COMPARATIVE STUDY OF DIFFERENT CLOUD SERVICE PROVIDERS BASED ON COST AND SERVICE AVAILABILITY

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Abstract- Cloud computing is an internet based on-demand technology which offers computing resources to its end users and support various IT business processes. Computing resources are physical infrastructure as a service that includes compute, storage and network etc. It refers to manipulating, configuring and accessing the applications online. In cloud environment, users assume infinite resources are available and pay according to the resources that they use. With the enhancement of technology, cloud service providers increases rapidly and provide new features. But to choose right service provider is very difficult for a cloud customer according to their requirements. In this study, five cloud service providers are discussed i.e. Amazon web services, Google, Rackspace, Microsoft azure, DigitalOcean and provides comparison of these cloud service providers. The cloud service providers were compared on the basis of service availability, cost, pricing model, access interface, customer support, documentation, programming languages, data security, operating system, windows support, free trial, and regions. From the findings of the study concluded that digital ocean cloud offers best cost and Rackspace provides 100% service availability using CloudHarmony benchmark provider.

Keywords- Cloud Computing, Cloud Service Providers, Amazon web services, Microsoft Azure, Rackspace, Google, and DigitalOcean.

I. INTRODUCTION

Cloud computing is a model that provides on-demand access to a shared pool computing resources like servers, networks, application and software access these resources at anywhere, anytime through internet. Cloud computing comprises of two words i.e. cloud and computing. Cloud refers to the internet, datacentre of hardware and software, or we can say that cloud is something that is present at remote location whereas, computing refers to usage or operation of computers. This mechanism of providing computing resources over the internet known as cloud computing [20].
Users have to pay according to the usage of computing resources on the monthly or yearly basis [9]. Cloud computing services are provided by different cloud computing service providers as and when it required. During last few years, tremendous development has been observed in the field of cloud computing and many cloud service providers are there in the market. Some providers focused on CPU, storage, databases, networking etc. while other focused on the reduction of cost. Due to many cloud service providers it is very difficult to choose a right cloud provider according to the customer requirements [7].

The most widely used definition of the cloud computing model is introduced by National Institute of Standards and Technology (NIST) [19] as "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."
Cloud computing is defined as a distributed system, related to a series over interconnected and virtualized computer systems up that is dynamically provisioned or introduced according to more unified computing resource that are primarily based concerning service level agreements [1].

Cloud service providers are the companies that offers network services, infrastructure, platform, software, or business application in the cloud. The cloud services are hosted through cloud provider's data centre that can be accessed by individual or by business customers through internet connectivity. Providers deliver cloud solutions to customers according to the demand of customer [18].

II. LITERATURE REVIEW

Rajkumar buyya et al**.** [1] proposed an architecture for market-oriented resource allocation of resources within clouds. It provides a comparative study of different cloud service providers according to marketing perspectives. It was concluded that end users can select more than one service provider according to their business needs.
C.N. Hofer and G. Karagiannis [2] created a tree-based taxonomy on the basis of key characteristics of service providers that are cost model, development tools, service models, supported languages, virtualization, license type, operating system, payment, security, developed tools, openness to classify the cloud service providers. It was concluded that proposed taxonomy is capable of classifying both current and future needs. Through this taxonomy comparing cloud service providers is more efficient than using table based comparisons.
B.P. Rimal et al. [6] developed taxonomy based on architecture, virtualization mechanism, service provided, mechanism for load balancing, the provider's architecture, programming languages and software, and virtualization mechanism etc. The findings of the study concluded that the proposed taxonomy will provide new ideas to researcher and developer on current cloud system, hype and challenges. In the study, they provided the information to evaluate and improve the existing and new cloud system.
Ang Li et al. [4] developed a tool called "cloudcmp", which is a systematic comparator of the performance and cost of the different cloud service providers and finally the study concluded that cloudcmp represents a first step towards the selection of fast and accurate cloud service provider. It is an end-to-end benchmark suite that serve as a progress card for provider's optimisations.

Shivangi Goel [3] presented a comparative study of various cloud computing service providers, based on parameters like pricing, maximum limit, data security, data backup, languages supported, platform supported. It was concluded that none of the service providers is weak and the user must choose service providers according to their business requirement.
AlexandruIosup et al. [5] proposed a framework "C-Meter", which is used for measuring performance in terms of response time, and wait time in queue of computing clouds. C-meter can also be used for assessing the overhead of acquiring and releasing the virtual computing resources, for evaluating different scheduling algorithms, and for determining the cost of the experiments.
G.Tajadod et al. [7] compared two public cloud providers according to architecture level security and application level security. It was concluded that Microsoft offers a better level of security.
Lipikabose [9] presented some techniques to make decision process for selecting the optimal service provider as per the business requirement. Provides comparative study on the basis of latest information available on websites of cloud providers. The study concludes that no provider is best, all providers provides some solutions with benefits.
M.Palankar et al. [28] evaluated Amazon S3 in terms of availability, performance, throughput and usage costs. Discussed some security features of S3, and the necessary support of storage service to satisfy the requirements of the scientific community and concluded that S3 is not targeting the scientific community and recommend user to use S3 when the costs of providing high data availability and durability are driven up by specialized hardware and needs nontrivial engineering effort.

III. NEED OF STUDY

A key importance of cloud service providers is to provide IT infrastructure and services at low cost. With the advancement of technology many customers are using cloud services, so cloud service providers increasing rapidly. To choose a right service provider is difficult according to the business requirements of a customer. So, comparison of different cloud service providers is important for customers as well as company competitors.

IV. OBJECTIVES OF STUDY

1. To study the basic concept of cloud computing and different cloud service providers.
2. To measure cloud service availability of different cloud service providers using CloudHarmony.
3. To compare and analyze the different cloud service providers on the basis of different parameters used in the study.

V. RESEARCH METHODOLOGY

To achieve the objectives theoretical as well as empirical approach was used. The Theoretical literature study is performed to compare four public cloud service providers that are Amazon AWS, Microsoft Azure, Google cloud, Rackspace and DigitalOcean. The literature survey shall comprised study of books, journals, research papers, thesis, online studies, etc. that helps in the analysis of cloud service providers. Comparison of different cloud providers that are based on cost, pricing model, access interface, customer support, documentation, programming languages, data security, operating system, windows support, free trial, and regions. CloudHarmony benchmark provider are used to measure service availability of cloud service providers.

VI. DIFFERENT CLOUD COMPUTING SERVICE PROVIDERS

6.1 Amazon Web Services

Amazon was launched in 2003 as a retail company providing computing infrastructure. Initially, it delivered Infrastructure-as-a-Service but now Amazon delivers Platform-as-a-Service also [7]. In 2006, Amazon starts with providing IT infrastructure services business in form of web services- now commonly known as cloud computing. Now, AWS provides scalable, reliable, and low-cost infrastructure that powers hundreds of thousands of thousands of business in 190 countries across the world [24]. Amazon mainly provides four kind of products: Compute, Storage, Database and Networking.

Compute

Amazon Elastic compute cloud **(**EC2) is a web service compute tool that provides secure, and dynamic scale compute capacity in the cloud. EC2 provides web service interface to launch and manage the instances based on Microsoft and Linux Operating system servers [14]. Key components of Amazon EC2 is Amazon Machine Images (AMI) that include an image of EC2 instances, its software and configuration that make a boot disk for the user instances [15]. EC2 reduces the time required to obtain and boot new server instances from hours to minutes [14].

Storage

Amazon S3 is a storage tool that provides two types of storage i.e. objects and buckets. Object are used to retrieve any amount of data from anywhere, as well as used to store and retrieve data as objects in buckets. Objects can store minimum 1 byte of data to max. 5GB of size.

Database

Amazon Aurora is a MySQL and PostgreSQL relational database, provides the features of high speed and availability according to commercial databases. Amazon Aurora provides up to five times better performance than MySQL in terms of security, availability, and reliability of a commercial database.

Network and content delivery

Amazon VPC is a section of the AWS Cloud in which a customer of AWS can launch AWS resources in a virtual private network. A customer can have a complete control on virtual networking environment, including selection of an IP address range, create subnets, and configuration of routing tables and network gateways [25], [7], [21].

6.2 Microsoft Azure

Microsoft azure is the main component of Microsoft, infrastructure-as-a-service model, was released in June 2012. As hypervisor tool, it uses Hyper-V. The Windows Azure Platform provides a programming model designed to create scalable applications, it also provides mechanisms to increase and decrease the computing resources of applications and services [25].Microsoft Azure is the cloud services operating system that serves as the development, service hosting, and service management environment for the Azure Services Platform. Windows Azure provides developer's on-demand compute & storage to host, scale, and manage web

applications and services on the internet in Microsoft data centers [26]. Microsoft consist of five components**:** Compute, Storage, Fabric controller, content delivery network, and Connect.

Compute

Microsoft azure compute services executes the application in the cloud. It provide a way to run application on cloud as well as on windows server that are running in Microsoft data center [26]. Azure applications use compute resources through compute containers called roles [25].Roles are of three different types that are used in windows azure i.e. web, worker, and virtual machine. These applications are created using in .NET framework, or some programming languages like C# and visual basic, or built in other languages also [25].

Storage

Windows Azure storage services are designed to be very simple and highly scalable. They provide fundamental services for BLOB storage, queue storage, and simple table storage. We interact with these services through a simple REST API based on HTTP requests, and manipulate data in the storage services through traditional POST, PUT, and DELETE requests, also retrieve information from the storage services using simple GET requests [16]. Storage service supports both structured and unstructured data. Storage component provide integrity, because each storage account has two account keys that use to control access to all data in that storage account, and thus access to the storage keys provides full control over the associated data [25].

Fabric controller

Fabric controller is a part of windows azure platforms for monitoring and managing the servers, provides coordination of resources for software application. Fabric controller is the brain of windows azure services, analyses the processes and make decisions. Fabrics are the group of machines in Microsoft's datacenter that are combined in the form of switch. The group of these machines are called cluster.

Content delivery network

CDN maintains good performance and high bandwidth for delivery of services by caching content at locations closest to customers. Content delivery can deliver content resources including windows software and compute roles. CDN provides availability because, users anywhere around the world can fast access to quality to frequently accessed data [5].

Connect

Windows Azure Connect has a user interface to configure IPsec protected connections between computer and VMs in an organization network [25], [26].

6.3 Google cloud

Google offers the Google App Engine platform as a full integrated solution. Developers use full package to write, link code with services, SDK, development environment other components for hosting and running it as a traditional web applications or mobile applications. Google app engine is also available as a high availability scalable solution on the cloud as PaaS. This solution minimizes the management overhead, which are caused by virtual machine during peak hours. Later, Google decided to enter into the market of IaaS and gave many cloud solutions to all cloud customers. Google cloud allows user to have a control on virtual machine running in cloud that can be accessed through hardware. Google also offers flexible pricing options and discounts. All these features make the Compute Engine of Google the leader of the price/performance competition between the four previously mentioned cloud providers [11].

6.4 Rackspace

Rackspace was started in 2008. It is an American based cloud computing company, infrastructure-as-a-service provider that provides infrastructure, resources, and services to customers. Rackspace support private, hybrid, and multi-cloud. Rackspace private cloud powered by OpenStack, RedHat, VMWare, and Microsoft that provides single-tenant environment with maximum security. Rackspace public cloud provides multi-tenant environment with pay-as-you-go pricing model, dynamic scalability, and for heavy traffic (i.e. unpredictable traffic).

Rackspace is mainly for website customers. Rackspace has fee for cloud storage, compute cycles and bandwidth usage, customer pay for services to Rackspace pay-as-you-go pricing model [10].

6.5 DigitalOcean

DigitalOcean is an American cloud Infrastructure-as-a-service provider. Headquartered in New York City with datacentres worldwide. It provides developers cloud services that helps to deploy and scale applications that run simultaneously on multiple computers. DigitalOcean offers virtual servers (VPS), or droplets, uses KVM as hypervisor. For storage, it provides block, object-based, and kubernetes- based container service [31].

VII. RESULT AND ANALYSIS

Comprehensive metrics for comparing cloud services

Different cloud service providers were compared according to two requirements i.e. functional and non-functional requirement.

Functional requirement describes the core functions of the cloud. **Non-functional requirement,** describes how well a service is executed.

Table 1: General Characteristics of various Cloud Service Providers based on Non-Functional Requirements

Parameters	Feature	Significance	Type
Pricing plan [2]	Pay as you go , subscription	High	Non functional
Free trial [3]	Months	High	Non functional
Access interface [2] [1]	Web- based application, API, Console based, web-based control panel	High	Non functional
Security [4]	Certification, protection	High	Non functional
Availability [4]	Updown and downtime	High	Non functional

In pricing plan, customers can pay for the resources that they used according to two models i.e. through subscription basis, or pay-as-you-go. In Subscription basis, customers can subscribe on hourly or monthly basis. Customer either use resources or not but have to pay for it. But in pay-as-you-go model, customer pay according to resources they use [22]. Some Providers give a free trial to test their services which are extremely helpful for users. The free trial period varies from two weeks to one month. Some providers offer free trials to users based on their nationality. For example, IaaS provider zettagrid provides 30 days free trial to Australian customers only. Some providers like virtual-server.net offer free trail on request, not as a regular option [23]. Access Interface is the end user interface provided to clients for access, configuration and deployment purposes. Windows azure, and Rackspace provide a control panel over the web, while Amazon AWS provide command line interface. Some providers like Google App Engine only provide an application programming interface to developer.

Security is main concern in terms of data, infrastructure, and virtualization. Cloud service providers must ensure their client data and applications are protected. Providers who offer most basic security feature (such as a basic firewall) or no features at all are deemed as poor and those who provide security automaton are considered as excellent [29]. Availability refers to how many time the services will be available [22].

Table 2: General Characteristics based on Functional Requirement

Parameters	Feature	Significance	Type
Customer support [2]	Live chats, documentation, forums,24*7*365 customer support	High	Functional
Regions [5]	Datacentre	High	Functional
Programming languages supported [6][2]	Client side, server side	High	Functional
Operating System and Windows supported [6]	Linux OS, windows OS	High	Functional
Cost [7]	Virtual machines	High	Functional

Cloud service providers provide support to customers through email, online support, white papers, documentation, and through phone call service 24*7*365 [21][10][11] [12]. A good provider should develop applications in many different programming languages, and enable us to deploy these applications on operating system such as windows, Ubuntu, Linux [23].

Table 3: Comparison based on Non-Functional Requirement of Cloud Service Provider

Parameters	Amazon AWS	Microsoft Azure	Google cloud platform	Rackspace	DigitalOcean
Types of Cloud Services [16] [27] [10]	IAAS, PAAS	PAAS,IAAS	PAAS, SAAS	IAAS, SAAS	IAAS
Starting date [25] [10]	2006	2010	2011	2008	2011
Pricing model [2]	Pay as you go, Subscription	Pay as you go, subscription	Pay as you go	Pay as you go	Pay as you go
Free Trial [21] [10] [11]	12 months	12 months	12 months	**	3-days

Data Security [9, 3, 10, 30]	• Encryption feature Such as SSL • AWS, KMS (to manage your encryption keys) • AWS cloud HSM (to generate, store, and manage cryptographic keys)	• Filtering routers • Firewall • Cryptoraphic • Protection of messages. • Software security patch management • Centralized, monitoring ,Correlation, and analysis system	• Google 2 step verification	• Confidentiality • Integrity • Availability of customer data. • Enterprise Firewall. • Email accounts include antivirus and span protection.	• Physical security • Infrastructure security • Access logging • Security monitoring • Droplet security and employee access • Snapshot and backup security
Access Interface [23, 31]	Command line interface	Web-based API, console	API	Web-based control panel	Web interface, doctl command line

Service Availability

Availability means to access services, tools and data at anywhere, anytime with the help of internet. Availability refers to how many time the services will be available. Let's take a 99.99% SLA (service-level-agreement), this means that in a given month (30 days a month), the service will be offline for about 4 minutes and about 50 minutes per year [13], [26]. In the study, benchmark provider CloudHarmony is used to measure service availability.

Table 4: Comparison based on Service Availability

Cloud service providers	SLA	30-days SLA	Service locations
Amazon AWS	99.99%	99.9996	60
Microsoft Azure	99.95%	99.9923%	62
Google Cloud platform	99.95%	100%	61
Rackspace	100%	100%	6
DigitalOcean	99.99%	100%	12

According to service availability, Rackspace provides 100% service availability.

Table 5: Comparison based on Functional Requirement of Cloud Service Provider

Parameters	Amazon AWS	Microsoft Azure	Google cloud platform	Rackspace	Digital ocean
Regions [10] [11] [12] [21][32]	18 geographic region + 1 local region	36	13 + 11 new regions	6 regions	12 regions
Customer support & Documentation [21] [10] [11] [33]	• 24*7*365 customer support • Documentation • White papers • Best Practices Guides • Fourms • E-mail(mon to fri 8:00 am to 6:00 pm)for developer level support • Chat, Phone, E-mail	• 24*7*365 customer support • Documentation • White papers • Support fourms • E-mail & business hours for developers	• Free support is available • 24*7*365 From onsite cloud hosting experts. • White papers • Documentation	• 24x7x365 Live Support and Expertise	• Live support
Programming Languages [9]	• Java • .Net • Node.js • PHP • Python • Ruby • C++	• .Net • Python • Java • PHP • Node.js • Azure REST API'S	• Java • .Net • Node.js • PHP • Python • Ruby	• Java • .Net • PHP • Python • Ruby	• Javascript • Phython • Java • PHP

O.S and Windows support [9]	• Ubuntu • Red hat enterprise Linux & fedora. • SUSE Linux • Cent OS Linux • Microsoft window server 2008. • Microsoft window server 2008 R2. • Microsoft window server 2012. • Microsoft window server 2012 R2. • Microsoft window server 2016	• Window 7 • Microsoft Window server 2008. • Microsoft window vista	• Red hat enterprise linux • Cent OS • Core OS • SUSE • Ubuntu • Free BSD • Microsoft window server 2008 R2 • Microsoft window server 2012 R2 • Microsoft window server 2016 • Debain	• Linux • Mac OS • Windows	• Windows 10 • ubuntu

Cost Comparison

Cost of each cloud provider are calculated according the usage of Virtual Machine. Monthly cost of each Virtual Machine category for each cloud service provider is calculated as the cost of the virtual machine and the cost of the block storage.

Virtual machine were tested according to four categories: small, medium, large and extra-large. Each category contained a pre-requisite allocation of virtual machine resources its virtual CPU, RAM and DISK SIZE in GBs [13].

Table 6: Cost comparison of four cloud service provider with respect to Virtual machine size (CPU, RAM, DISK SIZE) [13, 15, 16, 17]

Cloud service providers	Small (2, 4GB, 100GB)	Medium (4, 8GB, 150 GB)	Large (8, 16GB, 200GB)	Extra-large (16, 32GB, 500 GB)
Amazon AWS	$83.00	$160.27	$310.54	$631.08
Microsoft Azure	$90.19	$163.92	$310.65	$652.02
Google cloud platform	$62.24	$115.98	$214.96	$446.92
Rackspace	$122.27	$219.54	$388.35	$826.70
DigitalOcean	$50	$95	$180	$530

VIII CONCLUSION

This paper provides a comparative study of cloud service providers i.e. Amazon AWS, Microsoft Azure, Google cloud, Rackspace and DigitalOcean on the basis of service availability, cost, pricing plan, free trail, customer support and documentation, access interface, programming language, data security, scalability, operating system. Some providers focused on highly reliable services while other concentrated on reduced billing. Based on results, Rackspace provides 100% service availability, but it is very expensive cloud. Based on cost, digital ocean cloud is cheap provider.

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