

Cloud Computing Simplified

Explore Application of Cloud, Cloud Deployment Models, Service Models and Mobile Cloud Computing

SURBHI RASTOGI



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*Explore Application of Cloud,
Cloud Deployment Models, Service
Models and Mobile Cloud Computing*

Surbhi Rastogi



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Preface

Cloud computing is a modern-day technology that provides you with an online infrastructure and services to fulfil the needs and demands of the business and organizations. It offers robust innovative technology which provides scalable, convenient, on-demand and pay-per-use access to a pool of resources and services. Cloud computing provides users with a vast number of services, which covers the basics of storage, networking and processing powers and office applications. It greatly impacts our real life in many ways.

This book is an effort to make the reader understand the basics of cloud computing in a simple, lucid way. This book has been designed keeping in mind the requirements of students studying in various educational programs at the college level. This book will serve as a text book on cloud computing for them. This book includes a comprehensive coverage of various topics related to cloud computing technology.

The book has been divided into four sections comprising a total of 12 chapters. Section I consists of the basics of cloud computing, which is necessary to understand the foundation of cloud computing technology. Section II acquaints the reader with cloud service models and deployment models. Each model represents a different part of cloud computing stack. Different cloud service models and deployment models are available that are helpful in fulfilling needs of the user.

Section III introduces the reader to virtualization technology. Virtualization is the foundation of cloud computing. It revolutionized the way same resources can be used in more than one organization. Part IV describes various advanced concepts of cloud computing. It includes cloud management, data storage and security, cloud operations, technologies, cloud service providers, cloud cube model, and mobile cloud computing.

Over the 12 chapters in this book, you will learn the following:

Chapter 1 includes a discussion regarding basics of cloud computing. It includes the significance of cloud computing along with its characteristics, advantages, and disadvantages. This chapter also introduces readers to cloud service models and deployment models.

Chapter 2 provides a detailed description of cloud architecture and applications with diagrams and examples. This chapter describes real-life applications of cloud computing.

Chapter 3 introduces readers with the concept of scalability and redundancy in the field of cloud computing. These features of cloud computing technology are very essential for tremendous growth of any organization or business.

Chapter 4 includes the concept of cloud service models. This chapter discusses various types of cloud service models along with their pros and cons.

Chapter 5 explores the various features related to cloud deployment models. It includes types of deployment models along with their advantages and disadvantages.

Chapter 6 introduces a key technology called virtualization, which play a major role in cloud computing. This chapter discusses the various types of virtualization.

Chapter 7 describes the cloud management, that is, it tells how various cloud services and products are managed.

Chapter 8 provides a detailed description about cloud storage and security. Both the tasks are crucial and primary concern for all service providers.

Chapter 9 introduces readers to various cloud operations and challenges that are faced during cloud computing.

Chapter 10 discusses various cloud technologies and service providers. This chapter gives a brief outline of various cloud technologies available in the market. It also discusses various prominent cloud vendors.

Chapter 11 gives a brief outline of the cloud cube model.

Chapter 12 explores the concept of mobile cloud computing. It discusses the role mobile phones in the growth of usage of cloud computing.

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CHAPTER 1

Overview of Cloud Computing

In this chapter, we will explore the meaning of and various concepts related to cloud computing. We will also discuss its history, characteristics, advantages, disadvantages, and cloud service models including a brief description of SaaS, PaaS and IaaS. This chapter also deals with an overview of various cloud computing models. At the end of the chapter, we will have a look at various companies that provide a range of cloud services.

Structure

In this chapter, we will discuss the following topics:

- Introduction to cloud computing
- What is cloud computing?
- History of cloud computing
- Characteristics of cloud computing
- Advantages of cloud computing
- Disadvantages of cloud computing
- Cloud service models
- Cloud computing deployment models

- Cloud computing companies
- Conclusion
- Questions and exercises

Objectives

After studying this unit, you will be able to:

- Understand the meaning of cloud computing
- Know from where the concept of cloud computing came from
- Gain knowledge of the various characteristics as well as the pros and cons of cloud computing
- Discuss various cloud service models and deployment models
- Know about companies providing cloud computing services

Introduction to cloud computing

To begin with cloud computing, let's take the example of a person named Saurish who owns a small business company. He has 20 employees in his company. These people perform different jobs such as accounting, taxation, etc. To do all this work, they need desks, chairs, computers, services for databases, software, backup system, servers, network to keep themselves connected, and of course, they need to be connected to their clients. Apart from this, Saurish needs an IT employee to install this set up, troubleshoot the problems, and maintain the safety and security of data. Now, as the company grows, Saurish needs to indulge in more employees, more space to accommodate people and data, and more data to secure, hence resulting in more risks and threats.

No doubt, this creates burden and stress for Saurish. He has to manage the availability of resources for all the people, provide them the access, and that too on time. He needs a large set up of IT infrastructure which will considerably result in spending a huge amount of money. To get rid of all these problems, the idea of cloud computing arose. With this technique, he can store all these things at a safe and secure place named as cloud. He can simply access all these things with the help of a web browser. All his company's work, including applications, media, and data can be saved on the internet and he can access all services including hardware, software, databases, networking, and applications over the internet whenever he requires. He doesn't have to care about the location of the hardware, software, and their working. He can access a shared pool of computing resources from anywhere and at any time. Moreover, he needs to pay only for those resources that he uses. Hence, this reduces a large amount of expenditure to a low amount by reducing the IT infrastructure cost.

Cloud computing is the latest generation technology that is designed to deliver services over the network or internet. In simple words, cloud computing is the process of storing and accessing all types of data including music, files, documents, videos, photos, etc. on the internet instead of your local disk or any other form of storage device. One can access services like applications, tools, and storage space rather than physically having all those services at the user's end. With this technique, one can store the data and program on the internet instead of the hard disk and can access from anywhere with the help of an internet connection. Every user is provided with a user ID and password to access data through cloud computing. Services offered by a cloud are available on demand and are sometimes free or bought on "pay-per-use" basis. By the term "pay-per-use," we mean that users or organizations have to pay for only those resources that they use. Hence, this it contributes to the idea of low expenditure also. You need not invest a huge amount of money to access cloud services.

What is cloud computing?

Cloud computing refers to the availability of an IT infrastructure and services like development platform, hard disk, computing power, software application, and database over the internet on an "on-demand" and "pay-per-use" basis.

The following figure shows a graphical illustration of cloud computing:

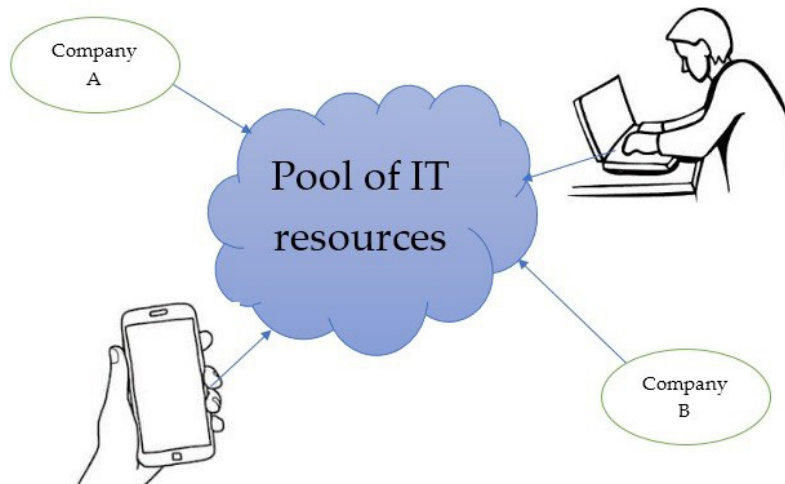


Figure 1.1: Cloud computing idea

We can easily connect to a cloud system using a laptop, computer, or mobile. Companies like Google, Oracle, Amazon, Microsoft, etc. provide us with the facility of cloud computing. These companies are solely responsible for the management of the cloud computing. They keep on updating and modifying their services which improves the accessing speed for data, the capacity of servers, and the quality of their services. They have ample amount of storage for data and fast processing of servers because of which, the user can access data quickly from anywhere at a high speed with just the help of an internet connection. The user does not need to bother about the details and can perform his/her job perfectly and sincerely.

Some examples of applications that use cloud computing from our daily life are as follows:

- While using e-mail, our data gets stored on the cloud server of the e-mail providers and not on our computer. We can access our e-mails from any computer and other devices connected to the internet.
- All pictures and videos that we post on Facebook get stored on the cloud system of Facebook.
- Videos that we watch on YouTube are stored on the cloud system. This is the reason that we can watch them anytime and anywhere.
- All digital photos stored on sites like Picasa and Flickr are actually stored on the cloud servers of these sites.
- Google Docs is also an example of a cloud service. With it, users can upload documents, spreadsheets, and presentations to Google's data servers and edit them using the Google application.

History of cloud computing

When we talk about cloud computing, it seems that it is a matter of the new generation that came into picture just a few years ago. However, this technique actually roots back to 60 years ago. In the 1950s, all organizations used to work on mainframe computers to process their data. At that time, mainframe computers were huge and expensive too. The idea of linking different computers at various places for scientific and military purposes was also developed at that time.

American scientist John McCarthy created the theory of a time-sharing system where time is allotted to each user of a group to access resources. In the middle of 1960, an American computer scientist named J.C.R. Licklider came up with the idea for an interconnected system of computers. This idea proved to be a boon to the world of technology. In 1961, John McCarthy, who coined the term AI (artificial intelligence), suggested that computing will be sold as a utility like electricity or water one day.

In 1969, Licklider's revolutionary idea helped Bob Taylor and Larry Roberts develop the concept of ARPANET (Advanced Research Project Agency Network). ARPANET was termed as the predecessor of the internet. It was the first network that could share information among different computers that were physically apart. This concept is the basis of cloud computing as it gives the picture of an interconnected world with the ability to access programs and data.

Following ARPANET, researchers began to assemble the network of networks which developed into the modern internet. In 1990, the computer scientist Tim Berners Lee invented the World Wide Web and the online internet was visible to all. He introduced the concept of hypertext documents. Then, data could be made accessible from any node on the network. With this, millions of machines were connected to the internet. By this time, e-commerce also started gaining popularity. The client-server model of computing was implemented.

Client-server computing is a type of computing in which all data and software applications reside on the server side. If a user wants to access any application or data, he needs to connect to the server, gain access, and perform his task. Then the concept of distributed computing came into picture. It is the process in which all the computers are networked together and resources are shared as per the requirement. Websites act as the front end for users and the servers on the WWW host the backend logic.

In 1997, Professor Ramnath Chellappa from Emory University delivered a lecture and mentioned the term "cloud computing" in his lecture. He is credited for being the person who coined the term cloud computing. Although at this time, the grid computing technique was very popular as it provides the access of grid-networked resources of organizations across continents, the problem was that non-specialist users or developers still did not have access to resources.

In 1999, the launch of salesforce.com became a major milestone in the history of cloud computing. It was the first company to offer business applications over the internet via the cloud, now known as software-as-a-service (SaaS). After that, in 2002, Amazon launched its Amazon Web Service (AWS). This was a platform designed to deliver cloud computing services including storage and computing power to customers. Then in 2006, Amazon launches their commercial web service named EC2 (Elastic Compute Cloud). It was a web service that allowed small organizations and individuals to rent computers on which they could run their own applications. EC2 became the basis for the emergence of web-scale businesses like Spotify, Uber, and Netflix.

In 2009, Google Apps was launched to deliver cloud services. It was available on both mobiles and the web. In 2010, Microsoft also entered the cloud arena with the launch of its cloud platform, Azure. Following this, IBM launched SmartCloud in 2011 to provide cloud computing business applications. Other companies like HP

and Oracle also joined the race to offer their services in cloud computing for fulfilling the need for greater storage.

Characteristics of cloud computing

Cloud computing is the need of the hour. It is becoming more and more popular day by day. Various companies are providing cloud computing services to store data along with unique characteristics. According to NIST, cloud computing is a model for enabling ubiquitous, convenient, and on-demand network access to a shared pool of configurable resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. The major characteristics of cloud computing model are given below.

On-demand self-service

It is one of the important and usable features of cloud computing. The cloud computing services does not require any human administrator. All computing services like storage, applications, networking, etc. can be accessed whenever required and without any interaction with service providers. Users or organizations can use the web self-service portal to access the required resources. Using this interface, they can also access their cloud account and have a look at the list of services and storage allotted to them.

Broad network access

All computing resources offered by cloud servers are available over the network and users can access them from anywhere and at anytime with the help of their devices and internet connection.

Resource pooling

In order to serve multiple customers, service providers create a pool of various physical as well as virtual computing resources. This pool should be large and flexible enough to meet all the requirements of multiple clients. These resources can be assigned and reassigned on the customer's demand. Customers generally don't have any knowledge or control over the exact physical location of the resources provided to them. But they have the capability to specify a location at a higher level of abstraction.

Rapid elasticity

It is one of the key features of cloud computing. In cloud computing, computing services can be elastically provisioned or released. This means that cloud computing

has the ability to assign resources when they are in need by the customers and remove them when they don't need them. Hence, whenever a user requires a service, it is provided to him and it is scaled out as soon as its requirement is over.

Computing services should have IT resources that can be scaled out and in quickly and on a need basis, so that they can be automatically provisioned and released. The usage, capacity, and cost can be scaled up or down with no additional contract or penalty.

Measured service

Cloud computing is based on the pay-per-use principle. Users are charged for the resources that they use. Hence, the cost is variable and is based on the consumption of resources. A cloud system leverages a metering capability to measure the resources used. All usage, that is, the amount of data transferred, the amount of storage space used etc. is measured. This measurement is also helpful for service providers in allocating resources to the customers in the best possible way. The resources usage is monitored, controlled, and reported. This maintains transparency for customers and providers.

Multi-tenancy

Cloud computing supports a multi-tenant model. By multi-tenancy, we mean that multiple customers can share the same resource or application while maintaining privacy and security. With this, only one server instance can run among a large number of customers and updates can be deployed to them easily. This is also cost efficient.

Advantages of cloud computing

Cloud computing is very popular among businesses as it provides efficiency, saves time and money, provides a platform for innovation, and has many more benefits. By using a cloud solution for your business, you can protect it from many problems. Let us discuss the benefits that a cloud system can provide to your business.

Economical

One of the biggest benefits of cloud computing is that you don't need to invest a large sum of money to buy IT infrastructure. Moving to cloud computing provides access to various computing resources at a low cost. You don't need to buy and maintain expensive infrastructure, hardware, facilities, or invest money to recruit an expert staff and IT team to manage the set up. There are no administrative, operational, and upfront costs. Your business can grow efficiently with the help of cloud computing.

Unlimited storage capacity and universal access

Cloud service providers provide you with ample amount of storage capacity to store your data. You can expand your storage capacity whenever you require. Cloud computing enables you to work and gain access from anywhere, that is, it provides universal access to your data. Uploading data to a cloud system corresponds to accessibility from any computer or device with just an internet connection.

Scaling

Scaling means the ability to increase or decrease the IT resources in your business infrastructure to meet the business demands. It is the major advantage of cloud computing. With this feature, a business can increase or decrease performance, functionalities, and resources as per the requirements. Scaling out and scaling in of IT resources as per the demand is the major reason for the popularity of cloud computing in the market.

Redundancy

Redundancy means to create duplicates. In cloud systems, various copies of our data are maintained by service providers on different machines so as to provide universal access and recovery of data in case any failure occurs at any data center or the data from one machine gets lost. It is a major benefit of cloud computing. The redundancy feature of cloud storage provides you with the facility of automatic data backups and access from any device at any time and any place.

Increased security and reliability

Data theft is a major concern for all organizations. Storing data in a cloud system helps you to secure the data. It provides the measures to protect your data and ensure the safety of the data. It protects your business from internal threats, guards you against internal threats, and prevents data loss.

Ensures backup and recovery of data

Storing data in cloud systems offers the feature of high availability. Because of this feature, you can recover your data as it is always available on many machines. If in any case, data on one machine gets lost or your phone gets damaged, you can easily retrieve the required data. Cloud based services provide quick recovery in any type of failure.

Disadvantages of cloud computing

Every technique has positive and negative impacts. The same goes for cloud computing. Although cloud computing is very popular among enterprises, it still has some issues. Let us discuss them here.

Internet connection

Cloud computing resources can be accessed only with the help of an internet connection. If you do not have an internet connection or the speed is slow, then you will not be able to access the cloud. There is no other way of accessing than to access the applications, software, and resources on the cloud. So, you are basically dependent on the quality of the internet connection to access the tools available on the cloud.

Security issues

Although cloud service providers provide us a great level of security. Sharing our data on cloud systems may be risky sometimes as it may provide a way for hackers to steal the information. The presence of data on the cloud may allow hackers to find loopholes in the framework and can hence be dangerous for the security of our information. Data stored on the cloud system is always a security challenge for service providers and a concern for businesses.

Downtime

Downtime is the worst disadvantage of cloud computing. Downtime means the time during which a machine or computer is out of use or not available. This may happen due to overload of traffic on servers from various clients and service providers may encounter technical problems. This may lead to a temporary downtime in cloud services. This may affect your business. Moreover, cloud systems are internet-based which means that if your internet speed is down, you will not be able to access resources stored on clouds. Similarly, the internet speed of a cloud provider, the demand for service maintenance, etc. also need to be considered.

Cloud service models

Cloud service models are the reference models on which cloud computing is based. These are the ways to describe how you can use the cloud for your business. These models are arranged in a pyramid form and can be categorized into three basic models:

- **SaaS (software as a service)**

- **PaaS (platform as a service)**
- **IaaS (infrastructure as a service)**

Cloud computing offers a range of services based on these three models. Each of the cloud models has a different set of benefits. These models are appropriate for different types of businesses. By understanding the pros and cons of each model, you can determine whether it suits your business or not. We can understand the concept of these models with the help of an example:

Taking a cab to go from one place to another is like SaaS (using applications on rent). When you call for a cab and drive it yourself to go from one place to another, it is like PaaS (All parts are already assembled and provided to you as a single unit and you can work in an easier way). This means that you have a car in which all the pieces are already assembled so that it can function properly and you just use it for some purpose. When you are given the parts of a car and you can make your own design, it is like IaaS (Building your own platform using tools and resources given by a vendor).

Let us discuss these cloud services briefly.

Software as a service (SaaS)

SaaS or software as a service is a service model that offers application software to users on demand. As it is an on-demand service, this model is also known as on-demand software. This service is platform-independent and you don't need to install the software on your PC. You can access the software from anywhere, i.e., from any device and anytime with the help of an internet connection. This service is accessible via a web browser. Everything is available online and you can access it online by logging into your account. The cloud runs a single instance of software which makes it available for multiple end-users. This service is cheap as all computing resources are managed by vendors. Organizations or businesses do not purchase software applications or hardware to support them. Rather, they pay for this service in the form of a subscription fee on a monthly basis or annual basis. So, the SaaS model basically provides the following services to the end user:

- **Applications:** Packaged software
- **Platform:** OS and Middleware
- **Infrastructure:** Servers, storage, network, security

SaaS provides services for various business applications including **customer relationship manager (CRM)**, **human resource management (HRM)**, financial management, database management, sales management, **enterprise resource planning (ERP)**, billing/payroll processing, document editing and management, email, and collaboration. SaaS applications provide a business with stronger network security

and greater collaboration. SaaS applications are used by IT professionals, business users, and small-scale businesses. SaaS applications are useful for those businesses or companies that require frequent collaboration on their projects. The leading SaaS providers are HubSpot, Google, Adobe, Shopify, Microsoft, Salesforce, etc.

Google Docs is an example of a SaaS application that delivers the basic automation capabilities. It also provides support for collaborative editing over the web. Similarly, Office 365, which is an online version of MS office suite, is also a SaaS application. Gmail and Netflix are also SaaS computing services.

Platform as a service (PaaS)

As the name suggests, PaaS or platform as a service provides a platform for developing different business applications. It is one of the service models in which service providers or vendors provide hardware and software to create, test, run and manage the applications required by organizations or businesses. This service is useful for developers. PaaS vendors provide all computing resources like server-side components and support for multiple programming languages. Due to these features, developers can focus on writing the code for different applications for various projects and run them directly on the PaaS layer. There is no need to worry about the infrastructure. Your PaaS vendor manages and delivers the entire platform structure. The underlying architecture including operating systems, storage, servers etc. is controlled by vendors and not by clients. The PaaS model comprises of the following services:

- **Platform:** OS and Middleware
- **Infrastructure:** Servers, Storage, Network, Security

PaaS simplifies the process of application development and hence, saves time and operational costs. Examples of PaaS include Google App engine, Microsoft Azure, Red Hat's OpenShift Platform, and OpenStack.

Infrastructure as a service (IaaS)

IaaS or infrastructure as a service is a cloud service model which provides pay-as-you-go or pay-per-use access to all computing resources like storage, database, servers and networking. Users don't have to deal with expenses incurred in buying and maintaining physical servers and other data center resources. Here, in this service, businesses and organizations rely on the vendor's infrastructure to build software applications on their own platforms. This simply means that the IaaS manages the infrastructure and organizations can purchase, install, configure, and manage their own software. Businesses or organizations can purchase IaaS services based on the consumption just like electricity or water supply billing. Briefly, the IaaS model provides the following services to businesses or organizations:

- Servers
- Storage
- Network
- Security

Infrastructure services are scalable, that is, you can scale in resources when needed and scale out when not in demand. Each resource is a separate entity and you can demand for the required entity and pay for that one only. Users can access these resources and services using a wide area network like the internet.

This is very popular among organizations as it is easier, faster, and cost-efficient to work on projects without needing to worry about buying and maintaining the underlying infrastructure. IaaS offerings to business include test and development, website hosting, storage, backup and recovery, and web apps.

IaaS examples are **Amazon Web Services (AWS)** and **Google Compute Engine (GCE)**.

Let us have a look at the overview of all three services with the help of the figure given below:

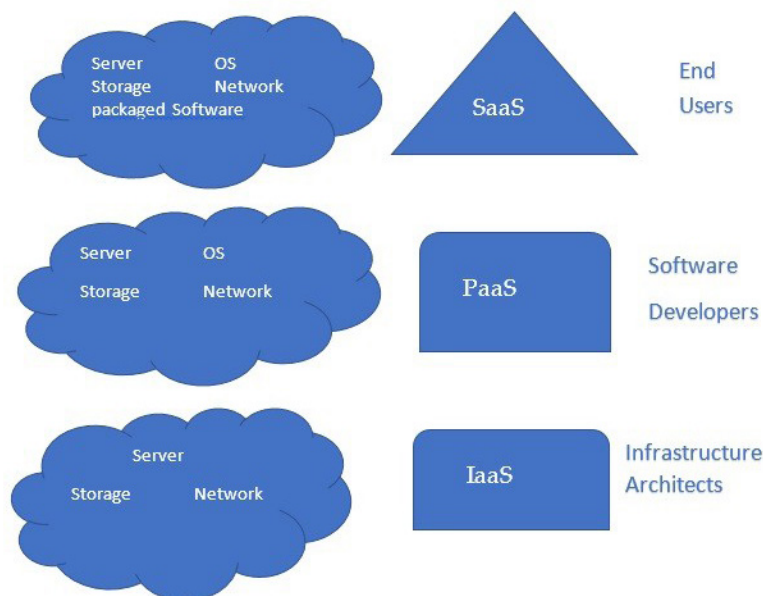


Figure 1.2: Figure representing overview of three service models

Apart from these models, cloud computing offers two more services to businesses and organizations. These services are **NaaS (network as a Service)** and **IdaaS (identity as a service)**. The NaaS service provides businesses with network services

virtually over the internet on the subscription or pay-per-use basis. NaaS providers manage and maintain network infrastructure, thereby making the work of users easier. IaaS provides identity and access management services over the cloud on a subscription basis. IaaS services include directory services, registration information, authentication services, profile management, and sign-on services.

Cloud computing deployment models

Cloud computing deployment models are the models which represent a specific type of cloud environment based on size, ownership, and access. They define the type of access that a cloud has, that is, who all can access its service and where it is located. There are four types of deployment models:

- Public
- Private
- Hybrid
- Community

The following figure depicts the types of deployment models:

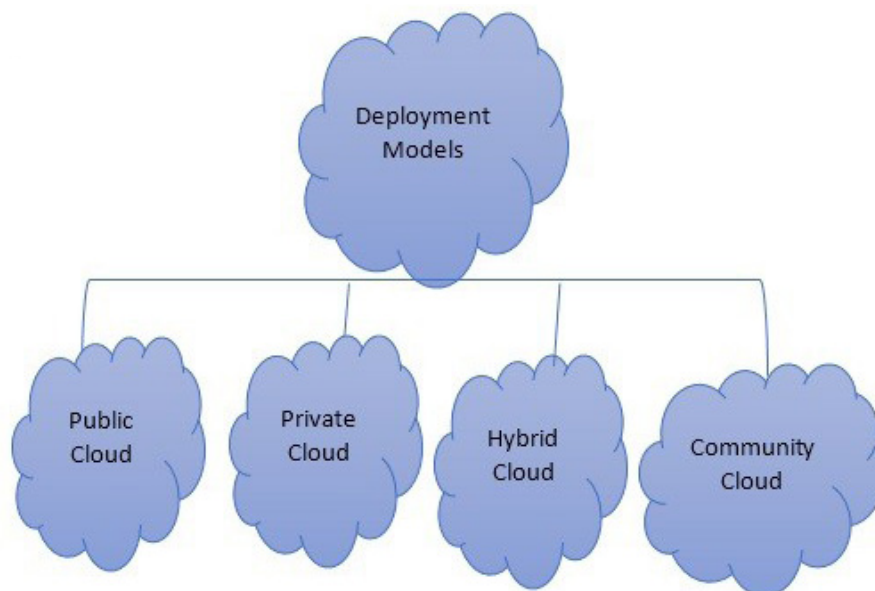


Figure 1.3: Types of cloud deployment model

Public cloud

As the name suggests, all computing resources including storage, database and network resources are made available to the general public. A public cloud allows

all users to access services and resources. It is open for use to the general public. The same hardware, storage, and network devices are shared among other businesses or organizations. All the services and infrastructures are delivered for free or on a pay-per-use basis through the internet. You just need a web browser to access all sorts of software and services. Users can scale in and out these services as per their requirement but they will never see the hardware used nor will they have any information regarding the location of the data. All the maintenance is done by the vendor only. Popular public cloud vendors include Amazon Elastic Compute Cloud (Amazon EC2), Microsoft Azure, Google App Engine, IBM Blue cloud, and Salesforce Heroku. Gmail and Office 365 are examples of public clouds as everyone can access them.

Private cloud

A private cloud is a cloud that is privately owned, managed, and operated by the business or organization. It is not open to the public and is exclusively owned by one business or organization. It is also known as internal or corporate cloud. Infrastructures and services in a private cloud can be accessed only within the organization and are always maintained on a private network. This means that no other organization can share one's resources. An organization that is using a private cloud is solely responsible for its management, maintenance, and regular updates. Servers can be physically located on your organization's premise or can be hosted by third-party service providers. A private cloud offers greater and direct control over data and greater range of security as data is protected behind a firewall. It also allows for customization of the cloud environment. Some third-party providers of private clouds include Microsoft, Apache, and OpenStack.

Hybrid cloud

Hybrid cloud is the deployment model that combines the private cloud of a company with a third-party public cloud. A hybrid cloud incorporates the on-premises infrastructure of a private cloud with public cloud to flourish the organization with the advantages of both. By merging the benefits of private and public cloud services, a hybrid cloud provides the private cloud's security and the public cloud's speed to the organization or business. This model provides flexibility to the organization as it provides the facility of using the private cloud for sensitive data (providing high range of security) and the public cloud for interaction with customers. Organizations can move between private and public clouds as per the changes in computing needs and costs.

A hybrid model is very valuable for the workload in an organization. For example, if an application or resource in a private cloud reaches a spike in demand, then the company can use the public cloud to increase the capacity of the resources and gain benefits of additional infrastructure and services. This is known as "cloud

bursting.” This model offers features like flexibility, scalability, and security. Some of the biggest providers include Microsoft, Dell, IBM, VMware, Amazon Web Services, and Rackspace.

Community cloud

A community cloud is just like a private cloud but it is used by a specified group of people or by various organizations having a similar background. A group of people from the same organization or several organizations with similar characteristics share the same infrastructure and services. This cloud is best for organizations that want to work on joint projects. This type of cloud deployment model is either managed and hosted internally or by third-party providers. Some examples of community cloud deployment models are GoogleApps for Government, Microsoft Cloud for Government, and Amazon AWS GovCloud.

Cloud computing companies

Most of companies are providing cloud services and many are planning to enter the market. The world’s top three cloud service companies are Amazon Web Services, Microsoft Azure, and Google Cloud Platform. Let’s have a brief overview of cloud computing service providers that can serve excellent cloud services.

AWS

AWS or Amazon Web Services is a secured cloud platform offered by Amazon that offers virtual computing services. It provides features like flexibility, scalability, security, and fast and cost-effective services. It is the oldest cloud service provider. AWS was the first one to introduce the pay-as-you-go model for using the cloud computing model. AWS includes a combination of the features of all three service models, namely SaaS, PaaS, and IaaS.

Microsoft Azure

Azure is an open and flexible cloud platform developed by Microsoft for building and deploying applications. This cloud company gives us the platform for building, testing, deploying, and managing services through a Microsoft-managed datacenter. It provides three main cloud computing services: SaaS (CRM, email, games), PaaS (execution runtime, web server, database) and IaaS (virtual machines, servers, storage).

Google Cloud Platform

Google Cloud platform is a platform for cloud computing services offered by Google. It provides services for compute, storage, networking, security, and tools

for developing and maintaining software. It includes products like Google Compute Engine, Google App Engine, Google Cloud Storage, and Google Container Engine. Its flexible and scalable features allow your business to achieve its goals.

Salesforce

Salesforce cloud computing offers multiple cloud services like Sales Cloud, Service Cloud, and Marketing Cloud to enhance the production of businesses and organizations. It is very helpful in maintaining customer information and automate business processing. Salesforce cloud services are easy, fast, and effective.

Oracle Cloud

Oracle Cloud is a cloud computing service offered by Oracle Corporation. It provides infrastructure, storage, database, and many other services to organizations and businesses on demand and the pay-as-you-go model. Services offered by the Oracle Cloud are innovative and help businesses in managing, deploying workloads, and reduce complexity.

IBM Cloud

IBM Cloud is a set of cloud computing services offered by IBM. It combines the services of SaaS and PaaS. The IBM cloud platform provides compute, storage, databases, AI and services to both small and big organizations.

Dell Cloud, VMware, Alibaba Cloud, Rackspace, and DigitalOcean are some other examples of cloud computing service providers.

Conclusion

Cloud computing is a popular technology which provides all computing resources as utilities to us. In this chapter, we have covered a basic overview of cloud computing with its features, merits, demerits, and the history of cloud computing. We have also understood the cloud service and the deployment models with diagrams. Some brief information regarding companies who provide cloud computing services and their clouds has also been given by us. Basically, we conclude that cloud computing is a precious technology for businesses as with it, users can devote their time for innovation and towards a better future of their organization. In the next chapter, we will deal with some more concepts of cloud computing.

Points to remember

- Cloud computing is the technology that provides us the means to use infrastructure and software services from anywhere and at anytime through the internet.
- Cloud computing is based on the on-demand and pay-per-use model.
- Cloud services can be categorized into SaaS, PaaS, and IaaS.
- The four types of clouds are public, private, community, and hybrid cloud.

Multiple choice questions

1. **It is the technology that provides universal access of computing resources to businesses**
 - a. DBMS
 - b. Networking
 - c. Cloud computing
 - d. Client server system
2. **Ramnath Chellappa coined this term**
 - a. Cloud computing
 - b. Grid computing
 - c. Utility software
 - d. AI
3. **This service is beneficial for end users**
 - a. PaaS
 - b. SaaS
 - c. IaaS
 - d. NaaS
4. **Hybrid cloud contains features of**
 - a. Public cloud
 - b. Private cloud
 - c. Community cloud
 - d. a and b

Answers

1. c
2. a
3. b
4. d

Questions

1. Elaborate on the concept of cloud computing with its meaning, characteristics, merits, and demerits.
2. Discuss the evolution of cloud computing.
3. State the services offered by cloud computing.
4. Explain the types of cloud computing deployment models.

Key terms

- **Pay-per-use:** Paying for those services that you use.
- **On-demand:** Resources that are available when the user needs them.
- **Scalability:** Resources can be increased or decreased based on the requirement.
- **Elasticity:** Ability of a system to handle workload by scaling in and scaling out resources.
- **SaaS:** Service model to provide application software to users.
- **PaaS:** Service model to provide platform to users.
- **IaaS:** Service model to provide infrastructure to users.
- **Public cloud:** All computing services are available to the general public.
- **Private Cloud:** All computing resources can be accessed by one organization only.
- **Hybrid Cloud:** Combination of private and public cloud.
- **Community cloud:** All computing resources can be shared by a group of people with the same interests.

CHAPTER 2

Cloud Architecture and Applications

Cloud computing is a very popular and emerging technology nowadays. For whatever we do or for the work that we perform on our desktop, laptop, or mobile, if we are using the internet for that, then we are somehow using cloud computing. You use interface to access data which is stored somewhere on the location of the service provider. Here, the interface is the front end and the location of the data is termed as the backend. Front end and backend are the two components of a cloud system. The following chapter explains the front end and backend concept of cloud architecture with the help of diagrams along with applications of cloud computing.

Structure

In this chapter, we will discuss the following topics:

- Cloud computing architecture
- Front end
- Backend
- Components of cloud computing architecture
- Working of cloud computing
- Applications

- Conclusion
- Questions and exercises

Objectives

After studying this unit, you will be able to:

- Understand the cloud system architecture
- Have a clear meaning of front end and backend
- Understand the concept of infrastructure
- Discuss the applications of cloud computing

Cloud architecture

Cloud computing architecture refers to the components and subcomponents required for cloud computing. Cloud computing architecture comprises of many cloud components. Each of these components are loosely coupled. This means that these components are not dependent on each other. Cloud architecture basically describes the communication between the client and server via network, which is mostly the internet. We can divide cloud architecture into two parts:

- Front end
- Backend

Frontend is the end which is used by the user and backend is managed by the host. Backend comprises of hardware and software that delivers the backend data from the database to the front end. Both the ends are connected to each other with the means of the internet. For example, if you use web browser to connect to any website, say AWS or Google Docs, then your web browser is the front end and the data center at Amazon or Google is the backend. You can only see the front end and

you do not have any information regarding the backend. The following figure gives you an overview of the cloud computing architecture:

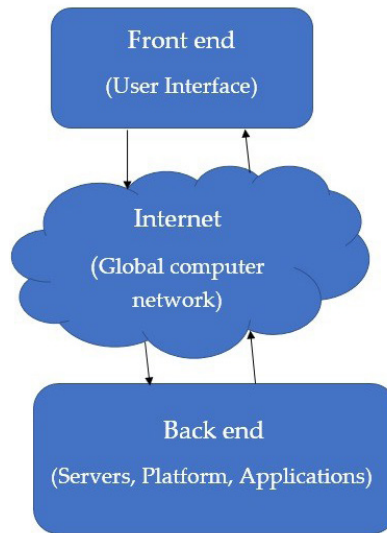


Figure 2.1: Basic overview of cloud architecture

Front end

Front end is that part of a cloud system which is visible to the user or client. All that which a user can see, whether it is on a computer, laptop, web browser, or apps come under the front end. It consists of the user or client's computer or computer network, interfaces, and applications that are required to access the cloud platform. Users can access all networked services through the front end which can be any web-enabled interface. For example, the web browser, mobile apps, or the app created by the company itself.

Let us consider an example. If you want to access email, open the web browser and go to your Gmail account. Whatever you see on the screen, i.e. the interfaces or applications are termed as the front end.

Backend

Back end refers to the cloud itself. By the term "cloud," we mean the data center where the cloud server provider stores and manages the data. It is managed by the host or cloud service provider. It comprises of huge data storage, virtual machines, security mechanisms, deployment models, service models, and servers. It is also responsible for managing traffic and protecting data. Various processes run inside the backend to ensure the smooth functioning of the cloud system. It also provides

protocols to connect networked computer for communication. Users do not have any information regarding the backend. It acts as a blind box for them.

Components of cloud computing architecture

A block diagram of cloud computing architecture is shown in the following figure:

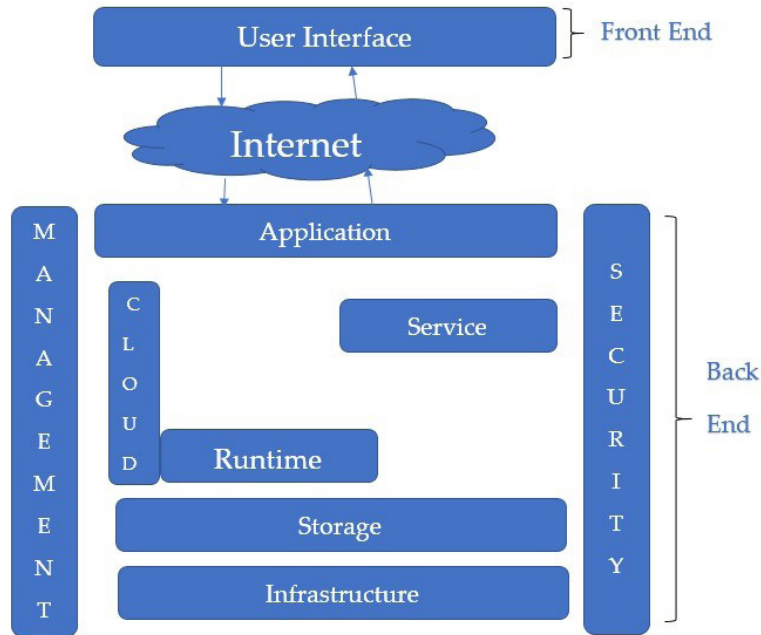


Figure 2.2: Block diagram of cloud computing architecture

Let us discuss some important components of cloud computing architecture.

Front end architecture

Front end architecture refers to the collection of hardware and software components on the client side that are needed to maintain communication between the user and cloud system. It includes user interface (for interaction with service provider), software, and devices like computer, laptop, or mobile phone. Examples of front end architecture include web browsers, web apps, computer, or computer network. The following are the sub-components of front end architecture:

- **User interface:** User interface is the means through which the user and computer interact with each other. It is the interface which allows the user to directly interact with the cloud system to fulfill their requests and access services. Examples of user interface include Gmail and Google docs.

- **Software:** This refers to the applications installed on the client side. Generally, it includes web browser or web apps.
- **Hardware:** This includes client devices like computer, laptop, or mobile phone or networked computer and input devices present on the client side.

Backend architecture

Components included in the backend are very crucial for maintaining efficient communication between the client and vendor and for providing computing power to the user end. The following are the vital components included in the backend:

- **Application:** This basically refers to the software or app that the client or user wants to access. Users can interact with applications with the help of a web browser or mobile app.
- **Services:** Services refer to any IT services delivered by the cloud service provider on the demand of the client. These services include email, storage, backup and data retrieval, creating and testing apps, analyzing data, entertainment, and software applications. Cloud computing mainly offers three types of services:
 - **SaaS:** Provides application services.
 - **PaaS:** Provides platform services.
 - **IaaS:** Provides infrastructure services.

These services can be accessed using the internet.

- **Cloud runtime:** This is the place where the service runs. It provides execution and runtime environment for the virtual machines. Hence, we can also consider it as the operating system of the cloud. It includes a technology like virtualization which allows multiple servers to exist on the same server.
- **Storage:** Storage is the place where the data of the client resides in the cloud system. Different cloud service providers provide their own segments for storing data. The capacity of the allocated segments may vary from vendor to vendor.
- **Infrastructure:** Infrastructure actually describes the set of components that frame the cloud system. It is the vital component of the cloud system architecture which consists of components like servers, storage devices, network, cloud management software, deployment software, and hypervisor. These components are important as they are needed to support the cloud system. The components that frame the infrastructure of the cloud system are as follows:

- Hypervisor
- Management software
- Deployment software
- Network
- Server
- Storage

Let us discuss these components briefly:

- **Hypervisor:** Hypervisor is also known as Virtual Machine Monitor or VMM. It is defined as a specialized firmware or software, or a combination of both that creates and runs virtual machines. It gives the facility to run numerous virtual operating systems on a single computer system. Physical hardware like memory, processor, and storage can also be shared among various virtual machines. These machines are termed as guest machines and the computer system on which the hypervisor runs the virtual machine is termed as the host machine. It is the primary task of the hypervisor to fulfill the need of the guest machines and manage them.
- **Management software:** Management software includes various schemes and strategies which are essential for the effective management of the cloud system. It is an important part of the infrastructure as it configures and maintains the infrastructure.
- **Deployment software:** This refers to a set of all steps, processes, and actions that are required to make a software available for use. It is used to deploy and integrate applications on the cloud. It enables SaaS, PaaS, and IaaS solutions that may be accessed by clients or end users on demand.
- **Network:** It is one of the vital components of infrastructure that enables users to connect to the cloud. Users can access cloud services with the help of network which is mostly the internet. The speed of data transfer depends on the network quality.
- **Server:** Cloud server, also known as virtual server, is a server that runs inside the cloud computing. It handles, allocates, de-allocates, and computes cloud resources to the organization. It is also responsible for sharing and monitoring the cloud resources. It is delivered through the cloud computing platform over the internet. Cloud servers prevent us from all the problems that are encountered with physical servers.

- **Storage:** This is the place where the data is stored on the cloud. Storage system is also an essential part of the cloud infrastructure. Multiple copies of your data are stored on the storage system so that if one system fails, you can access your data from anywhere.
- **Management:** Management is responsible for the effective and smooth functioning of the cloud system. It manages the communication between the front end and backend. Cloud providers manage resources and their performance. It is their job to provide efficient functioning of cloud computing resources.
- **Security:** Security of data is the primary concern for every organization, business, or personal users. Everyone wants to keep their information safe and secure. So, to keep cloud data secure, a lot of emphasis is laid on the security tools, policies, mechanisms, and technologies. All of these policies, tools, technologies work together to provide a safe environment for cloud users. It is the responsibility of the backend to secure the cloud system with firewall, redundancy concept, and preventing data loss.

Working of cloud computing

The front end, backend, and network are integrated to achieve the effective working of the cloud computing system. The front end allows the user to access the data stored on the cloud using the web browser or mobile app. For this, the user should register on the cloud's website. Then, he is provided with an id and password. After logging into the cloud application, the user enters his request. After verification, the user is granted permission to download and upload data on the cloud and access other services provided by the vendor. The user can access the data from anywhere. Initially, a user gets a small amount of storage space for storing his valuable data.

Every cloud application has a host. It is the responsibility of the hosting company to manage their data centers and provide security, storage capacity, and infrastructure to the end users. The backend comprises of the servers, storage, databases, computer networks, and central servers. The backend is the primary component of a cloud system. All the operations inside the cloud system are managed by the central server. It ensures flawless functioning of the cloud system. It also controls traffic of the cloud system. The cloud system follows some set of rules known as protocols. It uses a software named Middleware which enables effective communication between networked computers.

Applications of cloud computing

Cloud computing is everywhere. Whether you are watching videos, listening to music, or searching for something, if you are using the internet for it, it means you

are accessing cloud computing. Cloud computing is used in almost all fields like business, entertainment, data storage and backup, social networking, education, and management. Let us discuss some important applications of cloud computing:

- **Business:** Cloud computing is very beneficial for businesses as it provides features like enhanced security, improved productivity, cost reduction, and maintenance. These features lead to the tremendous growth of a business. Businesses use cloud computing to access data from anywhere through the internet with the help of compatible devices. With cloud computing, data is stored on the cloud so the business users can access information from the central server. It also provides the facility of data synchronization on all devices connected to the cloud, thereby keeping the users updated with real-time information. Some popular business applications are:
 - **MailChimp:** MailChimp is an integrated marketing platform that helps businesses to maintain communication with its clients via email. It is the most popular email marketing service in the world that allows you to send automated emails to your clients, customers, and other parties to manage healthy contacts and increase the growth rate of your business. It is a web-based application that can work in mostly all web browsers, so you don't need to install any software for this.
 - **Chatter:** Chatter is a business app developed by Salesforce that helps the employees to share information about the organization in real time. It is an enterprise collaboration platform that can be used as company intranet or employee directory where employees can share their work-related information and access documents regarding sales, services, campaigns, projects, and tasks.
 - **Google Apps for Business:** Google Apps for Business is a web-based and collaborative SaaS solution provided by Google. It is an email and messaging software for various small and medium-scale businesses.
 - **Quickbooks:** Quickbooks is a small business accounting software developed by Intuit. This app is used by businesses to manage the income and expenses incurred in the business. It also keeps track of the financial status of the business, pays and manages bills, generates reports like profit and loss report, balance sheet, etc. Quickbooks provides many web-based features like online banking and reconciliation, mapping features, electronic payment functions, and better mail functionality with Microsoft Outlook.
- **Data storage and backup service applications:** Data storage apps provide the facility to store data on the cloud. Various copies of data are maintained

to provide the backup facility in case of failure. Let us discuss some popular data storage and backup apps:

- **Dropbox:** Dropbox is an online storage service that is easy to use and reliable. It is very popular as you can share and store files including photos, music, documents, and videos and access them later.
- **Google Drive:** Google drive is a cloud-based file storage and sync service offered by Google. With this, you can share your data on the Google Cloud and retrieve it when needed. It also gives the facility of synchronizing your data. Google gives you free 15 GB space on their cloud.
- **OneDrive:** OneDrive is an online storage service developed by Microsoft. This service is best for Windows users. You can save, share, and protect your data on the Microsoft cloud servers and access them from multiple devices. It provides 5 GB of free storage to its users.
- **Box.com:** Box.com provides an online storage service to store documents, PDF files, photos, and spreadsheets on the cloud. This service provides the drag and drop feature for files. Here, users can drop their files on cloud and access them when needed.
- **IDrive:** IDrive is a cloud-enabled backup service that protects our data by doing backups at regular intervals.
- **Management applications:** Cloud computing enables you to organize and manage your workloads. It provides various tools for managing simple as well as complex management tasks and applications in an easy way. Some popular cloud-based management applications are:
 - **Accelo:** Accelo is an easy to use, automated, and intelligent cloud-based platform that integrates all aspects of business under one roof. It lets you manage all your clients from one place.
 - **Centrallo:** Centrallo is a simple and easy to use organizational app that lets you create and share lists and notes. You can add photos and videos also. It is perfect for both personal and professional tasks.
 - **Easynote:** Easynote is a simple, affordable, and convenient task management tool that enables users to create, track, and assign tasks. This app allows you to organize everything from personal tasks to multi-platform projects. It is very popular among the world's biggest firms.
 - **Trello:** Trello is a cloud-based platform that is used for managing projects and personal tasks. It is a very popular business productivity software that provides collaboration tools and support for different multimedia tools.

- **Social applications:** Social applications provide a platform for connecting people with each other. Cloud-based social applications allow users to store their memories, photos, and videos etc. on the cloud for future and universal access. Some social media applications that store your data on the cloud system are:
 - **Facebook:** Facebook is the largest social media platform that enables you to connect with millions of people across the globe. With this, you can share photos, music, videos, and messages with your friends and relatives present on Facebook.
 - **Twitter:** Twitter is a microblogging and social networking website that allows you to post messages and interact with other users. These messages are termed as tweets.
 - **Instagram:** Instagram is a free online social media platform that allows you to edit and upload photos and short videos.
 - **LinkedIn:** LinkedIn is a social networking site that is designed for business people. Here, users can share their work-related information and communicate with other people to get new jobs. This website is mainly used for professional relations. Employers can search for employees by posting new jobs and job seekers can search and apply for jobs.
- **Entertainment applications:** Besides other applications, cloud computing plays an important role in providing entertainment to its users. Users can watch movies, videos, play online games, and listen to songs. They can even make their own videos and post them on the cloud. Some popular entertainment applications are:
 - **Amazon Prime Video:** This app is a great entertaining app that allows you to watch movies and TV shows anywhere and anytime.
 - **Google Play Books:** Google Play Books is another entertaining app that provides you access to dozens of digital books. This may include fiction, non-fiction, and poetry.
 - **YouTube:** Owned by Google, YouTube is very popular app that enables you to watch online videos and music; and upload your videos and share them with the family of YouTube.
 - **Netflix:** Netflix is a subscription service that allows you to watch movies and shows online.
 - **Spotify:** Spotify is a digital music streaming service that enables you to listen to millions of songs.

- **Education applications:** Cloud computing is very beneficial for students and teachers. It provides a way for remote learning and teaching. Teachers can teach from anywhere and upload their content and keep on updating them as required. In the same way, students can access the tutorials anytime and from anywhere with the significance of updated information and cost savings. Some cloud-based education apps are given below:
 - **Google:** Google provides a wide platform for cloud-based education. It includes Google Drive, Google Docs, Google Slides, Google Forms, Google Sheets, Google Drawings, and Google Hangouts. These apps allow students to work from any device on documents and projects. Another product of Google is Classroom that helps students, teachers, and learners create and organize assignments and promote the means of online education.
 - **Coursera:** Coursera is a worldwide online education platform that provides a variety of online courses.
 - **Blackboard:** The Blackboard app is a cloud-based learning app that provide an intuitive way for students to interact with courses, content, and instructors. With this app, student can submit their assignments and post on discussion boards.
 - **A Cloud Guru:** A Cloud Guru is an online training platform that enables people to learn the concepts of cloud computing. It includes various courses that are designed to teach and train people about cloud.
- **E-commerce applications:** E-commerce applications help firms develop a deeper connection with their customers, increase sales, and scale up and down the services as per the demand. Some popular cloud-based e-commerce applications are:
 - **Amazon:** Amazon is the leading online marketplace that allows its users to do home-based shopping. You can find and buy almost all items in an easy way.
 - **H&M:** The H&M app provides you with a variety of fashion trends anywhere and anytime.
 - **Grofers:** Grofers in an Indian online grocery delivery store. You can get a wide range of groceries, baby care products, fresh fruits and vegetables from there.
 - **Trivago:** Trivago is a hotel search and price comparison website that allows you to find the best possible accommodation.

Conclusion

Cloud computing architecture can be considered as the blueprint that describes the way in which all components and technologies are connected together to provide a cloud environment. While the architecture refers to design, infrastructure tells us about the details regarding the set of components. We have covered two basic parts of the architecture, i.e., front end and backend, and their role in this chapter. We have also discussed the applications of cloud computing in today's age. Everything that we do using the internet is somehow related to cloud computing. Hence, there are worldwide applications of cloud computing. In the next chapter, we will discuss the two popular and dominant features of cloud computing—scalability and redundancy.

Points to remember

- The cloud computing architecture comprises of two parts, namely front end and backend.
- Front end refers to the user interface and backend refers to the cloud section of the system which includes server, database, and applications.
- Front end and backend are connected through the internet.
- There are numerous uses of cloud computing in the field of business, education, data storage, social networking, education, and e-commerce.

Multiple choice questions

1. _____ refers to the cloud itself.
 - a. Front end
 - b. Backend
 - c. Infrastructure
 - d. None of these
2. Two components of cloud architecture.
 - a. Front end
 - b. Backend
 - c. a & b both
 - d. Servers and databases

Answers

1. b
2. c

Questions

1. Discuss the cloud computing architecture with the help of a block diagram.
2. What are the various applications of cloud computing?

Key Terms

- **Architecture:** Architecture refers to the design of the system.
- **Infrastructure:** Infrastructure refers to the set of components that frame the system.
- **Front end:** Front end refers to the user interface.
- **Backend:** Backend refers to the cloud itself.

CHAPTER 3

Scalability and Redundancy

Scalability and redundancy are the core concepts of cloud computing. These two are very beneficial features that can be considered as the factors for the tremendous growth of cloud computing. Scalability gives the power to handle the rise and fall in resources demand while redundancy corresponds to the maintenance of copies of data to overcome the problem of failure. This chapter deals with these two topics. It explains how scalability and redundancy benefit cloud computing.

Structure

In this chapter, we will discuss the following topics:

- Meaning of scalability
- Key features of cloud scalability
- Types of scalability
- Ways to scale cloud
- Benefits of cloud scalability
- Concept of redundancy
- Benefits of redundancy

- Conclusion
- Questions and exercises

Objectives

After studying this chapter, you will be able to:

- Understand the importance of scalability in cloud computing
- Gain knowledge about the features, types, and benefits of scalability
- Understand the concept of redundancy in cloud computing

Meaning of scalability

Scalability can be defined as the ability of a system to increase or decrease the quantity of resources as per the demand. It is one of the biggest advantages of cloud computing. Users can increase the number of resources when there is workload and decrease the resources level when there is less or no demand. Let us understand the concept of scalability in cloud computing with the help of an example. Imagine this situation. Raman is handling his business firm. Users can access his business through an app. Raman uses cloud computing services to manage and maintain his business firm effectively. It may happen that suddenly thousands of visitors start accessing his business supplies through the app. Users visit his app to order the products and search for beneficiaries. This may increase the traffic on his app, leading to workload. This is the capability of cloud computing to handle the load and not let the app crash. As crashing or slow accessing of the app may make the user upset and create the wrong impression about its services. Cloud scalability enables your resources to grow as your business grows or traffic increases, and shrink when the load diminishes.

Cloud scaling enables cloud computing resources, services, and applications to get scaled up and down to meet demands based on season, projects, and growth. It optimizes the overall efficiency of the system and also saves costs. It is also one of the reasons for cloud computing becoming so successful in the market. Scalability can be applied to four general areas which include Disk I/O, memory, Network I/O, and CPU.

Key features of cloud scalability

Scalability allows you to scale up or down and scale in or out the capability of your system to meet the demands of your growing business. Whenever your business grows, it enables increment of resources, i.e., storage space or the number of servers in your system, and you can get back to your original configuration when the

increased demand is reduced. In the same way, you can handle traffic and workload also. Scalability also provides flexibility of time and money. Let us discuss some key features of a scalable cloud:

- **Growing or shrinking:** Scalability allows you to increase or decrease resources to meet the demands of the business.
- **Performance:** Scalability gives the facility of handling traffic burst and huge workload, thereby increasing the performance of the business or organization.
- **Cost-efficient:** You have to pay only for those resources that you use. It gives the ability to scale out the resources that are of no use, thus saving money and making your system cost-efficient.
- **Capacity:** A scalable cloud automatically increases the storage capacity of the system as your business grows. So you don't have to worry about additional space needed for handling the organization's continuously growing data.

Types of scalability

Cloud scaling can be divided into three categories. They are:

- Vertical scaling
- Horizontal scaling
- Diagonal scaling

Let us explore their meaning briefly:

- **Vertical scaling:** Vertical scaling refers to adding more power to the existing infrastructure by adding more resources. It means either adding a more powerful processor (CPU), more memory (RAM), faster storage such as solid-state drives (SSDs), or I/O resources to an existing server. But you are limited to the capacity of the server. You can't add resources beyond that.

To make it simple, let's understand this with the help of an example. Imagine a guest house with 20 rooms. Guests usually move in and out. Space is often available for all guests as not all guests arrive at the same time. So, people can come, use the rooms, and access the guest house resources. Space will be allocated to the guests as long as it does not exceed the capacity of the guest house. This is vertical scaling. In the same way, in cloud computing, resources can be increased or decreased for the existing machine while keeping in mind the capacity of the machine. Hence, the resources can be scaled up or down easily till the capacity of the machine does not exceed. Here, machines are added in the vertical direction. An example of vertical scaling is MySQL-Amazon RDS.

The following figure depicts vertical scaling technique:

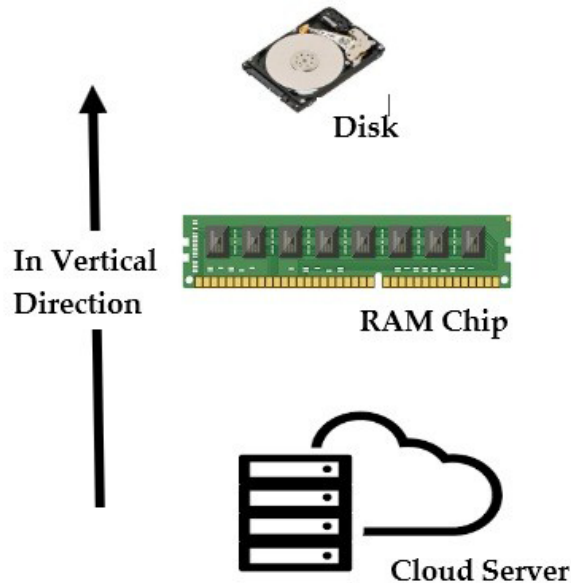


Figure 3.1: Vertical scaling

- **Horizontal scaling:** In the example discussed above, no problem will occur as long as the number of guests is less than the capacity of the guest house. If during the summer season or any weekend, the number of guests exceeds the capacity of the guest house, the problem arises then. There will be congestion in the guest house and all the guests will not be able to get efficient services. In order to avoid these issues, the owner of the guest house needs to build additional rooms for them. More rooms will be added and extension of the guest house will be built to accommodate more guests. Although it will take time, the problem will be solved. This is horizontal scaling.

Horizontal scaling refers to adding more servers to the system so that they can work together as a single unit. Nodes are added in the horizontal direction to accommodate additional workload. Workload is divided among servers to limit the number of requests that the individual server is handling. This leads to an increase in performance. As this scaling means adding more servers and configuring them so that they can work together, it takes a long time and planning to implement. Examples of horizontal scaling are Cassandra, MongoDB, and Google Cloud Spanner.

The horizontal scaling technique is shown in the figure given below:

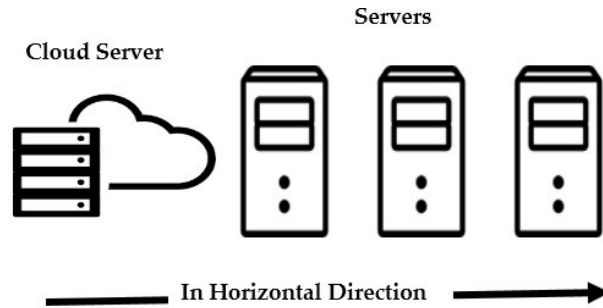


Figure 3.2: Horizontal scaling

- Diagonal scaling:** Diagonal scaling is a combination of vertical and horizontal scaling. When you implement diagonal scaling, you firstly grow vertically within your existing infrastructure until it reaches the limit. Now, when your server limit exceeds, the system is scaled horizontally, i.e., you simply clone the server to add more resources to the new server. This enables you to deal with all the requests and traffic concurrently. Just see the example given for vertical and horizontal scaling. While implementing diagonal scaling, you will first allot rooms in the current guest house. Then, when it is full, you will open the rooms built in the extension of the guest house.

The following figure illustrates the concept of diagonal scaling:

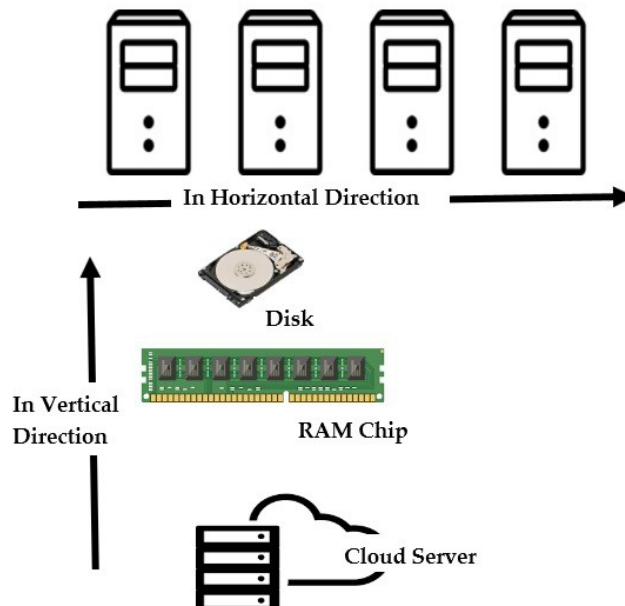


Figure 3.3: Diagonal scaling

Ways to scale cloud

There are three ways to scale cloud. They are:

- **Manual:** As the name suggests, manual scaling requires an engineer or the concerned professional to manage the scaling up and down of resources in the cloud. This can be accomplished by using a push button for scaling up and down the server. The concerned person should always have a look at the load and traffic of the server so that he does not miss any chance of scaling up the resources to meet the demands. Moreover, he should never forget to scale down the resources when the demand is low. Otherwise, it may lead to extra cost. This type of scaling is prone to human error.
- **Scheduled:** Instead of keeping an eye on the market trends and manually scaling up and down the resources, you can schedule your scaling for the peak time. This means that you can consider the timings when your application is most likely to suffer from traffic or workload and set up a scheduled time to scale up or in the resources during that particular period, and scale down or out during normal routine. Say that from Friday night to Monday morning (as mostly weekends correspond to more traffic), you can schedule scaling up or in and for the rest of the time, it will remain at the normal scale. Scheduled scaling can be a failure if unexpected traffic or peak time occurs.
- **Automatic:** Automatic or auto scaling refers to the process of automatically scaling up or down and scaling in or out the resources to meet the demands. Auto scaling monitors your business trend and automatically adjusts the scaling up or down to maintain consistent growth at low cost. Resources are automatically increased during demand spikes and decreased when demand drops.

Benefits of cloud scalability

Scalability accounts for good performance and flexibility in terms of money and time. It provides customizable infrastructure according to the customer's need. There are numerous benefits of cloud scalability. Let us discuss them here:

- The main benefit of cloud scalability is that it improves the performance of your business. Its capability of handling traffic burst and heavy workload enhances the growth of your business.
- It provides flexibility in terms of money and also time. You can scale down the resources that are not usable for that current period and thus save the cost that was incurred while implementing them.

- It is very easy to apply scalability in your business. You can access additional resources with just a few clicks without any delay. You don't have to take extra load for that.
- As your business grows, scalability itself automatically increases the capacity of the cloud storage system to store additional data of the business.
- Scalability ensures availability of your application even during the peak time, thus maintaining your reputation as well.
- Scalability ensures the possibility of increasing or decreasing the power and resources of the system based on the business's need as well as the availability of customers.

Concept of redundancy

As we all know, cloud computing provides us with storage capacity to store our valuable data. Almost every one of us uses that cloud storage for storing our precious information. But what if the cloud server where your data is stored fails or needs to be updated? It would be a devastating loss for you or your company if you had failed to back up your data. But don't worry, cloud computing has paved a way for this too. It allows us to keep multiple copies of data on multiple servers so that if one server fails, your data is safe and secured on other servers. This concept is known as redundancy.

Redundancy means duplication. It refers to the act of duplicating data or files so as to provide universal access and backup for clients. Its main motive is to prevent or recover from any failure. With redundancy, cloud computing saves your data on multiple cloud servers such that if any server becomes corrupted or is unavailable, or if that particular server requires maintenance or needs to be upgraded, you can still access your data from other servers (where data is stored for the backup facility).

Redundancy is not only limited to creating multiple copies of data. It also means to have a duplicate copy of your server, system, and other devices so that if any one out of these gets failed, you can access the redundant option for that. Cloud storage allows companies to have a safe and secure copy of their important documents and databases, thereby ensuring data protection.

Benefits of redundancy

Redundancy is a major benefit of cloud computing. It provides us the following benefits:

- **Automatic data backups:** Cloud storage enables automatic data backup for all the applications and data that we store and process using cloud

computing. When we work on any application like Google Docs, the data is auto-saved on the cloud and if any disruption occurs, the next time that you use the application, it gives you the facility of resuming your work from that point only where the disruption occurred.

- **Access from any device, any time, any place:** When we store data on the cloud then the cloud vendor automatically stores our data on multiple servers. This allow us to access our data from any device, any time anywhere.
- **Data security:** Cloud vendors ensure security of our data. Since data is stored on multiple servers, if one system fails, then the other can be used for accessing the data. You will not face the problem of data loss. Thus, it provides a sense of comfort to the user who is concerned about the protection of his data.
- **Uptime guaranteed by service-level agreement (SLA):** Data and applications are always available for use. Cloud vendors ensure a continual uptime for data and application performance.

Conclusion

The reason behind the popularity of cloud computing is that it has the ability to meet the demands of the customers. The facility of scalability and features like redundancy make it more powerful. Scalability and redundancy help your business or organization grow and provide a sense of comfort and safety for the data. In this chapter, we have understood these two key concepts of cloud computing. In the next chapter, we will explore the services provided by cloud computing.

Points to remember

- Scalability is the major advantage of cloud computing which allows us to scale in and out or scale up and down the resources to meet the demands of the business or organization.
- Benefits of scalability include good performance, cost-efficiency, and availability of resources at peak times.
- Redundancy ensures universal access to data stored on cloud for businesses and organizations.
- Redundancy is an effective way of minimizing downtime and enabling fast and effective recovery in case of a failure or any disruption.

Multiple choice questions

1. **Key features of scalability include**
 - a. Growing or shrinking
 - b. Capacity
 - c. Performance
 - d. All of these
2. **This feature of cloud computing allows us to have a quick recovery in case of a failure**
 - a. Scalability
 - b. Redundancy
 - c. Concurrency
 - d. Relativity

Answers

1. d
2. b

Questions

1. Explain the importance of scalability in business.
2. How does redundancy help us to ensure availability of resources anytime and anywhere?

Key terms

- **Scalability:** The property of cloud computing to enable clients to increase and decrease the resources to meet the demands of business.
- **Redundancy:** It is the act of creating multiple copies of data stored on cloud so as to provide universal access and recovery from disaster.

CHAPTER 4

Cloud Services

Cloud vendors provide us with a variety of services as per the demand of customers, businesses, or organizations over the internet. These services are very helpful for us as they provide the access to different applications and resources in an easy and friendly way. We don't need to know the detailed description of the internal architecture of the applications. We can just go for them. We use cloud services in mostly every task in our daily life whether that is checking our email, storing photos or videos on cloud, or searching for information on the internet. Similarly, these services are very beneficial for the growth of any business or organization. This chapter teaches us about cloud services. Here, we will discuss in detail about IaaS, SaaS, and PaaS. We will also explain the NaaS and IdaaS services in this chapter.

Structure

In this chapter, we will discuss the following topics:

- Cloud services
- Benefits of cloud services
- Types of cloud service models
- SaaS

- PaaS
- IaaS
- NaaS
- IdaaS

Objectives

After studying this chapter, you will be able to:

- Understand the meaning of cloud services and their benefits
- Discuss the types of cloud service models
- Understand the meaning, advantages, and disadvantages of cloud service SaaS
- Have a look at the facilities provided by PaaS
- Discuss the services that come under IaaS and its benefits
- Understand the concept of NaaS
- Discuss the benefits of IdaaS

Cloud services

Cloud services are the services that are provided by cloud vendors on demand to various companies and businesses to facilitate various functionalities and applications over the internet. These services make their work easier and also affordable. A business or organization can focus on their target without worrying about the internal architecture of the system. These services are designed in a way that they provide a flexible and scalable approach to various applications, resources, and storage anywhere and anytime. All these services are fully managed and maintained by cloud vendors.

Businesses or organizations can use cloud services for backup and recovery, for managing their relationship with customers, for managing peak time of the business with scalability feature, to perform analysis of data, for database processing, for communication such as emails and chatbots, creating and processing documents remotely by using services like Google Docs and Office 365, for maintaining social networking sites, application development, testing, and many other things.

The following figure gives us an outlook of cloud services offered by cloud vendors:

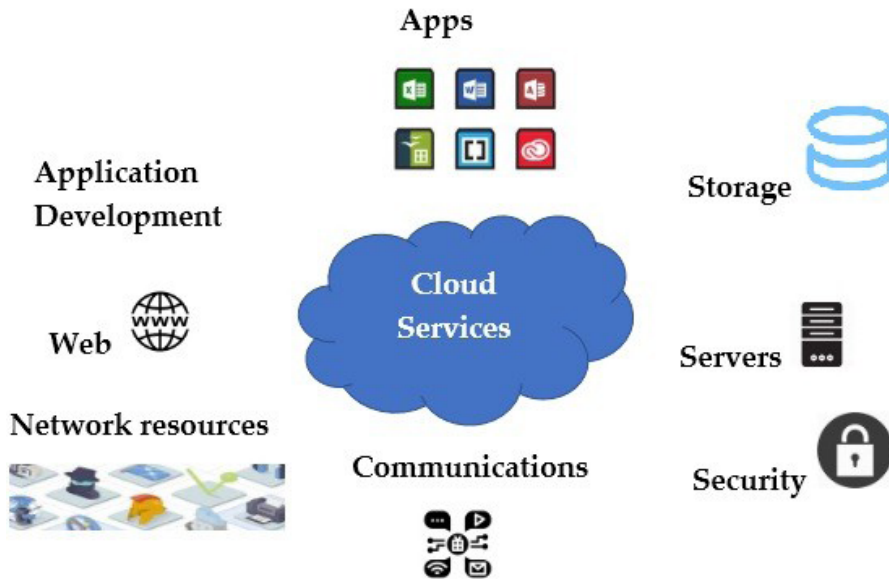


Figure 4.1: Cloud services

Benefits of cloud services

Cloud services provide tremendous advantages to businesses, organizations, and also individuals. They enable extreme and efficient growth with reduction in cost. Their scalable and redundant nature allow availability of resources anytime and anywhere to meet the demands of businesses. Moreover, all resources, hardware as well as software, are provided by the cloud vendor so there is no need to employ an IT person for managing the system. Hence, cloud services are very beneficial. Let us discuss the benefits of cloud services:

- **Power of scaling:** With cloud services, users can access the required applications and resources without any worry about their maintenance. The cloud vendor is solely responsible for scaling in and out of resources to satisfy the demands of the users, businesses, or organizations.
- **Secure environment:** Cloud vendors provide us with a safe and secure environment with universal access to their services. Users can access applications through the user interface and developers can use the platform for coding. Also, infrastructure can be accessed as a service. You are purely concerned with the type of services that you are using with a sense of comfort that comes from the safety of your data.
- **Increased flexibility:** Cloud services are very flexible. You can access them on demand and when they are of no use, you can cancel your subscription.

- **Cost reduction:** You only use and pay for those services that you need and scale them out when there is no demand. This factor of cloud computing signifies reduction in cost. Moreover, you don't have to pay for software license or any other infrastructure.
- **Higher speed:** Users can work on their application with high speed as they don't have to deal with problems like traffic, inefficient resources, malicious attacks, or unreliable networks.

Types of cloud service models

Cloud computing offers different services based on various service models. These service models are reference models on which the cloud computing is based. Generally, there are three types of cloud service models. They are as follows:

- **Software as a Service (SaaS)**
- **Platform as a Service (PaaS)**
- **Infrastructure as a Service (IaaS)**

Let us have a brief overlook at the tasks that come under the three basic cloud services through the following figure. This figure illustrates the management of all tasks of each cloud service, i.e., which tasks are managed by cloud vendors and which ones are managed by customers or clients.

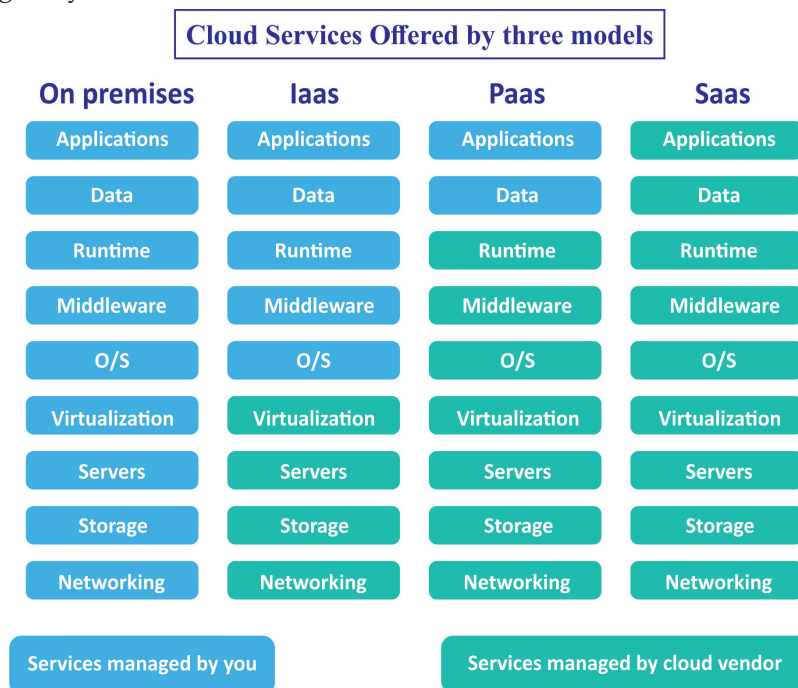


Figure 4.2: Cloud services management

Software as a Service (SaaS)

SaaS is the major category out of the three categories of cloud services. SaaS is a type of cloud service model that provides software to end users over the internet. SaaS vendors provide the applications through the internet and clients can access them using user interface. End users can access these applications remotely and there is no need to install the setup of the application or software on their machine. They can directly use the applications anywhere and anytime. The actual application runs inside the cloud servers that may reside far away from the user's location.

The SaaS model grants access to the software on a subscription basis either monthly or yearly, or you can pay on a usage basis. To access any application, you just have to login into your account and access the software directly through the web browser. Downloads and installations are not required but some applications may need plug-ins. In simple language, it can be thought of as fully-furnished flat that you can take on rent on a monthly basis. You use all its resources and pay charges to the owner for using them in the form of rent charges.

In the SaaS model, everything (i.e., applications, runtime, data, middleware, virtualization, servers, storage, and security network) is managed by cloud vendors. Various protocols are used by vendors to justify the security of the user's data. End users have don't need to have any concerns regarding this. Hence, businesses or end users can focus on their goals and on enhancing the growth and support of their system. They can access, store, share and secure their information using these services and pay for the resources they use.

The SaaS service model grants applications for the following services:

- Email and collaboration
- Customer relationship management
- Healthcare
- Billing and invoicing System
- Database management
- Document editing and management
- Social networking

Examples of SaaS cloud providers include Google Apps, BigCommerce, Salesforce, Dropbox, MailChimp, and Slack.

The SaaS model supports multitenant architecture. This means multiple users and clients use the same instance of the application. Each customer shares the same copy of the database and application. Many organizations and businesses share the same software to store and save data. These software and applications are maintained and

managed centrally. All clients share the same code, thereby the maintenance cost and cost incurred in updates is shared by all of them concurrently which reduces the overall cost of the service for each user.

Advantages of SaaS

SaaS applications are very beneficial for end users, businesses, and organizations as they are easily available, updated, scalable, and cost efficient. SaaS can help your business as it saves money, time, as well as human resources. Let us briefly discuss the advantages of SaaS:

- **Universal access:** As all applications are delivered over the internet, users can access them from any devices that are connected to the internet. These services are easily and always available and can be accessed from any location.
- **Scalable:** SaaS provider gives us the feature of scaling up and down the features of applications or software. It also gives you the scalability of changing plans whenever the business grows to meet the demands. One can change its plan as per their usage.
- **Saves time and money:** As the SaaS model works on the “pay as you go” model, you have to pay only for those resources that you use. Moreover, you don’t have to install and buy the software and infrastructure to support them, and no maintenance responsibilities are there. This eliminates the working hours and cost that were supposed to be spent on all these tasks. Hence, it saves time and money both.
- **Updated:** SaaS vendors always offer you the updated software and also automatically update the software on the client’s machine. This eliminates the end user’s responsibility of regularly updating the services.

Disadvantages of SaaS

Just like how every coin has two faces, every technology has pros and cons. Despite having so many benefits, SaaS also possesses some limitations. Let’s discuss them:

- **Availability of internet connection:** We can access SaaS services with the help of an internet connection only. Hence, if we do not have an internet connection or if we lose our connection while working, we will not be able to access the application which may cause damage to our work.
- **Security:** As many organizations or businesses use the same instance of the application and also share the database for saving and securing their data, this may hamper the security of their data. Unauthorized access, loss of data, and insufficient security protocols are the major security concerns for SaaS users.

- **Performance:** The speed of the application depends on the internet connection bandwidth. Hence, slow speed may affect our outcome. One must have a reliable internet connection with optimal speed to maximize the performance.
- **Limited Application:** It is not possible for SaaS vendors to provide each and every application with all its features. So, they provide applications with limited features and some applications are still there that don't offer a hosted platform.

Popular SaaS providers

The following table gives you a list of popular SaaS providers and the services that they provide:

SaaS provider	Offered services
Google	Document searching, digital analytics, search engine, online advertising
HubSpot	CRM, social media marketing, content management, web analytics
Slack	Internal messaging, video conferencing, productivity bots
MailChimp	Email marketing platform
Microsoft	Online office suite
Zoom	Video conferencing tools
Dropbox	Cloud based solution for documents and data
Salesforce	On-demand CRM solution
NetSuite	Cloud-based ERP platform

Table 4.1: List of SaaS companies with services

Platform as a Service (PaaS)

Platform as a Service (PaaS) refers to the cloud computing service that provides developers with the platform to create, test, run, and deploy web applications. This service model provides a runtime environment for building an application on rent that organizations can purchase on a pay-per-use basis. It is the responsibility of PaaS vendors to manage the infrastructure (servers, storage, networking), middleware, and development tools. This service is mainly used by developers with the help of an internet connection.

PaaS is very helpful for developers as they can develop coding for simple as well as complex web applications using the platform provided by PaaS vendors. They do not need to install hardware and software in their premises to support web

applications. This saves the time of the developers also. They can just focus on the side of application development.

In the PaaS model, developers can write the code for their applications on the runtime environment and deploy it directly to the PaaS layer. They only need to manage the application. They don't have to be concerned about management of the software, hardware, or network infrastructure on which their application is running.

PaaS vendors provide the following services to the organizations:

- Application design and development
- Application testing and deployment
- Development team collaboration
- Web service integration
- Information security
- Database integration

PaaS examples include Microsoft Azure, Google App Engine, Google Cloud Function, AWS Lambda, AWS Elastic Beanstalk, Red Hat Open Shift, etc.

Advantages of PaaS

PaaS removes the problem of adequate storage space, management of infrastructure, consistent hardware and software updates, and enables security resources to protect the data and information. PaaS provides the following benefits to organizations or businesses:

- **Simple and easy:** PaaS provides a simple and easy solution for complex programming. You can get all of the resources within a few clicks. Hence, developers can focus on the coding part instead of worrying about the operating system and infrastructure.
- **Enhanced development capabilities:** It provides the organization with skilled facilities so that developers can work efficiently. They do not need skilled employees for every particular task.
- **Low cost:** Since PaaS provides you with all the infrastructure capabilities required to run your application, you don't have to invest money in buying, installing, maintaining and updating them. Hence, it also provides you with considerable savings. You just have to pay for services that you use on the pay-per-use basis.
- **Development options for multiple platforms:** PaaS provides you with options to build applications on multiple devices like computer, mobile, and laptop. You can access your developed application from multiple platforms too.

- **Fast and flexible tools:** PaaS provides us with fast and flexible tools to help in working on innovative applications easily and quickly. These tools ensure faster development and quicker delivery of applications.

Disadvantages of PaaS

The following are the disadvantages of PaaS:

- **Security risks:** All of our applications' data is saved on the cloud storage offered by PaaS vendors. Although they ensure full security of our applications and data by employing the best security protocols, there may be loopholes for hackers and they may be more prone to security risks like data theft and unauthorized access.
- **Vendor lock-in:** This is the potential disadvantage of the PaaS environment. Since we build our application using the vendor's resources and platform, it may become impossible to move to another vendor. It may be possible that different vendors may possess different architecture. There is also the possibility of use of a different programming language for coding or it may be possible that another vendor does not support the platform that you had used to run your application. So, there are chances that you may have to alter your application or rebuild it in order to switch to another vendor.
- **Internal changes:** We are fully dependent on the PaaS vendor for building our application through this model. If in any case the PaaS vendor makes some changes to its services like a change in support for the current programming language or operating system, it will directly affect the performance of our web application.

Types of PaaS

PaaS can be divided into the following types:

- Public, private, and hybrid
- Communications Platform as a Service (CPaaS)
- Mobile Platform as a Service (MPaaS)
- Open PaaS

Let us discuss them briefly.

Public, private, and hybrid

Public PaaS is a category of the PaaS service model that allows the developer to develop their own software without worrying about the maintenance and management of infrastructure resources. The public PaaS vendor grants access to

the developers to set up, configure, and manage servers and databases. Earlier, only public PaaS used to be there. The public PaaS service model is used by small and medium-sized companies.

The private PaaS service model provides developers the access to generate their own software but with restrictions defined in the private data center. Developers need to follow all the security protocols and are restricted to the rules of the private organization. It grants access to platforms for developing and deploying applications along with maintenance of strict security and privacy requirements of the company's on-premise data center.

Hybrid PaaS combines the facilities of public and private PaaS.

Communications PaaS

Communications PaaS is a cloud-based platform that allows developers to add communication features like audio, video, or messages in their applications. CPaaS provides developers a complete development framework for adding communications features. They don't need to worry about infrastructure management. CPaaS vendors also provide support and product documentation which serve as a guide for developers while developing software using CPaaS. Examples include Skype, WhatsApp, FaceTime, etc.

Mobile PaaS

Mobile PaaS or MPaaS grants development capabilities for creating mobile apps. It offers **Integrated Development Environment (IDE)** for the configuration and creation of mobile apps. Developers do not require coding skills for this and are blessed with the drag and drop interface which simplifies the development of mobile apps.

Open PaaS

Open PaaS is a free open source software that provides useful web apps like calendar, contacts, and mail applications.

PaaS providers

Let's have a look at the list of various PaaS providers and the services provided by them:

PaaS Providers	Services
AWS Elastic Beanstalk	Run and deploy web applications, load balancing, provisioning, application health monitoring, and auto-scaling

PaaS Providers	Services
Microsoft Azure	Deploy applications, services, and support for multiple platforms
AppFog	Easy to deploy applications fast
Google App Engine	Develop, deploy, and manage applications
Oracle Cloud Platform	Build, deploy, integrate, and manage web applications

Table 4.2: Popular PaaS providers

Infrastructure as a Service (IaaS)

Infrastructure as a service or IaaS is a type of cloud computing service that provides organizations with computing infrastructure like servers, storage, virtual machines, and networks. Organizations or customers can access these services through the internet using the pay-per-use model. It provides an alternative for on-premise infrastructure which in turn results into reducing cost that would have incurred otherwise while buying expensive resources.

Organizations use their own platform and applications to do their tasks with support from the IaaS infrastructure. The IaaS vendor provides you with a virtual infrastructure environment as per your demands. It saves the organization from the burden of managing and maintaining servers, database, and networks. Hence, the cloud vendor manages the infrastructure and users can focus on installing, maintaining, and configuring the software applications.

With the IaaS technology, cloud vendors host the infrastructure components. Each component can be treated as a separate entity and can be taken on lease when required. Users can access these resources with the help of an internet connection to establish their own platforms. IaaS provides the following services:

- Providing virtual servers access
- Cloud storage for storing data
- Access to virtual networks and load balancers
- Provision for services like IP addresses, software bundles, firewalls, etc.

Some leading providers of IaaS are AWS, Microsoft Azure, Google Compute Engine, Rackspace, and IBM SmartCloud.

Advantages of IaaS

IaaS is a cloud computing service that provides numerous benefits to organizations or businesses such as reduction in cost, increment in growth rate of business, time management. Let us have a look at some of the important advantages of IaaS:

- **Saves time and cost:** It is very costly and time consuming to maintain on-premise resources. IaaS vendors provide us with a virtual infrastructure environment as per our need. Moreover, you don't have to spend money and time on their maintenance and updates. Hence, it contributes to reduced cost and time-saving.
- **Scalable and flexible:** IaaS infrastructures are highly scalable and flexible. You can change, i.e., increase or decrease the resources as per the requirements of the organization or business. IaaS vendors ensure availability of resources to the users as per their demands.
- **Access to the resources:** IaaS allows accessing all hardware resources to support the infrastructure environment over the internet.
- **Location independence:** Users can access the infrastructure resources provided by IaaS vendors from anywhere in the world and at any time.
- **Pay per use:** Resources are allocated on the basis of demand from users and they have to pay for only those resources that they actually used.
- **Focus on business growth:** With IaaS, users do not need to be concerned about the maintenance of the infrastructure. Hence, the time and cost that they use to indulge in complex operations related to servers, storage, and networks can be consumed in tasks related to business growth. They can use their time, money, and energy in extending the growth of their business.

Disadvantages of IaaS

Just like any other technology, IaaS also faces some challenges. Let us discuss them briefly. The following are the disadvantages of IaaS:

- **Security:** The organization is dependent on the cloud security protocols for the security of its data. Hence, one must carefully examine the security levels of the IaaS vendors and then decide which one to opt for.
- **Technical problems:** Organizations may face downtime due to some technical problems encountered in the IaaS infrastructure environment.
- **Upgrading and maintenance:** The organization is solely responsible for upgrading and maintaining its software applications.
- **Dependency on the internet:** The organization needs a good internet connection for accessing IaaS resources.

IaaS providers

The following table shows a list of some popular IaaS providers:

IaaS provider	Services
Amazon EC2	Provides resizable compute capacity in the cloud
Google Compute Engine	Scalable and high-performance virtual machine
Azure Virtual Machines	Provides flexibility of virtualization for various computing solutions like development, and testing and running applications.
Rackspace Managed Cloud	Tools needed to build scalable websites and applications
Digital Ocean	Provides cloud VMs, manages databases, server storage, loads balancers

Table 4.3: Popular IaaS providers

Network as a Service (NaaS)

As the name suggests, NaaS is a cloud computing service that offers network services to the businesses on a subscription basis. It uses virtual network infrastructure to provide network services to the customers on the basis of the pay-per-use model. The NaaS vendor manages and maintains the network infrastructure. Hence, customers do not have to worry about the infrastructure and complicated operations like configuring and operating routers and protocols, firewalls, etc. and can focus on their business.

NaaS provides the following services to the businesses:

- Flexible and extended **Virtual Private Network (VPN)**
- Bandwidth on demand
- Custom routing
- Multicast protocols
- Security firewalls
- Intrusion, detection, and prevention
- Wide area network
- Content monitoring and filtering
- Antivirus

Benefits of NaaS

The few benefits of NaaS are given below:

- The NaaS technology grants access to virtualized network environment to the customers. Hence, customers can focus on the growth of their business without worrying about network infrastructure.
- NaaS corresponds to reduced cost. All expensive networking hardware and software are delivered on the pay-per-use model by NaaS providers.
- The NaaS technology is a boon for businesses or organizations as it can detect network issues in advance and rectify them before the customers can know about them.
- The NaaS model provides us with enhanced security and increased level of uptime. It also maximizes performance and increases productivity.

Identity as a Service (IdaaS)

Identity as a Service refers to the cloud computing service that provides identity and access management service on the subscription basis. It provides cloud-based authentication or identity management to the businesses or organizations. The IdaaS technology allows users to access their data in a secure manner. This technology manages the employee or user's identity information as a digital entity. IdaaS includes the following services:

- Registration information
- Directory services
- Authentication services
- Risk and event monitoring
- Profile management
- Sign-on services

The IdaaS technology provides identity and access management services like **single-sign on (SSO)**, federated identity management for access governance, etc. Single-sign on or SSO is a session and user authentication service that permits a user to use one set of log-in information (e.g. name and password) to access multiple informations. This allows the user to login into a system once and manages access to other systems. So, the user does not need to login again and again. This service also enables administrators to manage levels of access to services and systems from a single point.

Advantages of IdaaS

The following are the advantages of IdaaS:

- With IdaaS, users have fewer accounts and passwords to manage and remember.
- It provides a central location for managing all administrative accounts.
- There is no need of re-authorization which improves the productivity of the organization.
- It also tackles the problem of forgetting passwords.

Conclusion

Cloud service models can be categorized mainly into three groups: IaaS, PaaS, and SaaS. Each of the service model possess unique features that can serve the needs of various businesses. IaaS is well-suited for large accounts, enterprises, or organizations capable of building and managing their own IT platforms. PaaS is ideal for companies who want to maintain control over their business applications. The SaaS model is widely used and preferred among companies. In this chapter, we have understood these service models of cloud computing. We have also studied the use of NaaS and IdaaS. In the next chapter, we will deal with cloud deployment models, i.e., public, private, hybrid, and community cloud.

Points to remember

- Cloud service models can be categorized into three models: SaaS, PaaS, and IaaS. All of these models provide services on the pay-per-use basis through the internet.
- SaaS stands for Software as a Service and provides access of software application to end users through the internet. The platform and infrastructure are managed by SaaS vendors.
- PaaS or Platform as a Service grants platform for developers where they can develop their own applications. PaaS vendors are responsible for managing infrastructure to support the platform.
- IaaS stands for Infrastructure as a Service and allows the use of infrastructure resources to users through the internet.
- NaaS provides network access to users and IdaaS provides identity and access management.

Multiple choice questions

1. **This cloud service model gives you the access of applications:**
 - a. SaaS
 - b. PaaS
 - c. IaaS
 - d. NaaS
2. **In the PaaS model, developers can**
 - a. Create, test and run the application
 - b. Use the software
 - c. Access the infrastructure
 - d. None of these
3. **SSO stands for**
 - a. Single sign off
 - b. Software signature offset
 - c. Single sign on
 - d. Software sign on
4. **IaaS can provide access to**
 - a. Servers
 - b. Software, platform, and infrastructure
 - c. Virtual machines
 - d. Servers, storage, and network

Answers

1. **a**
2. **a**
3. **c**
4. **d**

Questions

1. Elaborate on the concept of cloud services models.
2. Give a detailed description of the SaaS model.

3. Explain the essence of the PaaS model
4. Write a note on IaaS.
5. Briefly explain NaaS and IdaaS.

Key terms

- **SaaS:** SaaS is a cloud service model that provides the access of software applications to end users through the internet.
- **PaaS:** PaaS is a cloud service model that grants platform access to developers where they can build their own software applications.
- **IaaS:** IaaS is a cloud computing service that provides virtual infrastructure to the organization on a pay-per-use basis.
- **NaaS:** NaaS grants the access of network resources to an organization through the internet.
- **IdaaS:** IdaaS is a cloud-based authentication service that provides authentication and identity management to organizations.

CHAPTER 5

Cloud Deployment Models

Cloud deployment models suggest us the ways for availability of cloud services to the users, i.e., they are made public or can be accessed within the system only. For this very task, cloud deployment models are divided into categories. As per NIST, there are four cloud deployment models—public, private, community, and hybrid. These models define the size, placement, and access level of the cloud environment. We should understand the concepts of these models to decide which deployment model is suitable for our organization or business. The right deployment model is necessary for acquiring better performance, scalability, and security for a business. This chapter deals with four models of cloud deployment. It explains how cloud services can be accessed by the organization and users.

Structure

In this chapter, we will discuss the following topics:

- Cloud deployment models
- Public cloud
- Private cloud deployment model
- Difference between private cloud and public cloud
- Community cloud deployment model

- Hybrid cloud deployment model
- Comparative study of all clouds
- Multi cloud

Objectives

After studying this chapter, you will be able to:

- Understand the clear definition of cloud deployment models
- Understand comprehensively the types of deployment models
- Understand where and when to use which type of cloud deployment model
- Discuss the meaning and advantages of public cloud
- Have a look at the concept of private cloud
- Discuss the meaning and benefits of community cloud
- Have a look at the meaning and advantages of hybrid cloud
- Understand multi cloud

Cloud deployment models

Cloud deployment models describe the way a cloud platform is implemented, how it is hosted, and who has access to it. These models tell us the way of enabling SaaS, PaaS, and IaaS in our organization or business. It means that they specify the extent to which various cloud service models can be accessed. A cloud can have any of the four types of accesses: public, private, hybrid, and community. Each model provides us with different levels of management, flexibility, and security.

- **Public:** It is available to the general public. Microsoft Azure and IBM cloud are public clouds.
- **Private:** Only one specific company owns a private one. Amazon, Dell, and Red Hat are private clouds.
- **Community cloud:** These are for organizations that work on joint projects.
- **Hybrid cloud:** They contain the best features of public, private, and community clouds.

Every model has pros and cons. It is the choice of the customers as to which model they want to implement according to their requirements or the organization's necessities. One must consider various factors like computing, networking, storage requirements, business goals, available resources, etc. before choosing the deployment model. Moreover, one should also consider that the cost and values of

each model are different. Hence, choosing the correct model for the organization or business is a very vital decision that had to be made by the clients themselves. Larger organizations, especially government bodies, prefer private clouds as security is priority for them. Hence, they build their own private clouds. In the case of small and medium scale businesses or organizations, having their own private cloud can be expensive. Hence, they prefer public clouds or community clouds.

Public cloud

Out of the four cloud deployment models, the public cloud deployment model is used mostly by the users. Public cloud refers to the cloud which provides services or infrastructure to everyone or to the general public. This type of cloud model is managed, owned, and operated by cloud service providers and they grant services to customers on rent. All the cloud services including resources, storage, servers, and applications are made available to the public through the internet on a pay-per-use basis. This means that you have to pay for the services, storage, or computing resources that you use. Cloud service providers provide services to customers on demand. All the resources that are made available through the cloud are shared by all customers. It offers higher degree of scalability and automated maintenance. Public cloud includes all the cloud services: SaaS, PaaS, and IaaS.

We can consider an example to demonstrate the use of public cloud. Let us assume a club which provides various activities like sports, dance, music, and arts on rent. You can visit that place and use their resources to entertain yourself. You can play in the gaming zone, enjoy tennis or badminton, learn western or classical dance, or enjoy doing painting. You can access the services provided by the club and pay them money in return. It's not that only you can use these services. Anyone who comes and pays there can use their resources. Hence, you are sharing these resources with other people. You are not the owner of these resources but you can access them. You can enjoy any activity and you don't need to buy and manage any equipment for that. It is the duty of the club manager to buy and maintain all the resources of the club and manage the availability of resources for all customers.

The same goes for public cloud. You don't have to buy any physical resources for your work. All the resources are open through the internet for public use in a public cloud. You have to share hardware, software, and network resources with other organizations accessing the same cloud. The cloud vendor manages the availability of all shared resources to the customers and provides different services on rent as per the demands of the users. Users have to pay for everything they use without having to invest on expensive infrastructure. Hence, public clouds are very beneficial in terms of money.

The following figure shows you the concept of a public cloud:

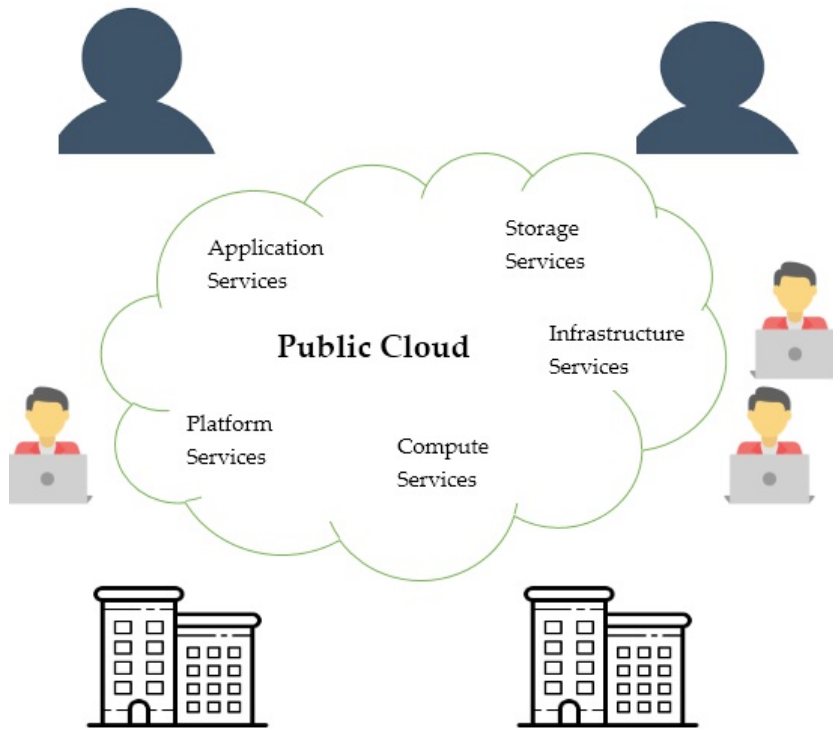


Figure 5.1: Public cloud

Public clouds are mostly used by companies for application development and testing, file sharing, email services, websites, time management, project management, antivirus services, etc. They are the best option for predictable computing needs. These clouds are suitable for those companies that want to minimize their operating costs and maintenance. The best public cloud providers include Amazon Web Services (AWS), Microsoft Azure, IBM cloud, and Google Cloud Platform. These cloud providers provide a huge pool of resources to the customers. These companies offer the following services via the public cloud:

- **Compute:** Resources that are used to process data are known as compute. This refers to applications and infrastructure that are related to computation and processing. For example: CPU.
- **Storage:** Storage refers to the place where data is stored. A public cloud allows the user to store and transmit data on the online space or remote storage server. This information is maintained, managed, and backed up there and it is made available to the users through network. Storing data online gives the user the facility of accessing the data anywhere and anytime via the internet.

- **Backup and disaster recovery:** Backup is a process of creating and storing copies of data for the purpose of saving and protecting it. Recovery means to restore the data at the original location in case any data loss or theft happens. Disaster recovery is a cloud computing service that enables us to store data on remote cloud-based storage servers and then recover our data in case any disaster or damage occurs.
- **Database and data warehouse:** The public cloud model gives us the facility of storing data in a place known as database. The public cloud model contains a large number of database servers to facilitate storage, accessibility, and retrieval of data. It also gives us the facility of data warehouse. Data warehouse comprises of information from various sources into one database. Various cloud vendors offer different types of data warehouse services. For example, Google offers BigQuery, Amazon has Redshift, and Microsoft has the Azure SQL data warehouse.
- **In-memory technology:** In-memory technology means storing information in the random access memory or RAM of servers. A public cloud offers dedicated servers where you can store your information in RAM instead of disk or relational databases. Storing information in RAM allows businesses to get quick responses and actions.
- **Analytics:** Analytics means to analyze data to make intelligent business decisions. Cloud computing gives users and businesses a set of technological and analytical tools that help them carry out important and meaningful information from a massive amount of data.
- **Artificial intelligence:** Artificial intelligence or AI refers to the intelligence of machines that is incorporated in them with the help of programs. These programs make them think like humans. Merging of AI in cloud computing is beneficial for a lot of people. Digital assistants like Alexa, Google Home, and Siri are example of AI and cloud computing. Cloud computing in collaboration with AI helps users and companies to manage their data and achieve customer satisfaction. It makes organizations more efficient and flexible.
- **Internet of things:** IoT or internet of things refers to the set of millions of physical devices that are connected to the internet and share data and communication. Using a cloud platform for IoT makes the system very scalable, secure, and ease of use. Various cloud platforms for IoT include Microsoft Azure IoT suite, Google's Cloud IoT platform, AWS cloud platform, Cisco IoT Cloud Connect, etc.
- **Machine learning:** Machine learning is the subset of artificial intelligence that provides systems with the ability to learn and improve their performance

from previous experience. It allows machines to gain the ability of thinking and solve problems.

Public cloud architecture

A public cloud model has a multi-tenant architecture where computing resources are shared among users. Users are not aware of each other's data. Every user's data is kept isolated from the other user's data. In the same way, all users have the right to access the resources that comes under a public cloud. All clients of a public cloud vendor can access the same infrastructure and servers but their data is kept separately and is secured.

While implementing multitenancy, the cloud vendor keeps the details about specifications of resources needed by each user. He maintains the metadata of each client and whenever any user requests for resources, he alters the resources or app configuration as per the specifications stored by him. In this way, each user shares and uses the same app or resource but experiences it differently.

The public cloud architecture helps us to achieve better use of resources and reduce cost. It requires high bandwidth network connectivity to transmit data from server to users or vice versa. The storage of the public cloud architecture possesses the redundancy feature which means that multiple copies of data are kept under multiple data centers.

Public cloud architecture can be further categorized into various service models. These models are:

- **Software as a Service (SaaS):** In SaaS, all the services and applications are hosted by third-party providers and are made available to the customers over the internet.
- **Platform as a Service (PaaS):** PaaS delivers software platform to its users or businesses that are required for application development.
- **Infrastructure as a Service (IaaS):** IaaS delivers infrastructure to the users via the internet or dedicated connections.

Advantages of public cloud

Public cloud offers cloud services to multiple customers with the benefits of high scalability, flexibility, cost saving, and no maintenance responsibility. Let us discuss the advantages of public cloud here.

- **Cost effectiveness:** Public cloud offers all necessary computing resources to the organizations on a subscription basis. Hence, you don't have to buy and manage expensive hardware and software resources needed for the efficient

operation of your business or organization. You can simply access them from any public cloud provider through the internet and pay them only for those resources that we use. Moreover, you don't have to bear the maintenance and update cost. Some companies even provide some services for free of cost like storage service by Google Drive. These factors make public cloud cost effective.

- **Saves time:** Organizations can directly use the applications and resources provided by service providers. They do not have to waste their time in installing, configuring software, and buying expensive hardware resources. They can use their time in developing strategies to increase the growth rate of the company.
- **Highly scalable:** Cloud resources can be scaled up automatically to cater to the needs of the businesses and these resources can be scaled down automatically when the peak time is over. This is very useful feature as it doesn't let the business down during the peak time and provides a sufficient amount of resources. In the same way, resources are scaled down automatically when they are not required which removes wastage of resources.
- **Reliability:** Public cloud providers provide a large number of resources and servers to work with. Hence, if any of the resources fail, one can access the other set of resources and continue their work without affecting the situation. Cloud network is very reliable and this advantage of cloud services is helpful in protecting our work even when any server fails.
- **Flexibility:** Services provided by public cloud are very flexible and anyone can use them by just using the internet. It provides the flexibility of scaling up and down the resources as per the requirements of the businesses. Users can add as many resources or application stack and remove them when the demand is over.
- **No maintenance:** Users do not have to worry about the maintenance of the infrastructure (provided by the cloud providers) that they are using for their organization. It is the responsibility of cloud providers to maintain and update the resources timely.
- **Security:** Sometimes, it is difficult to protect and secure your data in the organization due to cyber-attacks and hard disk failures. You may also incur loss of data due to damage to storage devices or any other natural calamities. Many small and medium scale companies do not have sufficient policies to implement security in their organizations. Hence, it is safe to store your data on cloud storage. Cloud offers a high level of security to protect your data against any loss or damage.

Disadvantages of public cloud

Besides many advantages, there are some disadvantages of public cloud also. Let us discuss them here.

- **Higher security risks:** Cloud provides high level of security, but storing data on cloud simply means that you are using the internet for storing your sensitive data. As we all know, the internet is prone to risks despite so many security measures. Hence, storing your sensitive data on public cloud is always a concern for cloud customers.
- **Lack of control:** Customers usually don't have any control over the resources since all resources are provided by cloud providers.
- **Higher level of accessibility:** Anyone can access the cloud services offered by public cloud, i.e., it provides a higher level of accessibility. Due to this factor, these services are more vulnerable to attacks.

Private cloud deployment model

Private cloud is a type of cloud model that is solely owned by a single organization and offers infrastructure services to that organization only. No other organization can access those resources and applications. They are the private property of that particular organization. Technically, private cloud architecture is similar to that of public cloud. But there is one difference between the two models. The resources and applications of a private cloud are accessible to that organization only that owns it while a public cloud is accessible to the general public. Private cloud contains resources that can be accessed by members of a single organization only. Members of that particular organization are granted the rights for accessing the resources. This provides a secure environment for an organization where no other person except the members can access the resources. Private cloud is the best option for companies that need to implement strict security rules and processing requirements.

Private cloud can exist on-premise or off-premise and it is managed by the company itself or a third-party provider can manage the private cloud of a company. But all the infrastructure and services belong privately to the business unit and it is the sole owner of all the software and hardware resources. Hence, these resources cannot be shared among other organizations. With private cloud, businesses can track information quickly and easily. It is also helpful in taking quick decisions as it is easy to retrieve and analyze the information.

Let us understand the concept of private cloud with an example. In the example given above, we considered a club whose resources can be accessed by anyone, just like in public cloud. Now, we will consider a society that contains a unit of people, just like any organization. The society manager has set up a club within the society

for its people only. All members of the society are assigned an ID card to enter the club area and enjoy facilities of the club. No other person can access the place. A secure environment is maintained, keeping in mind the safety of the resources and privacy of the society members. The security manager is responsible for the maintenance of the club resources. The same scenario goes for private cloud. All the resources are owned and managed by the organization and only the employees of the organization can access them, keeping in mind the safety and privacy of the organization's data.

Let us see the idea behind private cloud with the help of the figure given below:

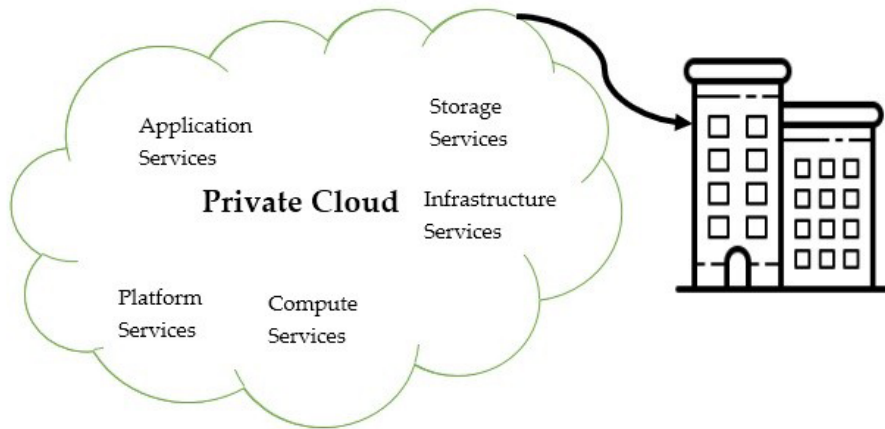


Figure 5.2: Private cloud

Since private cloud belongs to the organization only, it is solely responsible for the maintenance of its resources and bears all cost related to resource maintenance and software update. This capital expenditure incurred due to maintenance and update cost makes private cloud expensive in comparison to public cloud. Private clouds are mostly used by government agencies, financial agencies, and large-scale companies as they want more control over their operations. As these companies handle a large amount of sensitive data, they need to follow strict accessibility rules. Employing private cloud is the best option for them.

Top private cloud providers are HPE (Hewlett Packard Enterprise), VMware, Dell, Oracle, IBM, Microsoft, Cisco, NetApp, and Red Hat.

Advantages of private cloud

Private cloud offers a great level of security with full control. Due to additional security provided by private cloud, a business unit can focus on other areas to enhance the growth of the business. Let us discuss the various benefits of private cloud:

- **Highly private and secured:** Private cloud offers us resources that are fully dedicated to a single organization. Resources of an organization cannot be shared beyond the boundaries of the organization. Only authorized people can access the resources. This creates an environment of security and privacy for the employees of an organization.
- **Control-oriented:** With private cloud, an organization has control over the set up and running procedure of its resources, server, and the security protocols that will be implemented in the organization. The organization has the right to employ privacy policies and decide the storage location of the data. All rights are reserved for the organization in private cloud. However, third-party providers can manage the functioning of its unit if any organization wishes so.
- **Increased performance:** Resources are solely dedicated to an organization in private cloud. This leads to increased performance.
- **Highly scalable and flexible:** Private cloud also provides the features of scalability and flexibility since you can access resources whenever there is demand.

Disadvantages of private cloud

As private cloud is the private property of an organization, it has to bear the whole cost of infrastructure itself. Hence, it becomes expensive. Moreover, an organization needs a lot of skilled IT people to handle the servers, storage, hardware, and software resources. This also increases the complexity in the organization. Let us discuss its disadvantages:

- **Expensive:** All the infrastructure cost, maintenance, and update cost together makes the cloud expensive. Also, since a company needs skilled IT staff to maintain all its IT operations, it overburdens the cost incurred in the organization. All these lead to an increase in the cost of the organization. Hence, an organization needs a huge budget to implement private cloud.
- **More skilled manual power:** Since all resources are handled and maintained by private cloud, an organization that implements private cloud needs to employ many skilled IT professionals. This requires use of more manpower to achieve the goals of the organization.

Types of private cloud

We can divide private cloud into three types as shown in the figure given below:

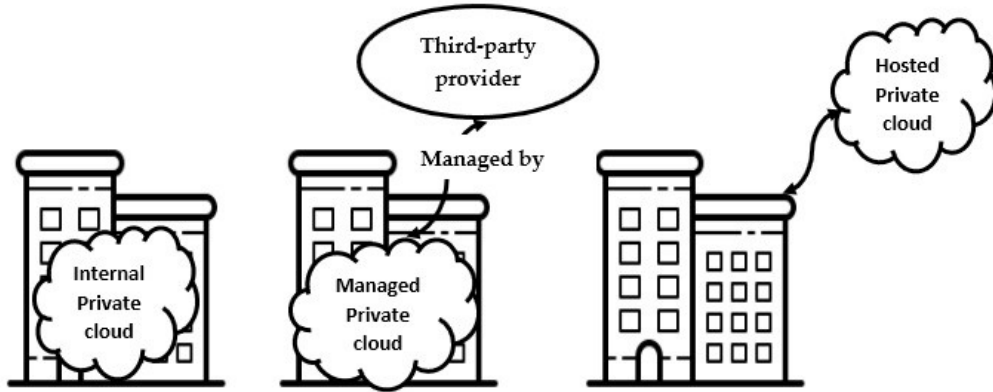


Figure 5.3: Types of private cloud

Internal private cloud

Internal private cloud refers to the environment in which it is the responsibility of the company to manage the infrastructure required for its cloud services itself. This type of private cloud is best for companies that want to work while maintaining security and keeping the access to data strictly private. These companies strictly follow security policies regarding data and apps.

Managed private cloud

Managed private cloud refers to the environment where the infrastructure of the company is hosted internally by the organization only. Here, management of the cloud services is done by the cloud service provider. It manages and maintains the cloud services. This type is appropriate for those companies that do not have skilled IT staff that can manage the infrastructure of the company. Therefore, they employ a cloud service provider to manage the private cloud. As the cloud provider manages all resources, it gives the advantages of flexibility, efficiency, and reliability to the company.

Hosted private cloud

Hosted private cloud refers to the environment where infrastructure is both hosted and managed by the cloud provider itself. The cloud provider allocates a particular server to a particular organization. The organization only uses the resources and can access them as per the demand. Here, the cloud provider is responsible for managing,

updating, and configuring the hardware, software, and network. One thing you should consider here is that if a server is allocated to a particular organization, then only that organization can access those resources. The server's resources are not shared among other organizations. The cloud provider works on behalf of the company and fulfills the requirements of the organization.

Comparison between private and public cloud

Both public and private cloud offer cloud computing services to the organization but they differ in some concepts like security, performance, and control. Private cloud is best for government and large-scale organizations that require a good level of performance, security, and control while the public cloud holds best for small and medium-scale organizations that need to manage their budget. Let us have a look at the differences between private and public cloud:

Public cloud	Private cloud
Public cloud supports multi-tenant architecture which means that the resources are shared among multiple customers.	Private cloud supports single-tenant architecture which means that the resources are used by a single organization.
It is maintained by cloud service providers only. Organizations can only access the resources.	It is owned solely by the organization but can be maintained by the organization or cloud service providers.
It is cost-efficient as organizations have to pay only for those resources that they use, i.e., the pay-per-use model is followed.	It is very costly as the organization bears all resource maintenance and update costs.
It doesn't require any specialized IT staff to deal with the maintenance of the hardware, software, and network resources.	Specialized skilled IT professionals are required to implement private cloud in the organization.
It is of immense use for organizations that need to follow a high level of strict security rules.	Although cloud providers provide a high level of security, sharing of resources may create a loophole in the security walls of the storage sector of the cloud.

Table 5.1: Difference between private and public cloud

Community cloud deployment model

Community cloud refers to the model in which infrastructure is shared among several organizations with similar interests. It can be managed and hosted either internally by organizations themselves or externally by the cloud providers. This type of model is very similar to the private model. The only difference is in the set of users accessing the cloud. This means that private cloud is for a single company while community cloud is for several organizations having the same backgrounds. Basically, the community model is just like the private cloud but with the sharing capability.

Community cloud can be either built by one single organization and it can share this cloud on a rent basis with other organizations having the same goals or interests. Or, it can be built by a group that is framed by the concerned people of various organizations, keeping the aim of the organizations in mind, and then the cloud can be shared among all the organizations.

Let's understand the community model with an example. Let us consider a group of CBSE schools that teach students of board classes. All of them have the goal of teaching their students all subjects online. Hence, instead of developing separate private clouds for study materials, they can together frame a cloud where they can all contribute their knowledge in developing the study material for all subjects of the board classes. Now, the students of all schools can access this cloud for their study materials. The access to this cloud would be restricted to teachers and students of only those schools that are a part of this cloud.

Under the community model, organizations with the same interests work together on projects jointly. Here, the cloud providers provide the services of project development, management, and implementation. As all organizations share resources and other services with each other, the cost is also shared among the organizations. This enhances the feature of cost reduction.

Basically, community cloud is the best option for government sectors like police departments within a state, sharing their resources and information on some crucial issues, education departments sharing studying material and other resources with all government schools within the state or country, universities involved in the same research, health care companies, or manufacturing companies.

The following figure gives an illustration of the community model:

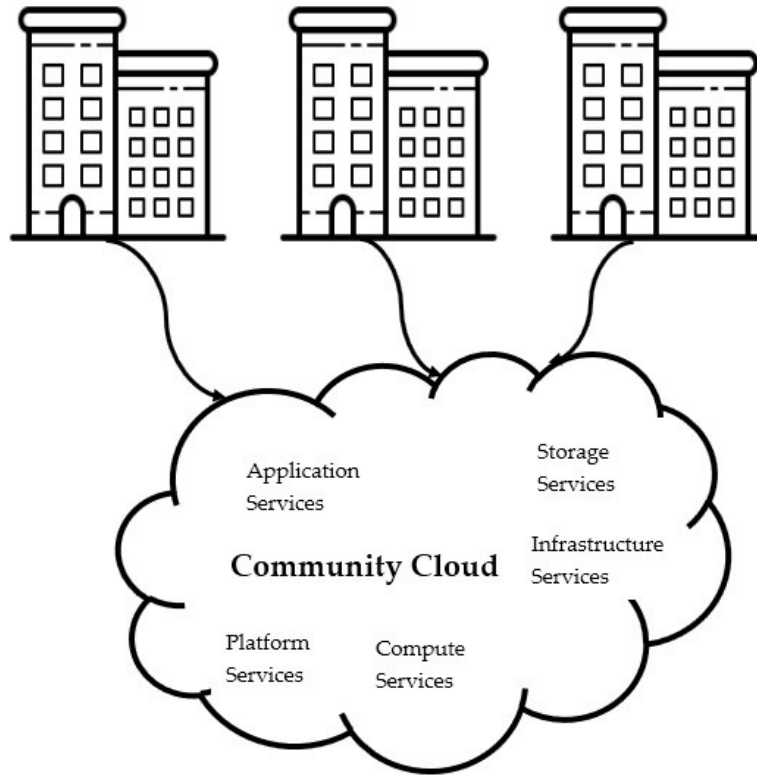


Figure 5.4: Community cloud

Advantages of community model

Community cloud is beneficial for organizations that have shared concerns like healthcare and defense departments. It provides the features of scalability, cost reduction, flexibility, and sharing to organizations. Let us discuss the advantages of community cloud.

- **Cost reduction:** As resources are shared among communities with the same interests cost is also divided among them which results in cost reduction in comparison to private cloud but it is still higher than the cost incurred in public cloud.
- **Ease of sharing and collaboration:** Community cloud provides easy sharing of infrastructure, resources, and other facilities among organizations.
- **Available and reliable:** With community model, resources are always available for users anytime and anywhere. Moreover, it provides a reliable environment.

- **Flexibility and scalability:** The community model is very flexible and scalable. Since organizations share the resources of community model, all the resources must be compatible for every user. Users can also modify the resources as per their requirements. This feature is very essential for the efficient functioning and continuous growth of the organization.

Disadvantages of community model

Community cloud is not a good and secure choice for all organizations. Since all that data is stored at one place, there are chances of one organization's data being accessed by the employees of other organizations. Let us discuss some disadvantages of community cloud.

- The community model is not suitable for all communities as they may differ in security policy and other features.
- Community cloud is costlier than public cloud.
- Since data is shared among all organizations, there are always chances of unauthorized access.
- All data is stored at one place so there is a need for every organization to employ a high level of security to protect their data.

Hybrid cloud deployment model

The hybrid cloud deployment model is a combination of private cloud (managed by the organization) and public cloud (managed by third-party cloud providers) deployment models. Hybrid cloud contains the best features of both models, i.e., for example, it provides the cost effective facility of public cloud with the security protocols of private cloud. Although public and private cloud together form the hybrid cloud, they still work as unique entities. This is the reason that in the case of more volume of data that doesn't require much security; we can prefer the public cloud option while for storing and managing high-sensitive data, we can use the private cloud option of hybrid cloud.

Hybrid cloud includes the infrastructure of both private and public cloud. This is the reason why the hybrid cloud tends to provide the benefits of both models. It gives us the opportunity of managing workloads as per the changing computing requirements of the company. We can shift our cloud access from private to public or from public to private as per the demands of the company for resources and storage. Implementing hybrid cloud in a company provides flexibility and scalability to the business. Hybrid cloud is the best option for companies that need security and control along with cost savings.

It's not that any if any company uses a public cloud and private cloud, then it is using hybrid cloud. Rather, hybrid cloud is an environment that utilizes the services of both clouds to enable the efficient growth of a business. Private and public clouds are interconnected together to form the infrastructure of hybrid cloud but they remain individual entities. We can use hybrid cloud to rapidly increase the volume of resources when demand suddenly occurs during peak season or weekends.

Let us consider an example of a company offering online shopping for its products. The development and workload are managed by the public cloud while tasks like data handling are performed using the private cloud. Here, the company can use private cloud for day to day business as there will be normal flow. But during weekends or the peak season, there will be more traffic. Therefore, there will be the need for more computing resources, storage, etc. Hence, to bear the workload, the company will shift to public cloud. This situation is known as cloud bursting.

Cloud bursting is a configuration in hybrid cloud in which if the demand for an application or resource that is available in private cloud increases and reaches beyond the limit, then the company can move to the public cloud to avail the benefits of additional computing resources and higher capacity. This is a set up between private and public cloud to deal with peaks in IT demand.

The following figure is the graphical view of a hybrid cloud:

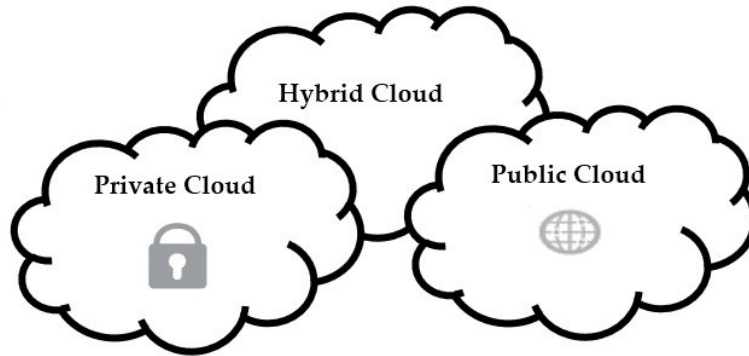


Figure 5.5: Hybrid cloud

Top hybrid cloud providers include Microsoft Azure, AWS, Google Cloud Platform, VMware, Rackspace, Hewlett Packard Enterprise, EMC, IBM, and Verizon Enterprise.

Types of hybrid cloud environments

There are two types of hybrid cloud environments. The environment defines the way in which infrastructures are chosen for hybrid cloud environments. These environments are:

- Homogeneous cloud environment
- Heterogeneous cloud environment

Let us discuss them briefly.

Homogeneous cloud environment

Homogeneous cloud environment is a type of environment where every component related to private and public cloud offerings is provided by the same vendor. Everything is pre-integrated and only the single vendor is responsible for its success and failure. The user is totally dependent on that single vendor for the successful operation of its business. If anything goes wrong, he is supposed to be held responsible.

In the homogeneous cloud environment for hybrid cloud, both the public cloud services and private cloud management, and the access are managed by a single vendor. The same vendor supplies the whole software stack which includes a hypervisor (cloud hosting provider), intermediate management layers, and end-user portal. So, the user is dependent on the single vendor technically and commercially.

Pros of homogeneous cloud environment

Some advantages of homogenous cloud environment are given as follows:

- This is easy to install and use.
- Both the private and public clouds are products of the same vendor, hence they have in-built cooperation between them. So, it easy to work with them technically as well as from the management point of view.
- These environments have features like disaster recovery, security; and governance and monitoring are integrated with them.
- This type of environment is cheaper in comparison to the heterogeneous one.

Drawback of homogenous cloud environment

Although homogenous cloud is very easy to use, the supply of both cloud models from the same vendor results in vendor lock-in. After the user decides to use a particular vendor model, he is bound to follow the guidelines given by him. It is the vendor's choice to update the technologies implemented by him. Moreover, the vendor can increase the amount of model in mid-time which may cause cost burden for users. They cannot even change the vendor in-between as it is risky, expensive, and a threat for the security policies of the organization.

Heterogeneous cloud environment

Heterogeneous cloud environment is a type of hybrid environment where the public and private cloud components are incorporated from different or more than one

vendor. For example, you can select the public cloud provider from Azure or AWS and correlate it with private cloud offered by VMware, CloudStack, or OpenStack.

Heterogeneous cloud computing enables users to get rid of the vendor lock-in feature as it includes components from different vendors.

Users or companies can choose the type of environment on the basis of the following factors:

- Requirements of the organization that you expect for your company in the present and in the future.
- According to the cost and resources.
- According to the skills of your organization's IT staff.
- According to the talent of the cloud engineer and architects.

Advantages of hybrid cloud

Hybrid cloud offers the benefits of being economical, scalability, flexibility, and security. Moreover, it is very helpful in managing risks. It has many other benefits. Let us discuss them here:

- **Flexibility and control:** Hybrid cloud provides a good level of flexibility and control to the customers. It provides us with a wide range of resources that we can use anytime and anywhere. It gives you the control to manage your infrastructure and scale the resources up and down as per the demands of the users.
- **Cost-effectiveness:** Hybrid cloud gives us the advantage that public cloud gives of being economical. Normally, businesses use private cloud for applications and resources, and they can scale up the resources using public cloud when there is a spike on the private cloud. Hence, they only have to pay for the public cloud resources when they use them. This saves the cost of organizations as you pay for the extra capacity only when you use it.
- **Enhanced organizational agility:** Agility is a feature of hybrid cloud that provides companies with the ability to develop, test, and launch business applications which increases business growth. It provides the facility of overcoming workload as well as quickly developing and launching new products. It enables the organizations to meet the demands of the customers.
- **Security:** Hybrid cloud is very beneficial as it protects our sensitive data with private cloud. It gives us the opportunity to save our data securely and manage workload. It implements various measures to enable the security of your organization and protect your data. The IT team of hybrid cloud enables standardized security protocols which allow data redundancy, and thus manages risk failure.

Disadvantages of hybrid cloud

Despite so many benefits, hybrid cloud is not suitable for all organizations. It also has some drawbacks. Let's discuss them here:

- **Requires more maintenance:** Since hybrid cloud means managing the services of two clouds, it requires more maintenance. Business owners need to manage hardware resources employed in private cloud and invest money in maintaining them. Owners are required to maintain their computing infrastructure which in turn causes more operating expenses for the company.
- **Initial costs:** The cost incurred for implementing both clouds in the company can be expensive.
- **Networking issues:** As hybrid cloud contains both public and private cloud, this may create some networking issues. The presence of two clouds may make the cloud networking complex.

Comparative study for all clouds

Each of the four clouds give us numerous benefits. Companies can implement them as per their requirements. Let us have a look at the features provided by all of them and compare their facilities with the help of the table given below:

Characteristics	Public	Private	Community	Hybrid
Installation	Easy	Requires skilled IT professionals	Requires skilled IT professionals	Requires skilled IT professionals
Cost effectiveness	It is very cheap as resources are shared	Costly as the whole set up is managed by IT professionals	Not costly as cost is shared among communities	Cheaper than private cloud but costlier than public cloud
Data security	Low	High	High	High
Scalability and flexibility	High	High	High	High
Data control	None or little	High	High	High
Maintenance	Not required	Business owner is responsible	Communities are responsible for individual infrastructure	Needs to manage hardware resources to satisfy computing needs.

Table 5.2: Comparative study of all cloud models

Multi cloud

Multi cloud is a technology in which an organization or enterprise uses more than one cloud platform. These cloud platforms can be public, private, or hybrid.

It is a strategy that is integrated by organizations to perform many tasks. These cloud platforms can be supplied from different vendors. Multi cloud can also be a combination of SaaS, PaaS, and IaaS.

Multi cloud means that instead of having one vendor for all services like cloud hosting, storage, applications, or services; organizations have the facility of selecting different vendors for each task. A multi cloud can be a hybrid cloud but both are different concepts. So, don't get confused.

With multi cloud, one can choose the best services for his organization. Users can select any vendor to get the best and unique application service and implement new technologies in the organization. This is also helpful in case any particular service provider is having any technical issues or experiencing downtime as then the organization or users can switch to another vendor for that particular task.

This strategy is best for organizations that do not want to depend on a single cloud provider for all its services and utilize various services from different cloud models so as to get the best benefit from each. The multi cloud strategy provides organizations with efficiency, cost reduction, and enables access to new and updated technologies. It provides flexibility of utilizing cloud platforms from more than one vendor with elimination of factors like vendor lock-in and dependency on single vendor for each task.

Although multi cloud is a good strategy and provides benefits like cost reduction, access to new and innovative technologies, selection of service and vendor as per the user's desire, it has some drawbacks too. The use of multiple cloud platforms raises the need for managing too many protocols, tools, and security policies. It makes the environment complex to handle.

The following figure shows the concept of multi cloud:

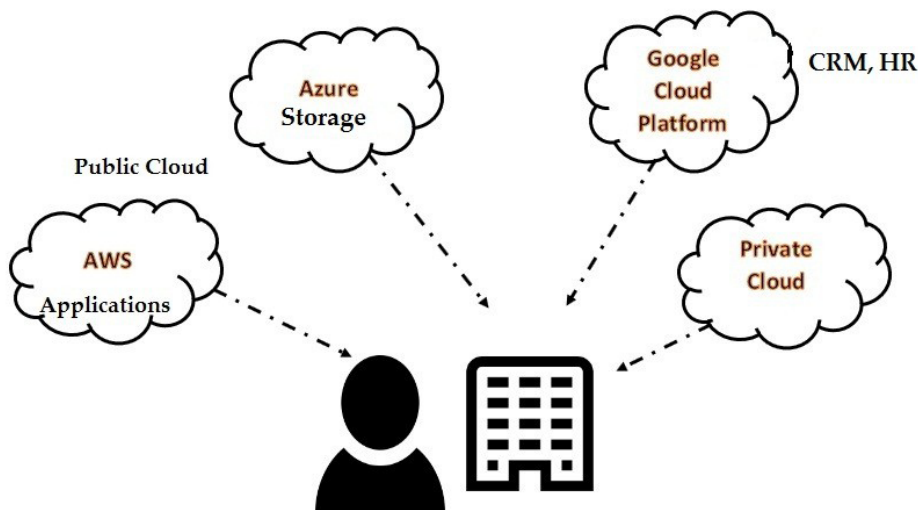


Figure 5.6: Multi cloud

Difference between multi cloud and hybrid cloud

Although both of them, i.e., hybrid and multi cloud use more than one cloud, they are different technologies. Hybrid cloud is a combination of private and public clouds that are interconnected to each other and work in cooperation, while multi cloud refers to the combination of different clouds wherein each cloud is designated for a different task. Let us have a look at the differences between them:

- Hybrid cloud is a cloud deployment model that consists of private cloud and public cloud. Both of them are connected via **virtual private network (VPN)**. On the other hand, multi cloud is a strategy that combines multiple clouds of different types. Here, all clouds are not connected to each other. Each of the cloud performs its own task for which it is defined for.
- In hybrid cloud, the private cloud firstly handles the workload of the company. When a hike occurs suddenly during peak time, public cloud is used to handle the workload and fulfill the demands of market trend. Hence, the goal of hybrid cloud is to handle the workload by implementing both of the clouds as per the need. Whereas in the case of multi cloud, the goal is to eliminate the dependency on single vendors and reduce problems created due to downtime of the vendors. Workload is distributed among multiple clouds supplied by different vendors. This eliminates the issue of vendor lock-in.

Conclusion

Cloud computing offers four types of cloud deployment models, namely public, private, community, and hybrid cloud. Private cloud is the best for organizing, managing, deploying, and using IT services in a flexible way. One can expand or reduce its business as per the requirements. Only authorized users are allowed to access the information in a private cloud. Public cloud is best for small and medium scale companies as it is very cost effective and gives the ability of sharing resources with other organizations. Community cloud is best for all communities that have the same goal or objective. Hybrid cloud is best for finance and healthcare organizations where critical activities are performed by private cloud and non-critical tasks by public cloud. We have studied the meanings, advantages, and disadvantages of these cloud models in this chapter. In the next chapter, we will study about the concept of virtualization.

Points to remember

- Cloud deployment model tells us the way in which a cloud is implemented in an organization. It specifies how various services are accessed by the cloud.

- Cloud deployment models are categorized into four types – public, private, community, and hybrid.
- In public cloud, resources are shared among many users. It provides the benefits of scalability and flexibility along with cost effectiveness.
- In private cloud, the infrastructure facility is accessed by a single organization. It gives the benefit of high security with full control.
- Community cloud is a cloud model in which cloud resources are shared among communities that share common interests. It gives the facilities of scalability and reliability along with cost savings.
- Hybrid cloud is a joint mixture of both private and public cloud which provides businesses with the security of private cloud and the scalability and cost effectiveness factors of public cloud. Here, the critical tasks are performed by the private cloud and the non-critical tasks are performed by the public cloud.

Multiple choice questions

1. **This cloud is only shared by an organization and provides full security to the organization:**
 - a. Private cloud
 - b. Public cloud
 - c. Company cloud
 - d. Organization cloud
2. **We use this model to pay for resources that we use in public cloud:**
 - a. Pay-per-use
 - b. Use-and-pay
 - c. Access-pay
 - d. Use-pay
3. **If more than one organization having the same interest wants to work together, then they can build their own _____ cloud.**
 - a. Public
 - b. Private
 - c. Community
 - d. Hybrid

4. **With this cloud, you can avail the benefits of more than one cloud environment:**
- a. Private
 - b. Public
 - c. Community
 - d. Hybrid

Answers

1. a
2. a
3. c
4. d

Questions

1. State the types of cloud deployment models with the benefits of each.
2. Discuss the use of public cloud with its merits.
3. Write the meaning of private cloud with its advantages and disadvantages.
4. Elaborate on the concept of community cloud and give its benefits.
5. Write the difference between private and public cloud.
6. Explain the concept of hybrid cloud with its advantages.

Key terms

- **Public cloud:** Cloud that is open to all and provides sharing of resources among many users.
- **Metadata:** Information about a file.
- **Private cloud:** Cloud whose access is limited to the single organization that owns it.
- **Community cloud:** Cloud that allows accessing of services and resources by a group of communities that share common interests.
- **Hybrid cloud:** Cloud that is a combination of public and private cloud.

CHAPTER 6

Virtualization

By the word ‘virtual,’ we mean something that is not real, and the technology called ‘virtualization’ refers to a virtual environment of anything. It may include a virtual version of hardware, software, storage devices, network resources, etc. Virtualization is the fundamental technology that powers cloud computing. It refers to creating virtual copies of the server, network, operating system, or resources and sharing it among multiple servers. Each virtual machine acts as a real machine and creates an environment which seems real to the user. They are very helpful as they enable full utilization of infrastructure and overcome the problem of workload on the server or network. This chapter describes the concept of virtualization. We will study the meaning, types, and benefits of virtualization. After going through this chapter, you will have a clear understanding of virtualization in cloud computing.

Structure

In this chapter, we will discuss the following topics:

- Meaning of virtualization
- How does virtualization work?
- Benefits of virtualization
- Types of virtualization

- Hardware virtualization
- Software virtualization
- Server virtualization
- Storage virtualization
- Operating system virtualization

Objective

After studying this chapter, you will be able to:

- Understand the meaning and benefits of virtualization
- Discuss the various types of virtualization
- Understand the meaning, types, and benefits of hardware virtualization
- Discuss the meaning, types, and benefits of software virtualization
- Understand the meaning, types, and benefits of server virtualization
- Elaborate the meaning, types, and benefits of storage virtualization
- Understand the concept of operating system virtualization

Meaning of virtualization

As we know, cloud computing is the act of providing the access of resources and storage to multiple organizations. Cloud vendors allocate resources, storage, and other services to organizations. Since they have a sufficient amount of physical hardware resources, software applications, network resources, and storage, they provide these resources on rent to the customers. However, if every customer demands for new resources, then it would be cumbersome to have so many physical instances of resources and it might overload the storage capacity of the cloud providers. Here, the concept of virtualization comes into existence. With virtualization, cloud vendors can create virtual copies of their infrastructures and servers and assign those copies of resources to the users or organizations.

Virtualization refers to the creation of a virtual version of hardware or software resources, storage devices, or network devices. This technique is helpful as it provides the users with multiple machines at the same time. Multiple OS and applications can run on the same machine. With virtualization, a single physical instance of a resource or application gets divided into multiple logical partitions and can be shared among multiple customers. Customers do not have any idea about logical partitions. To them, it seems that they solely access the applications or resources. A physical resource is assigned a logical name for its address. When a user demands for a resource, a pointer is assigned to that physical resource.

Virtualization is a technology in cloud computing that provides the facility of sharing a single physical instance of a resource, server, or operating system among multiple users or organizations. It creates a virtual environment where virtual copies of all infrastructures including servers, networks, hardware, software, and operating systems is created and used by the users accessing the cloud computing services. Virtualization is very beneficial as it helps in reducing workload which results in increased utilization and flexibility of hardware. This technique helps companies in implementing cloud computing.

The following figure illustrates the concept of the virtualization technique.

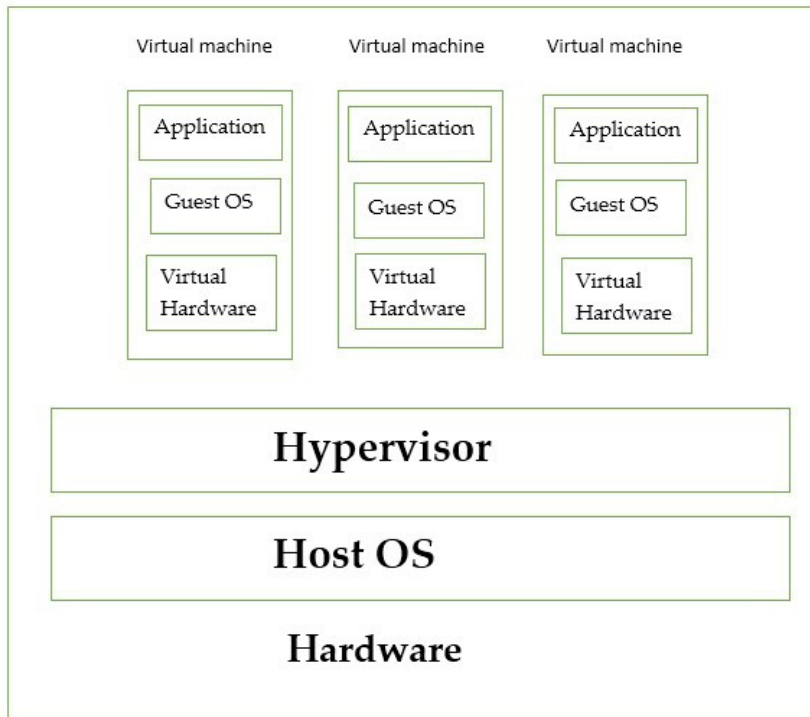


Figure 6.1: Virtualization technique

With virtualization, a single application becomes virtual and is shared among multiple users. This eliminates the need for installing software on every machine. Moreover, virtualization also constitutes creating virtual hardware, storage, server, and network. All the data stored by various clients or organizations through virtual applications get stored at one place in the cloud, thereby ensuring the safety and reliability of the data. Virtualization is very crucial as it provides the maintenance of resources in an efficient manner.

The machine on which the virtual machine is created is known as the host machine and the virtual machine is termed as the guest machine. The virtual machine or VM

creates a virtual environment which is managed by firmware. This is firmware is termed as hypervisor in cloud computing.

Features of virtualization

Virtualization is considered to be the backbone of cloud computing because of the following features:

- **Partitioning:** Virtualization technology divides the available resources into multiple partitions and provides the allocation of resources and applications in the virtual form among multiple users or organizations.
- **Isolation:** Although virtualization gives us the facility of creating virtual versions of single physical resources or storage, it keeps all virtual versions isolated from each other. This technique is very powerful because the crashing of one VM doesn't affect another one. An organization or user can use another virtual machine in case the machine on which the work is going on gets damaged or crashes. Apart from this, the data of one virtual machine remains unshared with the other sets of virtual machines running on the same platform.
- **Scalability:** Scalability, i.e., the feature of scaling up and down the resources as per the demands of the customers, is a very important characteristic of virtualization. It enables the efficient growth of a business.
- **Flexibility:** The virtualization technology gives us the feature of flexibility which enables the availability of resources or applications to multiple clients or organizations at the same time.
- **Security:** Virtualization provides a high level of security and protection for guest machines. It uses firewalls and encryption for ensuring the security of data and applications. It protects the host machine from any harm or damage caused by the guest machines.

How does virtualization work?

Virtualization is an approach that enables the sharing of virtual copies of physical resources or applications among multiple users or organizations. IT specialists of cloud use a specially designed software to create multiple virtual versions of a single physical resource or application. Each virtual version of a resource acts like a unique physical resource. Each virtual version is assigned a logical name. Whenever a user demands for the physical resource, a pointer to the physical resource is provided. The virtual machines created here are managed by the hypervisor. It is a firmware that can be understood in terms of an operating system.

Benefits of virtualization

Virtualization is the pillar of cloud computing. It increases the efficiency of cloud computing by providing immense benefits. It lowers the cost of the resources and enables their full utilization. Virtualization enables the users to scale up and down the resources as per the demands of the organizations or users. It is a very beneficial technology and provides the following benefits to the organizations or users:

- **Reduced operating costs:** Virtualization gives us the ability of sharing physical resources. It provides us with as many resources we want anytime and anywhere. Hence, there is no need to buy those resources. Moreover, since we don't have to buy the resources, there is no headache of maintaining them. This saves a lot of the cost incurred in operating them. Also, having less hardware on your premises means less power consumption and less space requirement, which in turn again results in cost savings.
- **Minimal downtime:** With virtualization, one can access resources however they want. Every time that a user demands for a resource or an application, the cloud vendor provides him with its virtual form. Instead of wasting hours in downloading and installing the setup of a new resource, you can use the virtual version of it. No time is wasted in installing the setup of a resource or application. Hence, it minimizes the downtime needed for accessing the resources or applications.
- **Speedy recovery time:** If there is a system failure or a need for data recovery, virtualization is a boon in that case. With virtualization, users can access a new resource instead of repairing the old one and restore its data with the help of the backup facility.
- **Simplified data center management:** Virtualization tends to provide servers for all critical operations that are required in the organizations. Cloud vendors themselves manage all the maintenance of the infrastructures allocated to the organizations by them. They also provide storage and security features. This enables redundancy and disaster recovery. In short, we can say that all operations are managed by third-party providers which simplifies the management at the data center.
- **Increased productivity for your IT team:** Since all the critical tasks like troubleshooting problems, preventing virus and malware attacks, hardware and software maintenance and updation are managed by the cloud providers, the IT team of an organization can focus on the productivity of the company. They can spend their time and efficiency on projects related to the efficient growth of the organization.

- **Faster provisioning:** Virtualization enables the availability of a huge amount of resources quickly in comparison to physical resources. You can provision them quickly whenever needed as per the demands of the organizations.

Difference between cloud computing and virtualization

Virtualization is a technique that create virtual instances of every resource or application from a single hardware system, while cloud computing refers to an IT setup which enables organizations or individuals to access hardware, software, storage and network infrastructures on demand anytime and anywhere. Although virtualization is the base for cloud computing, some people consider them to be the same. Let us have a look at the differences between them:

Virtualization	Cloud computing
Virtualization is a process of creating multiple copies of hardware and software on the same machine.	Cloud computing is the on-demand access of hardware and software resources.
It is very simple to set up virtualization software.	Setting up a cloud environment is a complicated task.
Users need to have proper authentication before accessing virtual resources.	Any user can access cloud resources anywhere and anytime.
Virtualization is more cost-efficient than cloud computing.	Cloud computing can be more costly than virtualization.

Table 6.1: Difference between virtualization and cloud computing

Types of virtualization

Virtualization makes it convenient for users to implement cloud computing. It enables the creation of virtual forms of hardware, software, servers, and operating system. Hence, virtualization can be divided into the following types:

- **Hardware virtualization:** This refers to the creation of virtual physical hardware resources so that multiple users can access the hardware resources at the same time.
- **Software virtualization:** In this type of virtualization, abstraction of software installation is done and users are given the access of working on virtual applications.
- **Server virtualization:** This means the partition of single physical servers into multiple virtual servers to effectively increase the utilization of resources and

enhance the productivity of the organization. Users can access the server's resources in the virtual form.

- **Storage virtualization:** In this type of virtualization, various storage devices are pooled into single storage and then divided into logical volumes to be accessed by the users.
- **Operating system virtualization:** In this type of virtualization, various versions of the operating system runs on the single system simultaneously.
- **Network virtualization:** Network virtualization means to create virtual networks that allow the network administrator to automate many tasks. It is the process of combining hardware, software, and network functionality into a single virtual network. This virtual network is responsible for deploying and managing network resources. Network is very beneficial as it helps in improving productivity and increasing network speed, reliability, flexibility, and security.

Let us discuss these in detail.

Hardware virtualization

Hardware virtualization refers to the act of creating virtual versions of physical hardware resources and sharing them among multiple users or organizations. A virtual machine is created over the existing operating system and hardware. It abstracts the physical hardware resource from the users. In hardware virtualization, the virtual machine software is directly installed on the hardware system. The program that is used to control the virtual machine is known as hypervisor. Hypervisor manages the physical resources that are shared between the cloud provider and the users. The hypervisor or virtual machine manager (VMM) is the fundamental element of hardware virtualization. Its primary task is to monitor the programs and control memory and hardware. Once the hardware virtualization is done, it is appropriate to install different operating systems and run various applications on them.

Working of hardware virtualization

Hypervisor or VMM acts as a control program in hardware virtualization. In hardware virtualization, a hypervisor or virtual machine manager is installed which creates an abstraction layer between the software and the underlying hardware. The machine on which we install the hardware is known as the host machine. It acts as a simulation environment where any guest software can perform its operations just like how it runs on the actual physical hardware. This guest software can be any software, including the operating system. Hence, after the installation of the hypervisor, the software works on the virtual resources like virtual processors rather than physical processors.

Hypervisor are of two types. These are as follows:

- Type – 1 Hypervisor
- Type – 2 Hypervisor

Let us understand these in detail.

Type – 1 hypervisor

The Type-1 hypervisor is also known as bare-metal or native hypervisor. It is a layer of software that runs directly on the host hardware system. It doesn't require any base operating system. Its main job is to control the hardware resources and manage the guest operating system. Type-1 is named as bare-metal because there is no software or operating system between the physical server and its underlying hardware. It is the most basic form of hypervisor which enables efficient functioning and excellent performance. These are mainly used in enterprise environments. Some popular Type – 1 vendors are VMware vSphere, KVM, Oracle – VM, and Citrix Hypervisor.

Type – 2 hypervisor

Type -2 hypervisor is also known as the hosted hypervisor. This type of hypervisor runs inside the operating system of a physical host system. In this type, the hypervisor runs as a second layer while the operating system runs as a third layer above the hardware. While the Type -1 hypervisor runs directly on the hardware, this type of hypervisor includes a layer of software below which the hardware is located. A typical Type – 2 hypervisor includes a physical machine, an operating system, type – 2 hypervisor installed in the operating system, and instances of virtual machines. This type of hypervisor also functions as a management console for all VMs. So, there is no need to install any other application to create and manage the virtual machines. The hypervisor enables us to create and manage the sets of virtual machines. The Type-2 vendors include Oracle VM VirtualBox, VMware Workstation Pro, and Windows Virtual PC.

Hypervisor enables the multiple guest **operating system (OS)** to run on a single host machine at the same time. It creates a virtualization layer that separates CPU / Processors, RAM, and other physical resources from the virtual machines. These virtual machines can be hosted at the same time. Each virtual machine is isolated from each other. Hence, any damage or virus attack on one VM doesn't affect another VM. Hardware virtualization done by installing the Type-1 hypervisor is known as bare-metal virtualization. Here, the hypervisor is directly installed on the computer hardware and operating system, and the other applications are installed later on. An alternative approach is to install a host operating system first and then install a hypervisor at the top of the operating system. This hardware virtualization is known as host virtualization.

The following figure depicts the two types of hypervisors:

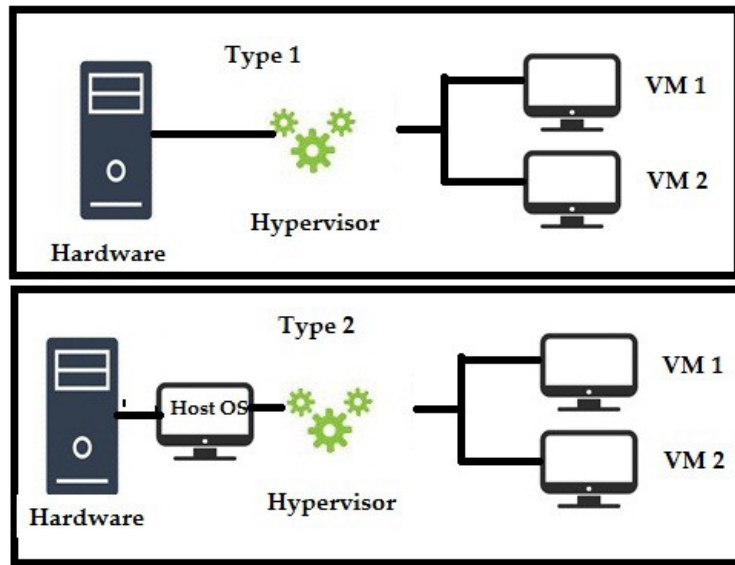


Figure 6.2: Types of hypervisor

Types of hardware virtualization

Hardware virtualization can be broadly divided into three types:

- Full virtualization
- Para-virtualization
- Hardware assisted virtualization

Let us learn about each of these.

Full virtualization

Full virtualization is a type of hardware virtualization that fully enables the simulation of the underlying hardware. This complete simulation allows a guest operating system (one being virtualized) to run in an isolated instance. In this type of hardware virtualization, the application runs on the top of the guest operating system. This guest OS operates on the top of the hypervisor and then the layer of the host OS and hardware comes. Here, the guest OS is unaware of the fact that it is running in a virtualized environment. It sends commands directly to the simulated hardware.

Full virtualization is a very popular and cost-efficient hardware virtualization. It enables the full simulation of the hardware and creates an environment that is quite similar to that of an operating system in a server. The virtual machine is capable of

accessing any software that can run on the physical hardware. Full virtualization gives the facility of running an unmodified guest operating system in isolation which gives the users a number of advantages. We don't need to do any modification in the application to run it. Each guest server runs on its own operating system.

The following figure illustrates the concept of full virtualization:

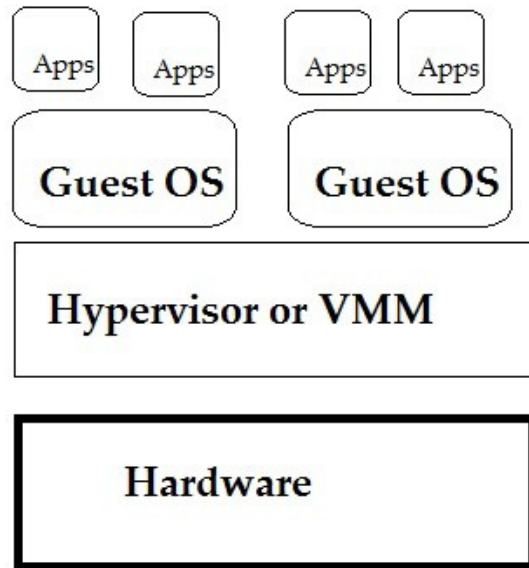


Figure 6.3: Full virtualization

Full virtualization provides the features of isolation and security to virtual machines and provides the virtual machines with all the services of a physical system. Here, the users can run multiple different guest OS simultaneously. It is the only virtualization that doesn't require any assistance from the hardware or the operating system to virtualize sensitive and privileged instructions. Full virtualization also gives the ability of combining both the existing and new systems. One must upgrade their hardware systems to newer systems in order to integrate old systems.

Para-virtualization

In para-virtualization, the simulation of hardware is not done. Rather, a modified and recompiled version of the guest operating system is made to run in the virtual machine. Here, the guest operating system is aware of the fact that it is a guest and can simply issue commands to the host operating system instead of issuing commands directly to the hardware. Hence, the guest can directly communicate with the hypervisor. The need for modifying the guest operating system is to minimize the execution time required in performing those operations that are otherwise difficult to run in a virtual environment.

Hardware uses an application known as **Application Programming Interface (API)** that helps in modifying guest OSs. The source code of the guest operating systems must be accessible such that one can modify the guest operating systems by replacing portions of the code with new instructions. Then, these OSs are recompiled to get a modified version of them. After modifications, the hypervisor provides various commands which are sent from the operating system to the hypervisor. These commands are known as hypercalls. The hypervisor then sends these commands to the hardware and returns the result. These hypercalls are further used for various kernel operations like memory and thread management.

Let us understand the concept of para-virtualization with the help of following figure:

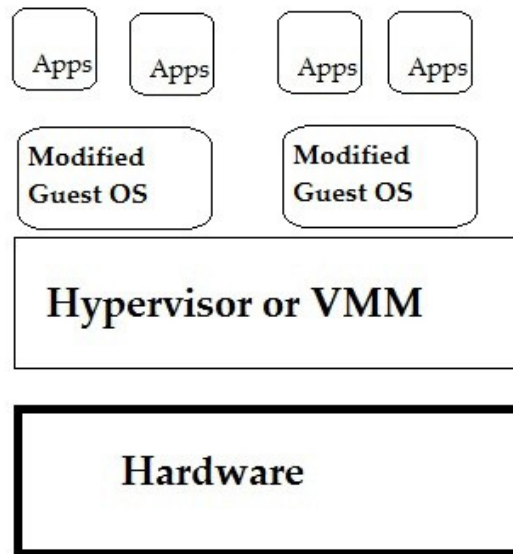


Figure 6.4: Para-virtualization

Para-virtualization ensures the optimization of the system performance. This is an efficient form of virtualization as it allows the users to make use of new or modified device drivers. The entire system under para-virtualization works as a cohesive unit. Also, hypervisor doesn't require a lot of processing power to manage the guest operating system.

Para-virtualization is very useful for many fields like disaster recovery, capacity management, and migrating data from one system to another.

Hardware assisted virtualization

Hardware assisted virtualization is a type of virtualization that makes use of the computer's hardware as architectural support to build and manage a fully virtualized

virtual machine. Here, the virtual machines are created using hardware instead of software as it is more efficient to implement virtualization functions using hardware capabilities. Developers used to experience a lot of overhead on the system while creating VMM using software. Hence, they started using hardware for implementing the virtualization functions. So, under this type, the hypervisor sends the call to the processor. Then, it is the processor's job to create and maintain the virtual machines. This reduces the overhead on the system which enables the host system to host a large number of VMs. This increases the performance of VMs. Hardware assisted virtualization was introduced firstly by IBM in 1972.

Benefits of hardware virtualization

Apart from the effective utilization of computer resources, hardware virtualization also provides flexibility and security. It creates and supports multiple virtual machines which lead to an increase in efficiency of the system and as these VMs can run simultaneously, it also increases the performance of the system. Hence, hardware virtualization is very beneficial for the systems. Let us discuss the benefits of hardware virtualization.

- **Economical:** With hardware virtualization, the virtual version of the hardware is used which is in turn used to serve multiple virtual machines. Hence, only one piece of the physical hardware resources is used. This reduces the number of hardware resources used which in turn results in cost reduction. Hardware virtualization makes the system economical.
- **Efficient resource utilization:** Hardware virtualization gives us the benefit of proper utilization of resources. Virtual machines can share physical resources among them. In case any VM needs a resource that is allocated to another VM and it is not using that resource at that time, then the VM that is in need can share that resource with the VM already having the resource.
- **Ensures backup and recovery:** Hardware virtualization gives us the facility of backing up data and ensuring its recovery in case there is any disaster which may cause loss of data.
- **Enhanced IT operations:** The IT staff can manage various IT operations efficiently instead of taking care of the hardware resources.

Software virtualization

The concept of software virtualization is the same as that of virtualization. Here, more than one virtual software runs on a single computer server. This creates a multi-virtual environment on the host machine using the same set of hardware. The installation procedure of the software is abstracted and the virtual software installation is created. This is also known as application virtualization. The purpose of software virtualization is to emulate the whole computer system and allow the

guest operating system to run on it. Some examples are VMware software and Virtual Box.

The installation process of the software is kept hidden from the user's computer that is accessing it. The software works as if it is present on the user's computer. The user can access the software as it is installed on his computer and perform operations on it as per his wish. The user's actions are sent to the server and then the server sends the result based on which the actions are carried out.

Software virtualization is an effective way for businesses and organizations to manage and implement applications. Administrators install the application on the centralized server instead of locally on each desktop computer. In the same way, applications are updated only once and that too on the central server. From there onwards, they are automatically updated. Moreover, if a user is not allowed to access the application, then the server can simply deny access of the application to that user instead of uninstalling the application.

Software virtualization also makes it possible to run even those applications that are not compatible with the desktop applications of the user. One can access the applications that are not immediately needed instead of waiting for too long for its installation or for it to load. It also ensures the security of our sensitive information in case of data is lost or stolen as all the information gets stored on the server.

Advantages of software virtualization

Software virtualization is beneficial for both customers and the host as it makes it easier to create virtual servers. It manages the workload by doing tasks virtually and saves time and money. Software virtualization provides us with numerous benefits. These are as follows:

- **Easier client deployment:** With software virtualization, it is very easy to copy and link an application to a network or workstation. Users can simply access applications without worrying about the installation process.
- **Easy management:** It is very easy to manage and update the applications. You don't need to worry about updating the application in every VM. Just update the application at one place and deploy it all at the virtual machine.
- **Flexible:** Software virtualization enables the users to modify the software as per the demands of their businesses or organizations. It gives the flexibility to modify the application and adjust it according to the changed occurrences in the workload.
- **Backup:** Software virtualization allows us to create a backup of the whole operating system or server installation. So, in case any failure or halt occurs, the users can restore their data from the backup done by the software virtualization.

- **Running multiple operating systems:** It enables the system to run more than one operating system by dividing the hard drive into partitions.
- **Running different versions of softwares:** Software virtualization allows us to keep different types of operating systems and different versions of softwares. Hence, it gives us the facility of running any version of the application. Also, since all versions can be placed at one system, it is much easier to migrate from one version of software to another.
- **Efficient and secure:** It allows us to create as many virtual machines with one physical system as we want. Hence, it eliminates the need to have as many physical systems as there are virtual machines. This feature makes them efficient. Moreover, it provides the system with security and protects it from virus attacks.

Types of software virtualization

There are three types of software virtualization. These are as follows:

- Operating system virtualization
- Application virtualization
- Service virtualization

Let's understand each one of them.

Operating system virtualization

In operating system virtualization, multiple operating systems can run on a single set of hardware resources. It consists of a software on which different operating systems can work. Each of the operating system perform their task efficiently and do not interfere with each other's work.

Application virtualization

Application virtualization includes hosting individual applications in a virtual environment which is separate from the native operating system. This technology encapsulates the computer program within the operating system.

Service virtualization

Service virtualization refers to the simulation of those components that are unavailable during testing. The reason for their unavailability can be either that these resources are under development, blocked, restricted or owned a by third-party,

or undergoing maintenance procedure. With service virtualization, one can access virtual copies of these components. This is very beneficial as it reduces dependency on any components required for testing. Moreover, it saves your time and money as you do not need any physical resource. You can get the necessary components through this type of virtualization.

Server virtualization

As we all know, virtualization refers to the creation of virtual instances of any resource or system. Hence, server virtualization means to divide the physical server into multiple virtual servers. Server administrators use a virtualization software to partition the single physical server into multiple isolated virtual environments. Each of the virtual environments can run independently without interfering with the working of each other. We can name these virtual environments as virtual private servers, guests, instances, containers, or emulations.

Every physical server has its own operating system, memory, and hardware resources including CPU and hard disk. In server virtualization, all these resources are hidden from the users. Virtual servers can run their own operating systems with different configurations. Server virtualization allows all the resources of physical servers to be shared among all the virtual servers. This enables organizations to cut down on the hardware resources used by them which leads to cost efficiency.

Server virtualization is very beneficial as it improves server availability and enables disaster recovery. It allows the efficient utilization of IT resources. The physical server centrally manages all the virtual servers and allocates resources virtually according to the demand of the systems.

Working of server virtualization

In server virtualization, the physical server is divided into multiple virtual servers. All these servers are different and work like unique devices. They seem to be real physical devices to the users. These servers possess a sufficient amount of computing power to perform their tasks effectively. The central server administrator uses a software to divide the physical server into more than one virtual environments. Each virtual environment runs its own operating system independently. All the physical resources of the central server are also shared among the virtual servers.

The physical server is known as the host and the virtual servers are termed as the guests. The following figure depicts server virtualization:

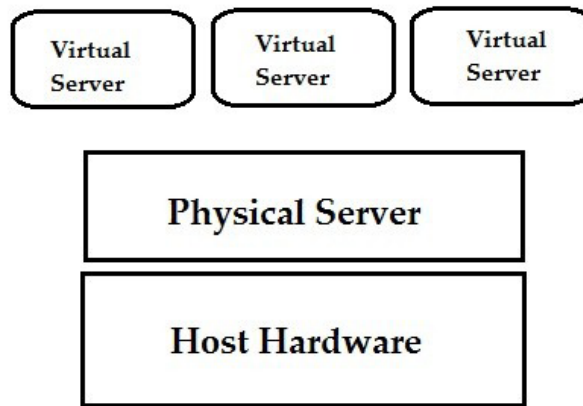


Figure 6.5: Server virtualization

Server virtualization performs its task by partitioning software from hardware using hypervisor. As we previously discussed, hypervisor is a layer between the hardware and the operating system. Hypervisors are of different types and serve different purposes. We mostly use two types of hypervisors, namely Type 1 and Type 2. With Type 1, users can directly work on the server. It is also known as bare-metal hypervisor. The Type 1 hypervisor enables us to virtualize the hardware platform which can be further used by the virtual machine. Type 2 hypervisor runs as a software layer on the top of the host operating system. It is used for testing purposes.

After the server is virtualized, the organization can use the resources of the server for other tasks. All virtual servers can utilize the resources of the server. Organizations should determine the resources and the quantity that can be allocated to each virtual machine. They should monitor the system to track the performance of the resources such as the memory, disk usage, and processor overload. Each virtual server can be dedicated to perform a specific task instead of buying a physical server for each task. This increases the efficiency of the organization.

Virtualization software is used to create virtual servers. Organization can deploy hypervisors like Microsoft Hyper-V and VMware vSphere or virtualization tools for this. Central server is virtualized and its resources are utilized by organization to increase the efficiency of the system.

Types of server virtualization

As you already know, each physical server is called a host and the VMs created to serve multiple organizations or customers are termed as guests. Every guest behaves like a unique physical device and the resources of physical server are granted to the

irtual machines according to their need. Each of the guests uses a different approach to allocate the physical resources of the server to the virtual machine. There are three approaches to server virtualization:

- Virtual machine model
- Para-virtual machine
- Virtualization at the OS-level

Virtual machine model

A virtual machine model is based on the host-guest paradigm. Here, virtualization of the hardware layer is done and every guest runs on that virtual environment of the hardware. The administrator has the right to create as many virtual machines as he/she wants. All guest machines can run without any modifications and can run with a different operating system. In this type of server virtualization, each guest machine is independent of the other guest machines in the system. They have no knowledge of the host's operating system and have no idea that they are running on the virtual hardware.

In server virtualization, a hypervisor is used to maintain the coordination between the host hardware and the guest operating system. It sends instructions to the CPU and demands for the host's computing resources. The hypervisor is also known as **virtual machine monitor (VMM)**. It is responsible for the successful operation of all operating systems running on different virtual machines. It monitors all the physical resources of the server. When the virtual machine performs its task, the hypervisor allocates the desired resources from the host's server to it. The hypervisor allocates the appropriate resources to all the virtual resources as per their need.

The hypervisor also needs processing power to do various tasks. This processing power is allocated by the physical server so that the hypervisor can run their applications efficiently. The VMware and Microsoft Virtual servers are examples of virtual machine models.

Para-virtual machine

The para-virtual machine model is based on the host-guest paradigm only and it also involves the use of the hypervisor or virtual machine monitor. But the difference is that here, the guests are fully aware about the fact that they are working on virtual hardware. The VMM has the right to modify the guest operating system in the para-virtual machine model. The act of modifying the guest operating system code is known as porting.

Porting or portability supports the virtual machine monitor and enables it to utilize privilege calls. In the para-virtual model, virtual machines can run different types of operating systems, for example, Linux at one VM and Windows at another VM.

All the guest servers are aware of each other and know about the demands of the resources that each VM will require beforehand. Hence, the hypervisor will require less processing power as it does not need to manage the coordination of resources between the host and the VMs. This technique is better for those organizations whose administrators work on servers that use different types of operating systems. The guest operating system can be modified in this model and this modified OS can directly communicate with the hypervisor which leads to removal of emulation overhead. Hence, this model increases the performance of the system.

Virtualization at the OS-level

In this approach of virtualization, host-guest paradigm is not used. Instead of implementing hypervisor, all the tasks of hypervisor are done by the host OS. The host OS is responsible for the virtualization and the allocation of the physical server and resources. It performs all the functions of a fully virtualized hypervisor. In this model, the host runs a single operating system kernel as its core and transfers the resources and other necessary operating system functionalities to all the guest VMs. Each of the guest VMs should have an operating system similar to the host operating system. They cannot run different operating systems on their machines. Since all operating systems must be the same as of host, it is also known as a homogenous environment.

Each of the virtual machines must be independent of each other. Each of the VMs are isolated from each other, so that any failure or fault in one virtual machine doesn't affect the other machines in the system. This approach eliminates the system calls between layers which results in reduced usage of CPU. Common libraries and binaries present on the physical machine can be shared with the guest virtual machine. This enables the OS-level virtual server to host multiple guests at the same time. This technique is the best one if all the guests are using the same OS as the host. Systems in this approach work fast and efficiently.

Advantages of server virtualization

The key benefits of server virtualization for any organization are flexibility and cost savings. Server virtualization is of immense use as it enables an organization to do a variety of tasks at the same time instead of being busy performing only one task. Let us take a look at some advantages of server virtualization that makes it so popular among organizations:

- **Cost efficient:** With server virtualization, organizations do not need to invest a lot of money in buying physical servers and resources. All resources are available virtually. It divides the single physical server into multiple virtual machines. These machines can be deployed, operated, and managed. This saves a lot of cost that would have been spent in buying hardware. This feature of facilitating simulated resources results in cost efficiency.

- **Increased uptime:** Since server virtualization provides all the advanced resources that are not available in the physical servers, it increases the uptime of the server. One can easily upgrade their resources, implement new technology/application, recover data, and share workloads between multiple virtual machines in less time with the help of server virtualization.
- **Improved efficiency:** Multiple virtual servers are used in the place of one physical server. This makes the system more efficient as multiple tasks can be completed at the same time. This feature lets the organization achieve a more efficient output and it also increases the system performance.
- **Ensures disaster recovery:** Server virtualization enables organizations to store their data on the server. There is no need to store data in storage devices. It gives us the opportunity of recovering the data whenever there is loss of data or any failure. Hence, with server virtualization, it is very easy to do backup and recover from disaster.
- **Independent environment for users:** This type of virtualization enables each virtual server to run independent of each other. Every user is given an isolated environment to work on. No interference is made from other users.
- **Increased productivity:** Since there are few physical resources to maintain, less processing power is used to manage all the operations of the server. Organizations can use this power and the resources in increasing their productivity.
- **Reduced need for physical infrastructure:** Since server virtualization supports the creation of instances of virtual servers, few physical resources are needed.
- **Reduced energy consumption:** The use of a single physical server in an organization corresponds to low consumption of power. Hence, the consumption of energy is reduced.

Disadvantages of server virtualization

Although there are many benefits of server virtualization, it possesses some drawbacks also. These are as follows:

- Implementation costs can be high.
- The virtual environments need to be created, managed, monitored, and configured.
- If the server goes down or becomes offline, then all the tasks related to that particular server will stop. This can degrade the performance of the system.
- Experienced IT staff is required for the maintenance of server virtualization.

- Upfront costs including the virtualization software and the organization's network can be high.
- Security risks are also there.
- There can be an issue of availability of resources.
- Migration to other environments is costly.

Uses and applications of server virtualization

Server virtualization is very helpful for IT industries as each virtual server can run its own operating system. It enables the virtual machines to perform complicated tasks. It is a cost-effective way of utilizing resources efficiently and provides web hosting services.

Server virtualization saves money and provides independent environments for each user. It is very beneficial as it supports redundancy which helps an organization to recover data in case of data loss or theft.

Some primary uses of server virtualization include:

- To centralize the server administration.
- To improve the availability of the server.
- To make the development and testing easy.
- To ensure disaster recovery.
- To make sufficient amount of resources available.

Storage virtualization

Storage virtualization refers to a set of physical storage devices that are grouped together so that it appears to be a single storage pool to the servers or the host. Then, this single storage system is partitioned into multiple logical storage forms and assigned to each customer. This logical storage works like real physical storage space and appears to the server or the host as physical storage devices. The data stored by users on these virtual storage devices gets stored on the cloud only and ensures the safety and protection of data.

Storage virtualization is a technique which is used to abstract physical storage resources from all users. It appears to them as a centralized storage space. It creates an artificial view of the storage space and the users are assigned virtual copies of that. These storage resources can be from different vendors and networks. Users do not have any idea about where all their data gets stored on the server but they can access it using the logical path.

Let us understand the concept of storage virtualization with the help of the following figure:

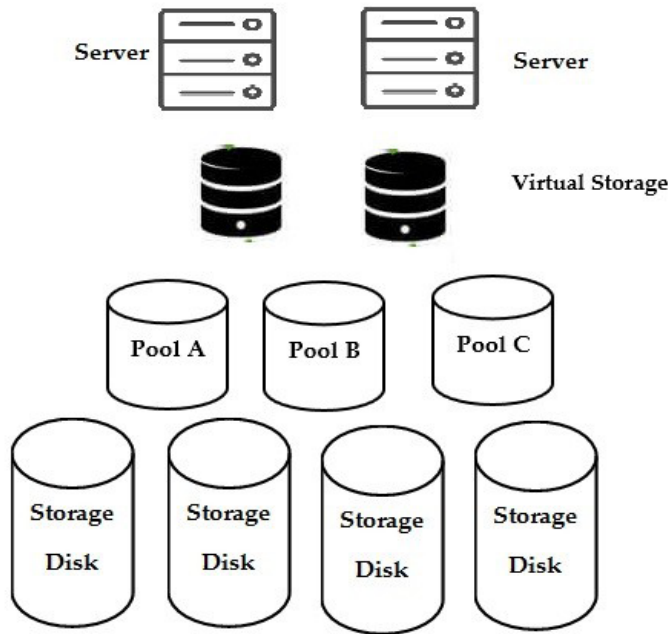


Figure 6.6: Storage virtualization

Storage virtualization is also known as cloud storage. It helps us to manage data and store devices efficiently and in less time. It enables users to maintain a backup of their data and ensures recovery of the data. Organizations should implement storage virtualization for better storage management and improved storage virtualization. It also facilitates easier data migration between drives without any downtime.

Users are not concerned about where the data is stored. They can simply access the data in the same way that they retrieve it on the local computers. The frequently accessed files are stored on flash storage while the files that are used rarely are stored on the slowest array. The user is not aware of the actual location.

Characteristics of storage virtualization

The various characteristics that make storage virtualization so beneficial are as follows:

- It ensures the availability of logical partition separately from the physical hard disk drive.
- It groups various storage devices from multiple vendors into a single storage pool and then allocates independent storage spaces to all the users.

- It provides automated storage optimization and management.
- There is centralized administration for allocation of virtual storage spaces.

Types of storage virtualization

There are two types of storage virtualization, namely block level and file level virtualization. Both the types provide virtual storage to store data. The block level stores data in the form of blocks while the file level stores data in the forms of files and folders. In block level virtualization, raw volumes are created and then the operating system is deployed. Lastly, you need to make a connection with these volumes while in file-level virtualization files and folders are handled by storage devices. Block level virtualization is popular for its features of flexibility while file level virtualization accounts for simplicity and is less expensive. Let us discuss them here.

Block virtualization

This is the most common type of storage virtualization. In this type of virtualization, logical storage is separated from physical storage so that the user or host can access them without having to access the physical storage. In block level virtualization, raw volumes of storage are created and each block can be controlled as an individual hard drive. These blocks are managed by the server storage system and can be used as independent hard drives.

Block level storage virtualization is seen and deployed in **storage area network (SAN)**. It can be used for almost every kind of application, say file storage, database storage, etc. It can be considered as a hard drive in a server that can be accessed using a fibre channel. Using block-based virtualization means that you are working on a blank hard drive on which you can do anything. This type of storage virtualization is very flexible and versatile in nature. Protocols like iSCSI, Fibre Channel, **FCoE (Fibre Channel over Ethernet)** are utilized to make the storage blocks visible and accessible by a server-based operating system.

Block-based storage is a technology that is popularly used to store data on a storage area network or cloud-based storage. It provides a fast, efficient, and reliable data storage facility. Users can be allocated multiple blocks to store data files in this type of virtualization. Each block has the power to run with a different operating system. SAN can store these blocks on different systems running different operating systems. So, when a user requests data from the block storage system, it reassembles all your data blocks using a logical path and presents all the data in front of you.

File virtualization

File level storage is simple to use and implement. Here, the files and folders of the clients and system are stored. Clients, as well as system administrators, have the

privilege of accessing the files and folders. File virtualization is seen and deployed in **Network Attached Storage (NAS)**. NAS stores the files in the storage system with the same concept that the network file system uses. It means that the user and clients can retrieve data from directory trees, folders, and files.

File level storage systems are used to store files and folders centrally. These file systems are attached to the network. Hence, they provide a platform for network attached storage. This type of storage is very beneficial as it provides file recovery very quickly. It can be used for applications that access data in the form of files rather than blocks.

This technology is most commonly used for storage devices which are found in hard drives and NAS systems. You can access the files stored with this type of technique in bulk. It operates with common file-level protocols like NTFS for Windows and NFS for Linux. It provides a centralized, highly available, and accessible place to store files and folders and that too at a low cost. Hence, it is mostly used by many organizations.

File storage is less expensive in comparison to block-level storage. In this technology, virtual storage is provided for storing the operating system and applications in the form of files and directories, and all the operations are performed by virtualization entities.

Methods of implementing storage virtualization

There are multiple ways through which storage can be applied to a virtualized environment. These methods are as follows:

- Host based storage virtualization
- Array based storage virtualization
- Network based storage virtualization

Let us discuss them one by one.

Host based storage virtualization

In this type of virtualization, virtualization is done at the host level. Multiple hosts are presented with various storage sets. Each storage set is of a different capacity. It doesn't matter whether the end user is working on a virtual machine or a physical computer to access the cloud storage. All the virtualization and management tasks are done via software at the host level and the physical device can be any device set.

This type of storage virtualization method is independent of the storage platform or the vendor and it is also not dependent on the underlying SAN technology. It is simple to design and code. It is also helpful in the utilization of storage. However, host-based virtualization is expensive and the virtualization software can be

complex. As the storage environment grows, it can become complex to manage resources since each host is managed individually and requires a separate software driver to be installed for its efficient operation.

Array based storage virtualization

In this type of storage method, we represent storage in the form of array. By array, we mean a set of similar items. Here, array is a set of various physical devices which can be used as storage sets to store information. These storages can be **hard-disk drives (HDD)** or **solid-state drives (SDD)**. Different softwares are used to manage and handle these sets of arrays that are present in the form of storage tiers. These softwares are hidden at the user/guest level.

No additional hardware/infrastructure is required in an array-based storage virtualization. This method of storage virtualization enables easier data migration and effective centralized management.

Network based storage virtualization

Network based storage virtualization is the most common form that is widely used in large enterprises nowadays. In this type of storage method, a fibre channel switch is used to connect the network devices to the **storage area network (SAN)** and it is represented as virtual storage pool to the guest user. This switch virtualizes and redirects all IO requests.

This method is completely independent of the storage platform, host platform, and the operating system. Since this connects the network devices to the SAN, it has access to all the hosts and devices connected to it.

The storage and network switch need to be compatible with each other. This method is very beneficial as it helps in improving performance and enables the system to achieve the true form of a heterogenous environment. Only one management device is involved for all types of storage. However, it is difficult to design and code. Network based virtualization provides high performance and scalability.

Each virtualization method has distinct benefits and provides a different level of performance and manageability.

Configurations of storage virtualization

There are two ways of configuring our storage virtualization. They are as follows:

In-Band

In-band storage virtualization is also known as symmetric virtualization. In symmetric virtualization, the virtual environment configuration is stored in the data

path itself. Here, the data and control path follow the same path. It is easy to manage and implement. It doesn't require any software to implement.

It is helpful in improving the device's performance.

In in-band storage, virtualization occurs when the virtualization engine works between the host and the storage. The virtualization engine provides the systems with advanced functionalities as both I/O requests and data can pass through the virtualization layer. Only a few host server resources are utilized here as this storage doesn't need to find multiple storage devices. This allows for data caching as well as replication.

Out-band

This type of storage virtualization is also known as asymmetric virtualization. In asymmetric virtualization, the virtualization environment configuration takes place outside the data path. Here, the data path and control flow are separated from each other which is achieved by separating our metadata from the data and placing it at another place.

Here, in asymmetric virtualization, only the control path passes through the virtualization device. Then, it intercepts the I/O request made by the host. After that, the server queries the metadata manager to determine the physical location of the data and issues an updated I/O request to the storage. Agents are installed on individual servers in order to direct the storage I/O to the virtualization devices. They communicate with the metadata manager so that the logical data access can be translated into physical access. Data does not pass through the virtualization device. Hence, caching is not possible.

Separating data flow from control flow gives us the advantage of using complete bandwidth as provided by SAN.

Benefits of storage virtualization

Storage virtualization helps users by facilitating easy backup and recovery tasks in less time. It reduces the complexity of storing data and protects our data from any malware. The various benefits of storage virtualization are:

- **Highly scalable:** With the help of storage virtualization, storage pools are created to store the data of the end users. The capacity of these storage pools can be increased or decreased as per the demands of the application. It gives you the flexibility of scaling the number of storage devices. Hence, storage virtualization offers the features of flexibility and scalability in terms of storage.

- **Easy retrieval and storage of data:** With storage virtualization, it is very easy to retrieve data from virtual storage. One can access its data in the same way that work is done on a local computer. Also, storing data on virtual storage is also as easy and effective as doing it on our physical computer. The users only need an internet connection and cloud access to store their data on the virtual storage.
- **Easy data migration:** Storage virtualization enables easy data migration from one place to another. Data can be transferred smoothly and with a fast speed without any movement barriers. The users experience none or very less downtime while transferring data to the apps by using virtual storage for their work.
- **Increasing or decreasing storage capacity:** You have the power to increase or decrease the storage capacity as per your software's requirement.
- **Easy and secure storage:** Storage virtualization provides users with easy and secure storage management. It uses different tools and protocols that ensure the safety of the data. All the data is stored in different locations so that if any fault occurs, the app can access data from the other location.
- **Better management:** Storage virtualization gives us the benefit of better management. It stores frequently-used data on a high-performance system and rarely-used data can be placed on a slower system. It ensures effective utilization of the storage resources.
- **Disaster recovery:** Storage virtualization also enables recovery of all data stored through it if any fault occurs. It actually saves data on different locations, i.e., it maintains more than one copy of all data on virtual storage devices. Hence, if any device fails, the user can recover its data from another virtual storage.

Operating system virtualization

Since virtualization is very crucial for the efficient working of any organization, every component of the computer system is virtualized whether it is hardware, software, or server storage. In the same way, we can virtualize the operating system also. We can create virtual copies of operating systems where various users can work simultaneously. They can run their applications on different platforms using a single machine.

Operating system virtualization refers to a virtualization technology that allows altering the host operating system in such a way that different applications are able to run on a single computer at the same time. The operating systems are altered in such a way that they work as different and separate systems. Various users can handle these types of applications at the same time. None of the operating systems interfere

with the working of another operating system. Various users running different applications on the same machine send commands to the virtualized environment and perform their work. The virtualized operating system is responsible for handling the users and requests made by them.

We can also define OS virtualization as partitioning the operating system into many divisions where the host kernel's resources are shared with every instance. Different versions of the operating system run inside the host machine. Under these flavors of the operating system, various applications can run.

Operating system virtualization works on the OS layer. The kernel of the host operating system creates various instances for different users. These instances are known as containers or virtualization engines. The kernel of the host operating system acts as the kernel of all virtual instances and provides them the functionality of the operating system. Since all the guests or instances share the same kernel, if any problem arises in the kernel, then all the instances suffer.

In OS virtualization, users don't need to have any resources or applications installed on their systems. They don't even need a hard disk. Everything is done through network by using a virtual disk. A virtual disk is a disk image file that is stored on the remote server and contains resources which can be allocated to various users. The two types of virtual disks are as follows:

- **Private virtual disk:** This is used by only one user. It works just like a physical local disk where a user can store and access his data in the same way that he stores it on the local hard disk.
- **Shared/common disk:** This is used by multiple clients to store and access their work at the same time. Any changes made by the users are stored on the cache. When the user restarts or shut downs the system, all the data stored on the cache is cleaned.

The client will be connected to the network with the help of a virtual disk and will use resources offered by this type of network.

Uses of operating system virtualization

Some prominent uses of OS virtualization are as follows:

- It can be used for the virtual hosting environment.
- It can be used by the system administrator to integrate server hardware by running services on separate hosts.
- It can be used for allocation of hardware resources to various users.

Working of operating system virtualization

The operating system is responsible for the smooth functioning of the system. It manages hardware and software resources of the company. Operating system virtualization uses a software that enables a user's system to run different operating systems on a single machine simultaneously. The components needed for OS virtualization are an OS virtualization server, virtual disk, and database. The following procedure is followed to establish an operating system virtualization:

- **Connection with the server:** Firstly, a connection to the OS virtualization server is made. The OS virtualization server is the central node in the virtualization infrastructure. It is the responsibility of the virtualization server to manage the information stored on the virtual disk and allocate the virtual disks to every client. The server can be attached to the virtual disk locally or through storage area network.
- **Connection with the virtual disk:** After connection is established between the server and the user, the server checks in its database whether the user has already been registered or is new to the server. If the user has already been registered, it checks which virtual disk is assigned to him. If more than one virtual disk is assigned to a particular user, then a menu appears that displays information about the virtual disk. If user is new, then a virtual disk is assigned to him. Then, the connection between the virtual disk and the user is made.
- **Connection between virtual disk and user:** Now, after the desired virtual disk is selected, the virtual disk is connected to the user through the OS virtualization server. Here, the OS virtualization server makes sure that the user is unique.
- **OS is streamed to the client:** After connecting the disk with the user, it is time to stream the contents of the virtual disk. The server performs this job and streams out only those sections which are necessary to run the operating system smoothly. This streamed information needs to be stored at some location. For this very task, you can either use the hard disk of the user or the disk of the operating system virtualization server.
- **Additional streaming is done:** When the first part is streamed, the operating system starts to run smoothly. Now, if the user requires another application or wants to perform another task, then he will be assigned another virtual disk and streaming will be done again.

Types of operating system virtualization

There are two types of operating system virtualization. These are as follows:

Linux virtualization

Linux virtualization refers to installing, running, and maintaining one or more virtual machines on the Linux operating system. With Linux virtualization, users can share and divide resources used by the Linux operating system among various virtual machines and processes running on the top of the Linux operating system. Each VM runs independently of the Linux OS, but they share its resources.

Linux virtualization is a process that is designed to achieve virtualization on a system that is running a Linux operating system. It is used for isolating specific apps, programming code, and testing applications. It enables better utilization of hardware resources, and saves energy and maintenance cost. Some popular Linux virtualization products include Xen, KVM, VirtualBox, and VMware.

Windows virtualization

Windows virtualization is designed to achieve virtualization on a system that is running the Windows operating system. Various virtual machines are installed on the system. Each of them share the Windows operating system's resources and runs independent of the Linux operating system. The users can install Windows OS virtually by installing VMware.

Benefits of operating system virtualization

Most organizations use OS virtualization as it is reliable, economical, and saves time. It is beneficial for both small and large-scale companies. Operating system virtualization provides us with the following benefits:

- Operating system virtualization works faster in comparison to server virtualization.
- It allows efficient utilization of memory and CPU resources as load balancing is appropriate.
- Since operating system virtualization provides everything in a virtual form, a lot of space and resources are saved which leads in saving of money.
- There is no involvement of hardware resources which saves time and cost indulged in the maintenance of hardware resources.
- It is used for testing applications on different operating system and platforms.
- It imposes little or no overhead.
- It supports live migration.

Conclusion

In this chapter, we have learned about the concept of virtualization. Virtualization is a technology that allows the creation of virtual platforms for hardware, software, storage, applications, and servers and operating system as well. We have also studied about the various types of virtualization, their types, and benefits in this chapter. Virtualization enables organizations to achieve the efficient usage and management of physical resources. It also helps companies in implementing cloud computing. In the next chapter, we will gather information about cloud management.

Points to remember

- Virtualization means creating the virtual form of anything. In reference to the computer, it means creating a virtual version of hardware, software, storage, operating system, or server.
- Virtualization efficiently manages resource utilization and helps the organization in effectively implementing cloud computing.
- Virtualization can be of various types. These are hardware virtualization, software virtualization, storage virtualization, operating system virtualization, and server virtualization.
- Hardware utilization refers to the virtual version of physical resources that are shared among multiple users.
- Software virtualization means to virtualize a software and allow multiple clients to work on it at the same time.
- Server virtualization refers to the act of dividing the physical server into multiple virtual servers which enables the sharing of the server's resources with multiple users.
- Storage virtualization refers to the process of combining various storage devices and then assigning logical storage partitions to the users.
- Operating system virtualization refers to the act of dividing the operating system into many virtual copies so that many applications can be executed concurrently at the same time on the same machine.

Multiple choice questions

1. This technique enables us to create virtual copies of any components:
 - a. Virtualization
 - b. Cloud computing

- c.* Simulation
 - d.* None of these
- 2. This type of virtualization allows us to create virtual versions of applications:**
 - a.* Hardware virtualization
 - b.* Server virtualization
 - c.* Application virtualization
 - d.* System virtualization
- 3. With server virtualization, users can access the resources of the**
 - a.* Organization
 - b.* Server in virtual form
 - c.* Client in virtual form
 - d.* Business
- 4. The types of storage virtualization are:**
 - a.* File based virtualization
 - b.* Block based virtualization
 - c.* File based and block based virtualization
 - d.* Real time virtualization
- 5. Virtual and para-virtual machines are types of:**
 - a.* Operating system virtualization
 - b.* System virtualization
 - c.* Software virtualization
 - d.* Server virtualization

Answers

- 1. a**
- 2. a**
- 3. b**
- 4. c**
- 5. d**

Questions

1. Discuss the concept of virtualization and its significance.
2. What is hardware virtualization? Is it beneficial? Explain.
3. Discuss the concept of software virtualization.
4. Explain the meaning and types of server virtualization.
5. Explain storage virtualization on the basis of the following factors:
 - a. Meaning
 - b. Types
 - c. Method of implementation
6. Discuss the operating system concept with its benefits.

Key terms

- **Virtualization:** The process of creating virtual versions of resources or applications.
- **Virtual machine (VM):** The virtual version of a physical computer.
- **Host machine:** A physical machine that handles one or more virtual machines.
- **Emulation:** The ability of a program or application to imitate another device or application.
- **Hypervisor:** A software program that manages multiple virtual machines on a single computer.
- **Guest OS:** An operating system that runs inside virtual machines.

CHAPTER 7

Cloud Management

In simple terms, cloud management refers to managing the cloud computing products and services. It is the responsibility of the cloud service provider to manage the resources of the cloud and magnify their performance. Efficient management of cloud resources is very crucial for effective functioning of the cloud. Management of resources includes performing tasks associated with operations like load balancing, deployment, backups, storage, performance etc. For these tasks, various management tools and strategies are provided by the cloud service provider. This chapter is dedicated to this very cause. We will study about how the management of a cloud is done and the tools and strategies that are available to achieve effective cloud management.

Structure

In this chapter, we will discuss the following topics:

- Cloud management
- Cloud provisioning
- Cloud management benefits
- Cloud management tools
- Components of cloud computing management

- Cloud management security
- Challenges faced during cloud management

Objectives

After studying this chapter, you will be able to:

- Understand the meaning of cloud management
- Discuss the types of cloud provisioning
- Understand the cloud management benefits
- Explain the various types of cloud management tools
- Discuss the components of cloud computing management
- Understand cloud management security and the challenges that are faced during cloud computing management.

Cloud management

Cloud management is the process of managing, maintaining, and optimizing a computer environment for achieving better performance, availability of resources, security, and to fulfill the requirements of the users. It is the process of controlling everything that operates in a cloud, i.e., the users, data, applications, and services. It actually refers to a set of various softwares and technologies that have been constructed to control and monitor the operations of various applications, data, and services available in a particular cloud.

Cloud management is necessary to get efficiency, the desired security, and an overall good performance of the cloud services and applications. It includes specially designed software and tools that are integrated in the cloud environment to ensure the smooth functioning of the cloud system and examine the communication flow between the users and vendors. It is the responsibility of the admin of the cloud to control every task that is undergoing within the cloud. Admins use cloud management tools to ensure efficient operations of cloud activities which include resource deployment, data integration, disaster recovery, etc. and to manage the infrastructure, applications, data, and requests from clients or organizations.

Various companies provide specialized tools to organize cloud management. These tools are of immense use for the customers as well as the sellers as they monitor, manage the cost, provide security, and improve the capabilities of the cloud. Companies like VMware, OpenQRM, and CloudKick use a variety of methods and tools to efficiently manage the cloud system activities and track performance trends.

The cloud management software is used by cloud service providers to build a strong interaction between the cloud vendors and users. This software is also used to manage the services offered by the cloud to different businesses and organizations. To accomplish these purposes, the cloud management software is deployed as a virtual machine into the given cloud environment. This software also includes a database and a server. First, the connection is established between the virtual resources of the cloud and database. For this, the server communicates with the application programming interface (API). It is the task of the database to collect information about the performance of the virtual resources. After that, the database sends this performance report to the web interface. Here, the report is analyzed. The cloud admin can view this report from here only.

This communication is handled by the operating system. The operating system is responsible for managing all the technologies that make up the cloud and it also installs various management software tools.

Cloud provisioning

Cloud provisioning means to allocate the resources and services owned by the cloud to the clients or organizations. We can consider it as the process of setting up the infrastructure which includes deciding the service or application that would be available to the client or organization as well as when, where, and how it would be available. It also refers to the procedure that is followed in managing the access to the resources, services, and applications and ensuring their availability to the clients and organizations.

It is a very important concept in cloud computing. By using this feature, the users can determine the time-period for the provision of the services by the cloud vendors. Cloud vendors can provision services that include platform as a service, infrastructure as a service, and software as a service. Customers can provision services in the public or private cloud environments.

Types of cloud provisioning

There are three types of delivery models that are used to conduct cloud provisioning. These are as follows:

- User self-provisioning
- Dynamic provisioning
- Advanced provisioning

Each type is different and tells how and when the customers will purchase the resources and services, the kinds of services and resources that they will purchase, the method that they will use to pay for the resources and services, and how and

when the cloud providers will provide the resources and services to the customers or organizations. Let us understand the meaning of these delivery models briefly:

User self-provisioning

This is also known as cloud self-service. In this type of cloud provisioning, the delivery model, web portal, or interface is used for buying the resources and services. Here, the customer creates a user account on the web portal of the cloud provider and selects the desired resources. Then, he/she can pay for those resources using a credit card. The cloud provider will make them available as soon as possible which may be within minutes or within hours. The customers can now use them just like they use their local resources.

This type of delivery model is known as self-provisioning because within this model, the user can themselves add the resources. You can understand this with the self-service that you normally encounter at Dominos or any other food court. There, you simply have to go to the counter of the food court, order your food items, and pay for them. When your order is complete, you receive a message about it and you can simply collect the order and finish eating it. In the same way, you order your resources at a web portal of the desired vendor, pay for it, and receive a message about the availability of the resources and how you can use them.

Dynamic provisioning

Also known as on-demand provisioning, dynamic provisioning allocates resources to the clients on demand. This model allows customers to provision the resources as per the need of their businesses or organizations. If there is a hike in the market and resources are needed to meet the demands, then the cloud vendor can provide the customers with as many resources they want. Dynamic provisioning also gives the facility of scaling down resources when the demand is over.

In dynamic provisioning, users have to pay for only those resources that they use, i.e., the pay-per-use model is used for the payment of the resources. The cloud vendor has the right to allocate and deallocate the resources as per the demands of the customers or organizations.

Advanced provisioning

Advanced provisioning refers to a delivery model in which the customer signs a contract with the cloud vendor for the allocation of applications and services for a specific time. The cloud service provider prepares the resources and services according to the contract and then delivers them to the customers. The customers pay for the resources in advance as mentioned in the contract.

Cloud provisioning is very beneficial for users and provides numerous benefits to businesses and organizations. It provides scalability and enables cost saving.

Cloud management benefits

Cloud management is very beneficial for businesses, organizations, users, and the cloud itself too. It helps to manage the cloud resources and services and enables perfect communication between the users and cloud vendors. It ensures the smooth functioning of the cloud and maintains the security of the cloud applications. It enables real-time monitoring of the applications and data which eliminates the chances of virus and malware attacks. All these factors give us a clear understanding of the fact that cloud management is very beneficial for users and organizations for systematic arrangement of everything in a cloud. Let us briefly discuss its benefits here:

- **Economical:** Cloud management helps us in providing the cloud's resources in the best and most efficient manner possible. It saves the cost of buying the resources and other services. Proper cloud management ensures the availability of resources at a low cost, hence making cloud services economical for the users or organizations.
- **Flexibility:** Cloud management provides flexibility to users to utilize cloud resources for as much time as they need. It also gives customers friendly memory, storage, and network resources.
- **Updated resources:** Cloud management ensures the availability of updated versions of services and resources to the organizations. Cloud management is solely responsible for the allocation of resources that work efficiently on the user's machine and will bring him profitability from time to time.
- **Scaling:** Cloud management allows organizations to scale in resources when they are needed and scale them out when the demand is over. This ensures the availability of resources anytime and anywhere in case there is a hike or increase in demand.
- **Security:** Cloud management imposes various security policies and firewall services to ensure the safety of the cloud's resources and applications. Secure management of cloud enables the user to access the data and resources remotely and store their data online on the cloud storage.
- **Quick delivery of resources:** Cloud provisioning allows allocation and deallocation of resources quickly. Hence, with proper cloud management, an organization can get fast delivery of resources. Every user or organization requires quick delivery of resources and services so that there is no pause in their work and they can efficiently use the resources and services. Quick delivery of resources is very crucial for the satisfaction of the customers.

Cloud management tools

Cloud management is a dashboard which provides a set of policies, rules, software, governance, and a group of people that signify the methods of how cloud computing resources and services are made available to users or organizations. Though it seems that cloud management is a simple task, it is actually a complex task to perform. It involves the management of multiple tasks between different users, cost evaluation of each service and application, maintaining all details such as which resource is consumed and by whom, and ensuring the security of everything and many other factors. For effective cloud management, various cloud management tools are used. Various cloud vendors offer different cloud management tools to deal with these complexities and ensure the smooth functioning of the cloud.

Various cloud management tools help customers or organizations to build, optimize, purchase, test, monitor, and track their cloud's resources. These tools enable organizations to save their time and efforts, and utilize their time in achieving organizational goals. They ensure effective communication between the customers and the cloud's infrastructure. They help in maintaining and managing resource allocation between various organizations. Moreover, these tools create a platform for the secure transmission of services and applications.

Three popular companies that provide management services are AWS, Google Cloud and Microsoft Azure. These companies allow users to access and manage cloud services. Google Cloud provides a management tool named Google Stackdriver which manages the performance and applications on Google Cloud Platform and AWS. Let us discuss some other popular cloud management tools here:

- **Cloudability:** Cloudability is a cloud management tool that is used for monitoring and analyzing cloud computing cost. With this tool, organizations can keep a check on the consumption of resources and maintain the details regarding that. It also provides reports so as to efficiently manage, analyze, and monitor the expenses of the company. It is a powerful cloud management tool which is easy to use and supports multiple public, private, and hybrid cloud vendors.
- **vRealize Business:** vRealize Business is a cloud management tool that is a product of VMware. It was formally known as VMware IT Business Management Suite. It integrates computation, storage, and networking into a single platform. This cloud management tool is used for consumption, cloud casting, planning, and comparison. It is easy to manage and puts a control on the cost of the resources in the cloud. It provides details regarding the cost of the virtual machines and utilization of shared resources running in the cloud which helps the users in selecting the appropriate resources and managing their budget.

- **Cloudyn:** Cloudyn is a cloud management tool that helps its clients in efficiently managing their clouds. It is a SaaS product that enables you to optimize the cost and performance of the public and hybrid cloud deployments. It is designed in such a way that it offers various functionalities for managing the cloud platform easily and smoothly. It is a multi-cloud solution that provides support for Azure, **Amazon Web Service (AWS)**, Google Cloud, and Openstack.
- **Dell Cloud Manager v11:** Dell Cloud Manager v11 is a popular cloud management tool. By using this tool, the manager can track and control the usage of the cloud services. The Dell cloud manager comprises of various functionalities to support cloud management. This software is easy to use and provides support for public, private, and hybrid clouds. It integrates various security features also.
- **RightScale Cloud Management:** RightScale cloud management tool is a cloud management tool that provides tools for managing all types of cloud say public, private and hybrid. It is designed in a way that it provides a single application for designing, deploying, operating, and governing infrastructure and applications. This software tool help organizations to configure, deploy and manage applications across various cloud platforms. It supports various public clouds like AWS, Google, HP, Rackspace, Microsoft Azure, and private cloud platforms like CloudStack, OpenStack, VMware.
- **Dynatrace:** Dynatrace is a cloud management tool offered by AWS. It includes AI for monitoring the applications and provides optimized customer experience. This tool constantly monitors your system so that you can manage the performance and the availability of resources on your system.
- **HP Hybrid Cloud Management:** HP Hybrid Cloud Management is also a powerful cloud management tool that helps organizations or businesses to plan, build, and operate cloud services. It offers centralized management for managing and allocating infrastructure and services. It also enables support for all types of cloud deployment models.

Each the cloud management tool possess different and unique features which helps organizations to achieve features like speed, flexibility, reliability, security, scalability, and cost efficiency. These tools help by simplifying cloud management and reducing complexities of cloud environment by working on problems such as cost evaluation and the management of multiple cloud resources and services.

Cloud management tools ensure administrative tools over the resources, applications, platforms, and data. These tools allow keeping track of various cloud activities and help in achieving efficient management under the cloud system.

Components of cloud computing management

There are several components of the cloud computing management system that enable achieving the characteristics of the cloud management system. Let us briefly discuss them here:

- **Network:** This is a primary component of the cloud management system as a good network determines the reliability of the system. Network reliability is very crucial for the tremendous growth of the organization.
- **Storage space:** Storage space refers to the area used for storing data. Storage space ensures data protection for your cloud system. Storage space allows you to save as much data as you require. It enables you to achieve the feature of scalability.
- **Computer system:** Computer system is a vital component for every cloud management system. It is needed to monitor your cloud management system. A good technical team is required for monitoring the system 24/7.
- **Applications:** Applications also play a great role in the management of cloud. They provide us various security policies and rules and regulations to track resource consumption and to maintain the costing strategies.
- **Cloud services:** Cloud management comprises of various services to make cloud computing beneficial and easier to use. These services include **Platform as a Service (PaaS)**, **Software as a Service (SaaS)** and **Infrastructure as a Service (IaaS)**. With these services, cloud providers provide the users or organizations with the platform to develop applications and software to perform your tasks and hardware to support your software. These services help businesses in growing tremendously.

These components provide the essential features that allow organization to achieve features like automation and easier application migration.

Cloud management security

Cloud management plays a crucial role in managing the security of the cloud system. Security of data is an important aspect of cloud management. To maintain security, cloud managers enforce various security laws, firewalls, and antivirus approaches in the cloud system. Cloud managers or cloud host and cloud users are equally responsible for the security of the data.

The users of the cloud or the employees of the organization using the cloud's resources should implement various security measures on their respective platforms to ensure

the cloud's security. They can impose password security and encryption methods to secure the data, firewalls to guard against intrusion, or antivirus software to keep the systems away from virus attacks. Cloud providers can implement methods to avoid any unauthorized access of data. They also use certain implications to get rid of hacking or data fraud. Proper management tools are required to remove problems that can hamper the security of the cloud.

Challenges faced during cloud management

Cloud management means to organize and control the cloud environment. Proper allocation of resources and services results in proper management of the work and resources between the users and the organizations. Although cloud computing management is very beneficial for various enterprises and businesses, there are certain challenges that are faced during cloud management. Let us discuss them here:

- **Security:** Security is the biggest challenge that is faced while managing cloud management. Public clouds are managed by cloud vendors themselves so they are highly secure and provide a great level of security for the cloud users' data. But when we talk about the companies who build and maintain their own clouds, then maintaining and managing the cloud tasks are typical tasks. They need to secure their cloud too and prevent any unauthorized access. For that very purpose, various cloud securities measures are enforced. However, managing cloud security is still a major concern for the employees of the organizations. They face problems like lack of resources, lack of skilled labor and training, and difficulty in managing the security of multiple cloud services and also the cost.
- **Performance:** Obtaining the desired performance is also a great concern that should be considered while managing cloud. For efficient performance of the cloud, the cloud management should ensure the continuous availability of data and resources.
- **Expertise:** Managing the cloud environment needs a skilled IT team of experts. Moreover, innovation in cloud demands learning new concepts time to time. Thus, cloud management calls for the best-skilled team which has high learning capabilities. This may cost a lot to organizations. This also serves as a challenge in cloud management.
- **Portability:** Cloud computing may lead to vendor lock-in, i.e., the organization may stick to a single vendor for its resources and services. This is a challenge for cloud management as it can be a complicated task for organizations to switch to another vendor. Further, it can also be costly. Hence, the portability of shifting from one vendor to another is also a challenge for cloud management.

- **Cost:** Moving to cloud for sharing workload reduces the cost expenses of an organization. However, bearing some operating expenses is still a challenge that is faced while managing the cloud.

Conclusion

Cloud management is a crucial task for the cloud environment. It provides a lot of benefits like lower capital expenses, high availability of resources, scalability, and improved disaster recovery. Efficient cloud management tools are required for effective cloud management. Different cloud vendors provide different cloud management tools. In this chapter, we have discussed the concept of cloud management. We have also studied the benefits and management tools provided by various cloud service providers. After going through the details of how cloud resources and services are managed efficiently, we will turn to the next topic which is cloud storage and security. In the next chapter, we will take a look at the details regarding cloud storage and the security policies that are to be followed to keep the data and information of the users safe and protected.

Points to remember

- Cloud management is the process of managing cloud resources and services efficiently among various users and organizations.
- It also manages proper interaction between the users and organizations using cloud resources.
- Cloud management provides us with many benefits such as economical service, scaling, disaster recovery, proper allocation of resources, updated services and applications, etc.
- Various cloud providers provide efficient management tools to manage the proper allocation of infrastructure and enable a secure communication between the vendors and the users.

Multiple choice questions

1. **These are used to maintain the proper allotment of resources and services**
 - a. Management resources
 - b. Allocation tools
 - c. Management tools
 - d. Dynamic tools

2. Cloud provisioning is of ____ types.
- a. 2
 - b. 3
 - c. 4
 - d. 5

Answers

- 1. c
- 2. b

Questions

- 1. What is cloud management? Discuss its benefits in detail.
- 2. Explain the concept of cloud provisioning.
- 3. Which management tools are used nowadays? Name and explain a few of them.
- 4. What challenges are faced during cloud management?

Key terms

- **Cloud management:** Management of cloud resources and services.
- **Cloud provisioning:** Allocation of cloud resources and services to organizations and users.

CHAPTER 8

Data Storage and Security

Data storage and security are both matter of primary concern for all service providers. Data storage or cloud storage simply means to store data on the Internet. It is a process of storing your data on the storage system provided by the various cloud service providers. These storage systems are completely handled by the storage providers only. It is the responsibility of the provider to host, manage, secure, and maintain the servers and other infrastructure associated with the storage. One can access their data from anywhere and anytime without any worry of the data being lost or stolen. These systems provide security to the data to keep the data safe and secure. In this chapter, we will highlight concepts related to cloud storage for storing our data and the advantages of using cloud storage instead of storing data on physical storage. You will also study the security policies being followed by the service providers to keep our data secure.

Structure

- Cloud storage basics
- Types of cloud storage
- Advantages and risks of cloud storage
- Infrastructure

- Data protection process
- Cloud security
- Measures and controls in cloud security
- Encryption

Objectives

After studying this chapter, you will be able to:

- Understand the meaning and basics of cloud storage.
- Understand the types of cloud storage.
- Understand the advantages and risks associated with cloud storage.
- Take a look at the security policies imposed in the cloud environment.

Cloud storage basics

Cloud storage means storing your data, files, valuable information, reports, important documents, photos, music, videos, movies etc. on the Internet. Data is stored and transmitted from remote data storage. Generally, these remote data storages are divided into various virtualized storage pools which are hosted and managed by the cloud service providers. The data stored in these logical pools is maintained, managed, backed up, and made available to the users via the Internet.

Cloud storage allows the users to store their data on cloud-based servers through the Internet. It is just like saving data on a computer or hard drive. The users can access this data anytime and from any place. It is the user's wish of granting permission of accessing their data to any other person. The users can access their data from multiple devices with just access permissions and the use of Internet. Users have to pay for only the amount of storage that they use. They pay for their cloud storage either on the basis of consumption or on a monthly basis. However, cloud service providers may add some sort of operating expenses.

Organizations and businesses use cloud storage to store their important documents and share them with others. In this way, they can share their data and get suggestions from various experts regarding their projects. It helps them in taking firmer decisions in their businesses. Apart from business, users can use cloud storage for personal use also. They can store their personal data including music, photos, emails, and videos on cloud storage. Some providers provide some amount of storage space free of cost. Some examples of cloud storage are Google Drive, iCloud, and DropBox.

Cloud storage is very beneficial as it is very secure and reliable. The information stored in cloud storage is easily accessible and can be shared between multiple

devices. It provides a backup and recovery facility so that users can recover their data if the data stored on one machine gets lost or corrupted. It is always available on demand and eliminates the need for buying infrastructure needed for storage purpose.

The following figure gives you an idea of cloud storage:

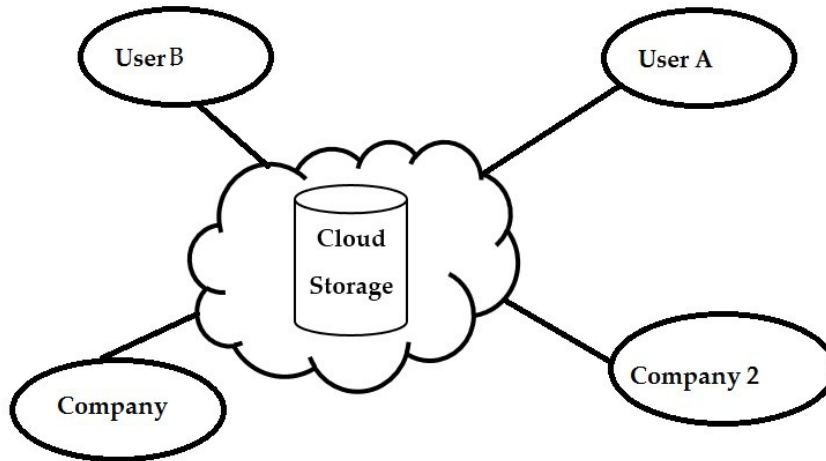


Figure 8.1: Cloud storage

Generally, in a cloud storage system, the users that subscribe to the cloud service providers send a copy of their file / files on the data server over the Internet. The data server records this information and then moves it to multiple data servers. When the user sends a request for the data, then the server can either send the file to the user's computer or grant access to the user to view his / her file on the server only. The users can access their data from a web-enabled interface.

Storage systems store copies of our data on multiple servers. Hence, we can access our data even if the server on which we have stored our data gets damaged, corrupted, needs to be repaired, or in case of any other circumstances. Storing multiple copies of data is known as redundancy. Redundancy is a very crucial feature that ensures the availability of information anytime and anywhere. Some examples of cloud storage include:

- Google Docs is an application provided by Google that allows users to upload documents, worksheets, and presentations on the Google data servers.
- Web e-mail providers like Gmail, Hotmail, and Yahoo! Mail give us the facility of storing emails on their servers so that we can access and read our e-mails from any device that is connected to the Internet.
- Social networking sites like Facebook and Twitter allow us to store our pictures and videos and post them so that our contacts on these social sites can also view them.

- Sites like Picasa and Flickr allow users to create online photo albums and YouTube allows users to upload and share videos with millions of people.

Types of cloud storage

In cloud the storage technology, data is stored on a remote database instead of your computer's hard drive. A connection between your computer and the database is made with the help of the Internet. You can store the data in different ways as different models are available. There are three types of cloud storage. These are as follows:

- Public cloud
- Private cloud
- Hybrid cloud

Let us discuss them here.

Public cloud

Public cloud storage is a storage model in which we store our data on the storage space that is made available by the cloud companies. These storage spaces are maintained by the service providers only and a single storage server is shared by multiple users. Although many users are allocated the same storage server, their data remains isolated from each other.

Public cloud services provide a multi-tenant storage environment where the storage space and data can be shared among multiple users. This type of storage model is basically used for unstructured data and the users pay on a subscription basis. The public cloud storage model is built, owned, managed, and maintained by cloud service providers. The users can access data from multiple devices including smartphones and tablets.

Public cloud storage examples include Amazon Web Services, IBM Cloud, Google Cloud, and Microsoft Azure. These providers themselves own and manage the infrastructure of the cloud, i.e., the hardware, software, and all other necessary resources and then, they provide these as storage services over the Internet.

Let us understand the public cloud storage model with the help of an example. You can consider the public cloud provider as a landlord who has various rooms or flats to allot to others. Users and businesses act as tenants that wish to take the landlord's rooms or flats on rent. This is similar to users or businesses asking cloud providers for providing them resources on rent. The users or businesses can access their services and pay for them on the basis of the "pay-as-you-go" model.

The benefits of public cloud are as follows:

- The public cloud storage model is highly scalable. You can demand for resources when you are in need of them and discontinue using them when the need is over.
- This type of storage service is cost-effective as you pay on the basis of consumption. Here, you only pay for those resources that you use.
- The public cloud storage model is highly reliable.
- The data stored on the public cloud storage model is secure and uses a variety of security policies, cloud firewall, encryption, and many other methods to protect your data.
- The public cloud storage model enables expert monitoring which helps users to store their data in a comfortable manner and makes it accessible from any geographic location.
- Since all the maintenance is done by the public cloud providers, the users or businesses don't have to spend their precious time in maintenance.

Private cloud

The private cloud model is used by only one organization. Here, the organization uses on-premises storage servers to store the data. These servers are controlled and managed by the organization only. These in-house storage structures are protected using firewalls inside the organization. This model is implemented by using the cloud computing and storage technology.

The private cloud storage model replicates the cloud model to store data inside the storage servers. The physical storage server is logically divided into multiple virtual servers to allocate isolated servers to each employee. The private cloud storage model is preferred by companies such as banks, the retail sector, government agencies, financial institutions, healthcare, etc. who need to process and store private data.

Like public cloud storage, private cloud storage also provides advantages such as usability, scalability, and flexibility. The only difference from public cloud is that it is owned by a single organization and its storage facility is not accessible to everyone. Only authorized users can access its storage servers. Some major benefits of this storage model are as follows:

- The private cloud storage model provides users with highly secure cloud environment. As only one organization is allowed to use one storage server hence there are less or no chances of data being accessed by any unauthorized person.
- The private cloud storage model is customizable. The users or organizations can customize their storage as per their requirement and scale resources in and out as per the demands of their respective market.

- Private cloud storage is highly efficient. Since all resources and storage are the sole property of one organization, private cloud storage is dedicated to single organization accounts for great performance of their businesses.
- Private cloud storage provides us with the features of scalability and reliability. It keeps the user's data safe from any form of attack and from being shared by any other third party.

Hybrid cloud

The hybrid cloud is a combination of the best features of both private and public cloud storage. Public and private cloud storages are united into a single unique cloud storage which contains the advantages of both types of storages. With a hybrid cloud, the data can be moved from the private to the public cloud as per the demands of the business or market. This type of cloud results into greater flexibility.

Some businesses wish to use a private cloud for their crucial data, but for some official tasks, they may need a public cloud storage. Bearing the cost of two types of storages, i.e., the private and public cloud storage can be costly for them. Hence, hybrid cloud storage is the best solution for them. The users can use the respective clouds as per their requirement. The main motive of using the hybrid cloud is to supplement the internal storage with the public cloud storage in an economical way. Its benefits are as follows:

- Since hybrid cloud storage includes the public cloud as well as the private cloud storage, it enables the users to have a greater control over the storage resources of the private cloud. Companies have the power of customizing the private storage infrastructure of their hybrid cloud. They have full control over the critical operations being performed in their organizations.
- Maintaining and storing data in private storage offers a greater level of security. Companies store their sensitive data in private storage. If they need to transfer that information to the public cloud for analysis, applications, or managerial decisions, then they transfer the information using an encryption method.
- The hybrid cloud storage model is cost-effective as it uses internal storage to store the data which is mostly available on-premises.

Advantages and risks of cloud storage

Cloud storage is very beneficial. It provides us many benefits with the major benefit of universal accessing of data. People can access their data from anywhere and from any place. It also allows the users to take advantage of unlimited storage. Let us discuss some advantages of cloud storage here:

- **Universal access:** Data stored in the cloud storage is accessible to the users from anywhere and at any time with a proper Internet connection and authentication.
- **Disaster recovery:** Cloud storage gives us the facility of storing the same data at multiple storage servers. This data is helpful in case the data on your computer gets lost or some damage occurs to the machine that contains your data. Disaster recovery enables the recovery of all data as it facilitates data storage on multiple computers.
- **Security:** Cloud storage provides a high level of security which protects our data against any unauthorized access, virus, or malware attack. Moreover, having multiple copies of the data also ensures the safety of the information.
- **Cost-efficient:** Utilization of cloud storage means the use of less physical storage infrastructure by businesses or organizations. It reduces the cost expenses incurred in buying physical infrastructure. It also saves expenses that would have been used to buy internal resources to store and maintain data in the organizations, thus making cloud storage cost-efficient.
- **Sharing:** It is very easy to share data among multiple users with the use of cloud storage. It also provides the facility of accessing another cloud environment if you have the authorization power.
- **Automatic backup:** Cloud storage enables the facility of creating a backup of all data automatically. This helps the users in recovering their data easily in case of data loss or theft. Cloud providers schedule the backup process in such a way that the backup of each and every day is updated and recorded automatically. This simplifies the backup process.
- **Scalability:** In cloud storage, you have to only pay for the amount of storage that you use and you can even increase or decrease the size of the storage. You can scale up or down the cloud storage environment.
- **Convenience:** It is very convenient to store and retrieve data from the cloud storage. You do not need to maintain, manage, and track the information. All the data is controlled and backed up online. You have the opportunity of accessing it from anywhere.

Apart from the advantages, there are also some risks related to cloud storage. These risks are as follows:

- **Dependency on the Internet:** Cloud storage accessibility totally depends on the Internet. If you have an Internet connection, then you can access your data with the proper username and password. Otherwise, you cannot access the cloud data.
- **Privacy concern:** When we store our data on cloud storage, then we are actually sharing our privacy with someone on the outside. Although the

cloud provider uses a great level of security, the sharing of information raises the question of privacy for every user.

- **Lifetime cost:** When a company opts for cloud storage, it has to pay for the amount of storage that it wants to occupy. The company is bound to pay the charges for the specific time-period, i.e., up to the time that the company wants to avail the services of the cloud storage. This cost can be increased up to lifetime as the storage of data over cloud is very essential to keep it safe and accessible for the future.
- **Data management:** Since cloud service providers are responsible for the safe storage of data in the cloud, it is their responsibility to manage all the operations related to the data in the cloud. Sometimes, it becomes a cumbersome task for them to manage and maintain the entire cloud storage framework. Moreover, customers have none or minimal control over the data.
- **Risk of unauthorized access:** When we share our information on cloud storage and share it with others, then the chances of unauthorized access increase. There are chances of misuse of our information by them. Although cloud providers employ security measures and controls, there are chances of some loopholes in the environment and those loopholes can become the reasons for any malicious attacks.
- **Shared servers:** Cloud providers do not provide a separate server to each user. The storage server is shared among various users and space is allocated to every user for that. Hence, no specific server is allocated to every user. This may be risky in case any user who is sharing storage space on your server uploads some sort of malicious information.
- **Data leakage:** Leakage of data from the cloud environment and its accessibility by an unauthorized person can be risky for businesses or organizations.

Infrastructure

Cloud storage is a remote platform that includes hardware and software as infrastructure. These hardware and software components include servers, operating systems, virtualization software, and storage. It is actually the framework that supports the computing requirements of the public and private cloud service sector.

Cloud storage uses a virtualized infrastructure where the various virtual versions of a single hardware are used. This type of virtualized infrastructure provides the organizations with scalable storage resources such that the organizations can provision resources on the requirement, or the resources can be automatically provisioned as per the demand of the market.

The cloud storage infrastructure is elastic, scalable, and multi-tenant. It is not the same as it used to be in physical devices. Storage infrastructure can be accessed using the web service application programming interface.

Each cloud provider provides the users with a unique Id and password to access and store their data in cloud storage. Users have to use their respective Ids and passwords in order to access their cloud storage anywhere and anytime. Various security measures are incorporated such that safe uploading and downloading of data occurs. Users are required to pay as per their usage of the storage only.

Both public and private clouds use the same set of infrastructures, i.e., the same set of servers, storage, and virtualization techniques. The only difference is that these set of infrastructures are owned and managed in-house in private cloud storage. The private cloud storage infrastructure is single tenant while the public cloud storages have multi-tenant infrastructures. However, enterprises can buy extra hardware and software components apart from these components.

Data protection process

When any company or enterprise stores or plans to store their data on cloud, then they wish to ensure the protection of their data. Data protection process means to follow the principals and policies that safeguard our data against corruption, loss, or damage. The data protection process involves techniques like backup, recovery and disaster recovery, and more.

The data protection process ensures the operation of various tasks like storage management, infrastructure security, and integrity. Many data protection techniques are developed to ensure a higher level of security but some risks or challenges always hamper the way to success. These challenges may be data loss or theft, replication of data, or insecure API.

Data protection is very critical for each and every enterprise. They need to take extra precautions for ensuring data protection. Some measures that organizations can follow are as follows:

- Keeping a backup of data locally also, i.e., in their systems.
- Never storing sensitive data on cloud storage.
- Always using encrypted data to avoid data theft.
- Going for a cloud service that provides encryption and decryption facilities for your files and information. This allows only administrators and cloud service providers to access your files. No other person is allowed to access these files and information.
- Always using a strong password to avoid unauthorized access from anywhere outside.

- Never using a public computer and unsecured or open Wi-Fi hotspots to access your cloud storage. It may cause you data loss or theft from hackers or unauthorized persons. Also, take care of not disclosing your password on these connections.
- Going for an effective and well-versed antivirus for your system to protect your data from bugs and viruses.

Cloud security

When we talk about cloud computing, the first thing that comes to the mind of users is the security of their data. Cloud security is the foremost concern for everyone nowadays. Since the use of cloud system is increasing day by day, the challenges for ensuring cloud security are also increasing. Cloud service providers enable proper and effective security measures to ensure the security of the cloud environment. Cloud security actually refers to the policies and the mechanism that is employed by the cloud providers to provide a bug and virus-free environment where the users can safely store, manage, and access their data and infrastructures.

Cloud security is also known as cloud computing security. It refers to the set of policies and mechanisms that work together to provide a secure cloud environment. With a secure cloud-based system, users can work on and flourish their organizations and businesses. It is designed in such a way that people can maintain, manage, and access their data and information in a secure way. Cloud service providers use the best measures and employ a skilled staff to ensure the safety of the data and information. They protect our data against cyber-attacks, theft, and losses.

The major risks that can hamper our cloud security are as follows:

- Risk of leakage or exposure of information to others.
- Risk of internal data of an organization being accessed by any unauthorized user or person who is not an employee of that particular organization.
- Any type of malicious attack that damages the cloud infrastructure results in data insecurity.
- Intrusion of a virus in the cloud storage.

Cloud security helps us in eliminating these risks and reduces the threats caused by these risks. It manages and protects the data and information and maintains user authentication and access. It also makes sure that the cloud system is functioning smoothly even in the case of an attack and is trying to resolve the problems caused by that attack.

Measures and controls in cloud security

Various measures and controls are used for ensuring cloud security. These controls help in minimizing or completely eliminating the risks that are related to cloud security.

We can divide security controls into the following four categories:

- Deterrent controls
- Preventive controls
- Detective controls
- Corrective controls

Let us take a brief look at all of these measures:

Deterrent controls

These types of controls give a warning to the attackers and make them aware that any act of data stealing or theft inside the cloud environment can be dangerous for them. These controls behave like a warning system and do not provide any type of security to the cloud environment or infrastructure. If any person tries to do a suspicious activity or causes some harm to the cloud data or information, then this type of control issues the warning that doing such an activity can cause an adverse effect. They are basically designed to discourage malicious activities by unauthorized people.

Preventive controls

These types of controls are used for managing and preventing vulnerabilities in a cloud. By eliminating vulnerabilities, these controls help in strengthening the cloud environment. A preventive control actually includes a piece of code that performs the job of blocking inactive ports so as to prevent the hackers from entering the system. It enables strong authentication of users which protects the system from any kind unauthorized access.

Detective controls

Detective controls are the type of attacks that are used to identify the attack. They identify the threat and the events that occur on the online platform and provide their information to the concerned person. The users take the corrective action to resolve the problem caused by that particular suspicious threat or event.

In case of any suspicious activity, the detective control sends a signal to the preventive or corrective control in order to resolve the issue. Example of this type of attacks are intrusion detection and prevention.

Corrective controls

Corrective controls are the controls that mostly come into action during or after the attack has occurred. These controls limit the damage caused by the threat or attacker. The goal of these corrective controls is to reduce the consequences of the attack. Keeping a backup of the system is an example of a corrective control.

Apart from these controls, cloud providers can also use various techniques like encryption, cloud firewalls, backup plans, etc. Perfect security configurations for cloud providers and users and employee education are some other measures to ensure the safety of the cloud environment.

Encryption

Encryption is a key technology that helps in providing cloud security. It is one of the most effective tools to protect the data in the cloud. It is a process in which the data is encrypted in such a way that only the authorized users can access the data and information. Encryption uses a mathematical algorithm to transform plain text, i.e., a text, image, file or any other type of data into an encrypted form. This method enables users or companies to protect their data from getting stolen, damaged, or read by unauthorized or malicious users. Cloud vendors encrypt the data and provide a decryption key to decode the encrypted information back into the readable form.

Let us understand this with an example. Suppose you store your data and information on a cloud service provider's data center that does not use an encryption method to store data. Then, if an attacker attacks your cloud environment, there are possibilities that he may be able to misuse your information, perform as many malicious actions as he wants, steal your valuable information, and leak it to your competitors. This may cause many adverse effects on your cloud system. However, if your system is encrypted, then only the authorized persons, i.e., those who have a decrypted key can view your business and personal information and have the right to access them. Encryption makes the cloud system a secure and safe environment for the users to store their data. Data can be either stored in an encrypted form or can be transitted from one place to another, i.e., between multi-clouds or a hybrid cloud in an encrypted form.

The encrypted data in a cloud comes in three forms. These are as follows:

- **Data-in-transit:** This refers to data that is being transferred from one place to another. For example, transferring our data from a laptop or PC using LAN.
- **Data-at-rest:** This includes data that is being saved on devices such as database server, USB, mobile devices, and physical or local storage system and is not being used or transferred to any place or any person.
- **Data-in-use:** This refers to the data that is being used by one or more applications.

Encryption is done with the help of key-based algorithms, and all the keys are stored by the respective cloud service providers. With this technique, data is presented in such scrambled form that it is impossible to understand it without using the decryption key. Some cloud providers can encrypt the data when it is being transferred while some can do it through web interfaces. Some cloud providers can also hire a dedicated client for data encryption.

The foremost benefit of encryption is that only the authorized user can read the encrypted information with the help of the key. The encrypted text is meaningless for the users without the keys. Hence, it ensures the safety of sensitive information even when it is stored and transmitted online. It provides end-to-end safe and secure transmission. Moreover, it prevents data loss and theft, and provides additional security against outside threats. Encryption provides protection of data at all times and maintains the privacy of the data.

Conclusion

Data storage inside cloud environment is a great benefit that is provided to users by cloud providers. Cloud storage enables the universal access of data and provides all time availability of information as per the requirement. With the facility of cloud storage, cloud providers also allow various measures and controls that ensure cloud security. In this chapter, we have studied about the two prominent features of cloud computing, that is, cloud storage and cloud security. In the next chapter, we will discuss about the various cloud operations and challenges faced by cloud computing.

Points to remember

- Cloud storage provides us the facility of storing data online. Various cloud providers provide space for storing data and allow it access to multiple customers with proper safety.
- Cloud storage provides various benefits like accessibility, total availability, reliability, strong protection, and backup.
- Cloud providers enable various security policies and measures to provide a safe cloud environment.
- Various techniques like encryption, data recovery, backup plans, cloud firewall etc. are used to ensure the safety of data and information in a cloud environment.

Multiple choice questions

1. This type of storage enables all time availability and accessibility from anywhere:
 - a. Cloud storage
 - b. Device storage

- c. Hard disk storage
 - d. USB
2. **The types of cloud storage are**
 - a. Private
 - b. Public
 - c. Hybrid
 - d. All of these
3. **This technique allows transferring data in a scrambled form:**
 - a. Firewall
 - b. Encryption
 - c. Backup
 - d. Recovery

Answers

1. a
2. d
3. b

Questions

1. Discuss the concept and usage of cloud storage.
2. Explain the various types of cloud storage.
3. Explain the meaning of cloud security.
4. What is the use of encryption in cloud computing?

Key terms

- **Cloud storage:** It means storing data and information online.
- **Cloud security:** The measures and policies to protect data and information in a cloud environment.
- **Cloud firewall:** The firewall that exists in the cloud environment to prevent various malicious viruses from entering the system.
- **Encryption:** The process of encrypting data and decrypting it using the decryption key.

CHAPTER 9

Cloud Operations and Challenges

Cloud operations refer to managing the data related to the infrastructure and environment and providing efficient cloud services. Cloud operations are very crucial for the efficient functionality of cloud computing. They are helpful in fulfilling the needs and requirements of the customers in real time. Various cloud operations are online marketplace, e-mail, content management, security, etc. This chapter is based on the explanation of cloud operations. Here, we will discuss the objectives and benefits of cloud operations. We will also discuss the risks and challenges related to cloud computing.

Structure

In this chapter, we will discuss the following topics:

- Defining cloud operations
- Cloud operations objective
- Cloud operations management
- Benefits of cloud operations
- Challenges related to cloud computing

Objectives

After studying this chapter, you will be able to:

- Understand the cloud operations
- Discuss the objectives and benefits of cloud operations
- Understand the management of cloud operations
- Discuss the various challenges related to cloud operations

Defining cloud operations

Cloud operations are also referred to as CloudOps. By the term cloud operations or CloudOps, we refer to a process that helps us in managing and delivering various cloud services and infrastructures to various cloud computing environments. Their main objective is to deliver efficient and superior quality cloud services. Cloud operations enable the smooth operation and functioning of the cloud infrastructures and the environment.

Cloud operations also lay emphasis on proper management of resources and services to ensure the efficient running of the cloud system. Apart from efficient management, they also allow total availability of resources and services to satisfy the needs and requirements of the businesses and clients. CloudOps focus on achieving service level agreement standards and ensuring the security and integrity of the cloud environment. They also cut down on various operational costs incurred in the cloud.

CloudOps is actually a process through which a company or a business maintains, delivers, and distributes a cloud infrastructure to its internal or external users. Its main objective is to efficiently manage the cloud environment and to meet the quality of the service requirements. It mainly focuses on fulfilling the customer's requirements and satisfying their demands.

CloudOps include various operations like content management, accounting services, email marketing, human management system, and online marketplace. The users can perform various cloud operations by using the internet. They can access these operations using web applications or mobile-based applications. This is the reason that makes cloud operations popular nowadays.

The various cloud operations are shown in the following figure:

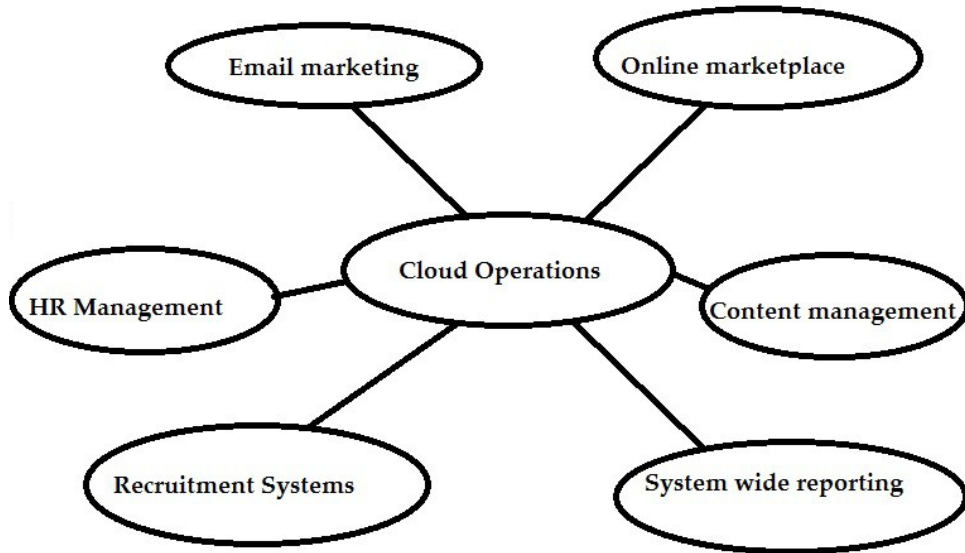


Figure 9.1: Cloud operations

A small group of targeted IT people are employed to manage these cloud operations. This group is normally referred to as the CloudOps team.

The various responsibilities of the CloudOps team are as follows:

- Resource allocation
- Configuration management
- Optimizing performance capacity
- Meeting service-level agreement standards

All companies are mostly hiring professionals to manage their cloud services. These cloud services can either be storage, compute, network, database, security, etc. CloudOps help in the refinement of the business processes. They provide methods to optimize the availability, flexibility, and efficiency of the cloud services. This is very beneficial for businesses in achieving their goals successfully.

Many public cloud providers offer various tools for performing CloudOps. Amazon, Google, Microsoft, and IBM are among the popular vendors that provide users with various cloud operations. The teams that aim to provide the best cloud operations can make use of tools from Apigee or RightScale. They can also use open tools, namely Ansible or Chef. All these tools help in achieving services like configuration management, cloud provisioning, and application deployment automatically.

Cloud operations objective

Cloud operations can be considered as the approaches or practices that allow cloud-based platforms, applications, and tools that run over these cloud platforms to function perfectly for a long duration. They rely on continuous operations such that they result in zero downtime. Their main objective is to provide an effective cloud-based platform that has a goal of achieving zero downtime. An organization or business uses cloud operations to achieve the following objectives:

- Delivering efficient cloud services and infrastructure to ensure proper cloud management.
- Helping to achieve service level agreement standards.
- Optimizing performance and capacity and proper resource management.
- Maintaining compliance and security.
- Maintaining confidentiality of the user's data and keeping it safe.
- Providing better backup and allowing disaster recovery.
- Allocating the storage requested by the user and calculating the storage charges as per their use.
- Automating service and management.

Cloud operations management

It is very essential to manage the cloud operations that occur inside the cloud environment. It is very important for both the cloud service provider and the client. Every phase or step of the cloud process is related to the cloud operations management. When we talk about cloud operations management, it includes the management of both hardware and software as well as network infrastructure.

We can define cloud operations management as the process of designing, overseeing, controlling, and redesigning cloud operational processes. Management is very crucial for the growth of an efficient and effective cloud environment. It is very important for cloud operations to be capable of ensuring total availability of cloud resources as well as network infrastructure, to meet the service level standards, and to enable high level of security and backup for the data stored in the cloud.

The main focus of cloud management is to fulfill the customer requirements and achieve a great level of customer satisfaction. Service providers and clients are both equally responsible for the proper management of cloud operations. They must ensure the best quality of service in less time and low cost. They must go for proper selection of tools and resources. It is very important for effective cloud environment.

Analytics is used in cloud operations management in order to maximize the visibility of the cloud environment. By the term 'analytics', we mean the use of remote public or private resources to analyze the data on demand. Nowadays, analytics is heavily used in cloud operations management. It helps the management to understand the information more precisely and take decisions to promote the growth of their business or organization. It also allows organizations to effectively control the resources and run services efficiently and cost-effectively.

Some major benefits of cloud operations management are as follows:

- It lays stress on improving efficiency and minimizing the risk of disruption.
- It increases the speed of resource allocation and services, and provides quality services, hardware, and software as well as network infrastructure.
- It reduces the cost of delivering the cost services and justifies the investments made by organizations and businesses.

The following is the list of procedures that are used to control, handle, and manage the cloud operations:

- **Use of efficient processes:** Efficient and effective processes should be used to manage and control cloud operations.
- **High QoS (Quality of Service):** It should be understood that the quality of the services should be maintained in order to provide a good environment.
- **Selection of efficient and proper resources:** It is essential to select the appropriate tools and resources for effective cloud operations management. One must go for tools that save time, cost, and efforts.
- **Standardization:** The standard processes should be used for the proper allocation of resources. Standardization should also be followed to efficiently and automatically manage the tasks.
- **Efficient and proper use of time:** Cloud operations should be managed in a proper way so as to complete all the cloud related tasks in the right time and economically.
- **Use of right tools:** The use of right tools is also recommended for proper cloud operations management.
- **Security:** Security also plays a vital role in cloud operations management. It is very essential to lay stress on safe and secure cloud operations so that the data and all the tasks related to cloud management remain protected. Cloud structure and infrastructure also rely on security protocols of the cloud environment.

Cloud providers must follow the following guidelines to ensure the effective management of cloud operations:

- In order to perform various cloud functions, the right tools must be employed and efficient resources should be used.
- They should try to complete their tasks in the right time and at an affordable cost.
- The quality of service should be good enough to make one avoid working on the same task again and again.
- The appropriate resources suitable for operation management should always be selected.
- Efficient processes should be used to eliminate the problem of redundancy and to get full rewards against the efforts of providers and clients.
- Standardized and automated processes should be employed to get rid of repetitive tasks.

Different approaches and practices are used to perform cloud operations management. These approaches ensure that all the resources and tools are managed properly. These are very essential in running the cloud smoothly. One of these approaches is resource capacity planning which is tremendously used by cloud providers and clients nowadays.

Benefits of cloud operations

Cloud operations are very important and essential for the smooth functioning of the cloud environment. They provide stability to the cloud and improve the efficiency of the cloud system. Cloud operations are very beneficial for the cloud and provide better cloud services. They are also very important for the success of cloud computing because these operations help in solving real business problems. Let us briefly discuss their benefits here:

- Cloud operations are very economical. With cloud operations, all services and infrastructures are mostly governed, owned, and managed by cloud vendors only. Hence, there is no need to buy these resources. Clients are supposed to pay for only those services that they use. These factors make CloudOps cost-effective.
- Cloud operations make most of the services automated. Hence, users don't have to worry about managing these operations. These operations are managed by the vendors automatically. Most of the steps are automated. Moreover, the services are also upgraded automatically.

- Cloud operations help us in simplifying the traditional structures and make all processes and tools easier to operate. They allow users to eliminate the headache of implementing complex operations and infrastructure.
- Cloud operations are very effective as they eliminate the need to buy and maintain expensive hardware and software resources.
- Cloud operations minimize the risk of disruption and maximize the efficiency of the cloud system. The use of automated tools and resources help in performing the tasks efficiently and achieving the goals of the organizations.
- The foremost benefit of cloud operations is provisioning. They allow us to scale out and scale in the resources and servers automatically as per the demands of the users or businesses. There are two ways to provision resources. One way is that the users can provision the resources as per the demands of the business or market. The other way is to provision the resources automatically. Here, the applications can themselves demand for resource allocation in case there is requirement and automatically de-allocate them when there is no requirement.
- With CloudOps, the infrastructure of the cloud is kept hidden from the management. This is a very efficient feature as it enables the management to take care of the essential requirements of the cloud system instead of worrying about the underlying infrastructure.
- Cloud operations are very user-friendly and flexible. They also deliver high quality service to the organizations and businesses. They also enable users to perform their tasks with high speed.
- CloudOps provides various tools that support the optimization of capacity utilization.
- Cloud computing operations are scalable which allow users to scale the resources and computing power for only when they need them. This factor makes the cloud environment economical.
- Fewer resources are utilized in performing the functions of the cloud in comparison to traditional approaches.
- CloudOps help organizations to maintain security and compliance and also enables them to meet the service level of standards.
- Cloud operations fix the various operational problems themselves without hampering any other applications or users. They use the automation feature for self-healing.

Challenges related to cloud computing

Cloud computing provides global access to a set of resources which include hardware, software, storage, network, servers, data security, and many other services. Cloud computing is based on the principle of the pay-per-use model and allow the provisioning of resources as per the demand. Hence, it accounts for cost-effectiveness, efficiency, reliability, and security also. Although it provides many benefits, there are some challenges that cloud computing faces. These are discussed as follows.

Cost

Although cloud computing decreases the cost of maintenance, management, and eliminates the need for buying new and expensive hardware, it may still cause some additional incurred charges for small as well as large scale industries. Tuning the business platform as per the cloud requirement can also be expensive. Moreover, the cost for transferring data from the company to the cloud can also result into additional cost. Apart from this, some other factors like the cost of bandwidth, the need for an expert team, and a training schedule for employees can also be cost-increasing factors. Hence, cost issues can be a matter of concern for most industries that want to include cloud as a part of their business.

Security and privacy

When any user or organization stores their respective data on the data centers of the cloud service providers, then it must consider all issues related to security and privacy of data. Cloud vendors should take care of all security factors and employ various measures like password, cloud firewall, authentication, etc. to secure and protect the data stored on their data centers. They must ensure that the sensitive data of the users should not be shared among third parties. It should also be noted that in case of data transfer, encryption should be used. Maintaining the security and privacy of data is also one of the biggest challenges faced by vendors nowadays.

Compliance

When users store their data and applications on cloud storage, then the cloud vendors automatically provide the facility of backup. They themselves maintain backup copies of all data stored on their storage servers. So, whenever the users transfer their data from the internal storage to the cloud, they need to be compliant with the rules and regulations of the company. Hence, this can also be a problem for the people who want to opt for cloud computing services.

Reliability and flexibility

Providing reliability and flexibility to users and organizations can be a challenge for cloud service providers. They must use such policies that there is no data leakage. Cloud vendors should provide reliability to their customers. They must monitor and supervise the cloud system to keep it safe from any intruder or data theft.

Lack of resources and expertise

Lack of resources and expertise is also one of the challenges that cloud computing organizations are facing today. As more and more companies and businesses are using cloud services and putting their workloads on a cloud environment, the cloud vendors are facing a lack of resources and a team of experts to handle all types of cloud operations. To bear the workload, more advanced tools are required. Since cloud technologies are growing rapidly, companies are in need of experts who are skilled and can handle these technologies easily and efficiently. Hence, the lack of tools to manage cloud services and a need for skilled employees are becoming bottlenecks in many organizations.

Downtime

Downtime is also a major challenge in cloud computing. No vendor can promise its client a service that is 100 percent free of downtime. Some internet connectivity problem can result in increase of downtime. So, a company facing the problem of bandwidth needs to think twice before adapting cloud computing technologies.

Dealing with multi-cloud environment

Nowadays, instead of using a single cloud, companies mostly use multiple clouds for their tasks. They are doing so because using a multi-cloud strategy is cost-effective. They can employ a private cloud for their sensitive data and the public clouds for some other tasks. Managing a multi-cloud is a complex task and a challenge for companies.

Cloud migration

Cloud migration means to transfer an existing application to the cloud. Transferring an application to a cloud environment is a challenge for many companies. They may face the problems of security, troubleshooting, etc. Cloud migration is also one of the challenges that companies are facing today.

Governance/Control

In cloud computing, all the infrastructure whether that is hardware, software, or network resources is managed and controlled by the cloud service providers. Hence, the clients or enterprises opting for cloud resources have to follow all the rules and regulations enforced by the cloud service providers. Proper IT governance should ensure that proper rules and regulations are followed and the resources are controlled and maintained in an effective way. But, in today's cloud-based world, IT does not have full control over the provisioning, de-provisioning, and allocation of resources. They do not have any control over how the data is managed and controlled and the operations of infrastructure. Hence, it has become difficult for IT to provide governance, compliance, data quality, and risk management. To overcome the difficulties that are encountered while transferring to the cloud, IT should switch to the traditional IT governance and control processes to include the cloud. This is very helpful in evolving the role of the IT teams in the cloud.

Performance

When a company or enterprise chooses to opt for cloud services, then it becomes dependent on the service providers. Hence, the performance of the cloud-based systems of that particular organization totally relies on the performance of the service provider. If somehow, any problem or disruption occurs at the vendor's end, it may affect the performance of the organization. Moreover, the quality of the service provided by the service provider also hampers the performance of the business.

Lack of vision

When an enterprise decides to switch to a cloud, it must consider all the necessary factors before moving to the cloud. It should also keep in mind all the future prospects that it aims to achieve. One must select a cloud service provider that can fulfill all their needs of the present and the future. Cloud vendors should also impose cloud services that contain each and every feature necessary for the potential growth of the company. Hence, a clear vision is very important for both the cloud clients and the vendors. A lack of vision can be a challenge for cloud computing.

Although cloud computing is a great technology with innovation and platform for growth, some of these challenges demand one to think for a bit before making the decision of using the cloud technologies for your businesses. Users should employ experts to get rid of these issues and maintain the efficiency of their organizations.

Conclusion

Cloud operations provide us with many superior cloud services. These are very popular nowadays as they not only support the growth of your business or enterprise, but also provide real life solutions to all kinds of business problems. In this chapter, we came to know about cloud operations and their benefits in the present scenario. We also talked about the management of these cloud operations. Cloud computing is a boon to our IT industry but it possesses some challenges also. We also discussed about these challenges in this chapter. In the next chapter, we will study about cloud technologies and the various cloud service providers.

Points to remember

- Cloud operations refer to the management and delivery of cloud services. These are the processes that help us in managing the cloud services and the infrastructure of the company.
- Cloud operations or CloudOps help organizations by promoting the growth of their businesses and by providing solutions for all their business problems.
- Cloud operations are very beneficial as they support various features like cost-efficient, provisioning, automation, increased efficiency, lowering the risk of disruption, etc.
- Besides the many benefits of cloud computing, there are also many challenges that are faced by the industries that opt for cloud computing. These challenges include cost, lack of resources, expertise, cloud migration, reliability and flexibility, downtime, security, and compliance.
- One must have a firm discussion on the cloud challenges and take advice from a team of experts before entering the world of cloud computing.

Multiple choice questions

1. **These are the processes that help in managing and delivering infrastructure:**
 - a. CloudOps
 - b. Cloud operations
 - c. Cloud processes
 - d. Both a and b
2. **Challenges of cloud computing include**
 - a. Delivery of cloud services
 - b. Cost

- c. Cloud infrastructure
- d. All of these

Answers

- 1. d
- 2. b

Questions

- 1. State the various cloud operations and their benefits for industries.
- 2. Discuss the meaning of cloud operations management.
- 3. What are the objectives of cloud operations?
- 4. State the various challenges faced by cloud computing.

Key Terms

- **Cloud operations:** The process through which a company manages, delivers, and distributes cloud infrastructure to its internal and external users.
- **Cloud operation management:** The process of designing, managing, and controlling cloud operations.

CHAPTER 10

Technologies and Service Models

Cloud computing technology is the latest technology that is emerging and has been helpful for many organizations. New technologies are emerging day by day to provide the best of cloud computing services. There are four types of cloud computing technologies available, namely virtualization, service-oriented architecture, grid computing, and utility computing. These technologies make the cloud computing platform flexible, reliable, and usable. This chapter is all about these technologies. We will discuss about some important cloud service providers. We will also discuss about MeghRaj, an initiative by the Indian government to support Cloud Computing.

Structure

In this chapter, we will discuss the following topics:

- Cloud computing technologies
- Types of cloud computing technologies
- Service-oriented architecture
- Grid computing
- Utility computing

- Service providers
- MeghRaj

Objectives

After studying this chapter, you will be able to:

- Understand the meaning of cloud computing technologies and the types of cloud computing technologies.
- Discuss the importance of service-oriented architecture.
- Understand the concept of grid computing.
- Understand meaning of utility computing.
- Know about the prominent cloud service providers.
- Discuss about the cloud initiative “MeghRaj” framed by the Indian government.

Cloud computing technologies

Cloud computing technology is an internet-based technology that provides the users with the access of software, storage, hardware, files, and servers. These services can be accessed via various internet-connected devices like computer, mobile devices, and laptops. The cloud computing technology is growing at a high speed and is making business organizations go through a revolutionary change. Basically, virtualization, service-oriented architecture, grid computing, and utility computing are considered as the technologies used in cloud computing. Nowadays, with new advancements and features, six emerging technologies related to cloud are evolving into the market. These are serverless, containers, microservices, DevOps, IoT, and artificial intelligence.

These technologies help businesses to make progressive developments by using various powerful software and IT infrastructures and by attaining the advantages of the cloud computing features. These technologies play a vital role in the successful operation of cloud computing services and make these services flexible, reliable, and agile. Each cloud technology possesses unique features and helps organizations to efficiently reach their goals.

Types of cloud computing technologies

Cloud service providers are working continuously to evolve the best cloud computing technologies. These technologies provide immense benefits to various organizations. We can divide cloud computing technologies into four basic types. They are as follows:

- Virtualization
- Service-oriented architecture (SOA)
- Grid computing
- Utility computing

Let us discuss them one by one.

Virtualization

You might remember the concept of virtualization that we studied in this book before. Virtualization is the cloud technology that creates virtual versions of cloud services like storage, servers, operating system, and hardware and software resources. It is very advantageous as it provides the users with the access of cloud services anytime and anywhere and that too, at an affordable cost. The users always have an illusion that they are using physical resources but are actually utilizing the virtual form of the resources. It helps organizations or businesses in lowering down the workload of the system and provides scalability. Virtualization can be applied to various layers which include hardware virtualization, software virtualization, storage virtualization, server virtualization, and operating system virtualization. Each the virtualization type holds different features and helps organizations to avail the benefits of the universal availability of services, reliability, and flexibility of resources.

Service-oriented architecture

Software-oriented architecture or SOA refers to an architectural approach which includes a collection of services. These services have the capability of communicating with each other. These services are delivered to other application components via communication protocols. SOA is very popular as it quickly responds to the changes and modifies the system as per the changes in the market. Service-oriented architecture makes it easy for software components available on various networks to co-relate and work with each other.

SOA is very important as it respond quickly to any type of change that occurs in the business or organization. Apart from that, it also supports new channels of interaction between the customers, partners, and suppliers. The SOA technology makes it easier for various components on the network to work with each other. SOA is independent of products, vendors, and technologies. Hence, a variety of products can be used to implement architecture. Organizations can use products and technologies based on the end goal of the system.

Service-oriented architecture can be considered as an approach of designing software where the components are arranged according to the business processes. SOA is a

type of service that is responsible for performing special tasks. These services are reusable and independent of the environment in which they are used. To understand these features of SOA, let us consider the example of removable batteries. We use removable batteries to operate toys, clocks, and remote controls. The function of the removable batteries is to provide power to all these devices. You will notice here that the function of the batteries to provide power remains the same in whatever device they are used in. Hence, we can say that batteries should provide power independent of the environment in which they are used. Moreover, these batteries are also unaffected by the connected components. The concept of SOA is the same. This means that the functionality and ability of SOA remains independent of the environment in which it is implemented and it remains unaffected by the connected components.

Some advantages of service-oriented architecture are as follows:

- The maintenance of any device that implements SOA is easy. SOA eliminates the complexities that are associated with interacting services within the environment. The services that implement SOA are easy to update, maintain, and manage.
- The services are reusable as all of them are complete and self-contained programs. The organization or company can use pre-build services and there is no need to rebuild them again. This lets the organization concentrate on just the website and achieving their goals.
- SOA services are always reliable so it is always easy to test, update, and maintain them.
- SOA services are available anytime.
- SOA services are very scalable. This means that if any service is in demand by many users, then that service is made scalable by attaching more servers to it. This will make the service available to the users at all times.
- The services generated using SOA are always stored on the same directory structure. This is very helpful for customers as they can always access the services from the same directory.

SOA is important for solving various business requirements. It can be used to develop multiple services that are independent of each other but can communicate with each other. It is also used to create reusable, independent, and reliable services.

Grid computing

Grid computing is a set of networked computers that work together to perform some specific tasks. These networked computers work as a virtual supercomputer to perform various tasks like analyzing huge sets of data. The workload is divided

among various machines so that each connected computer can use its resources to attain a particular goal. Grid computing is used to process internal data and provides services over the internet.

The grid computing system can be as simple as a collection of computers running on the same operating system or it can be as complex as a system of inter-networked computers with different platforms. Each computer present in the grid computing system is allowed to access all the resources of the other computers present in that network. The users can make use of the processing power, storage, and memory for performing their tasks.

Let us understand the concept of grid computing with the help of an example. Suppose you and your friends are working on a drawing project. One of your friends arranges stationary for the drawing creation. The other one arranges a vehicle to reach the sight scene. Another one draws the sketch. All of your friends share ideas and skills to create a perfect drawing project. They have shared their workload to achieve their goal of making an excellent drawing project. This is the concept of grid computing: The workload is shared between every computer on the group to achieve the goal of the business efficiently and quickly.

The size of the grid can vary from a small workstation to large networks. Grid computing can be used by a wide range of applications for mathematical, scientific, or educational tasks, etc. and it is also helpful in weather and economic simulations. Let us discuss some benefits of grid computing. They are as follows:

- Grid computing enables users to share, access, and manage information efficiently.
- Grid computing systems do not have a single point of failure. This means that if any server / computer of the grid fails, it doesn't affect the functionality of the system. The job of that failed server / computer is handled by the other servers / computers.
- Grid computing helps users in solving large and complex problems in less time.
- It enables multiple tasks to be performed parallelly.

Utility computing

Utility computing is defined as a model in which computing resources are supplied to customers as per their demands. These resources include servers, hardware, software, storage, and applications. The users are charged for only that part of the service that they use. Here, the providers are the owners of all the computing resources and are responsible for managing and maintaining the infrastructure and resources. The users can access these resources as per their demands and pay for their services as per their usage.

Utility computing is an example of on-demand computing where the use of efficient resources is maximized and the cost associated with it is minimized. It is based on the principle of an organization paying to another organization to buy the computing resources. The company that offers utility computing provides various hardware, software, storage resources, processing power, and computer applications on rent.

Some benefits of utility computing are as follows:

- Utility computing is very convenient. The users or clients are not required to buy resources; rather they can get these from the utility computing company. Moreover, they are not even responsible for managing and administrating these resources.
- The services provided by utility computing are cost-efficient as the users have to pay for only those services that they use.
- It enables the companies to subscribe to a single service and use it throughout the company.
- Utility computing provides greater flexibility and is easier to manage.

Apart from these basic cloud computing technologies, some other emerging technologies are as follows:

- **Containers:** The container technology became popular in 2014 with the introduction of Docker. Containers actually refer to a packing mechanism which enables us to abstract the application from the environment in which it is running. This packaged interface contains the application code along with its libraries and dependencies. This allows the code to run anywhere and anytime from any desktop, laptop, or on cloud.

Containers are fast, lightweight, and portable as they do not contain a guest OS. They share the machine OS kernel. Containers enable developers and IT professionals to deploy applications along various environments with little or no modifications at all. The benefits of containers are as follows:

- o Containers are portable and platform independent.
 - o They are lightweight. This feature makes them more supportive for cloud-based applications.
 - o Containers are the best option for modern development and architecture.
 - o Containers are made to run anywhere which is very helpful for easy development and deployment.
- **Serverless:** The serverless technology is a very popular technology that provides significant benefits to developers and organizations. It provides backend services to the users as per their demands. The users can write and deploy their code without worrying about the underlying infrastructure.

They only have to pay for those services that they use and all the functions and services can be scaled as per their requirements.

The serverless technology enables users to run and build applications without thinking about the physical servers. They don't have to worry about the maintenance, management, and operation of the servers. They can use their valuable time in developing the core products. This technology gives us the benefits of agility and lower cost. Some benefits of serverless technology are as follows:

- o Serverless computing is very cost-effective as users don't have to buy powerful servers for their tasks. They can use the services as per their requirement and build their applications.
- o These services can be scaled elastically as per the need of the organization or enterprise. This means that this technology has auto-scaling.
- o The serverless technology is completely dynamic. This means that everything is automated here.
- o There is no infrastructure to maintain. The users can write and deploy the code directly in the cloud without worrying about the hardware, operating systems, or servers.
- o The serverless technology gives us the benefit of high availability.
- **Microservices:** Microservices is an architectural pattern in which an application is built as a suite of modular components. It is a variant of **service-oriented architecture (SOA)** where software applications are developed. A single application is made up of independent deployable and modular services. Each service runs its own process and is independent of each other. These services can communicate with each other or with clients using lightweight protocols.

Microservices are very beneficial because of the following benefits:

- o Microservices are very simple. It is very easy to design and build applications and even re-build them. The services can be implemented by using different programming languages and databases.
- o A microservice is a set of modular services. Each service is independent of each other. Hence, if any malfunctioning occurs in one service, it doesn't affect the whole system.
- o It enhances the productivity and speed of the system as the applications are combinations of different independent services that are easier to manage and develop.

- o Microservices are very flexible. The users can use the new technology as per the requirement and they eliminate the need for depending upon a single vendor.
 - o Microservices gives us the advantage of scalability also. Since all services are independent, the users can scale out the services as per their need instead of using the whole application.
- **Internet of Things:** Internet of Things (IoT) simply refers to all things and physical devices that are connected to the internet and are collecting and sharing data. IoT is an essential technology that is useful for almost all everyday tasks. Data is collected and transferred over a wireless network without any human intervention. IoT enables companies to automate all the functions and reduce the cost of the employees. This technology is making the lives of the people smarter.

Some examples of IoT include smart appliances, smart security systems, smart locks and doorbells, smart home hubs that can control light, and cooling and heating appliances of the home. Moreover, smart assistants like Amazon's Alexa and fitness trackers are also examples of IoT technology.

IoT is very helpful in making our life smarter and to work perfectly. It has automated almost all tasks in our lives and has made our life easier and smarter. Some advantages of IoT are as follows:

- o IoT makes our work and life smarter.
 - o It automates all the processes of the businesses and saves the cost of labor.
 - o It helps in reducing waste and improves service delivery.
 - o It increases safety and improves quality of the services.
 - o It increases productivity and improves the customer experiences.
- **Artificial intelligence:** Artificial Intelligence or AI refers to the technology that simulates human intelligence in computers. AI includes algorithms that are used to classify, analyze, and draw predictions on the basis of the available data. This technology consists of programmable machines that can think like humans. AI lets the machine thinks like humans and takes corrective decisions based on real-time data. AI is a branch of computer science that is becoming popular day by day. It is used in various activities like speech recognition, learning, planning and problem-solving, social media, and for self-driving cars.

AI is very useful in various fields like gaming, natural language processing, expert system, etc. Some of the major benefits of AI are as follows:

- o With AI, organizations can complete their tasks in lesser time and also easily since it supports multitasking.
 - o AI greatly reduces the use of labor by employing smart automation in companies.
 - o It enhances the safety on the roads and provides good customer support in the form of AI chat-bots.
 - o This technology is helpful in predicting disasters and reacting to them quickly.
- **Machine Learning:** Machine learning is a technology that provides systems with the ability of learning automatically and improving their decision-making capability from past experiences. It is an application of artificial intelligence which allows machines to learn automatically without any interference from humans. It focuses on the development of computer programs that can access data and then use it to learn automatically. They study the pattern of the data and changes occurred in past years. This helps them in taking better decisions by considering the future trends also. Currently, it has been widely used in various industries and fields. Some common examples of machine learning include self-driving cars, effective and refined web search, speech recognition, image recognition, prediction systems, online customer support, etc. Some of the major benefits of machine learning are as follows:
 - o Machine learning provides the systems with the capability of identifying trends and patterns.
 - o Machine learning doesn't require any human intervention. The machines can themselves make predictions and improve their decision-making.
 - o It can be used in a wide range of applications, i.e., from education to business.
 - o It provides the capability of learning from past data. It helps machines in improving their accuracy and efficiency as new data is provided to them. It gives us the benefit of continuous improvement.
- **DevOps:** DevOps is a combination of two words: dev and ops. Here, "Dev" stands for development and "Ops" stands for operations. DevOps can be defined as a set of practices and tools that combines software development with various IT operations. DevOps is a technique that helps in executing various IT projects that are essential to fulfill the needs of the businesses. DevOps helps businesses to respond better to their customers and achieve their goals in a more efficient way. Some benefits of DevOps are as follows:

- o It provides continuous delivery of software and faster resolution to problems.
- o It enables organizations to better serve their customers and compete more effectively in the market.
- o It enables high collaboration between teams.
- o It enables continuous software updates through automation.

Apart from the technologies mentioned above, various other cloud technologies are available in the market. These technologies provide us with high availability, scalability, and reliability of resources. These are very popular among all industries nowadays and they provide clients with many benefits like resource allocation, multitasking, agility, the pay-per-use model, on-demand service, and the capability of scaling up and down the resources.

Service providers

Cloud service providers are the companies or vendors that offer various types of services like hardware, software, network, storage, processing power, and business applications in the cloud. They ought to provide various information technology services over Internet. These companies provide cloud-based platforms to various organizations.

The users or organizations have to pay for all the services that they use from these companies. These companies provide various beneficial features to the users or organizations that use cloud services. These services can be available in various forms, i.e., **SaaS (Software as a Service)**, **PaaS (Platform as a Service)**, or **IaaS (Infrastructure as a Service)**. The users can access them as per their requirements.

Many cloud computing companies are available in the market nowadays. Each of the company promise to provide best and efficient cloud services to each business that implement cloud computing. Let us have a look on some popular cloud service providers:

- **Amazon Web Services:** Amazon Web Services (AWS) is a cloud computing platform provided by Amazon. It offers a mixture of services like IaaS, SaaS, and PaaS. It includes a variety of cloud services and products. It provides servers, storage, network, processing power, email, mobile development, and security. It was the first cloud computing platform and become very popular among various cloud service users. It offers fast, flexible, reliable, and cost-effective solutions to its users. AWS can be used to create and deploy any kind of application in the cloud. It is very secure, scalable, and reliable.
- **Microsoft Azure:** Microsoft Azure is a public cloud computing platform launched by Microsoft in February 2010. Formerly, it was known as Windows

Azure. This is a flexible and open-source cloud platform which helps in development, data storage, service management, and hosting solutions. It is scalable, flexible, cost-effective, and provides efficient solutions to organizations or businesses. It ought to provide various consistent tools and resources and gives the ability of scaling up and down the IT resources as per the needs of the business.

- **Google Cloud Platform:** Google Cloud Platform or GCP is one of the most popular cloud service providers which are launched by Google. GCP runs on the same infrastructure which Google uses for its end-user products like Gmail, Google Search, You Tube, etc. Apart from GCP, G Suite is also offered by Google Cloud. It helps the users to meet their business challenges easily and efficiently.
- **Oracle Cloud:** Oracle cloud is one of the leading cloud service providers of India. It offers a variety of services which include servers, storage, applications, and network to various organizations or businesses on a demand basis. These services are provisioned by Oracle Cloud on-demand by various users over the internet. Oracle Cloud lets the users build, deploy, and manage the workload in the cloud as well as in the premises. It helps users by providing solutions to their complex problems in their businesses. To achieve their business goals, Oracle Cloud grants innovative and efficient cloud services.
- **DigitalOcean:** DigitalOcean is a cloud service provider which offers Infrastructure as a Service to organizations implementing cloud computing. The users can avail services like storage, security, and monitoring capabilities. These services enable the users to run their organizations smoothly. DigitalOcean offers cloud VMs, managed databases, server storage, and load balancers.
- **IBM cloud:** The IBM cloud is a cloud computing platform that provides an open and secure public cloud to businesses. It offers services such as Software as a Service, Platform as a Service, and Infrastructure as a Service. This cloud computing service comprises of various advanced and AI tools which help a business to gain value and achieve its goal.
- **VMware:** VMware is a cloud service provider that provides the cloud services required to build, operate, deploy, and manage the cloud. It offers flexible and agile services.

Many organizations are opting for cloud services as they provide a lot of flexibility to the organizations or users. They are suitable for both medium and small-scale organizations.

MeghRaj

MeghRaj is a cloud computing initiative that has been made by the Government of India to harness the benefits of cloud computing services. It is a GI cloud that offers various types of services including **Software as a Service (SaaS)**, **Platform as a Service (PaaS)**, **Infrastructure as a Service (IaaS)**, and **Storage as a Service (SaaS)**. All these services are provided to the users so that they can perform their operations smoothly.

MeghRaj enables government organizations to maximize the utilization of infrastructure and facilitates the efficient and effective development of all eGov applications. It makes the development speedy and cost-effective. It also enables the government to make use of cloud computing services in order to perform all e-tasks efficiently.

MeghRaj is the name given to the GI cloud on the basis of its meaning. Here, "*megh*" is a Hindi word that means "cloud" and "*raj*" means "rule". Some advantages of MeghRaj as mentioned by Vikaspedia are as follows:

- It supports the effective utilization of the existing infrastructure.
- It enables rapid deployment and supports the concept of reusability. This means that any application made for a specific government department can also be used in any other department. It can be made available to any administrative department of India without incurring any additional cost.
- All infrastructure related to cloud computing services is managed and maintained at a single location. Moreover, it manages the **Information & Communication Technology (ICT)** infrastructure in India.
- It enables the efficient delivery of resources.
- MeghRaj allows the scalability of resources, i.e., resources can be increased or decreased as per the demands of the users.
- The security framework of the GI cloud help in minimizing the risk of viruses.

Conclusion

A lot of advancement has been done in the field of cloud computing. New technologies are emerging every day that are very beneficial for the growth of businesses or organizations. Various vendors are working to provide businesses or users with the best cloud computing services and technologies. A large number of efficient cloud companies are available in the market and they provide innovative and useful cloud technologies, resources, and applications. We have studied about these concepts in this chapter. The next chapter is dedicated to the cloud cube model.

Points to remember

- The cloud computing technology refers to various services and technologies that provide resources, storage, processing power, and applications over the internet.
- The various cloud computing technologies include virtualization, service-oriented architecture, grid computing, and utility computing.
- Other new advanced technologies in the field of cloud computing include containers, microservices, IoT, and artificial intelligence.
- A large number of cloud vendors are available in the market whose aim is to provide excellent cloud services to promote the growth of businesses.
- To harness the benefits of cloud computing, the government of India has created a GI cloud named as MeghRaj. It is very crucial in the successful implementation of e-services in India.

Multiple choice questions

1. **The cloud technology that promote the virtual version of any resource or application:**
 - a. Servers
 - b. Virtual technology
 - c. Virtualization
 - d. Artificial intelligence
2. **This type of computing lets you share your workload among different computers on the network:**
 - a. Utility computing
 - b. Virtualization
 - c. Internet of Things
 - d. Grid computing
3. **Companies that ought to provide cloud services are known as**
 - a. Service providers
 - b. Companies
 - c. Cloud Industries
 - d. Organizations

Answers

1. c
2. d
3. a

Questions

1. State the various cloud technologies that are playing a vital role in promoting the growth of businesses or organizations.
2. Write a note on the service providers that offer cloud services in India.
3. Write a short note on MeghRaj.
4. Write the significance of the following technologies:
 - a. Virtualization
 - b. Grid computing
 - c. SOA
 - d. IoT
 - e. AI
 - f. Serverless
 - g. Containers
 - h. Microservices
 - i. Utility computing

Key terms

- **Virtualization:** The technology in which virtual versions of actual resources are created to enable the smooth sharing of resources.
- **Service-oriented architecture:** The technology in which services are provided to other components and each service is independent of each other.
- **Grid computing:** A collection of computers in a network in the form of a grid that enables the sharing of workload among every networked computer.
- **Utility computing:** The technology that allows the provision of resources on a demand basis and the payment is done on the basis of the pay-per-use model.

- **Containers:** A standard unit that is a combination of a packaged application and all its dependencies in a single bundle.
- **Microservices:** The collection of several different independent services.
- **Serverless:** The technology that refers to the allocation of backend services as per the demand of the organization.
- **Internet of Things:** Internet of Things or IoT refers to all things that are related to the internet and the transfer data over the network.
- **Artificial intelligence:** The technology which simulates human intelligence in machines.

CHAPTER 11

Cloud Cube Model

The Cloud Cube Model is a model that is designed to ensure the security of the cloud network. This model was designed and developed by the Jericho Forum. According to this model, the cloud network is categorized into four-dimensional factors. These factors are the physical location of the data (internal/external), the ownership of the services and the technology (proprietary/open), the security range (de-perimeterised/perimeterised), and the source of the data (insourced/outsourced). This model is very useful as it provides a secure and protected network. We will study about the Cloud Cube Model in this chapter. We will also discuss the various dimensions of the Cloud Cube Model that help in categorizing network.

Structure

In this chapter, we will discuss the following topics:

- Cloud Cube Model
- Securing data
- Dimensions of Cloud Cube Model
- Location
- Ownership

- Security range
- Sourcing

Objectives

After studying this chapter, you will be able to:

- Discuss the meaning of the Cloud Cube Model
- Understand how to secure data in the cloud
- Discuss about the various dimensions of the Cloud Cube Model
- Explain the concept of location, ownership, security range, and sourcing

Cloud Cube Model

The Cloud Cube Model is a model formed by the Jericho Forum whose main motive is to provide security to the cloud. It defines various methods that signify how to protect and secure the cloud. This model categorizes a cloud network on the basis of four-dimensional factors. As we all know, security is an important criterion that should be taken care of in a cloud system. The Cloud Cube Model helps in the selection of cloud formation in order to enable security collaboration.

The Cloud Cube Model is also of immense importance as it provides a secure and protected cloud network to IT managers, organizations, and business people. It is the need of a business and organization to ensure a safe environment and all the cloud service providers also understand this need for a secure environment. They should ensure that the cloud system follows all the rules and policies that are framed for enabling the security of the cloud.

A large number of cloud formations are available. By the word “cloud formation,” we are referring to the forms of cloud computing. Each cloud formation has different features, varying policies for security, and different criteria to deal with risks and availing opportunities. They offer a varying range of flexibilities and also provide different collaborative challenges. Choosing the best cloud formation for their business is one of the major challenges that every cloud user faces. The Cloud Cube Model helps the cloud users in selecting a cloud formation out of these different cloud formations available.

Choosing the right cloud formation is very crucial for the tremendous growth of a business. The perfect selection of the cloud formation by the cloud customers is necessary as it ensures the security in the cloud network. The selection of the correct cloud formation ensures that all the cloud users remain secure in the network and can securely communicate with other parties as per the demand of their business.

Securing data

Security of data is very important. Secure collaboration between a cloud network is very crucial to help flourish the business growth in the correct terms. The Cloud Cube Model is used to enable a secure and protected network. One must consider some points before securing data in the Cloud Cube Model. These are as follows:

- The categorization of the data. The users must have knowledge about the rules and policies that must be applied to secure and protect the data.
- It should be ensured that the data only exists in particular trust levels.
- It also includes the examination of whatever regulatory compliance and constraints are applicable. For example, the data must be placed in a specific limit and it should be seen to if it has to stay in a safe harbor.

When the categorization of the data has been done and has been put in the required zone, the concerned person has the right to take the decision regarding the following factors:

- The data and processes that should be move into the cloud.
- The level that the user wants to operate at in the cloud, i.e., whether at the infrastructure platform or the software level.
- The cloud formations that are compatible as per the requirements of the cloud system.
- The level of operation in the cloud since it can be different as per the requirements.

After deciding all these factors, data can be stored in the various forms of the cloud.

Dimensions of the Cloud Cube Model

According to the Jericho Forum, there are four criteria that can be used to differentiate various cloud formations from each other. These four dimensions are as follows:

- **Location:** It defines the location of the data by using two factors, i.e., internal (I) and external (E). This factor defines the boundary of the organization.
- **Ownership:** This factor determines the ownership of the cloud technology and the interfaces. It can be either proprietary or open.
- **Security:** It determines whether the cloud operations are under security control or not. Security can be determined using two factors, namely de-perimeterised/perimeterised.

- **Sourcing:** It determines whether the services are provided by the company or are sourced from the cloud service providers. The factors used to identify the source of the services are insourced/outsourced.

The following figure shows four dimensions of the Cloud Cube Model:

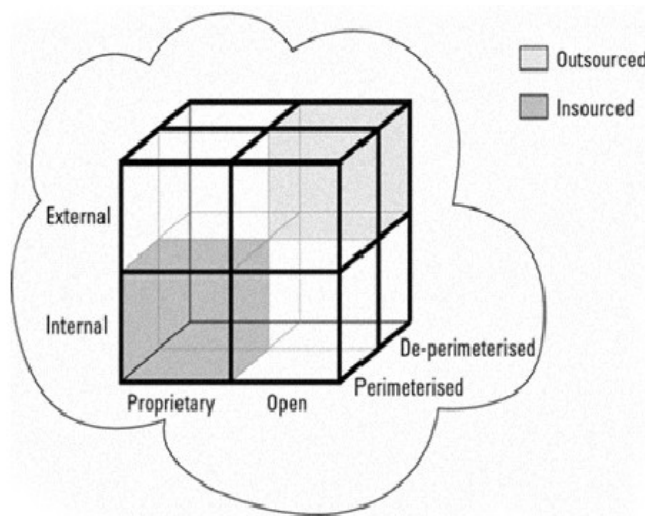


Figure 11.1: Cloud Cube Model

Let us discuss them briefly in the following sections.

Location of data: internal/external dimension

This dimension defines the location of the data, i.e., the physical location where the data is stored. It states the location of the particular cloud form that you want to use. It states whether it exists within the organization or outside the organization.

In order to define the location of the data, two dimensions are used, namely internal and external. The letter “I” is used to define internal location while the letter “E” is used to define the location that is outside the organization’s boundary. If the data, technology, or any service of the cloud tends to be located inside the boundary of the organization, then it is termed as the internal dimension. If the data, technology, or any other type of service exists outside the boundary of an organization, then it is termed as the external dimension.

We can also understand this in another way. If we are using the components of a private cloud deployment that exists inside the boundary of our particular organization, then it is called as internal dimension while the resources that are located outside that

particular cloud fall under the external dimension. The following figure shows the concept of the internal/external dimensions as per the Jericho Cloud Cube Model.

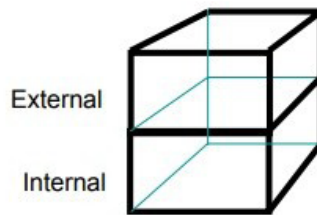


Figure 11.2: Internal/external dimension

For example, the use of virtualized hard disks in an organization comes under the internal dimension while when that organization demands for online storage location from any service provider, say Amazon, then this comes under the external dimension.

Proprietary/open

Proprietary/open is the second type of dimension which defines the ownership of the technology, interfaces, and services. It states who will own the technology, services, and interfaces. It indicates the degree of interoperability and also enables the data/application transportability between the various cloud forms and your system environment. It also indicates the ability to move data from your system to any of the cloud form or to withdraw it from a cloud form and move it to another cloud form without any hurdles. If any problem occurs while transferring the data or sharing the application, then this dimension indicates all constraints that occur in transferring or sharing. “P” is used by an organization to indicate its cloud technology and services as proprietary and “O” is used to declare all the services and interfaces as open to all.

The following figure shows the proprietary/open dimension.

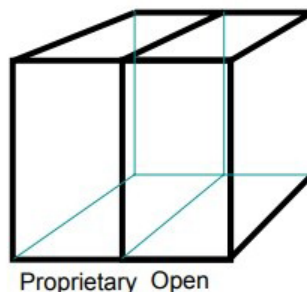


Figure 11.3: Proprietary/open dimension

When we declare the dimension as proprietary, it means that the organization has the right to grant the provision of the resources, technology, or services. Here, the organization is responsible for securing and protecting the cloud technology, services, and interfaces. When the technology and services of a cloud come under proprietary ownership and you are operating in that cloud, it is quite difficult for the users to move to another cloud owner. They need significant effort or investment to use another cloud form or technologies. All innovative technologies are kept under proprietary ownership so that the organization can enforce some rules and restrictions on their use.

The open dimension refers to the state where more and more suppliers are allowed to use the technology, services, and interfaces. No restrictions are enforced on the transfer of data from one cloud form to another. By using open technology, the users can transfer their data from one form to another and share their data and maintain collaboration with third parties.

Perimeterised/de-perimeterised

The perimeterised/de-perimeterised dimension is the third dimension of the Cloud Cube Model which represents the architectural pattern of the cloud form. It states whether the users are working inside the traditional IT perimeters or outside it. Here, “Per” is used to symbolize perimeterised and D-p is used to indicate the de-perimeterised dimension.

Perimeterised dimension means that the users can continue to work in the traditional IT perimeter which often gets signals from network firewalls. When any system operates in the perimeterised dimension, it enables the users to extend their organizations’ perimeters into the external cloud computing. This is done by the use of VPN and by operating the virtual server in their own IT domain. The access can be controlled by using their own directory services. When the computing tasks of the users are over, they can withdraw their perimeter and again switch to their traditional positions.

When we talk about the de-perimeterised dimension, it means that the system perimeter is architected on the basis of the principles outlined in the Jericho Forum’s Commandments and Collaboration Oriented Architectures Framework. In a de-perimeterised environment, the organization maintains collaboration with selected parties in a secure way. These selected parties include the business partner, suppliers, clients, and outworkers. In the de-perimeterised environment, the data can be encapsulated with metadata and mechanisms. This saves the environment and the data from any inappropriate usage and protects them.

The following figure depicts an idea of the perimeterised and de-perimeterised dimensions:

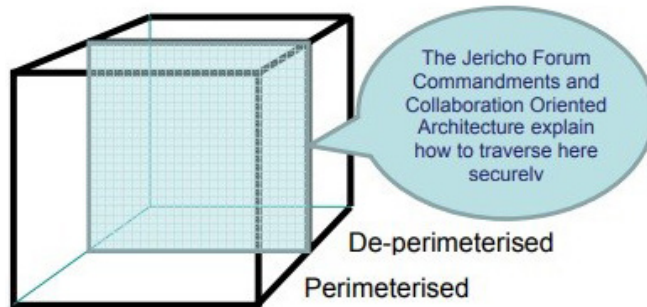


Figure 11.4: Perimeterised/de-perimeterised dimension

Insourced/outsourced

As per our discussion in the preceding sections, we can conclude that there are eight forms of clouds. These states are Per (IP, IO, EP, EO) and D-p (IP, IO, EP, EO). The fourth dimension can have any two states out of these eight cloud forms. The insourced dimension states that the services are provided by their own staff under their control. The outsourced dimension refers to the state where the service is provided by the third party.

The insourced/outsourced dimension describes who is responsible for the management of the cloud services. It helps in managing the delivery of the cloud services in an efficient way. The insourced dimension consists of internal, proprietary, and perimeter boundaries while the outsourced dimension comprises of external, open, and de-perimeterised boundaries.

This dimension is shown by two colors in the Cloud Cube Model as shown in the following figure:

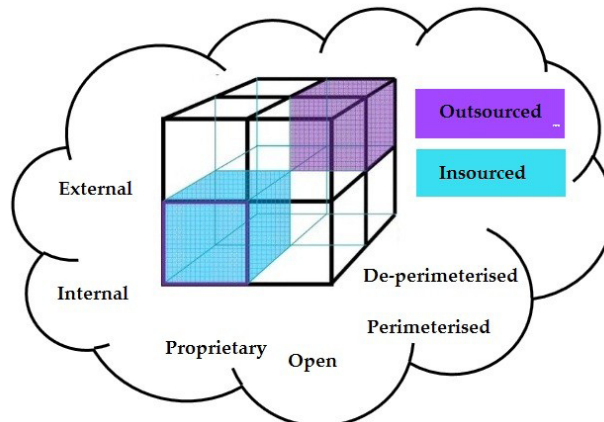


Figure 11.5: Insourced/outsourced dimension

The Cloud Cube Model is very beneficial for business-users in decision-making. The use of cloud-form can add value to a business.

Conclusion

The Cloud Cube Model is used to provide a secure cloud environment to the organization. It helps the users in decision-making which in turn promotes the growth of the company. We have studied about the Cloud Cube Model in this chapter. We have also learned about the dimensions of the Cloud Cube Model. In the next chapter, we will gather some knowledge regarding mobile cloud computing.

Points to Remember

- The Cloud Cube Model is developed and designed by the Jericho Forum to provide security to the cloud.
- The Cloud Cube Model consists of four dimensions. These are internal/external, proprietary/open, perimeterised/de-perimeterised, and insourced/outsourced.
- The internal/external dimension defines the location of the data, i.e, the place where the data is stored, whether inside the organization or outside it.
- The proprietary/open dimension tells where the ownership of the data is and the technology that is defined. In the proprietary dimension, the use of services is limited to a particular organization and open means that the services and the technology are open to all.
- The perimeterised/de-perimeterised dimension discusses the architectural pattern of the cloud.
- The insourced/outsourced dimension tells us about the source of the services and technologies.

Multiple Choice Questions

1. **The Cloud Cube Model has been developed by**
 - a. SJericho Forum
 - b. David Chrome
 - c. Jericho Cube
 - d. Nelson Forum

2. The Cloud Cube Model has _____ dimensions.
- a. 2
 - b. 3
 - c. 4
 - d. 5

Answers

- 1. a
- 2. c

Questions

- 1. State the significance of the Cloud Cube Model.
- 2. Discuss the dimensions of the Cloud Cube Model.
- 3. How can you secure the cloud?
- 4. State the meaning of the various dimensions of the Cloud Cube Model.

Key Terms

- **Cloud Cube Model:** It is formed by the Jericho Forum to provide security the cloud.
- **Cloud formation:** This refers to the various forms of cloud.

CHAPTER 12

Mobile Cloud Computing

Mobile cloud computing is the combination of cloud computing and mobile computing. This is the most trending technology. One can access the cloud services remotely with the help of a mobile phone and internet connection. It makes the mobile device more useful and powerful by incorporating cloud computing. It provides easy access of data and secure storage to the users. The user can access the data from anywhere and at anytime. **Mobile cloud computing (MCC)** is economical and saves time. We will study about mobile cloud computing and its significance in today's era in this chapter. We will also learn about the difference between cloud computing and mobile computing.

Structure

In this chapter, we will discuss the following topics:

- Meaning of mobile cloud and mobile computing
- Mobile cloud computing
- Architecture of mobile cloud computing
- Benefits of mobile cloud computing
- Difference between mobile computing and cloud computing
- Applications of mobile cloud computing

Objectives

After studying this chapter, you will be able to:

- Understand the meaning of mobile cloud and mobile computing
- Discuss the concept of mobile cloud computing
- Explain the architecture and benefits of mobile cloud computing
- Understand the difference between mobile computing and cloud computing
- Understand the applications of mobile cloud computing

Meaning of mobile cloud and mobile computing

Mobile cloud refers to the internet-based data, services, and applications which can be accessed by using smartphones, tablets, and other portable devices. Mobile cloud comprises of various cloud services and applications that are designed specifically to be used on mobile phones. Mobile users can take benefits of these cloud-based data, applications, and services stored on any remote cloud server.

Mobile cloud refers to the technology that includes the combination of features from mobile development and cloud-based services. Users can access these applications and services through the apps installed on their mobile phones. Mobile phones comprise of apps and services which only allow the users to take advantages of various features. All tasks related to processing, storage, and computing are done via the remote cloud server.

Mobile computing is a technology that allows access of data (audio and video) and services from any place with the help of mobile devices. This technology is based on the use of battery-powered, portable, and wireless computing and communication devices like mobile phones and PDAs. No physical link is required to avail the services of mobile computing. Mobile devices are connected to LAN, Wi-Fi, or wireless technology. This technology allows people to access information and data from any place.

Mobile computing is very beneficial. It provides the following advantages:

- It provides location flexibility to the users. They are allowed to access information from anywhere.
- By providing the availability of data and information at the user's location only, this technology saves time and corresponds to the enhancement of productivity.

- It provides sources for entertainment and makes the research work of users easier and faster.
- It enables businesses to conduct their meeting, seminars, and conferences securely.

Mobile cloud computing

As you all know, cloud computing is a technology that provides clients with various infrastructures and services on demand. They can access resources, storage, processing power, and other cloud applications remotely from any place with just the help of the internet. MCC is a technology which allows users to access all types of cloud services with the help of mobile phones. To utilize the benefits of mobile cloud computing, the clients just need internet connections and mobile phones. They can access cloud services anywhere and anytime through MCC.

In mobile cloud computing, applications are only made to run on mobile devices. Data processing and data storage is done outside the mobile devices. MCC provides its users with the advantage of performing these tasks on the cloud. Hence, the mobile devices don't need to have high configuration in terms of power. All the complicated tasks are performed under the cloud. Apart from this, all mobile applications are built and updated by the cloud services in an easy way. Mobile cloud computing is very beneficial for various business organizations. It is economical, location flexible, time-saving, and provides an excellent experience to the users.

The following figure shows you an outline of mobile cloud computing:

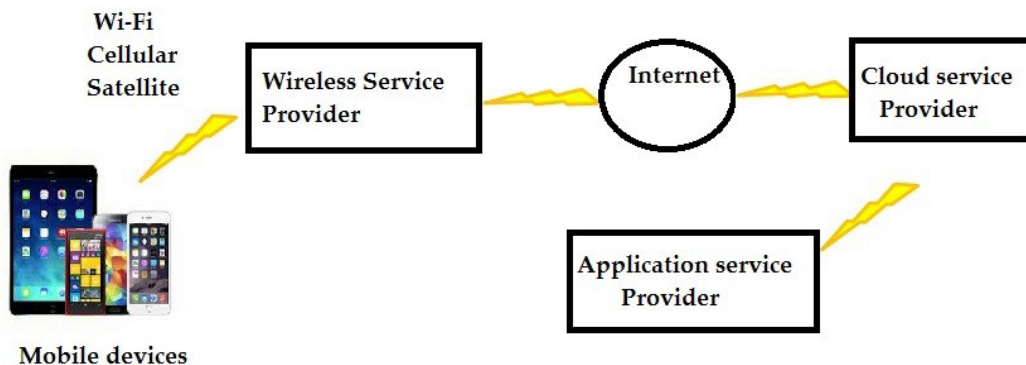


Figure 12.1: MCC concept

Some key features of mobile cloud computing are as follows:

- Mobile cloud computing allows users to achieve quick development and share resources.

- The applications generally use all resources that are provided by the cloud services. Only few device resources are used.
- It provides portability which allows users to perform their work easily and efficiently.
- Mobile computing applications are full of security and reliability.
- It supports the development of applications that can run on a variety of platforms.
- It enables users to back up and store information in the cloud.

Architecture of mobile cloud computing

Mobile computing is the latest platform that combines cloud computing and mobile devices. This combination creates a new infrastructure. The following figure shows the architecture of mobile computing:

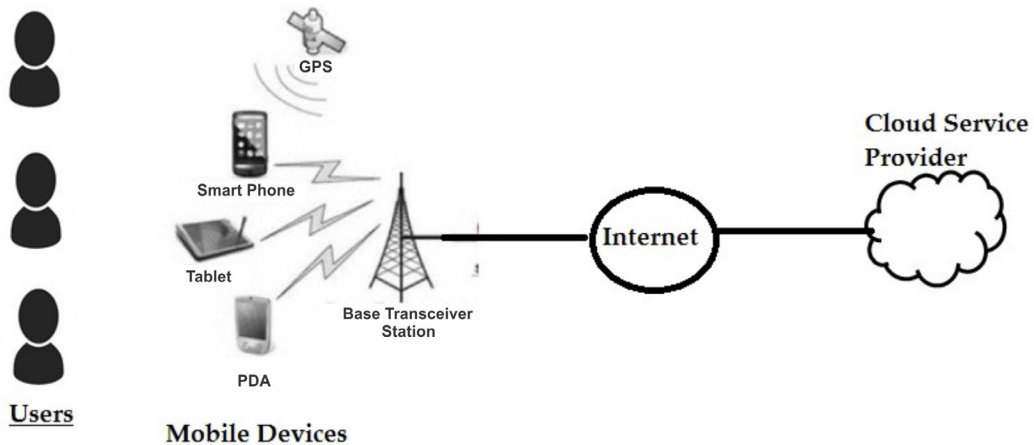


Figure 12.2: MCC architecture

As depicted in the preceding figure, users can access various mobile cloud computing services with their mobile devices that are connected to the internet. These mobile devices are connected to the wireless or mobile networks via base stations. A base station is a transmitter/receiver that relays wireless signals. These base stations can be base transceiver stations, access points, or satellites. Base stations are used to establish and control the connections and functional interfaces between the networks and mobile devices. Mobile users send their requests to access a particular service through the mobile devices connected to the internet. The requests and information (i.e. ID and information) sent by the mobile users are transmitted to the central processors. These central processors are connected to the servers that provide services from mobile networks. After that, the subscriber's requests are sent to the

cloud through the internet. After the cloud controller receives the requests from the subscribers, the requests are processed so that the mobile users are provided with the corresponding cloud services that they demand. With MCC, mobile devices use the features of cloud computing to enhance the productivity and efficiency of the businesses and organizations.

Benefits of mobile cloud computing

With recent developments in the field of smartphones, the use of mobile cloud computing has been increasing day by day. It provides its customers with all the benefits of cloud computing in a simple and lucid way through mobile phones. Some prominent benefits of mobile cloud computing are as follows:

- **Rapid development:** As the technology is growing, new and modified versions of mobile applications are coming into effect. Application providers keep on updating their apps to enhance their applications with each and every recent development occurring in the technology. They themselves take care of the efficiency of their apps which corresponds to rapid development.
- **Flexible:** Applications that are supported by MCC are very flexible. They allow the users to access data from any location as per their comfort and allow the transfer of data between two devices in an easy way. Moreover, there are a variety of applications that are supported by MCC. The users can select one as per their choice and need. These applications have the capability of running on different devices with different operating systems.
- **Economical:** Mobile cloud applications are very cost-effective as they are managed, built, and upgraded by the cloud services automatically. The mobile users don't have to worry about their maintenance and don't need to spend a penny for the same.
- **Integrated data:** With mobile cloud computing, the users have the opportunity of collecting and integrating data from various sources quickly in a secure way. The location of the data doesn't matter here.
- **Backup and recovery:** Mobile cloud computing provides the facility of creating a backup of the data and enables data recovery in the case of failure or loss of data. When you work on mobile apps that are using cloud services, then the cloud controllers automatically create multiple copies of the data and store it at different locations. This feature is very useful and helps users in taking the advantage of the disaster recovery tool. Hence, if any disaster occurs, then it automatically changes the server and no loss is occurred to the user.
- **Security:** Applications provided by MCC are very reliable and confirm high level security of your data.

- **Increases storage and processing power:** As mobile apps use cloud storage and processing power to store data and perform processing on the data, hence storage and processing capacity of mobile devices increases.

Although mobile cloud computing is very advantageous, some challenges are faced by customers while using mobile computing. These issues include connectivity problem due to low bandwidth, availability of services, problems related to more battery usage, and the privacy of the user. If all these issues are solved, then mobile cloud computing proves to be the best technology that allows the easy access of data and applications over the cloud without the need for spending a huge cost on resources, storage, and other requirements.

Difference between mobile computing and cloud computing

Cloud computing is a technology that allows users and enterprises to access data and services via a wireless system while mobile cloud computing refers to the combination of cloud services and mobile devices. Here, the users can access cloud services with the help of mobile devices. Mobile cloud computing is based on the concept of cloud computing. Both technologies use wireless systems to enable the accessing of data and services but they differ at some points. Let's take a look at the differences between mobile cloud computing and cloud computing:

Cloud computing	Mobile cloud computing
Cloud computing is the technology that allows accessing and transferring of data from and to any remote location with the help of the internet.	Mobile cloud computing refers to the transmission of data in the form of voice or video from any mobile device with the help of the internet.
Cloud computing is a service that is used by businesses or organizations. Although individuals can take the benefits of cloud computing, it is mostly aimed for enterprises.	Mobile cloud computing mostly has consumer-facing services.
Distance doesn't matter in cloud computing.	Distance matters in mobile cloud computing. It may cause network latency due to increase in distance.
Cloud computing involves the emergence of new networking services which are helpful in serving many devices.	Mobile cloud computing involves the emergence of new featured smartphones.

Cloud computing	Mobile cloud computing
Cloud computing acts as a bridge between the local network of clients and their storage and backup on cloud storage servers.	Mobile cloud computing allows users to make use of various functions like accessing the internet through mobile browsers and making use of applications.

Table 12.1: Difference between cloud computing and mobile cloud computing

Applications of mobile cloud computing

Mobile cloud computing is very helpful as it keeps employees productive the provides flexibility and elasticity of services to customers and keeps them fully engaged. Mobile cloud computing provides the following applications to users:

Mobile email

Nowadays, it is very easy to check your emails. You can view them on your mobile phones only. Every smartphone gives you the facility of checking and responding to your emails with the help of apps. Mobile email is the most commonly used application of mobile computing.

Users can connect with mobile email to become aware of their daily emails. They can access all types of emails, whether they are official or personal. This application allows you to access, manage, and reply to your mails while just sitting anywhere and at any time. What you need is an internet connection and the presence of a mobile email app on your respective mobile device.

Mobile sensing

Mobile sensing is another example of mobile cloud computing in our real life. You must have come across such devices like smart watches. A smartwatch is a wearable mobile device with a touch screen display that can be worn on the wrist. Apart from showing time, it allows the user to monitor his heartbeat, track his activity, and also reminds him of his daily schedule. It can even send notifications, voice messages, and perform other activities. To do all these activities, smartwatches are equipped with a sensor. They are connected to the smartphones through applications. These applications on smartphones are used to track details regarding health, social networking, and other activities.

The following figure shows you a smartwatch:



Figure 12.3: Smartwatch with apps for different activities

All mobile sensing applications use smartphones that contain sensors in them. These sensors allow them to gather data from various mobile cloud computing applications regarding healthcare, social networking, and environment/health monitoring.

Mobile healthcare

The use of mobile devices in the field of medicine is termed as mobile healthcare. We can consider mobile healthcare as an extension of electronic healthcare. It is used for medical treatment, patients tracking, etc. on the mobile devices. This application has the capability of storing a large number of patient records at one location. From here, doctors can use the records to track the medical history of the patients.

Mobile cloud computing enables a patient's data to get stored on the cloud. Hence, this data can be used by any mobile device for remote diagnosis.

Mobile healthcare or a mHealth application allows mHealth users to access the patient's records easily and conveniently anytime and anywhere. They provide custom apps on mobile devices for healthcare. The main motive of mobile cloud computing in medicine is to overcome the limitations of traditional medical treatment.

The Aarogya Setu app was provided by the government of India to manage various health issues related to the coronavirus is an outstanding achievement in the field of mobile healthcare. This app gives us information regarding the number of

coronavirus cases in your nearby places and all over India. It is a coronavirus tracking app developed by NIC to warn the users against this disease. It also provides details regarding emergency contact numbers in case you have symptoms related to this particular disease.

m-health provides the following facilities to the customers through various available apps:

- It provides 24-hour online health monitoring services for patients so that they can be monitored anytime and anywhere by being connected to the internet.
- Various healthcare apps are available for calculating pulse-rate, blood pressure, sugar level, and for detecting many other health statuses.
- It provides an emergency management system for emergency vehicles to manage them in case of any emergency.
- There are apps to store the entire medical history of the patients.

Mobile gaming

A mobile gaming application provides mobile users with various apps that can be used to play games on a mobile. This is a great source of entertainment. All the complex resources like graphics are provided and managed by the mobile cloud computing. Gamers only interact with the screen interface on their mobiles and do not have to worry about the underlying operations that are run and managed under the cloud.

Mobile social networking

Mobile social networking includes a variety of social networking apps that enable people to communicate with each other. With this, the application users can post their data in the form of photos, audios, and videos on the social networking apps. These apps are very beneficial as they connect millions of people that are living anywhere in the world. These apps not only provide a platform for storing data but also help in maintaining the security and integrity of the data.

Location-based mobile service

While searching for some goods like food, clothes, accessories, or anything else, you must have come across a message asking to determine your location in order to present you information based on your particular location. This helps vendors in presenting relevant information to customers about the availability of goods in that particular location. A location-based mobile service application does the same

thing for you. It provides the users with information based on the locations of the users requesting for data. The location server determines the location of the user and presents relevant information according to that only.

Mobile commerce

Mobile commerce refers to the act of doing commerce transactions like shopping, advertising, and banking using mobile devices. It includes buying and selling of goods online. Mobile commerce or m-commerce includes various mobile apps that give users the fun of virtual shopping and banking. Users can easily access the resources and perform their tasks by just sitting at home with the help of these apps.

Mobile cloud computing provides the features of scalability and flexibility to mobile commerce and maintains the security of the transactions that are occurring using these apps. It maintains the security of the data even when there is a lot of traffic when users are simultaneously accessing the mobile commerce apps.

Multimedia sharing

Mobile cloud computing provides a secure way of transmitting multimedia data from one mobile to another. With this, users can share their videos and photos with multimedia effects and upload them on social networking sites. It is the responsibility of mobile cloud computing to maintain a high level of security to avoid any unauthorized access. It provides administrative controls to manage the access rights of the users.

Mobile learning

Mobile learning is trending nowadays. As the name suggests, mobile learning refers to learning through mobile apps. It enables users to get educated through their mobile devices. Students can read about topics online and maintain their notes. Teachers have the facility to upload their materials on the learning apps. Mobile learning allows users to access the information from anywhere and anytime.

The mobile cloud computing application in mobile learning allows users to have centralized storage for their data and high processing power and speed to access them. It helps learners by solving problems like low transmission rate, limited educational resources, and high cost of resources. The use of cloud provides a large storage area and high processing speed. Users can now access the desired topics for free of cost or on the basis of the pay-per-use model.

Mobile cloud computing is a developing technology that is continuously growing with many advancements. With the increment in the number of mobile devices and features offered by them, it is becoming much easier for users to access the services

offered by mobile cloud applications. The rapid growth in mobile cloud computing is very beneficial for the development of the IT industry, the commerce industry and the business industries as well.

Conclusion

With advancements in the field of mobile devices, services that can be accessed by mobile users are increasing day by day. They need more storage space, high processing speed, and high transmission rate. Mobile cloud computing is a developing technology which helps users in overcoming these limitations of normal mobile devices. In this chapter, we have studied about the various concepts of mobile cloud computing. We have also learned the benefits and applications of mobile cloud computing in this chapter.

Cloud computing is a new and innovative technology that has the potential of promoting major developments in the IT industries. It has many benefits for the users and businesses. In this book, the concepts related to the fundamentals of cloud computing have been explained in simple and easy to understand language. This book has 12 chapters and each chapter includes detailed descriptions about the topics that are based on this very technology. After going through this book, you must have understood how this new developing technology is greatly impacting the entire world. This book has been designed for beginners to understand the cloud computing concepts in a friendly way.

Points to remember

- Mobile cloud computing combines the features of mobile devices with cloud computing.
- MCC help users in achieving efficiency and enhancing their productivity.
- MCC provides users with flexibility, scalability, location independence, security, backup, and disaster recovery.
- Both cloud computing and mobile cloud computing use a wireless system to access and transfer but both are different technologies.
- Mobile cloud computing is based on cloud computing.
- Mobile cloud computing has the potential of becoming a progressive trend in the future.

Multiple Choice Questions

1. **Mobile cloud computing is based on**
 - a. Mobile devices
 - b. Cloud storage
 - c. Computing
 - d. Cloud computing
2. **An example of mobile cloud computing application includes**
 - a. E-learning
 - b. M-learning
 - c. E-commerce
 - d. All of these

Answers

1. d
2. b

Questions

1. Discuss the concept of mobile cloud computing along with its benefits.
2. Explain the architecture of MCC with a diagram.
3. Discuss the applications of mobile cloud computing.
4. State the differences between cloud computing and mobile cloud computing.

Key Terms

- **Mobile cloud:** Mobile cloud refers to accessing internet-based data with the help of mobile phones.
- **Mobile cloud computing:** It is the combination of mobile phones with the features of cloud computing.

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