Software Defined Systems

Week 6 Virtualization Technologies

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Contents

Virtualization Technologies

Learning objectives

- Understand the concept of virtualization and its significance in modern IT.
- Identify different types of virtualization and their applications.
- Analyze the benefits and challenges associated with virtualization.
- Explore the role of hypervisors and virtual machine monitors in virtualization.
- Examine security considerations and best practices for managing virtual environments.
- Discuss the future trends and innovations in virtualization technology.

What is Virtualization?

- Virtualization is the process of creating a virtual version of physical resources.
- Multiple virtual machines (VMs) can run inside a single physical machine (PM).Each VM provides an illusion of running on dedicated hardware.
- Virtualization is fundamental for cloud computing.
- It enables multiple clients to share cloud computing resources efficiently.

What is Virtualization?

- Virtualization simplifies management of physical resources.
- It abstracts underlying resources, isolates users, and supports replication.
- Increases system elasticity.

How Virtualization Works?

- Multiplexing: Creates multiple virtual objects from one physical instance.
- Aggregation: Combines multiple physical objects into one virtual object.
- Emulation: Constructs a virtual object of one type from a different type of physical object.
- **Examples** - Virtual memory multiplexes real memory and disk; a virtual address emulates a real address.

Similarities and Differences with Multiprogramming

- Multiprogramming is an operating system capability that allows multiple programs to reside in memory and execute concurrently.

Virtualization

- CPU is shared among OSs.
- Memory is shared using more level of indirections.
- Multiple Page tables.
- OS may or may not know that it is being managed

Multi Programming

- CPU is shared among processes
- Memory is shared using Page Tables.
- Process knows it is being managed- uses system calls.

Virtual Machine Monitor (VMM / Hypervisor)

- A VMM (hypervisor) partitions computer resources into multiple VMs
- Enables concurrent operation of several operating systems on a single hardware platform.
- Provides an execution environment for operating systems.

Features of a Virtual Machine Monitor (VMM)

- 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.

How VMM Virtualizes CPU and Memory?

- Traps the privileged instructions executed by a **guest OS** and enforces the correctness and safety of the operation
- Traps interrupts and dispatches them to the individual guest operating systems
- Controls the virtual memory management
- Maintains a **shadow page** table for each **guest OS** and replicates any modification made by the guest OS in its own shadow page table.
- Monitors the system performance and takes **corrective actions** to avoid performance degradation.

Types of Hypervisors

Types of Hypervisors

- Hypervisors are crucial for virtualization, allowing multiple operating systems to run on a single physical machine.
- There are two main types of hypervisors.
    - Type 1 Hypervisors
    - Type 2 Hypervisors

Type 1 Hypervisors

- Installed directly on hardware, without an underlying OS.
- Known as "bare-metal" hypervisors.
- Examples - VMware ESXi, Microsoft Hyper-V, Citrix Hypervisor.

Advantages

- High performance and efficiency.
- Direct access to hardware resources.
- Ideal for enterprise-level virtualization.

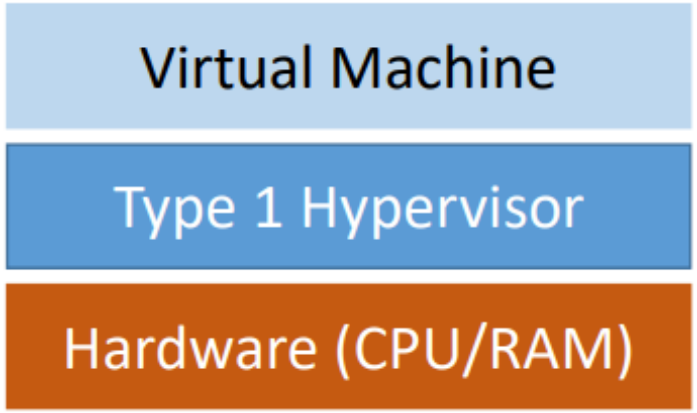
Type 2 Hypervisors

- Installed on top of an existing operating system.
- They are also known as "hosted" hypervisors.
- Examples - VMware Workstation, Oracle VirtualBox, Parallels Desktop.

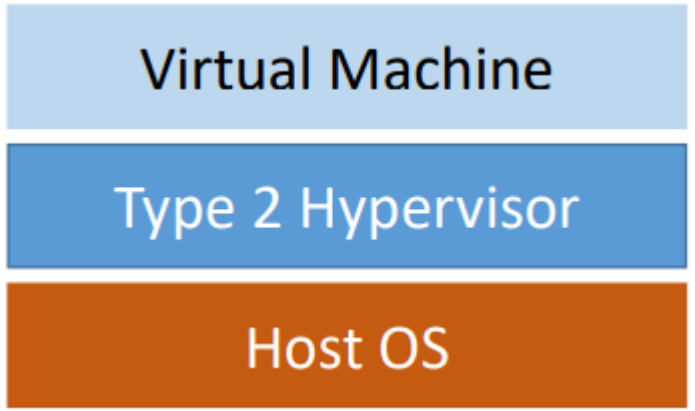
Advantages

- Easier to set up and use.
- Leverages existing OS functionality.
- Commonly used for personal computers and development environments.

Type 1 and 2 Hypervisors



- Type 1 (bare metal) hypervisor - runs directly on hardware, no need for host OS



- Type 2 (hosted) hypervisor - runs as an application on top of host OS

Virtual Machine migration

- Virtual Machine migration refers to the process of moving a running virtual machine from one physical host or environment to another.
- This can be done for various reasons, such as load balancing, maintenance, disaster recovery, or infrastructure upgrades.
- There are two main types of VM migration:
  - Live Migration
  - Cold Migration

Live Migration

- Live migration is the process of moving a running virtual machine from one physical host to another without interrupting the VM's operation or user experience.
- Live migration allows for continuous uptime and service availability, making it particularly useful for mission-critical applications.
- **Examples** of live migration technologies include VMware vMotion, Microsoft Hyper-V Live Migration, and KVM Live Migration.

Cold Migration

- Cold migration, also known as offline migration, involves shutting down the virtual machine, transferring its disk image and configuration files to the new host, and then restarting the VM on the new host.
- This method is simpler and does not require specialized migration capabilities, but it results in downtime for the VM during the migration process.
- Cold migration is often used for non-critical VMs or during planned maintenance windows.

Key Steps in VM Migration

- **Preparation**: Ensure target host has sufficient resources.
- **VM state capture**: Capture current state of the VM.
- **Data transfer**: Move VM's disk image and configuration.
- **VM restoration**: Restore the VM on the target host.

Benefits of virtualization

- Instant provisioning - fast scalability
- Live Migration is possible
- Load balancing and consolidation in a Data Center is possible.
- Low downtime for maintenance
- Virtual hardware supports legacy operating systems efficiently
- Security and fault isolation

Types of Virtualization

Types of Virtualization

- There are several types of virtualizations in the world of information technology.
  - Server Virtualization
  - Desktop Virtualization
  - Storage Virtualization
  - Network Virtualization
  - Application Virtualization
  - Hardware Virtualization

Server Virtualization

- This involves running multiple virtual machines (VMs) on a single physical server.
- Each VM runs its own operating system and applications, isolated from the others.
- **Examples** - VMware ESXi, Microsoft Hyper-V, Citrix Hypervisor.

Desktop Virtualization

- Also known as Virtual Desktop Infrastructure (VDI).
- It involves hosting desktop environments on a centralized server, and users access their virtual desktops remotely.
- Allows for centralized management and data security.
- **Examples** - Citrix Virtual Apps and Desktops, VMware Horizon.

Storage Virtualization

- This combines multiple physical storage devices into a single logical storage pool.
- Provides abstraction from the underlying physical storage.
- Enables features like automated tiering, backup, and disaster recovery.
- **Examples** - NetApp ONTAP, VMware vSAN, Red Hat Ceph Storage.

Network Virtualization

- Involves the creation of virtual networks on top of the physical network infrastructure.
- Allows for programmatic control and configuration of network resources.
- Enables features like software-defined networking (SDN) and network function virtualization (NFV).
- **Examples** - VMware NSX, Microsoft Azure Virtual Network, Cisco ACI.

Application Virtualization

- This isolates applications from the underlying operating system.
- Allows applications to run without being installed directly on the client device.
- Simplifies application management and deployment.
- **Examples** - Microsoft App-V, Citrix App Layering, VMware ThinApp.

Hardware Virtualization

- Also known as server virtualization or platform virtualization.
- Allows multiple virtual machines to run on a single physical server.
- Provides the ability to create and manage virtual machines.
- **Examples** - VMware ESXi, Microsoft Hyper-V, Citrix Hypervisor.

Virtual Machine Management

- Image Management
- Access Control
- Monitoring and Logging
- Network Security
- Backup and Disaster Recovery
- Compliance

Security of Virtualization

- **Isolation** - Virtualization allows VMs to be isolated from each other and the host operating system, reducing the attack surface.
- **Containment** - Even if a VM is compromised, the damage can be contained and prevented from spreading to other VMs or the host.
- **Snapshot/Rollback** - The ability to quickly snapshot and roll back VMs can help recover from security incidents.
- **Patching** - Virtualization makes it easier to rapidly patch and update VMs compared to physical machines.

Challenges of Virtualization

- Security risks, Increased attack surfaces, VM-to-VM attacks, privilege escalation.
- Performance overhead on Resource sharing and contention issues.
- Complexity in managing virtual infrastructure.
- High availability and disaster recovery challenges.
- Vendor lock-in issues with proprietary platforms.
- Licensing and compliance complexities.

What is Load Balancing?

What is Load Balancing?

- Load balancing is the process of distributing network traffic efficiently among multiple servers to optimize application availability and ensure a positive end-user experience.
- Load balancing directs and controls internet traffic between the application servers and their visitors or clients.
- As a result, it improves an application’s availability, scalability, security, and performance.

What is Load Balancing?

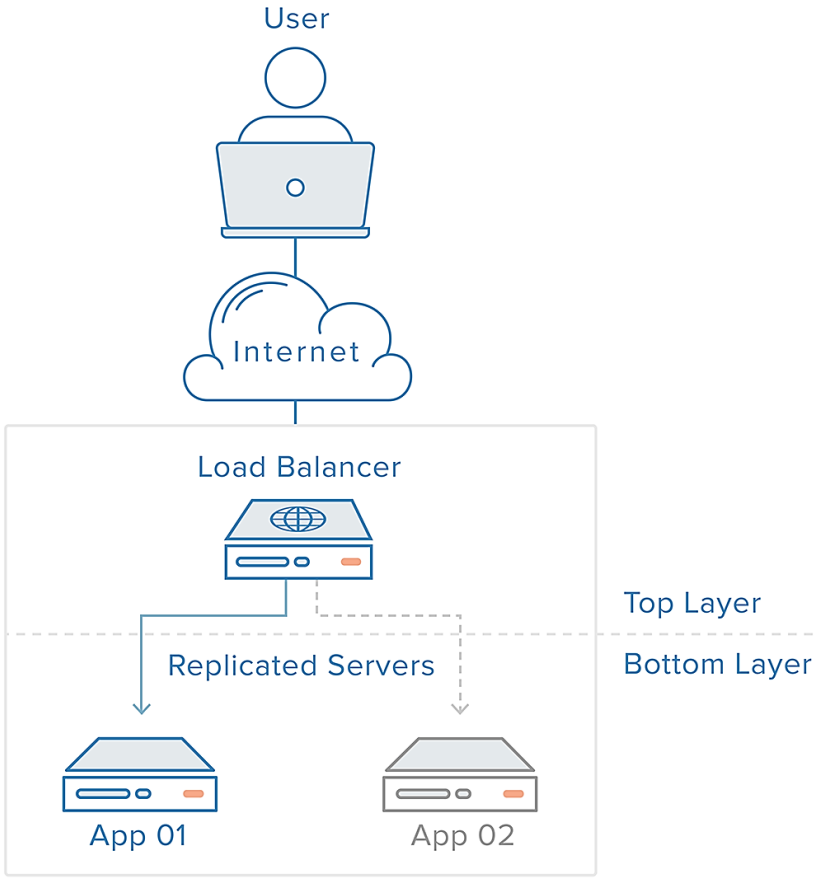
- Because high-traffic websites and cloud computing applications receive millions of user requests each day, load balancing is an essential capability for modern application delivery.

What is Load Balancing?

- A web infrastructure with no load balancing might look something like the following, user connects directly to the web server, at yourdomain.com.

Source: https://www.digitalocean.com/community/tutorials/what-is-high-availability

What is Load Balancing?



- This single point of failure can be mitigated by introducing a load balancer and at least one additional web server on the backend.

Source: https://www.digitalocean.com/community/tutorials/what-is-high-availability

How Virtualization Enhances Cloud Computing

- **Resource Pooling** - Multiple VMs on shared physical hardware.
- **Dynamic Resource Allocation** - Adjust resources based on demand in real time.
- **Cost Efficiency** - Reduces operational costs for cloud providers and customers.

Disaster Recovery Benefits of Virtualization

- **Rapid Recovery Options** - Quick restoration from snapshots or backups.
- **Geographic Redundancy** - Replication of VMs across multiple locations.
- **Cost-Effective Solutions** - Reduced need for duplicate hardware.

Cloud-Based Disaster Recovery

- **Case Study: E-Commerce Company**
  - **Challenge** - Managing peak traffic efficiently.
  - **Solution** - Cloud-based disaster recovery using virtualization.
  - **Results** - Seamless operations during outages.

Future Trends in Virtualization

- Increased use of AI and machine learning in virtualization.
- Growing importance of edge computing.
- Enhanced automation and orchestration capabilities.

Summary

- **Foundational Technology** - Creates virtual versions of physical resources.
- **Key Benefits** - Improved efficiency and scalability, Instant provisioning and enhanced disaster recovery, Advanced security features.
- **Types of Virtualization** - Server, Desktop, and Network Virtualization
- **Role of Hypervisors** - Manage virtual environments effectively.

Test Your Knowledge

1. Which of the following is a benefit of server virtualization?

    A) Increased hardware costs.

    B) Improved resource utilization.

    C) More complex management.

    D) Limited scalability.

Test Your Knowledge

1. Which of the following is a benefit of server virtualization?

A) Increased hardware costs

B) Improved resource utilization

C) More complex management

D) Limited scalability

Reason: Server virtualization improves resource utilization by maximizing the use of available hardware and reducing the number of physical servers needed.

Test Your Knowledge

2. What is a Type 1 hypervisor?

A) A hypervisor that runs on top of an existing operating system

B) A software application used for server management

C) A type of virtual machine

D) A hypervisor that is installed directly on the hardware

Test Your Knowledge

2. What is a Type 1 hypervisor?

A) A hypervisor that runs on top of an existing operating system

B) A software application used for server management

C) A type of virtual machine

D) A hypervisor that is installed directly on the hardware

Reason: Type 1 hypervisors, also known as bare-metal hypervisors, run directly on the physical hardware of a server.

Thank you!

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