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Layers of Cloud – IaaS, PaaS and SaaS: A Survey

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***Abstract* - Cloud computing has become the latest buzzword as this trend has revolutionized the field of computer science to greater heights. This paradigm of computing has bought down the onus of enterprises and end users by providing agility - not only to deploy applications more quickly but also to respond to changes in demand, focus – having people to focus on higher levels of stack rather than worrying about underlying infrastructure, and economics – pricing based on usage as this factor reduces the overall cost. The layers that provides services in cloud computing include infrastructure as the base layer, platform as the interface between applications and hardware and finally the top layer software being the front end with which the users interact. This paper can be regarded as a handout which gives a complete description of the layers. Illustrations corresponding to each layer such as Amazon Web Services (AWS), Google App Engine (GAE) and Microsoft Office 365 are provided for a better picture on the inner workings of the layers. This paper also contains a brief view on the architecture of cloud and deployment models, as it attempts to bring out the functioning of the each layer.**

***Keywords* - Cloud Computing, Amazon Web Services, Google App Engine, and Microsoft Office 365.**

I. INTRODUCTION

Cloud Computing is a new style of computing in which dynamically scalable resources are provided as a pay per use service analogous to electricity distribution in the electrical grid. Prior to this model websites and web-based applications were configured on a single system. With the advent of this technology, the resources were confined together as a virtual computer. The advantages of cloud computing for enterprises are that, the web services offered enable companies to connect and make collaborations possible globally without setting up additional infrastructures like adding servers, datacenters and more. The environment is scalable to accommodate vast number of users. The significant reasons to shift to this paradigm of computing are reduced cost, reduced usage of personnel, robust scalability and so on [1]. This paper is categorized into six sections. Section II, III and IV provides a detailed view on the layers of cloud along with the illustrations for each layer. Section V concludes the paper and section VI contains the references of the paper.

II. INFRASTRUCTURE AS A SERVICE (IaaS)

This is a comprehensive platform which is used by large scale enterprise customers. IaaS provides infrastructure like unlimited storage and computing power for developers without requiring any physical hardware on site. It is the base layer for cloud computing which basically deals with virtual machines, storage, servers, networks, load balancers, and the IaaS cloud providers supply these resources on-demand. Minimal requirements to build IaaS cloud employs: Hypervisor – VMM (Virtual Machine Monitor), and Networking topology – public or private. IaaS mitigates the need for a data center, and maintaining hardware at the local level. Sometimes IaaS is otherwise regarded as Hardware as a Service (HaaS). Examples include Amazon Web Service (AWS), Rackspace, Windows Azure etc.

A. *Amazon Web Services*

AWS is a collection of remote computing services to make up a cloud computing platform [2]. Popular customers that benefit from AWS are Netflix, NASDAQ, SmugMug, Pinterest and wetransfer. Main components in AWS are:

1. AWS Storage Services

AWS Storage Services provide reliable, secure, and inexpensive infrastructure and also allow the users to store and retrieve any amount of data at any time [3].

Amazon Glacier: Amazon Glacier is extremely low cost storage service as it allows the customers to store massive or trivial amounts of data. The cardinal feature of Amazon Glacier is that it provides secure and durable storage of data. With Amazon Glacier, companies need not calculate the requirements and their capacity instead the companies pay only for what they use. One can store any data virtually in any format and Amazon just keeps track of data stored by the customer for billing purposes. Data in Amazon Glacier is stored as an archive and is assigned with a unique archive id and this is used to retrieve data. An individual archive can contain a maximum of 40 terabytes. Amazon allows the clients to utilize vaults to organize data and it is stored as an archive in the vaults of the user's choice [4].

Amazon Simple Storage Service (S3): Amazon S3 is a web service that presents online file storage structure [5]. It can store and retrieve voluminous data through web services interfaces like SOAP, REST and BitTorrent. It manages data with object storage architecture and aims to provide high availability, scalability and inexpensive infrastructure. It plays a vital part in content storage and distribution, backup, archiving, and disaster recovery.

Amazon EBS (Elastic Block Storage): EBS is a virtualized SAN (Storage Area Network).Amazon uses RAID storage for the data to be durable since RAIDs are redundant. As the name stipulates it dispenses raw block devices that can be linked with EC2 instances. The facilitated feature of EBS includes snapshotting and cloning. EBS volumes can be of 1TB in size and uses redundancy technique as these volumes are built on replicated back end storage. EBS volumes are to be used when the user wants the data to change frequently at block level storage. It is also virtualized, so the clients can utilize the allocated storage area and attach it to the servers with interface like API. The customers can use the allocated volume like any physical hard drive and hence it is necessary to attach the volume to an instance [6]. Two types of EBS volumes are Standard Volumes and Provisioned IOPS (Input Output Operations Per Second) volume. These two volumes mentioned above differ in performance and price. The features are multiple volumes can be created on the same instance and the usage of public data sets with the AWS cloud based application which provides effortless access of data sets.

2. *AWS Compute Service:*

Compute services provide resizable compute capacity, automatic parallelization and job scheduling in the cloud.

Amazon Elastic Compute Cloud (EC2): Amazon EC2 is a web service that provides a virtual computing environment through which the user can boot Amazon Machine Image (AMI) which the Amazon calls as an "instance" [7]. AMI is fundamentally a collection of application software, libraries, data, operating system and associated system configuration settings. AMIs can be used to provision multiple instances by using static IP addresses. The instances are provided with persistent storage and can be scaled up or down based on requirement changes.

3. AWS Database Service

AWS provides different databases for the developers and customers to store huge data sets. Users can run their data sets either on fully managed relational and NoSQL databses or can create their own database in Amazon EBS and Amazon EC2.

Amazon Redshift: Amazon Redshift is a petabyte-scale data warehouse service in the cloud. Amazon Redshift uses SQL-based tools for performing queries and launching a Redshift cluster quite easy which ranges from few hundreds of gigabyte to petabyte or more. Amazon Redshift by default creates a database after creation of a cluster. Initial step is to create data warehouse to launch set of compute nodes which is called as Amazon Redshift cluster and this cluster is managed by Amazon Redshift Management Console [8].

Cluster Management:

- As per the requirements of the customer one can utilize small cluster and also can scale the resources either by adding or removing the compute nodes.
- Amazon Redshift allows distributed tables. These distributed tables are similar to concept of distributed processing.

Amazon DynamoDB: Amazon DynamoDB is a fully managed NoSQL database service and it stores data in a structured way. DynamoDB has a single master design and it is different from other databases as it allows the customers to own the service based on the throughput instead of storage. DynamoDB does not scale the resources automatically, it allows the customers to claim the requirements like more throughput and manage the traffic over number of servers using Solid State Drives (SSD). In DynamoDB, tables have no limit and are capable of managing increasing amounts of data without including complex queries [9].

Amazon ElastiCache: Amazon ElastiCache is a web service that makes it facile to manage, operate and scale a distributed in-memory cache environment in the cloud. To begin with ElastiCache users have to create cache cluster and this cluster is meant to be a collection of cache nodes. A cache node is the smallest building block each of which has its own memory, storage and other processor resources, which run on cache engine software like Memcached or Redis [10]. Customers can efficiently customize the cache engine software as they have some parameters to reduce the memory usage. The technique provided by Amazon ElastiCache is In-memory Caching which helps in managing intensive workloads for applications like gaming, social networking etc.

Amazon RDS (Relational Database Services): Amazon RDS is a web service that eliminates the complexity in set up and scales relational databases and it also manages back up, recovery of databases in the cloud. The fundamental building block of Amazon RDS is the DB instance. A DB instance can be created or modified by using either Amazon Management Console or Amazon RDS CLI (Command Line Interface) or Amazon API. The basic information of DB instance like its memory capacity and computation is determined by DB instance class and each DB instance runs on DB engine.

4. Application Service

Amazon Simple Queue Service (SQS): Amazon SQS is a distributed message queuing service. This service is used to store messages, when they are transferred between computers and application components and these are highly scalable. It provides authentication procedures for secure handling of data. Messages are stored on multiple servers for redundancy and to ensure availability. The service supports both unlimited queues and message traffic [11].

III. PLATFORM AS A SERVICE (PaaS)

PaaS provides computing platform which primarily includes resources like operating system, programming language, database, web server that automatically scales to meet the application demands. In this model, developers with proprietary APIs develop an application that will run in a specific environment and further controls software deployment and configuration settings. Thus the app is confined to a particular platform using which it was developed. PaaS reduces the cost and complexity of application deployment by casting off the need to buy and manage the underlying hardware and software and to provision hosting capabilities.

A. Google App Engine

Google App Engine (GAE) is cloud computing platform for developing and managing web applications in Google's infrastructure. Development and maintenance of applications are easy and these applications can be scaled up as the traffic and the storage needs grow. The capitation cost for getting started with GAE is zilch. Infrastructure facilities like servers and its maintenance are not required as the idea is to just upload the application in GAE and it is thus deployed. It provides dynamic web serving, persistent storage, automatic scaling and load balancing. Apps written in several programming languages are supported in GAE [12]. Applications in GAE are sandboxed. Sandbox is a security mechanism for running programs from illegitimate users and websites. This separates the application in a reliable environment which is independent of the operating system and hardware infrastructure [13].

1. Runtime Environment

This is the place where the actual application is executed. When an HTTP request is processed using some interface like web-browser an application is then invoked. The request handler forwards the HTTP request and then the application is immediately deployed by selecting any Google server by GAE. The next step is that the application does some computing and the result is forwarded back by GAE request handler to the client by a HTTP response. Applications can run in one of several runtime environments like sandbox, Go, Java, PHP and Python environment. Each of these environments provides standard protocols and technologies for application development. Only at the time of computation applications will run on selected runtime environments. The type of runtime environment depends on the programming language used by the client

2. Datastore

Usage of relational database for applications results in persistent storage of data – this is used in traditional architecture. But GAE uses a different approach called Bigtable. Different options provided by GAE for data storage are NoSQL – object data store, Cloud SQL – relational SQL DB and Cloud Storage – stored as objects and files and are accessible from Python, PHP and Java applications.

Data sets in GAE are stored as objects or entities which are "schemaless". It uses different methodology to process the queries, they are not processed during runtime rather they are represented with an index which is later used at the time of run time. This technique results in faster access, as it employs only a table scan using the index. A query includes: Entity Kind, Filters, Sort orders. A transaction is nothing but an attempt to insert, delete or update an entity and it is atomic. Multiple actions can be performed by the client on an entity in a single transaction. The Datastore uses optimistic concurrency which handles the situation when two transactions try to update the same entity and the first transaction only succeeds in updating while others fail. Another kind of transaction that is enabled by GAE is Cross Group Transactions, they allow a single transaction been applied to multiple entities. Two phases in which data is written into Datastore are commit phase where the entity is recorded and apply phase where the entity and index rows for data are written.

Features:

- Languages and frameworks to be used - java, PHP, Flask and webapp2
- Applications can be integrated with technologies like – Hadoop, MongoDB etc.
- Built-in services - Task Queue, Memcache
- Development tools - Eclipse, Maven, Jenkins, Get etc. These tools can be used in SDK which provides simulated environment for users to use their apps with desktop launcher.

3. Services

- MEMCACHE - used for temporary storage of data. As the name suggests the data will be stored in memory of servers which leads to faster access of data.
- URL FETCH - used to send a HTTP request to internet servers asynchronously as the request handler can be busy in doing other things. It is necessary for the user to specify a port number. HTTP methods used for fetch are GET, HEAD, DELETE, POST, PUT.
- XMPP - Used for instant messaging and correlated tasks.
- TASK QUEUES - The role of task queues come into play when some applications remain incomplete or could not proceed in correct manner and these are put in task queue which helps in execution of applications.

IV. SOFTWARE AS A SERVICE (SaaS)

SaaS is the top layer and most basic form of cloud computing. It follows multitenant architecture in which all users share a common infrastructure. In this, the software and associated data are deployed and hosted on the internet which is accessed by the user via a web browser. The customer can use the software by using the SaaS provider's license and is subjected to pricing on the basis of pay per use. In this layer a single application with customizable configuration can be used by many customers. The advantage is that it requires zero installation of the software and hardware structures and is capable of being accessible from anywhere with an internet connection.

A. Microsoft Office 365

Office 365 is Microsoft's software offer in cloud computing. It aims to provide small and medium sized organizations with end-to-end services at low cost IT solutions [14]. Using this, clients can virtually connect and collaborate. Customers can efficiently utilize the numerous products and services in Office 365, as they are allowed to create documents and presentation, manage their tasks using calendar, check mails, share their files with others, incorporate social networks for communication, design and create websites, host online meetings, use office web apps and much more. It facilitates the creation of a virtual office, where the clients can work with information securely on the go. This cloud service safeguards the data with disaster recovery, data centers located in multiple places and a strict privacy policy. It further protects the e-mail environment with most recent antivirus and anti-spam solutions [15].

1. SharePoint Online

SharePoint comprises a set of web technologies that helps to create sites to share documents and information with customers and colleagues. The features include:

- Centralizes information and application on a corporate network
- Keep teams in sync by efficiently by sharing and managing major projects.

2. Exchange Online

Microsoft Exchange Online provides email, calendar and contact manager services online. It is a server program that runs on e-mail over globally redundant servers. It protects mailboxes with advanced anti-malware and anti-spam filtering. The features are:

- Provides 50 GB mailboxes and can send messages up to 25MB.
- Data Prevention Loss (DLP) prevents users from mistakenly sending classified documents to unauthorized people.
- Safeguards the data with continuous backup and disaster recovery.
- Automatic patching eliminates the need to maintain and service individual's email system.
- Integration with Outlook provides email access offline.

3. Lync Online

Lync Online is the latest generation cloud communication service with multi-tenant architecture that connects people everywhere virtually at any time. This software runs on Microsoft Lync Server which provides the infrastructure for instant messaging, VOIP, ad-hoc and audio, video and web conferencing.

The features include:

- Real-time communication, availability status and augmented Instant Messaging (IM).
- Create and join audio, video, and web meetings spontaneously.
- Online presentations with screen-sharing and virtual whiteboards.
- Customers can participate in Lync conference calls despite not being Lync Online customers.

4. Office Web Apps

Office Web Apps are convenient web-based versions of Word, Excel, PowerPoint and OneNote that allows users to view, edit and share their documents directly within a Web browser. It allows collaboration with others to prepare presentations, create spreadsheets and documents across platforms and devices.

V. CONCLUSION

In this paper, an overview about cloud computing and its service layers are provided with their respective illustrations. Organizations like Amazon, Google, and Microsoft are providing a prominent platform for users to utilize the enormous power of cloud seamlessly. A major challenge encountered by cloud computing are security concerns over the information stored in the cloud. This fact is nothing new because, everything as a single service makes it much vulnerable for breaching the security and privacy of confidential information stored online. Interoperability is a factor to be integrated in cloud for eradicating the difficulty of users to migrate from one cloud provider to another. Although the there are some obvious factors for some enterprises and end users being tentative in picking up cloud services, it is growing at a rapid phase to become a trustworthy technology in the future.

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