Chapter 2

Cloud Computing Architecture

Simplicity is the ultimate sophistication.
— Leonardo da Vinci
(Italian Painter, Sculptor, Architect and Engineer, 1452-1519)

2.0 INTRODUCTION

In this chapter we will discuss the architectural principles which constitute cloud computing services. Cloud computing requires co-existence and co-working of several technologies and service providers who together make this new model a success. We will understand the roles played by each one of them and the prevalent technologies being used in the cloud computing space. We will also examine the advantages and disadvantages of some of them.

2.1 ARCHITECTURE DEFINED

The term architecture originates from building construction where it refers to the art or practice of designing and constructing buildings. While in ordinary terms it refers to the art form, this term in essence also conveys how the functionality is achieved using common principles. In the world of information technology it
one of the components is not working properly along the access chain, the cloud implementation will fail.

- **Multiple users or multiple tenant application design:** while most discussion happens on the infrastructure aspect of cloud implementation, the application architecture that facilitates multi-user design is called multi-tenant architecture. Having a monolithic application design would create multiple instant and will make cloud implementation less than optimum. Multi-tenancy feature distributes costs across a large pool of users and better sharing of resources leading to lower costs, higher peak time capacity utilization and efficiency. We will discuss about it later in this chapter.

- **Pay as you use:** This refers to the ability to measure (or meter) the usage of cloud based implementation so that a charge out mechanism can be built.

- **Ability to reuse resources** like hardware and software achieved through virtualization, is yet another important feature.

### 2.3 LAYERS OF CLOUD ARCHITECTURE IMPLEMENTATION

Cloud architecture implementation consists of several layers. On top of these layers is the browser running on desktops and mobile devices which a user uses to access applications hosted on the cloud environment. Cloud user uses Cloud services and applications which form the next two layers. These services and applications run on software platforms (e.g. Oracle, SAP, .Net etc) which forms the next layer of the cloud architecture. Further down the architecture comprises of
infrastructure layer having servers, data base, storage, CPU etc. These are shown in figure 2.1

2.4 UNDERSTANDING CLOUD ECOSYSTEM

The cloud computing architecture is implemented through several components and players. We will understand each one of them through figure 2.2 and define their roles and responsibilities.

Users or cloud subscriber: Primarily these are the people who use the cloud services either as SaaS, PaaS or IaaS model.

Brokers: While the actual users may want a service they will (or may) need an intermediary who represents their interest and combines various users requirements into on standardized requirement. For example, a user wants a driving direction but he will have to need an intermediary who understands and provides these requirements or may acts a front end. These could be car companies who sell navigational systems or popular web sites.
The role played by a cloud broker is to act as an intermediary between the cloud provider and the user to make the user transparent from the complexity of the cloud. They play their role as service consumer as well as service provisioner by doing service intermediation, aggregation and service arbitrage. This entity provides intermediary services like identity management, performance reporting, enhanced security and also provides service aggregations such as data integration and movement across various cloud users and providers.

**Service conceptualizer:** These would be people or entity who conceptualize and develop services and present them to users/brokers at a fee. So this person constructs an application and presents to users and brokers. This entity also hosts this service on the cloud environment offered by a cloud service provider.

**Resources Allocator:** It liaises between the users and the cloud service provider. This entity takes care of resources management and guarantees service levels.

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**Fig. 2.2.** Cloud architecture components.
Cloud Provider: The central player amongst all in the cloud ecosystem is called cloud provider who provides cloud services. e.g., are Amazon, Microsoft, IBM or Google. This entity provides and operates computing infrastructure both hardware and software to deliver the cloud services to users through the Internet. The role played by the cloud provider will be different depending upon the type of cloud services such as SaaS, PaaS or IaaS.

1. In case of SaaS the role played by the cloud provider is to take complete ownership of application and infrastructure and make it available to the end-user. In this case the cloud provider would install, maintain and upgrade applications and will ensure uptime, response time and security aspects of the application software. In this case the cloud user has practically no administrative control on the management of application.

2. However, in case of PaaS, the cloud provider limits its responsibility to look after the infrastructure platform. In addition it creates and enables an environment in such a way that the cloud user can develop and deploy its application. The cloud provider creates integrated development environments (IDEs), software development kits (SDKs), and deployment and management tools. While the end-user manages the application parameters and controls the balance responsibility of underlying infrastructure such as OS, storage, network etc are managed by the cloud provider.

3. In the most basic of cloud services i.e., IaaS the cloud provider just manages the hardware, host OS, storage and network and hosting infrastructure. The only services run by the service provider are a set of services such as
virtual machines and virtual network interfaces. The rest of the overlaying layers are run, managed and controlled by the cloud user. The IaaS user has far greater control on software, application and also the OS. The cloud provider’s responsibility includes deployment, combination, management, security, and privacy of the cloud services.

Service request examiner and controller: This person (or an automated system under monitoring of an expert) allocates and reallocates resources based on predefined priority, such as resource availability and criticality.

Pricer: Based on the request type and payment plan this person (or an automated system under monitoring of an expert) does the pricing and accounts for usage.

VM Monitor: Virtual machine (VM) monitor looks after the virtual machines and their availability.

The other players in cloud ecosystem are as follows:
• The cloud carrier provides connectivity between the cloud services users and devices such as desktop computers, laptops, mobile phones, I-phone, I-pad etc.
• Load dispatcher is a system that accepts service requests and allocates virtual machines as required.
• Monitor of services (MOS) compares the performance levels of services with the agreed service levels.
• Cloud auditors are independent agencies that check cloud service control, verify adherence to standards and examine areas such as privacy and performance levels. The role played by a cloud auditor is to conduct security audit including privacy impact and performance assessment. Use of cloud auditors is necessary to minimize
disputes between the users and the providers and also to recognise weak areas. Usually these are objective agencies set up by the standards organizations aided or supported by the government bodies. Like credit rating agencies who specify the reliability of the investment proposals (such as mutual funds) or other agencies who specify fire safety standards of buildings, the need of cloud auditors is necessary. Such a third party agency can make periodic checks if the data backups are being taken, data archives are being maintained, data privacy or encryption are being done or other controls are being enforced.

2.5 CLOUD ARCHITECTURAL COMPONENTS

Cloud computing architecture comprises two main components, front-end and the back-end.

- The part which is visible to the end-user is called the front-end. This comprises the desktop or any other end-user device (mobile phone, I-pad etc.), browser and network.
- The remaining part of the cloud computing architecture is hidden behind the network that comprises various applications, software, computers and data storage devices.

Cloud architecture encompasses a variety of systems and technologies as well as service and deployment models, and business models. It is mix of three sub-architectures, viz., business, technical and operational. As we have seen
the architecture designs the sub-elements and their interfaces with each other to achieve the end objectives, these subdivisions together complete the cloud architecture.

- **Business architecture** designs the business aspects of the cloud services covering pricing, service contract, and cost models. It also entails the business model and its communication to various stakeholders.

- **Technical architecture** details out the design of various cloud components. It covers amongst others which cloud platform to adopt, creating a structure of various cloud components showing relationships, choice of middleware and security considerations.

- **Operational architecture** covers operational feasibility, network availability, legal issues related with location of hosting of data, monitoring of operational performance.

Figure 2.2 shows various clouds architecture components and their relationship.

**Management of cloud** includes activities such as event management, configuration and compliance, provisioning of resources, workload balancing and service integration.

**Security of cloud** includes features such as identity and access management, data encryption, segregation between the users and protection, VM isolation, secure VM migration, virtual network isolation, security intelligence and software, platform, and infrastructure security and security event and access monitoring. Security ensures:

- Access authentication and authorization
- Ensuring uninterrupted availability
- Maintaining client confidentiality
- Subscriber identity management
an agile cloud infrastructure which is designed for quick access of security features enabled virtual server environments. This can be used for development, test as well for web hosting, developing application pilot, running statistical model and conducting research activities. This is an infrastructure as a service (IaaS) cloud offering. This provides features such as:

- Software licensing options by choosing from cloud asset catalogue containing wide range of ready-to-deploy software.
- Flexibility to deploy open source software or other owned licensed software on cloud virtual machines.
- Choose and use appropriate workloads (software products and services).
- Users can configure their x86 servers and storage in the cloud.
- User can set up a global, private or public, enterprise web file sharing system.
- Facility to use virtual private networks, firewalls and filtering of network traffic.
- Ability to create user configured platform-as-a-service and software-as-a-service offerings.
- Delivers at least 99.5 per cent availability.

IBM cloud offers all services across planning, design and implementation and operations of cloud services.

- **IBM Cloud Planning** services include cloud readiness assessment, ROI and migration strategies. In addition it will help enterprises to assess and build a security roadmap with IBM Professional Security Services.

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• After planning, IBM can help in **building cloud platform** using IBM SmartCloud Enterprise. IBM Cloud Service Provider Platform (CSP2) accelerates and simplifies deployment of a complete cloud services environment.

• Finally, the cloud hosted applications can be accessed through **IBM cloud delivery platform** which in addition gives on-line collaboration tools for file sharing, web conferencing and instant messaging with IBM LotusLive™ Collaboration Suite. IBM Information Protection Services allows backup of data and integration of applications with Cast Iron Systems.  

• IBM also offers IBM CloudBurst 2.1™ solution using IBM BladeCenter® platform which expands core service management capabilities across hardware, middleware and applications.

• Other services offered by IBM on cloud are:
  • Business continuity and resiliency services (BCRS) and BCRS information protection services.
  • IBM vulnerability management services to assess vulnerability, its remediation, and customizable reporting.
  • IBM managed email and web security to protect from spam, viruses, worms, spyware, and unwanted content for hosted email.

**IBM Cloud Implementation**

IBM cloud environment is supported through three building blocks, virtualisation, service delivery manager and Tivoli automated monitoring. We will explain each one of them in the following section.

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6 Some of the terminologies used are IBM trade mark protected ones.  
7 [http://www-935.ibm.com/services/in/gts/cloud/workload-solution/] accessed 14012012
• Availability of virtualized infrastructure: This includes virtualized server, storage, application infrastructure and networking virtualization services.

• IBM Service Delivery Manager is a self-service portal for users to reserve resources (hardware, software and network) in an automated provisioning and de-provisioning mode. The users can also monitor cloud resources and see how the usage and accounting chargeback is being done.

• IBM Tivoli® Service Automation Manager feature helps the users to request, deploy, monitor and manage cloud computing services. Advantages claimed by IBM are reduced skill requirements and faster deployment. This also has IBM CloudBurst™ capability to provide extension of private cloud and integrates with IBM WebSphere® CloudBurst. It supports Linux operating systems supported and its NetApp Storage Extension helps entire life cycle of (StaaS - Storage as a Service) and management of file systems with VMWare virtual machines.

2.8 AMAZON ELASTIC COMPUTE CLOUD (EC2)

Amazon Elastic Compute Cloud (EC2) offerings of cloud includes a web service which can be expanded on demand and computing capacity can be built to host different software systems. Thus it helps the software designer to easily make web-scale computing and they can create, launch, and terminate server instances as needed. Since they can pay hourly rate to active servers this is called Elastic Compute.

8 http://aws.amazon.com/ec2/ accessed 14012012
scalable non-relational data store that offloads the work of database administration. SimpleDB helps in creating geographically dispersed data automatically to facilitate high availability and data durability. The charges of this service are only for the amount of data stored or computing power consumed for query, read or write.

Access of various user instances are facilitated through assigning two addresses—a private and a public IP address. For example, a replacement instance will have a different public IP address. Amazon EC2 also offers Elastic IP addresses (static IP addresses) for dynamic cloud computing.

Amazon EC2 offers other features such as load distribution, load balancing and cloud monitoring tools. It also provides API for starting computing instances with any of the operating systems supported.

2.9 MICROSOFT WINDOWS AZURE

Microsoft also offers a cloud platform in the name of Window Azure. This is a development, hosting, and management environment and facilitates enterprise-level on-demand computing capacity, such as computing power and storage on-request for a cost. For using Azure Cloud features one needs to use Azure API.

Windows Azure is hosted in Microsoft data centre and provides OS, development tools to build web based applications which can also have interface with local devices. These applications can be developed using Visual Studio development environment and the .NET Framework. It also supports multiple Internet protocols, including HTTP, REST, SOAP, and plain XML. Its various supporting components are as follows:

- SQL Azure gives Microsoft SQL Server capabilities for cloud based application to store

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9 For more details refer to http://www.azurepilot.com/ accessed 14012012
structured, semi-structured, and unstructured data.

- Windows Azure Marketplace is an online marketplace for application developers to buy and sell code, components, training, service templates, and many other features that are needed for developing Windows Azure applications.
- Windows Azure Services helps in collaboration across organizational boundaries by maintaining security across domains with simplicity. It gives authentication and access control features using powerful, secure, standards-based infrastructure.
- Windows Azure HPC Scheduler gives modules and features to launch and manage high-performance computing (HPC) applications within a Windows Azure service.

### 2.10 GOOGLE APP ENGINE

Google App Engine enables development environment for developers to design, develop and deploy Java and Python-based applications in Java, Go and Python environment.

It promises same reliability, availability and scalability at par with its own applications.

Interface is software programming based. It also provides comprehensive programming platform irrespective of the size (small or large) for its users. Some of the useful features include range of templates and appspot, excellent monitoring and management console for cloud based applications.

### 2.11 ACADEMIC AND COMMUNITY CLOUD INITIATIVES

We have discussed about community cloud to define
facilitated through large computing capabilities using multi-core servers and storage, large bandwidth and virtualization.

All this led to the development and need of high powered computing such as data mining, searching information across web pages (Google, Bing and Ask). In the current knowledge economy data is an important asset to any organization. By churning huge data bases new knowledge can be discovered and that need an expandable, as required capacities. In addition newer programming models, and supporting algorithms and data structures are needed to search this maze of data of various types.

**Google File System**: It was created to address massive data search of write once and read many (WORM) data typically found in web pages. Google developed MapReduce operation run on a special file system called Google File System (GFS) which is highly optimized for this purpose. Data contained on the Internet pages are very large in number. The average number of the Internet pages cross peta scale. This data is different from traditional business data stored on enterprise servers. They are not “write once and read many times” as in enterprise systems. Here the data changes is fast, is volatile and grows. In order to address searching this large data Google created its Google file system (GFS). Google MapReduce algorithm run on this optimized file system. GFS usage Map reduce algorithm which is explained in the subsequent section.

However GFS is not open source.

**Google MapReduce**\(^\text{10}\) is a programming model used by Google for processing large amount of data while performing the web based searches. Google is known

AJAX uses a combination of XMLHttpRequest object JavaScript/DOM (to display/interact with the information), CSS (to style the data) and XML (often used as the format for transferring data). AJAX applications are browser and platform independent and therefore can be used in any application effectively. One good example of AJAX is Google Suggest which uses AJAX, send the letters being types in Google tool bar through a JavaScript to a server and the server returns a list of suggestions.

Mashup application uses and combines data, presentation or functionality from two or more sources to create new services. This became popular to describe combined features or functions of more than one website with another. General-purpose functionality Mashups are likely to be promoted by market-leading web development companies such as Google. The term implies easy, fast integration, frequently using open APIs and data sources to produce enriched results that were not necessarily the only reasons for producing the raw source data.

SUMMARY

In this chapter we discussed the architectural principles which constitute cloud computing services. We defined the essential features of cloud architecture which are flexible, scalable, standard, reliable, using open source products, interoperable with wider variety of infrastructure and facilitating multiple users or multiple tenant application design. Cloud architecture also facilitates pay as you use features and ability to reuse resources.

We then described the various layers of cloud architecture implementation and developed the understanding of cloud ecosystem covering various