
CLOUD
COMPUTING

Agenda

- Introduction to Cloud Computing
- Cloud Architecture
- Characteristics of Cloud Computing
- Cloud Deployment Model
- Cloud Services Model
- NIST Cloud Architecture

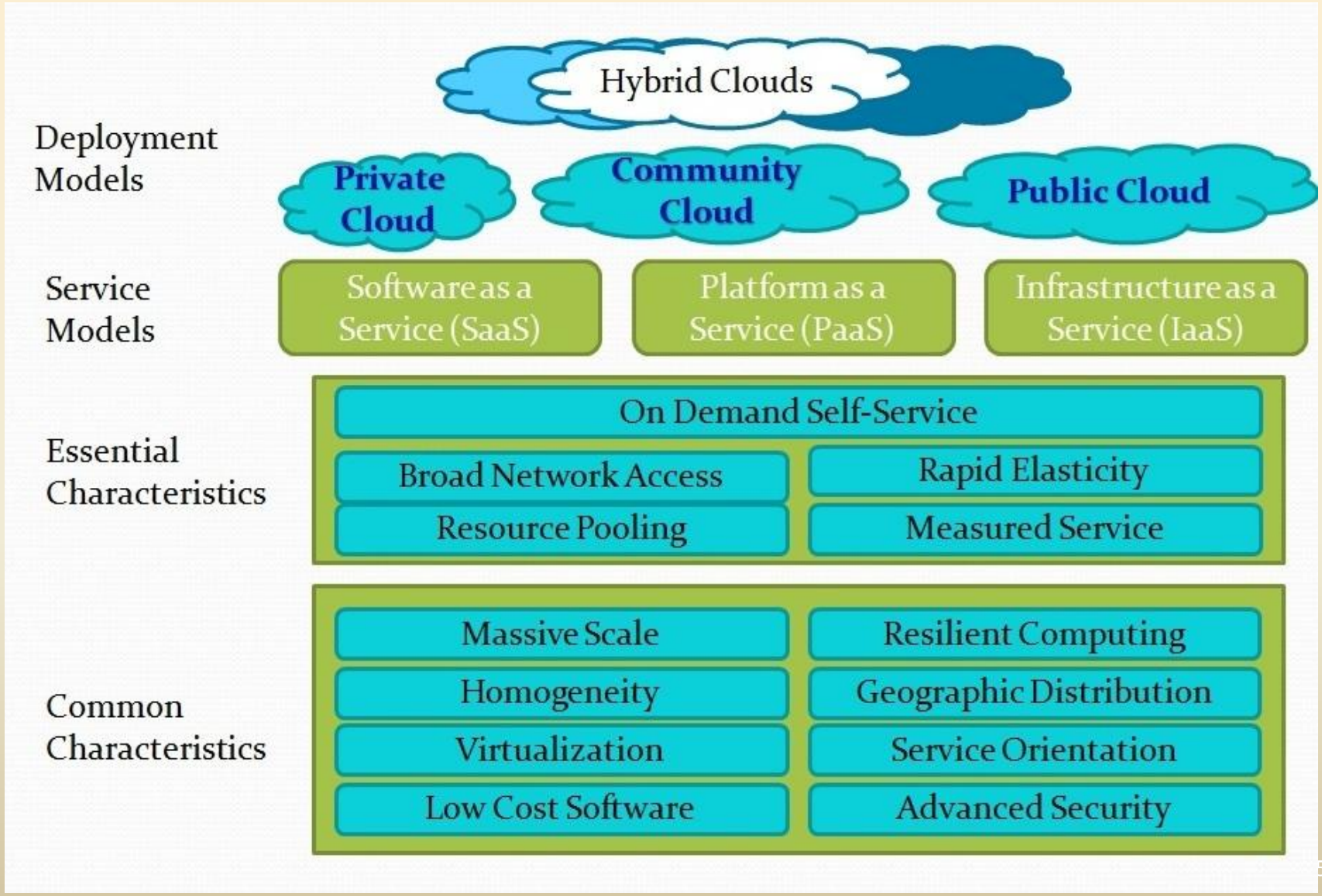
Cloud Computing Definition

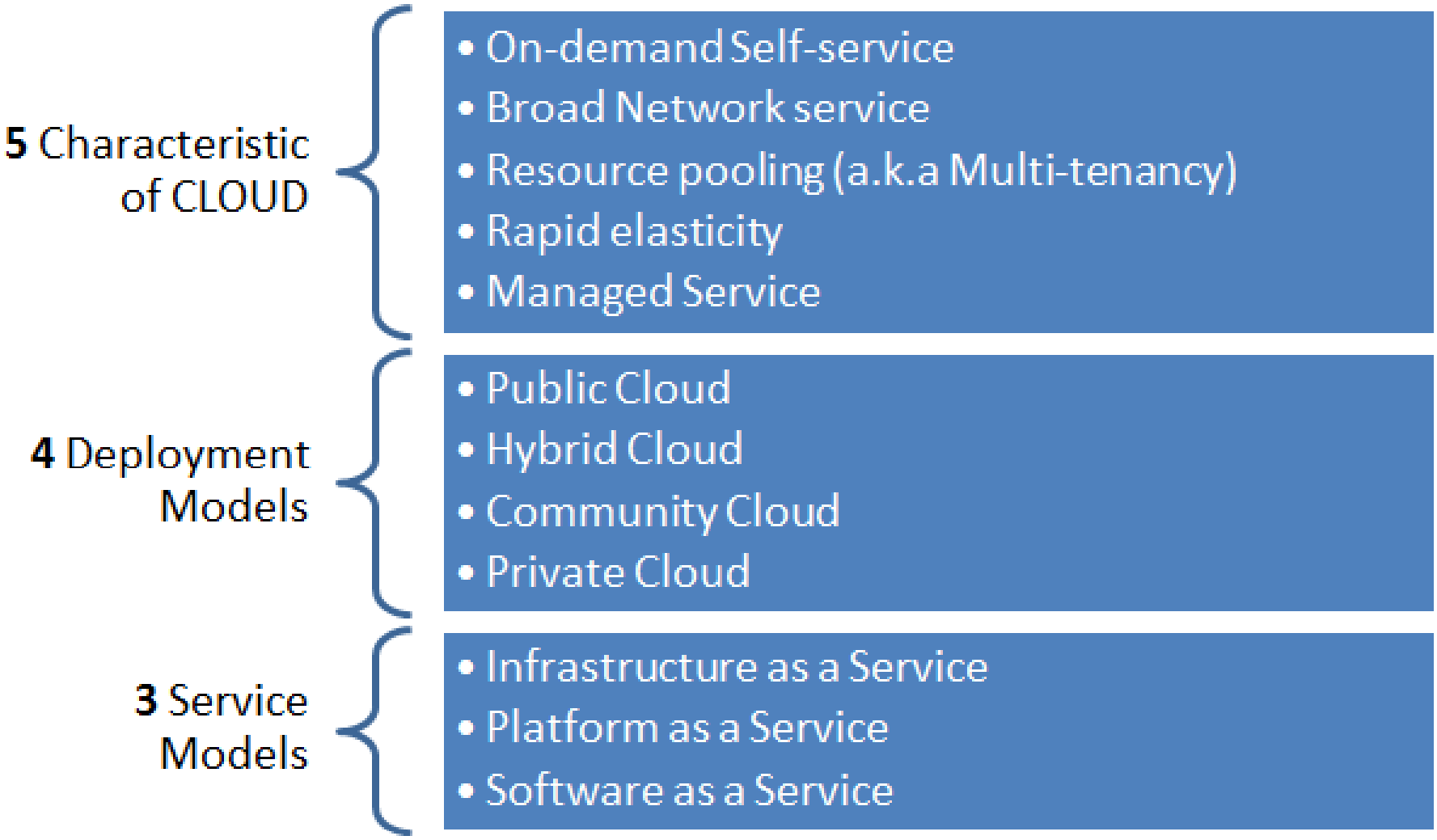
- Cloud is a parallel and distributed computing system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers.”

Cloud Computing Definition

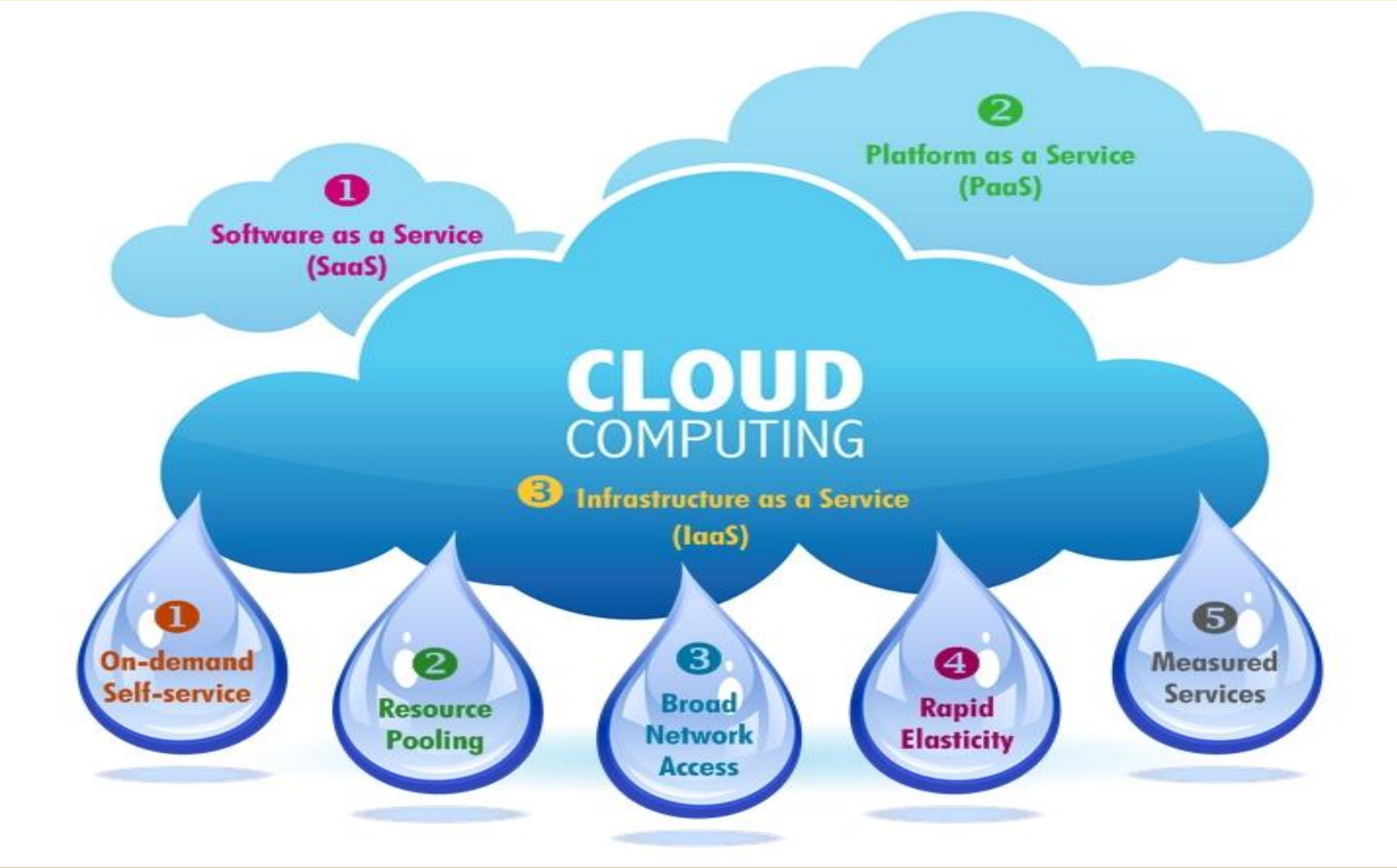
- Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization.
- This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements.”

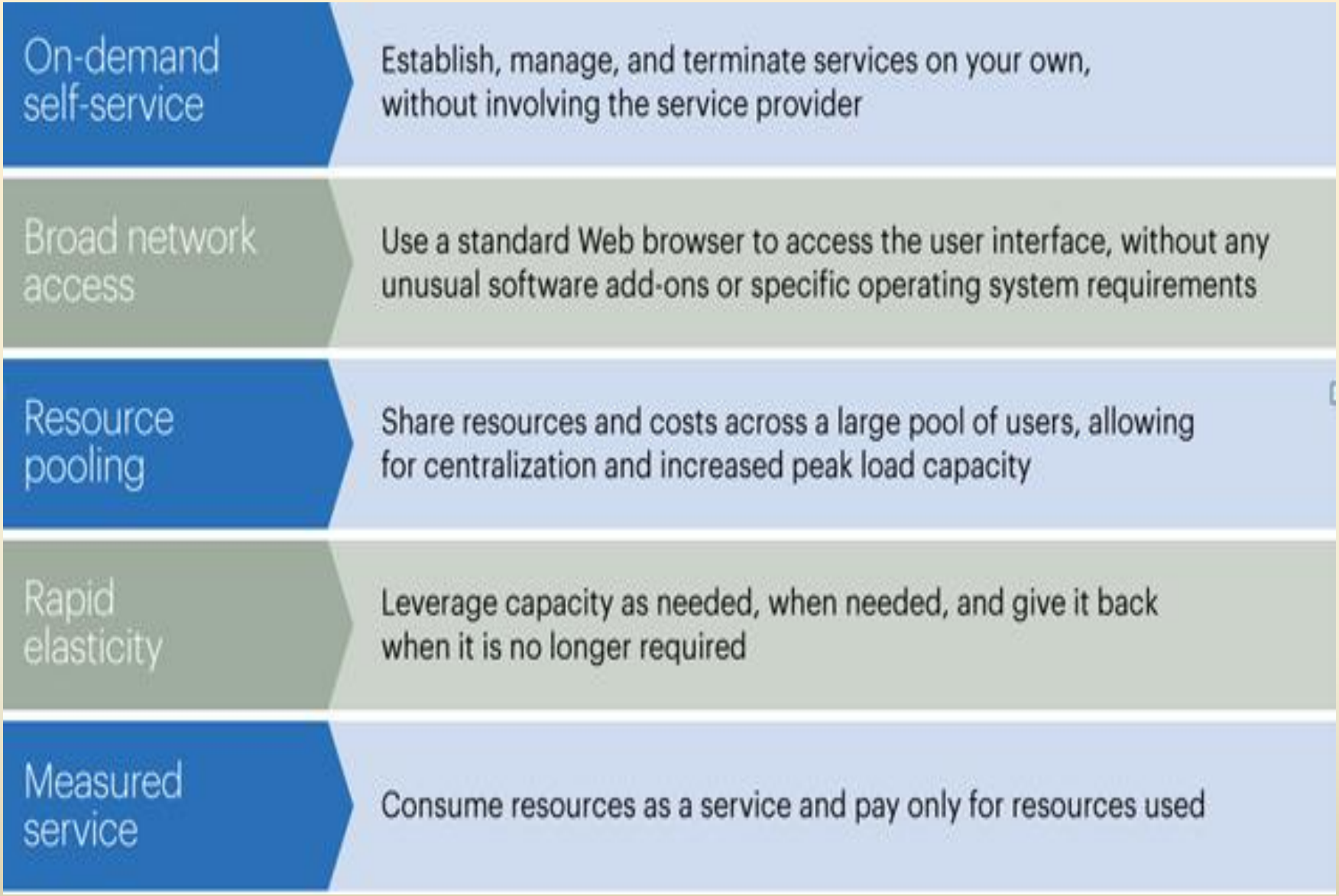
Cloud Architecture




5 Characteristic of CLOUD
• On-demand Self-service
• Broad Network service
• Resource pooling (a.k.a Multi-tenancy)
• Rapid elasticity
• Managed Service
4 Deployment Models
• Public Cloud
• Hybrid Cloud
• Community Cloud
• Private Cloud
3 Service Models
• Infrastructure as a Service
• Platform as a Service
• Software as a Service

Characteristics Of Cloud Computing




On-demand self-service
Establish, manage, and terminate services on your own, without involving the service provider
Broad network access
Use a standard Web browser to access the user interface, without any unusual software add-ons or specific operating system requirements
Resource pooling
Share resources and costs across a large pool of users, allowing for centralization and increased peak load capacity
Rapid elasticity
Leverage capacity as needed, when needed, and give it back when it is no longer required
Measured service
Consume resources as a service and pay only for resources used

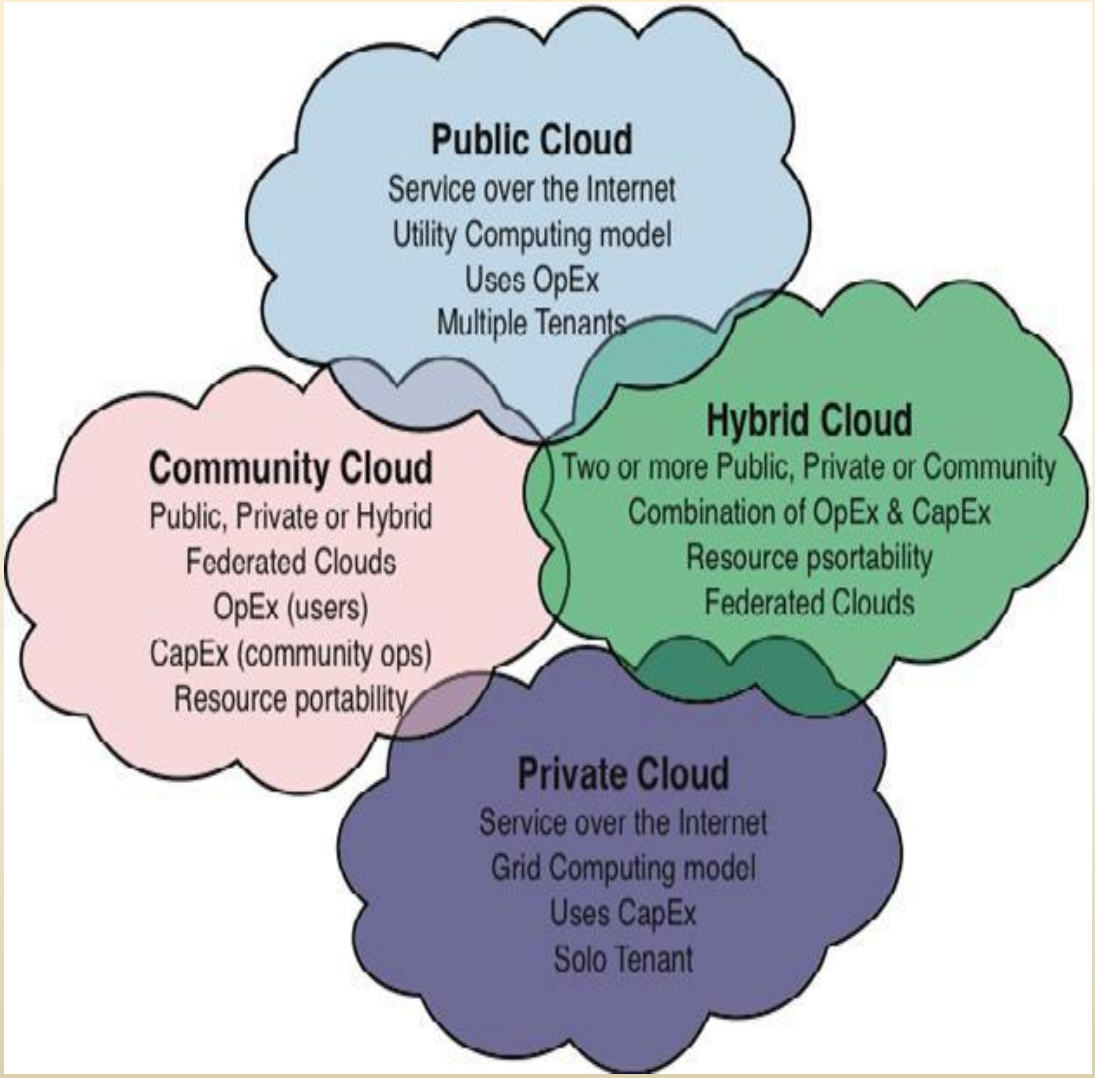
Cloud Deployment models

- The concept of cloud computing has evolved from cluster, grid and utility computing.
- Cluster and grid computing leverage the use of many computers in parallel to solve problems of any size.
- Utility and Software as a Service (SaaS) provide computing resource as a service with notation of pay per use.
- Cloud computing is a high throughput computing (HTC) paradigm whereby the infrastructure provides the service through a large data centre or server farms.
- The cloud computing model enables users to share to resources from anywhere at any time through their connected devices.
- All computations in cloud applications are distributed to servers in a data centre, cloud platforms are systems distributed through virtualization.

Cloud Deployment Models

The major cloud deployment models are

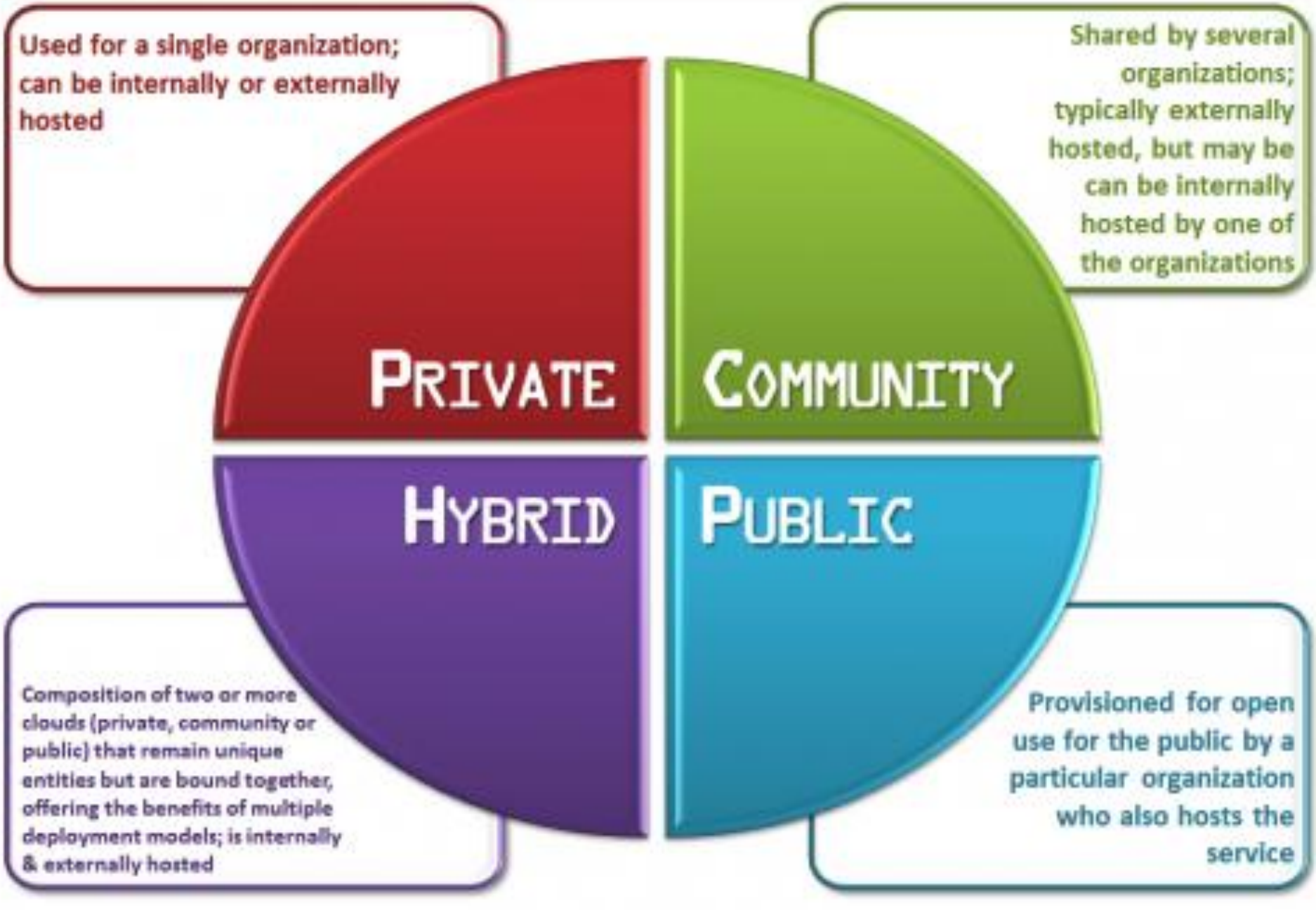
1. Public Cloud
2. Private Cloud,
3. Hybrid Cloud
4. Community Cloud

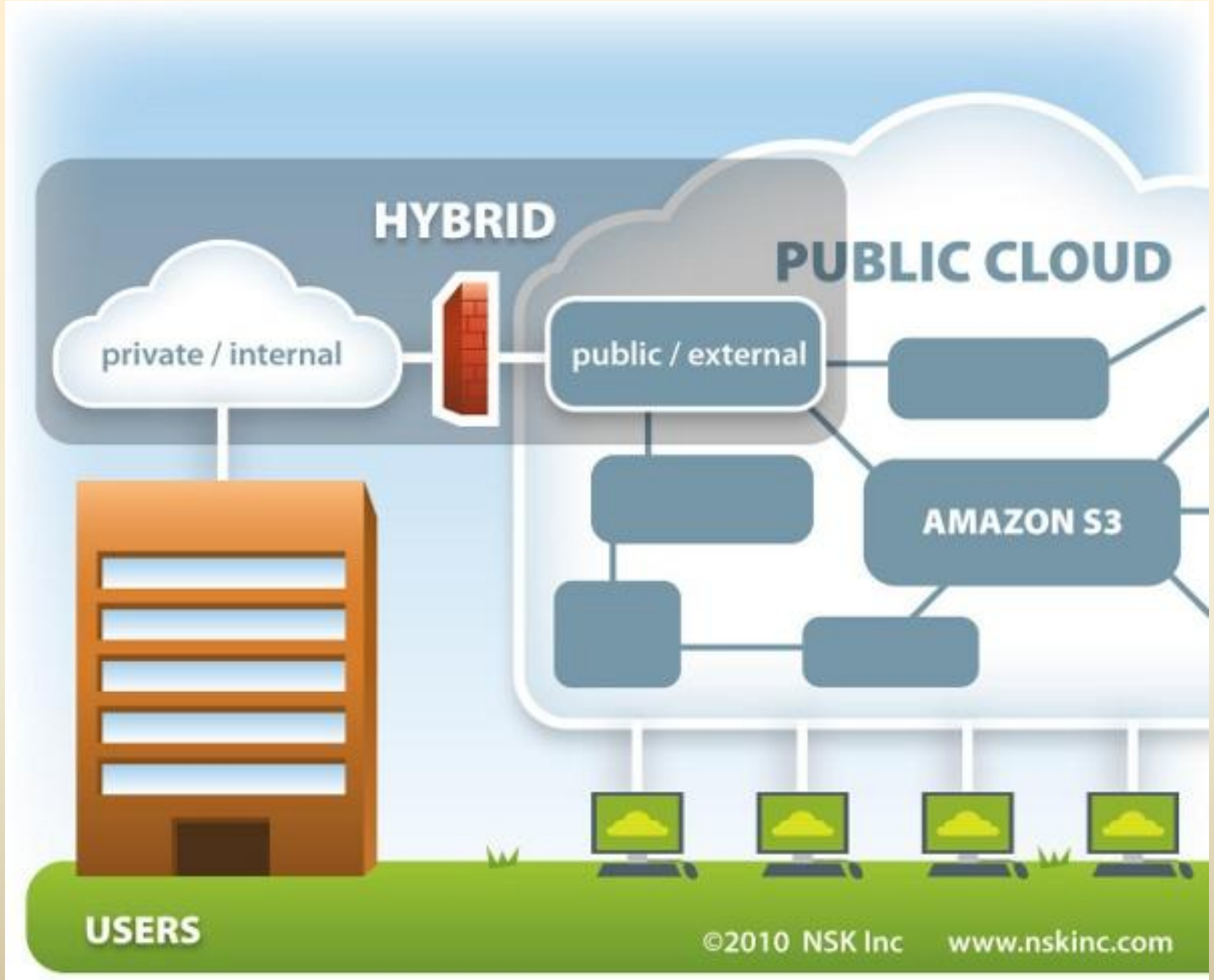


Deployment Models

- **Private cloud.** The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
- **Community cloud.** The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

- **Public Cloud.** The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
- **Hybrid Cloud.** The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).


Used for a single organization; can be internally or externally hosted
PRIVATE
Shared by several organizations; typically externally hosted, but may be can be internally hosted by one of the organizations
COMMUNITY
HYBRID
Composition of two or more clouds (private, community or public) that remain unique entities but are bound together, offering the benefits of multiple deployment models; is internally & externally hosted
PUBLIC
Provisioned for open use for the public by a particular organization who also hosts the service


HYBRID
PUBLIC CLOUD
private / internal
public / external
AMAZON S3
USERS
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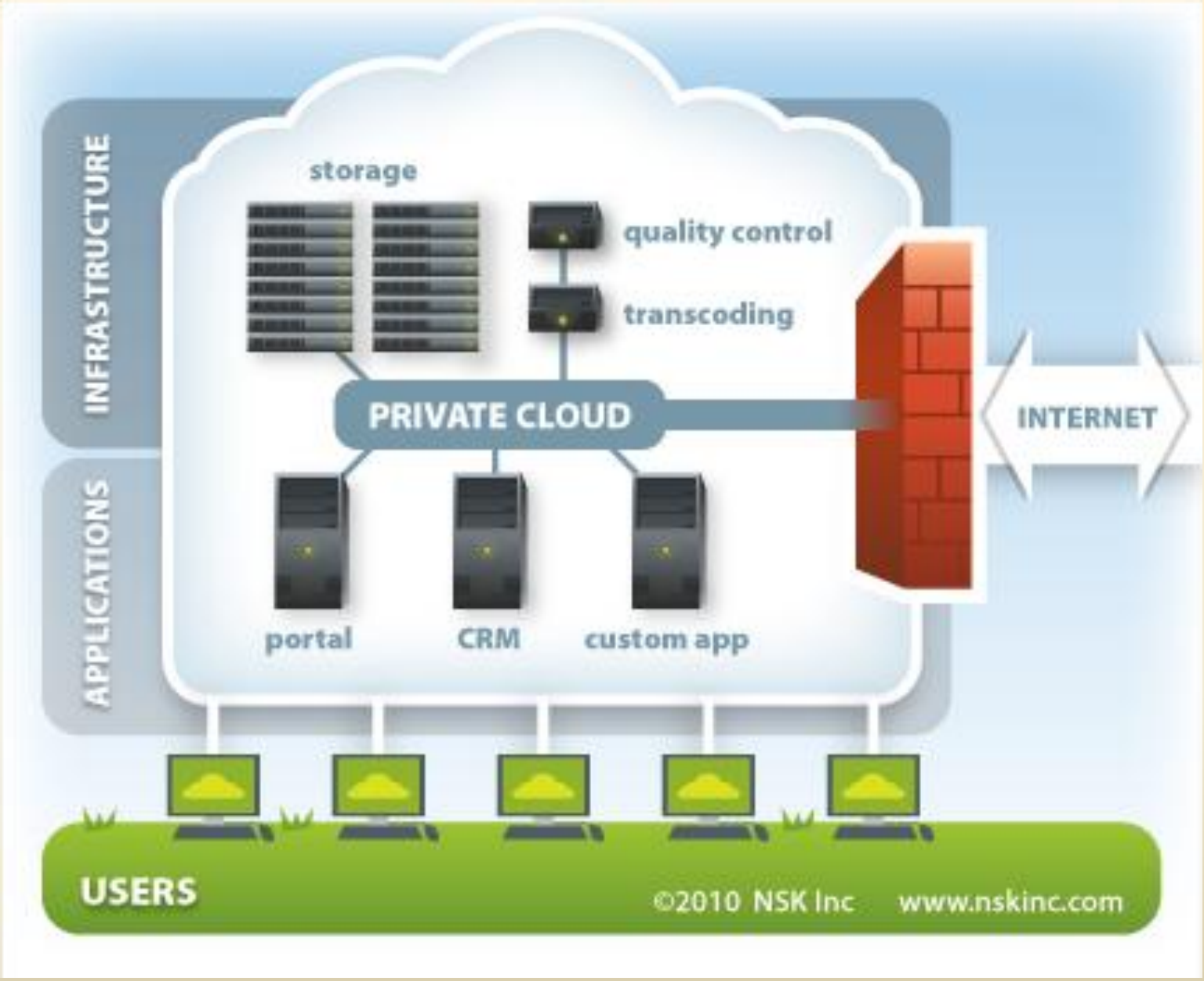

INFRASTRUCTURE
APPLICATIONS
storage
quality control
transcoding
PRIVATE CLOUD
INTERNET
portal
CRM
custom app
USERS
©2010 NSK Inc
www.nskinc.com

	Managed* By	Owned By	Located*	Accessible and Consumed By
Public	Third Party Provider	Third Party Provider	External Internal	Trusted or Untrusted
Private	Organization	Organization Third Party Provider	Internal External	Trusted
Hybrid	Organization or Third Party Provider	Organization or Third Party Provider	External and Internal	Trusted or Untrusted

**Management includes: operations, security, compliance, etc...*
Location is both physical and relative to and Organization's management umbrella

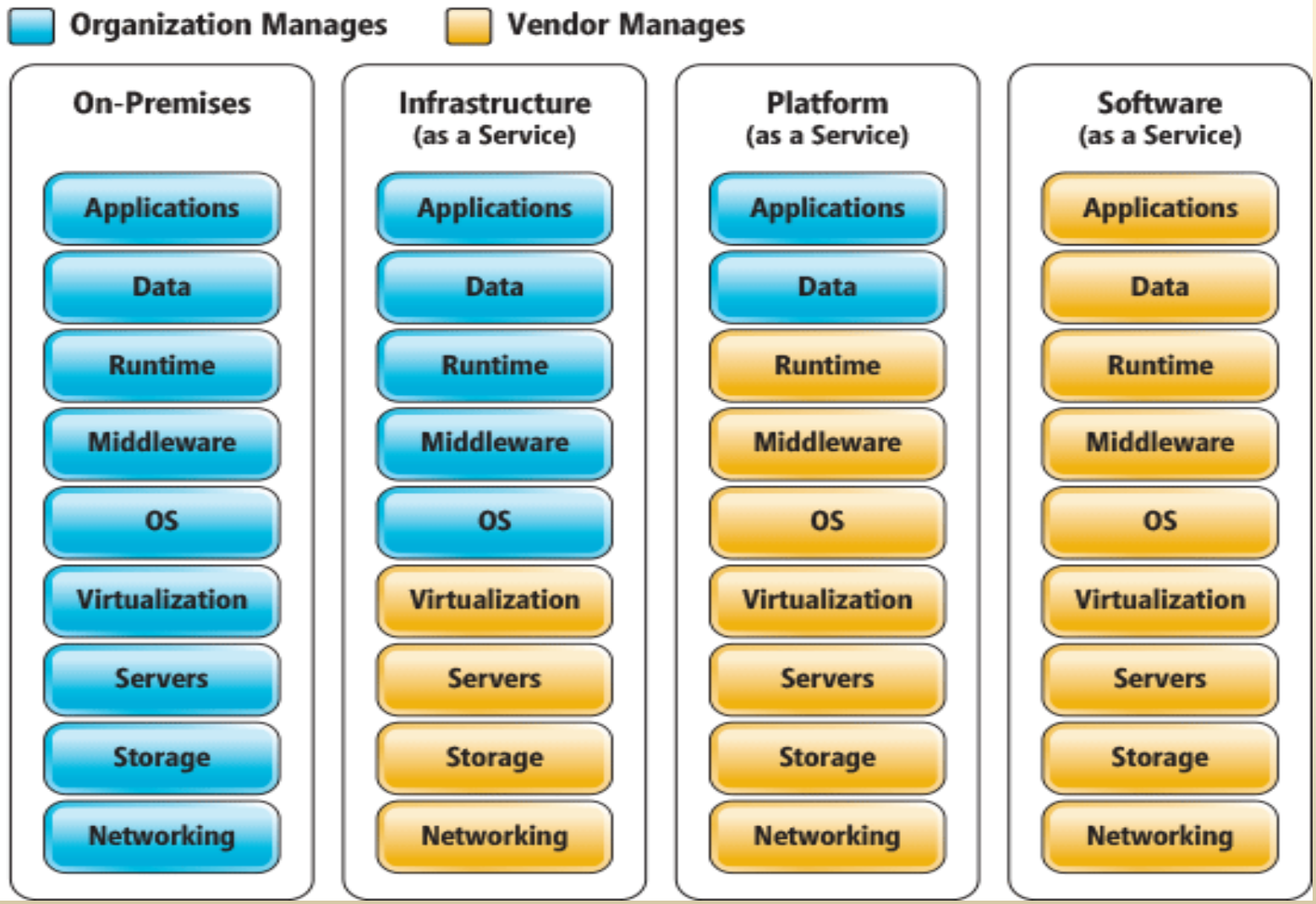
PUBLIC vs. PRIVATE vs. HYBRID
CLOUD STORAGE

Characteristic	Public cloud storage	Private cloud storage	Hybrid cloud storage
Scalability	Very high	Limited	Very high
Security	Good, but depends on the security measures of the service provider	Most secure, as all storage is on-premise	Very secure; integration options add an additional layer of security
Performance	Low to medium	Very good	Good, as active content is cached on-premise
Reliability	Medium; depends on Internet connectivity and service provider availability	High, as all equipment is on premise	Medium to high, as cached content is kept on-premise, but also depends on connectivity and service provider availability
Cost	Very good; pay-as-you-go model and no need for on-premise storage infrastructure	Good, but requires on-premise resources, such as data center space, electricity and cooling	Improved, since it allows moving some storage resources to a pay-as-you-go model

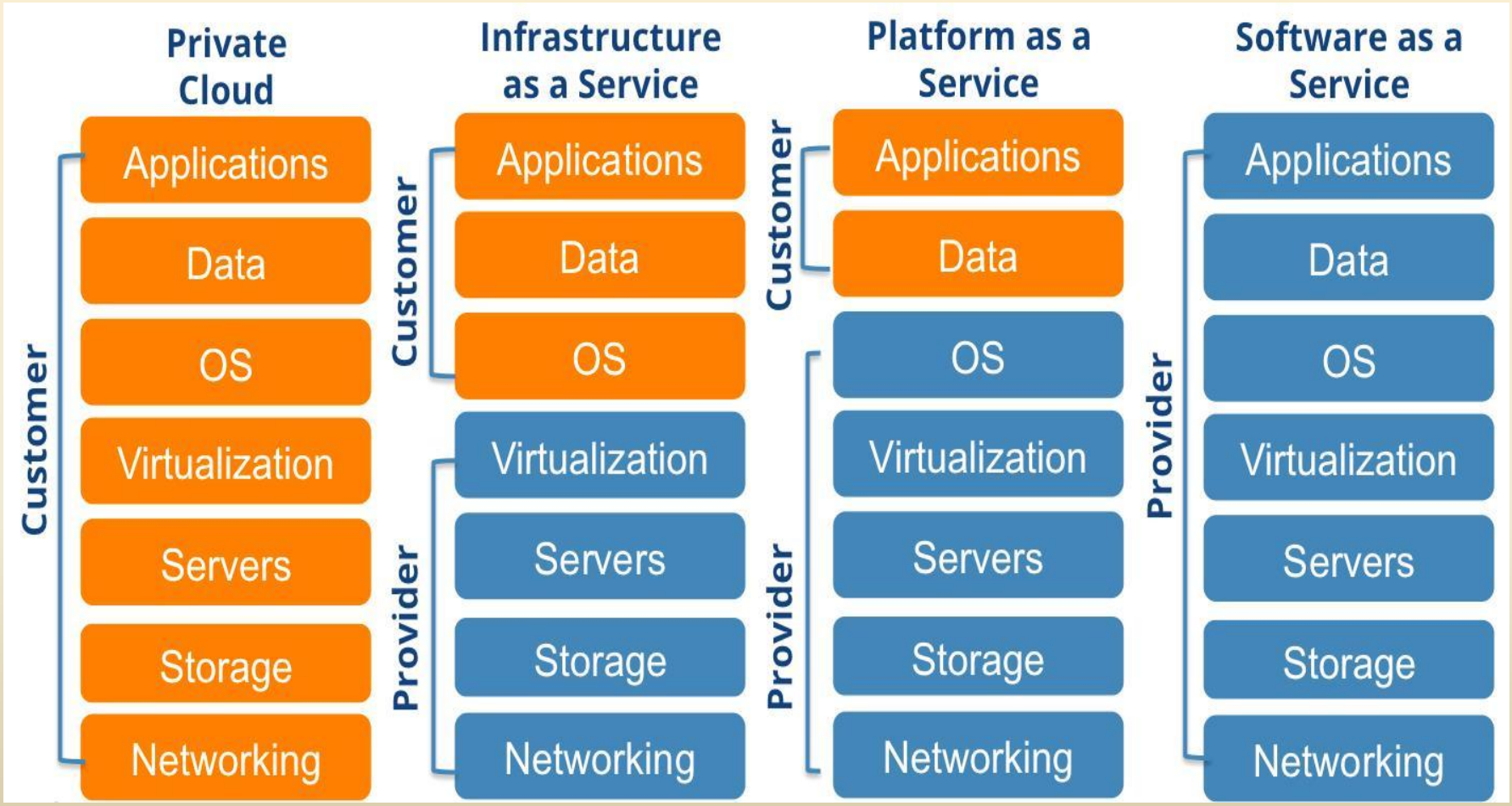
Service Models

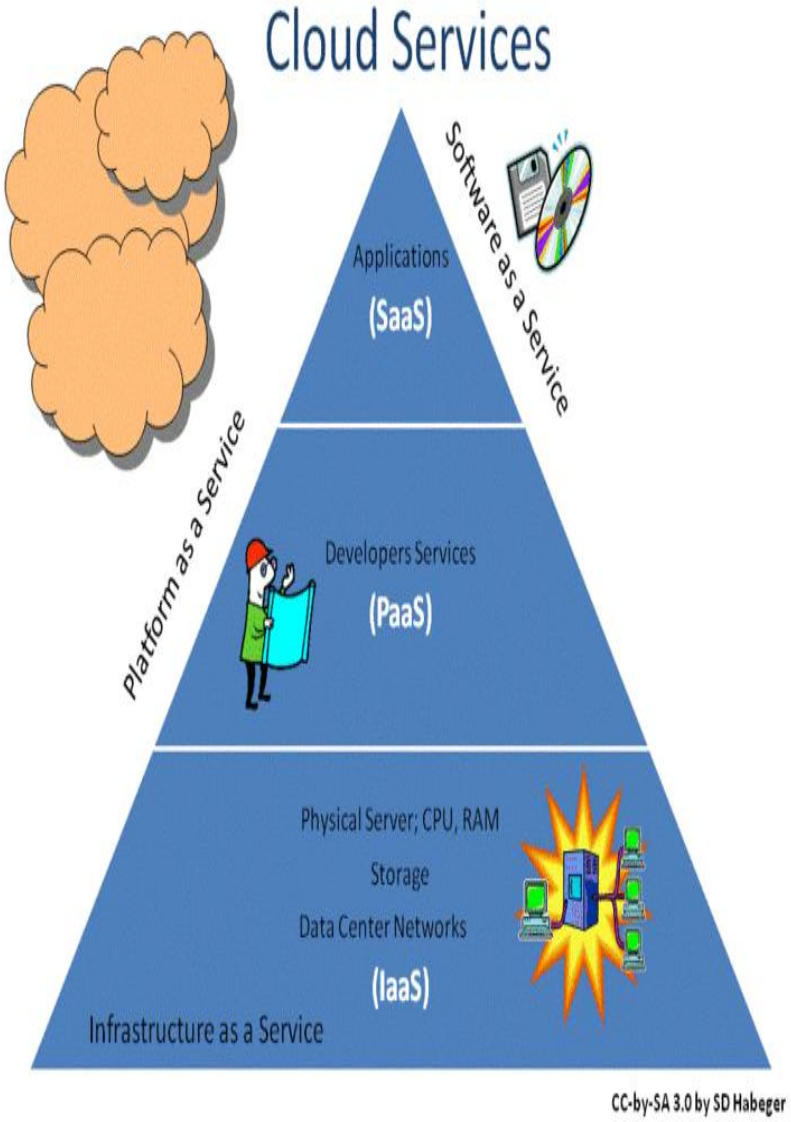
- Software as a Service (SaaS).
- Platform as a Service (PaaS).
- Infrastructure as a Service (IaaS).

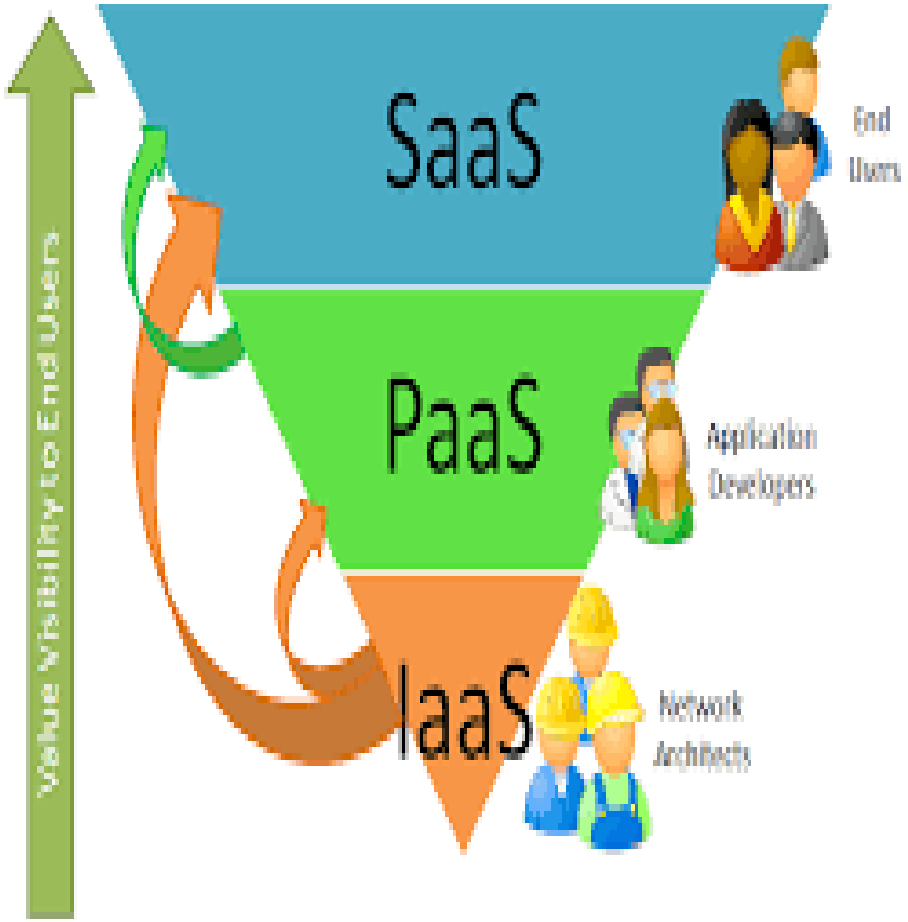
Cloud service models offer customers varying levels of control over assets and services, which presents performance visibility challenges.



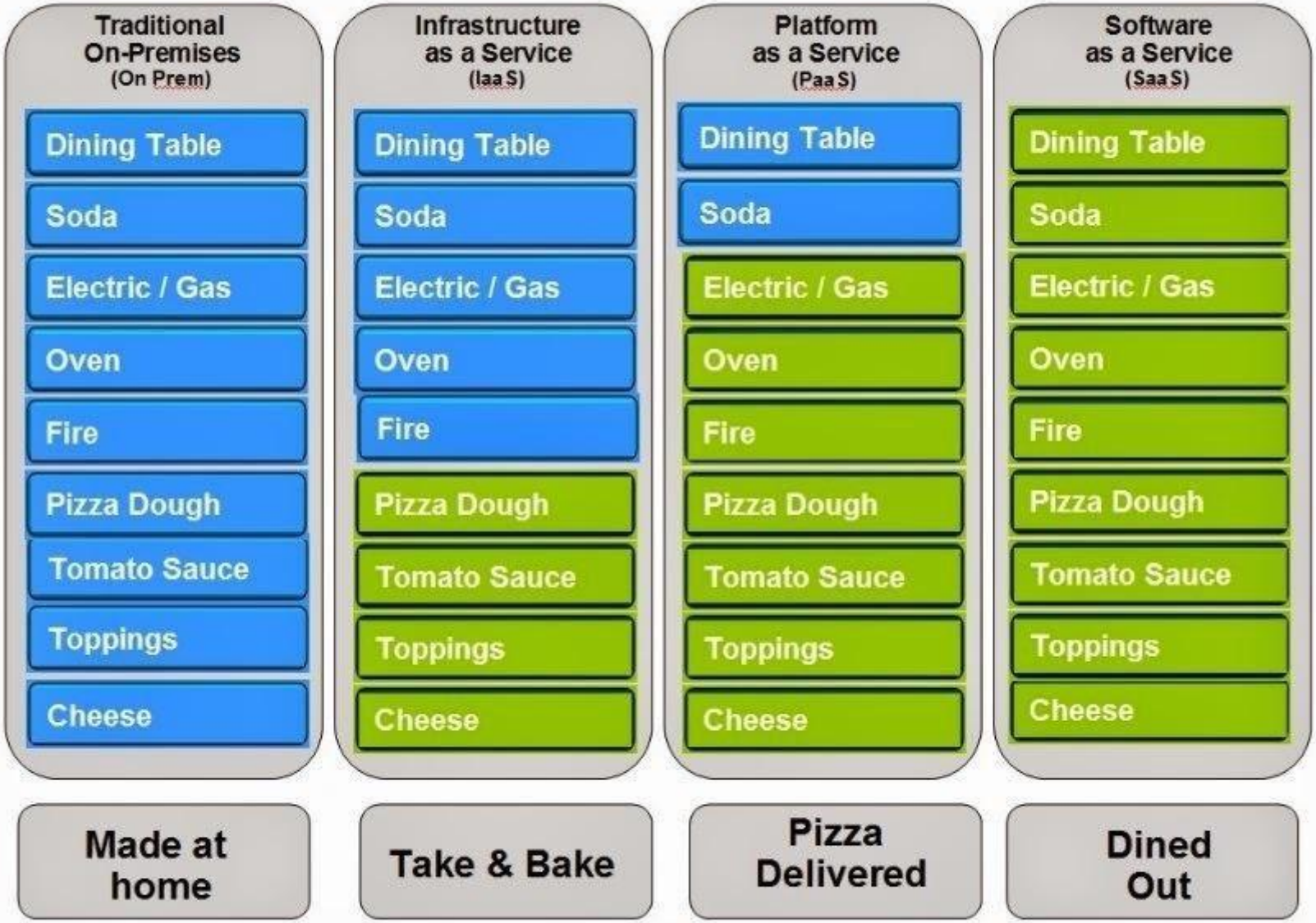
The platform and ecosystem views of cloud computing represent a new paradigm, and promote a new way of computing.

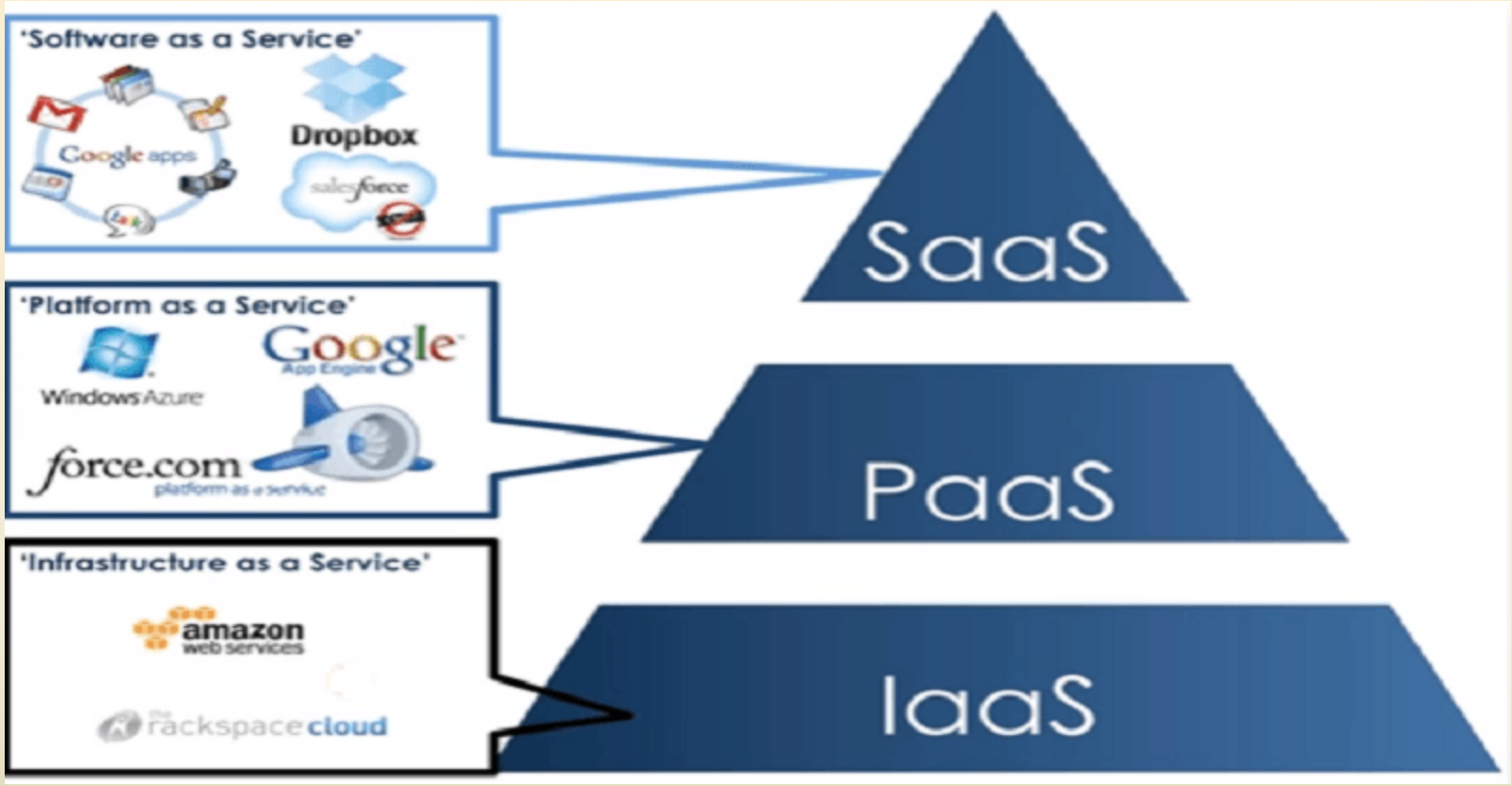



Cloud Services
Applications
(SaaS)
Software as a Service
Platform as a Service
Developers Services
(PaaS)
Physical Server; CPU, RAM
Storage
Data Center Networks
(IaaS)
Infrastructure as a Service
CC-by-SA 3.0 by SD Habeger


Value Visibility to End Users
SaaS
End Users
PaaS
Application Developers
IaaS
Network Architects

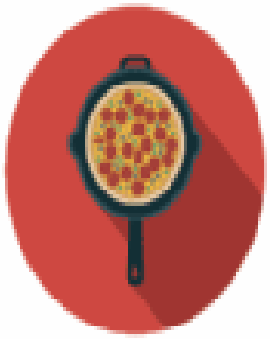
Pizza as a Service




'Software as a Service'
Google apps
Dropbox
salesforce
'Platform as a Service'
Windows Azure
Google
App Engine
force.com
platform as a service
'Infrastructure as a Service'
amazon
web services
rackspace cloud
SaaS
PaaS
IaaS

Pizza as a service

The variety of cloud services can obfuscate the level of an organization's ownership of the stack. Albert Barron, executive software client architect at IBM, uses this analogy to provide clarity:



ON-PREMISES MANAGEMENT

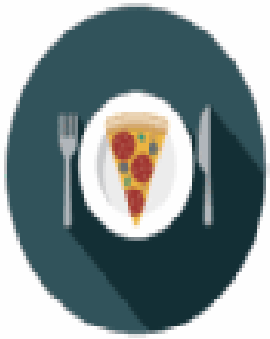
Making a pizza at home

IAAS

Take-and-bake service

PAAS

Delivery



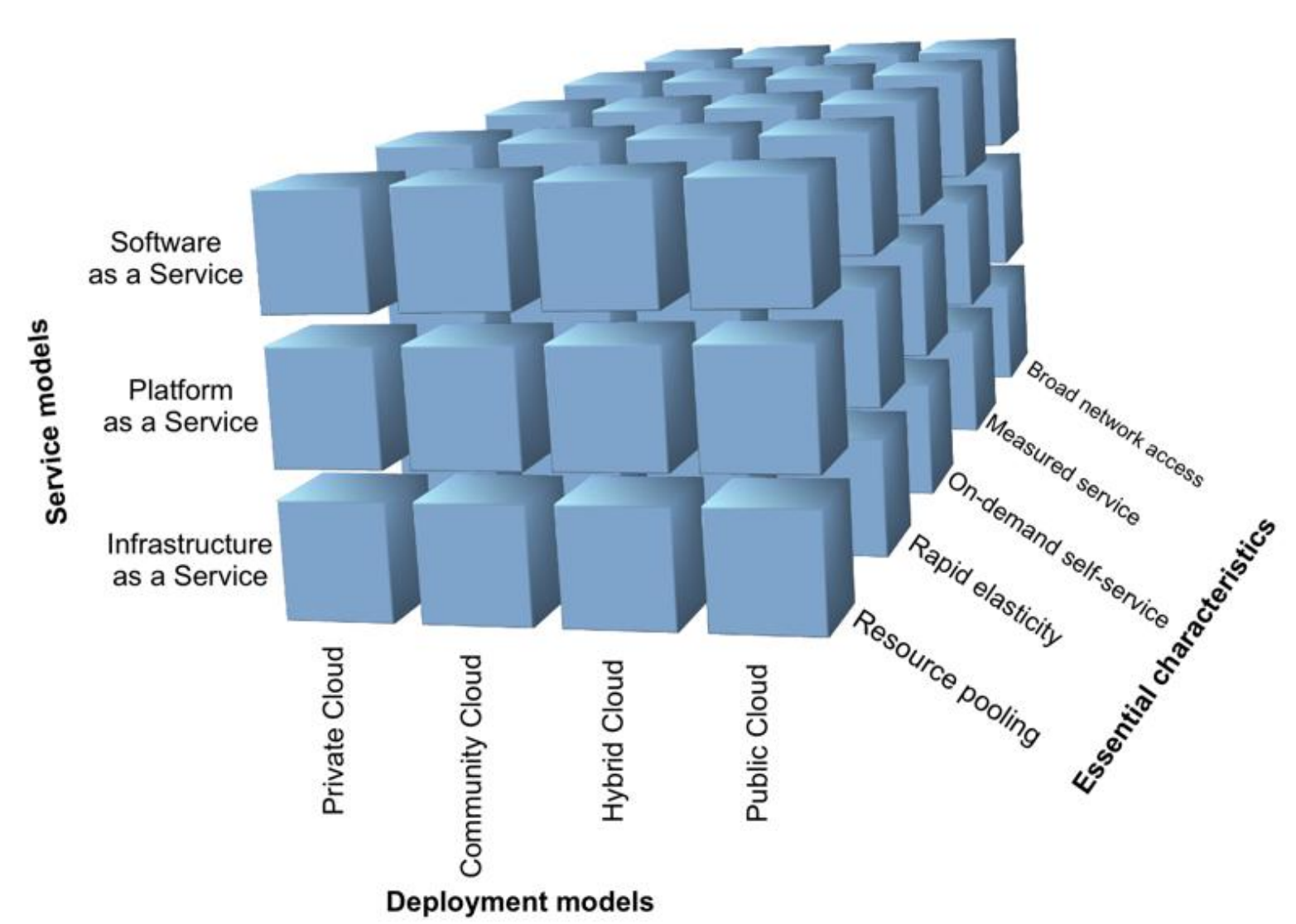
SAAS

Eat-in restaurant

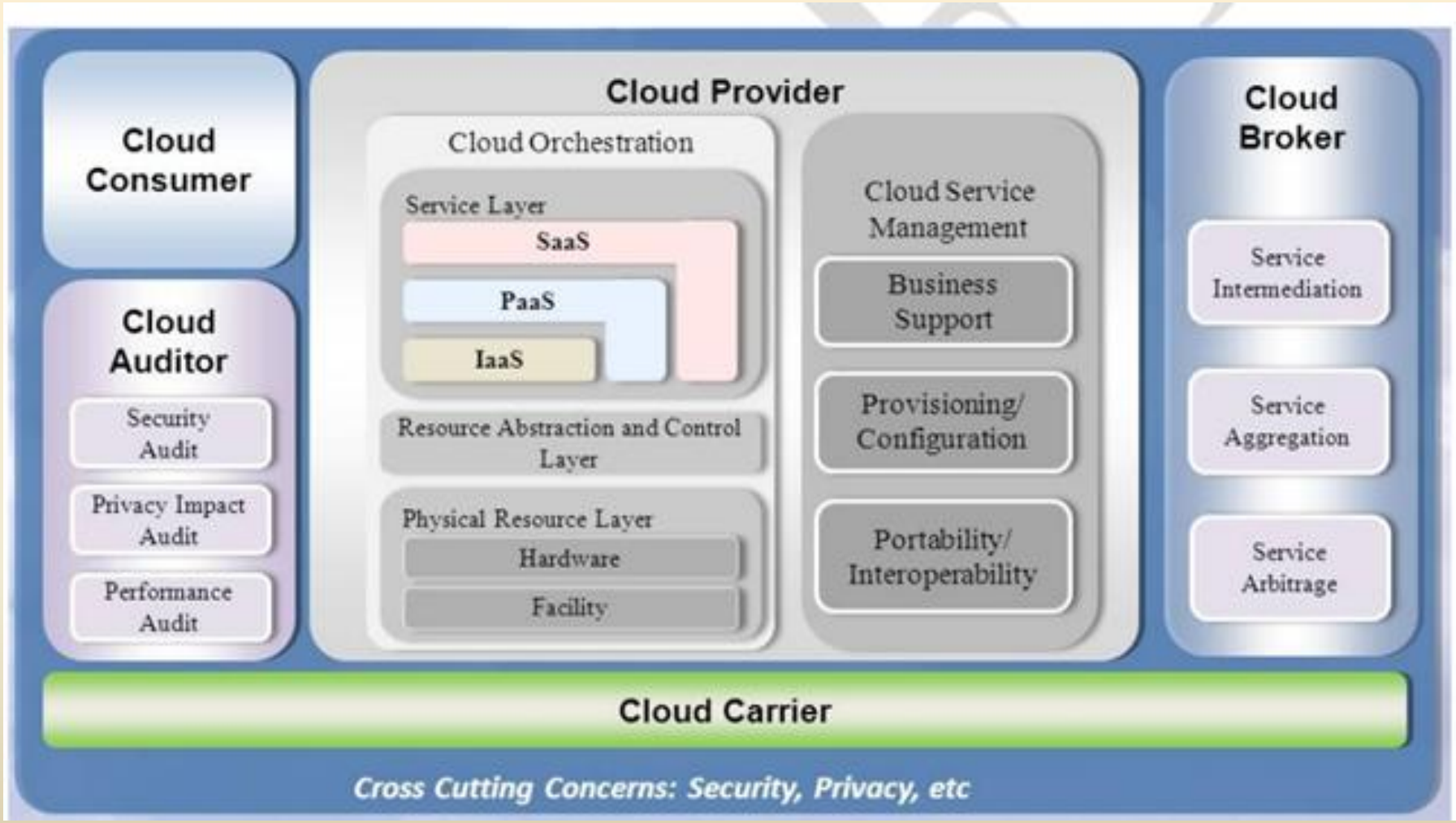
NIST DEFINITOIN

- Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

NIST Cloud Model



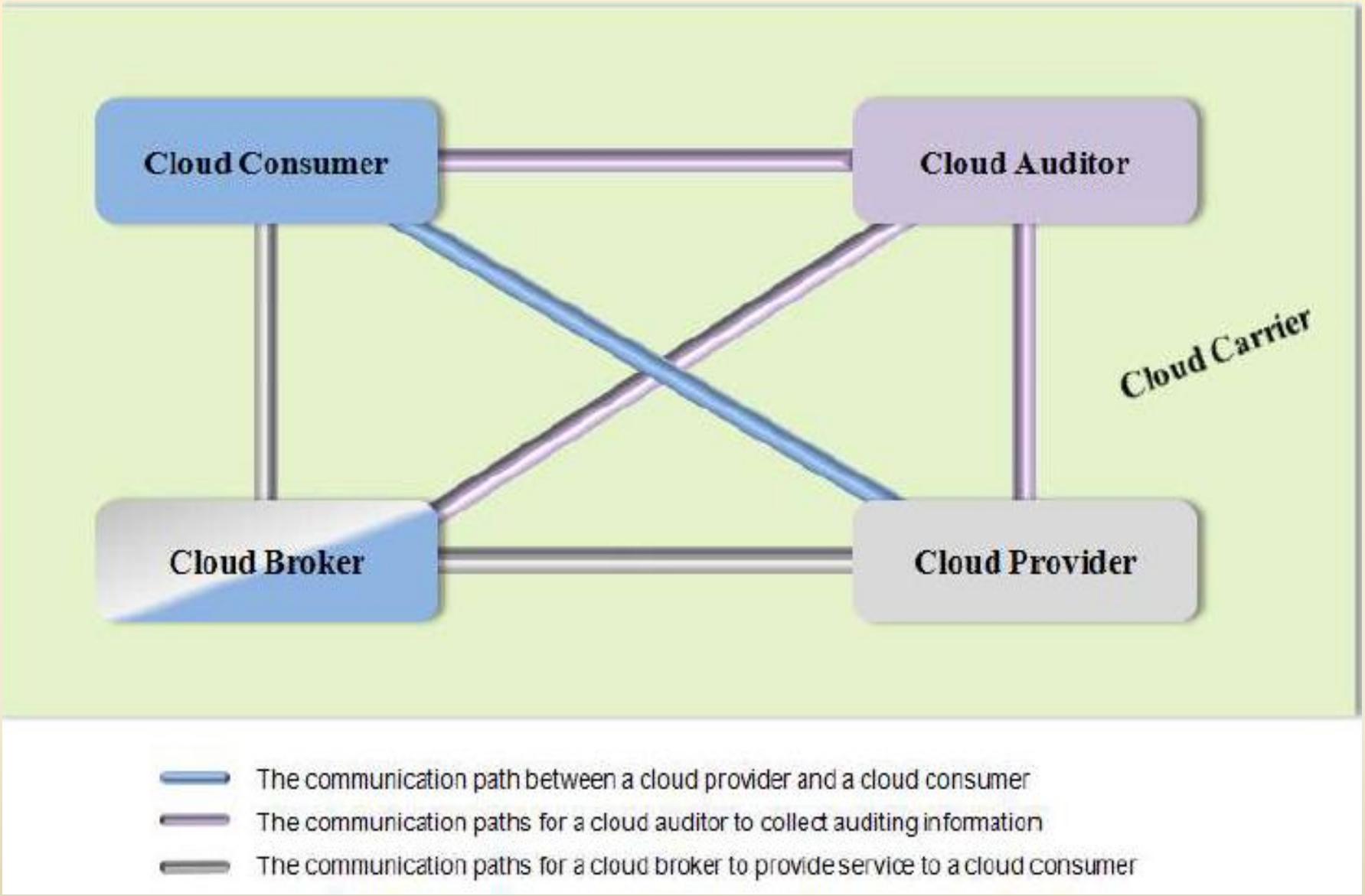
Cloud Computing Architecture



The Conceptual Reference Model

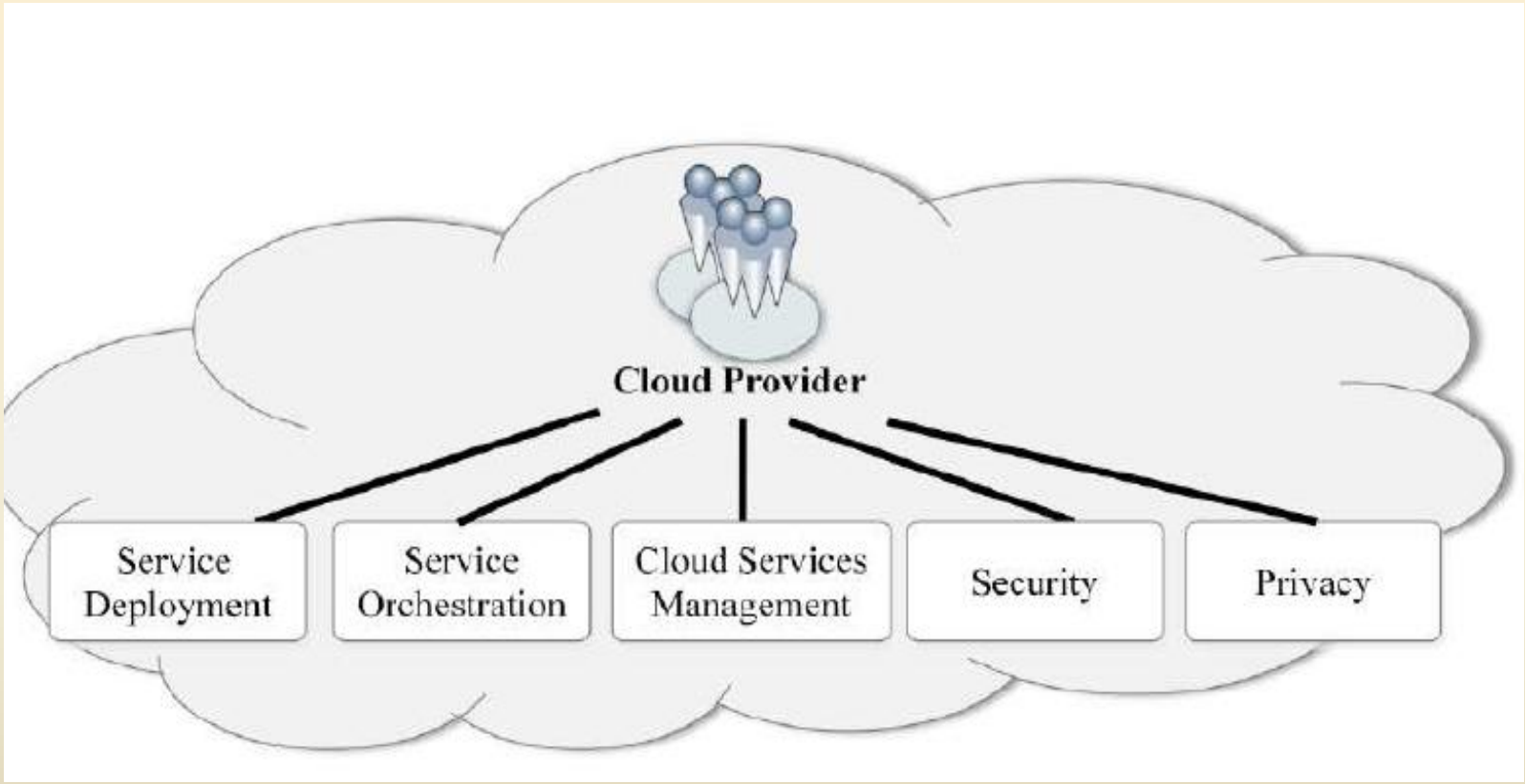
NIST Cloud Agents

- **Cloud Consumer** A person or organization that maintains a business relationship with, and uses service from, Cloud Provider
- **Cloud Provider** A person, organization, or entity responsible for making a service available to interested parties.
- **Cloud Auditor** A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.
- **Cloud Broker** An entity that manages the use, performance and delivery of cloud services, and negotiates relationships between Cloud Providers and Cloud Consumers.
- **Cloud Carrier** An intermediary that provides connectivity and transport of cloud services from Cloud Providers to Cloud Consumers.

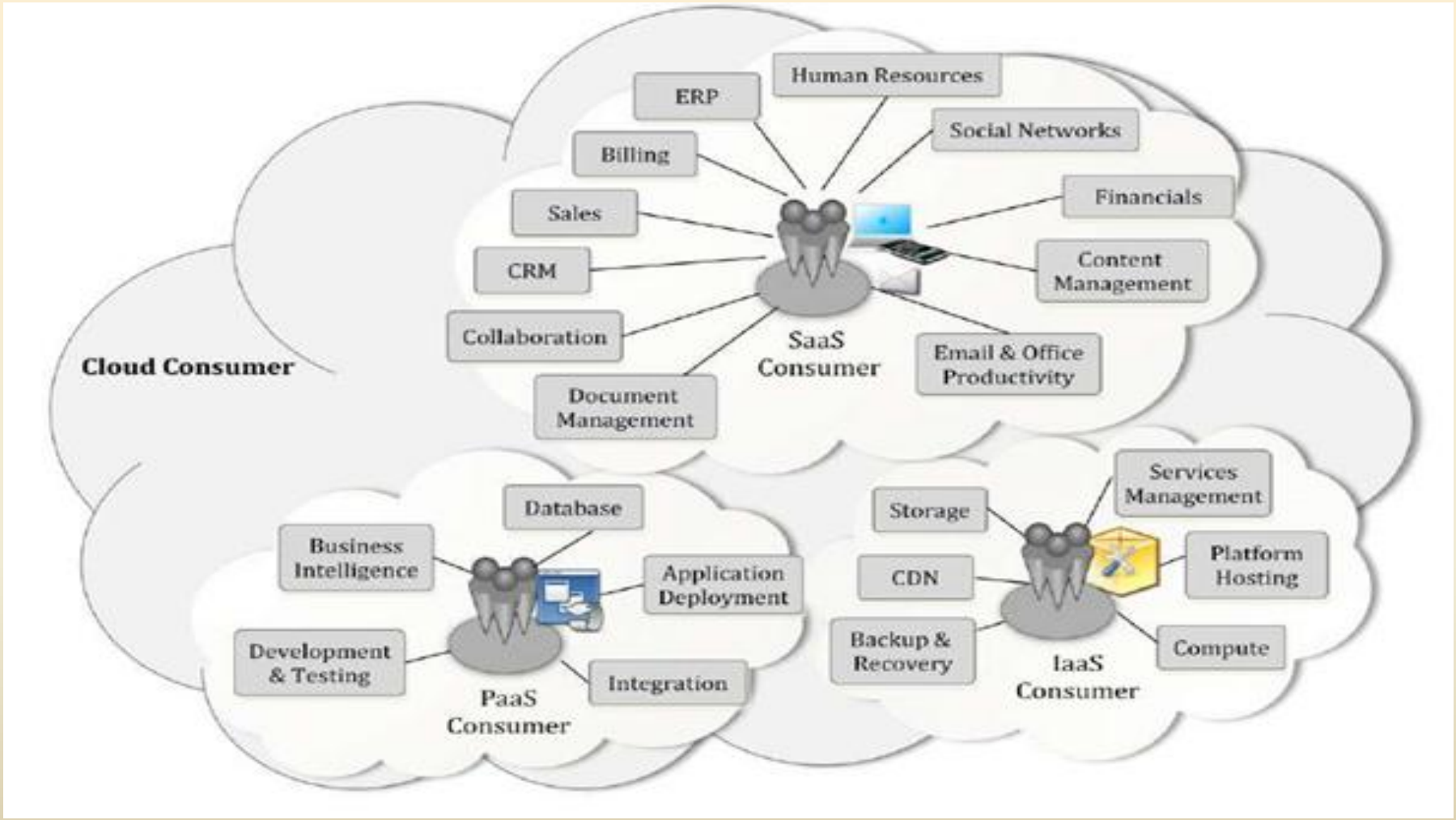


Interactions between the Actors in Cloud Computing

CLOUD PROVIDER

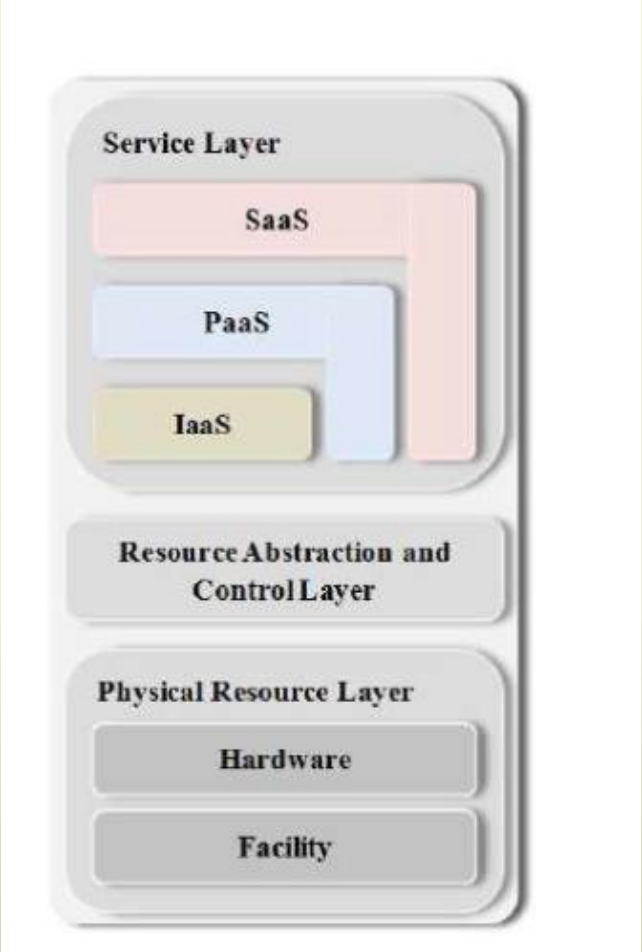


CLOUD CONSUMER

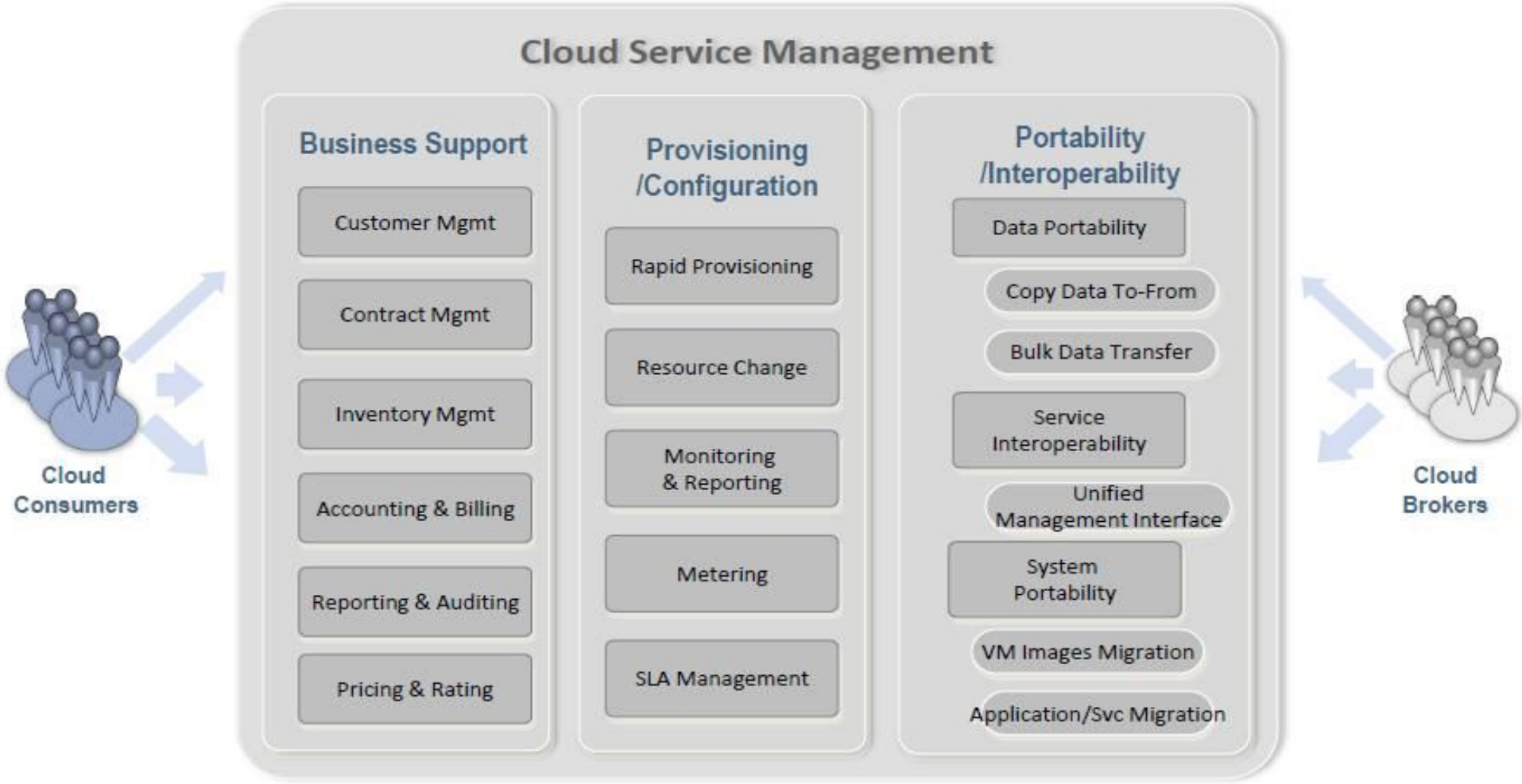


Example Service Available to a Cloud Consumer

Cloud Provider
Service Orchestration

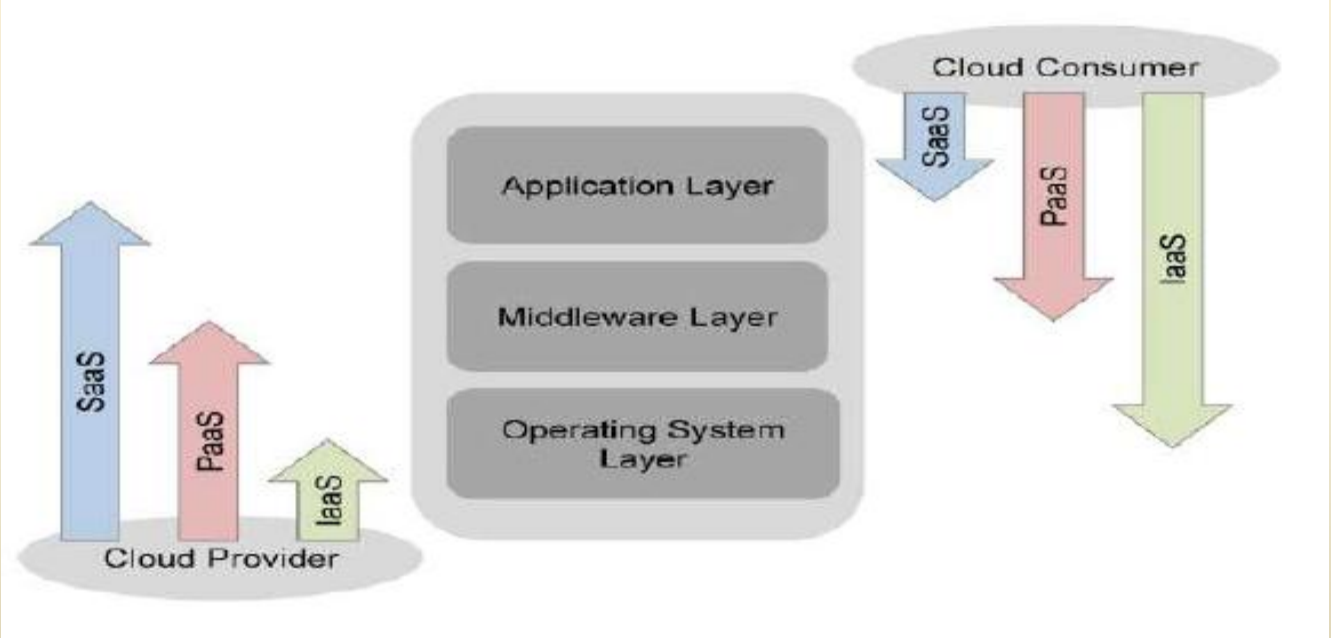


Cloud Provider
Cloud Service Management



Cloud Carrier

- provides connectivity and transport of cloud services between cloud consumers and cloud
- providers (network, telecommunication, access devices)



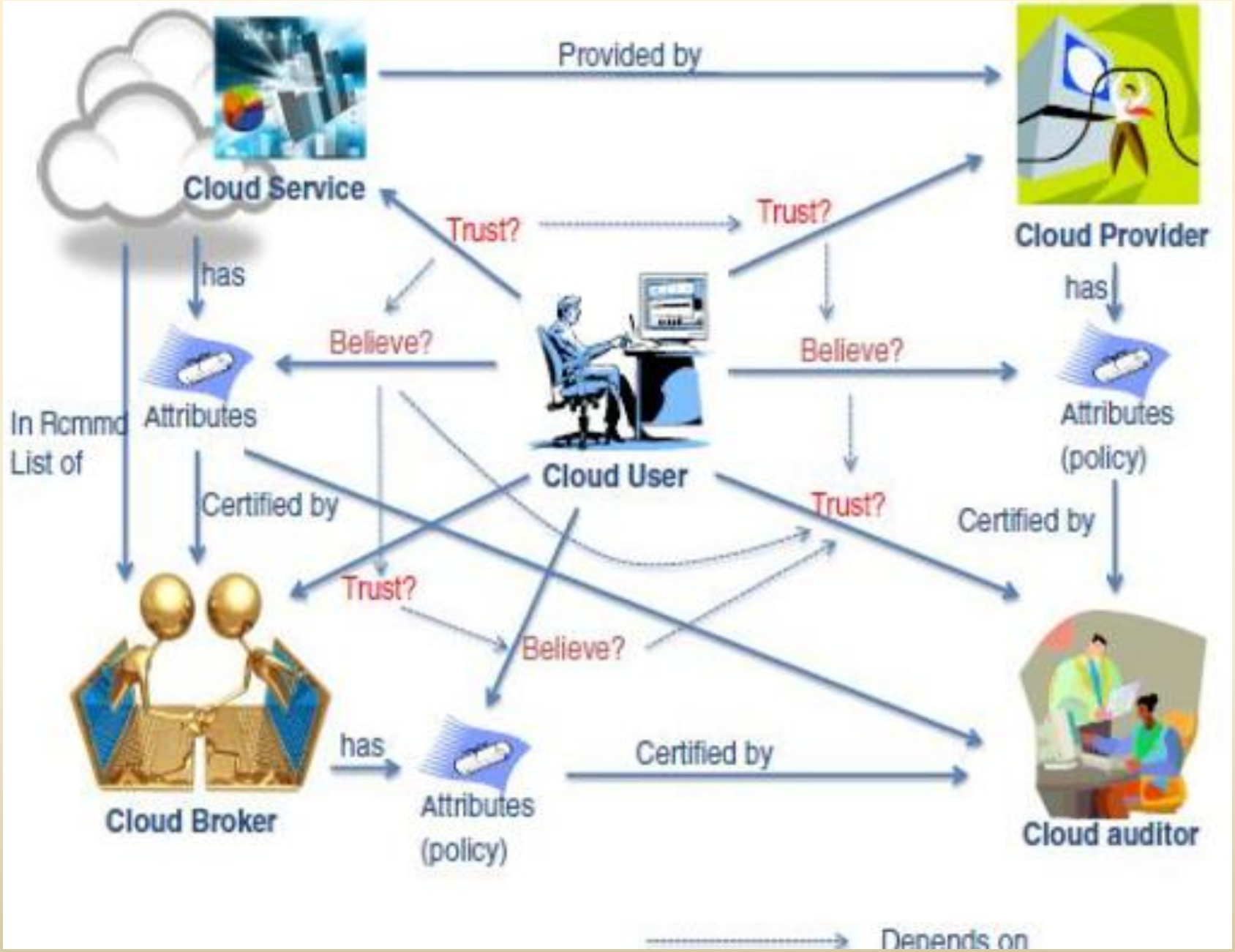
Scope Of Control between Provider and Consumer

Cloud Auditor

=>Security controls, Privacy impact, Performance

Cloud Broker

=> Intermediation, Aggregation, Arbitrage


Provided by
Cloud Service
Cloud Provider
Trust?
Trust?
has
has
Believe?
Believe?
Attributes
Attributes
(policy)
In Rcmmd
List of
Cloud User
Certified by
Certified by
Trust?
Trust?
Believe?
has
Certified by
Cloud Broker
Attributes
(policy)
Cloud auditor
Depends on

THANK YOU

CLOUD COMPUTING
UNIT II
VIRTUALIZATION
DATA CENTER TECHNOLOGY

How many users and objects?

- Flickr has > 10 billion photos
- Facebook has 2 billion monthly users
- Google is serving > 3.5 billion queries/day on more than 130 trillion pages
- > 5 billion videos/day watched on YouTube
- 300 hours of video are uploaded to YouTube every minute!

How much data?

- Modern applications use massive data:
  - Rendering 'Avatar' movie required >1 petabyte of storage
  - CERN's LHC will produce about 15 petabytes of data per year
  - In 2008, Google processed 20 petabytes per day
  - Dropbox has > 500 petabytes of user data
  - Google now designing for 1 exabyte of storage
  - NSA Utah Data Center is said to have 5 zettabyte (!)
- How much is a zettabyte?
  - 1,000,000,000,000,000,000,000 bytes (10^{21})
  - A stack of 1TB hard disks that is **25,400 km high**

How much Computation?

- No single computer can process that much data
  - Need many computers!
- How many computers do modern services need?
  - Facebook is thought to have more than 60,000 servers
  - 1&1 Internet has over 70,000 servers
  - Akamai has > 95,000 servers in 71 countries
  - Intel has ~100,000 servers in 97 data centers
  - Microsoft has > 1 million servers in 2008
  - Google is thought to have more than 1 million servers, is planning for 10 million (according to Jeff Dean)

Scaling up

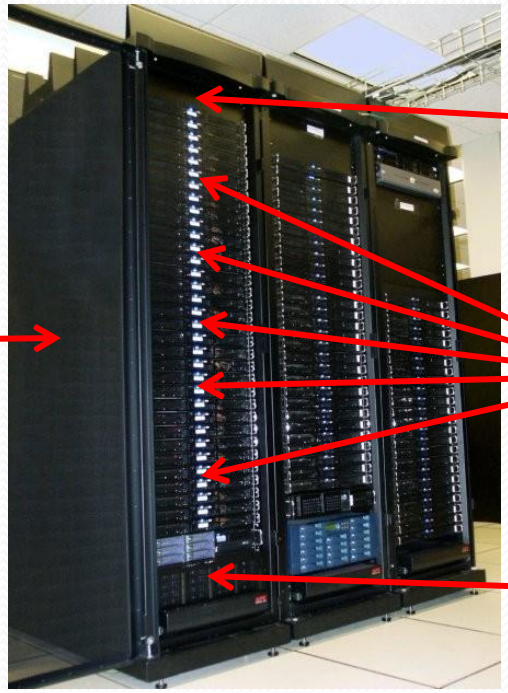
PC

Server

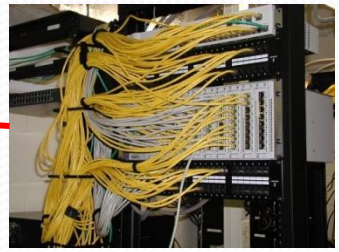
Cluster

- What if one computer is not enough?
  - Buy a bigger (server-class) computer
- What if the biggest computer is not enough?
  - Buy many computers

Clusters



Rack



Network switch (connects nodes with each other and with other racks)

Many nodes/blades (often identical)

Storage device(s)

- Characteristics of a cluster:
  - Many similar machines, close interconnection (same room?)
  - Often special, standardized hardware (racks, blades)
  - Usually owned and used by a single organization

Power and cooling

- Clusters need lots of power
  - Example: 140 Watts per server
  - Rack with 32 servers: 4.5kW (use special power supply!)
  - Most of this power is converted into heat

- Large clusters need massive cooling
  - 4.5kW is about 3 space heaters
  - And that's just one rack!

Scaling up

PC

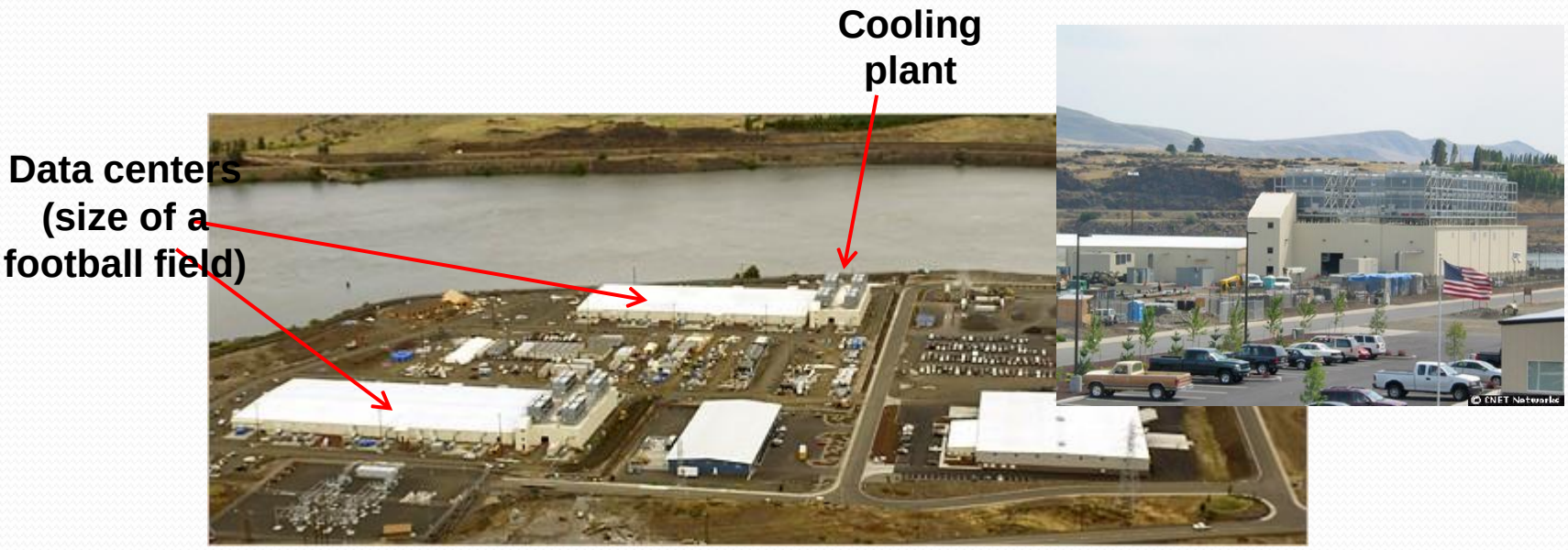
Server

Cluster

Data center

- What if your cluster is too big (hot, power hungry) to fit into your office building?
  - Build a separate building for the cluster
  - Building can have lots of cooling and power
  - Result: Data center

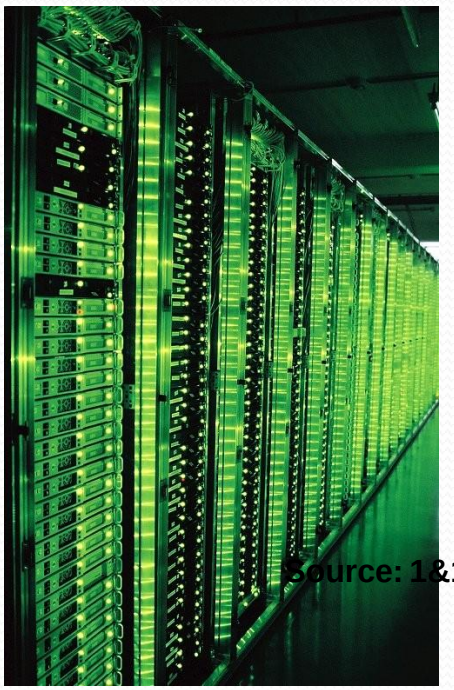
What does a data center look like?



Google data center in The Dalles, Oregon

- A warehouse-sized computer
  - Asingle data center can easily contain 10,000 racks with 100 cores in each rack (1,000,000 cores total)

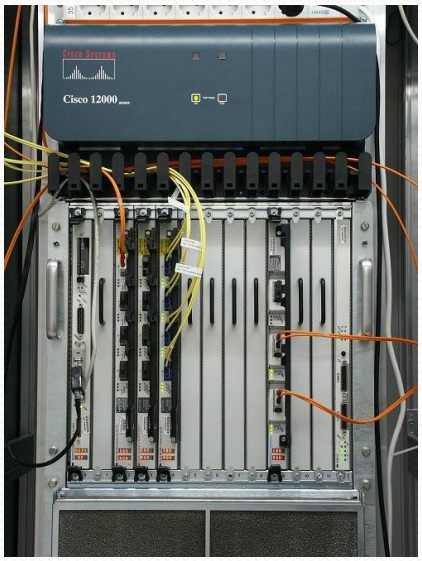
What's in a data center?



Source: 1&1

- Hundreds or thousands of racks

What's in a data center?

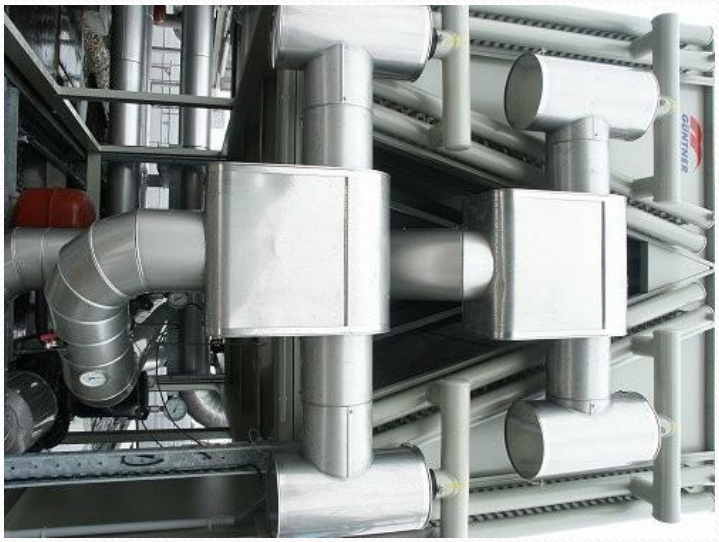


- Massive networking

What's in a data center?

- Emergency power supplies

What's in a data center?



- Massive cooling

Energy matters!

Company	Servers	Electricity	Cost
eBay	16K	~0.6*10^5 MWh	~$3.7M/yr
Akamai	40K	~1.7*10^5 MWh	~$10M/yr
Rackspace	50K	~2*10^5 MWh	~$12M/yr
Microsoft	>200K	>6*10^5 MWh	>$36M/yr
Google	>500K	>6.3*10^5 MWh	>$38M/yr
USA (2006)	10.9M	610*10^5 MWh	$4.5B/yr

- Data centers consume a lot of energy
  - Makes sense to build them near sources of cheap electricity
  - Example: Price per KWh is 3.6ct in Idaho (near hydroelectric power), 10ct in California (long distance transmission), 18ct in Hawaii (must ship fuel)
  - Most of this is converted into heat → Cooling is a big issue!

Scaling up

PC

Server

Cluster

Data center

Network of data centers

- What if even a data center is not big enough?
  - Build additional data centers
  - Where? How many?

Global distribution

- Data centers are often globally distributed
  - Example above: Google data center locations (inferred)
- Why?
  - Need to be close to users (physics!)
  - Cheaper resources
  - Protection against failures

Virtual Machine Hypervisors

Hypervisors

- A **Hypervisor** or virtual machine monitor (**VMM**) is a piece of computer software, firmware or hardware that creates and runs virtual machines. A computer on which a **hypervisor** is running one or more virtual machines is defined as a host machine. Each virtual machine is called a guest machine.

- In virtualization technology, hypervisor is a software program that **manages multiple operating systems** (or multiple instances of the same operating system) on a single computer system. The hypervisor manages the system's processor, memory, and other resources to allocate what each operating system requires. Hypervisors are designed for a particular processor architecture and may also be called **virtualization managers**.

Hypervisor Types

- "Formal Requirements for Virtualizable Third Generation Architectures" Gerald J. Popek and Robert P. Goldberg classified **two types** of hypervisor.

- **Type - 1** : Native or Bare – Metal Hypervisors.
- **Type - 2** : Hosted Hypervisors.

Type - 1 Hypervisors

- These hypervisors run directly on the host's hardware to control the hardware and to manage guest operating systems. For this reason, they are sometimes called bare metal hypervisors. A guest operating system runs as a process on the host.
- The Type 1 hypervisor is often referred to as a hardware virtualization engine.
- Examples include VMware ESXi Server, Microsoft Hyper-V, Citrix/Xen Server.

Type - 1 : In brief

- It works directly on the hardware of the host and can monitor operating systems that run above the hypervisor.
- It is completely **independent** from the Operating System.
- The hypervisor is small as its main **task is sharing and managing hardware resources between different operating systems.**
- A major advantage is that any problems in one virtual machine or guest operating system do not affect the other guest operating systems running on the hypervisor.

Type - 2 Hypervisors

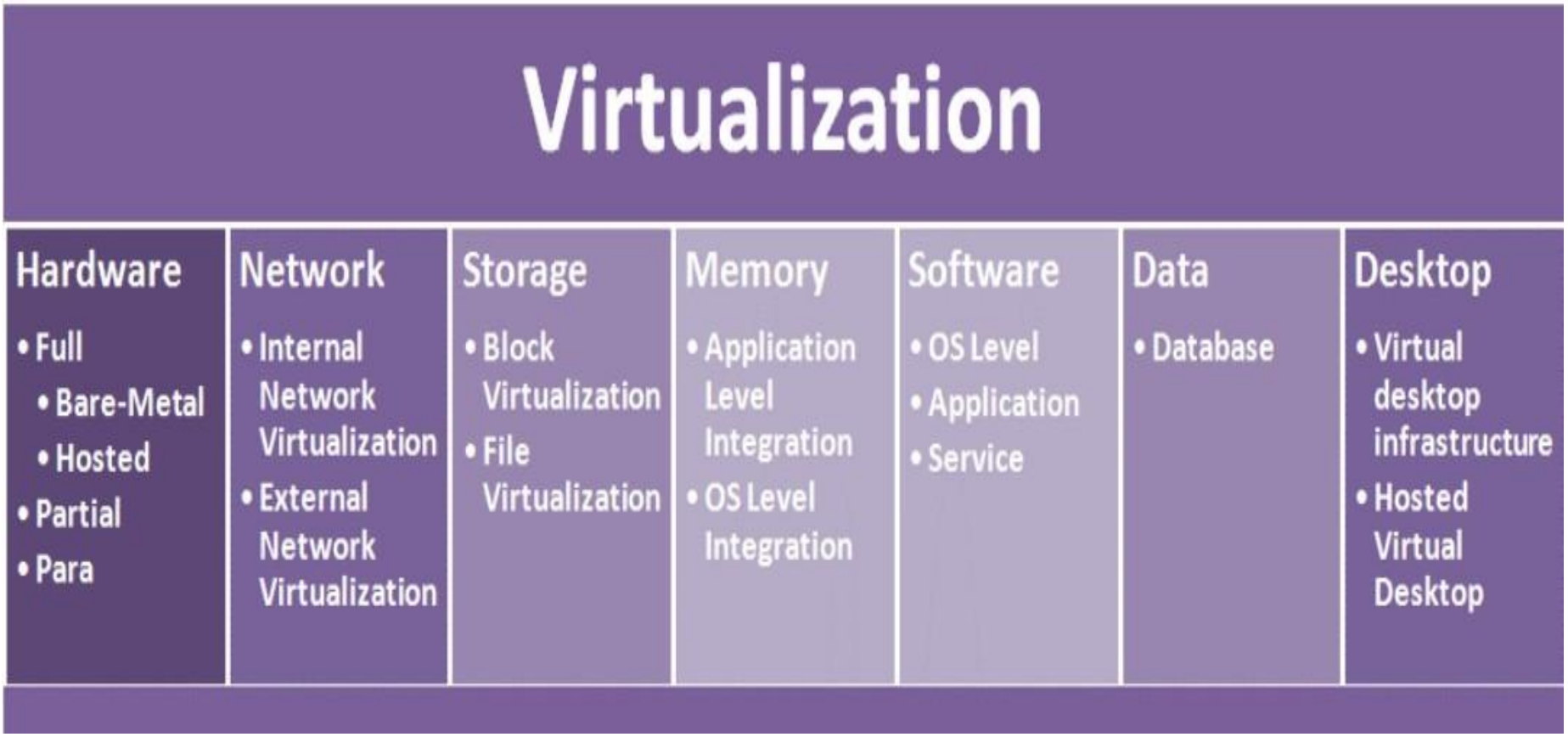
- These hypervisors run on a conventional operating system just as other computer programs do. Type-2 hypervisors abstract guest operating systems from the host operating system.
- Type 2 hypervisors support guest virtual machines by coordinating calls for CPU, memory, disk, network and other resources through the physical host's operating system. This makes it easy for an end user to run a virtual machine on a personal computing device.
- Examples of this type of hypervisor include VMware Fusion, Oracle VM, Parallels and VMware Workstation.

Type - 2 : In brief

- In this case, the hypervisor is installed on an operating system and then supports other operating systems above it.
- It is **completely dependent** on host Operating System for its operations
- While having a base operating system allows better specification of policies, any problems in the base operating system affects the entire system as well even if the hypervisor running above the base OS is secure.

Types of Virtualization

Major Types of



Types of Hardware virtualization

Hardware virtualization is further subdivided into the following types:

- **Full Virtualization** – In it, the complete simulation of the actual hardware takes place to allow software to run an unmodified guest OS.
- **Para Virtualization** – In this type of virtualization, software unmodified runs in modified OS as a separate system.
- **Partial Virtualization** – In this type of hardware virtualization, the software may need modification to run.

Network Virtualization

Internal Network Virtualization:

It refers to the management and monitoring of a computer network as a single managerial entity from a single software-based administrator's console. It is intended to allow network optimization of data transfer rates, scalability,reliability, flexibility, and security. It also automates many network administrative tasks. Network virtualization is specifically useful for networks experiencing a huge, rapid, and unpredictable increase of usage.

External Network Virtualization:

Combine many networks, or parts of networks into a virtual unit. External Network Virtualization involves and actual physical device that caters to your network.This type of virtualization has been around for some time now, a typical example of this would be a CISCO networking switch that provides VLAN (virtual LAN) capabilities through its internal CISCO iOS software.

Storage Virtualization

In this type of virtualization, multiple network storage resources are present as a single storage device for easier and more efficient management of these resources. It provides various advantages as follows:

- Improved storage management in a heterogeneous IT environment
- Easy updates, better availability
- Reduced downtime
- Better storage utilization
- Automated management

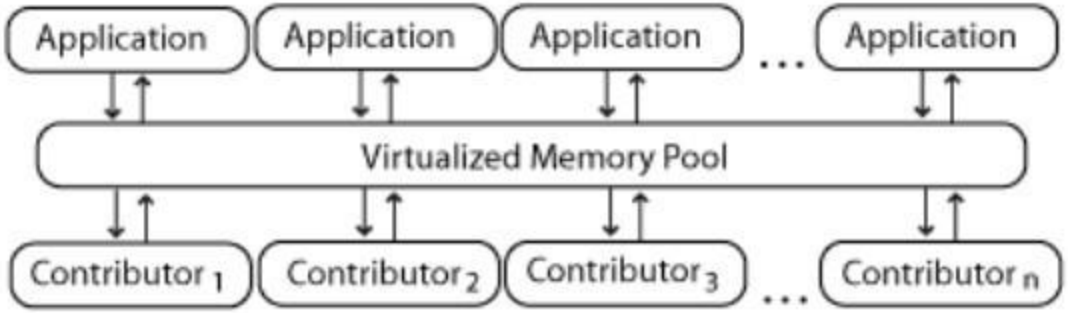
In general, there are two types of storage virtualization:

Block virtualization - It works before the file system exists. It replaces controllers and takes over at the disk level.

File virtualization - The server that uses the storage must have software installed on it in order to enable file-level usage.

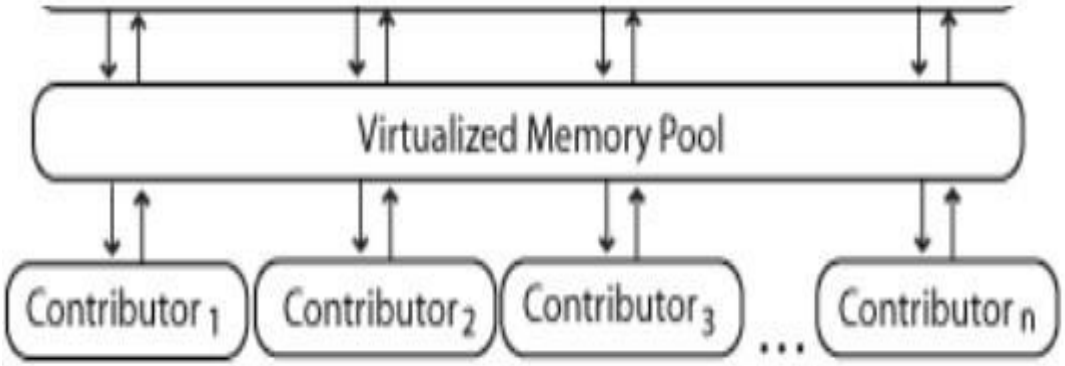
Memory Virtualization

- It introduces a way to decouple memory from the server to provide a shared, distributed or networked function. It enhances performance by providing greater memory capacity without any addition to the main memory. That's why a portion of the disk drive serves as an extension of the main memory.
- Application level integration – Applications running on connected computers directly connect to the memory pool through an API or the file system.



Memory Virtualization…

- Operating System Level Integration – The operating system first connects to the memory pool, and makes that pooled memory available to applications.



Software Virtualization

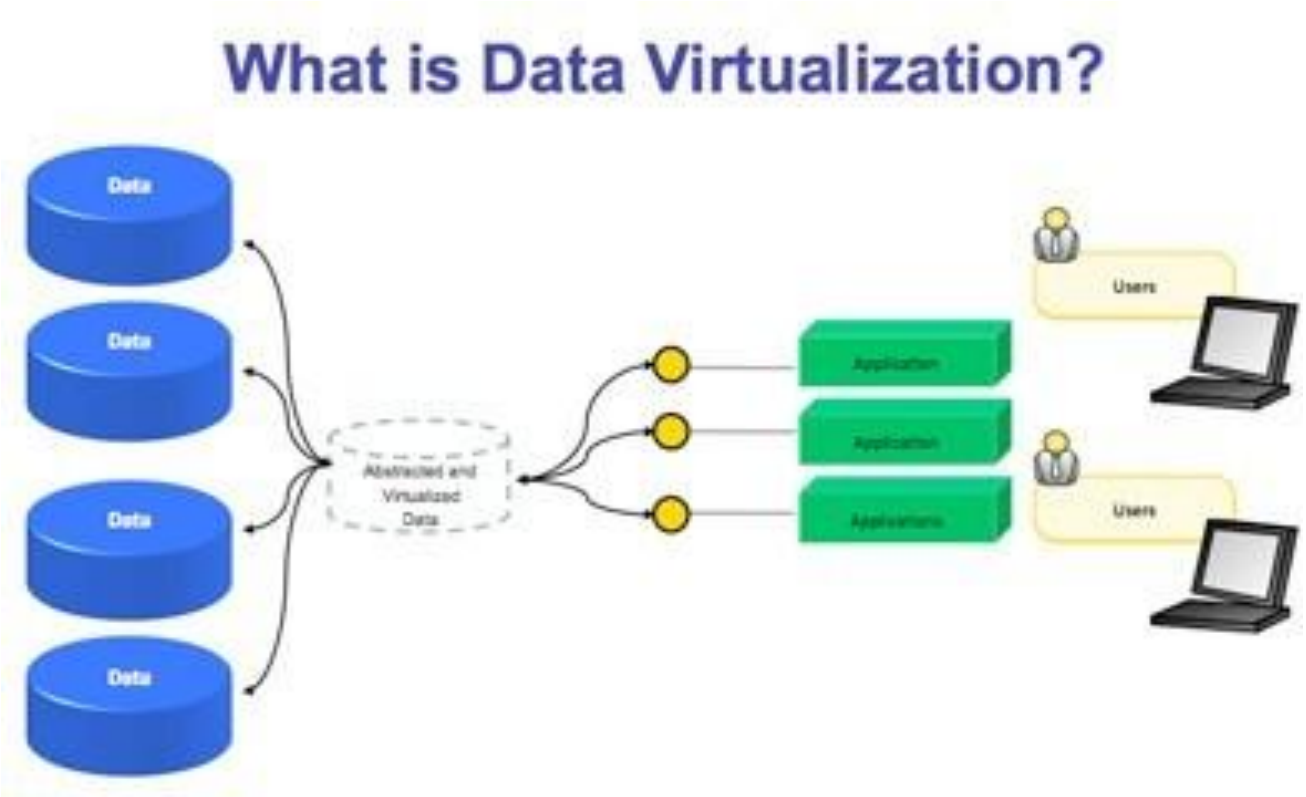
- It provides the ability to the main computer to run and create one or more virtual environments. It is used to enable a complete computer system in order to allow a guest OS to run.
- For instance letting Linux to run as a guest that is natively running a Microsoft Windows OS (or vice versa, running Windows as a guest on Linux)

Types:

- ❖ Operating system
- ❖ Application virtualization
- ❖ Service virtualization

Data Virtualization

Without any technical details, you can easily manipulate data and know how it is formatted or where it is physically located. It decreases the data errors and workload.



Desktop virtualization

It provides the work convenience and security. As one can access remotely, you are able to work from any location and on any PC. It provides a lot of flexibility for employees to work from home or on the go. It also protects confidential data from being lost or stolen by keeping it safe on central servers.

Virtualization and hypervisors

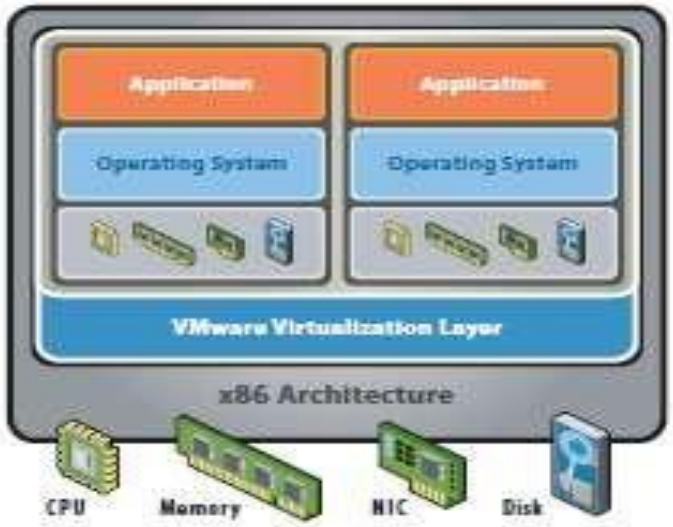
MAJOR PROJECT
MID-EVALUATION

What is a virtualization?

Virtualization allows multiple operating system instances to run concurrently on a single computer; it is a means of separating hardware from a single operating system.

Before Virtualization:

- Single OS image per machine
- Software and hardware tightly coupled
- Running multiple applications on same machine often creates conflict
- Underutilized resources
- Inflexible and costly infrastructure



After Virtualization:

- Hardware-independence of operating system and applications
- Virtual machines can be provisioned to any system
- Can manage OS and application as a single unit by encapsulating them into virtual machines

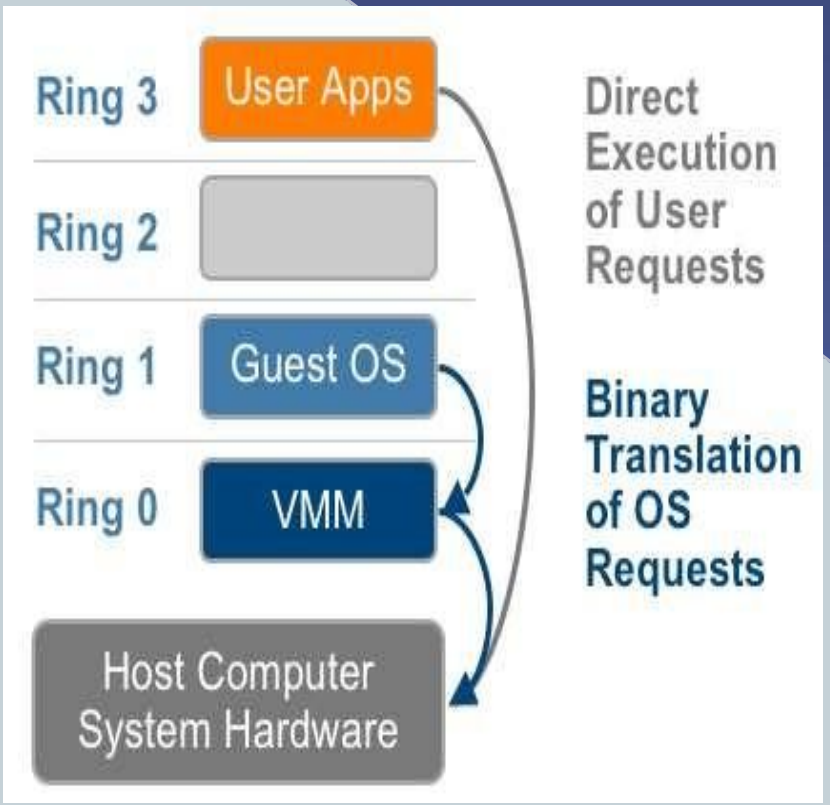
Advantages of virtualization

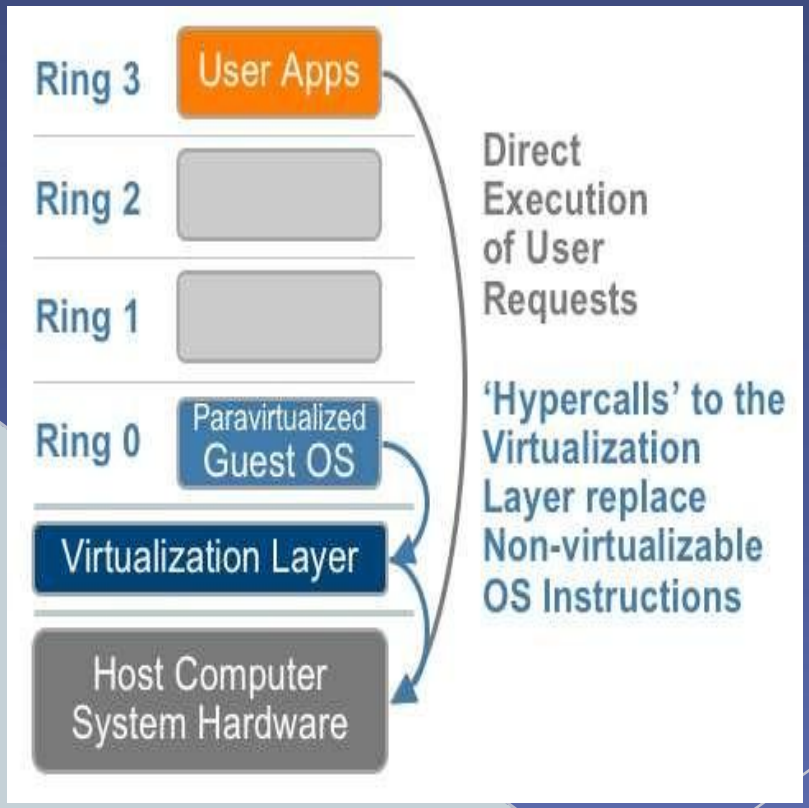
- Coexistence of Operating Systems on the same machine
- Protection
- Operating System research
- Software testing and runtime debugging
- Optimization of hardware utilization
- Job migration
- Virtual storage
- Back Up an Entire Operating System
- AND MANY MORE…..

Types of virtualization

1. CPU virtualization
    1. full virtualization
    2. para-virtualization
    3. hardware assisted virtualization
2. Memory virtualization
3. Device and I/O virtualization

Full vs. paravirtualization

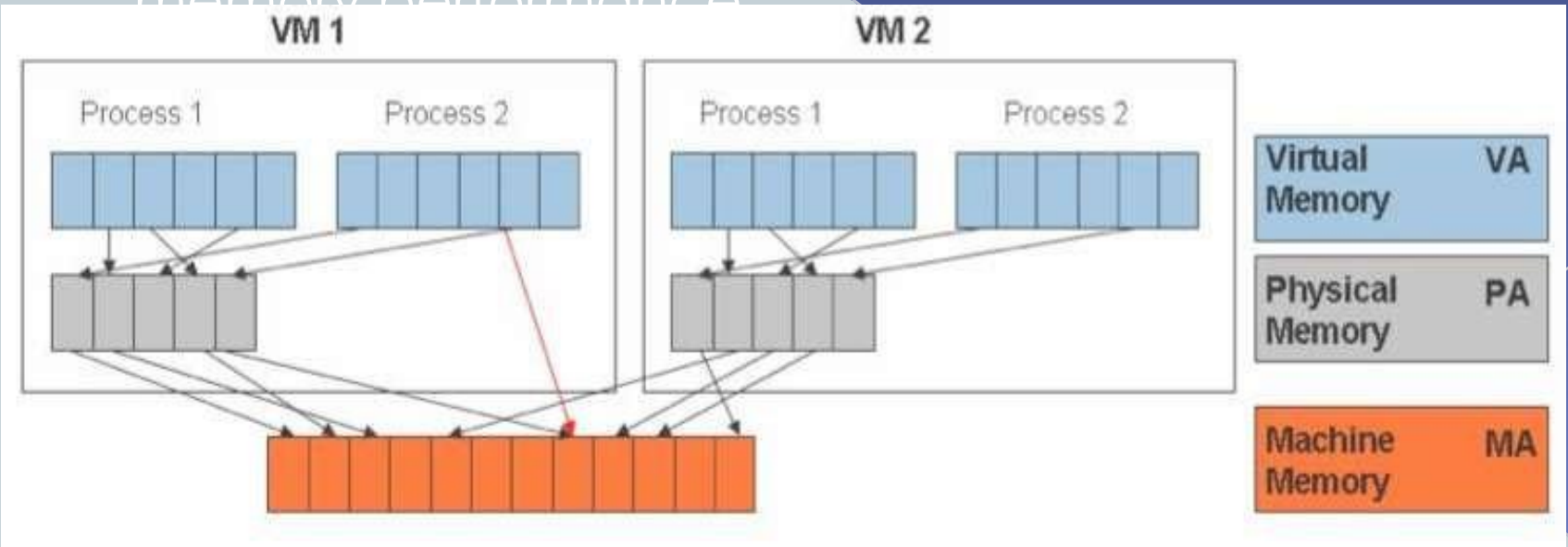




Unlike Full virtualization, Paravirtualization involves modifying the OS kernel to replace nonvirtualizable instructions with hypercalls that communicate directly with the virtualization layer hypervisor.

Memory virtualization

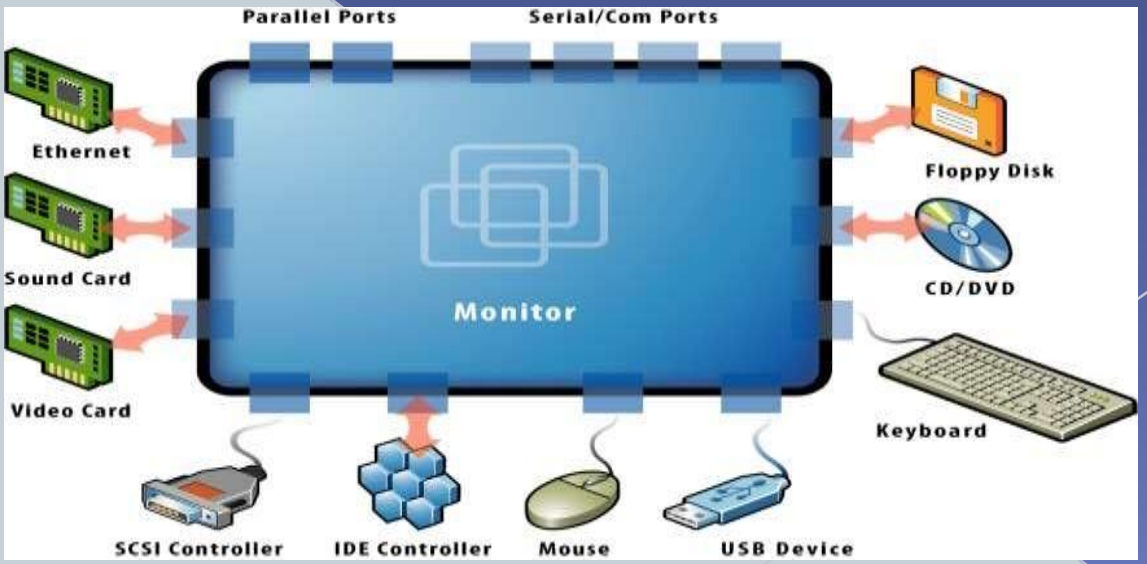
- Beyond CPU virtualization, This involves sharing the physical system memory and dynamically allocating it to virtual machines.
- The operating system keeps mappings of virtual page numbers to physical page numbers stored in page tables. All modern x86 CPUs include a memory management unit (MMU) and a translation lookaside buffer (TLB) to optimize virtual memory performance.



Device and I/O Virtualization

- The final component required beyond CPU and memory virtualization is device and I/O virtualization. This involves managing the routing of I/O requests between virtual devices and the shared physical hardware.

The hypervisor virtualizes the physical hardware and presents each virtual machine with a standardized set of virtual devices as seen in Figure .



What is a hypervisor?

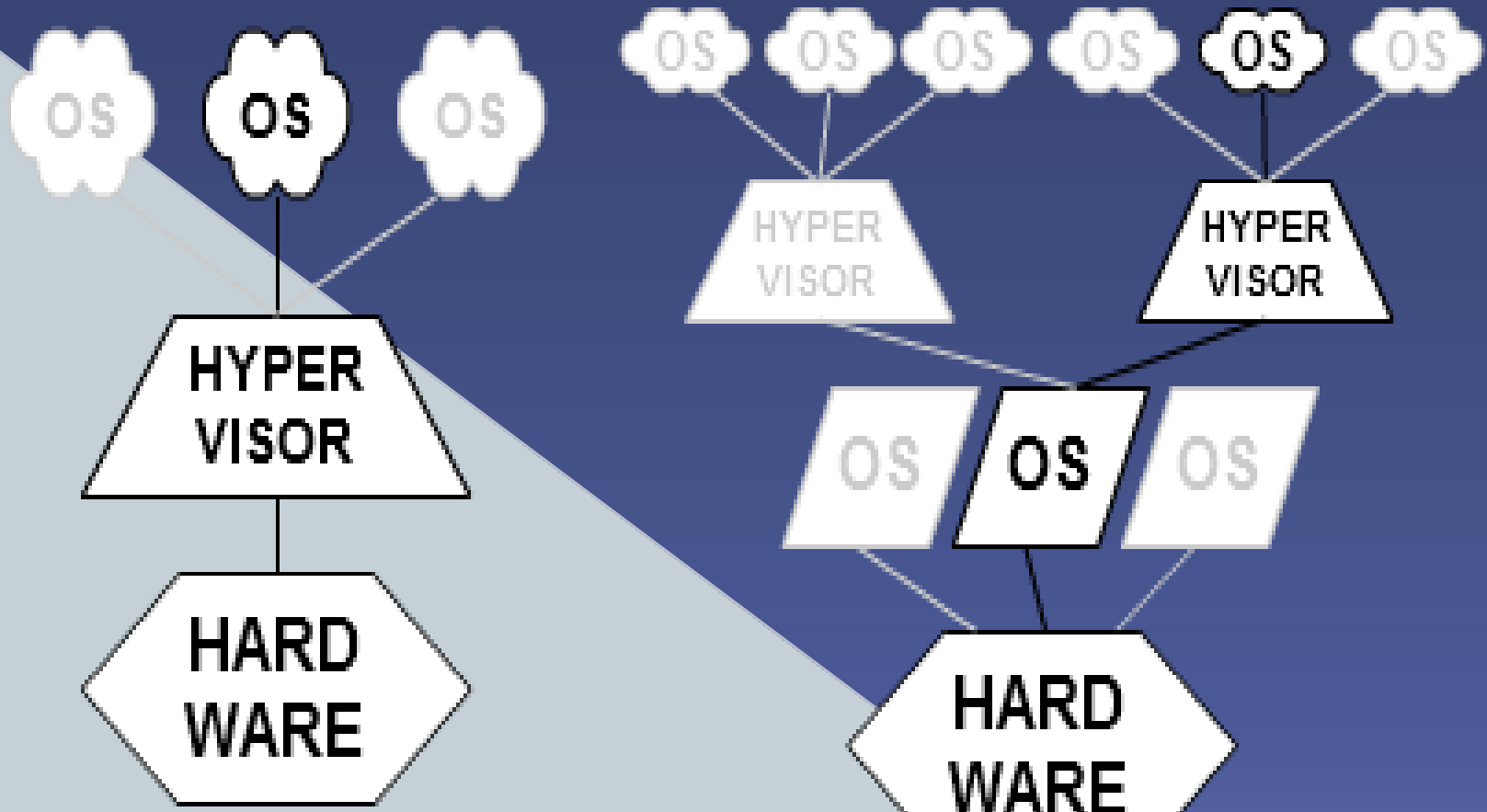
- A **hypervisor** or **virtual machine monitor** (**VMM**) is a piece of computer software, firmware or hardware that creates and runs virtual machines.
- A computer on which a hypervisor is running one or more virtual machines is defined as a *host machine*.
- Each virtual machine is called a *guest machine.*

Types of hypervisor

- **Type 1** hypervisor is installed directly on bare-metal hardware, it doesn't require an additional OS, it is the OS, even it it is a light or minimal OS.
- **EX.** Kvm and Xen
- **Advantages:** System is thin, the hypervisor has direct access to the HW, higher density hardware.
- **Disadvantages:** Really, Really large VMs are not supported, HW should support virtualization technology, costlier and Really bad console interface.

Types of hypervisor

- **Type 2** is more of an application installed on an operating system and not directly on the bare-metal.
- **EX.** VirtualBox and Vmware Workstation
- **Advantages:** Run on a greater array of HW because the underlying Host OS is controlling HW access, Easy user interface, Data can be secured on the desktop .
- **Disadvantages:** Decreased security, Loss of Centralized Management, Lower VM Density, Cannot support as many VMs are the first type.



TYPE 1

native

(bare metal)

TYPE 2

hosted

Top hypervisors

Table 1: Hypervisor Usage

Metrics	Primary	Also Use	Plan To Stop	Evaluating
VMware	52%	21%	1%	8%
Xen (Citrix & Oracle)	18%	32%	7%	31%
KVM (Fedora, Ubuntu, SUSE)	9%	30%	5%	19%
Microsoft Hyper-V	9%	16%	6%	18%
Red Hat (RHEL, RHEV)	6%	29%	5%	11%
Other	6%	14%	8%	12%

- **Primary** — The single main hypervisor used as the standard for virtualizing their servers. The survey allowed only one response in this category.
- **Also Use** — Respondents were asked to report other hypervisors deployed in their datacenter. There was no limit to the number of these responses and many organizations had more than one secondary hypervisor.
- **Plan to Stop** —This was to capture which hypervisors organizations have currently deployed but planned to cease using in the near future.
- **Evaluating** — Aberdeen asked if there were hypervisors that are being evaluated or considered for future datacenter deployment.

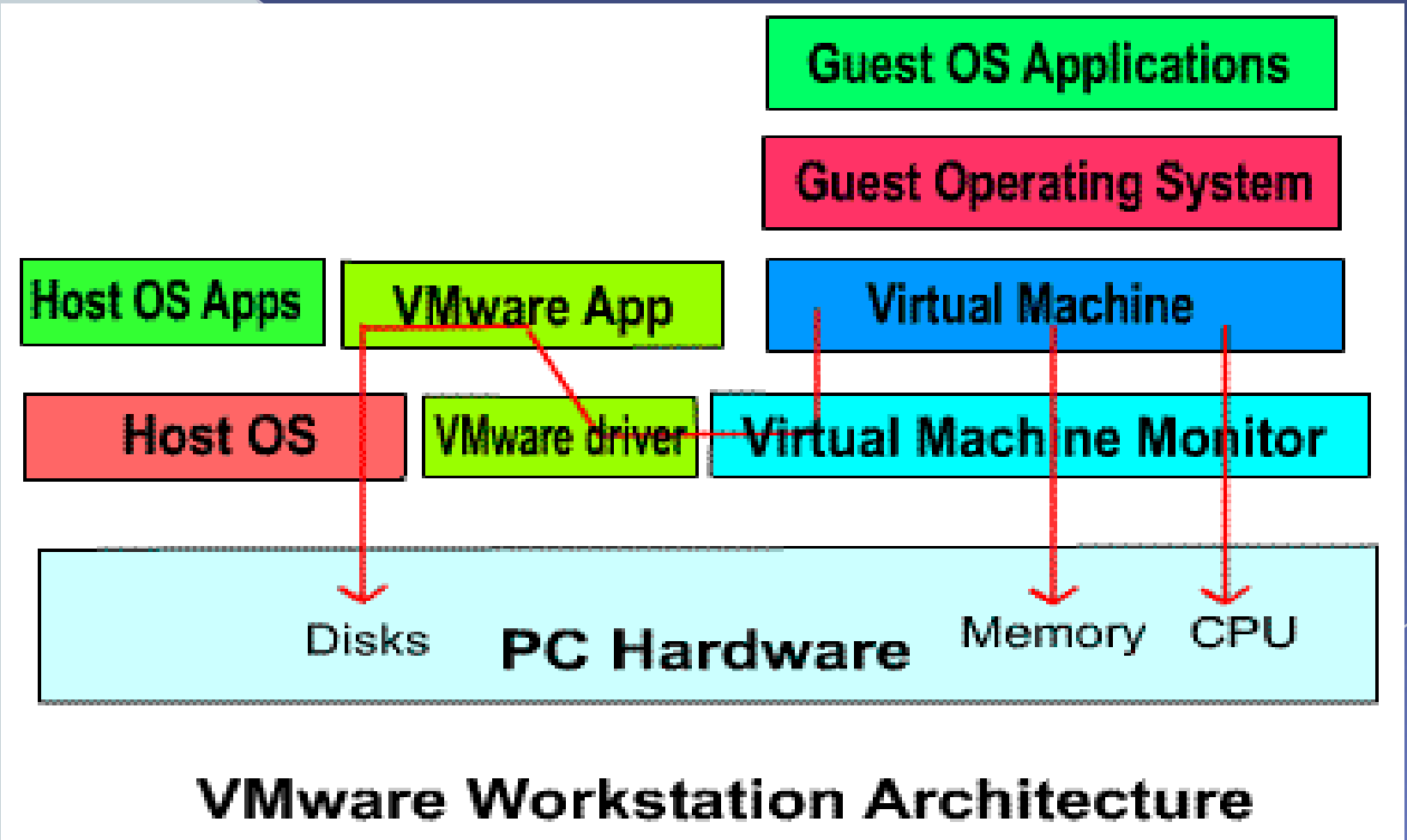
Vmware workstation– features

- Supports bridging existing host network adapters and share physical disk drives and USB devices with a virtual machine.
- It can simulate disk drives. It can mount an existing ISO image file into a virtual optical disc drive so that the virtual machine sees it as a real one. Likewise, virtual hard disk drives are made via .vmdk files
- VMware Workstation can save the state of a virtual machine (a "snapshot") at any instant. These snapshots can later be restored, effectively returning the virtual machine to the saved state.

architecture

- **Infrastructure** : Vmware Virtual machine file system(VMFS), Vmware Virtual Symmetric Multi processing(SMP), Virtual Infrestucture web access, Vmware Vmotion, Vmware Distributed Resource Scheduler
- **Storage And Arrays**:Fiber Channel SAN arrays, iSCSI SAN arrays and NAS arrays are widely-used storage technologies supported by Vmware Infrastructure to meet different data center storage needs
- **Ip Networks**: Each computing server can have multiple gigabit Ethernet network interface cards(NICs) to provide high bandwidth and reliable networking to the entire data center

Vmware Workstation-architecture



Vmware

pros

- Encrypts a virtual machine as a way to keep it from being used by unauthorized personnel
- Each VM can now support up to 16 virtual CPUs and 16 cores per virtual CPU, up to 64GB of RAM
- Can configure up to 20 virtual networks within a single instance of Workstation.
- Availability of hardware-specific features to guests is constrained by the actual machine

cons

- VMware is overpriced.
- Availability, reliability, Complexity issue.
- Reduced application performance
- Hyper-V and XenServer are better alternatives
- Hardware compatibility
- Application compatibility

Virtualbox – features

- **Portability.** VirtualBox runs on a large number of 32-bit and 64-bit **host** operating systems.
- **No hardware virtualization required.**
- **Guest Additions.** After installing the Guest Additions, a virtual machine will support automatic adjustment of video resolutions, seamless windows, accelerated 3D graphics and more. Hence, improving the performance of the guest OS and providing additional integration and communication with the host system.
- **Great hardware support.**
- **Guest multiprocessing-** VirtualBox can present up to 32 virtual CPUs to each virtual machine, irrespective of how many CPU cores are physically present on your host.
- USB device support, Hardware compatibility, Full ACPI support, PXE Network boot, Built-in iSCSI support.
- **Multigeneration branched snapshots.**
- **Clean architecture; unprecedented modularity.**
- **Remote machine display.**
- **Extensible RDP authentication, USB over RDP**

VirtualBox - pros

- Offers built-in GUI-based wizard for cloning a VM.
- Offers built-in VM snapshot, and supports multiple snapshots.
- Supports multiple types of disk image (e.g., vdi, vmdk, vhd, hdd, qed, qcow).
- Supports multiple virtual monitors for a guest VM. Multiple virtual monitors belonging to a VM can be displayed in multiple windows of host machine, or via multiple physical monitors.
- Can be installed on OS X, Windows 7, Windows 2008 Server, Solaris, OpenSolaris, FreeBSD host operating systems.
- More frequent minor version upgrades.
- Comprehensive built-in command-line interface for creating and running VMs (e.g., VBoxManage).

VirtualBox cons

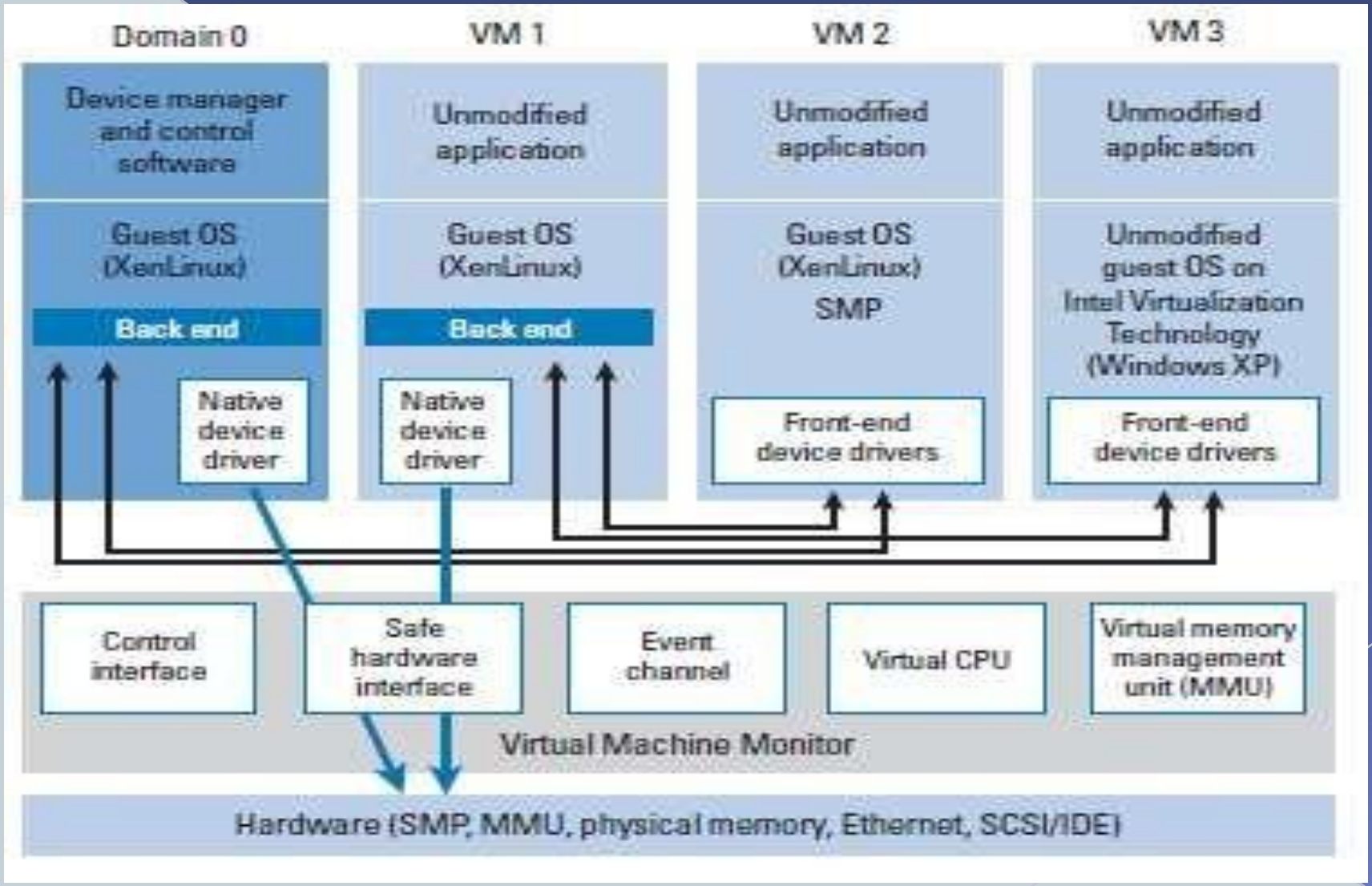
- OVF localization (multiple languages in one OVF file) is not yet supported.
- Cannot access NATed guest VMs from host machine without enabling port forwarding on host machine.
- NATed guest VMs are isolated from one other, and cannot communicate with one another.
- Bridged networking or host-only networking is required if guest VMs need to communicate with one another on the same Layer-2 network.
- Can add up to eight vNICs to a guest VM, while VMware Player can create up to ten vNICs per guest VM. You can configure only four vNICs via VirtualBox GUI. To add more than four vNICs, you need to use VirtualBox CLI.
- Does not support nested hardware-assisted virtualization.
- No support for USB 3.0.

XEN – features

- EFI (extensible Firmware Interface) support for hypervisor. Allows Xen to boot on machines which use EFI rather than a traditional BIOS
- Support up to 4095 Host CPUs for 64 bit h/v (from 256)
- Support for dom0 kernels compressed with xz
- Per-device interrupt remapping (increases scalability)
- Support for PVHVM guest direct physical IRQ injection (improves performance for PCI passthrough to Linux Guests)
- Multiple PCI segment support
- Lots of XSM / Flask fixes (security)
- AMD SVM "DecodeAssist" support (AMD CPU feature that avoids emulation and increases performance)
- Credit Scheduler tuning parameters:
  - sched_ratelimit_us
  - tslice_ms

- AMD OSVW (OS Visible Workarounds): Disables OS workarounds for hardware errata which are not necessary to workaround in guests because it is handled at the host level.
- Early boot time CPU microcode patching. Xen can supplied with the microcode image by the bootloader and load it early rather than relying on the domain 0 kernel to supply it later.
- Improvements to paging and sharing, enabling higher VM density for VDI use-cases
  - Heavily reworked page sharing. This remains a tech preview though due to limited tools support.
- Enhanced memaccess interfaces allowing increased introspection of guest memory by tools.
- Initial support for nested virtualisation. This allows HVM guests access to hardware virtualisation features such that they can run their own hypervisor.

XEN - architecture



XEN

pros

- It is more modernized than KVM, user friendly and can run without hardware support
- Support for multiple hardware platforms
- High security isolation features, independent of operating systems
- Offers paravirtualization and hardware assisted virtualization
- A different, user-friendly interface

cons

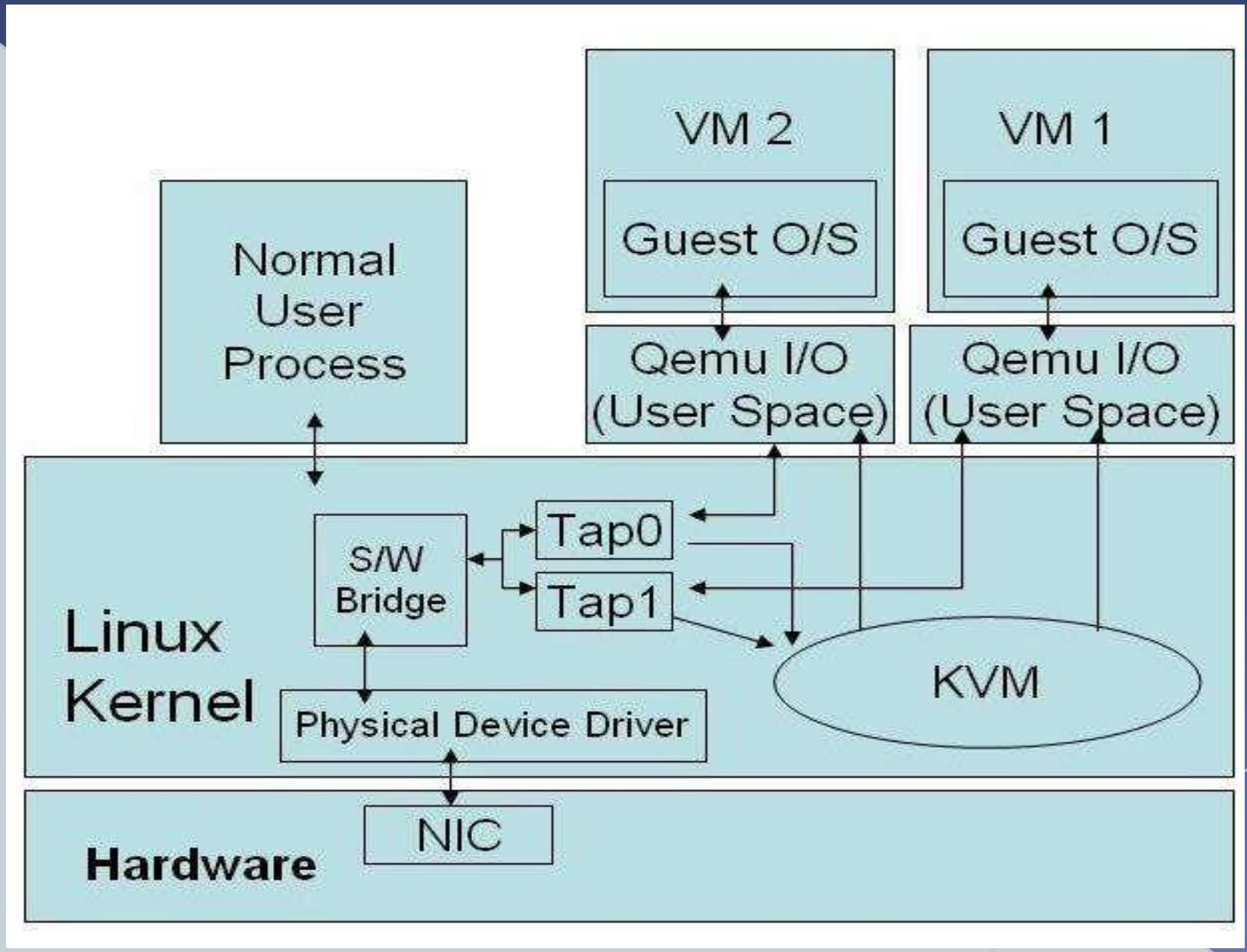
- It is not included in Linux except in recent versions
- It has minimal power management features
- It has a different dom0 structure increasing overload on CPU.
- More complex than other hypervisors

KVM – features

- NPT/EPT support (server boost)
- KSM (share memory with COW)
- Disk image cloning, sharing, snapshot
- Ballooning
- Live migration (nfs as shared storage)
- Save and restore VM
- Virtio paravirtualization
- PCI-passthrough VT-D/IOMMU support

KVM - architecture

- Each virtual CPU appears as a regular Linux process
- Emulation is handle by a modified version of QEMU
- Linux as a VMM
- Resource management
- The KVM control interface
- Emulation of hardware


VM 2
Guest O/S
VM 1
Guest O/S
Normal
User
Process
Qemu I/O
(User Space)
Qemu I/O
(User Space)
Tap0
S/W
Bridge
Tap1
Linux
Kernel
KVM
Physical Device Driver
NIC
Hardware

KVM

pros

- It is free.
- It is a part of Linux
- Powerful CPU virtualization on Intel and AMD platforms, leverages hardware virtualization and Linux kernel, memory management, I/O capabilities
- Real time scheduling
- Powerful GUI
- Powerful command line scripting tools for better productivity
- Leverages security, kernel capabilities and memory managemnt of Linux

cons

- A bit dated
- Difficult to master for novices and those used to GUI based usage
- Very slow when CPU does not support virtualization and when it works in QEMU mode
- Heavy I/O overhead
- Lack of flexibility in device assignment
- Issues in memory and power management

Comparison

1. TECHNICAL COMPARISON
2. BENCHMARKS
3. REAL-WORLD SCENARIOS

TECHNICAL COMPARISON in vmware and virtualbox

Host operating system support(virtualbox is better)

Ease of editing virtual machine's configuration (virtualbox is better)

Usb support (vmware is better)

Range of virtual hard disks (virtualbox is better)

Remote connections (virtualbox is better)

VM cloning (virtualbox)

7. Ease of boot (vmware is better)
8. USB over RDP (virtualbox is better)
9. "Teleportation" migration functionality.(virtualbox is better)
10. Command-line options.(virtualbox is better)
11. Graphics(VMware is better)
12. Ovf support(vmware is better)

TECHNICAL COMPARISON in XEN and KVM

HOST OS - KVM isn't an option on older CPUs made before the virtualization extensions were developed, and it rules out newer CPUs (like Intel's Atom CPUs) that don't include virtualization extensions.

Red Hat drops XEN and anoints KVM

Market of KVM and XEN - If you're going with RHEL over the long haul, bank on KVM. If you're running on Amazon's EC2, you're already using Xen, and so on

Operating system overhead - Xen is not burdened with any operating system overhead that is unrelated to processing a series of guests on a given machine

Security - Xen ensures a high level of security via a variety of methods/features: guest isolation,priviliged access, small code base and operating system seperation

6. **Maturity -** The Xen hypervisor has been available for enterprise deployment since 2004 and is the first open source hypervisor to successfully be deployed by industry leading Linux vendors
7. **Scheduling -**Xen uses its own kernel for thread scheduling and dispatching virtual machines, while KVM, accepted into mainline Linux kernel sources, uses that kernel for these operations
8. **Ease of use -** KVM is generally considered easier to configure and operate given it is just a single module that you load in the Linux kernel.
9. **Memory page sharing -**XEN doesn't implement memory page sharing and KVM does it very efficiently.
10. **Lack of Dom0 in kvm -**KVM introduces many performance benefits, such as less I/O latency due to lack of Dom0
11. **I/O and network operations –**

Kvm- VM -> Virtio -> CentOS with KVM

XEN- VM -> PV-OPS Driver -> Dom0 -> Xen