CLOUD COMPUTING

Concepts and Technologies

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Cloud Computing

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To All Our
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Contents

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Foreword

As Cloud continues to revolutionize applications in academia, industry, government, and numerous different fields, there are some genuine difficulties at both theoretical and practical levels that will regularly require new approaches and practices in all domains. Comprehensive and timely, this book titled, *Cloud Computing: Concepts and Technologies*, details progress in Cloud computing and offers bit by bit guidance on the best way to understand and implement it.

Motivation for This Book

Gartner, in a February 2, 2009 press release, posted the question of why, and when "the Cloud computing market is in a period of growth and high potential but still requires several years and many changes in the market before it becomes a mainstream IT effort." However, this concern, while valid, is not insurmountable. We already have many examples of successful Cloud computing implementations, from small organizations up to large enterprises, such as the U.S. Department of the Navy. The National Institute of Standards and Technologies (NIST) released its first guidelines for agencies that want to use Cloud computing, and groups such as Jericho forum brought security executives together to collaborate and deliver solutions.

The issues, however, does exist with regard to data ownership rights, performance and availability. While these are all valid concerns, solutions do exist and are being fine-tuned everyday; the challenge is in bringing executives out of a state of unawareness and fear, giving them the understanding and knowledge necessary to make informed, educated decisions regarding their Cloud initiatives.

This book is an attempt by us to educate the readers and novice researchers with a proper understanding of Cloud computing. The book offers a thorough and detailed description of Cloud computing concepts, architectures, and technologies. It serves as a great reference for both newcomers and experts and is a must-read for any IT professional interested in Cloud computing.

About the Authors

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Preface

With the advancements in Information Technology, we are witnessing tremendous development in computer and communication technologies. There has been a lot of work happening in the area of Cloud computing. The Cloud users are demanding various resources, viz. software, platform and infrastructure with better quality of services from the Cloud service providers. Hence, it has become essential for engineers, scientists and professionals to know about Cloud computing and underlying technologies.

The book provides an explanation on the Cloud computing concepts, architectures, functionalities, technologies and applications. It covers the multicore architectures, distributed and parallel computing models, virtualization, Cloud developments, workload and Service-Level-Agreements (SLA) in Cloud, resource management, issues etc. This book is ideal for a broad audience that includes researchers, engineers, IT professionals and graduate students. This book comprises of twelve chapters followed by laboratory setups and experiments. Each chapter has Multiple Choice Questions (MCQs) questions with answers, review questions and critical thinking questions. The contents of each chapter has a smooth flow of contents provided through practically-focused topics.

Organization of the Book

The topics discusssed in various chapters are as follows:

- Chapter 1 gives a brief history of Cloud computing. Basic terminology and concepts are introduced, along with descriptions of common benefits and challenges of Cloud computing adoption and a discussion of business drivers and technology innovations. Cloud delivery and Cloud deployment models are also elaborated.
- Chapter 2 focuses on discussion of parallel and distributed systems, and how these technologies differ from the conventional centralized computing systems.
- Chapter 3 deals with multicore architectures for Cloud computing environment, and exploiting the parallelism in the hardware and software.

- Chapter 4 discusses the heart of Cloud computing i.e virtualization, virtualization techniques, virtualization technologies e.g., Xen, VmWare etc. The Pros and Cons of virtualization is also covered.
- Chapter 5 covers description of Infrastructure as a Service (IaaS) in Cloud. Here we discuss virtual machines provisioning and migration services for management of virtual machines which helps in capacity planning in Cloud, conserving energy efficiency in Clouds.
- Chapter 6 considers PaaS and SaaS business model in Cloud.
- Chapter 7 deals with capacity planning in Cloud.
- Chapter 8 discusses SLA management in Cloud computing.
- Chapter 9 discusses resource management in Cloud.
- Chapter 10 covers Cloud computing development tools.
- Chapter 11 focuses on Cloud security.
- Chapter 12 discusses research issues for novice researchers.

Appendix chapters 13 and 14 cover experiments on CloudSim and Cloud platforms, respectively.

Why the Book Is Different

- This book lays a good foundation to the core concepts and principles of Cloud computing, walking the reader through the fundamental ideas with expert ease.
- The book advances on the topics in a step-by-step manner and reinforces theory with a full-fledged pedagogy designed to enhance students' understanding and offer them a practical insight into the subject.
- There are chapters on resource allocation issues and security, which is widely talked in research domain.
- Includes seperate chapters on technical and legal issues in Cloud.
- Provides CloudSim-based simulations and real Cloud platforms based experiments for practical experience.

Acknowledgments

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We are also greatly thankful to our family members, Bharathi Manvi, Sanket Manvi, Priyanka Bharti, Prayuta Krishna, relatives and friends for their love and moral supportfor successful completion of the book. We thank our parents for their encouragement.

Finally, we thank our publisher, CRC, for their continuous support. We welcome all comments and suggestions for future enhancement of the book.

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Symbols

Symbol Description

$Sp(n)$	Speedup
$E(n)$	Efficiency
C_i	Capacity of ith autonomic service
$N(t)$	Actual number of autonomic services allocated at a given time
$M(t)$	Number of autonomic services to be added/removed at a given time
C^{av}	Average capacity among all system autonomic services
$L_i(t)$	Load of autonomic service i computed at time t over timeframe $(t - T^m, t)$ (percent with respect to autonomic service capacity)
$L^{av}(t)$	Average load per autonomic service of the system, computed at time t over timeframe $(t-T^m, t)$ for all autonomic services in the system (percent)
$\tilde{L}_i^{av}(t)$	Average load per autonomic service of the neighborhood of autonomic service i, computed at time t over timeframe $(t - T^m, t)$ (percent)
L^{min}	Minimum load threshold (percent)
L^{max}	Maximum load threshold (percent)
L^{des}	Desired load threshold, which is equal to $(L^{max} - L^{min})/2$ (percent)
T^s	Period between two successive runnings of the autoscaling algorithm on a autonomic service
T^m	Length of monitoring timeframe for the actual load
$neig_i$	Neighborhood of autonomic service i: contains autonomic service i and its neighbors
$queue_i$	Number of enqueued requests in autonomic service i
R_{max}	Maximum response time for completed requests (from SLA)

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1

Introduction

Learning Objectives

After reading this chapter, you will be able to

- Define the limitations of traditional technologies
- Appraise the concept of Cloud computing
- Discuss the applications, tools and technologies in Cloud computing

Three decades prior, the personal computers (PCs) brought change in the manner in which individuals worked. Yet, over the ongoing years another technology called the Cloud has pulled in research network since it guarantees to address different information technology (IT) challenges. Physical areas for asset access, gigantic expense to benefit interminable power, improvement in the courses of events for applications have bothered IT and its customers since long time. Cloud computing guarantees to offer access to gigantic measures of information and computational power, empowering creators to take care of issues in a better approach to accomplish a dependable IT foundation.

The Cloud framework can be seen as containing both a physical layer and a virtualization layer. The physical layer comprises of the equipment assets that are important to help the Cloud administrations, and regularly incorporates server, stockpiling and system parts. The virtualization layer comprises of the product sent over the physical layer which shows the fundamental Cloud attributes. Reasonably, the virtualization layer is positioned over the physical layer.

This chapter presents Cloud service delivery models, characteristics, benefits, platforms and technologies.

1.1 Cloud Computing

A Cloud is defined as a space over network infrastructure where computing resources such as computer hardware, storage, databases, networks, operating systems, and even entire software applications are available instantly,

on-demand. It is true that Cloud computing may not involve a whole lot of new technologies, but the fact that it surely represents a new way of managing IT cannot be denied. For example, scalability and cost savings can be achieved to the largest extent from Cloud computing.

Cloud computing is bound to be compared with service oriented architectures (SOA), Grid computing , Utility computing and Cluster computing. Cloud computing and SOA are persued independently. Platform and storage services of Cloud computing offers value addition to SOA's efforts. With technologies like Grid computing, computing resources can be provisioned as a utility. Whereas, Cloud computing goes a step further with on-demand resource provisioning. It also removes the necessity of over-provisioning to accomodate the demands of several customers. Utility computing is paying for resource usage, similar to the way we pay for a public utility (such as electricity, gas, and so on).

Cluster computing is a cheaper-cost form for processing applications that can run in parallel. The summary of the features of each of these computing techniques is listed in Table 1.1. Figure 1.1 depicts the construction and deployment for Cloud service delivery model. End-users access Cloud services such as computing and datacenter resources via the Internet. The user needs to have an account with the Cloud service provider (CSP) for security and billing schemes. The required resources are specified by the users. The CSP provisions resources in the form of virtual machines directly to user accounts. This offering facilitates users more flexibility in building their own applications on top of remotely hosted resources. Users essentially rent operating systems, CPU, memory, storage and network resources from the CSP to improve elasticity and scalability of workloads.

TABLE 1.1
Computing techniques

Computing techniques	**Features**
Cloud computing	Cost efficient, almost unlimited storage, backup and recovery, easy deployment
SOA	Loose coupling, distributed processing, asset creation
Grid computing	Efficient use of idle resources, modular, parallelism can be achieved, handles complexity
Cluster computing	Improved network technology, processing power, reduced cost, availability, scalability.

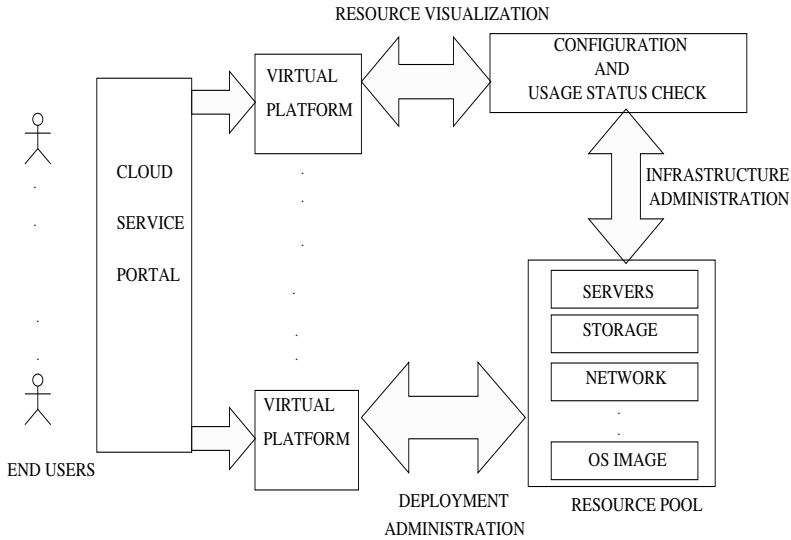

FIGURE 1.1
Cloud scenario

1.2 Service Delivery Models

A Cloud delivery model represents a specific, pre-packaged combination of IT resources offered by a Cloud provider. Three common Cloud delivery models (IaaS, PaaS, SaaS) which have become widely established and formalized are explained as follows:

Infrastructure as a Service (IaaS): The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources. Example: running CPU/memory intensive application using Amazon IaaS Cloud.

Platform as a Service (PaaS): The capability provided to the consumer is to deploy onto the Cloud infrastructure consumer-created or acquired applications using programming languages, libraries, services and tools supported by the provider. Example: building and deployment of application using Google Cloud Platform.

Software as a Service (SaaS): The capability provided to the consumer is their applications running on a Cloud infrastructure. Example: opening word/PDF files using Google Apps without installation of MS Office/Adobe

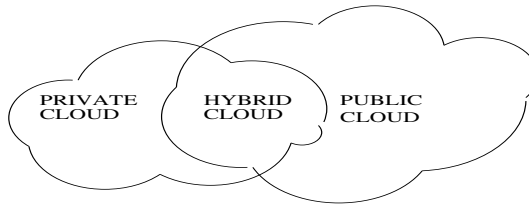

FIGURE 1.2
Cloud deployment models

Reader software in the networked system.

Many specialized variations of the three Cloud delivery models have emerged, each of distinct combination of IT resources. Some examples are as follows.

- Database-as-a-Service (DaaS): It is a database that is delivered to clients via a Cloud computing platform. Access to it is provided as a service. Database services take care of scalability and high availability of the database.
- Communication-as-a-Service (CaaS): It is an outsourced enterprise communications solution that can be leased from a single vendor. Such communications can include voice over IP (VoIP or Internet telephony), instant messaging (IM), collaboration and videoconference applications using fixed and mobile devices.
- Integration-Platform-as-a-Service (IPaaS): It is a Cloud service that provides a platform to support application, data and process integration projects, usually involving a combination of Cloud-based applications and data sources, APIs and on-premises systems.
- Testing-as-a-Service (TaaS): It is related to the outsourcing of testing activities to a third party that focuses on simulating real-world testing environments as specified in the client requirements. In other words, TaaS is an outsourcing model.

1.3 Deployment Models

Cloud hosting deployment models represent the exact category of Cloud environment and are mainly distinguished by the proprietorship, size and access. It tells about the purpose and the nature of the Cloud. In order to know which

deployment model matches any of the workload requirements, it is necessary to know the four deployment models (shown in Figure 1.2), discussed as follows.

Public Cloud is a type of Cloud hosting in which the Cloud services are delivered over a network which is open for public usage. This model is a true representation of Cloud hosting ; in this, the service provider renders services and infrastructure to various clients. Hybrid Cloud is a type of Cloud computing, which is integrated. It can be an arrangement of two or more Cloud servers, i.e. private, public or community Cloud that is bound together but remain individual entities.

Private Cloud is the platform that is implemented on a Cloud-based secure environment that is safeguarded by a firewall which is under the governance of the IT department that belongs to the particular corporate. Private Cloud permits only the authorized users, gives the organisation greater and direct control over their data.

Community Cloud is a type of Cloud hosting in which the setup is mutually shared between many organisations that belong to a particular community, i.e. banks and trading firms. It is a multi-tenant setup that is shared among several organisations that belong to a specific group which has similar computing apprehensions.

1.4 Characteristics and Benefits of Cloud Computing

Cloud computing is really becoming popular worldwide as it offers innumerable benefits to the clients. Most of the companies have realized the importance of this technology as it offers plenty of storage options. This type of a storage process permits all the organizations to take benefit without actually having to reimburse any additional costs that are usually connected with such type of storage resources. The characteristics and benefits of Cloud computing are as follows.

On-demand self-service: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

Broad network access: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops and workstations).

Resource pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory and network bandwidth.

Rapid elasticity: Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.

Measured service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth and active user accounts). Resource usage can be monitored, controlled and reported, providing transparency for both the provider and consumer of the utilized service.

1.5 Cloud Computing Platforms and Technologies

Those who develop applications for Cloud computing resources in both public and private may have to make a decision on which specific Cloud computing platform to use. The wrong choice could negatively impact everyone involved, so it is important to look at the choices carefully and consider short and long term issues in our decision. The key Cloud architectures available to make this decisions are: (i) Amazon's Elastic Compute Cloud or EC2, (ii) IBM Computing or Blue Cloud, (iii) Microsoft's Azure Cloud computing, (iv) Sun Cloud, (v) Salesforce.com's Force.com Cloud and (vi) Google's AppEngine Cloud.

In addition, there are a number of open source Cloud computing tools, and several of these work together. Here, we describe five Cloud management platform (CMP) solutions, two commercial Cloud services and three open-source offerings. The open-source solutions: Apache CloudStack, Eucalyptus Cloud computing software and the OpenStack platform, typically provide a low-cost point of entry for the software and the prospect of application portability, but require a significant amount of in-house development. Commercial vendors Microsoft and VMware offer commercial off-the-shelf capabilities, and

are typically higher cost than open-source offerings. Choosing the appropriate CMP for our Cloud environment depends on virtualization environment, the scope of Cloud strategy and business requirements, availability of skilled resources and the budget. Let us discuss some of them.

Apache CloudStack software is a top-level project of the Apache software foundation and calls itself a "turnkey" solution. CloudStack software provides an open and flexible Cloud orchestration platform for private and public Clouds. It offers self-service IaaS capabilities and features such as compute orchestration, user and account management, native API and Amazon Web Services (AWS) API translator. Apps written for CloudStack can run in AWS, alongside resource accounting of network, compute, storage resources, multitenancy and account separation.

Eucalyptus Systems is an open-source provider of Cloud management software with strong technical ties to Amazon Web Services. One of the advantages to deploying the Eucalyptus Cloud platform is the ability for a company to move seamlessly from a private Cloud to a hybrid model by bursting into the Amazon public Cloud as needed. Eucalyptus software supports industry-standard AWS APIs, including Amazon Elastic Compute Cloud (Amazon EC2), Amazon Simple Storage Service (Amazon S3), Amazon Elastic Block Store (Amazon EBS) and Amazon Identity and Access Management (Amazon IAM). It supports three hypervisors: VMware ESXi with vSphere technology, KVM software and the Xen Cloud Platform (XCP).

Microsoft Hyper-V Software and Microsoft System Center is referred to as Microsoft Cloud OS, a set of technologies, tools and processes built on the Windows Server operating system with Hyper-V software, the Microsoft System Center and the Windows Azure platform. Together, these technologies provide a consistent platform for infrastructure, applications and data.

OpenStack Cloud Software was cofounded by Rackspace and NASA in 2010 and is currently available under the Apache 2.0 license. Growth in the use of the OpenStack platform has been rapid, with dozens of companies, many of them well known, such as AT&T, HP and IBM, signing on to use OpenStack as the base for their private Cloud offerings. This gives IT departments two options for deploying OpenStack for private Cloud either as a free software download with in-house deployment or from a vendor.

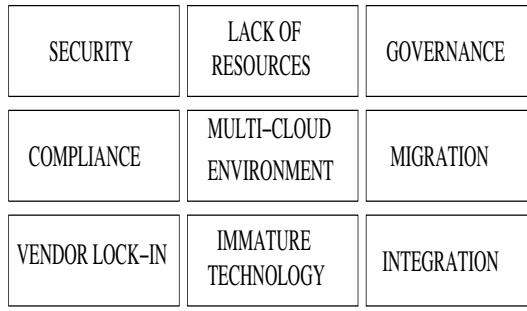

FIGURE 1.3
Challenges of Cloud computing

VMware vCloud Director is a comprehensive, integrated Cloud platform that includes all the elements to build Cloud environments and operationalize VMware vSphere virtualized environments. VMware vCenter Server manages the compute, storage, and networking resources, and VMware vCloud Director ties all the pieces of the Cloud together so that we can deploy a secure, multitenant Cloud (where multiple independent instances of one or multiple applications operate in a shared environment) using the resources from VMware vSphere environments.

Whether it's on-premises or in the Cloud, an application platform can be thought of as comprising three parts: (i) A foundation: Nearly every application uses some platform software on the machine it runs on. This typically includes various support functions, such as standard libraries and storage, and a base operating system, (ii) A group of infrastructure services: In a modern distributed environment, applications frequently use basic services provided on other computers. It is common to provide remote storage, for example, integration services, an identity service, and more and (iii) A set of application services: As more and more applications become service-oriented, the functions they offer become accessible to new applications. Even though these applications exist primarily to provide services to end users, this also makes them part of the application platform. It might seem odd to think of other applications as part of the platform, but in a service-oriented world, they certainly are.

Open Research Challenges: Cloud computing introduces many challenges for system and application developers, engineers, system administrators and service providers (see Figure 1.3). These include the following:

Security : Since the advent of the public Cloud, enterprises have worried about potential security risks, and that has not changed. A 2018 Crowd Research Partners survey found that 90 percent of security professionals are concerned about Cloud security. More specifically, they have fears about data loss and leakage (67 percent), data privacy (61 percent) and breaches of confidentiality (53 percent).

Lack of resources: Many companies are hoping to overcome this challenge by hiring more workers with Cloud computing certifications or skills. Experts also recommend providing training to existing staff to help get them up to speed with the technology.

Governance: Governance and control were fourth in the list of Cloud computing challenges in the RightScale survey with 71 percent of respondents calling it a challenge, including 25 percent who see it as a significant challenge. Experts say organizations can alleviate some of these Cloud computing management issues by following best practices, including establishing and enforcing standards and policies.

Compliance: The recent flurry of activity surrounding the EU General Data Protection Regulation (GDPR) has returned compliance to the forefront for many enterprise IT teams. Among those surveyed by RightScale, 68 percent cited compliance as a top Cloud computing challenge, and 21 percent called it a significant challenge.

Multi-Cloud environment: Most organizations are not using just one Cloud. According to the RightScale findings, 81 percent of enterprises are pursuing a multi-Cloud strategy, and 51 percent have a hybrid Cloud strategy (public and private Clouds integrated together).

Migration: While launching a new application in the Cloud is a fairly straightforward process, moving an existing application to a Cloud computing environment is not an easy task.

Vendor lock-in: Currently, a few vendors, namely Amazon Web Services, Microsoft Azure, Google Cloud Platform and IBM Cloud, dominate the public Cloud market. For both analysts and enterprise IT leaders, this raises the specter of vendor lock-in.

Immature technology: Many Cloud computing services are on the cutting edge of technologies like artificial intelligence, machine learning, augmented reality, virtual reality and advanced big data analytics. The potential downside to access to this new and exciting technology is that the services do not always live up to enterprise expectations in terms of performance, usability and reliability.

Integration: Lastly, many organizations, particularly those with hybrid Cloud environments report challenges related to getting their public Cloud and on-premise tools and applications to work together.

This challenge, like the others mentioned, is unlikely to disappear any time in the near future. Integrating legacy systems and new Cloud-based applications requires time, skill and resources. But many organizations are finding that the benefits of Cloud computing outweigh the potential downside of the technology.

Summary

Following a brief history of Cloud computing and a discussion of business drivers and technology innovations, basic terminology and concepts are introduced in this chapter, along with descriptions of common benefits and challenges of Cloud computing adoption. Cloud delivery and deployment models are discussed in detail, followed by sections that establish common Cloud characteristics and roles and boundaries. Tools and technologies in Cloud computing are also presented. The chapter concludes with the open challenges in the field of Cloud computing.

Keywords

Cloud Computing	Private Cloud	IaaS
Virtual Machines	Hybrid Cloud	PaaS
Public Cloud	CloudSim	SaaS

Objective type questions

1. _____ computing refers to applications and services that run on a distributed network using virtualized resources.

   (a) Distributed (b) Cloud (c) Soft (d) Parallel

2. Point out the wrong statement:

   (a) The massive scale of Cloud computing systems was enabled by the popularization of the Internet

   (b) Soft computing represents a real paradigm shift in the way in which systems are deployed

   (c) Cloud computing makes the long-held dream of utility computing possible with a pay-as-you-go, infinitely scalable, universally available system

   (d) None

3. _____ as a utility is a dream that dates from the beginning of the computing industry itself.

   (a) Model
   (b) Computing
   (c) Software
   (d) All of the mentioned above

4. Which of the following is essential concept related to Cloud ?

   (a) Reliability
   (b) Productivity
   (c) Abstraction
   (d) All of the mentioned above

5. Point out the wrong statement:

   (a) All applications benefit from deployment in the Cloud
   (b) With Cloud computing, you can start very small and become big very fast
   (c) Cloud computing is revolutionary, even if the technology it is built on is evolutionary
   (d) None

6. Which of the following Cloud concept is related to pooling and sharing of resources ?

   (a) Polymorphism
   (b) Abstraction
   (c) Virtualization
   (d) None of the mentioned

7. _____ has many of the characteristics of what is now being called Cloud computing.

   (a) Internet
   (b) Softwares
   (c) Web Service
   (d) All of the mentioned

8. Which of the following can be identified as Cloud ?

   (a) Web Applications
   (b) Intranet
   (c) Hadoop
   (d) All of the mentioned

9. Cloud computing is an abstraction based on the notion of pooling physical resources and presenting them as a _____ resource.

   (a) real
   (b) virtual
   (c) Cloud
   (d) None of the mentioned

10. Which of the following is Cloud Platform by Amazon ?

    (a) Azure (b) AWS

    (c) Cloudera (d) All of the mentioned

11. _____ describes a Cloud service that can only be accessed by a limited amount of people.

    (a) Data center (b) Private Cloud

    (c) Virtualization (d) Public Cloud

12. _____ describes a distribution model in which applications are hosted by a service provider and made available to users.

    (a) Infrastructure-as-a-Service (IaaS) (b) Platform-as-a-Service (PaaS)

    (c) Software-as-a-Service (SaaS) (d) Cloud service

13. Access to a Cloud environment always costs more money compared to a traditional desktop environment.

    (a) True (b) False

14. _____ is the feature of Cloud computing that allows the service to change in size or volume in order to meet a user's needs.

    (a) Scalability (b) Virtualization

    (c) Security (d) Cost-savings

15. A Cloud environment can be accessed from anywhere in the world as long as the user has access to the Internet.

    (a) True (b) False

Objective type questions -answer

1: b 2: b 3: b 4: c 5: a 6: c 7: a 8: c 9: b 10: c 11: b 12: c 13: b 14: a 15: b

Review questions

1. What are the advantages of using Cloud computing ?
2. Mention the platforms which are used for large scale Cloud computing.
3. Explain different models for deployment in Cloud computing.
4. Mention platforms which are used for large scale Cloud computing.