5COSC022W
Client-Server Architectures
Virtualization

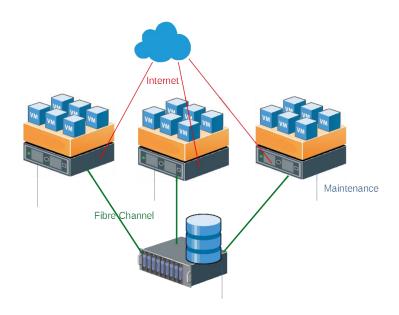Dr. Hamed Hamzeh

This content will cover

- Understand the benefits of virtualization

- Be able to describe virtualization, virtual machines and hypervisors

- Describe typical data center components that are virtualized

- Cloud Computing
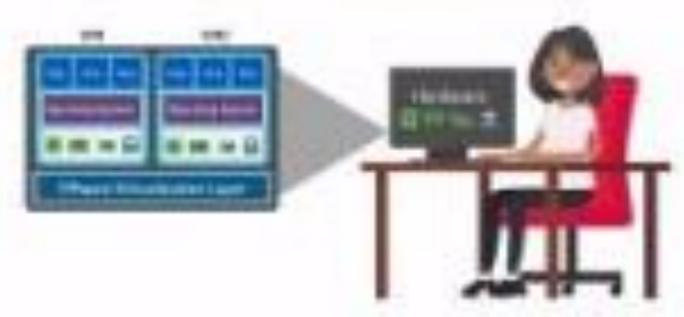
What is virtualization?

What is Virtualisation?

Definition: Creating a virtual (rather than actual) version of something, such as a computer operating system, server, storage device, or network resource.

Abstraction Layer: Virtualisation acts as an abstraction layer between the physical hardware and the software that uses it.
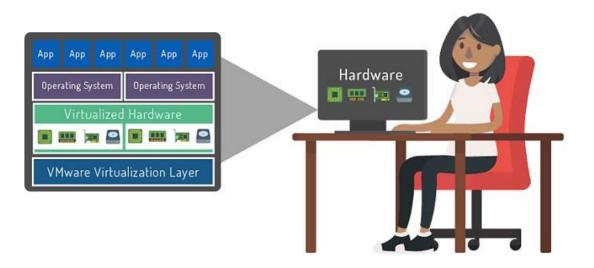
Key Idea: To run multiple operating systems or applications on a single physical machine, or to pool resources and present them as a single entity.

Analogy: Think of it like running multiple apps on your smartphone - each app operates independently, even though they share the same underlying hardware.

Now that you are aware of the roles of hardware and software, the concept of virtualization will be easier to grasp. Virtualization is the "layer" of technology that goes between the physical hardware of a device and the operating system to create one or more copies of the device.

Why is Virtualisation Important?

- **Cost Savings:**
  - Reduced hardware costs (fewer physical servers needed).
  - Lower energy consumption and cooling expenses.
- **Increased Efficiency and Agility:**
  - Faster deployment of new servers and applications.
  - Improved resource allocation and management.
  - Simplified maintenance and patching.
- **Enhanced Disaster Recovery:**
  - Easier replication and migration of virtual machines.
  - Faster recovery times in case of failures.
- **Improved Testing and Development:**
  - Ability to easily create and tear down isolated test environments.
- **Better Resource Utilization:**
  - Maximizing the use of available hardware resources.

Key Terminology - Part 1

Host Machine (or Host): The physical computer on which the virtual environment is running.

Guest Machine (or Guest): The virtual computer or operating system that is running within the virtual environment.

Hypervisor (or Virtual Machine Monitor - VMM): The software or firmware that creates and manages virtual machines. It allocates and manages resources for the guest machines.

Virtual Machine (VM): A software-based emulation of a physical computer. It has its own operating system, applications, and resources (CPU, memory, storage, network).

Key Terminology - Part 2

Virtual Appliance: A pre-configured virtual machine image that includes an operating system and one or more applications.

Snapshot: A point-in-time copy of the state of a virtual machine. Useful for backups and reverting to previous configurations.

Template: A master image of a virtual machine that can be used to quickly create new virtual machines with the same configuration.

Resource Pooling: Aggregating physical resources (CPU, memory, storage, network) and making them available to be dynamically allocated to virtual machines.

History of Virtualisation - Early Days

1960s: Mainframe Partitioning: The earliest forms of virtualisation appeared on mainframe computers, allowing them to run multiple applications concurrently by dividing resources. IBM's CP/CMS (Conversational Monitor System) was a key example.

Focus: Primarily aimed at maximizing the utilization of expensive mainframe hardware.

History of Virtualisation - The Rise of x86

- **Late 1990s - Early 2000s:** The rise of powerful x86 servers and the need for better resource utilization led to the development of modern virtualisation technologies.

- **Key Players:** VMware was a pioneer in this era, offering software-based virtualisation solutions for x86 architectures. Microsoft (Virtual PC, Hyper-V), Citrix (XenServer), and open-source projects (Xen, KVM) also emerged.

- **Drivers:** Server consolidation, cost reduction, and improved manageability were major driving forces.

What is a VM?

- Virtualization creates virtual hardware by cloning physical hardware

- The hypervisor uses virtual hardware to create a virtual machine (VM)

- A VM is a set of files

- With a hypervisor and VMs, one computer can run multiple OS simultaneously

Virtual Machine Files

- VMs can be exported and moved to other hosts

- Files are created by the hypervisor and stored in a directory

- Example VM files:

File Type	File Name	Description
Log File	<vmname>.log	Keeps a log of VM activity
Disk File	<vmname>.vmdk	Stores content of VM's disk drive
Snapshot Files	<vmname>.vmsd and <vmname>.vmsn	Stores information about VM snapshots (saved VM state)
Configuration File	<vmname>.vmx	Stores information about VM name, BIOS, guest OS, and memory

Server Virtualization

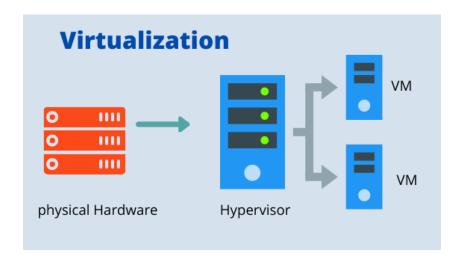Divides physical servers into multiple isolated virtual environments using software called a hypervisor.

Maximizes resource utilization by partitioning physical servers into smaller virtual servers.

Benefits: Cost savings, energy efficiency, and improved disaster recovery processes.

Technologies: Hypervisors like VMware ESXi, Microsoft Hyper-V, and Citrix XenServer.

Virtualization

physical Hardware   Hypervisor   VM   VM

Client-Side Virtualization

Allows a single workstation to run multiple operating systems simultaneously, often used for testing and development
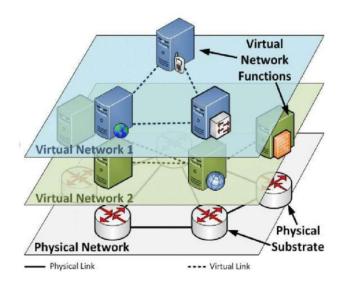
Enables a personal computer to run multiple operating systems or multiple instances of an operating system.

Benefits: Flexibility, testing environments, and legacy application support.

Technologies: VMware Workstation, Oracle VirtualBox, Parallels Desktop.

Network Virtualization

Virtual Network Functions

Virtual Network 1

Virtual Network 2

Physical Network

Physical Substrate

— Physical Link   ---- Virtual Link

Combines hardware and software network resources into a single, software-based administrative entity

Creates a virtualized network environment that can include virtual switches, routers, firewalls, and load balancers.
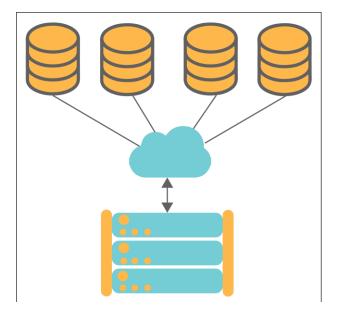
Benefits: Simplifies network configuration and management, enhances security, and facilitates cloud computing.

Technologies: VMware NSX, Cisco ACI.

Storage Virtualization

Pools physical storage from multiple network storage devices into what appears to be a single storage device managed from a central console

Abstracts storage resources across multiple physical storage devices to appear as a single storage device.

Benefits: Easier management, improved performance, and enhanced data mobility.
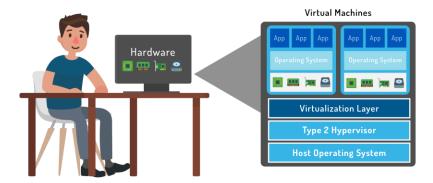
Technologies: SAN (Storage Area Network), NAS (Network Attached Storage).

The Hypervisor
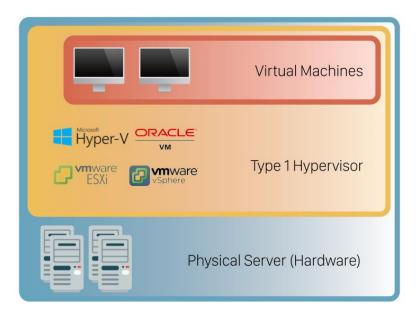
What is a Hypervisor?

- Software installed on top of hardware that created virtualization layer

- Hosts VMs

- Type 1 Hypervisor – Bare metal hypervisor (VMware ESXi)

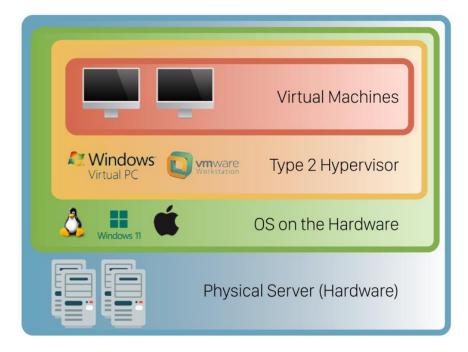- Type 2 Hypervisor – Hosted hypervisor (VMware Workstation)

Type 1 Hypervisors

Also known as bare-metal hypervisors, they run directly on the host's hardware to control the hardware and to manage guest operating systems.
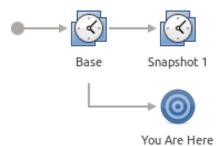
Type 2 Hypervisors

Run on a conventional operating system just like other software applications.

What is a snapshot?

- Working on a VM and need to save progress or state

- Snapshots are saved as files in the VM folder (`<vmname>.vmx`)

- What is saved by a snapshot?
  - State of VM disks
  - Contents of VM memory
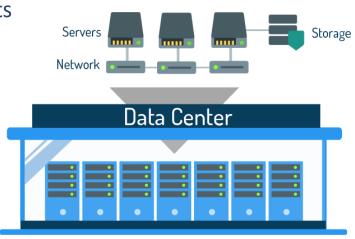 - VM settings

Base   Snapshot 1

You Are Here

The Data Center
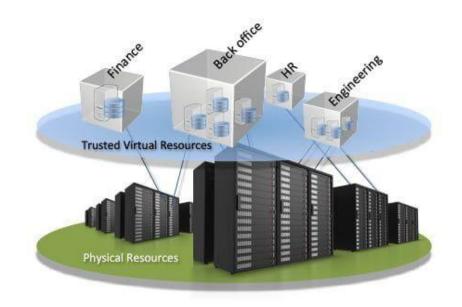
What is a Data Center?

- **Hardware** infrastructure that supports virtualization

- Focus is on processing large amounts of data

- What are the three main components?
  - Compute
  - Storage
  - Networks

More details of a Data Center? Let's create another slide for that.

A **virtual data center (VDC)**

A virtual data center (VDC) is a cloud-based environment that provides organizations with computing, storage, networking, and other IT resources on demand, without the need to own and manage physical data center infrastructure.

It essentially replicates the functionality and capabilities of a traditional physical data center in a virtualized environment.

VDC Benefits?
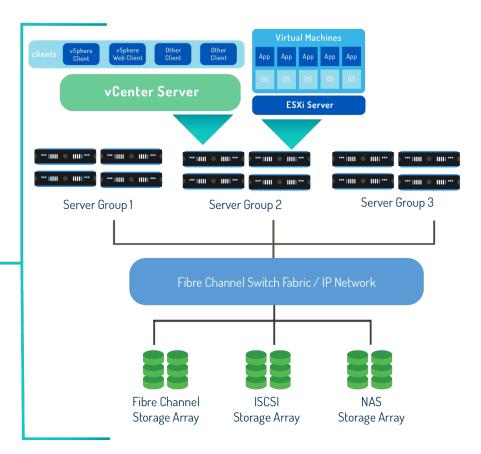
Cost Savings

Scalability and Flexibility

Faster Deployment

Increased Agility

Improved Reliability and Availability

What is vSphere?

- Suite of virtualization technology designed for larger enterprise data center management

- vSphere virtualization tools include:
    - **ESXi**: Type 1 Hypervisor
    - **vCenter**: Management software (installed on management server)
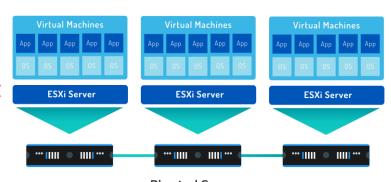   - **vSphere Client**: Program that controls host servers and VMs

What is ESXi?

- ESXi is VMware's Type 1 hypervisor software installed directly on the physical server and creates the virtual layer

High Performance

Scalability
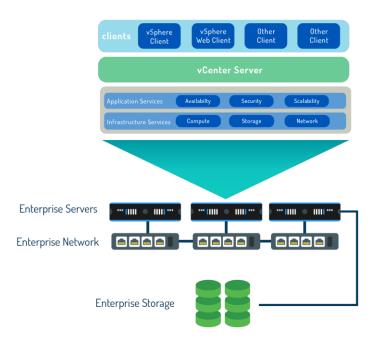
Resource Management

VMFS (Virtual Machine File System)

Integration with vCenter Server
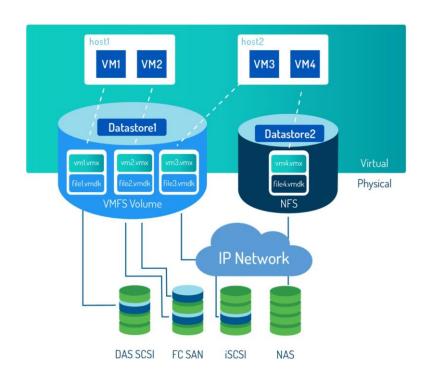
vCenter and vSphere Client

- **vCenter**: Software installed on a dedicated server to manage ESXi servers and other components of a virtualized data center

- **vSphere Client**: Program with a graphical user interface (GUI) that allows data center administrators to connect to vCenter and ESXi remotely
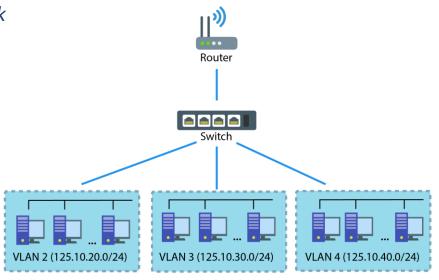
Storage Virtualization

- Storage capacity is pooled and distributed to the VMs
    - Physical storage devices are partitioned into logical storage (**LUNs**)
    - LUNs are used to create a **datastore**

- How do VMs access data center storage?
    - VMs are stored as VMDK (*.vmdk*) files on datastore
    - VM configuration files (VM settings) are stored as VMX (*.vmx*) files

Network Virtualization

- Physical components that make up the physical network are virtualized to create a *virtual network*

- What is a vSwitch?
    - Virtual switch that virtual devices can connect to in order to communicate with each other

- What is a vLAN?
    - Virtual Local Area Network that is segmented into groups of ports isolated from one another, creating different network *segments*

Router

Switch

VLAN 2 (125.10.20.0/24)   VLAN 3 (125.10.30.0/24)   VLAN 4 (125.10.40.0/24)
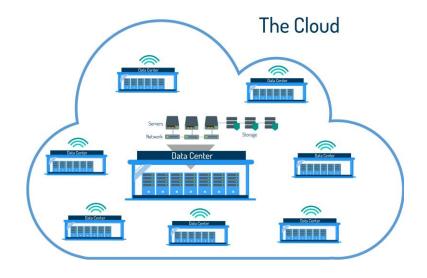
What is the Cloud?

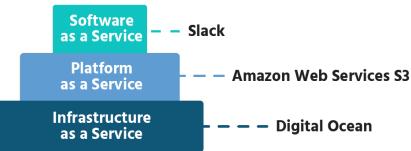# What is Cloud Computing?

The Cloud

- Cloud computing is the delivery of <u>shared computing resources</u> (software and/or data) on-demand through the internet

Types of Cloud Computing

Cloud computing is categorized into different service models. The major types of cloud computing are:

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

Wait... what is Cloud again?

TRADITIONAL ON-PREMISES	INFRASTRUCTURE AS A SERVICE (IaaS)	CONTAINERS AS A SERVICE (CaaS)	PLATFORM AS A SERVICE (PaaS)	FUNCTION AS A SERVICE (FaaS)	SOFTWARE AS A SERVICE (SaaS)
Data & Configurations	Data & Configurations	Data & Configurations	Data & Configurations	Data & Configurations	Data & Configurations
Application Code	Application Code	Application Code	Application Code	Application Code	Application Code
Scaling...	Scaling...	Scaling...	Scaling...	Scaling...	Scaling...
Runtime	Runtime	Runtime	Runtime	Runtime	Runtime
OS	OS	OS	OS	OS	OS
Virtualization	Virtualization	Virtualization	Virtualization	Virtualization	Virtualization
Hardware	Hardware	Hardware	Hardware	Hardware	Hardware

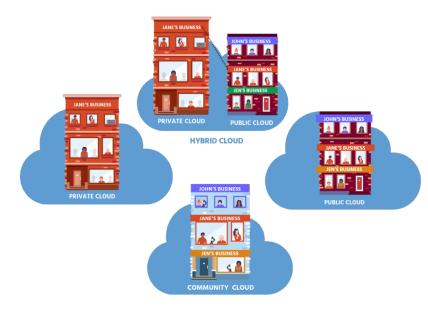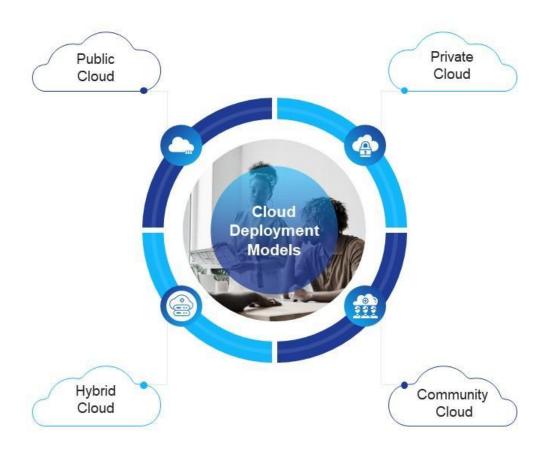You Manage   Cloud Provider Manages

Cloud Deployment Models

Cloud deployment includes an emphasize on <u>where</u> the hardware or software is running and <u>who</u> is controlling it.

- Private Cloud
- Community Cloud
- Public Cloud
- Hybrid Cloud

Cloud Computing Deployment Models

Public
Cloud

Private
Cloud

**Cloud
Deployment
Models**

Hybrid
Cloud

Community
Cloud

Public Cloud

- All users that wish to access infrastructure like computational resources, storage, database services, and so on can do so

Private Cloud

- More expensive than the public cloud, it provides companies with greater security and privacy control

Hybrid Cloud

- Mixture of public and private clouds achieves an excellent mix of security, scalability, and cost

Community Cloud

- Community deployment approach is similar to the private cloud deployment paradigm, except for data sharing between companies

Cloud Providers

Cloud VS Virtualization

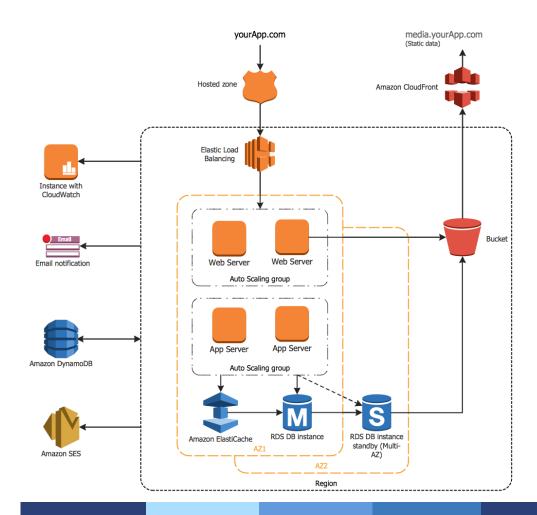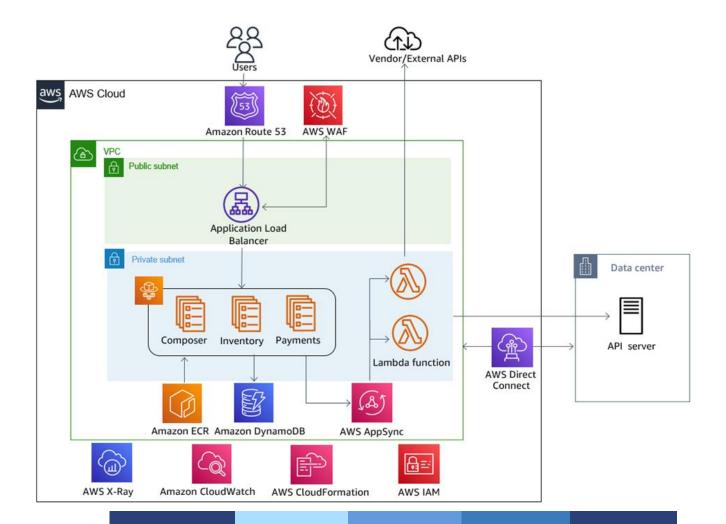|	Virtualization	Cloud
Definition	Technology	Methodology
Purpose	Create multiple simulated environments from 1 physical hardware system	Pool and automate virtual resources for on-demand use
Use	Deliver packaged resources to specific users for a specific purpose	Deliver variable resources to groups of users for a variety of purposes
Configuration	Image-based	Template-based
Lifespan	Years (long-term)	Hours to months (short-term)
Cost	High capital expenditures (CAPEX), low operating expenses (OPEX)	Private cloud: High CAPEX, low OPEX Public cloud: Low CAPEX, high OPEX
Scalability	Scale up	Scale out
Workload	Stateful	Stateless
Tenancy	Single tenant	Multiple tenants

References

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Module Evaluation

Method 1

Each student will receive evaluation invites, sent to their University email account, one invite for each module they are taking. Each email will contain a direct link to the evaluation.

Method 2

By logging into Blackboard and following the pathway *Courses > Select a module from the list displayed > Books and Tools > Student Module Evaluation.*

Method 3

By accessing the SME Student Portal