| Cos/POs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 3 |
| **CO2** | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |

## PSO

PSO1: Ability to interpret and analyze network specific and cyber security issues, automation in real word environment.

PSO2: Ability to Design and Develop Mobile and Web-based applications under realistic constraints.

## SYLLABUS

**UNIT 1: Introduction:** Objective, scope and outcome of the course.

**UNIT 2: Introduction:** Objective, scope and outcome of the course. Introduction Cloud Computing: Nutshell of cloud computing, Enabling Technology, Historical development, Vision, feature Characteristics and components of Cloud Computing. Challenges, Risks and Approaches of Migration into Cloud. Ethical Issue in Cloud Computing, Evaluating the Cloud's Business Impact and economics, Future of the cloud. Networking Support for Cloud Computing. Ubiquitous Cloud and the Internet of Things.

**UNIT 3: Cloud Computing Architecture:** Cloud Reference Model, Layer and Types of Clouds, Services models, Data centre Design and interconnection Network, Architectural design of Compute and Storage Clouds. Cloud Programming and Software: Fractures of cloud programming, Parallel and distributed programming paradigms-Map Reduce, Hadoop, High level Language for Cloud. Programming of Google App engine.

**UNIT 4: Virtualization Technology:** Definition, Understanding and Benefits of Virtualization. Implementation Level of Virtualization, Virtualization Structure/Tools and Mechanisms, Hypervisor VMware, KVM, Xen. Virtualization: of CPU, Memory, I/O Devices, Virtual Cluster and Resources Management, Virtualization of Server, Desktop, Network, and Virtualization of data-centre.

**UNIT 5: Securing the Cloud:** Cloud Information security fundamentals, Cloud security services, Design principles, Policy Implementation, Cloud Computing Security Challenges, Cloud Computing Security Architecture . Legal issues in cloud Computing. Data Security in Cloud: Business Continuity and Disaster Recovery , Risk Mitigation , Understanding and Identification of Threats in Cloud, SLA-Service Level Agreements, Trust Management

**UNIT 6: Cloud Platforms in Industry:** Amazon web services , Google AppEngine, Microsoft Azure Design, Aneka: Cloud Application Platform -Integration of Private and Public Clouds Cloud applications: Protein structure prediction, Data Analysis, Satellite Image Processing, CRM

## Unit 3: Virtualization

*Virtualization* technology is one of the fundamental components of cloud computing, especially in regard to infrastructure-based services. Virtualization allows the creation of a secure, customizable, and isolated execution environment for running applications, even if they are untrusted, without affecting other users' applications. The basis of this technology is the ability of a computer program—or a combination of software and hardware—to emulate an executing environment separate from the one that hosts such programs. For example, we can run Windows OS on top of a virtual machine, which itself is running on Linux OS. Virtualization provides a great opportunity to build elastically scalable systems that can provision additional capability with minimum costs. Therefore, virtualization is widely used to deliver customizable computing environments on demand.

This chapter discusses the fundamental concepts of virtualization, its evolution, and various models and technologies used in cloud computing environments.

### Introduction:

The Concept of virtualization comes in the market in the year 1960 and 1970 when IBM developed robust time sharing solutions. Time-sharing means the shared usage of computer resources between large group of users working on the efficiency increase of the users and shared computer resources. The best method to increase resource utilization and simplification of data center management is by using virtualization.

Now a days Data centers are using virtualization techniques to make abstraction of the physical hardware, create large aggregated pools of logical resources containing CPUs, memory, disks, file storage, application, networking and offer those resources to users in the form of quick, scalable, consolidated virtual machine.

### Understanding the Virtualization:

Virtualization is a very fast growing infrastructure in the IT industry. It characterizes the logical view of data representation:

- The power to compute in virtualized environment
- Storing the data at different geographies

- Various computing resources.

To virtualize systems separate the physical resources from logical resources.

**Definition of Virtualization:**

Virtualization means to create a virtual version of a device such as a server, storage device, network or operating system. Partitioning a hard drive is considered as virtualization too because one drive is taken and divided it into two or many separate hard drives. Devices, applications and human users are able to interact with the virtual resource if it is a logical resource.

Virtualization allows multiple machines with heterogeneous operating system to run OS separately and as well as on the same physical machine after virtualization of the machine.

**components of virtualized environment**

there are three major components: *guest*, *host*, and *virtualization layer*.

The *guest* represents the system component that interacts with the virtualization layer rather than with the host, as would normally happen. The *host* represents the original environment where the guest is supposed to be managed. The *virtualization layer* is responsible for recreating the same or a different environment where the guest will operate

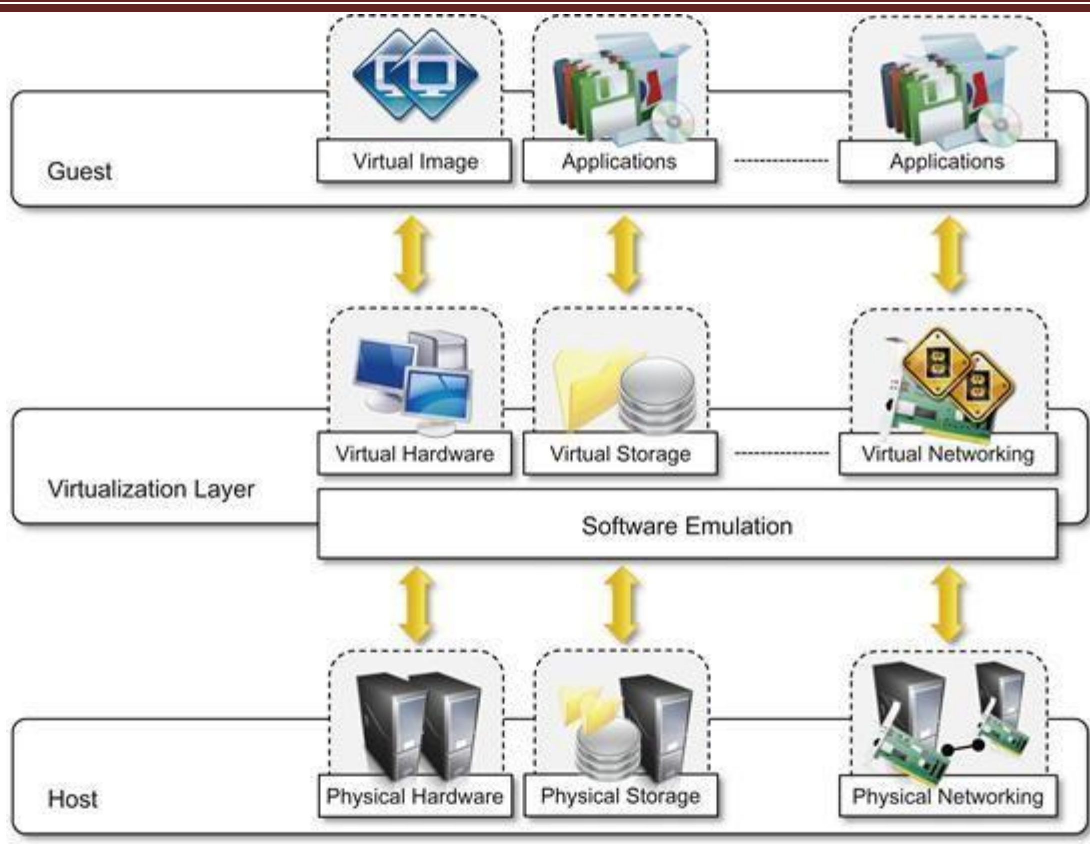


**FIGURE 3.1** The virtualization reference model.

## Characteristics of virtualized environments

### 1. Increased Security

The ability to control the execution of a guest in a completely transparent manner opens new possibilities for delivering a secure, controlled execution environment.

All the operations of the guest are generally performed against the virtual machine, which then translates and applies them to the host. This level of indirection allows the virtual machine manager to *control* and *filter* the activity of the guest, thus preventing some harmful operations from being performed.

Moreover, sensitive information that is contained in the host can be naturally hidden without the need to install complex security policies. Increased security is a requirement when dealing with untrusted code.

By default, the file system exposed by the virtual computer is completely separated from the one of the host machine. This becomes the perfect environment for running applications without affecting other users in the environment.

2. Managed Execution

Virtualization of the execution environment not only allows increased security, but a wider range of features also can be implemented. In particular, *sharing*, *aggregation*, *emulation*, and *isolation* are the most relevant features

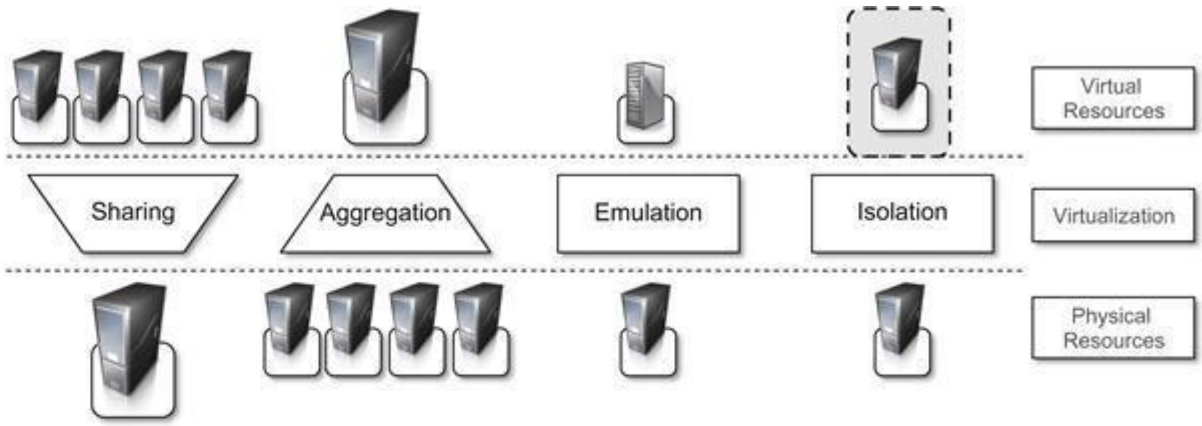


**FIGURE 3.2** Functions enabled by managed execution.

*Sharing.* Virtualization allows the creation of a separate computing environments within the same host. In this way it is possible to fully exploit the capabilities of a powerful guest, which would otherwise be underutilized. sharing is a particularly important feature in virtualized data centers, where this basic feature is used to reduce the number of active servers and limit power consumption.

*Aggregation.* Not only is it possible to share physical resource among several guests, but virtualization also allows aggregation, which is the opposite process. A group of separate hosts can be tied together and represented to guests as a single virtual host. This function is naturally implemented in middleware for distributed computing, with a classical example represented by cluster management software, which harnesses the physical resources of a homogeneous group of machines and represents them as a single resource.

- *Emulation.* Guest programs are executed within an environment that is controlled by the virtualization layer, which ultimately is a program. This allows for controlling and tuning the environment that is exposed to guests. For instance, a completely different environment with respect to the host can be emulated, thus allowing the execution of guest programs requiring specific characteristics that are not present in the physical host. This feature becomes very useful for testing purposes, where a specific guest has to be validated against different platforms or architectures and the wide range of options is not easily accessible during development. Again, hardware virtualization solutions are able to provide virtual hardware and emulate a particular kind of device such as *Small Computer System Interface (SCSI)* devices for file I/O, without the hosting machine having such hardware installed. Old and legacy software that does not meet the requirements of current systems can be run on emulated hardware without any need to change the code. This is possible either by emulating the required hardware architecture or within a specific operating system sandbox, such as the MS-DOS mode in Windows 95/98. Another example of emulation is an arcade-game emulator that allows us to play arcade games on a normal personal computer.

- *Isolation.* Virtualization allows providing guests—whether they are operating systems, applications, or other entities—with a completely separate environment, in which they are executed. The guest program performs its activity by interacting with an abstraction layer, which provides access to the underlying resources. Isolation brings several benefits; for example, it allows multiple guests to run on the same host without interfering with each other. Second, it provides a separation between the host and the guest. The virtual machine can filter the activity of the guest and prevent harmful operations against the host.

### 3. Portability

The concept of *portability* applies in different ways according to the specific type of virtualization considered. In the case of a hardware virtualization solution, the guest is packaged into a virtual image that, in most cases, can be safely moved and executed on top of different virtual machines. Except for the file size, this happens with the same simplicity with which we can display a picture image in different computers.

**<u>Virtualization in Business:</u>**

Virtualization provides the following benefits in the Business:

- **Save Money:** Reduces the number of physical servers so a huge cost in the maintenance and operational cost saves.

- **Increases control:** Provides capacity on demand to organization. New servers can be deployed easily and service of the servers can be done in a minute.
- **Disaster recovery:** Efficient and cost effective disaster recovery solution can be used with virtualization technologies by bringing servers and business online at another site within minutes. It is possible by using virtualization.
- **Business willingness valuation:** It introduces a shared computing model for enterprises which makes easy to understand the infrastructure requirements in virtualized environment and there is no need to implement it physically.

**Benefits of Virtualization:**

The concept of the virtualization provides the following benefits in Cloud Computing on the Traditional and modern basis:

- Server merging
- Green IT by reducing power and cooling requirements
- Reduced hardware costs
- Increased availability, business stability and disaster recovery
- Maximized hardware resources
- Reduced administration and labor cost
- Efficient application and desktop software deployment and maintenance
- Reduced time for server provisioning
- Increased security at the desktop client level
- Dynamic and extensible infrastructure to rapidly address new business requirements

**Implementation level of Virtualization:**

Virtualization makes possible to manage user applications and operating systems which runs on the same hardware but independently to the host OS. This is done by adding additional software called a virtualization layer. Which is also known as hypervisor or virtual machine monitor (VMM).

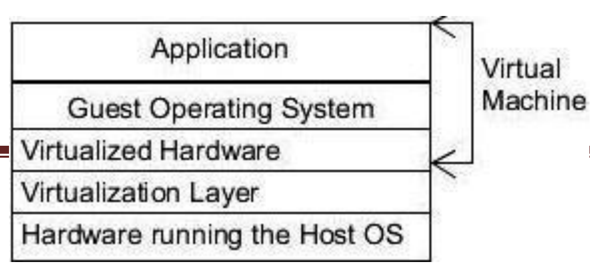

Fig 4.1: Architecture of Virtualization Common virtualization layers include the following levels:

- Instruction set architecture (ISA) level
- Hardware level
- Operating system level
- Library support level
- Application level.

- **Instruction Set Architecture Level:** At the ISA level virtualization is done by resembling a given ISA by the ISA of the host machine. It is possible to run a huge amount of binary code written for various processors on any new hardware host machine in ISA level.

  It is done by using code interpretation. An interpreter program interprets the source instructions to target instructions one by one. One single source instruction requires tens or hundreds of instructions to perform its function.
- **Hardware Abstraction Level:** It is performed right on top of the bare hardware. This approach generates a virtual hardware environment for a VM and also manages the process of the hardware by using virtualization. Means virtualization of the computer resources like processors, memory and I /O devices is to be done.

- **Operating System Level:** Abstraction layer is to be added between traditional OS and user applications. OS level virtualization creates remote container on physical server. The containers behave like real servers. OS level virtualization is usually used for creating virtual hosting environments for allocating hardware resources between users.

- **Library Support Level:** Applications use APIs distributed between user-level libraries rather than using lengthy system calls by the OS. Virtualization by using library interfaces is possible by controlling the communication link between applications and system through API support.

- **User-Application Level:** Virtualization at the user level virtualizes an application as a VM. On traditional OS applications normally runs as a process. Because of this User level virtualization is also known as process-level virtualization.

**Virtualization Structure, Tools and Mechanisms:**

In virtualization a virtualization layer is inserted between the hardware and the operating system. So the virtualization layer is responsible for converting the real hardware into virtual hardware. By using this different operating systems such as Linux and Windows can run on the same physical machine simultaneously.

In this section we will discuss about the virtualization software's/Tools like Hypervisor VMware, KVM and Xen which are used for the development of the virtualized structure in between the hardware and operating system.

**Hypervisor VMware:**

The hypervisor works on hardware level for virtualization of devices like CPU, memory, disk and network interfaces. The hypervisor software assembles directly between the physical hardware and OS. The virtualization layer developed on hardware is known as the VMM or the hypervisor. The hypervisor provides hyper calls for the guest OS and applications. Hypervisor uses a microkernel architecture like the Microsoft Hyper-V or monolithic hypervisor architecture like the VMware ESX for server virtualization.

The device drivers and some unreliable components are not used in the hypervisor. A monolithic hypervisor uses all functions like device drivers. Size of the hypervisor code of a micro-kernel hypervisor is smaller than that of a monolithic hypervisor.

**Xen:** Xen is an open source hypervisor program developed by Cambridge University. Xen is a micro- kernel hypervisor which implements only the mechanisms. And the policies are to be handled by Domain 0. Xen does not contain any device drivers. It just provides a mechanism to guest OS for getting direct access to the physical devices. Size of the Xen hypervisor is generally very small. Xen provides a virtual environment between the hardware and the OS. Development of Xen hypervisors in not done yet.

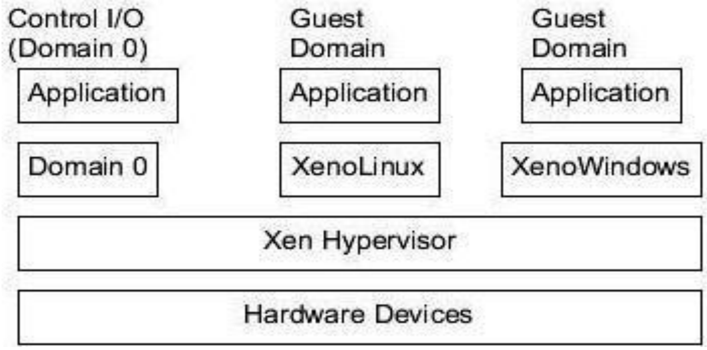


Fig 4.2: Xen Architecture

The core components of a Xen system are the hypervisor, kernel and applications. In Xen system guest OS works on top of the hypervisor.

**KVM (kernel based VM):**

This is a Linux para-virtualization system and is a part of the Linux version 2.6.20 kernel. Memory management and scheduling is done by using existing Linux kernel and KVM does all the remaining work. It is very simple than the hypervisor and also controls the complete machine. KVM improves the performance of the system.

**Virtualization of CPU, memory and I/O Devices:**

To perform virtualization the Virtual machine and OS runs in applications installed in the virtual machine. To save processor processing is done by hardware.

- **Hardware Virtualization:** Multiple processes runs in parallel in the modern operating systems and processors. The crash occurs in the process when different processes from multiple processors accesses the hardware by using no any protection rule. So, all the processors have to use two modes for making controlled access of the hardware:
    - User mode
    - Supervisor mode

    Instructions working in supervisor mode are called privileged instructions and all other instructions are known as unprivileged instructions.

- **CPU Virtualization:** Virtual Machine is a copy of existing system and instructions of it are executed on the host processor in native mode. Unprivileged instructions of Virtual Machine runs directly on the host machine for higher efficiency.

CPU is virtualized if it executes the Virtual Machine's privileged and unprivileged instructions in the CPU user mode and VMM executes in supervisor mode. Privileged instructions like control and behavior instructions of a VM are executed by securing in the VMM. Here VMM works like a unified mediator for hardware access from different VMs to guarantee the correctness and stability of the whole system. But all CPU's not support virtualization. As RISC CPU can be virtualized but x86 CPU not support virtualization.

- **Memory Virtualization:** The traditional operating systems supports virtualization by making page tables. All modern CPUs contains memory management unit (MMU) and translation look-a-side buffer (TLB) to perform virtualization. The memory of the physical system is virtualized and allocated to the virtual machine as its physical memory.

  So that means two stage mapping is implemented by the guest OS and VMM for virtual memory to physical memory and physical memory to machine memory. Virtual OS of virtual machine controls the mapping of virtual memory with the physical memory but it cannot directly access the machine memory. VMM performs the mapping of the physical memory with the machine memory.
- **I/O Virtualization:** I/O virtualization manages the I/O requests between virtual machine and the physical machine. There are three ways to implement I/O virtualization:
  - **Full device emulation:** It provides the emulation of the well-known real world devices.
  - **Para-virtualization:** It is also known as the split driver model which contains frontend driver and backend driver. They both works on different domains and they interacts with each other by using block of shared memory. Frontend driver manages the I/O requests of the virtual OS and the backend driver manages the real I/O devices. So para-virtualization is better than full device emulation.
  - **Direct I/O virtualization:** It allows Virtual machine to access devices directly.

**Virtual Cluster and Resources Management:**

A physical cluster is a collection of physical machines interconnected by a physical network such as a LAN. Here we will study about the three critical design issues of virtual clusters:

- live migration of VMs
- Memory and file migrations

- Dynamic deployment of virtual clusters.

When a traditional VM is initialized then the administrator has to manually write configuration information or has to specify the configuration details. When more VMs join a network than an inefficient configuration always causes problems like overloading or underutilization.

**Physical versus Virtual Clusters:**

Virtual clusters are built with VMs installed at distributed servers by using one or more physical clusters.

- The VMs in a virtual cluster that is interconnected logically by a virtual network across several physical networks.
- Each virtual cluster is formed by using physical machines or a VM hosted at multiple physical clusters.

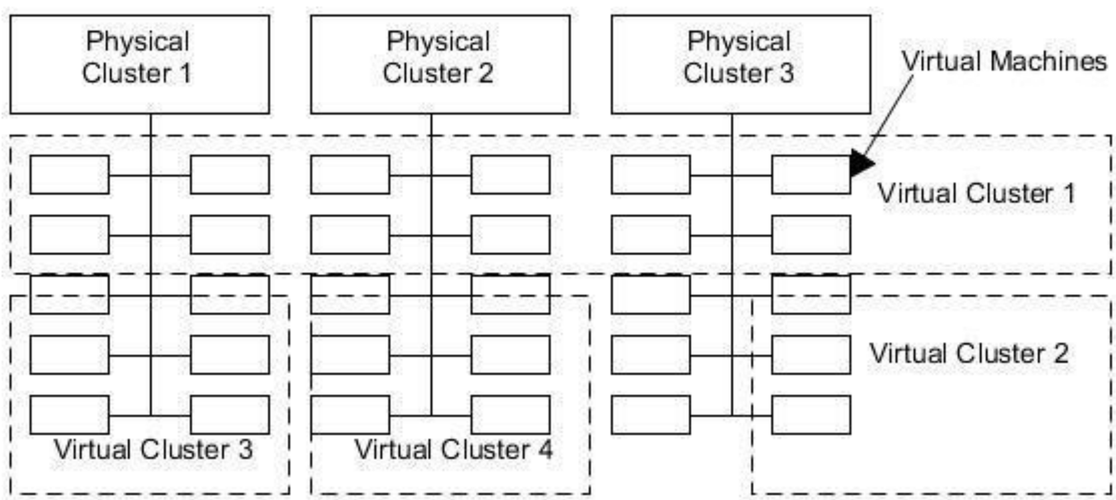


Fig 4.3: A cloud platform with four virtual clusters over three physical clusters

The provisioning of VMs to a virtual cluster is done dynamically and which have the following interesting properties:

- The virtual cluster nodes can be either on physical or virtual machines.
- Multiple VMs running with different OS can be deployed on the same physical node.
- A VM runs with a guest OS and which is totally different from the host OS.
- Host OS manages the resources in the physical machine, where the VM is implemented.

- The purpose of using VMs is to combine multiple functionalities on the same server. This will provide huge server utilization and application flexibility.
- VMs can be replicated in multiple servers for the purpose of promoting distributed parallelism, fault tolerance, and disaster recovery.
- The number of nodes of a virtual cluster can grow or shrink dynamically as similar to the overlay network size varies in size in a peer-to-peer (P2P) network.
- The failure of any physical nodes may disable some VMs installed on the failing nodes. But the failure of VMs will not pull down the host system.
- It is necessary to manage VMs running on a virtual clusters and to build a high-performance virtualized computing environment.
- This involves virtual cluster deployment, monitoring and management over large-scale clusters, as well as resource scheduling, load balancing, server consolidation, fault tolerance and other techniques.
- The different type of nodes are represented in different virtual clusters in figure 4.4.

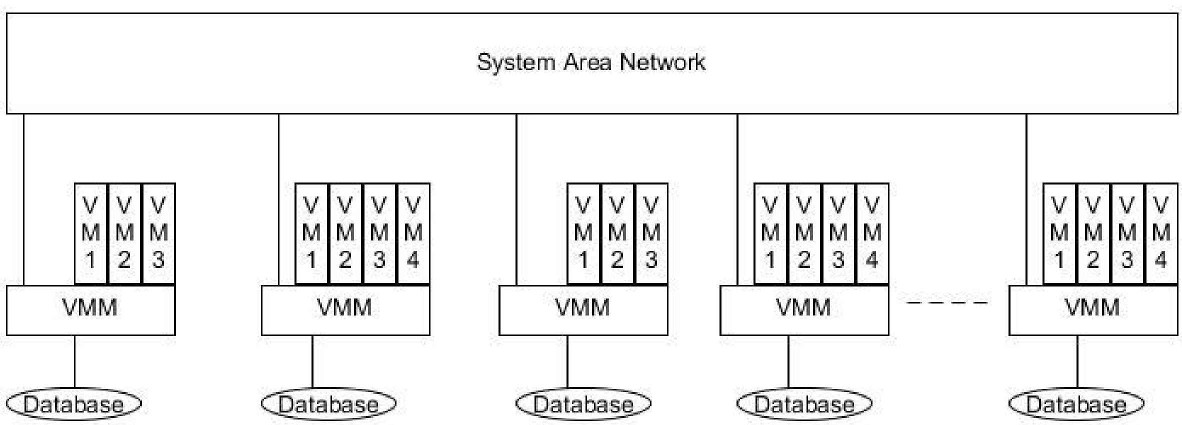


Fig 4.4: Virtual cluster based on application partitioning

- The VMs are guest systems. The host and guest systems may run with different operating systems.
- Each VM can be installed on a remote server or replicated on multiple servers

belonging to the same or different physical clusters.

- The boundary of a virtual cluster can be changed as VM nodes are added, removed, or migrated dynamically over time.

**High-Performance Virtual Storage:**

Template VM can be distributed to several physical hosts within the cluster to customize other VMs. In addition to that pre-designed software packages reduce the time required for customization and switching between virtual environments. Management of the disk spaces is very important.

Storage architecture design can be applied to reduce duplicated blocks within a distributed file system of virtual clusters. Hash values are used to compare the contents of data blocks. Users have their own account for storing data block identification in corresponding VMs within a user- specific virtual cluster. When users modify the data than it creates new data blocks. And new created blocks are used to be shown in users account.

There are four steps to deploy a group of VMs onto a target cluster:

- Prepare the disk image
- Configure the VMs
- Choose the destination nodes
- Execute the VM deployment command on every host

Many systems use templates to simplify the disk image preparation process:

- A template is a disk image that includes a preinstalled OS with or without certain application software.
- Users chooses a template according to their requirements and makes a backup of it to use as their own disk image.
- Templates comes in the Copy on Write (COW) format.
- A new COW backup file is small and easy to create and transfer. So, it reduces disk space consumption.
- VM deployment time is much shorter than copying the whole raw image file.
- Every VM is configured with a name, disk image, network setting, and allocated CPU and

memory.

- This method is inefficient when it is managing a large group of VMs.
- VMs with the same configurations could use pre-edited profiles to simplify the process.
- The system configures the VMs according to the chosen profile.

Most configuration items use the same settings. Some of them such as universally unique identifier, or UUID, VM name and IP address are assigned with automatically calculated values. Normally, users don't care which host is running their VM.

**Virtualization of Server, Desktop and Network:**

Virtualization of server includes different types of virtualization such as client, storage, desktop and network virtualization. Here different implementation of virtualization process, management software, and support for virtualization platforms are discussed.

Server virtualization is a process of virtualizing the host server resources including the number and identity of individual physical servers, processors and operating systems. The server administrator uses a software application to divide one physical server into multiple isolated virtual servers. The virtual servers provide an abstraction of a complete independent server to the server users.

**Virtual Machine:**

A virtual machine is a server that does not physically exist but is created over another physical server. Virtual machine is called a guest while the platform on which it run within is called a host. One host can run multiple VMs at once. Because VMs are separated from the physical machines they use. The host is able to dynamically assign resources to virtual machines.

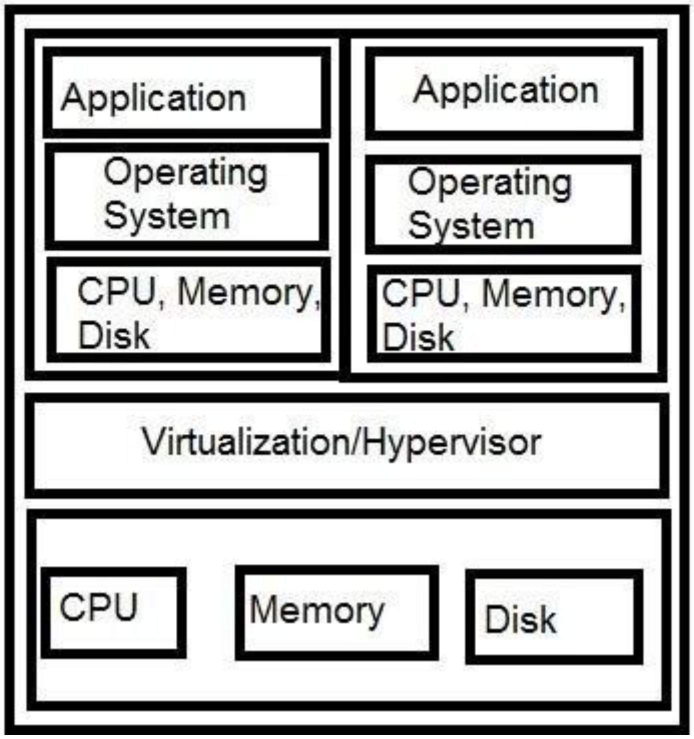


Fig 4.5: Server virtualization

Virtual machines look like real physical machine to the users. That means the user would access to an operating system and machine resources like CPU memory, hard disk and network. For example a hypervisor virtualizes a physical machine with architecture into multiple virtual machine. Each VM is a virtualized server using physical machine resources and an operating system.

## Virtualization Technologies:

Two types of technologies are used for server virtualization:

- **Hardware virtualization:** virtualizes the server hardware.
- **OS virtualization:** virtualizes the applications which runs over physical hardware.

## Hardware Virtualization:

In this virtualization technology virtualization layer runs immediately on the hardware and divides the physical machine into several virtual machine or partitions by using guest operating system. Hardware virtualization is also known as Hypervisor-based Virtualization, Bare-metal Hypervisor, Type-1 Virtualization or simply Hypervisor.

Hardware virtualization provides binary transparency because provide transparency to the operating system, applications, and middleware.

**OS virtualization:**

Server virtualization is also known as OS-based virtualization, OS-level virtualization or Type-2 virtualization. OS virtualization creates virtual OS for a single partition of a hardware. The virtual OS created by OS virtualization are also called containers.

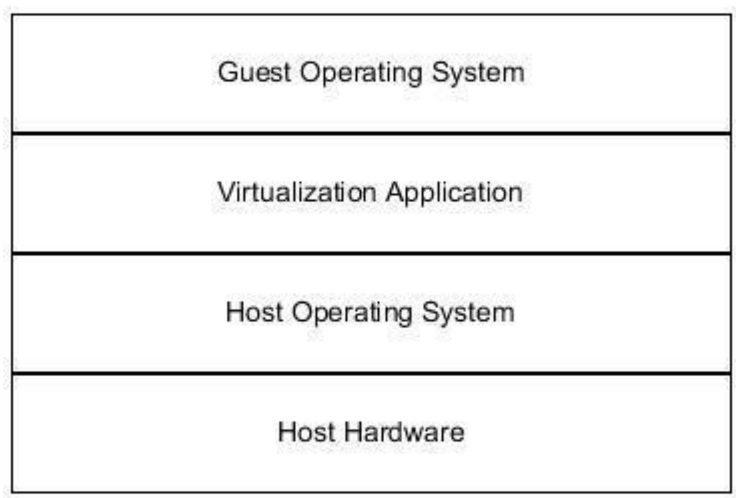


Fig 4.6: OS Virtualization

Because all virtual OS share resources of a single operating system. Implementation of this technology may alter file system orientation and also sometime introduce access restrictions to global system configuration or settings of host OS.

**Virtualization of Data-center:**

Data centers are grown rapidly in recent years and all major IT companies are transferring their resources into new data centers. All companies are investing billions of dollars in datacenter construction and automation. Data-center automation means huge amount of hardware, software, and database resources in data centers can be allocated dynamically to millions of Internet users simultaneously, with guaranteed QoS and cost-effectiveness.

Automation process is started by the demand of virtualization and cloud computing services in the market. Virtualization is increasing mobility, reducing maintenance and increasing the number of virtual clients.

**Server Consolidation in Data Centers**:

In data centers a huge amount of heterogeneous workloads runs on servers at many times. Heterogeneous workloads is divided into two categories:

- **Chatty workloads:** This workload generally burst at some point and return to a silent state at some other point. For example web video, exam results, cricket match score and etc.
- **Non-interactive workloads:** This workload do not require efforts to make progress after they are submitted. For example High-performance computing.

Sometimes the requirement for resources by these workloads are different. To guarantee that the workload will always reach requirement level the workload is used to be allocated statically so that demand is satisfied.

Most servers in data centers are always used. A large amount of hardware, space, power and management cost in these servers is always wasted. Server consolidation is a technique to improve the low utility ratio of hardware resources by reducing the number of physical servers. There are many server consolidation techniques available in the market like centralized and physical consolidation but virtualization-based server consolidation is most powerful. Data centers have to optimize their resources.

The use of VMs increases the complexity in resource management. Resource utilization and QoS in data centers is the main challenge to solve. Server virtualization has the following effects on the data centers:

- Consolidation increases hardware utilization.
- Consolidation also provide backup and disaster management.
- Provides more active provisioning and deployment of resources.
- The total cost of ownership is reduced.

- Also improves availability and business continuity.

**<u>Virtual Storage Management:</u>**

Storage virtualization is used for the aggregation and repartitioning of disks at very coarse time scales for use in physical machines. In system virtualization virtual storage contains the storage maintained by VMMs and guest OS. The data stored here is classified into two categories:

- **VM images:** special to the virtual environment
- **Application data:** all other data which is same as the data in host OS.

The most important aspects of system virtualization are encapsulation and isolation. Host operating systems and applications running on it are encapsulated in VMs. Only one operating system runs in a virtualization while many other applications run in the operating system. System virtualization allows multiple VMs to run on a physical machine and VMs are completely isolated. For encapsulation and isolation both the system software and the hardware platform like CPUs and chipsets are required. The storage systems is the main requirement for VM deployment.

In virtualization a virtualization layer is inserted between the hardware and host operating system. This procedure complicates storage process.

- Storage in the guest OS is done though real hard disk while the guest OS cannot access the hard disk directly.
- Some guest OS contains hard disk when there VMs are running on a single physical machine. So, storage management in VMM is more complex than that of guest OS.
- Many researchers tried to solve the problems in virtual storage management.
- The main reason of the research is to increase performance and reducing the amount of storage by the VM images.
- Parallax is a distributed storage system designed for virtualization.
- Content Addressable Storage (CAS) is a solution to reduce the total size of VM images and it supports a large set of VM-based systems in data centers.
- In parallax designs architecture storage features are implemented directly on high-end storage arrays and switchers are relocated in VMs.
- It supports all system virtualization techniques like para virtualization and full virtualization.

**Trust Management in Virtualized Data Centers:**

- A VMM changes the computer architecture.
- VMM generates a layer of software between the operating systems and hardware to create one or more VMs on a single physical platform.
- Machine is shared over the network and that is a challenge to VM security.
- VMM provide secure accesses to hardware resources. So VMM is the base of the security of a virtual system.
- If hacker enters the VMM than the whole system is in danger.