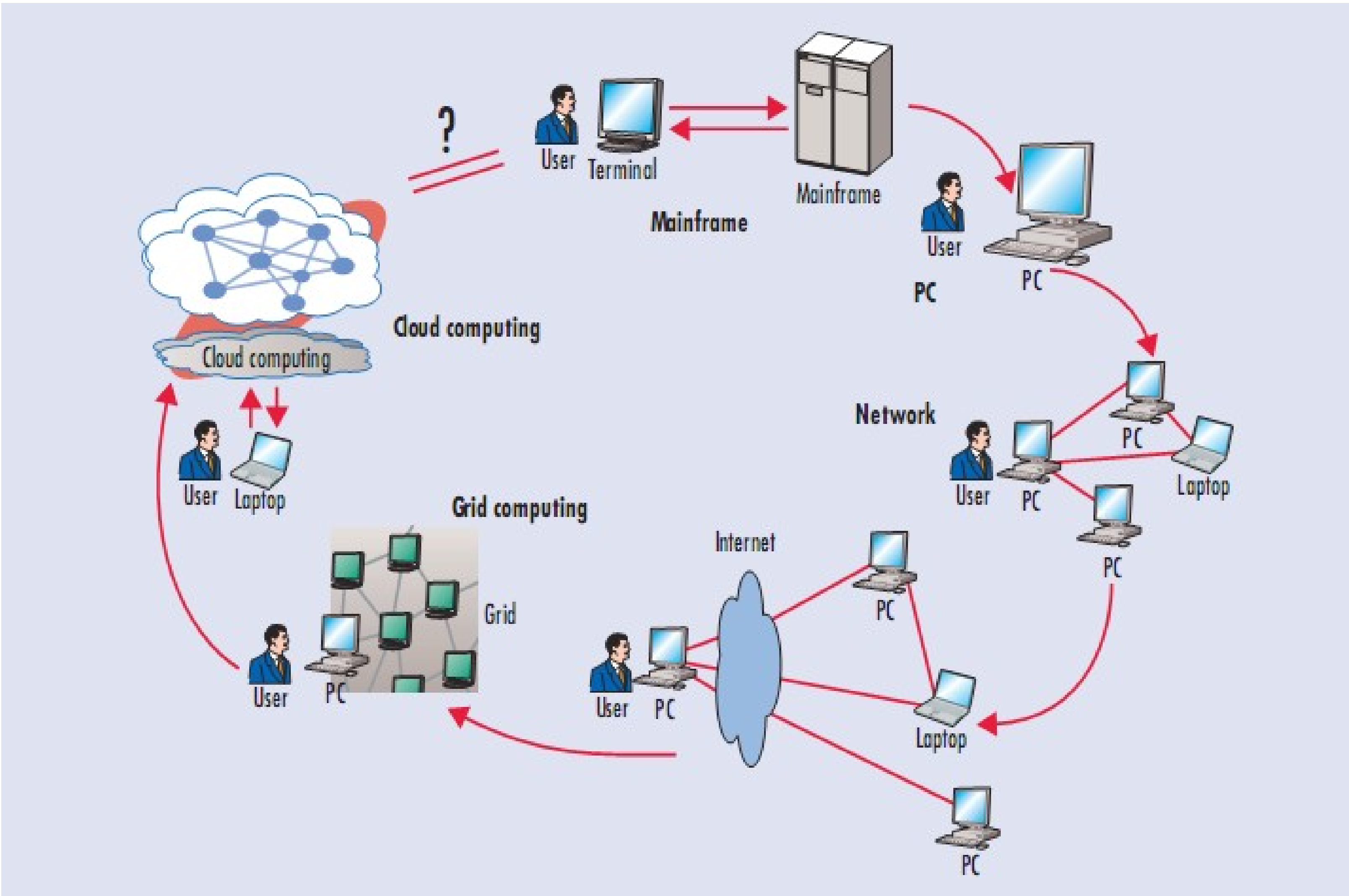
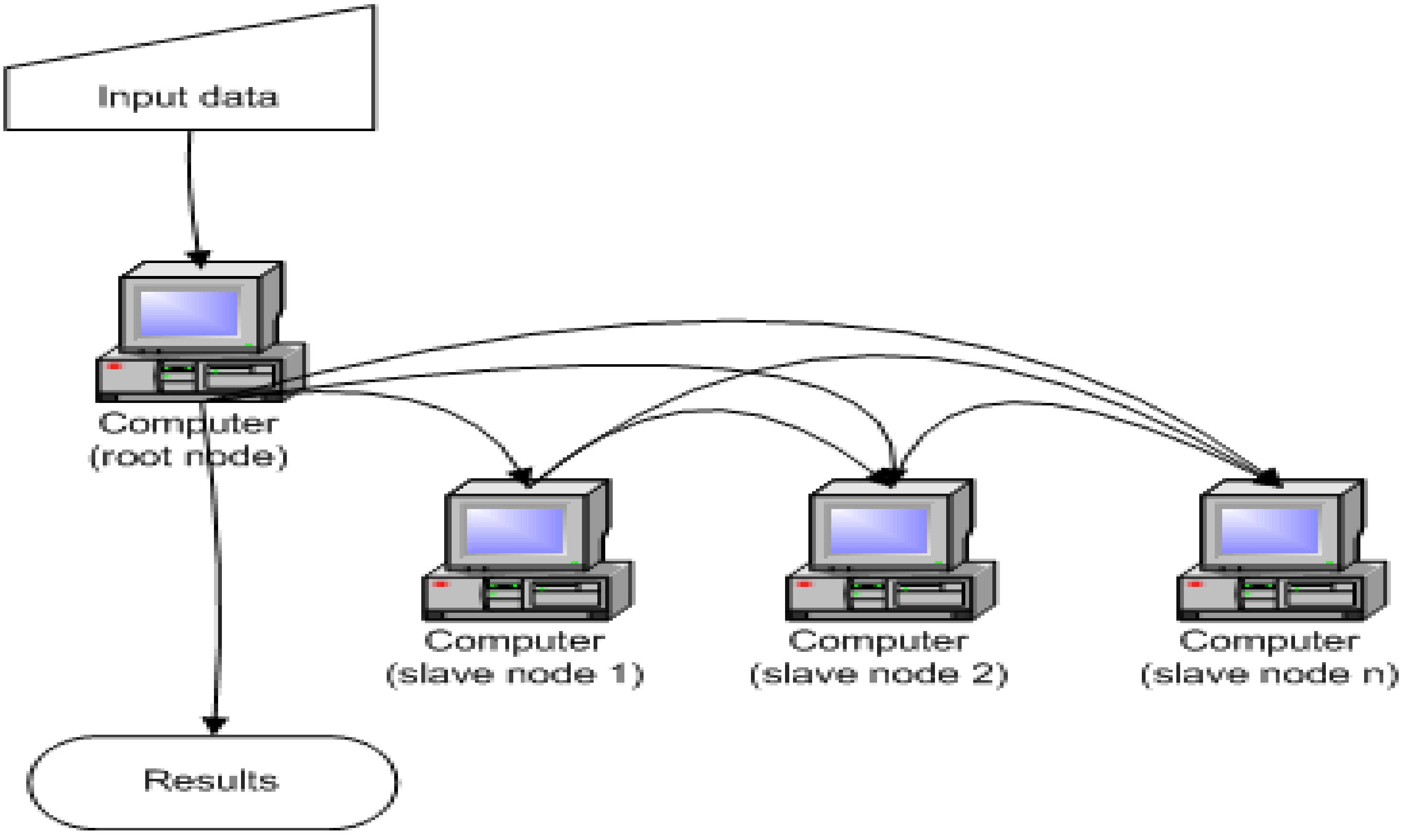
Computing Paradigm Shift



Computing Paradigm Shift

- Mainframe Computers
- Mini Computers
- Personal Computing
- Networked Computing
- Internet and Intranet
- Cluster Computing
- Grid Computing
- Cloud Computing

Cluster Computing



Cluster Computing

- A computer **cluster is a group of computers** that work together closely so that in many respects it can be viewed as though it were a single computer.

- Clusters are commonly connected through **fast local area networks.**

- Clusters are usually deployed to **improve speed and/or reliability** over that provided by a single computer, while typically being much more cost effective than single computer the of comparable speed or reliability .

Cluster Computing

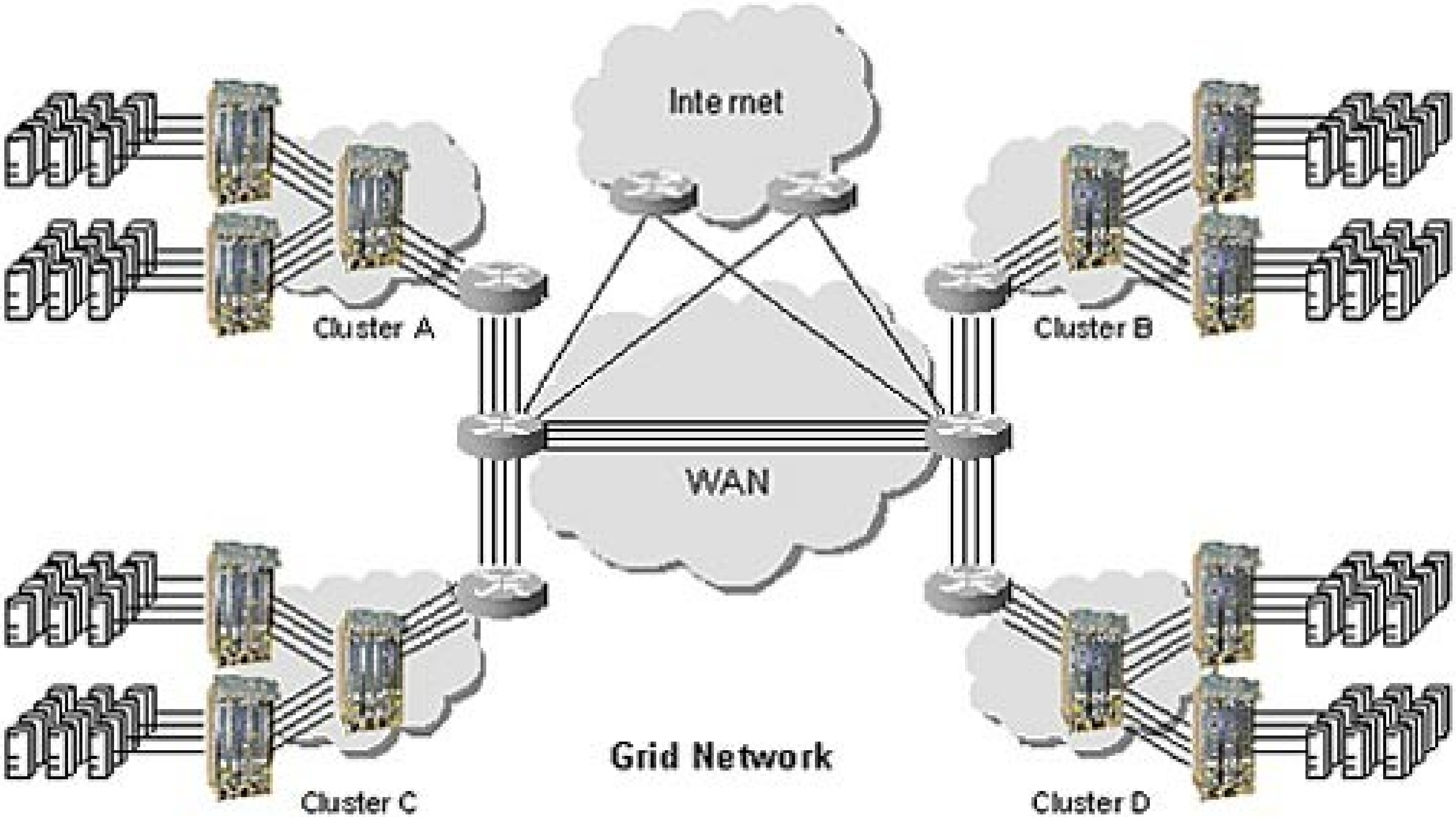
- In cluster computing **each node within a cluster is an independent system**, with its own operating system, private memory, and, in some cases, its own file system. Because the processors on one node cannot directly access the memory on the other nodes, programs or software run on clusters usually employ a procedure called "message passing" to get data and execution code from one node to another.

- Clusters have evolved to support applications ranging from **ecommerce to high performance database applications.**

Advantages of Cluster

- Cheaper to build than a mainframe supercomputer
- Different sizes of clusters
- Scalable – can grow a cluster by adding more PCs

Grid Computing



Grid Computing

- Grid computing involves connecting geographically remote computers into a single network to create a virtual supercomputer by combining the computational power of all computers on grid.

- COMPUTATIONAL GRIDS

  Homogeneous

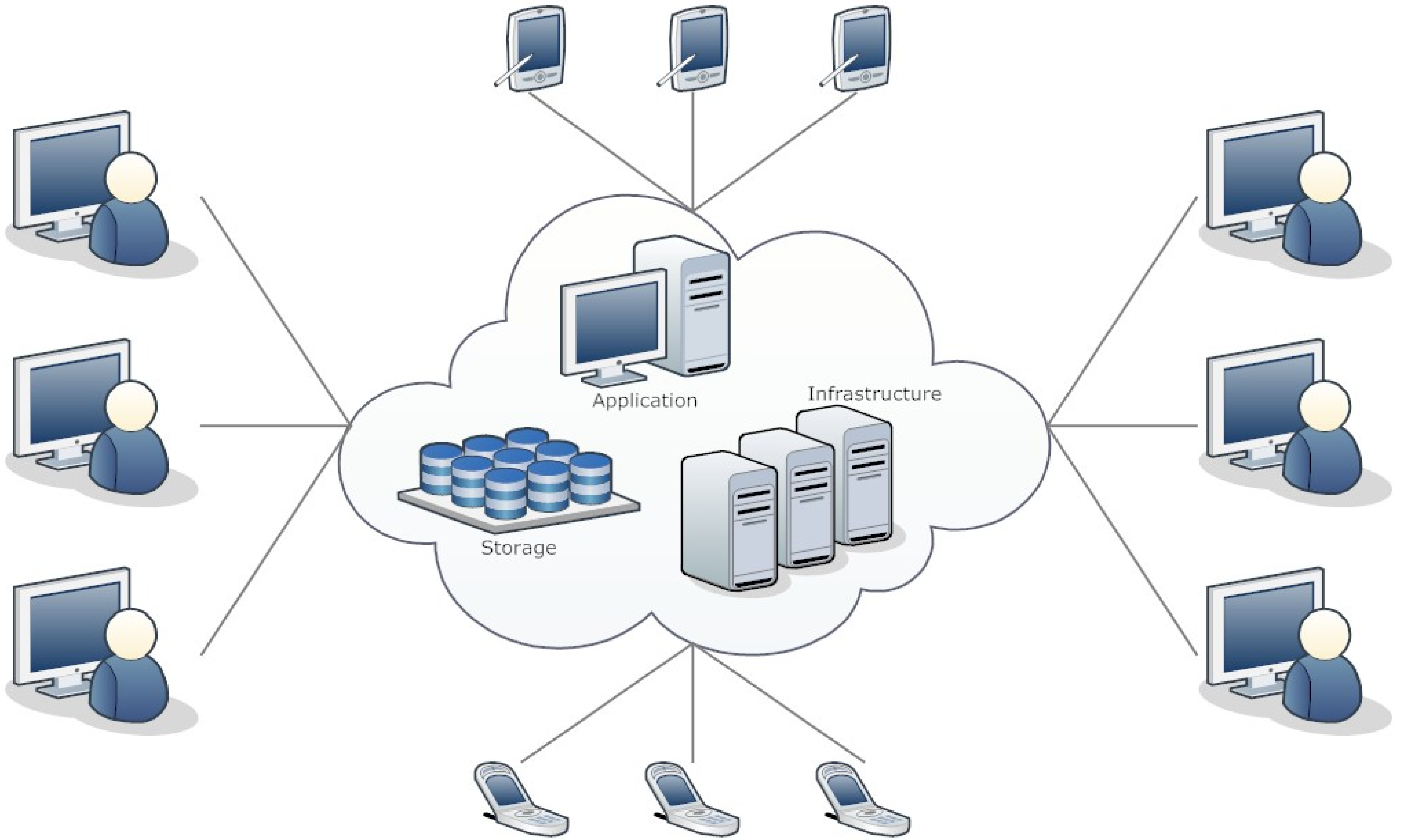
  Heterogeneous

Grid Computing

- A network of geographically distributed resources including computers, peripherals, switches, instruments, and data.

- Resources may be owned by diverse organizations

Cloud Computing



Cloud Computing

- A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and **virtualized computers** that are dynamically provisioned and presented as one or more unified computing resource based on service level agreements established through negotiation between service provider and consumers

Comparison

Characteristics	Clusters	Grids	Clouds
Population	Commodity Computers	High End Computers	Commodity Computers and High End Servers
Size	100s	1000s	100s to 1000s
Node Operating system	One of the standard OS (Linux or windows)	Any Standard OS (dominated by Unix)	A hypervisor (VM) on which multiple OSs run
Ownership	Single	Multiple	Single
Interconnection	Dedicated, high end with low latency and high bandwidth	Mostly internet with high latency and low bandwidth	Dedicated, high end with low latency and high bandwidth

What is big data?

- "Every day, we create 2.5 quintillion bytes of data — so much that 90% of the data in the world today has been created in the last two years alone. This data comes from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records, and cell phone GPS signals to name a few.

This data is "big data."

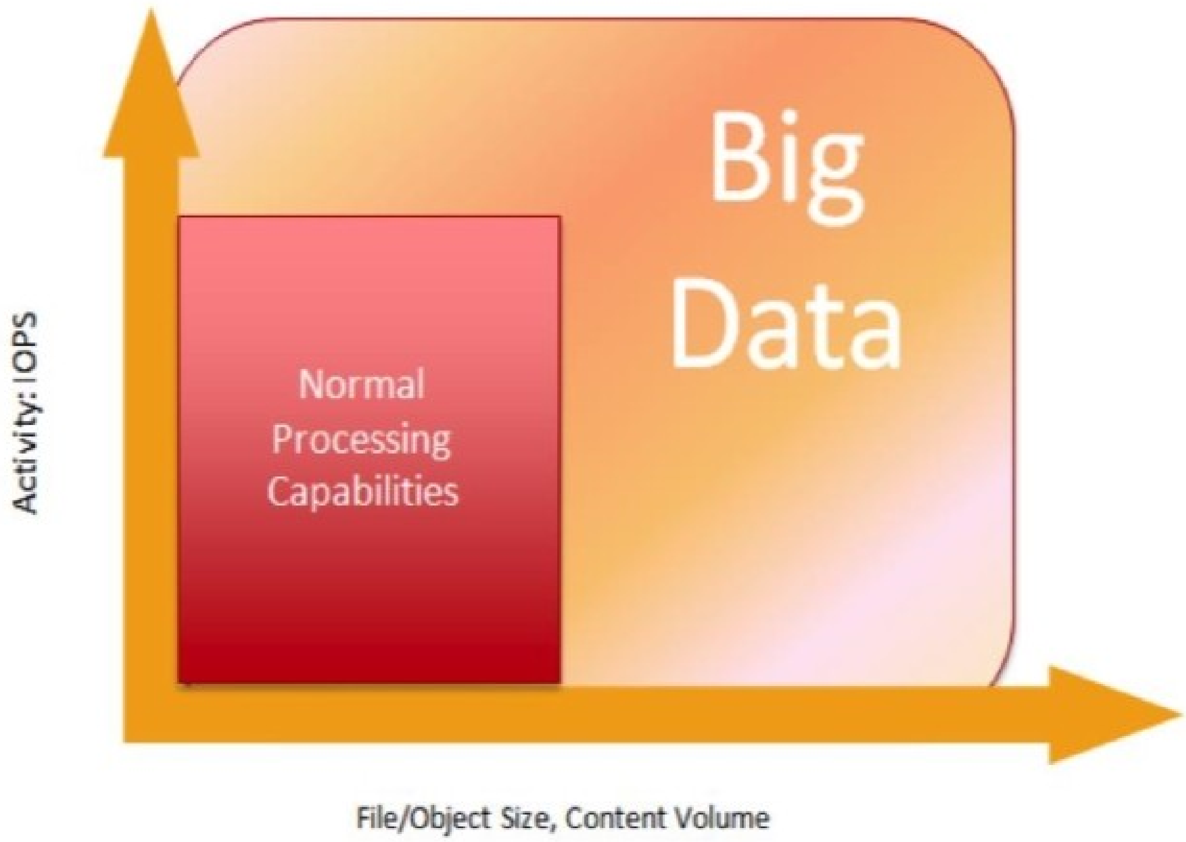
What Is Big Data?

- There is not a consensus as to how to define big data

"Big data exceeds the reach of commonly used hardware environments and software tools to capture, manage, and process it with in a tolerable elapsed time for its user population." *- Teradata Magazine article, 2011*

"Big data refers to data sets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze." *- The McKinsey Global Institute, 2011*

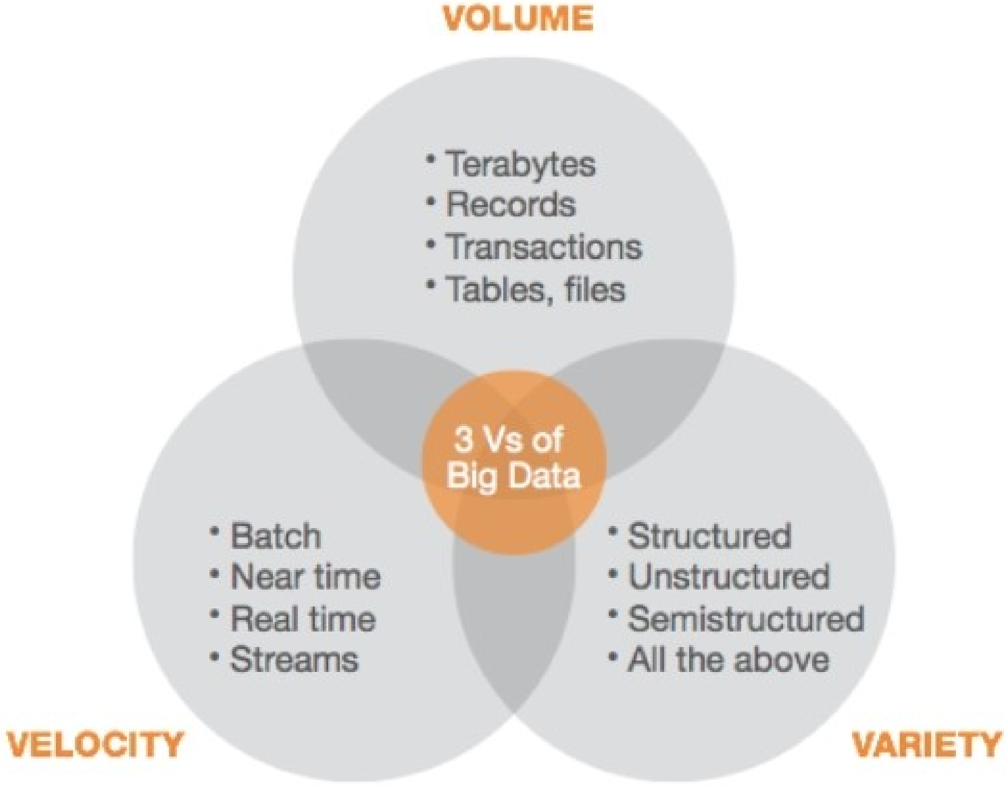
What Is Big Data?



IOPS(Input/Output Operations Per Second)

3 Vs of Big Data

- The "BIG" in big data isn't just about volume



Big data spans three dimensions: Volume, Velocity and Variety

- **Volume:** Enterprises are awash with ever-growing data of all types, easily amassing terabytes—even petabytes—of information.
  - Turn 12 terabytes of Tweets created each day into improved product sentiment analysis
  - Convert 350 billion annual meter readings to better predict power consumption

- **Velocity:** Sometimes 2 minutes is too late. For time-sensitive processes such as catching fraud, big data must be used as it streams into your enterprise in order to maximize its value.
  - Scrutinize 5 million trade events created each day to identify potential fraud
  - Analyze 500 million daily call detail records in real-time to predict customer churn faster

Big data spans three dimensions: Volume, Velocity and Variety

- **Variety:** Big data is any type of data - structured and unstructured data such as text, sensor data, audio, video, click streams, log files and more. New insights are found when analyzing these data types together.
  - Monitor 100’s of live video feeds from surveillance cameras to target points of interest
  - Exploit the 80% data growth in images, video and documents to improve customer satisfaction

Finally….

`Big- Data' is similar to 'Small-data' but bigger

.. But having data bigger it requires different approaches:

Techniques, tools, architecture

… with an aim to solve new problems

Or old problems in a better way

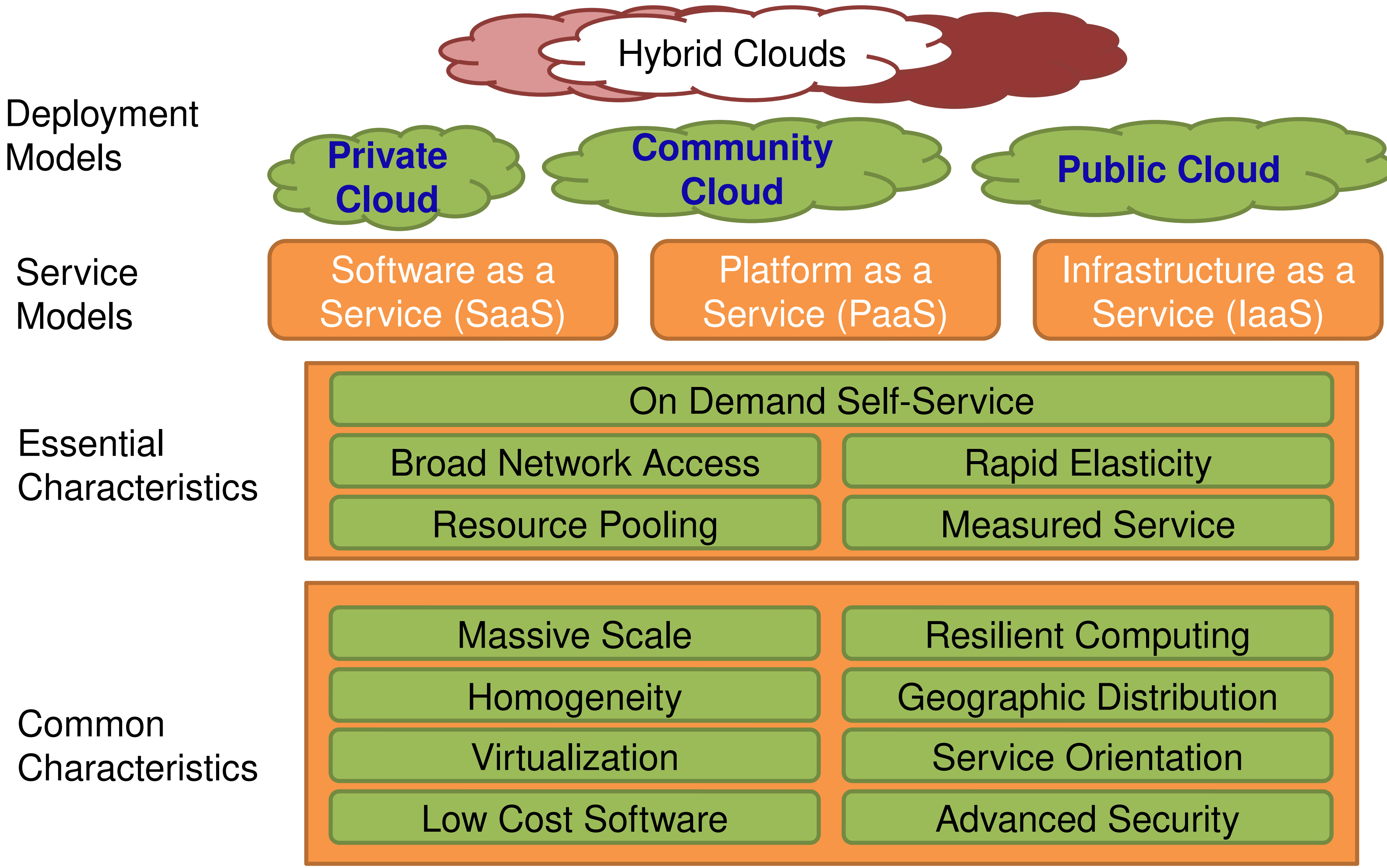
The NIST Model

A Working Definition of Cloud Computing

- Cloud computing is a model for enabling 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.

- This cloud model promotes availability and is composed of five essential **characteristics,** three **service models**, and four **deployment models**.

The NIST Cloud Definition Framework



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Deployment Models

A deployment model defines the purpose of the cloud and the nature of how the cloud is located.

The NIST definition for the four deployment models is as follows:

- **Public cloud**: The public cloud infrastructure is available for public use alternatively for a large industry group and is owned by an organization selling cloud services.

- **Private cloud**: The private cloud infrastructure is operated for the exclusive use of an organization. The cloud may be managed by that organization or a third party. Private clouds may be either on- or off-premises.

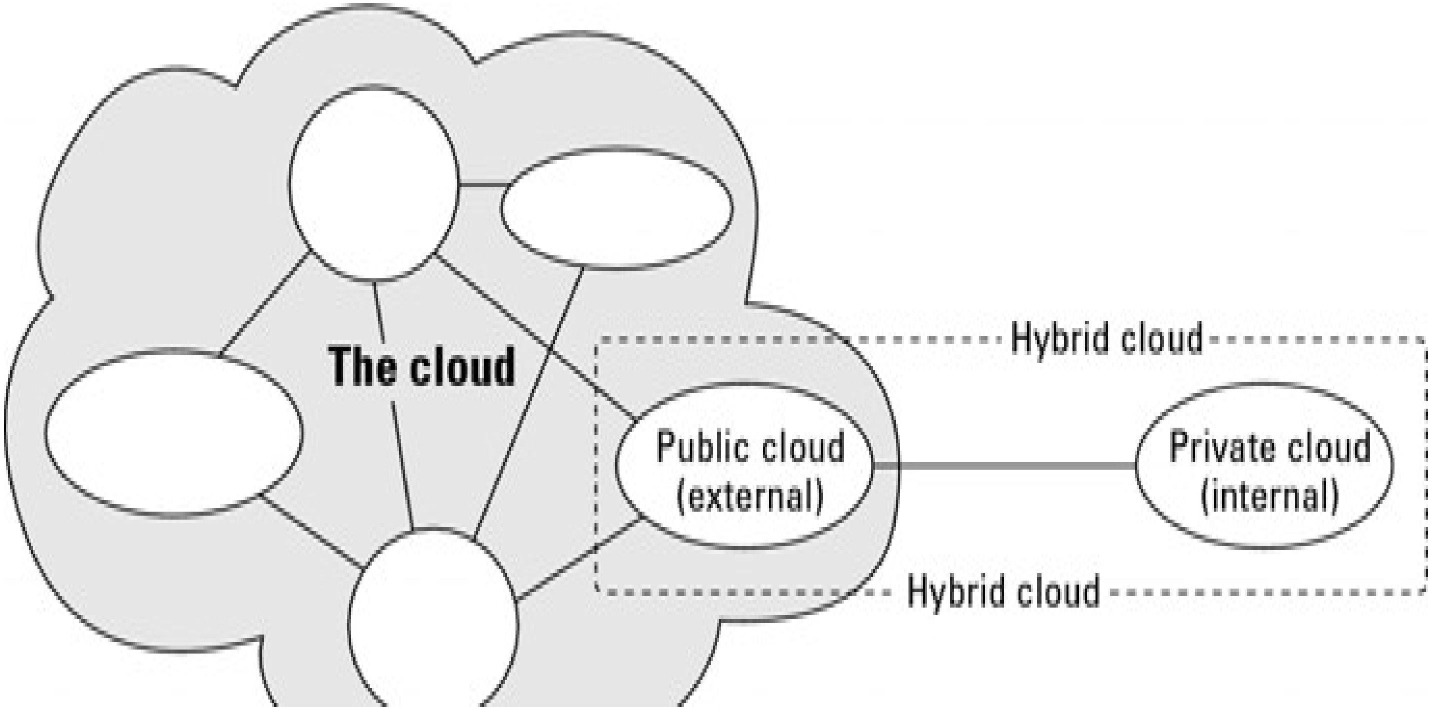
Deployment Models

- **Hybrid cloud**: A hybrid cloud combines multiple clouds (private, community of public) where those clouds retain their unique identities, but are bound together as a unit. A hybrid cloud may offer standardized or proprietary access to data and applications, as well as application portability.

- **Community cloud**: A community cloud is one where the cloud has been organized to serve a common function or purpose.

It may be for one organization or for several organizations, but they share common concerns such as their mission, policies, security, regulatory compliance needs, and so on. A community cloud may be managed by the constituent organization(s) or by a third party.

Deployment Models



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Service Models

In the deployment model, different cloud types are an expression of the manner in which infrastructure is deployed. One can think of the cloud as the boundary between where a client's network, management, and responsibilities ends and the cloud service provider's begins. As cloud computing has developed, different vendors offer clouds that have different services associated with them. The portfolio of services offered adds another set of definitions called the service model.

Three service types have been universally accepted:

Service Models

- **Infrastructure as a Service**:
  IaaS provides virtual machines, virtual storage, virtual infrastructure, and other hardware assets as resources that clients can provision. The IaaS service provider manages all the infrastructure, while the client is responsible for all other aspects of the deployment. This can include the operating system, applications, and user interactions with the system.

Service Models

- **Platform as a Service**:

  PaaS provides virtual machines, operating systems, applications, services, development frameworks, transactions, and control structures. The client can deploy its applications on the cloud infrastructure or use applications that were programmed using languages and tools that are supported by the PaaS service provider. The service provider manages the cloud infrastructure, the operating systems, and the enabling software. The client is responsible for installing and managing the application that it is deploying.

Service Models

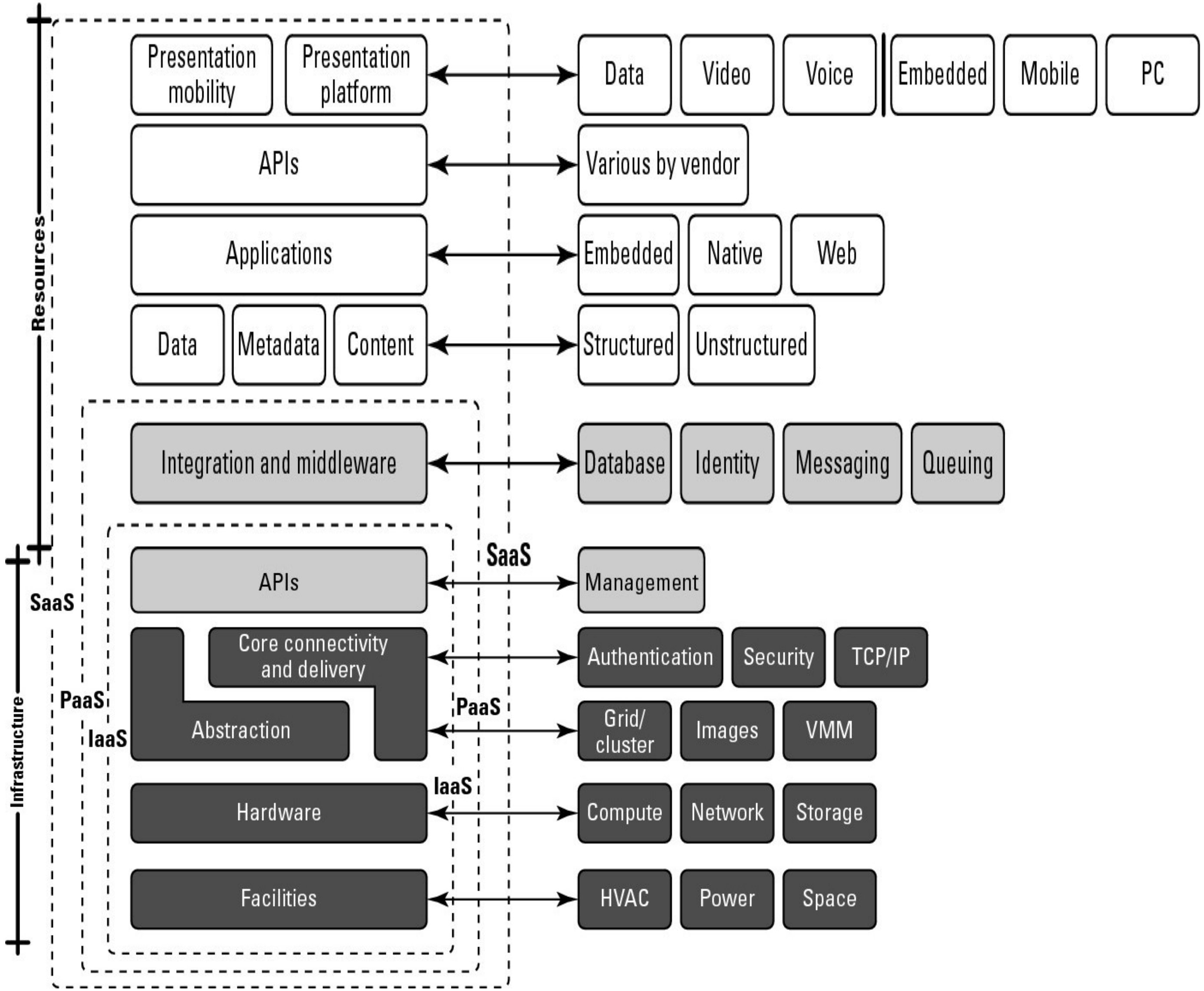
- **Software as a Service**:

  SaaS is a complete operating environment with applications, management, and the user interface. In the SaaS model, the application is provided to the client through a thin client interface (a browser, usually), and the customer's responsibility begins and ends with entering and managing its data and user interaction. Everything from the application down to the infrastructure is the vendor's responsibility.

Service Models

The three different service models taken together have come to be known as the SPI model of cloud computing. It is useful to think of cloud computing's service models in terms of a hardware/software stack. One such representation called the Cloud Reference Model is shown in Figure . At the bottom of the stack is the hardware or infrastructure that comprises the network. As you move upward in the stack, each service model inherits the capabilities of the service model beneath it. IaaS has the least levels of integrated functionality and the lowest levels of integration, and SaaS has the most.

The Cloud Reference Model



Service Models

Examples of IaaS service providers include:

- Amazon Elastic Compute Cloud (EC2)
- Eucalyptus
- GoGrid
- FlexiScale
- Linode
- RackSpace Cloud
- Terremark

All these vendors offer direct access to hardware resources. On Amazon EC2, considered the classic IaaS example, a client would provision a computer in the form of a virtual machine image, provision storage, and then go on to install the operating system and applications onto that virtual system. Amazon has a number of operating systems and some enterprise applications that they offer on a rental basis to customers in the form of a number of canned images, but customers are free to install whatever software they want to run. Amazon's responsibilities as expressed in its Service Level Agreement, which is published on Amazon's Web site, contractually obligates Amazon to provide a level of performance commensurate with the type of resource chosen, as well as a certain level of reliability as measured by the system's uptime.

Service Models

A PaaS service adds integration features, middleware, and other orchestration and choreography services to the IaaS model. Examples of PaaS services are:

- Force.com
- GoGrid CloudCenter
- Google AppEngine
- Windows Azure Platform

When a cloud computing vendor offers software running in the cloud with use of the application on a pay-as-you-go model, it is referred to as SaaS. With SaaS, the customer uses the application as needed and is not responsible for the installation of the application, its maintenance, or its upkeep.

Benefits of cloud computing

Benefits of cloud computing

The NIST Definition of Cloud Computing that classified cloud computing into the three SPI service models (SaaS, IaaS, and PaaS) and four cloud types (public, private, community, and hybrid), also assigns five essential characteristics that cloud computing systems must offer:

- **On-demand self-service**: A client can provision computer resources without the need for interaction with cloud service provider personnel.

- **Broad network access**: Access to resources in the cloud is available over the network using standard methods in a manner that provides platform-independent access to clients of all types. This includes a mixture of heterogeneous operating systems, and thick and thin platforms such as laptops, mobile phones, and PDA.

Benefits of cloud computing

- **Resource pooling**: A cloud service provider creates resources that are pooled together in a system that supports multi-tenant usage. Physical and virtual systems are dynamically allocated or reallocated as needed. Intrinsic in this concept of pooling is the idea of abstraction that hides the location of resources such as virtual machines, processing, memory, storage, and network bandwidth and connectivity.

- **Rapid elasticity**: Resources can be rapidly and elastically provisioned. The system can add resources by either scaling up systems (more powerful computers) or scaling out systems (more computers of the same kind), and scaling may be automatic or manual. From the standpoint of the client, cloud computing resources should look limitless and can be purchased at any time and in any quantity.

Benefits of cloud computing

- **Measured service**: The use of cloud system resources is measured, audited, and reported to the customer based on a metered system. A client can be charged based on a known metric such as amount of storage used, number of transactions, network I/O (Input/Output) or bandwidth, amount of processing power used, and so forth. A client is charged based on the level of services provided.

While these five core features of cloud computing are on almost anybody's list, you also should consider these additional advantages:

- **Lower costs**: Because cloud networks operate at higher efficiencies and with greater utilization, significant cost reductions are often encountered.

Benefits of cloud computing

- **Ease of utilization**: Depending upon the type of service being offered, you may find that you do not require hardware or software licenses to implement your service.

- **Quality of Service**: The Quality of Service (QoS) is something that you can obtain under contract from your vendor.

- **Reliability**: The scale of cloud computing networks and their ability to provide load balancing and failover makes them highly reliable, often much more reliable than what you can achieve in a single organization.

Benefits of cloud computing

- **Outsourced IT management**: A cloud computing deployment lets someone else manage your computing infrastructure while you manage your business. In most instances, you achieve considerable reductions in IT staffing costs.

- **Simplified maintenance and upgrade**: Because the system is centralized, you can easily apply patches and upgrades. This means your users always have access to the latest software versions.

Benefits of cloud computing

- **Low Barrier to Entry**: In particular, upfront capital expenditures are dramatically reduced. In cloud computing, anyone can be a giant at any time.

This very long list of benefits should make it obvious why so many people are excited about the idea of cloud computing. Cloud computing is not a panacea, however. In many instances, cloud computing doesn't work well for particular applications.

Disadvantages of cloud computing

Possible Downtime

Cloud computing makes small business dependent on the reliability of your Internet connection. When it's offline, you're offline. If your internet service suffers from frequent outages or slow speeds cloud computing may not be suitable for your business. And even the most reliable cloud computing service providers suffer server outages now and again.

Disadvantages of cloud computing

Security Issues

Cloud computing means Internet computing. Established cloud computing vendors have gone to great lengths to promote the idea that they have the latest, most sophisticated data security systems possible as they want your business and realize that data security is a big concern; however, their credibility in this regard has suffered greatly in the wake of the recent NSA snooping scandals.

Cloud data is accessible from anywhere on the internet, meaning that if a data breach occurs via hacking, a disgruntled employee, or careless username/password security, your business data can be compromised.

Disadvantages of cloud computing

Inflexibility and Vendor Lock Ins

While choosing a cloud computing vendor the organizations are locking their business into using their proprietary applications or formats. E.g. one can't insert a document created in another application into a Google Docs spreadsheet.

Disadvantages of cloud computing

Control and Reliability

The biggest fear of cloud computing is found in its major benefit – the ability to outsource the IT burden to a specialized vendor or provider. It sounds great, but with a move to the cloud organizations give up the in-house control of a traditional IT department.

Multi-tenancy

Multi-tenancy is the sharing of resources among two or more clients. One key difference between the NIST model and the CSA (Cloud Security Alliance) is that the CSA considers multi-tenancy to be an essential element in cloud computing. Multi-tenancy adds a number of additional security concerns to cloud computing that need to be accounted for. In multi-tenancy, different customers must be isolated, their data segmented, and their service accounted for. Because data stored in the cloud is usually stored from multiple tenants, each vendor has its own unique method for segregating one customer's data from another.

Multi-tenancy

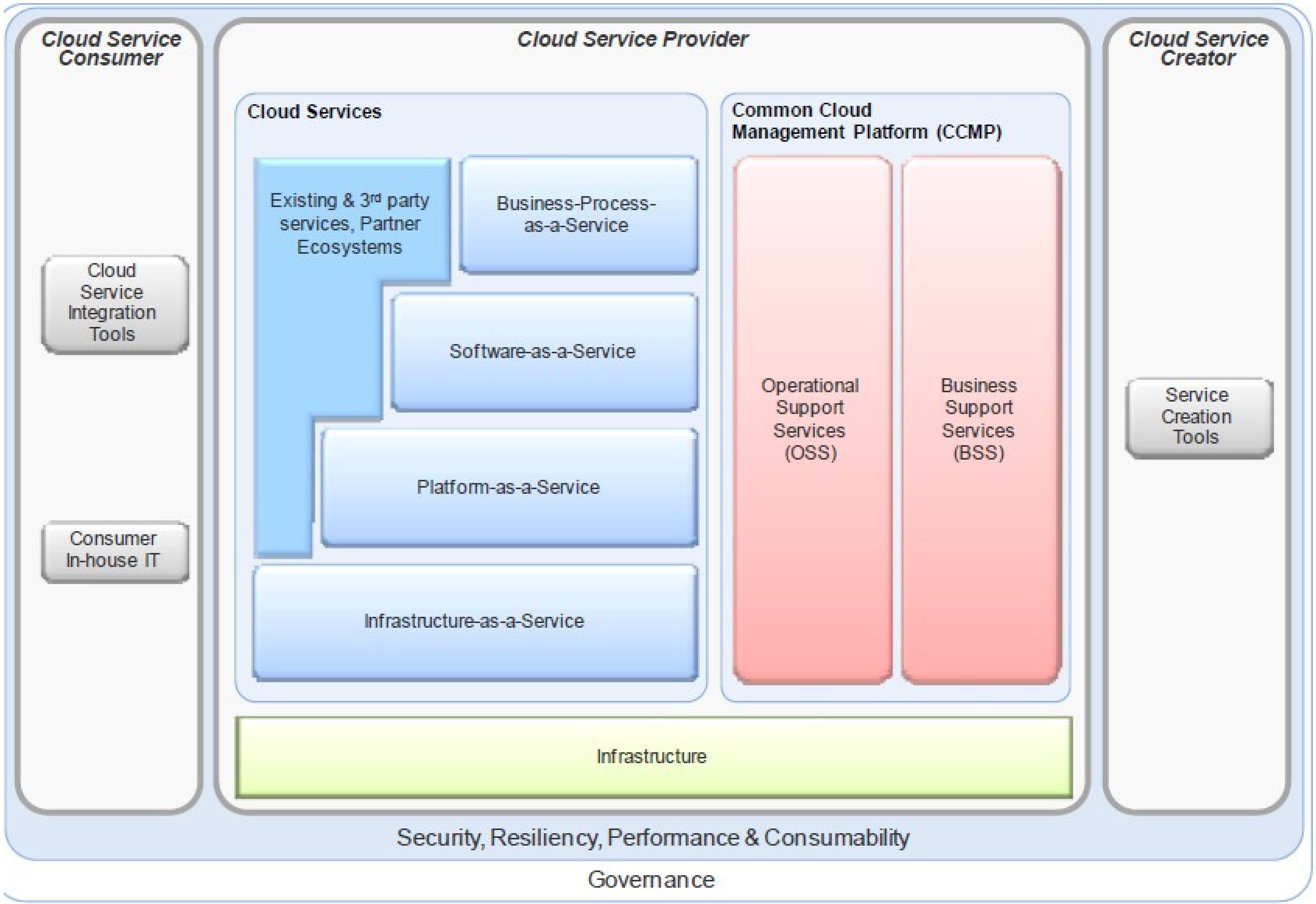
Different cloud storage vendors may implement their own proprietary management interfaces to connect distributed hosts or tenants to their provisioned storage in the cloud and to provide for security services. One open interface standard is the Storage Networking Industry Association's Cloud Data Management Interface (CDMI) To provide these features, the cloud service provider must provide a policy-based environment that is capable of supporting different levels and quality of service, usually using different pricing models. Multi-tenancy expresses itself in different ways in the different cloud deployment models and imposes security concerns in different places.

Common Cloud Management Platform Reference Architecture

Cloud Computing Reference Architecture

A Reference Architecture provides a technical blueprint for a system with a well-defined scope, the requirements it satisfies, and the architectural decisions it realizes. It ensures consistency and quality across development and delivery projects.

The Cloud Computing Reference Architecture (CC RA) is a design for cloud services which optimizes resource and labor utilization and achieves economies of scale during operation. The Cloud Computing Reference Architecture is based on real-world input from many cloud implementations. It defines the fundamental architectural elements which underpin and provide guidelines for creating a cloud environment. The architecture defines three main roles: **Cloud Service Consumer, Cloud Service Provider and Cloud Service Creator**. Each role can be fulfilled by a single person or by a group of people or by one or more organizations.



Cloud Service Consumer
Cloud Service Integration Tools
Consumer In-house IT
Cloud Service Provider
Cloud Services
Existing & 3rd party services, Partner Ecosystems
Business-Process-as-a-Service
Software-as-a-Service
Platform-as-a-Service
Infrastructure-as-a-Service
Common Cloud Management Platform (CCMP)
Operational Support Services (OSS)
Business Support Services (BSS)
Infrastructure
Cloud Service Creator
Service Creation Tools
Security, Resiliency, Performance & Consumability
Governance

Cloud Service Consumer

A Cloud Service Consumer is an organization, a human being or an IT system that consumes service instances delivered by a particular Cloud Service Provider. Besides IT capabilities consumed as cloud services, consumers may continue to have *in-house IT managed in a traditional non-cloud fashion. The functionality of Cloud Service Integration Tools is required to integrate the existing in-house IT with cloud services consumed from a cloud service provider.*

Cloud Service Provider

The Cloud Service Provider has the responsibility of providing cloud services to Cloud Service Consumers. Those services are delivered by a Common Cloud Management Platform (CCMP) either by running CCMP infrastructure or consuming one as a service. Cloud Services represent any type of (IT) capability provided by the Cloud Service Provider to Cloud Service Consumers. These services have cloud characteristics (on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service). There are four cloud service models within the context of the IBM Cloud Computing Reference Architecture: Infrastructure as a Service (Iaas), Platform as a Service (PaaS), Software as a Service (SaaS) and Business Process as a Service (BPaaS). IaaS, PaaS and SaaS are defined according to the definition of Cloud Computing released by NIST; BPaaS is an IBM-specific definition ("Business Process Services are any business process delivered through the Cloud service model"). The Common Cloud Management Platform (CCMP) exposes a set of Operational Support Services (OSS) and Business Support Services (BSS); it also includes User Interfaces serving the three main roles defined in the Cloud Computing Reference Architecture: a Service Consumer Portal to be used by Cloud Service Consumers for self-service delivery and management; a Service Provider Portal serving Cloud Service Provider administrators to support production operations; and a Service Creator Portal.

Cloud Service Provider

Development Portal used by Cloud Service Creators. Operational Support Services represents the set of operational management and technical-related services exposed by the CCMP and needed by Cloud Service Creators to implement a cloud service. Many management domains of the OSS are also encountered in traditionally managed data centers (e.g. monitoring and event management, provisioning, incident and problem management, etc.) while other components are new and specific to the degrees of automation and efficiency associated with clouds (e.g. service automation, image lifecycle management, etc.). Business Support Services represents the set of business-related services exposed by the CCMP, which are needed by Cloud Service Creators to implement a cloud service. Infrastructure represents all infrastructure elements needed to provide cloud services (data center facilities, servers, storage, system software and network resources, etc.).

Cloud Service Creator

The Cloud Service Creator is responsible for creating a cloud service which can be run by a Cloud Service Provider and exposed to Cloud Service Consumers. A Cloud Service Creator designs, implements and maintains runtime and management artifacts specific to a cloud service. Service Development Tools are used by the Cloud Service Creator to develop new Cloud Service Definitions, including runtime artifacts and management-related aspects (monitoring, metering, provisioning, etc.).

Virtualization

Virtualization

- Virtualization involves a shift in thinking from physical to logical
  - –Treating IT resources as logical resources rather than separate physical resources

- With virtualization, one can consolidate the following resources into a virtual environment:
  - –Processors
  - –Storage
  - –Networks

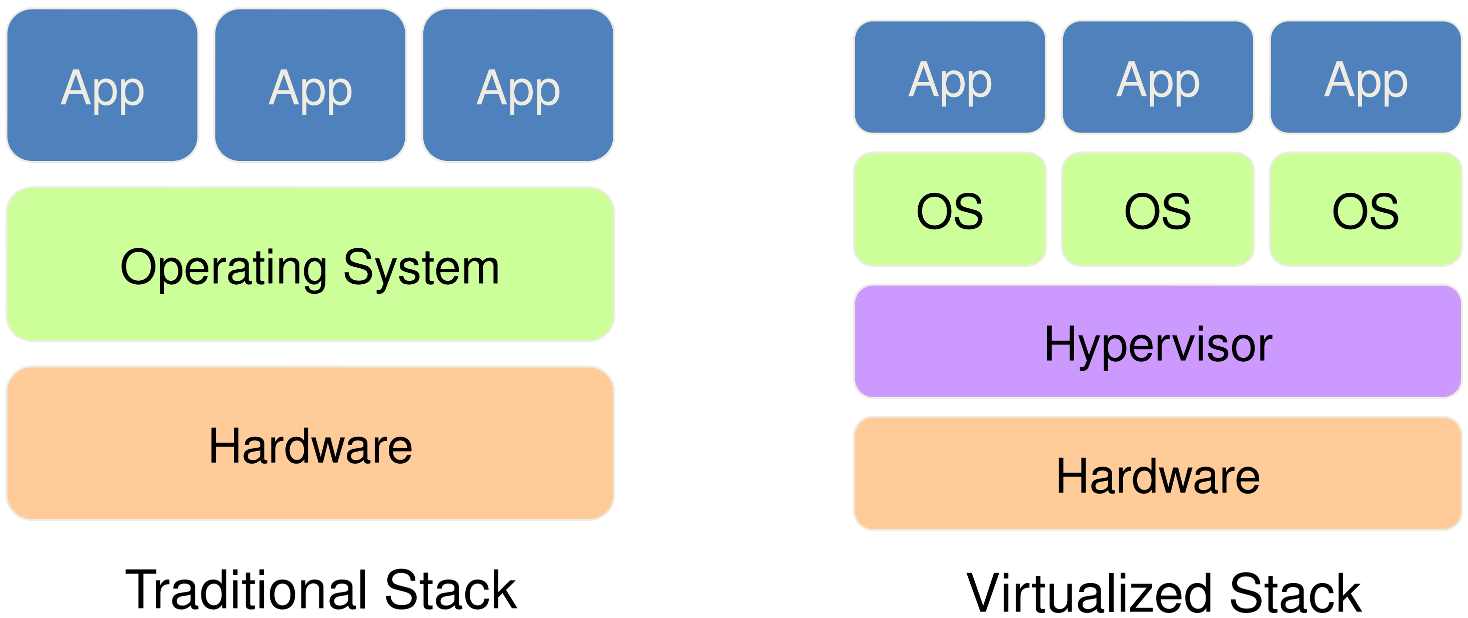
- With virtualization, one physical resource can be made to look like multiple virtual resources
  - –Virtual resources can have functions or features that are not available in their underlying physical resources.

What can be virtualized?

- Virtualization may refer to:
  - –Hardware
  - –Networks
  - –Storage
  - –Operating systems
  - –Applications
  - –Desktop

- The main advantage of virtualization in cloud computing is that the software is decoupled from the hardware
  - –Decoupling allows hosting an individual application in an environment that is isolated from underlying operating system

Key Technology: Virtualization



Virtualization

Virtualization is the technology that abstract physical resources such as processors, memory, disk, and network capacity into virtual resources. In cloud computing, we are accessing pooled resources using a technique called virtualization. Virtualization assigns a logical name for a physical resource and then provides a pointer to that physical resource when a request is made. Virtualization provides a means to manage resources efficiently because the mapping of virtual resources to physical resources can be both dynamic and facile. Virtualization is dynamic in that the mapping can be assigned based on rapidly changing conditions, and it is facile because changes to a mapping assignment can be nearly instantaneous.

Virtualization

These are among the different types of virtualization that are characteristic of cloud computing:

- **Application**: A cloud has multiple application instances and directs requests to an instance based on conditions.

- **CPU**: Computers can be partitioned into a set of virtual machines with each machine being assigned a workload. Alternatively, systems can be virtualized through load-balancing technologies.

- **Storage**: Data is stored across storage devices and often replicated for redundancy.

Virtualization

Virtualization is a key enabler of key attributes of cloud computing:

- **Service-based**: A service-based architecture is where clients are abstracted from service providers through service interfaces.
- **Scalable and elastic**: Services can be altered to affect capacity and performance on demand.
- **Shared services**: Resources are pooled in order to create greater efficiencies.
- **Metered usage**: Services are billed on a usage basis.

Characteristics of Virtualization

Virtualization has three characteristics that make it ideal for cloud computing:

- **Partitioning:** In virtualization, many applications and operating systems are supported in a single physical system by *partitioning* (separating) the available resources.
- **Isolation:** Each virtual machine is isolated from its host physical system and other virtualized machines. Because of this isolation, if one virtual-instance crashes, it doesn't affect the other virtual machines. In addition, data isn't shared between one virtual container and another.
- **Encapsulation:** A virtual machine can be represented (and even stored) as a single file, so you can identify it easily based on the service it provides. In essence, the encapsulated process could be a business service. This encapsulated virtual machine can be presented to an application as a complete entity. Therefore, encapsulation can protect each application so that it doesn't interfere with another application.

Benefits of Virtualization

- **Consolidation to reduce hardware cost**

  –It enables to have a single server function as multiple virtual servers.

- **Optimization of workloads**

  –Can increase the use of existing resources by enabling dynamic sharing of resource pools.

- **IT flexibility and responsiveness**

  –Enables you to have a single, consolidated view of, and easy access to, all available resources in the network, regardless of location

Load Balancing and Virtualization

One characteristic of cloud computing is virtualized network access to a service. No matter where you access the service, you are directed to the available resources. The technology used to distribute service requests to resources is referred to as load balancing. Load balancing is an optimization technique; it can be used to increase utilization and throughput, lower latency, reduce response time, and avoid system overload. Without load balancing, cloud computing would very difficult to manage. Load balancing provides the necessary redundancy to make an intrinsically unreliable system reliable through managed redirection. It also provides fault tolerance when coupled with a failover mechanism. Load balancing is nearly always a feature of server farms and computer clusters and for high availability applications.

Load Balancing and Virtualization

A load-balancing system can use different mechanisms to assign service direction. In the simplest load-balancing mechanisms, the load balancer listens to a network port for service requests. When a request from a client or service requester arrives, the load balancer uses a scheduling algorithm to assign where the request is sent. Typical scheduling algorithms in use today are round robin and weighted round robin, fastest response time, least connections and weighted least connections, and custom assignments based on other factors.

Load Balancing and Virtualization

A session ticket is created by the load balancer so that subsequent related traffic from the client that is part of that session can be properly routed to the same resource. Without this session record or persistence, a load balancer would not be able to correctly failover a request from one resource to another. Persistence can be enforced using session data stored in a database and replicated across multiple load balancers.

Understanding Hypervisors

Load balancing virtualizes systems and resources by mapping a logical address to a physical address. . From the standpoint of applications or users, a virtual machine has all the attributes and characteristics of a physical system but is strictly software that emulates a physical machine. A system virtual machine (or a hardware virtual machine) has its own address space in memory, its own processor resource allocation, and its own device I/O using its own virtual device drivers. Some virtual machines are designed to run only a single application or process and are referred to as process virtual machines.

Understanding Hypervisors

Virtual machines provide the capability of running multiple machine instances, each with their own operating system. From the standpoint of cloud computing, these features enable VMMs or hypervisors to manage application provisioning, provide for machine instance cloning and replication, allow for graceful system failover, and provide several other desirable features. The downside of virtual machine technologies is that having resources indirectly addressed means there is some level of overhead. A low-level program is required to provide system resource access to virtual machines, and this program is referred to as the hypervisor or Virtual Machine Monitor (VMM).

Types of Virtual Machines

1. Type I VM
2. Type 2 VM

Types of Virtual Machines

A hypervisor running on bare metal is a Type 1 VM or native VM. Examples of Type 1 Virtual Machine Monitors are LynxSecure, RTS Hypervisor, Oracle VM, Sun xVM Server, VirtualLogix VLX, VMware ESX and ESXi, and Wind River VxWorks, among others. 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. Type 1 VMs have no host operating system because they are installed on a bare system.

An operating system running on a Type 1 VM is a full virtualization because it is a complete simulation of the hardware that it is running on.

Types of Virtual Machines

Some hypervisors are installed over an operating system and are referred to as Type 2 or hosted VM. Examples of Type 2 Virtual Machine Monitors are Containers, KVM, Microsoft Hyper V, Parallels Desktop for Mac, Wind River Simics, VMWare Fusion, Virtual Server 2005 R2, Xen, Windows Virtual PC, and VMware Workstation 6.0 and Server, among others. This is a very rich product category. Type 2 virtual machines are installed over a host operating system; for Microsoft Hyper-V, that operating system would be Windows Server. On a Type 2 VM, a software interface is created that emulates the devices with which a system would normally interact. This abstraction is meant to place many I/O operations outside the virtual environment, which makes it both programmatically easier and more efficient to execute device I/O than it would be inside a virtual environment. This type of virtualization is sometimes referred to as paravirtualization, and it is found in hypervisors such as Microsoft's Hyper-V and Xen. It is the host operating system that is performing the I/O through a para-API.

Types of Virtual Machines