

Cloud Computing

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What is Cloud Computing?

Cloud Disclaimers

We've redefined Cloud Computing to include everything that we already do. I don't understand what we would do differently other than change the wording of some of our ads.

- Larry Ellison (Oracle CEO)



Cloud Disclaimers

It's stupidity. It's worse than stupidity: it's a marketing hype campaign. Somebody is saying this is inevitable - and whenever you hear somebody saying that, it's very likely to be a set of businesses campaigning to make it true.

- Richard Stallman



Cloud Definition (1/3)

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 - ➋ the **hardware and systems software** in the datacenters that provide those services.
- ▶ The **services** themselves have long been referred to as **Software as a Service (SaaS)**.



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- ▶ Cloud Computing refers to both
 - ➊ the applications delivered as services over the Internet, and
 - ➋ the hardware and systems software in the datacenters that provide those services.
- ▶ The services themselves have long been referred to as Software as a Service (SaaS).
- ▶ The datacenter hardware and software is what we will call a Cloud.



Cloud Definition (2/3)

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- ▶ The **service** being sold is **Utility Computing**.
 - Amazon Web Services, Google App Engine, and Microsoft Azure



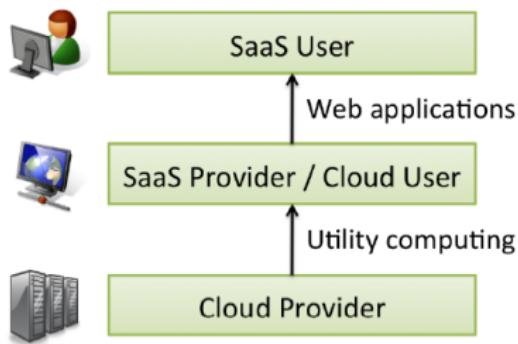
Cloud Definition (2/3)

- ▶ When a Cloud is made available in a **pay-as-you-go** manner to the public, we call it a **Public Cloud**.
- ▶ The **service** being sold is **Utility Computing**.
 - Amazon Web Services, Google App Engine, and Microsoft Azure
- ▶ **Private Cloud** refers to internal datacenters of a business or other organization that are **not made available to the public**.



Cloud Definition (3/3)

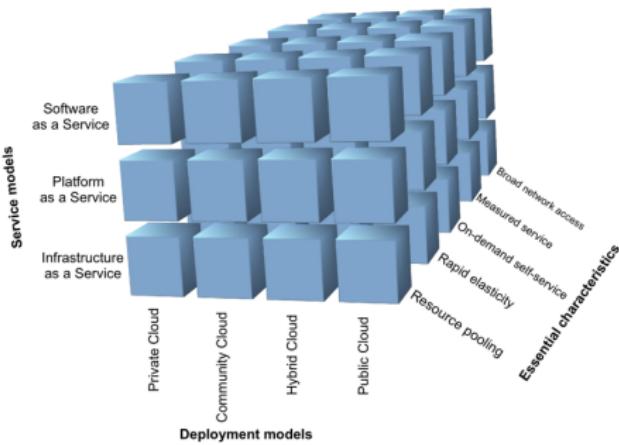
Cloud Computing is the sum of **SaaS** and **Utility Computing**, but does not normally include Private Clouds.



- ▶ Based on the NIST definition, the cloud model is composed of:
 - Five **characteristics**
 - Three **service models**
 - Four **deployment models**



Cloud Characteristics



[<http://cdn.katescomment.com/wordpress/wp-content/uploads/2010/02/CloudCube1.png>]

Cloud Characteristics

- ▶ On-demand **self-service**
- ▶ Broad network **access**
- ▶ Resource **pooling**
- ▶ Measured service
- ▶ Rapid **elasticity**

Cloud Characteristics - On-demand Self-Service

- ▶ A consumer can **unilaterally** provision **computing capabilities** without **human interaction** with the service provider.
- ▶ Computing capabilities
 - Server time, network storage, number of servers, ...

Cloud Characteristics - Broad Network Access

- ▶ Capabilities are
 - Available over the **network**.
 - Accessed through **standard mechanisms**.
- ▶ Promote use by
 - Heterogeneous thin or thick client platforms, e.g., mobile phones, laptops, ...

Cloud Characteristics - Resource Pooling

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- ▶ Computing resources
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 - Storage, processing, memory, network bandwidth and virtual machines
- ▶ Location independence
 - No control over the exact location of the resources

Cloud Characteristics - Measured Service

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- ▶ Control and optimize resource use automatically.
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 - Storage, processing, bandwidth, active user accounts, ...
- ▶ Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer.

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- ▶ Capabilities can be purchased in any quantity at any time.

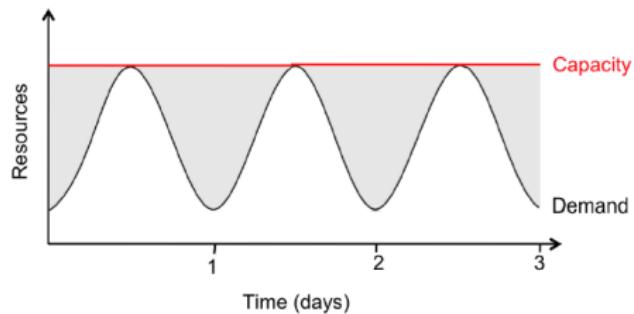
More About Elasticity

Elasticity

- ▶ Cloud Computing's ability to **add** or **remove resources** at a **fine grain** and with a lead time of minutes rather than weeks allows matching resources to workload much more closely.

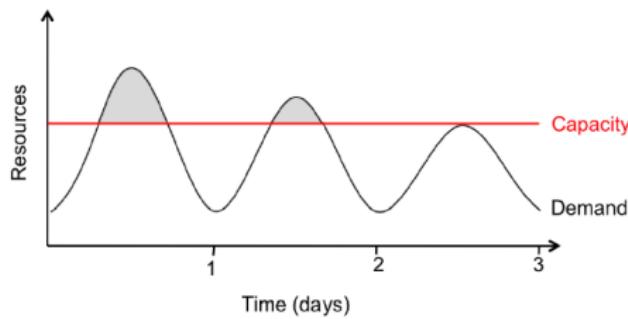
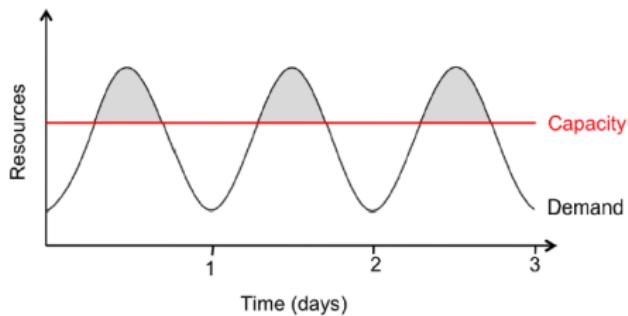
[Armbrust et al., Above the Clouds: A Berkeley View of Cloud Computing, Tech. Doc, 2009]

Over Provisioning



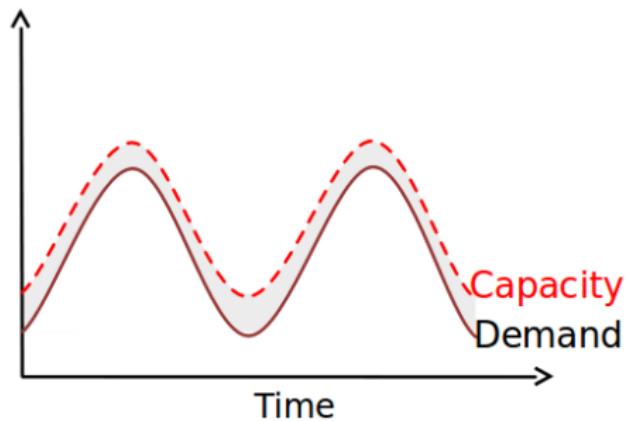
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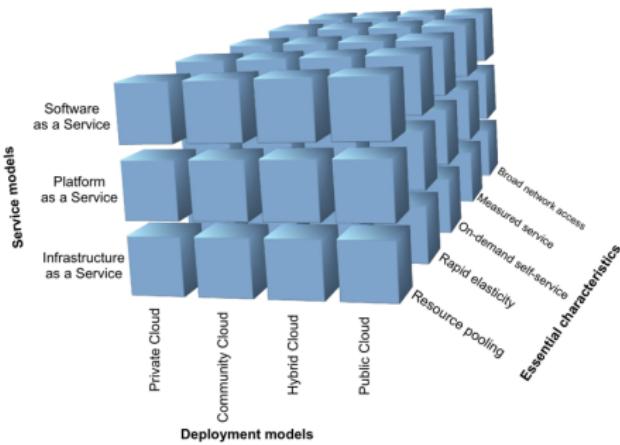


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Dynamic Provisioning



Cloud Service Models



[<http://cdn.katescomment.com/wordpress/wp-content/uploads/2010/02/CloudCube1.png>]

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

- ▶ Assume, you just moved to a city and you are looking for a place to live.



- ▶ What is your choice?



- ▶ What is your choice?
 - Built a new house?



- ▶ What is your choice?
 - Built a new house?
 - Buy an empty house?



► What is your choice?

- Built a **new house**?
- Buy an **empty house**?
- Live in a **hotel**?



- ▶ Let's built a **new house!**



- ▶ Let's built a **new house!**
- ▶ You can **fully control** everything you like your new house to have.
- ▶ But that is a **hard work.**



- ▶ What if you buy an **empty house**?



- ▶ What if you buy an **empty house**?
- ▶ You can **customize** some part of your house.
- ▶ But never change the original architecture.



- ▶ How about live in a **hotel**?



- ▶ How about live in a **hotel**?
- ▶ Live in a hotel will be a good idea if the only thing you care is enjoy your life.
- ▶ There is **nothing you can** do with the house except living in it.



Let's translate it to
Cloud Computing

- ▶ Infrastructure as a Service (**IaaS**): similar to **build a new house**.
- ▶ Platform as a Service (**PaaS**): similar to **buy an empty house**.
- ▶ Software as a Service (**SaaS**): similar to **live in a hotel**.

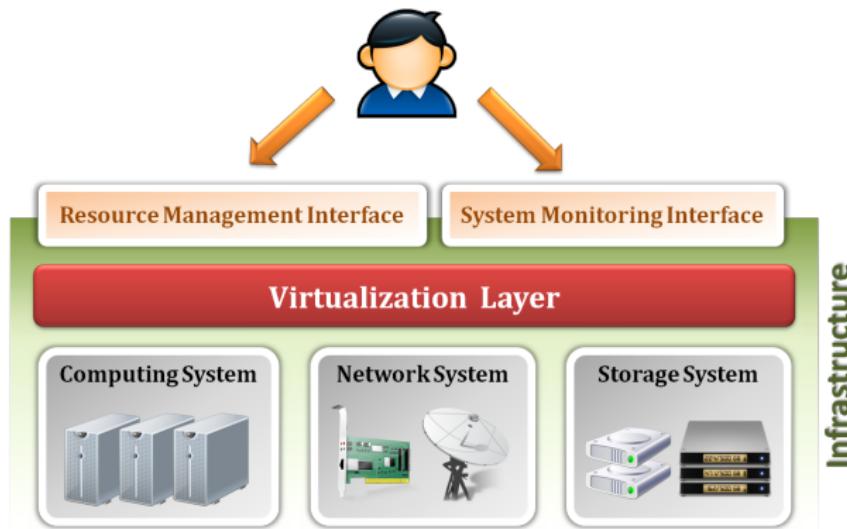
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- ▶ Example: Amazon Web Services (AWS), Rackspace, ...

- ▶ System architecture



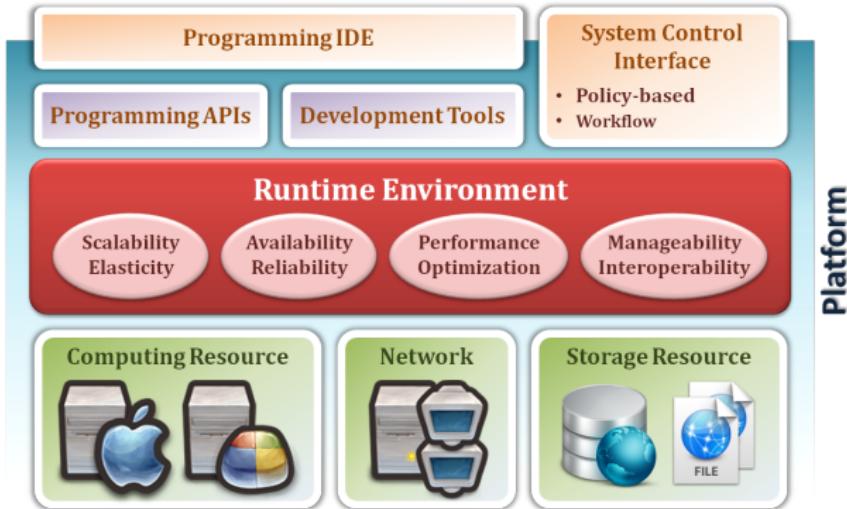
► Advantages:

- Infrastructure **scalability**
- Native integrated **management**: performance, resource consumption/utilization, load
- Economical **cost**: hardware, IT support

- ▶ Vendor provides **development environment**.
 - Tools and technology selected by vendor.
 - Control over data life-cycle.

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► **Advantages:**

- Rapid development and deployment
- Small startup cost

► **Disadvantages:**

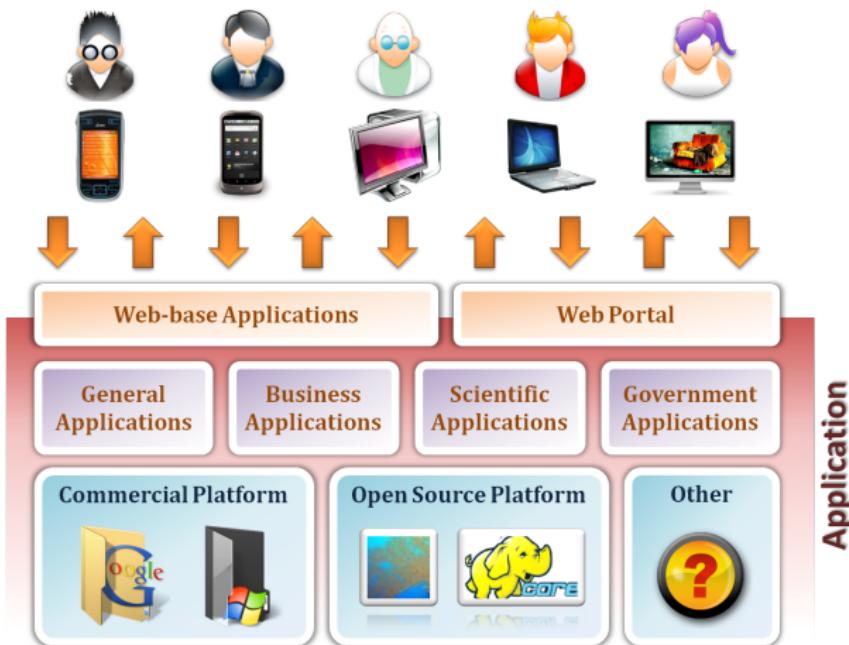
- Choice of development technology is limited to vendor provided-supported tools and services

- ▶ Vendor provides **applications** accessed over the network.

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- ▶ Example: Google Docs, Salesforce.com

SaaS - (2/4)

► System architecture



- ▶ Web Service
- ▶ Web 2.0 is the trend of using the full potential of the web.
- ▶ Viewing the Internet as a computing platform.
- ▶ Running interactive applications through a web browser.



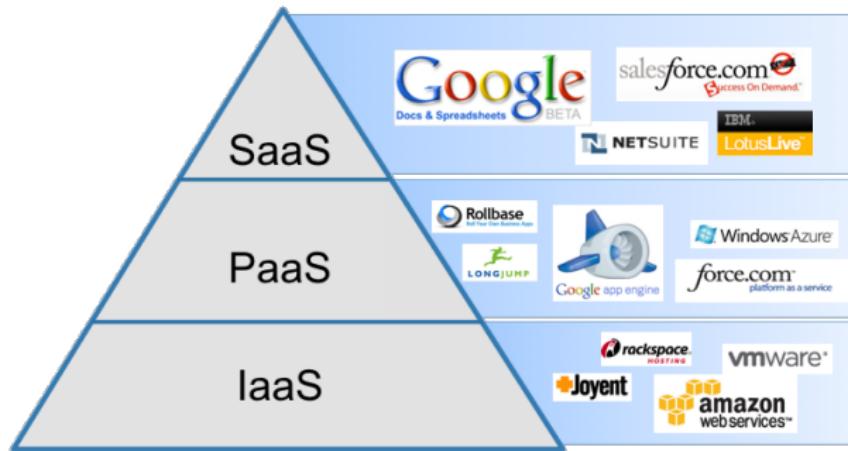
► Advantages:

- Easy to use
- Scalability startup
- Lower cost
- Upgrades

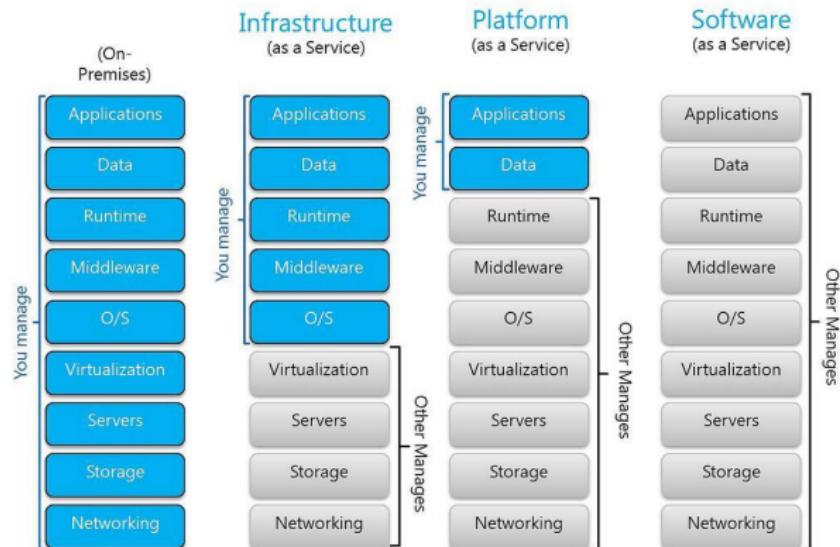
► Disadvantages:

- Dependency on network, cloud service provider
- Performance: limited client bandwidth
- User privacy

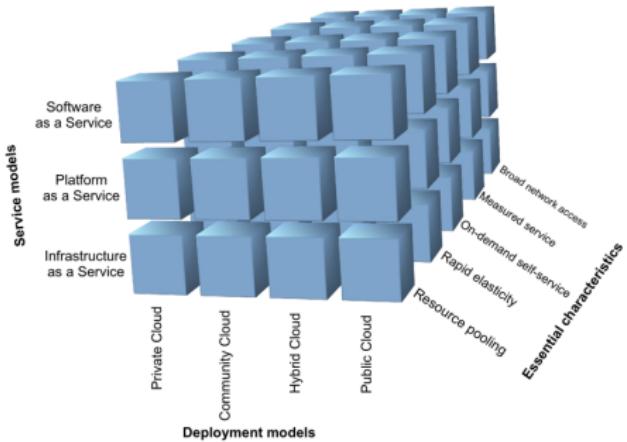
IaaS - PaaS - SaaS



IaaS - PaaS - SaaS



Cloud Deployment Models



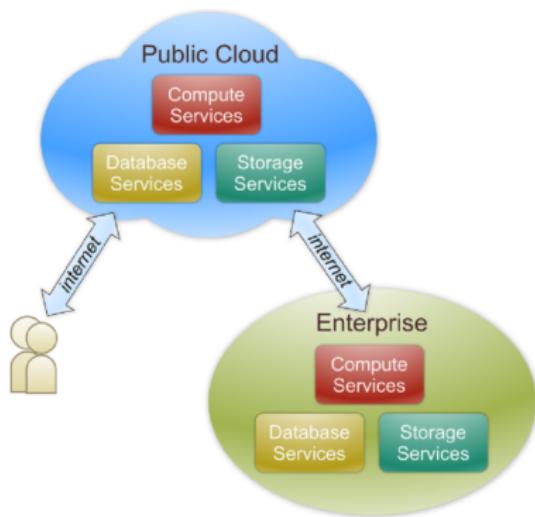
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Deployment Models

- ▶ **Public** cloud
- ▶ **Private** cloud
- ▶ **Community** cloud
- ▶ **Hybrid** cloud

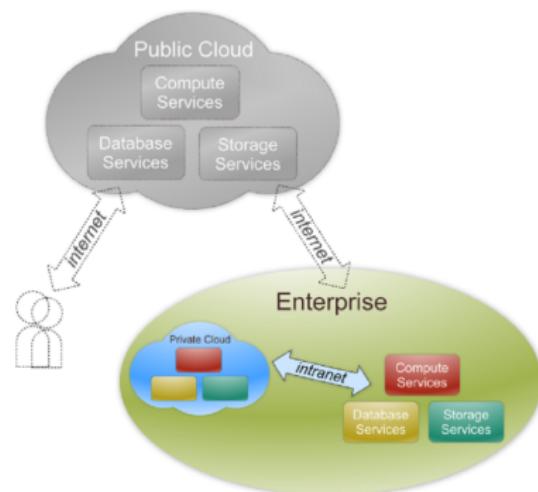
Public Cloud

- ▶ Infrastructure is made available to the **general public**.
- ▶ Owned by an organization selling cloud services.



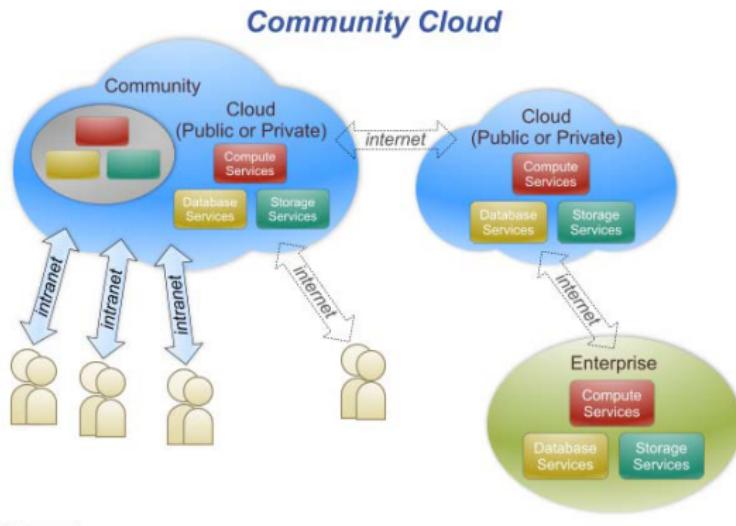
Private Cloud

- ▶ Infrastructure is operated **solely for an organization**.
- ▶ Managed by the organization or by a third party.



Community Cloud

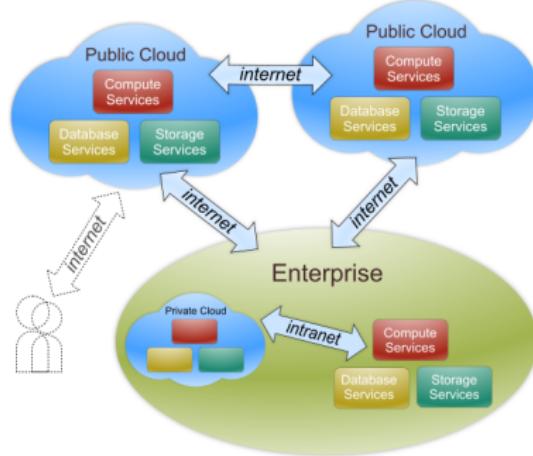
- ▶ Supports a specific **community**.
- ▶ Infrastructure is **shared** by several organizations.



Hybrid Cloud

- ▶ Infrastructure is a **composition** of two or more clouds deployment models.
- ▶ Enables data and application portability.

Hybrid Cloud



Cloud Providers

Main Players



Cloud Platform Services

- ▶ Computing
- ▶ Storage

- ▶ Computing

- Platform as a Service ([PaaS](#))
- Infrastructure as a Service ([IaaS](#))

- ▶ Storage

- [Relational](#) storage: with [support SQL](#)
- [NoSQL](#) databases: massively scalable, but [not support SQL](#)
- [Blobs](#): storage for [Binary Large OBjects](#) in the cloud, e.g., videos, backups, ...

Amazon Web Services (AWS)



Provider	Computing		Storage		
	IaaS	PaaS	Relational	NoSQL	Blobs
AWS	Elastic Compute Cloud (EC2)	Elastic Beanstalk	Relational Database Service (RDS)	SimpleDB DynamoDB	Simple Storage Service (S3)



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Google		App Engine		Datastore	Blobstore



Windows Azure™

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Google		App Engine		Datastore	Blobstore
Microsoft		Windows Azure	Windows Azure Tables	SQL Azure	Windows Azure Blobs

Cloud Platforms

Cloud Platforms

- ▶ Tools to **deploy** a cloud infrastructure plan.
- ▶ These tools provide different services, i.e., **IaaS**, **PaaS**, and **SaaS**.



EUCALYPTUS

cloudstack



OpenStack

- ▶ Open source **cloud computing platform**.



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- ▶ It **controls** large pools of compute, storage, and networking resources throughout a datacenter.



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- ▶ All managed through a **dashboard** through a web interface.

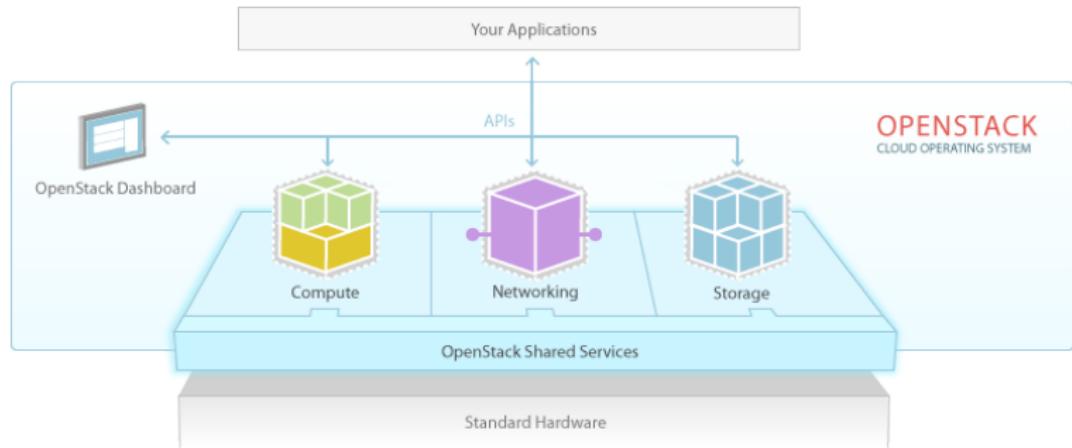


OpenStack

- ▶ Open source **cloud computing platform**.
- ▶ It **controls** large pools of compute, storage, and networking resources throughout a datacenter.
- ▶ All managed through a **dashboard** through a web interface.
- ▶ Launched by **NASA** and **Rackspace** in 2010.



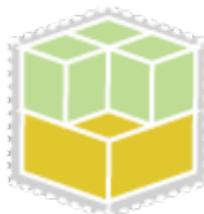
OpenStack Architecture



[<http://www.openstack.org/software/>]

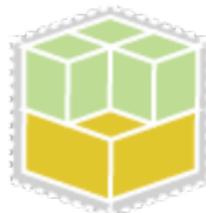
OpenStack Compute - Nova

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- ▶ **Provision** and manage large networks of **virtual machines**.



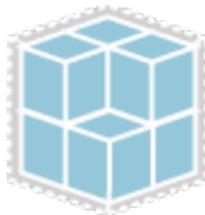
OpenStack Compute - Nova

- ▶ **OpenStack Compute**: cloud computing controller, called **Nova**.
- ▶ **Provision** and manage large networks of **virtual machines**.
- ▶ Compute resources are accessible via **APIs** for **developers**, **web interfaces** for **administrators** and **users**.



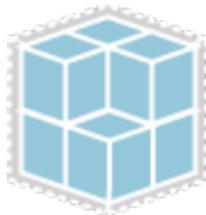
OpenStack Storage - Swift/Cinder

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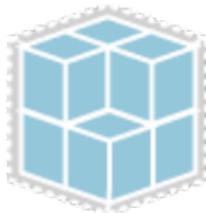
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- ▶ **Swift**: distributed storage system for static data, e.g., VM images, photo storage, email storage.
 - Redundancy, backup, archive and failover management



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- ▶ **Swift**: distributed storage system for static data, e.g., VM images, photo storage, email storage.
 - Redundancy, backup, archive and failover management
- ▶ **Cinder**: block storage, e.g., databases, and file systems



OpenStack Networking - Neutron

- ▶ **OpenStack Networking:** network and IP management, called **Neutron**.
 - Provides flexible networking models.
 - Manages IP addresses, allowing for dedicated static IPs or DHCP.
 - Software Define Network (SDN)
 - Different network services, e.g., intrusion detection systems, load balancing, firewalls and virtual private networks.



OpenStack Administration - Horizon (1/3)

- ▶ **OpenStack Administration:** administration interface (dashboard), called **Horizon**.
 - Automate complex deployments
 - Control provisioning



OpenStack Administration - Horizon (2/3)

The screenshot shows the Ubuntu OpenStack Dashboard interface. The top navigation bar includes the logo, user information (Logged in as: demo), and links for Settings and Sign Out. The main menu on the left has categories: Project, Admin, System Panel, Instances, Services, Flavors, **Images** (which is selected and highlighted in blue), Projects, Users, and Quotas. The central content area is titled "Images" and displays a table of two items:

<input type="checkbox"/>	Image Name	Type	Status	Public	Container Format	Actions
<input type="checkbox"/>	ubuntu 12.04 amd64 Server	Image	Active	Yes	AMI	<button>Edit</button> <button>⋮</button>
<input type="checkbox"/>	ubuntu 12.04 amd64 Kernel	Image	Active	Yes	AKI	<button>Edit</button> <button>⋮</button>

Below the table, a message says "Displaying 2 items". A red "Delete Images" button is located on the right side of the table header.

OpenStack Administration - Horizon (3/3)

The screenshot shows the Ubuntu OpenStack Dashboard under the 'demo' project. The left sidebar includes 'Project' and 'Admin' tabs, and sections for 'Manage Compute' (Overview, Instances & Volumes selected), 'Images & Snapshots', 'Access & Security', 'Object Store', and 'Containers'. The main content area is titled 'Instances & Volumes' and displays a success message: 'Success: Instance "demo1" launched.' Below this, the 'Instances' section lists one instance: demo1 (IP 10.1.0.3, 172.16.1.1, 512MB RAM | 1 VCPU | 0 Disk, Active, None, Running). A 'Launch Instance' button is at the top right of the instances table, and an 'Edit Instance' button is next to the instance row. The 'Volumes' section shows no items displayed.

ubuntu® OpenStack Dashboard

Logged In as: demo Settings Sign Out

Project Admin

demo

Manage Compute

Overview Instances & Volumes Images & Snapshots Access & Security Object Store Containers

Instances & Volumes

Success: Instance "demo1" launched.

Instances

<input type="checkbox"/>	Instance Name	IP Address	Size	Status	Task	Power State	Actions
<input type="checkbox"/>	demo1	10.1.0.3 172.16.1.1	512MB RAM 1 VCPU 0 Disk	Active	None	Running	Edit Instance

Displaying 1 item

Volumes

<input type="checkbox"/>	Name	Description	Size	Status	Attachments	Actions
No items to display.						

Displaying 0 items

Create Volume

Virtualization

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Virtualization

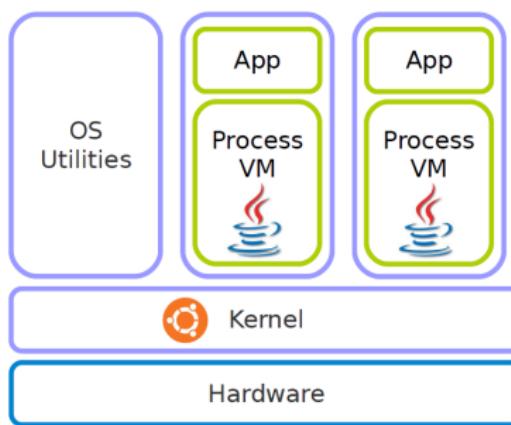
- ▶ Technique for **hiding** the **physical characterizes** of computing resources from the way other **systems**, **applications** or **end users** interact with them.
- ▶ Offer a **different interface**.
- ▶ Virtualized interface is **not necessarily simpler**.

Different Types of Virtualization

- ▶ Process-level virtualization
- ▶ OS-level virtualization
- ▶ System-level virtualization

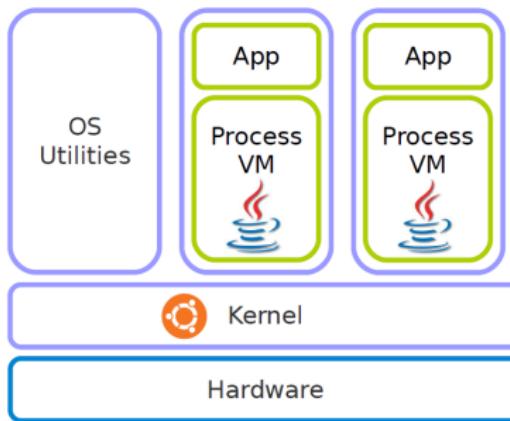
Process-Level Virtualization (1/2)

- ▶ Usually implemented on top of an OS.



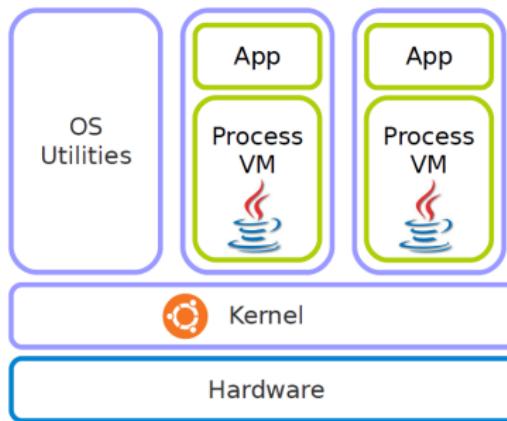
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- ▶ Application has to be written **specifically** for the VM.



Process-Level Virtualization (1/2)

- ▶ Usually implemented on **top of an OS**.
- ▶ Application has to be written **specifically** for the VM.
- ▶ The virtual machine runs **one application** (one process).

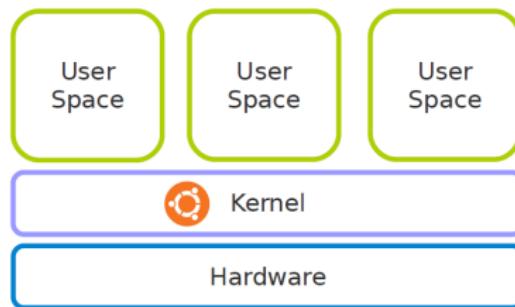


Process-Level Virtualization (2/2)



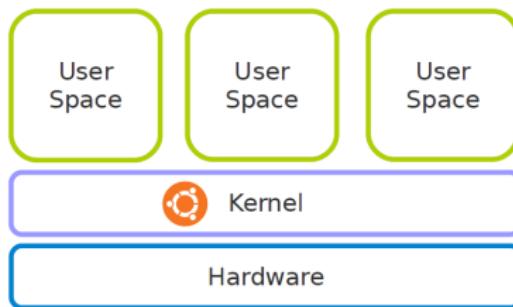
OS-Level Virtualization (1/2)

- ▶ The virtual machine runs a set of **userland processes**.



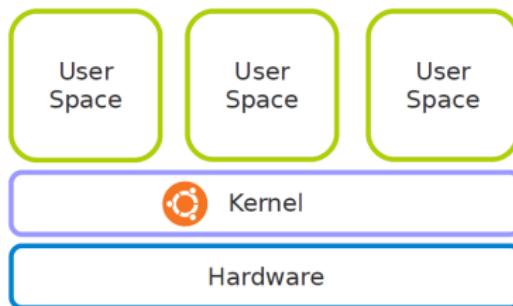
OS-Level Virtualization (1/2)

- ▶ The virtual machine runs a set of **userland processes**.
- ▶ Userland domains are **separated**.

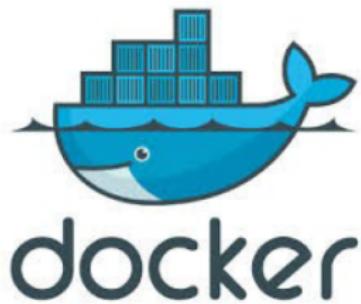


OS-Level Virtualization (1/2)

- ▶ The virtual machine runs a set of **userland processes**.
- ▶ Userland domains are **separated**.
- ▶ **Kernel** is the **same** for all userland domains.

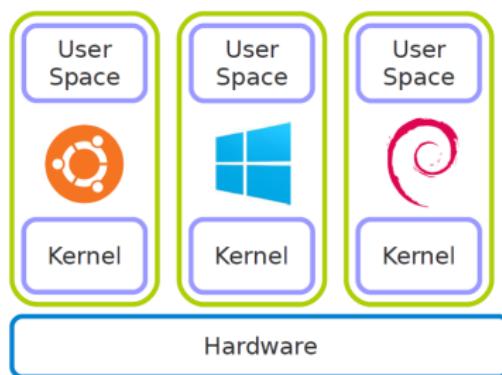


OS-Level Virtualization (2/2)



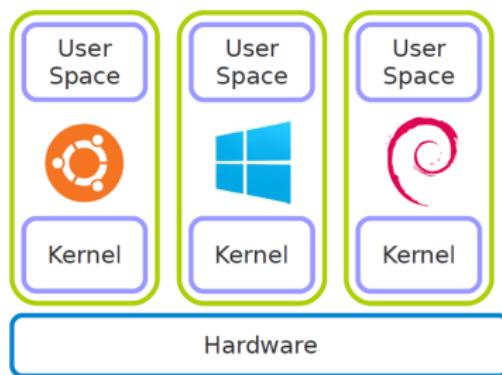
System-Level Virtualization (1/3)

- ▶ Emulates a computer similar to a real physical one.
 - With CPU(s), memory, disk(s), network interface(s), etc.



System-Level Virtualization (1/3)

- ▶ Emulates a computer similar to a **real physical one**.
 - With CPU(s), memory, disk(s), network interface(s), etc.
- ▶ The virtual machine runs a **full OS**.



System-Level Virtualization (2/3)

- ▶ Full virtualization vs. Paravirtualization.

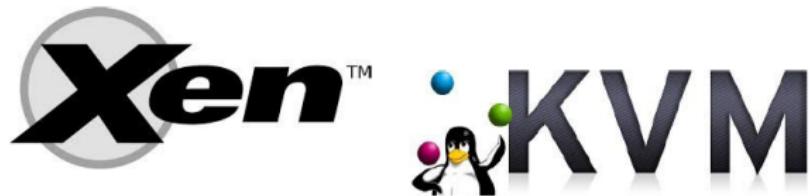
System-Level Virtualization (2/3)

- ▶ Full virtualization vs. Paravirtualization.
- ▶ Full virtualization: the guest OS is not aware it is being virtualized and requires no modification.

System-Level Virtualization (2/3)

- ▶ Full virtualization vs. Paravirtualization.
- ▶ Full virtualization: the guest OS is not aware it is being virtualized and requires no modification.
- ▶ Paravirtualization: the guest OS should be modified in order to be operated in the virtual environment.

System-Level Virtualization (3/3)



vmware®

Hypervisor

- ▶ In the **system-level virtualization**, virtual machines are managed by another **software layer**.

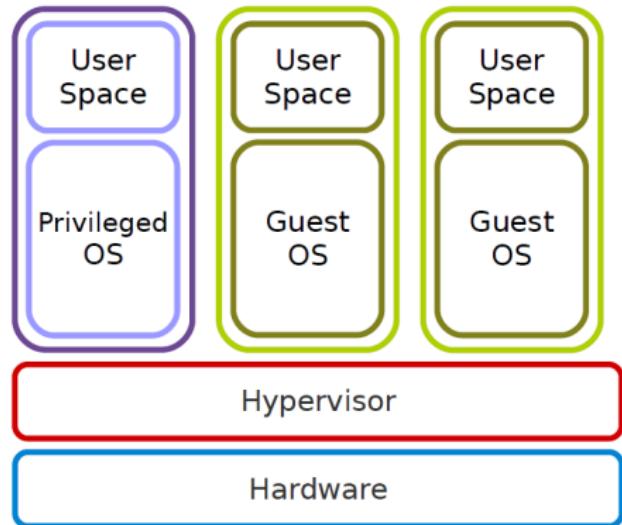
Hypervisor

- ▶ In the **system-level virtualization**, virtual machines are managed by another **software layer**.
- ▶ It is called **hypervisor** or **Virtual Machine Manager (VMM)**.

Hypervisor

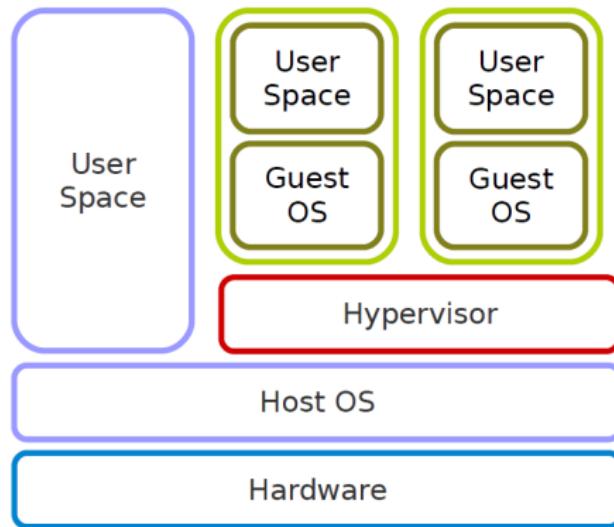
- ▶ In the **system-level virtualization**, virtual machines are managed by another **software layer**.
- ▶ It is called **hypervisor** or **Virtual Machine Manager (VMM)**.
- ▶ Two types of hypervisors:
 - Type 1: runs directly on hardware (**Native/Bare-Metal**)
 - Type 2: hosted on top of another operating system (**Hosted**)

Bare Metal Hypervisor



- ▶ Xen, ...

Hosted Hypervisor



- ▶ VMWare, KVM, Virtualbox, ...

Summary

Cloud Marketplace	
Cloud Broker Platform	
Cloud Management	
SaaS	
PaaS	
IaaS	
Cloud Platform	
Virtualization Software/Mgmt	
Hardware	

References:

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- ▶ Peter Mell et al., The NIST Definition of Cloud Computing, National Institute of Standards and Technology, 2011
- ▶ VMWare, Understanding Full Virtualization, Paravirtualization, and Hardware Assist, 2007
- ▶ Daniel Firestone, A Comparison of Public Clouds: Amazon Web Services, Windows Azure and Google App Engine, 2011
- ▶ <http://docs.openstack.org>

Questions?