# Introduction

# 2CEIT603:Cloud Computing Course Outline

- Introduction
- Software As a service(SaaS)
- Infrastructure as Service(IaaS)
- Platform As a Service(PaaS)
- MapReduce Programming
- Management and Monitoring
- Security
- Cloud Middleware

# Text and Reference Books

- Text Books:
  - “Cloud Computing: Principles and Paradigms” by RajkumarBuyya, James Broberg, Andrzej M Goscinski, Wiley publication
  - Cloud Computing: A Practical Approach by Toby Velte, Anthony Velte, McGraw-Hill Osborne Media.
- Reference Books:
  - Cloud Application Architectures: Building Applications and Infrastructure in the Cloud by George Reese, O'Reilly Publication.
  - Cloud Computing Explained: Implementation Handbook for Enterprises by John Rhoton, Recursive Press

# Chapter outline

- Needs of Cloud Computing
- Virtualization
- Types of Virtualization
- Cloud Architecture
- Types of Cloud Computing
- Opportunities and Challenges
- Advantages and Disadvantages
- Future

# What is Cloud Computing

- *"Cloud Computing is a computing paradigm shift where computing is moved away from personal computer to a "Cloud" of computers "*

- *Cloud computing is a type of Internet-based computing that provides shared computer processing resources and data to computers and other devices on demand*
- These platforms hide the complexity and details of the underlying infrastructure from users and applications by providing very simple graphical interface or API (Applications Programming Interface).
- *"A distributed network using virtualized resources and accessed by common internet protocols and networking standards"*

# Needs of Cloud Computing

- For example in organization the basic components are required to have an E-Mail Services for staff members.
- All these components are bundled together.

| **E-Mail Application** |
| --- |
| Web(Email) Server |
| Server Operating System |
| Server Hardware |

- Web(Email)- Server is dependent on Server Hardware everything (every component) below it.
- If any of the component fails (or stop working, for example .Due to hard drive, cpu failure or virus) then Webserver will stop working.
- So if your hardware/OS fails your service will go down.

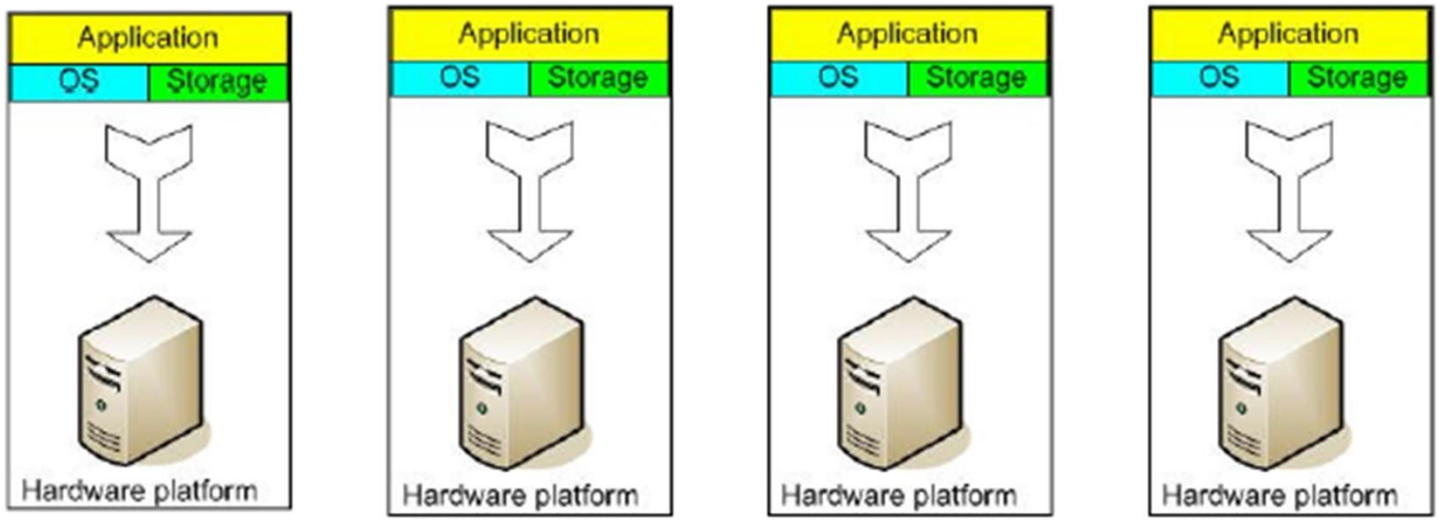
# Needs of Cloud Computing

- Idea of cloud computing is to detach disconnect the service from OS and Hardware.
- Separating OS from the hardware that run OS( virtual computing).
- Separate storage for to store emails.
- Separate and elastic computing power required
- Web Service required for communication among all detached resources

# What is Virtual Computing

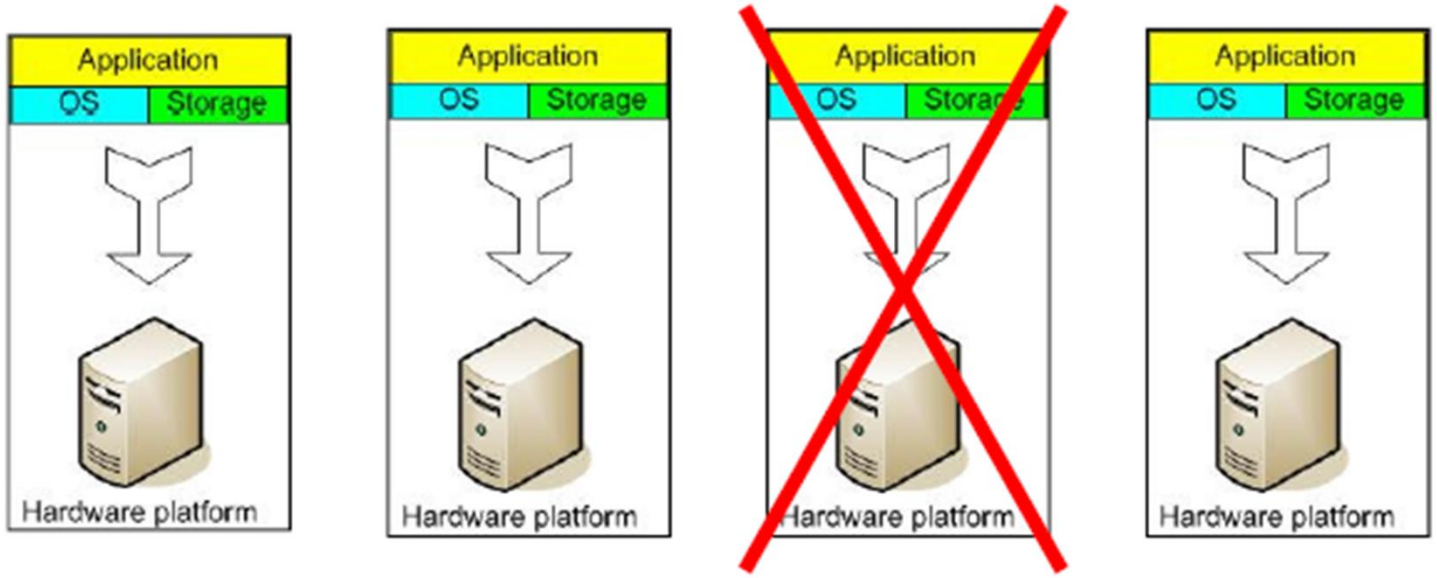
- Separating OS from the hardware that run OS.
- Virtual computing puts OS into a container and that container is running on hardware.
- If hardware fails then you can migrate running instance of OS (with applications, settings) to another machine/hardware.
- Before virtualization, if we want to migrate OS from one server hardware to another server hardware then we have to take backup of all the data. The process is time consuming.
  - We have to install OS on new hardware.
  - We have to reinstall all applications on new hardware.
- With virtualization, the migration of OS becomes easy and less time consuming.

# What is Virtual Computing




| Web Server | App Server | DB Server | EMail |
|---|---|---|---|
| Windows | Linux | Linux | Windows |
| IIS | Glassfish | MySQL | Exchange |

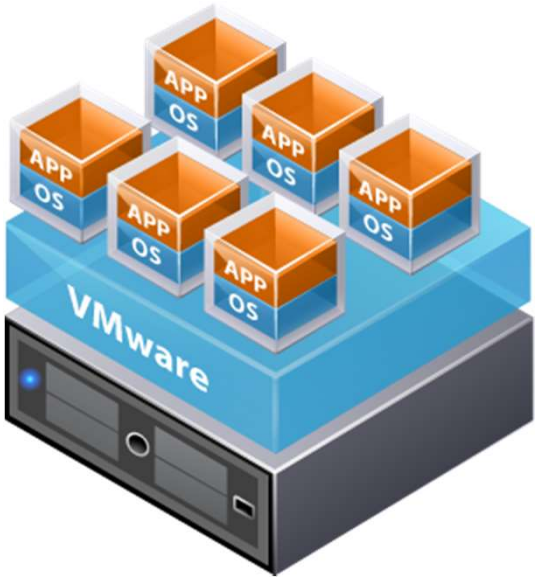
# What is Virtual Computing




| Web Server | App Server | DB Server | EMail |
|---|---|---|---|
| Windows | Linux | DOWN! | Windows |
| IIS | Glassfish | | Exchange |

# Traditional Vs Virtual Architecture


Traditional Architecture




Virtual Architecture

# What is virtual machine?

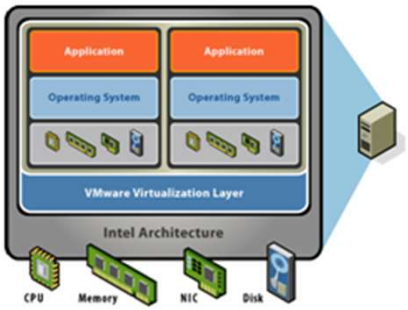
Virtual machine (VM): *A software implementation of a machine (computer) that executes programs like a physical machine.*

Types of virtual machine categories:

- System virtual machines - Hardware virtual machine provides a complete system platform environment which supports the execution of a complete operating system (OS).
- Process virtual machine - Application virtual machine provides a platform-independent programming environment that abstracts away details of the underlying hardware or operating system from software or application runtime.
- Example:
  - Hardware virtual machine: VMWare, Xen, VirtualBOX ..
  - Application virtual machine: Java Virtual Machine, .NET Framework

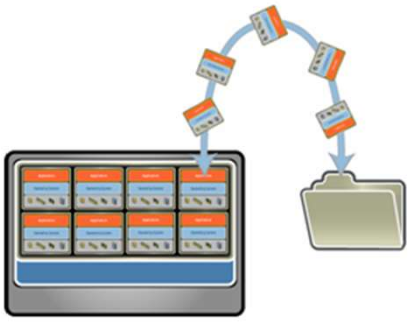
# What virtual machines provides?

- Hardware independence: VM sees the same hardware regardless of the host hardware.




- Isolation: VM's operating system is isolated from the host operating system.

- Encapsulation: Entire VM encapsulated into a single file



# How Virtual Computing is Useful?

- **Test before we go:** You are able to test your application on different kind of system in same machine. It's easy to destroy, rebuild or backup your whole testing environments - Virtual Machine.
- **Server consolidation:** Many small physical servers could be replaced by virtual machine, runs on virtualization environment provided by one powerful physical server. The large server can "host" many such "guest" virtual machines.
- **Increase hardware utilization:** To increase the utilization of costly hardware resources such as CPU, memory or even like storage space.
- **Rapid provisioning, dynamic fault tolerance**

  For example:
  - Computing task can now be utilized down to core of CPU level.
  - Big system memory can partition as smaller portions for legacy system runs within a virtual machine.

# Virtualization

- **Server virtualization:** hiding of server resources (number and identity of individual physical servers, processors, and operating systems) from server users, e.g. VMs (virtual machines)

- **Network virtualization:** division of available bandwidth into channels that can be assigned to a particular resource in real time

- **Storage virtualization:** combination of physical storage devices into what appears to be a single storage device , e.g. SAN (storage area network)

# Server Virtualization

- Server virtualization makes it possible for the OS of a physical server to run on a virtual layer (the hypervisor).
- This allows to run multiple virtual machines (VMs),each with their own OS, on the same physical server.

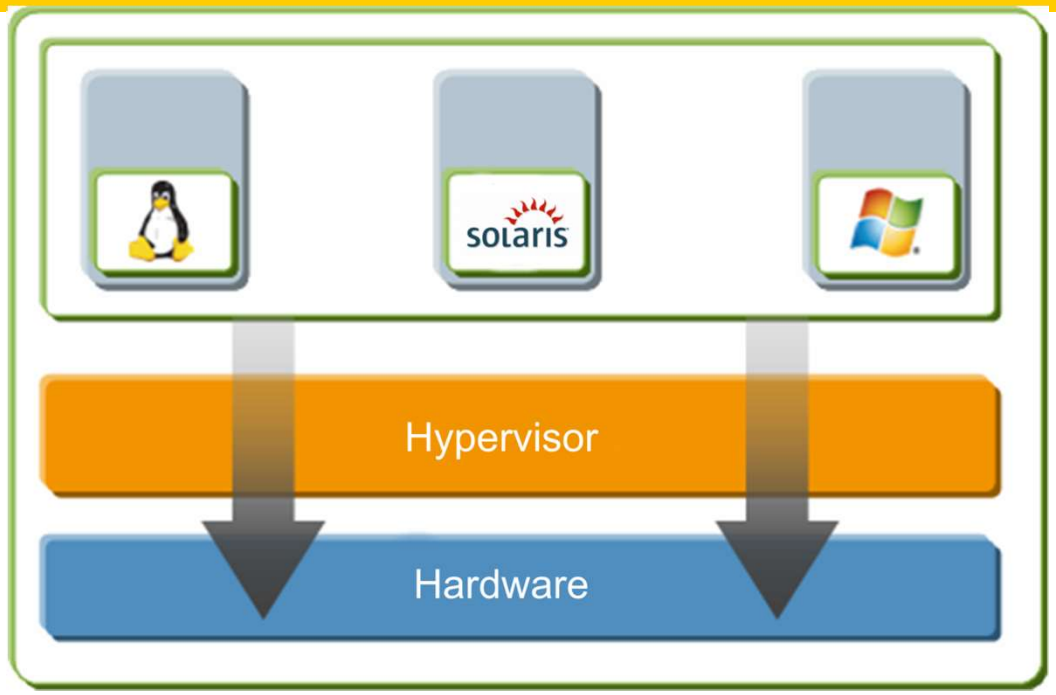
**Virtual Host**

Physical Server with virtualization layer

**Virtual Machine**

Each Guest OS Running on Host

# Virtualization




- Virtual machine layer
- Hypervisor layer
- Hardware/physical layer

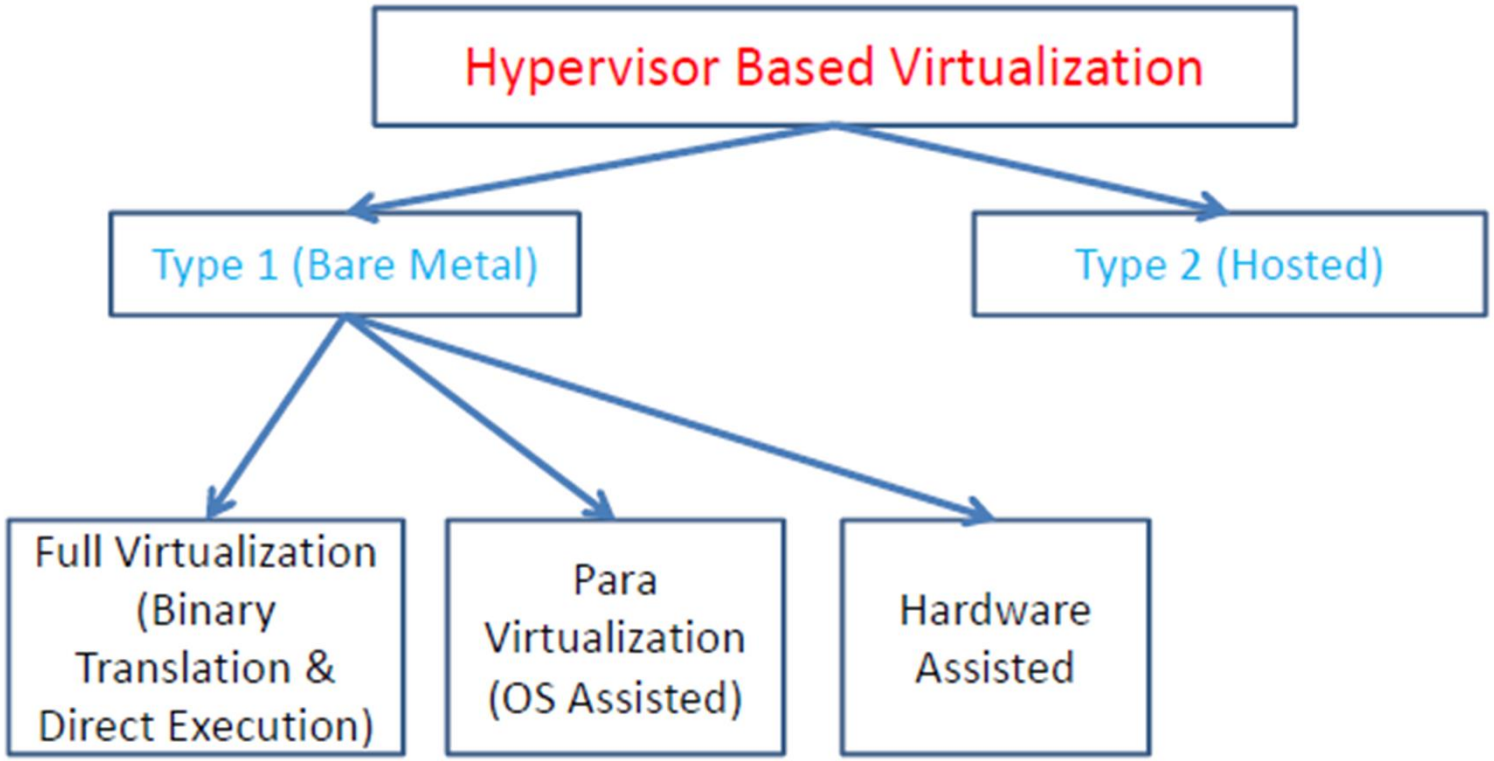
- **Hardware or physical layer:** Physical hardware components including memory, CPU, network cards, and disk drives.
- **Hypervisor layer:** Thin layer of software that runs on top of the hardware. The Xen hypervisor gives each virtual machine a dedicated view of the hardware.
- **Virtual machine layer:** Operating system hosted on the hypervisor and appearing to the user as a separate physical computer. However, the machine shares physical resources with other virtual machines, and it is portable because the virtual machine is abstracted from the physical hardware.

# Hypervisor

- **Hypervisor ( Virtual Machine Manager)**
  - A program that allows multiple operating systems to share a single hardware host.
  - Creates the virtualization layer that makes server virtualization possible.
  - Contains the virtual machine manager (VMM).Manages multiple virtual machines running on single host.

- **Examples of Hypervisors:**
  - VMWare ESX/ESXi (Elastic Sky X Intergrated)
  - Hyper-V
  - VMWare Workstation
  - Virtual Server
  - Xen Server

# Classification of Server Virtualization Techniques



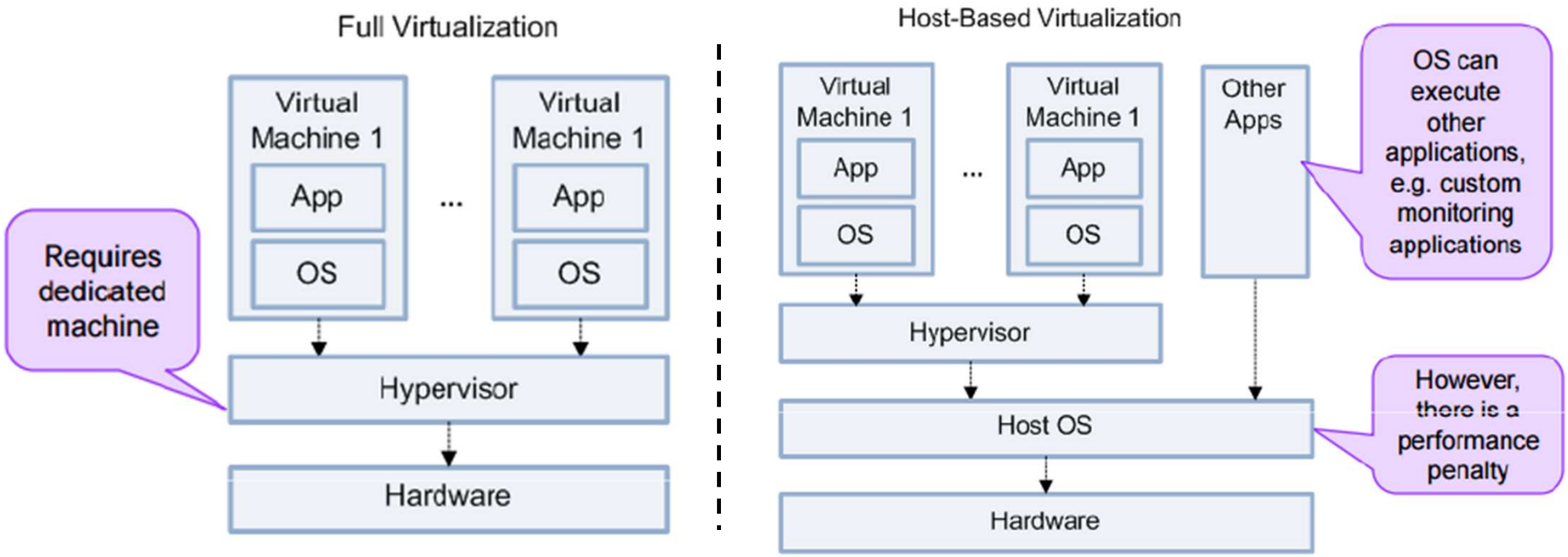
# Type 1 Vs Type 2 Hypervisors

- Depending on the location of the virtualization layer (hypervisor), there are two main hardware virtualization architectures:
- Type 1 Hypervisor (Full or Bare-Metal)
  - Loaded directly on hardware
  - Wind River VxWork, VMWare ESX / ESXi, Xen Server
- Type 2 Hypervisor (Hosted – Architecture)
  - Loaded in OS running on hardware
  - Microsoft Hyper V , VMWare Fusion (Macintosh) , VMWare Workstation, KVM
- Performance of Type 2 hypervisor is not good as compared to Type 1 hypervisor.

  – Because OS layer is in-between virtualization layer and hardware. There is greater overhead in using Type 2 hypervisor. You can not create same no. of VMs on same hardware as compare to Type 1 hypervisor.

  – Type 2 has more points of failure since anything that affect the stability of the base operating system can also affect the guest OS and the virtual machine.

# Type 1 Vs Type 2 Hypervisors




- Guest operating systems: The operating system loaded into a virtual machine is referred to as the guest operating system, and there is no constraint on running the same guest on multiple VMs on a physical system. Guest operating systems are isolated from each other. Guest OS kernels use the interfaces provided by the hypervisor to access their privileged resources.
- Host operating system: The host operating system is the base operating system, under which the hypervisor is installed, in the hosted architecture case

# Virtualization

- Problem with Host-based:
  - Not all instructions of the standard x86 architecture can be virtualized and hence, standard x86 processors do not support direct execution.

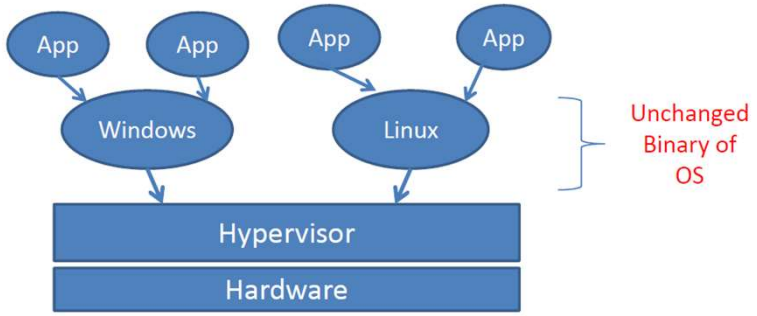
- Solutions
  - Full Virtualization(Binary Translation & Direct Execution)
  - Para Virtualization.
  - Hardware Assisted.

# Full Virtualization (Binary Translation & Direct Execution)

- This technique uses a combination of binary translation for handling privileged and sensitive instructions and direct execution techniques for user-level instructions.
- Binary translation basically translates kernel code by replacing non-virtualizable instructions with new sequences of instructions that have the intended effect on the virtualized hardware. *Results in significant virtualization overhead.*
- Full Virtualization means the virtualization is achieved with no assistance of hardware or OS.
- Full virtualization provides a complete simulation of the underlying hardware which represents total abstraction of the underlying physical system, and create a complete virtual system in which the guest operating system can execute.
- No modification is required in the guest operating system or application; the guest operating system or application is not even aware that it is running within a virtualized environment.
- Typical solution of Full-Virtualization:
  -*Commercial:* VMWare ESX, Microsoft Virtual Server, Citrix XenServer.
  -*Opensource:* Linux Xen hypervisor – Hardware Virtual Machine (HVM), KVM.

# Full Virtualization (Binary Translation & Direct Execution)

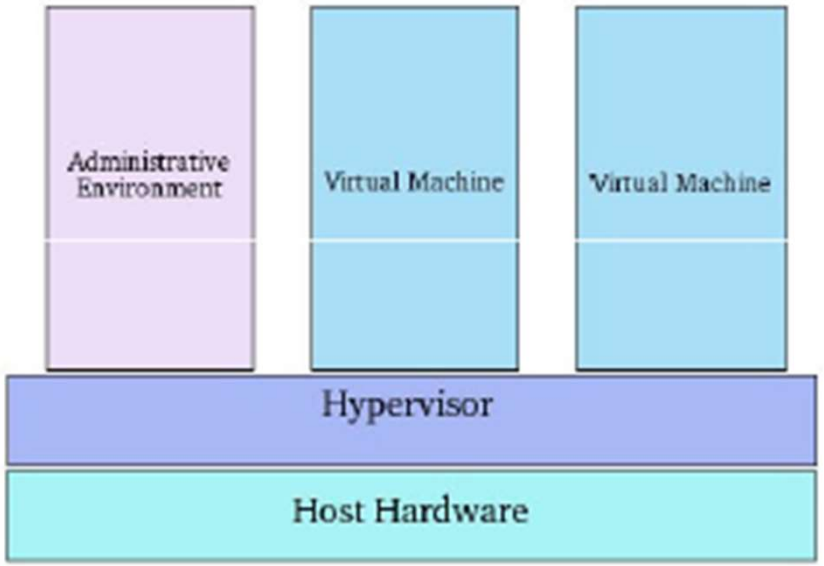
- OS running on top of Hypervisor as user level processes. They are not running with the same level of privilege as they run on hardware. When OS runs privileged instructions, they have to be in kernel (privileged) mode to execute the instructions on Hardware.
- These instructions will get trap in Hypervisor and Hypervisor emulate intended functionality of OS (Trap & Emulate Strategy). In some architecture, some privileged instructions may fail silently.
- You may never know about failure of execution of instructions. To overcome this problem, the Hypervisor will apply binary translation strategy: The hypervisor knows what all instructions might fail silently in binary of each unmodified OS and through binary editing strategy those instructions are deal with carefully (The hypervisor can catch these instructions and take appropriate actions).
- VM ware Product family utilize Para virtualization technique.



# Full Virtualization (Binary Translation & Direct Execution)

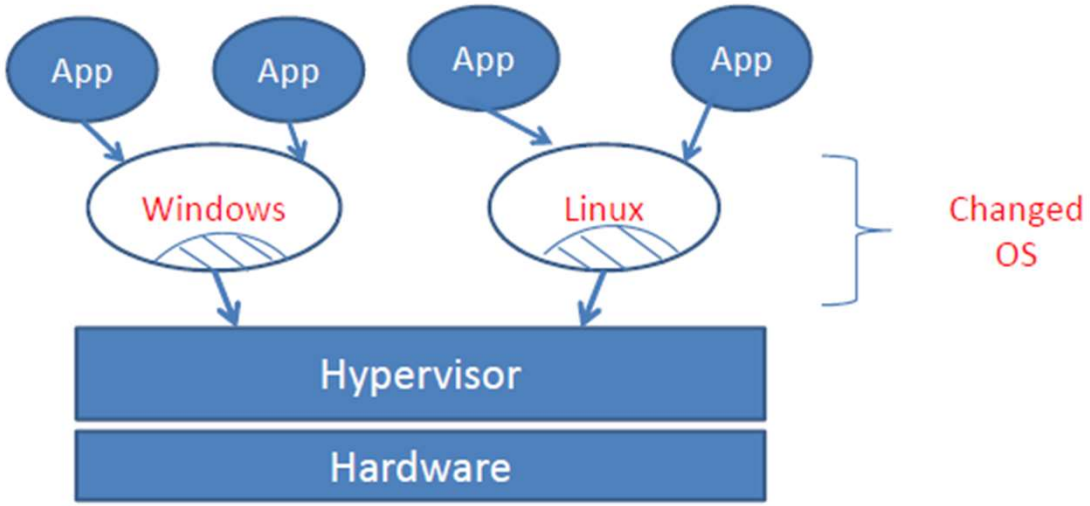
**Disadvantages:**

- Since the hypervisor is installed directly on top of the hardware, it should include all device (network and storage) drivers.
- The lack of a base operating system makes the installation of these hypervisors more difficult and requires more customization and configuration.
- Some Virtual Machine require CPUs with special virtualization support built in (such as Intel-VT and AMD-V)



# Para Virtualization (OS Assisted Virtualization)

- In this approach type of Server Virtualization is modify the source of Guest OS.
- Not only avoid problematic instructions but also include optimization.
- Example: Allowing OS to access/exploit characteristics of real H/W resources (underlying Hypervisor)
- From Applications point of view nothing has been changed: Same Interface.
- 1.4 % of Code Base for Linux, 0.04% of Code Base for WinXP.




- Zen Product family utilize Para virtualization technique.

# Para Virtualization (OS Assisted Virtualization)

- The VMM (Hypervisor) provides an “almost” identical abstraction of the underlying ISA (Instruction Set Architecture). Any operating system running in a para-virtualized VM must be adapted to support the changed instruction set which limits the set of possible guest OSs.
- On the other hand, para-virtualization provides better performance since guest systems can be further optimized for their virtualized execution.
- Example: Xen hypervisor.
- Unlike hardware emulation, which has device drivers installed in the hypervisor, para-virtualization uses device drivers of the Domain.
- All the guest operating systems have stub drivers that communicate with the stub drivers in the privileged guest.

# Para Virtualization (OS Assisted Virtualization)

- Benefit of having stub driver: The hypervisor does not have to have its own device drivers. Therefore, the users of the virtual machine never have to depend on the hypervisor software provider for driver software. Faster run time translation for system calls is the second benefit of this approach of device driver.

## Disadvantage

- Requirement of modifying (kernel of) guest operating system to execute and communicate with the hypervisor

# Full Vs Para Virtualization

- Full virtualization – almost complete simulation of the actual hardware to allow software, which typically consists of a guest operating system, to run unmodified.
- Para-virtualization – a hardware environment is not simulated; however, the guest programs are executed in their own isolated domains, as if they are running on a separate system. Guest programs need to be specifically modified to run in this environment.
- In a full virtualization scheme, the VM is installed as a Type 1 Hypervisor directly onto the hardware. All operating systems in full virtualization communicate directly with the VM hypervisor, so guest operating systems do not require any modification. Guest operating systems in full virtualization systems are generally faster than other virtualization schemes.
- Para virtualization requires that the host operating system provide a virtual machine interface for the guest operating system and that the guest access hardware through that host VM. An operating system running as a guest on a para virtualization system must be ported to work with the host interface.

# Full Vs Para Virtualization

- In Full Virtualization, Guest OS doesn't know that it is running on hypervisor, whereas in Para virtualization, Guest OS know that it is running on Hypervisor.
- No need to modify OS in case of Full Virtualization, OS kernel needs to be modified in case of Para virtualization

# Hardware-Assisted Virtualization

- Hardware providers (e.g., Intel and AMD) started supporting virtualization at the hardware level.
- In hardware-assisted virtualization (e.g., Intel VT-x, AMD-V), privileged and sensitive calls are set to automatically trap to the hypervisor. This eliminates the need for binary translation or para virtualization.
- Moreover, since the translation is done on the hardware level, it significantly improves performance.

# Selection of Hypervisor

- The performance of tightly coupled hypervisors (ex., OS assisted hypervisors) is higher than loosely coupled hypervisors (ex., hypervisors based on binary translation).
- On the other hand, tightly coupled hypervisors require the guest operating systems to be explicitly modified, which is not always possible.
- One of the Cloud infrastructure design challenges is to have hypervisors that are loosely coupled, but with adequate performance.
- Having hypervisors that are operating system agnostic increases system modularity, manageability, maintainability, and flexibility, and allows upgrading or changing the operating systems on the fly.

# Type -2 ( Hosted Architecture

**Advantages:**

- Hypervisor is easy to install and configure on most
- Computers without the need for customization

**Drawbacks:**

- A hosted architecture may result in performance degradation, because the I/O requests of the virtual machines need to be directed through the hosted OS.
- Unable to run real-time operating systems directly inside the virtual machines.

# Why Cloud service is popular?

- Reduce the complexity of networks
- Do not have to buy software licenses
- Customization
- Cloud provides that have specialized in a particular area can bring advanced services that a single company might not be able to afford or develop.
- Scalability
- Reliability
- Efficiency.

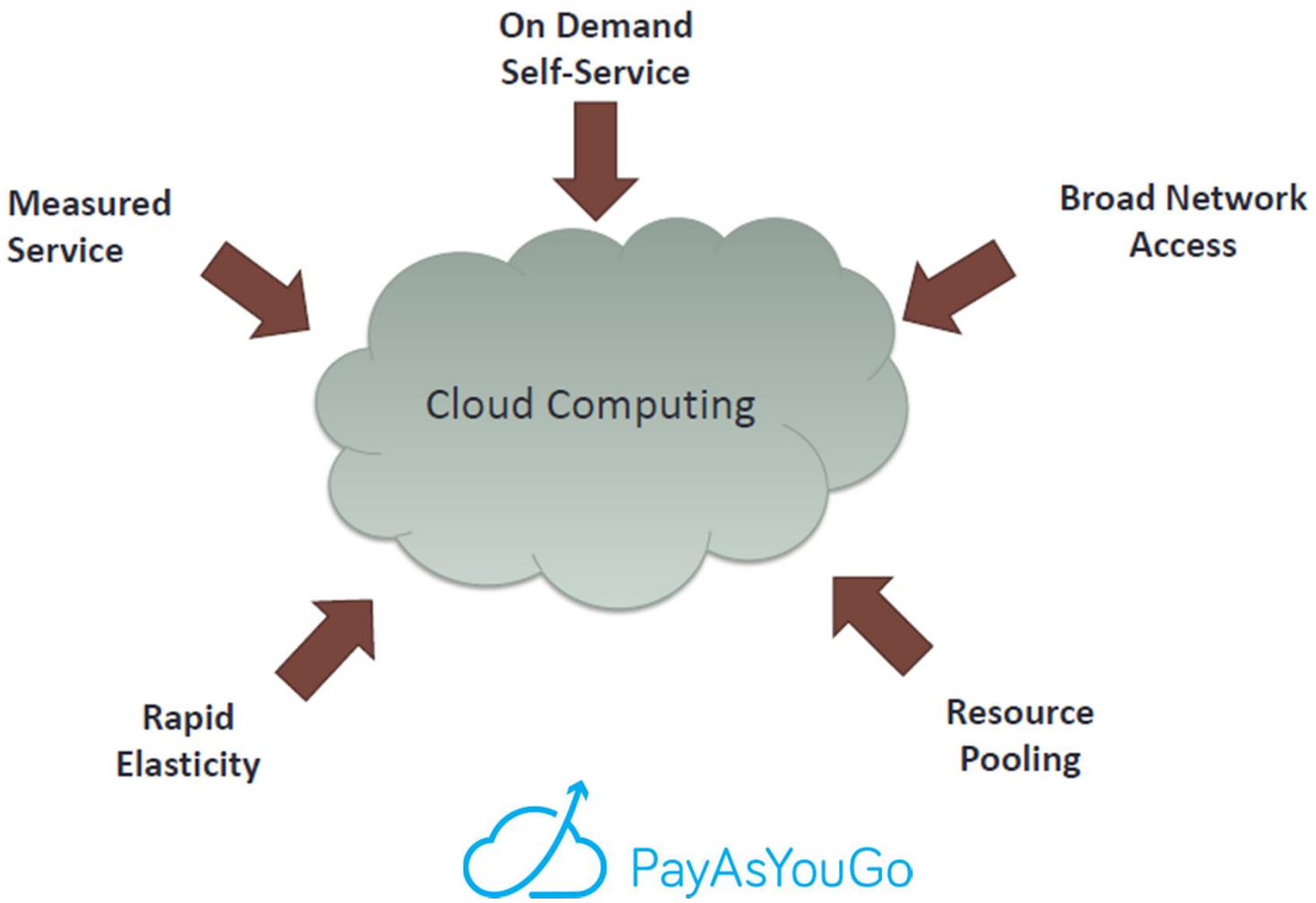
# Characteristics of Cloud Computing

## Common Characteristics:

- Massive Scale
- Resilient Computing
- Homogeneity
- Geographical Distribution
- Virtualization
- Service Orientation
- Low Cost software
- Advanced Security

# Characteristics of Cloud Computing

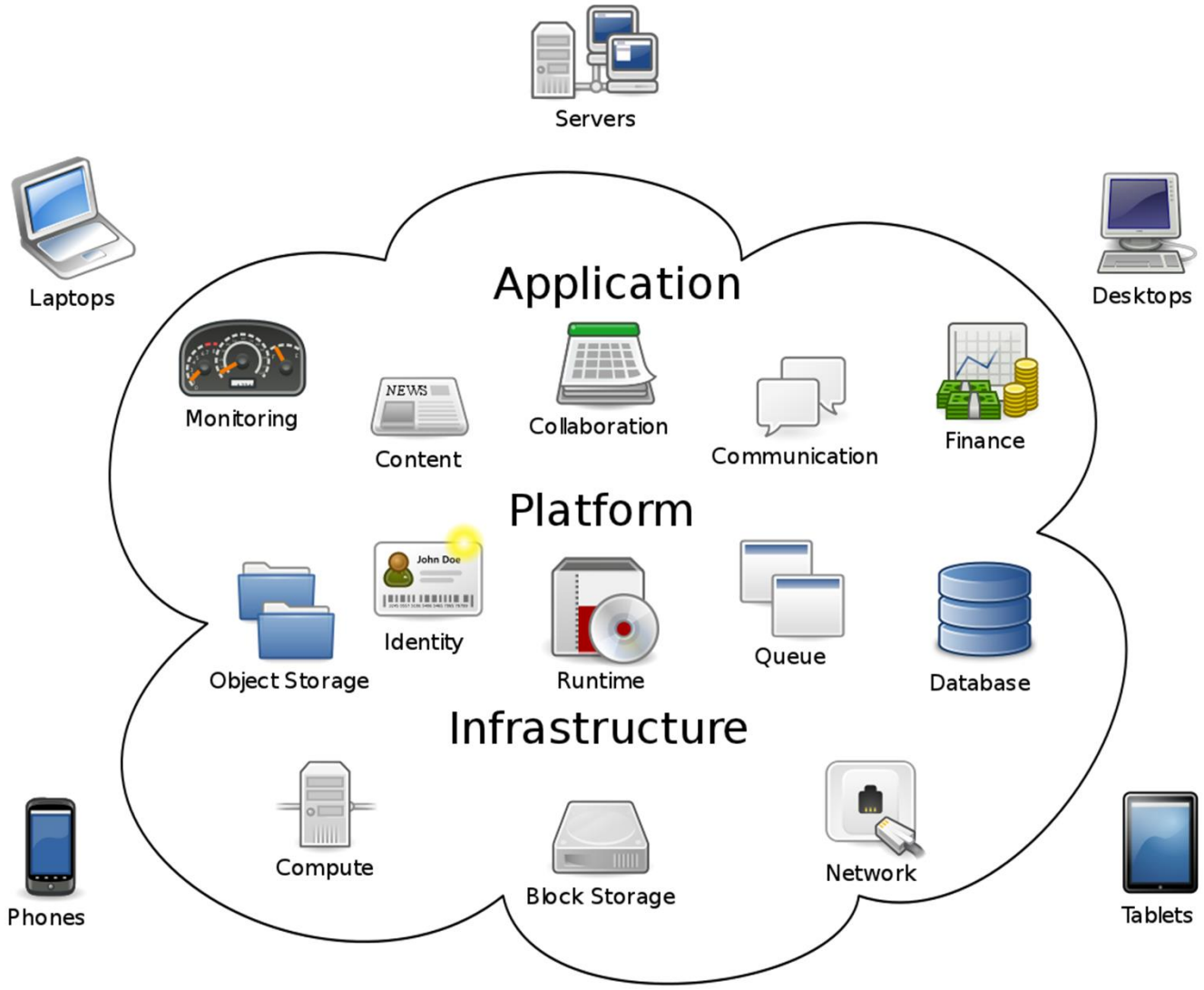
Essential Characteristics:



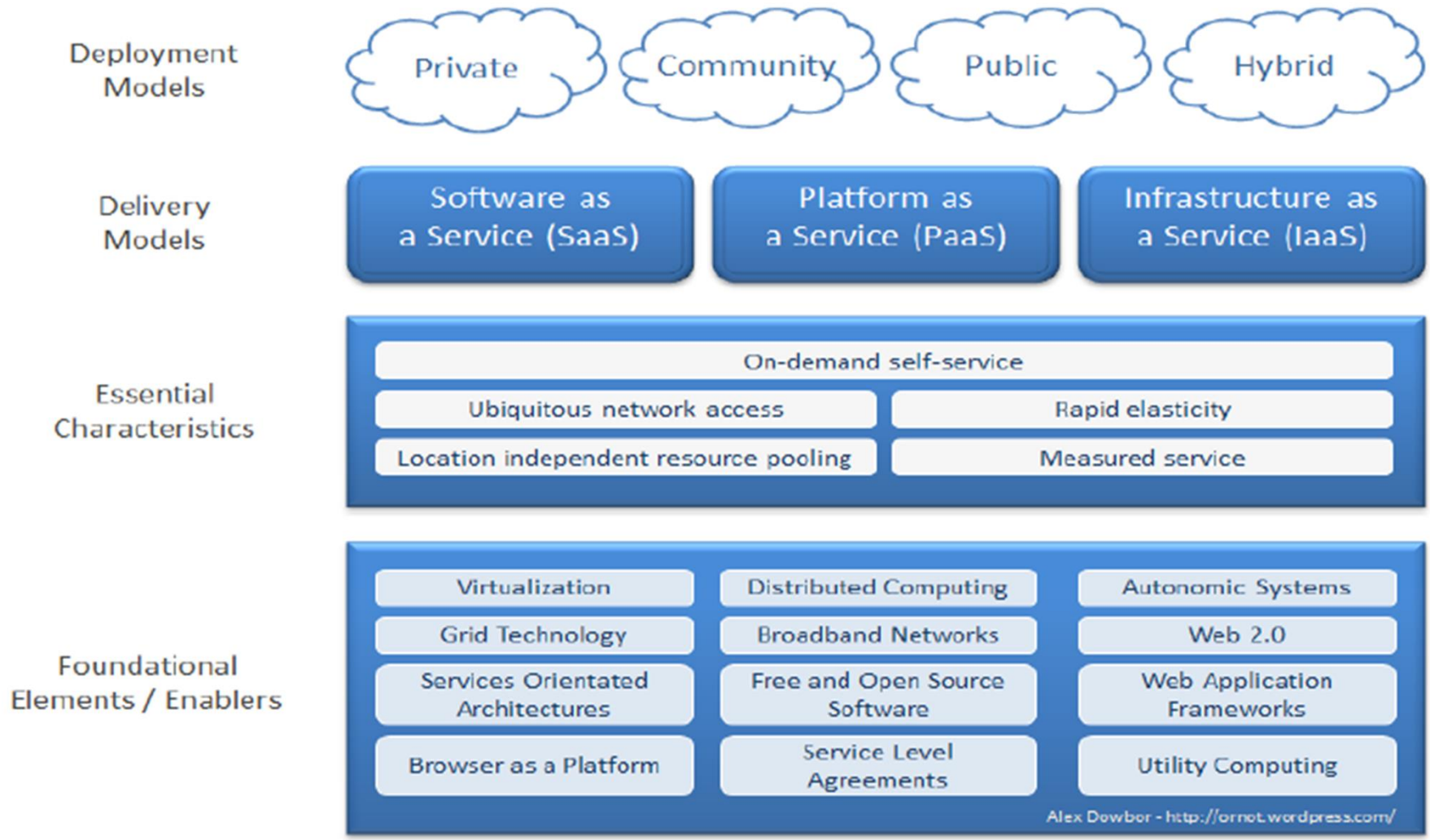
# Characteristics of Cloud Computing

- **On-demand self-service:** a consumer of cloud computing solution should be able to automatically acquire and release the IT resources without requiring any action from the service providers when ever the need for such resources increases or decreases.
- **Broad network access:** The cloud computing based IT resources are available over the network and accessed by thin or thick client platforms.
- **Resource pooling:** the available computing resources, physical or virtual, are pooled together and are dynamically assigned and reassigned based consumers demand multiple consumers are served using a multi-tenant model.
- **Rapid elasticity**: the provisioning and releasing of the resources, instantly and elastically, are preferably done in an automatic way in order to enable a consumer to quick scale out and in; compared to customer's demand, the resources may appear to be unlimited, available in any quantity at any time
- **Measured Service:** a cloud computing solution also has the ability to measure the consumption of resources, and to automatically control and optimize the resources; this happens on some level of abstraction corresponding to the type of service the consumption can be monitored, controlled and reported.
- **Flexible billing (Pay as you go):** fees can be levied on a subscription basis or can be tied to actual consumption of resources.

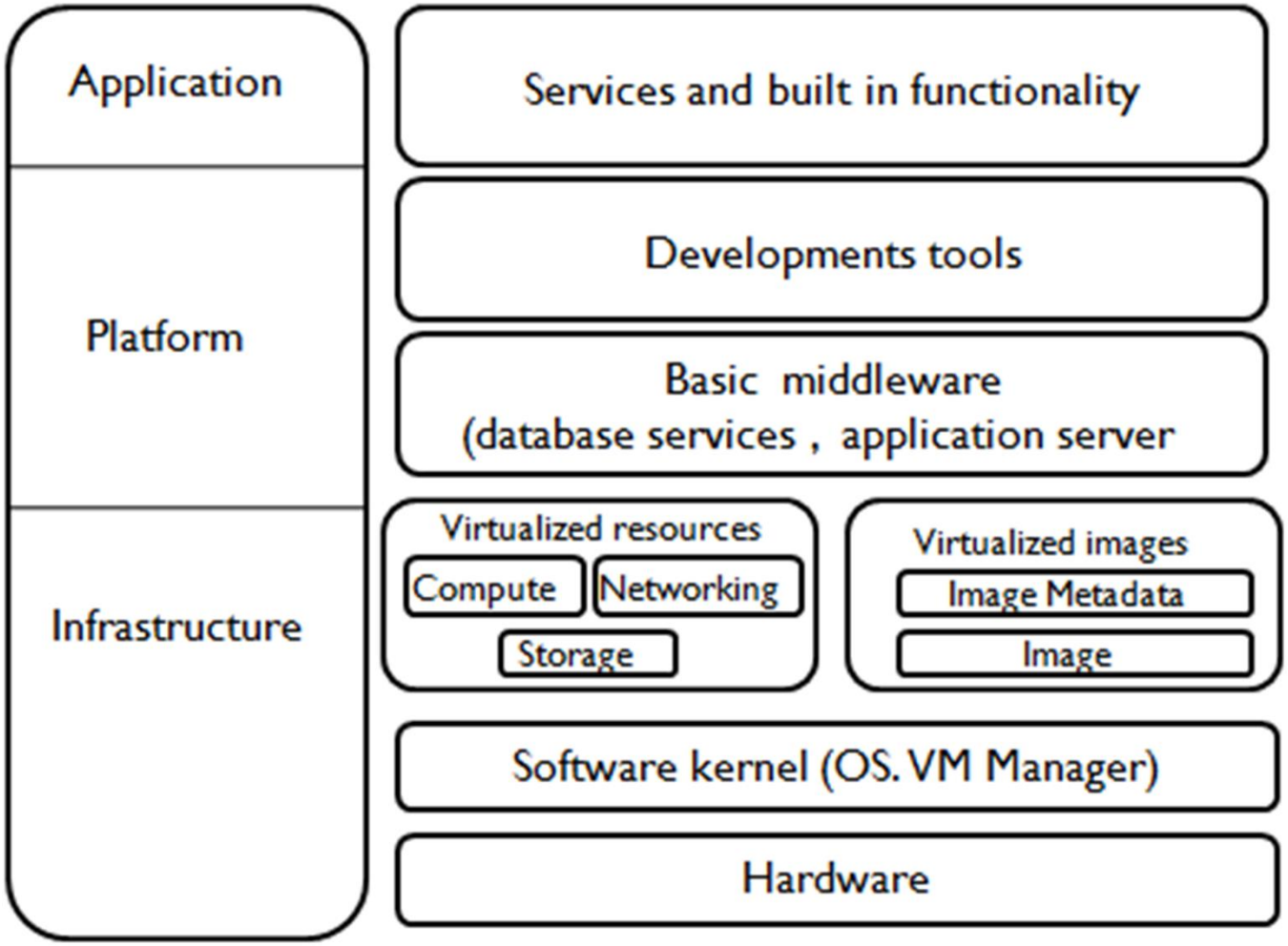
# Cloud Architecture



# Cloud Architecture



# Cloud Computing Layers



# Cloud Computing Layers

| | |
|---|---|
| **Application Service (SaaS)** | ▪ MS Live/ExchangeLabs, IBM,<br>▪ Google Apps; Salesforce.com<br>▪ Quicken Online, Zoho, Cisco |
| **Application Platform** | ▪ Google App Engine, Mosso,<br>▪ Force.com, Engine Yard,<br>▪ Facebook, Heroku, AWS |
| **Server Platform** | ▪ 3Tera, EC2, SliceHost,<br>▪ GoGrid, RightScale, Linode |
| **Storage Platform** | ▪ Amazon S3, Dell, Apple, ... |

# Cloud Types

- Cloud Computing separated into two distinct sets of models: Service models and Deployment models.

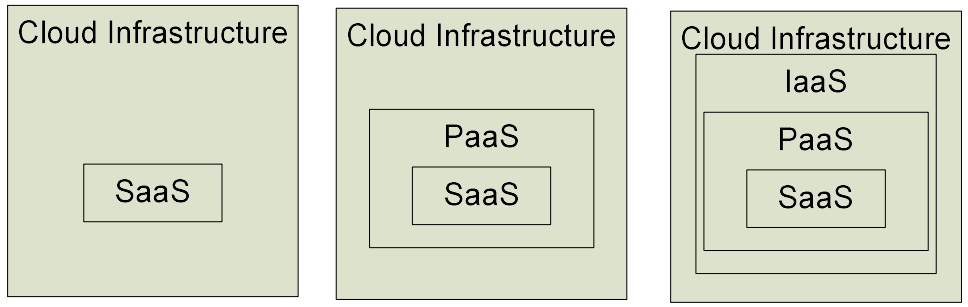
- **Service Models:** Types of services that you can access on a cloud computing platform.
  - SAAS (Software As A Service)
  - PAAS ( Platform As A Service)
  - IAAS (Infrastructure As A Service)

- **Deployment Models:** Refer to the location and management of the cloud's infrastructure.
  - Public Cloud
  - Private Cloud
  - Hybrid Cloud
  - Community Cloud

# Service Model Architectures

SalesForce CRM

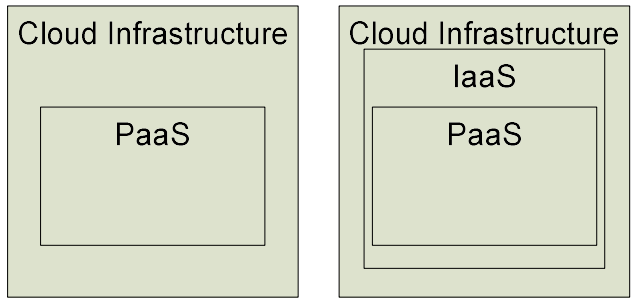
LotusLive




Software as a Service (SaaS) Architectures

Google App Engine

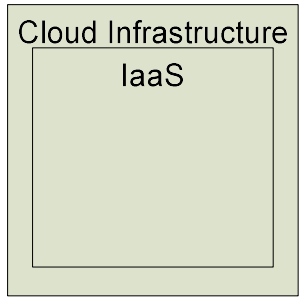
Windows Azure
The Future Made Familiar




Platform as a Service (PaaS) Architectures

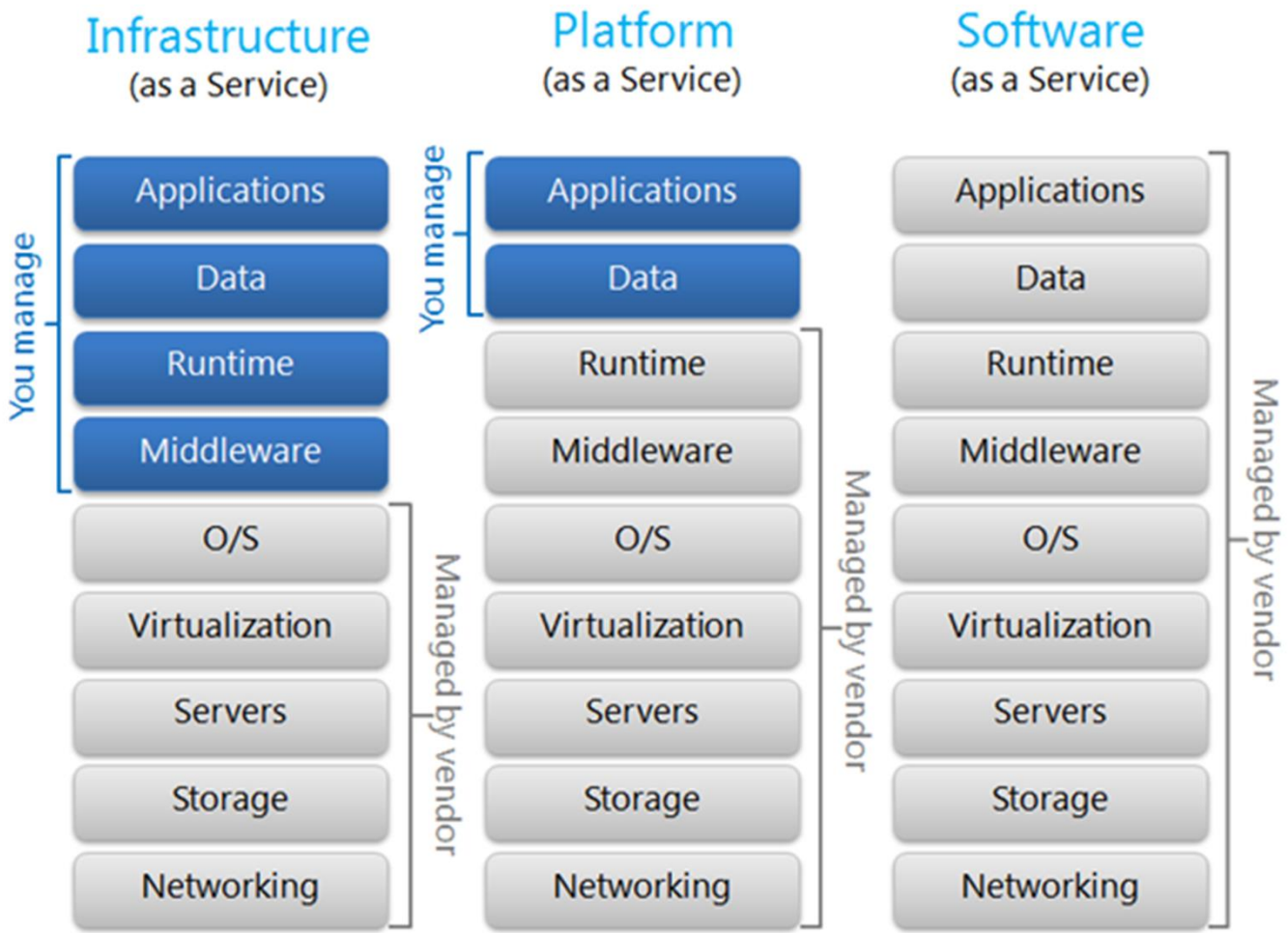
amazon web services™

rackspace HOSTING




Infrastructure as a Service (IaaS) Architectures

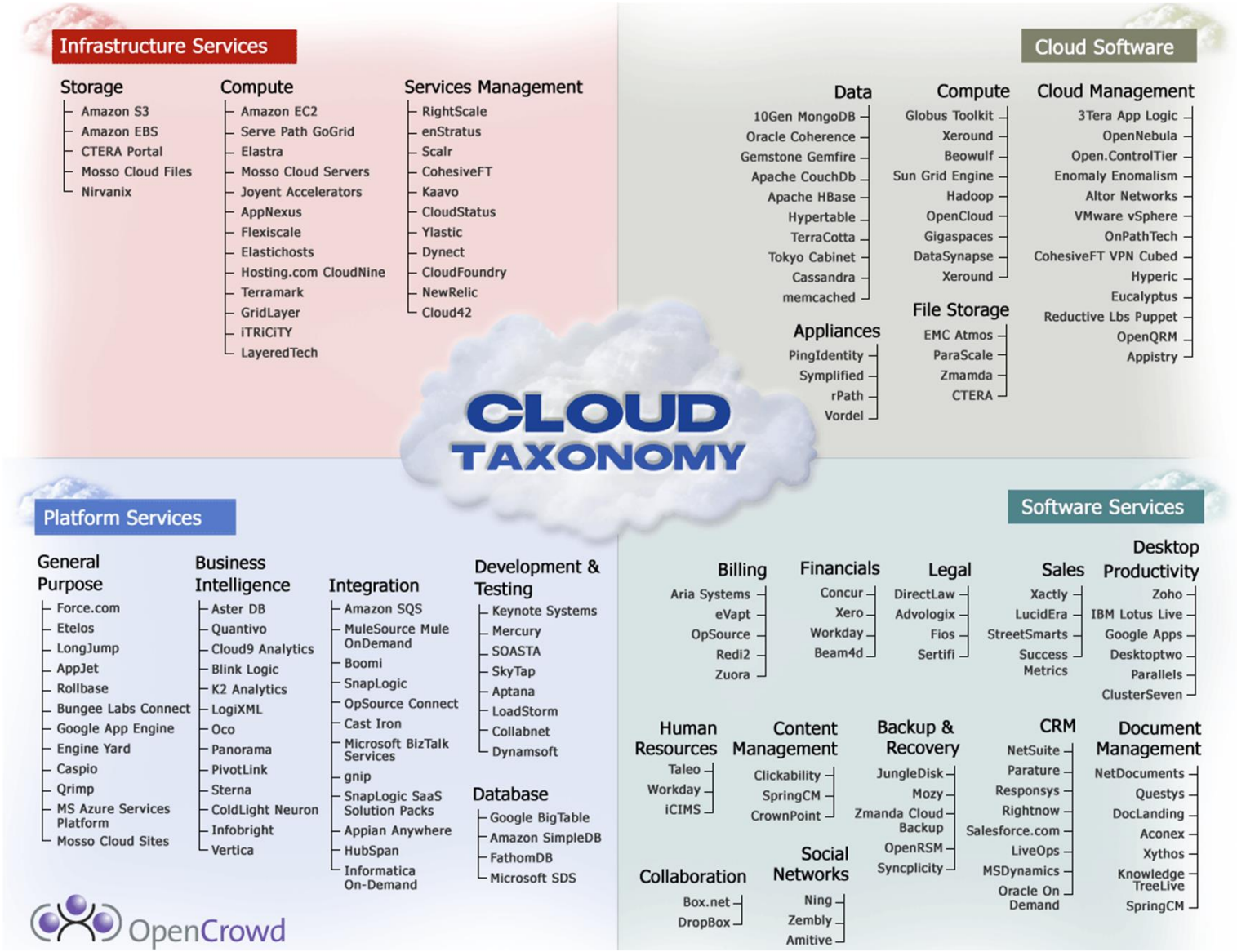
# Service Model Architectures



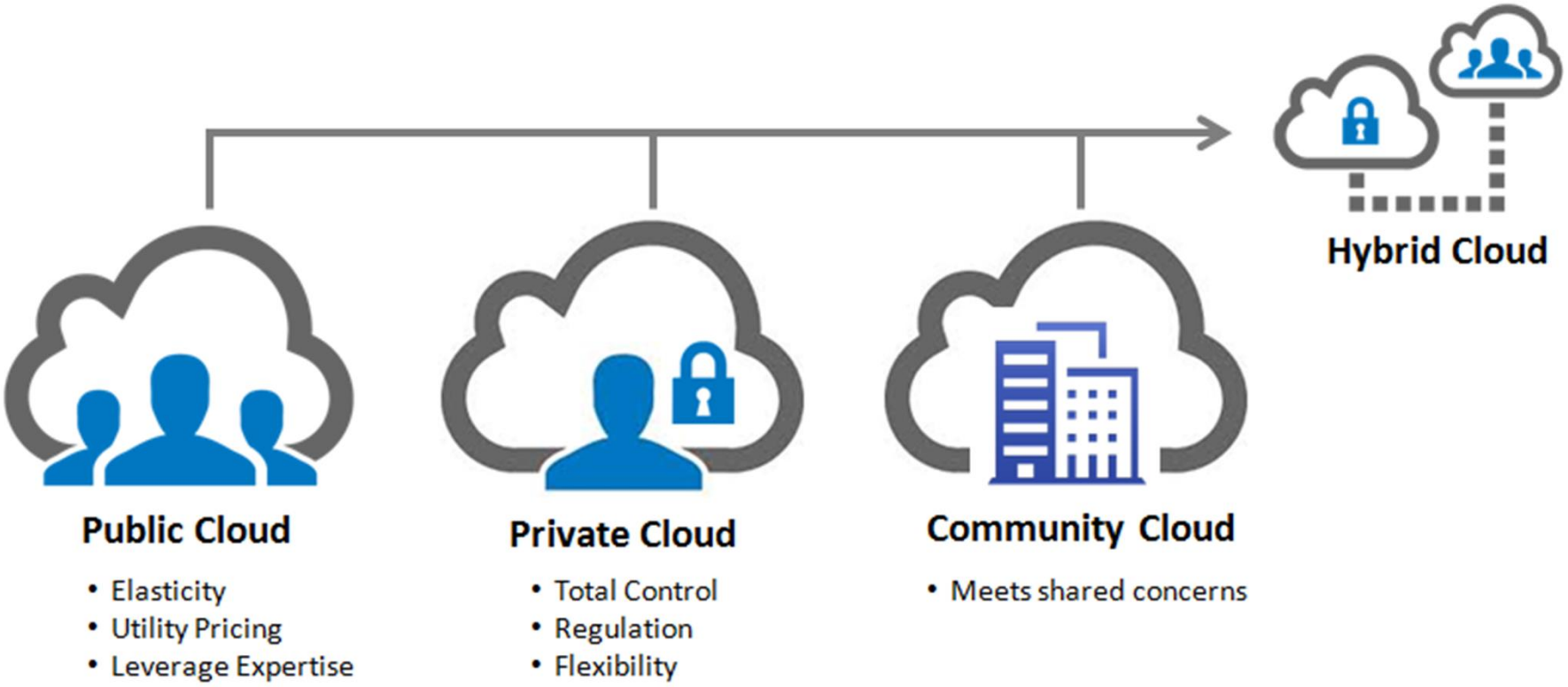
# IaaS, PaaS and SaaS

| Features | IaaS | PaaS | SaaS |
|---|---|---|---|
| **What you get** | You get the infrastructure & pay accordingly .Freedom to use or install any OS, software or composition | Here you get what you demand. Software, hardware, OS, web environment. You get the platform to use & pay accordingly | Here you don't have to worry about anything. A pre-installed, pre-configured package as per your requirement is given and you only need to pay accordingly. |
| **Importance** | The basic layer of Computing | Top of IaaS | It is like a Complete package of services |
| **Technical Difficulties** | Technical knowledge required | You get the Basic setup but still the knowledge of subject is required. | No need to worry about technicalities. The SaaS provider company handles everything. |
| **Deals with** | Virtual Machines, Storage (Hard Disks), Servers, Network, Load Balancers etc | Runtimes (like java runtimes), Databases (like mySql, Oracle), Web Servers (tomcat etc) | Applications like email (Gmail, Yahoo mail etc), Social Networking sites (Facebook etc) |
| **Popularity Graph** | Popular among highly skilled developers, researchers who require custom configuration as per their requirement or field of research. | Most popular among developers as they can focus on the development of their apps or scripts. They don't have to worry about traffic load or server management etc. | Most popular among normal consumers or companies which reply on softwares such as email, file sharing, social networking as they don't have to worry about the technicalities. |

# Cloud Taxonomy



# Cloud Deployment Models



# Cloud Deployment Models

- **Public Cloud:** allows systems and services to be easily accessible to the general public. Public cloud may be less secure because of its openness, e.g., e-mail.
- **Private Cloud:** allows systems and services to be accessible within an organization. It offers increased security because of its private nature.
- **Community Cloud:** allows systems and services to be accessible by group of organizations.
- **Hybrid Cloud:** is mixture of public and private cloud. However, the critical activities are performed using private cloud while the non-critical activities are performed using public cloud.

# Cloud Deployment Models


Private cloud the cloud infrastructure is

1) provisioned for exclusive use by a single organization with
2) multiple consumers,
3) for example individual business units
4) owned, managed, and operated by the organization


public cloud infrastructure is

1) provisioned for open use by public
2) Owned, managed and operated by a business, government or university
3) Mostly in the premises of a cloud provider

# Cloud Deployment Models


community cloud for use by a community

1. Owned by specific community of consumers from organizations that have shared concerns , missions of security etc.
2. owned, managed, and operated by the organization in the community


Hybrid cloud infrastructure is

1) Consists of two or more distinct cloud infrastructures
2) Can be private, public, or community based
3) Can be proprietary or standardized
4) More complex integrated systems
5) Subject to implications and constraints

# Opportunities and Challenges

- The use of the cloud provides a number of opportunities:
  - It enables services to be used without any understanding of their infrastructure.
  - Cloud computing works using economies of scale:
    - *It potentially lowers the outlay expense for start up companies, as they would no longer need to buy their own software or servers.*
    - *Cost would be by on-demand pricing.*
    - *Vendors and Service providers claim costs by establishing an ongoing revenue stream.*
  - Data and services are stored remotely but accessible from “anywhere”.

# Opportunities and Challenges

- In parallel there has been backlash against cloud computing:
  - Use of cloud computing means dependence on others and that could possibly limit flexibility and innovation:
    - *The others are likely become the bigger Internet companies like Google and IBM, who may monopolise the market.*
    - *Some argue that this use of supercomputers is a return to the time of mainframe computing that the PC was a reaction against.*
  - Security could prove to be a big issue:
    - *It is still unclear how safe out-sourced data is and when using these services ownership of data is not always clear.*
  - There are also issues relating to policy and access:
    - *If your data is stored abroad whose policy do you adhere to?*
    - *What happens if the remote server goes down?*
    - *How will you then access files?*
    - *There have been cases of users being locked out of accounts and losing access to data.*

# Advantages of Cloud Computing

- Lower computer costs:
  - You do not need a high-powered and high-priced computer to run cloud computing's web-based applications.
  - Since applications run in the cloud, not on the desktop PC, your desktop PC does not need the processing power or hard disk space demanded by traditional desktop software.
  - When you are using web-based applications, your PC can be less expensive, with a smaller hard disk, less memory, more efficient processor...
  - In fact, your PC in this scenario does not even need a CD or DVD drive, as no software programs have to be loaded and no document files need to be saved.
- Improved performance:
  - With few large programs hogging your computer's memory, you will see better performance from your PC.
  - Computers in a cloud computing system boot and run faster because they have fewer programs and processes loaded into memory…

# Advantages of Cloud Computing

- Reduced software costs:
  - Instead of purchasing expensive software applications, you can get most of what you need for free-ish!
    - *most cloud computing applications today, such as the Google Docs suite.*
  - better than paying for similar commercial software
    - *which alone may be justification for switching to cloud applications.*
- Instant software updates:
  - Another advantage to cloud computing is that you are no longer faced with choosing between obsolete software and high upgrade costs.
  - When the application is web-based, updates happen automatically
    - *available the next time you log into the cloud.*
  - When you access a web-based application, you get the latest version
    - *without needing to pay for or download an upgrade.*

# Advantages of Cloud Computing

- Improved document format compatibility.
  - You do not have to worry about the documents you create on your machine being compatible with other users' applications or OSes
  - There are potentially no format incompatibilities when everyone is sharing documents and applications in the cloud.
- Unlimited storage capacity:
  - Cloud computing offers virtually limitless storage.
  - Your computer's current 1 TB hard drive is small compared to the hundreds of PB available in the cloud.
- Increased data reliability:
  - Unlike desktop computing, in which if a hard disk crashes and destroy all your valuable data, a computer crashing in the cloud should not affect the storage of your data.
    - *if your personal computer crashes, all your data is still out there in the cloud, still accessible*
  - In a world where few individual desktop PC users back up their data on a regular basis, cloud computing is a data-safe computing platform!

# Advantages of Cloud Computing

- Universal document access:
  - That is not a problem with cloud computing, because you do not take your documents with you.
  - Instead, they stay in the cloud, and you can access them whenever you have a computer and an Internet connection
  - Documents are instantly available from wherever you are
- Latest version availability:
  - When you edit a document at home, that edited version is what you see when you access the document at work.
  - The cloud always hosts the latest version of your documents
    - *as long as you are connected, you are not in danger of having an outdated version*

# Advantages of Cloud Computing

- Easier group collaboration:
  - Sharing documents leads directly to better collaboration.
  - Many users do this as it is an important advantages of cloud computing
    - *multiple users can collaborate easily on documents and projects*
- Device independence.
  - You are no longer tethered to a single computer or network.
  - Changes to computers, applications and documents follow you through the cloud.
  - Move to a portable device, and your applications and documents are still available.

# Disadvantages of Cloud Computing

- Requires a constant Internet connection:
  - Cloud computing is impossible if you cannot connect to the Internet.
  - Since you use the Internet to connect to both your applications and documents, if you do not have an Internet connection you cannot access anything, even your own documents.
  - A dead Internet connection means no work and in areas where Internet connections are few or inherently unreliable, this could be a deal-breaker.
- Does not work well with low-speed connections:
  - Similarly, a low-speed Internet connection, such as that found with dial-up services, makes cloud computing painful at best and often impossible.
  - Web-based applications require a lot of bandwidth to download, as do large documents.
- Features might be limited:
  - This situation is bound to change, but today many web-based applications simply are not as full-featured as their desktop-based applications.
    - *For example, you can do a lot more with Microsoft PowerPoint than with Google Presentation's web-based offering*

# Disadvantages of Cloud Computing

- Can be slow:
  - Even with a fast connection, web-based applications can sometimes be slower than accessing a similar software program on your desktop PC.
  - Everything about the program, from the interface to the current document, has to be sent back and forth from your computer to the computers in the cloud.
  - If the cloud servers happen to be backed up at that moment, or if the Internet is having a slow day, you would not get the instantaneous access you might expect from desktop applications.
- Stored data might not be secure:
  - With cloud computing, all your data is stored on the cloud.
    - *The questions is How secure is the cloud?*
  - Can unauthorized users gain access to your confidential data?
- Stored data can be lost:
  - Theoretically, data stored in the cloud is safe, replicated across multiple machines.
  - But on the off chance that your data goes missing, you have no physical or local backup.
    - *Put simply, relying on the cloud puts you at risk if the cloud lets you down.*

# Disadvantages of Cloud Computing

- HPC Systems:
  - Not clear that you can run compute-intensive HPC applications that use MPI/OpenMP!
  - Scheduling is important with this type of application
    - *as you want all the VM to be co-located to minimize communication latency!*
- General Concerns:
  - *Each cloud systems uses different protocols and different APIs*
    - *may not be possible to run applications between cloud based systems*
  - *Amazon has created its own DB system (not SQL 92), and workflow system (many popular workflow systems out there)*
    - *so your normal applications will have to be adapted to execute on these platforms.*

# The Future

- Many of the activities loosely grouped together under cloud computing have already been happening and centralised computing activity is not a new phenomena
- Grid Computing was the last research-led centralised approach
- However there are concerns that the mainstream adoption of cloud computing could cause many problems for users
- Many new open source systems appearing that you can install and run on your local cluster
  - *should be able to run a variety of applications on these systems*