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Cloud Computing: The Next phase in the Evolution of Computing

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Abstract: ***Traditional business applications have always been very complicated and expensive. The amount and variety of hardware and software required to run them are daunting. You need a whole team of experts to install, configure, test, run, secure, and update them. Cloud Computing is a flexible, cost-effective, and proven delivery platform for providing business or consumer IT services over the Internet. However, cloud Computing presents an added level of risk because essential services are often outsourced to a third party, which makes it harder to maintain data security and privacy, support data and service availability, and demonstrate compliance. Cloud Computing leverages many technologies (SOA, virtualization, Web 2.0); it also inherits their security issues. You only pay for what you need, upgrades are automatic, and scaling up or down is easy. Cloud computing provides various deployment models as public, privet, hybrid and community. Cloud computing delivers everything as a service by using three service delivery models as IaaS, PaaS and SaaS. Cloud-based apps can be up and running in days or weeks, and they cost less. With a cloud app, you just open a browser, log in, customize the app, and start using it.***

Keywords: Cloud computing, Cloud computing models, computing issues, cloud storage, virtualization & SOA.

1. History

The underlying concept of cloud computing dates back to the 1950s, when large-scale mainframe computers became available in academia and corporations, accessible via thin clients/terminal computers, often referred to as "static terminals", because they were used for communications but had no internal processing capacities. To make more efficient use of costly mainframes, a practice evolved that allowed multiple users to share both the physical access to the computer from multiple terminals as well as the CPU time. This eliminated periods of inactivity on the mainframe and allowed for a greater return on the investment. The practice of sharing CPU time on a mainframe became known in the industry as time-sharing. During mid 70s it was popularly known as RJE Remote Job Entry process mostly associated with IBM and DEC.

John McCarthy opined in the 1960s that "computation may someday be organized as a public utility." Almost all of the modern-day characteristics of cloud computing (elastic provision, provided as a utility, online, illusion of infinite supply), the comparison to the electricity industry and the use of public, private, government, and community forms, were thoroughly explored in Douglas Parkhill's 1966 book, The Challenge of the Computer Utility.

In the 1990s, telecommunications companies began offering virtual private network (VPN) services with comparable quality of service, but at a lower cost. By switching traffic as they saw fit to balance server use, they could use overall network bandwidth more effectively. They began to use the cloud symbol to denote the demarcation point between what the providers was responsible for and what users were responsible for. Cloud computing extends this boundary to cover servers as well as the network infrastructure. Amazon initiated a new product development effort to provide cloud computing to external customers, and launched Amazon Web Services (AWS) on a utility computing basis in 2006.

In early 2008, Eucalyptus became the first open-source, AWS API-compatible platform for deploying private clouds. In early 2008, Open Nebula, enhanced in the RESERVOIR European Commission-funded project, became the first open-source software for deploying private and hybrid clouds, and for the federation of clouds.[1] By mid-2008, Gartner saw an opportunity for cloud computing "to shape the relationship among consumers of IT services, those who use IT services and those who sell them" and observed that "organizations are switching from company-owned hardware and software assets to per-use service-based models" so that the "projected shift to computing ... will result in dramatic growth in IT products in some areas and significant reductions in other areas."

On March 1, 2011, IBM announced the IBM SmartCloud framework to support Smarter Planet.[2] Among the various components of the Smarter Computing foundation, cloud computing is a critical piece.

On June 7, 2012, Oracle announced the Oracle Cloud.[3] While aspects of the Oracle Cloud are still in development, this cloud offering is posed to be the first to provide users with access to an integrated set of IT solutions, including the Applications (SaaS), Platform (PaaS), and Infrastructure (IaaS) layers.

2. Introduction

2.1 What is Cloud computing?

Cloud computing is the next stage in the Internet's evolution, providing the means through which everything — from computing power to computing infrastructure, applications, business processes to personal collaboration — can be delivered to you as a service wherever and whenever you need.

Cloud computing involves distributed computing over a network, where a program or application may run on many connected computers at the same time. It specifically refers to a computing hardware machine or group of computing hardware machines commonly referred as a server connected through a communication network such as the Internet, an intranet, a local area network (LAN) or wide area network (WAN). Any individual user who has permission to access the server can use the server's processing power to run an application, store data, or perform any other computing task. Therefore, instead of using a personal computer every-time to run the application, the individual can now run the application from anywhere in the world, as the server provides the processing power to the application and the server is also connected to a network via internet or other connection platforms to be accessed from anywhere. [4] All this has become possible due to increasing computer processing power available to humankind with decrease in cost as stated in Moore's law. In common usage the term "the cloud" is essentially a metaphor for the Internet.

The “cloud” in cloud computing can be defined as the set of hardware, networks, storage, services, and interfaces that combine to deliver aspects of computing as a service. Cloud services include the delivery of software, infrastructure, and storage over the Internet (either as separate components or a complete platform) based on user demand.

In general the cloud — similar to its namesake of the cumulus type — is fluid and can easily expand and contract. This elasticity means that users can request additional resources on demand and just as easily deprovision (or release) those resources when they’re no longer needed. This elasticity is one of the main reasons individual, businesses, and IT users are moving to the cloud. In the traditional data center it has always been possible to add and release resources. However, this process couldn’t be done in an automated or self service manner.

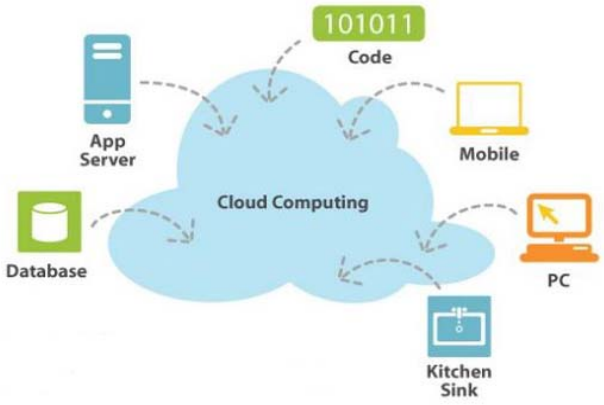

Figure 1: Cloud computing structure

2.2 Cloud computing Characteristics

Cloud computing has four essential characteristics:

- Elasticity and the ability to scale up and down
- Self-service provisioning and automatic deprovisioning.
- Application programming interfaces (APIs)
- Billing and metering of service usage in a pay-as-you-go model.

This flexibility is what is attracting individuals and businesses to move to the cloud.

2.2.1 Elasticity and scalability

The service provider can’t anticipate how customers will use the service. One customer might use the service three times a year during peak selling seasons, whereas another might use it as a development platform for all of its applications. Therefore, the service needs to be available all the time (7 days a week, 24 hours a day) and it has to be designed to scale upward for high periods of demand and downward for lighter ones. Scalability also means that an application can scale when additional users are added and when the application requirements change. This ability to scale is achieved by providing elasticity.

2.2.2 Self-service provisioning

Customers can easily get cloud services without going through a lengthy process. The customer simply requests an amount of computing, storage, software, process, or other resources from the service provider.

2.2.3 Application programming interfaces (APIs)

Cloud services need to have standardized APIs. These interfaces provide the instructions on how two application or data sources can communicate with each other. A standardized interface lets the customer more easily link a cloud service, such as a customer relationship management system with a financial accounts management system, without having to resort to custom programming.

2.2.4 Billing and metering of services

A cloud environment needs a built-in service that bills customers. And, of course, to calculate that bill, usage has to be metered (tracked). Even free cloud services (such as

Google's Gmail or Zoho's Internet-based office applications) are metered.

2.3 Participants in cloud computing

The world of the cloud has lots of participants:

- **The end user** who doesn't have to know anything about the underlying technology.
- **Business management** who needs to take responsibility for the governance of data or services living in a cloud. Cloud service providers must provide a predictable and guaranteed service level and security to all their constituents.
- **The cloud service provider** who is responsible for IT assets and maintenance.

2.4 Players in cloud computing

Many players make up the world of cloud computing:

- The **vendors** providing applications and enabling technology, infrastructure, hardware, and integration.
- The **partners** of these vendors that are creating cloud services offerings and providing support services to customers.
- The **business leaders** themselves who are either using or evaluating various types of cloud computing offerings.

3. Cloud Deployment Models

Cloud computing can completely change the way companies use technology to service customers, partners, and suppliers. Some businesses, such as Google and Amazon, already have most of their IT resources in the cloud. They have found that it can eliminate many of the complex constraints from the traditional computing environment, including space, time, power, and cost.

With cloud computing technology, large pools of resources can be connected through private or public networks. This technology simplifies infrastructure planning and provides dynamically scalable infrastructure for cloud based applications, data, and file storage. Businesses can choose to deploy applications on Public, Private, Hybrid clouds or the newer Community Cloud.

3.1 Public clouds

Public clouds are virtualized data centers outside of your company's firewall. Generally, a service provider makes resources available to companies, on demand, over the public Internet. A public cloud is a cloud computing model in which services, such as applications and storage, are available for general use over the Internet. Public cloud services may be offered on a pay-per-usage mode or other purchasing models.

Public clouds are made available to the general public by a service provider who hosts the cloud infrastructure. Generally, public cloud providers like Amazon AWS, Microsoft and Google own and operate the infrastructure and offer access over the Internet. With this model, customers have no visibility or control over where the infrastructure is located. It is important to note that all customers on public clouds share the same infrastructure pool with limited configuration, security protections and availability variances.

Public Cloud customers benefit from economies of scale, because infrastructure costs are spread across all users, allowing each individual client to operate on a low-cost, pay-as-you-go model. Another advantage of public cloud infrastructures is that they are typically larger in scale than an in-house enterprise cloud, which provides clients with seamless, on-demand scalability. These clouds offer the greatest level of efficiency in shared resources; however, they are also more vulnerable than private clouds. A public cloud is the obvious choice when:

- Your standardized workload for applications is used by lots of people, such as e-mail.
- You need to test and develop application code.
- You need incremental capacity (the ability to add compute resources for peak times).
- You're doing collaboration projects.

3.2 Private clouds

Private clouds are virtualized cloud data centers inside your company's firewall. It may also be a private space dedicated to your company within a cloud provider's data center. Private cloud is cloud infrastructure dedicated to a particular organization. Private clouds allow businesses to host applications in the cloud, while addressing concerns regarding data security and control, which is often lacking in a public cloud environment. It is not shared with other organizations, whether managed internally or by a third-party, and it can be hosted internally or externally. There are two variations of private clouds:

1. On-Premise Private Cloud: This type of cloud is hosted within an organizations own facility. A businesses IT department would incur the capital and operational costs for the physical resources with this model. On-Premise Private Clouds are best used for applications that require complete control and configurability of the infrastructure and security.
2. Externally Hosted Private Cloud: Externally hosted private clouds are also exclusively used by one organization, but are hosted by a third party specializing in cloud infrastructure. The service provider facilitates an exclusive cloud environment with full guarantee of privacy. This format is recommended for organizations that prefer not to use a public cloud infrastructure due to the risks associated with the sharing of physical resources.

When is a Private Cloud for you?

- You need data sovereignty but want cloud efficiencies
- You want consistency across services
- You have more server capacity than your organization can use
- Your data center must become more efficient
- You want to provide private cloud services

3.3 Hybrid clouds

Hybrid clouds combine aspects of both public and private clouds. Hybrid Clouds are a composition of two or more clouds (private, community or public) that remain unique entities but are bound together offering the advantages of multiple deployment models. In a hybrid cloud, you can leverage third party cloud providers in either a full or partial manner; increasing the flexibility of computing. Augmenting a traditional private cloud with the resources of a public cloud can be used to manage any unexpected surges in workload.

Hybrid cloud architecture requires both on-premise resources and off-site server based cloud infrastructure. By spreading things out over a hybrid cloud, you keep each aspect of your business in the most efficient environment possible. The downside is that you have to keep track of multiple cloud security platforms and ensure that all aspects of your business can communicate with each other. Where a hybrid environment is best:

- Your company wants to use a SaaS application but is concerned about security.
- Your company offers services that are tailored for different vertical markets. You can use a public cloud to interact with the clients but keep their data secured within a private cloud.
- You can provide public cloud to your customers while using a private cloud for internal IT.

3.4 Community clouds

A community cloud is an infrastructure shared by several organizations which supports a specific community. A community cloud is a is a multi-tenant cloud service model that is shared among several or organizations and that is governed, managed and secured commonly by all the participating organizations or a third party managed service provider. Community clouds are a hybrid form of private clouds built and operated specifically for a targeted group. These communities have similar cloud requirements and their ultimate goal is to work together to achieve their business objectives. The goal of community clouds is to have participating organizations realize the benefits of a public cloud with the added level of privacy, security, and policy compliance usually associated with a private cloud. Community clouds can be either on-premise or off-premise. Where a community cloud environment is best:

- Government organizations within a state that need to share resources
- A private HIPAA compliant cloud for a group of hospitals or clinics
- Telco community cloud for Telco DR to meet specific FCC regulations

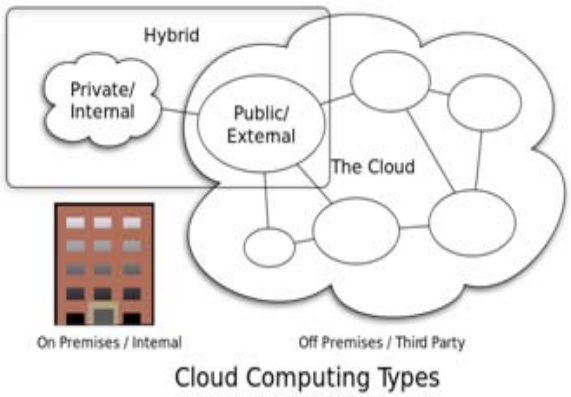

Figure 2: Cloud deployment models

4. Cloud Computing Models

Cloud computing models vary: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Manage your cloud computing service level via the surrounding management layer.

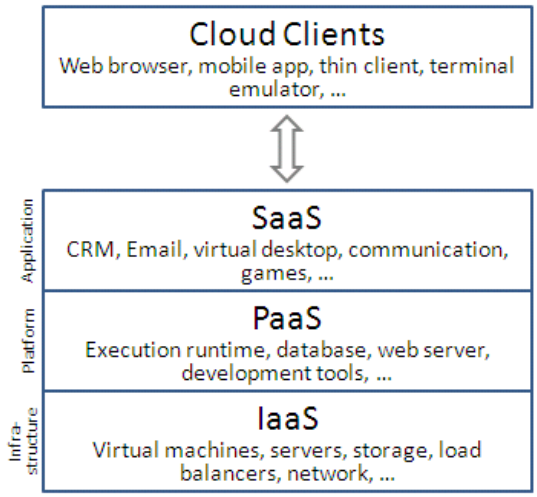

Figure 3: Cloud computing models

4.1 Infrastructure as a Service (IaaS)

The IaaS layer offers storage and compute resources that developers and IT organizations can use to deliver business solutions. Pools of hypervisors within the cloud operational support-system can support large numbers of virtual machines and the ability to scale services up and down according to customers' varying requirements. IaaS clouds often offer additional resources such as a virtual-machine disk image library, raw (block) and file-based storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles.[5] IaaS-cloud providers supply these resources on-demand from their large pools installed in data centers.

4.2 Platform as a Service (PaaS)

The PaaS layer offers black-box services with which developers can build applications on top of the compute infrastructure. This might include developer tools that are offered as a service to build services, or data access and database services, or billing services.

In the PaaS models, cloud providers deliver a computing platform, typically including operating system, programming language execution environment, database, and web server. Application developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers. With some PaaS offers like Microsoft Azure and Google App Engine, the underlying computer and storage resources scale automatically to match application demand so that the cloud user does not have to allocate resources manually. The latter has also been proposed by an architecture aiming to facilitate real-time in cloud environments. [6]

4.3 Software as a Service (SaaS)

In the SaaS layer, the service provider hosts the software so you don't need to install it, manage it, or buy hardware for it. All you have to do is connect and use it. SaaS Examples include customer relationship management as a service. In the SaaS model, cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients. Cloud users do not manage the cloud infrastructure and platform where the application runs. This eliminates the need to install and run the application on the cloud user's own computers, which simplifies maintenance and support. Cloud applications are different from other applications in their scalability—which can be achieved by cloning tasks onto multiple virtual machines at run-time to meet changing work demand.[7] Load balancers distribute the work over the set of virtual machines. This process is transparent to the cloud user, who sees only a single access point. To accommodate a large number of cloud users, cloud applications can be multitenant, that is, any machine serves more than one cloud user organization. It is common to refer to special types of cloud-based application software with a similar naming convention: desktop as a service, business process as a service, test environment as a service, communication as a service.

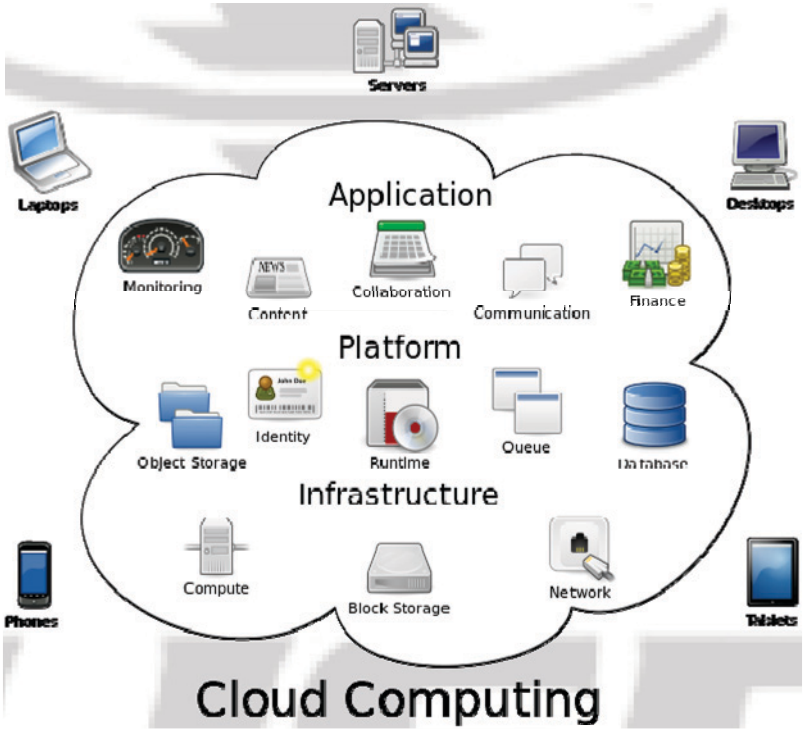

Figure 4: Cloud computing models

5. Virtualization in Cloud

Virtualization is a fundamental mechanism for delivering services. Virtualization is using computer resources to imitate other computer resources or whole computers. Indeed, virtualization provides a platform for optimizing complex IT resources in a scalable manner (efficiently growing), which is ideal for delivering services. In computing, virtualization means to create a virtual version of a device or resource, such as a server, storage device, network or even an operating system where the framework divides the resource into one or more execution environments. Even something as simple as partitioning a hard drive is considered virtualization because you take one drive and partition it to create two separate hard drives. Devices, applications and human users are able to interact with the virtual resource as if it were a real single logical resource.

5.1 Characteristics

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

5.1.1 Partitioning
In virtualization, many applications and operating systems (OSes) are supported in a single physical system by partitioning (separating) the available resources.

5.1.2 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.

5.1.3 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.

5.2 Applications

Virtualization can be applied very broadly to just about everything that you could imagine:

- Memory
- Networks
- Storage
- Hardware
- Operating systems
- Applications

To understand how virtualization helps with cloud computing, you must understand its many forms. In essence, in all cases, a resource actually emulates or imitates another resource. Here are some examples:

- **Virtual memory:** Disks have a lot more space than memory. PCs can use virtual memory to borrow extra memory from the hard disk. Although virtual disks are slower than real memory, if managed right, the substitution works surprisingly well.
- **Software:** There is virtualization software available that can emulate an entire computer, which means 1 computer can perform as though it were actually 20 computers. Using this kind of software you might be able to move from a data center with thousands of servers to one that supports as few as a couple of hundred.

6. Service-Oriented Architecture (SOA)

Service-oriented architecture (SOA) is a software design and software architecture design pattern based on discrete pieces of software providing application functionality as services to other applications. This is known as service-orientation. It is independent of any vendor, product or technology. [7]

A service is a self-contained unit of functionality, such as retrieving an online bank statement. [8] Services can be combined by other software applications to provide the complete functionality of a large software application. SOA makes it easy for computers connected over a network to cooperate. Every computer can run an arbitrary number of services, and each service is built in a way that ensures that the service can exchange information with any other service in the network without human interaction and without the need to make changes to the underlying program itself.

The purpose of SOA is to allow users to combine together fairly large chunks of functionality to form ad hoc applications built almost entirely from existing software services. The larger the chunks, the fewer the interfaces required implementing any given set of functionality; however, very large chunks of functionality may not prove sufficiently granular for easy reuse. Each interface brings with it some amount of processing overhead, so there is a performance consideration in choosing the granularity of services.

Cloud services benefit the business by taking the best practices and business process focus of SOA to the next level. These benefits apply to both cloud service providers and cloud service users. Cloud service providers need to architect solutions by using a service-oriented approach to deliver services with the expected levels of elasticity and scalability. Companies that architect and govern business processes with reusable service-oriented components can more easily identify which components can be successfully moved to public and private clouds.

A Service-Oriented Architecture (SOA) is software architecture for building business applications that implement business processes or services through a set of loosely coupled, black-box components orchestrated to deliver a well-defined level of service.

This approach lets companies leverage existing assets and create new business services that are consistent, controlled, more easily changed, and more easily managed. SOA is a business approach to designing efficient IT systems that support reuse and give the businesses the flexibility to react quickly to opportunities and threats.

7. How Cloud Computing Works

The goal of cloud computing is to apply traditional supercomputing, or high-performance computing power, normally used by military and research facilities, to perform tens of trillions of computations per second, in consumer-oriented applications such as financial portfolios, to deliver personalized information, to provide data storage or to power large, immersive computer games. To do this, cloud computing uses networks of large groups of servers typically running low-cost consumer PC technology with specialized connections to spread data-processing chores across them. This shared IT infrastructure contains large pools of systems that are linked together. Often, virtualization techniques are used to maximize the power of cloud computing.

8. Cloud Computing Issues

Cloud computing issues [9] span models (IaaS, PaaS, or SaaS) and types (public, private, or hybrid). Computing on the cloud requires vigilance about security, manageability, standards, governance, and compliance:

8.1 Cloud Security

The same security principles that apply to on-site computing apply to cloud computing security.

- **Identity management.** Managing personal identity information so that access to computer resources, applications, data, and services is controlled properly.
- **Detection and forensics.** Separating legitimate from illegitimate activity.
- **Encryption.** Coding to protect your information assets.

8.2 Cloud manageability.

You need a consistent view across both on-premises and cloud-based environments. This includes managing the assets provisioning as well as the quality of service (QOS) you're receiving from your service provider.

8.3 Cloud standards.

A standard is an agreed-upon approach for doing something. Cloud standards ensure interoperability, so you can take tools, applications, virtual images, and more, and use them in another cloud environment without having to do any rework. Portability lets you take one application or instance running on one vendor's implementation and deploy it on another vendor's implementation.

The standards for connecting the computer systems and the software needed to make cloud computing work are not fully defined at present time, leaving many companies to define their own cloud computing technologies. Cloud computing systems offered by companies, like IBM's "Blue Cloud" technologies for example, are based on open standards and open source software which link together computers that are used to deliver Web 2.0 capabilities like mash-ups or mobile commerce.

8.4 Cloud governance and compliance

Governance defines who's responsible for what and the policies and procedures that your people or groups need to follow. Cloud governance requires governing your own infrastructure as well as infrastructure that you don't totally control. Cloud governance has two key components: understanding compliance and risk and business performance goals.

8.5 Data in the cloud

Managing data in the cloud requires data security and privacy, including controls for moving data from point A to point B. It also includes managing data storage and the resources for large-scale data processing.

9. Cloud Storage

Cloud storage is a model of networked enterprise storage where data is stored in virtualized pools of storage which are generally hosted by third parties. Hosting companies operate large data centers, and people who require their data to be hosted buy or lease storage capacity from them. The data center operators, in the background, virtualizes the resources according to the requirements of the customer and expose them as storage pools, which the customers can themselves use to store files or data objects. Physically, the resource may span across multiple servers and multiple locations. The safety of the files depends upon the hosting companies, and on the applications that leverage the cloud storage.

Cloud storage services may be accessed through a web service application programming interface (API) or by applications that utilize the API, such as cloud desktop storage, a cloud storage gateway or Web-based content management systems. Cloud storage is based on highly virtualized infrastructure and has the same characteristics as cloud computing in terms of agility, scalability, elasticity and multi-tenancy, and is available both off-premises (Amazon S3) and on-premises (ViON Capacity Services)

Cloud storage is: [10]

- Made up of many distributed resources, but still acts as one - often referred to as federated storage clouds
- Highly fault tolerant through redundancy and distribution of data
- Highly durable through the creation of versioned copies
- Typically eventually consistent with regard to data replicas.

9.1 Cloud storage Advantages

- Companies need only pay for the storage they actually use, typically an average of consumption during a month. This does not mean that cloud storage is less expensive, only that it incurs operating expenses rather than capital expenses.
- Storage availability and data protection is intrinsic to object storage architecture, so depending on the application, the additional technology, effort and cost to add availability and protection can be eliminated.
- Storage maintenance tasks, such as purchasing additional storage capacity, are offloaded to the responsibility of a service provider.
- Cloud storage provides users with immediate access to a broad range of resources and applications hosted in the infrastructure of another organization via a web service interface.[11]
- Cloud storage can be used for copying virtual machine images from the cloud to on-premise locations or to import a virtual machine image from an on-premise location to the cloud image library. In addition, cloud storage can be used to move virtual machine images between user accounts or between data centers.

10. Conclusion

Businesses are running all kinds of apps in the cloud, like customer relationship management (CRM), HR, accounting, and much more. Some of the world's largest companies moved their applications to the cloud with salesforce.com after rigorously testing the security and reliability of our infrastructure. As cloud computing grows in popularity, thousands of companies are simply rebranding their non-cloud products and services as "cloud computing." The latest innovations in cloud computing are making our business applications even more mobile and collaborative, similar to popular consumer apps like Facebook and Twitter. As consumers, we now expect that the information we care about will be pushed to us in real time, and business applications in the cloud are heading in that direction as well.

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