CHAPTER 3

Benefits and Challenges

The emergence of cloud computing provides benefits of the utility service model to the computing users. Users of computing are now being called subscribers or consumers as they move towards cloud computing. Cloud computing is delivered to its subscribers over the internetwork as well as Internet. Subscribers can access the computing facility on subscription basis, anytime and anywhere.

The scores of benefits of cloud computing are attracting users towards it. But any new innovation comes with few challenges and cloud computing is not an exception. This chapter discusses various benefits of cloud computing and also presents the challenges before it.

The biggest challenge is related to data security and compliance issue. Most of the other critical challenges are due to the absence of *open standards* where vendors develop clouds using their own proprietary standard or technology. The good aspect is that, significant efforts have been undertaken to resolve all of these issues. Apart from these, this chapter briefly presents the role of web services in cloud computing development.

3.1 ORIGIN OF THE TERM 'CLOUD COMPUTING'

The origin of the term 'cloud computing' dates back to the early 1990s. In those early days of network design, network engineers used to draw network diagrams representing different devices and connections among them. In such diagrams, they used to represent outer network arenas with cloud symbol since those details were not in their knowledge. This was known as 'network cloud' or 'cloud' in the networking industry during that period, but today we do not mean 'cloud computing' in the same sense.

With the beginning of utility computing initiatives towards the end of the last century, major software firms focussed on deliver applications over the Internet. Email services gained pace during this period as the vendors started to offer the facility to their users. And the most remarkable initiative came from Salesforce.com when they delivered business application for enterprises over the Internet in 1999. But all of these efforts were seen as part of utility computing facility development. Cloud computing did not emerge till then.

> *The term 'cloud computing' appeared in the market with its present meaning in the year 2006.*

During the earlier years of the current century, few industry people involved in the development of utility computing facility started to call it as 'cloud'. But it was not until 2006 that the term 'cloud computing' emerged in the commercial arena with its present meaning. The term 'cloud computing' probably was first used in an official forum by the then Google CEO Eric Schmidt in 2006 during a conference. Widespread use of the term was also observed during that time as

several companies like Amazon, Microsoft, IBM started to publicize their own cloud-computing efforts. Amazon launched its revolutionary Elastic Compute Cloud (EC2) services in 2006.

The literal meaning of the word 'cloud' is fog, veil or blur. It means an obscure area, or a mass of similar particles such as dust or smoke. It is hard to say exactly on which context technologists in those days started to call it cloud computing. But the reasoning that fits best is, 'a collection of computing resources and the detail of which remains hidden from users'.

3.2 EARLY INITIATIVES

The initiative from Salesforce.com in the year of 1999 to deliver business (enterprise) applications via a 'normal' website is considered as the first-of-its-kind effort. The success of Salesforce's effort encouraged other software firms to deliver business applications via Internet. That was the breaking point, when computing technology firms started to take initiatives in developing cloud computing based business applications.

> *Salesforce.com launched in 1999 was the first successful commercial initiative to deliver enterprise applications over the Internet. This was the first step towards cloud computing.*

Next major initiative came from Amazon with launching of Amazon Web Service (AWS) in 2002 which delivered *computing services* over the Internet. AWS provided a suite of services including storage. Amazon played the key role in the development of utility model based computing services during that period, and soon many software firms started to modernize their data centers to support utility computing. A *data center* is an organized physical repository of computing systems and associated components, like storage and networking, which enterprises maintain to build their computing facility.

The movement slowly turned towards what is known as cloud computing today. In 2006, Amazon launched its EC2 web service, where companies and individuals could rent (virtual) computers for running their own computer applications. Soon after EC2 started attracting the attention of experts, 'Google Docs' introduced by Google (in 2006) brought cloud computing service to the public attention.

In 2007, Salesforce.com launched another service called force.com, where anyone could built applications and launch websites. 2009 saw Microsoft's commercial entry into cloud computing arena with the launch of 'Windows Azure'. The goal of Azure was to provide customers the facility of running their Windows applications over the Internet.

Apart from these commercial initiatives, many research organizations and open-source forums started their cloud computing initiatives during those years. For instance, NASA developed and launched an open-source cloud computing platform called as 'Nebula' in 2008 for its internal use.

> *Elastic Compute Cloud (EC2) introduced by Amazon in 2006 is the first concrete cloud service launched in the market.*

3.3 UTILITY COMPUTING

Utility computing is a computing business model in which a party called vendor or provider arranges, owns, maintains and delivers computing facilities on-demand. Use of the computing

facility is metered at provider's end. Subscribers can access the computing facility as and when required on payment basis. The billing can be of two types: fixed rental or actual use-basis. In fixed rental model, a fixed amount is charged depending on subscriber's need for some fixed duration (generally counted in months). In actual use-basis approach, billing is done as per actual consumption of the service by a subscriber over a period.

Utility computing model is the implementation of utility model of service delivery in computing.

Figure 3.1 describes the two important aspects of *utility model* for service delivery. The service is available as per user's demand (in little or in big volume) and it is a measured service that is metered. Service providers can impose charge on subscribers based on the metering of their usage.

In utility model, computational facilities are delivered along with computing resources (including processor, storage etc.) in packaged form that can be accessed from remote location. Computing cost reduces under this computing model as same set of resources are shared among large number of subscribers. Here, subscribers can access virtually unlimited supply of computing solutions using network communication paths or internetworks.

Supply of resources by provider party as per users' demand is known as 'on-demand service'.

IBM, HP and Sun Microsystems started their utility computing initiatives towards the end of the last century. These companies invested huge capital to conduct research on on-demand computing. They were the leaders in the utility computing development initiatives. Later on, Microsoft, Google, Amazon and others joined in the race.

3.3.1 The Benefits

It has already been discussed in Chapter 1 how electric power as utility service raised concerns and doubts among people in early twentieth century. Computing as *utility service* also raises similar concerns. Debates are regular on pros and cons of outsourcing computing as utility service. There are two choices available; either to maintain own data center, or consume cloud computing service.

For electric power more than a century ago, when electricity did not come as utility service, businesses either had to maintain *in-house* team or outsource the job of maintaining and running the power generation plants inside their premises. Computing in its traditional form is maintained in similar way at organization's own data center. But what happens when an enterprise or organization outsources the job of running their own data center to some third party? Or how apt is it to run own data center by deploying in-house team, when organization does not have expertise in computing? Here comes the third choice. The cloud computing where

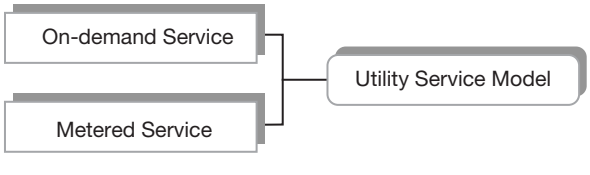

FIG 3.1: Utility model of service delivery

almost the entire computing facility is outsourced but in entirely different form. The question arose that if it would not be the safer option than earlier two choices to give the responsibilities to those reputed organizations who already did have the expertise in the field of computing. The utility model of outsourcing reduces the cost of IT operations remarkably for customers which is a big advantage in this highly challenging market. Utility computing also shifts the investment model from one time large investment to small variable payments.

This sort of the computing model also brings benefit to the providers of computing services. The capital they invest to build hardware and software infrastructures can provide multiple solutions and serve a large number of users. This ultimately leads to better *return on investment* (ROI).

Utility service model provides the facility of very low initial investment as well as overall cost saving for subscribers.

3.4 METERING AND BILLING IN CLOUD

Actual metering of computing service has become possible in cloud computing. Earlier, in cluster computing models, few basic metering functions were available. But, those were not enough for measuring the actual service usage. The combined technological advancements adopted in cloud computing enable this capability where consumption by subscribers can be measured accurately.

Usages are measured for different types of facilities like processing, storage or network bandwidth. Subscribers are billed as per their use of computing resources. For instance, a subscriber using compute facility in cloud computing will be billed against his/her use of computing power (both processor and memory), storage usage (if any) and network bandwidth consumption over a period of time. Subscribers using storage facility in cloud are billed against the volume of actual storage used by them. The metering capability of cloud results in significant cost saving for users.

In traditional computing, the basic metering functions were not adequate for measuring the actual use of computing. Cloud computing is empowered with this facility.

3.5 SEPARATION OF DATA CENTER OPERATION

Computing data center operation has always been a burden for most of the consumers of computing, specially enterprises. *Data center* operations involve arranging space for infrastructure development, ensuring uninterrupted electric supply, establishing cooling system and most importantly, building computing infrastructure etc. Apart from these, maintaining the system, running upgrades, recovery in case of system failure or protecting the system from network attack are all activities at the end of data center.

The cloud model of computing completely separates the data center operations from user end's computing tasks (like application development). Software developers or application users have always tried to avoid the computing infrastructure management tasks. Thus, in traditional computing model, outsourcing the management of data center was a common feature.

In cloud computing, data centers reside at some remote end and are managed by some computing vendors. The vendor arranges and manages everything. Users can simply and solely concentrate on their specific tasks. This facility comes as a huge relief for users of computing.

Cloud computing separates data center operations from other activities at the users' end.

3.6 BENEFITS OF CLOUD COMPUTING

Cloud computing has introduced a real paradigm shift in the scope of computing. Unlike the conventional uses of computer technology, it facilitates computing as a utility service which is delivered on demand. The computing facility is managed by providers and can be measured in usage volume or usage time.

All these features of cloud computing provide several benefits. It has the flexibility where users can have as much or as little of it as they want at any given time. The advantages influence the adoption of cloud computing over the traditional computing process. Following section discusses different benefits that subscribers of cloud computing can enjoy.

3.6.1 Less Acquisition/Purchase Cost

In traditional computing, users have to purchase or procure computing resources in significant amount at very beginning. Cloud computing is delivered following the utility service model. Since vendor arranges all necessary resources in this model, subscribers' initial investment for acquiring hardware or software drops down drastically. They need not to arrange anything apart from client systems to access cloud services. Thus, initial capital expenditure of user gets reduced considerably.

The initial investment of users adopting cloud computing is very low.

3.6.2 Reduced Operational Cost

With the outsourcing model of utility computing the cost of running any systems round the clock moves towards the provider's end. Subscribers get rid of the responsibility of system administration, maintenance, and 24×7 energy support as well as its cooling support. This is a basis for cost savings because subscribers can use the service by paying very nominal. The provider on the other hand can offer the service at nominal fee to subscribers because of their volume of business (due to large customer base).

Subscribers of cloud computing service need to bear nominal operational cost.

3.6.3 Reduced System Management Responsibility

Be it a data center for enterprises or single standalone machine (PC, laptop etc.) for normal users, management of the computing setup (both hardware and software) is an extra headache for consumers of traditional computing. Cloud computing model shifts majority of the infrastructure and other system management tasks towards cloud vendors. Dedicated teams at the vendor's end takes care of all of these activities. Thus, the users can enjoy a sense of relief

and can concentrate only on their area (layer) of computing interest without bothering about the management of the underlying computing layers.

Cloud computing releases users from the task of managing underlying computing system.

3.6.4 Use-basis Payment Facility

Cloud computing does not charge its subscribers when they do not use it. Even the charge is not fixed; it depends on the duration of usage. Rather, any use is metered and users are charged a reasonable fee according to their consumption. This reduces the cost of computing.

3.6.5 Unlimited Computing Power and Storage

In cloud computing, users can easily access supercomputer like computing power at reasonable cost, if necessary. Earlier in traditional approach, only big corporate could afford high-end computing. Storage is another important issue for users. Cloud provides as much storage as required. It is virtually unlimited which is viewed as a big benefit for users.

3.6.6 Quality of Service

In traditional computing, enterprises often used to outsource major portion of computing related jobs to some third party. Thus, service quality was broadly dependent on the expertise of those third parties or the in-house teams managing it. Whereas in cloud computing, high quality of service (QoS) is ensured as it is provided by renowned computing vendors having well-trained staffs and expertise exclusively in the field of computing.

When service is provided by reputed vendors, QoS is assured and it becomes a responsibility of the vendor.

3.6.7 Reliability

The ability to deliver the quality service and support load balancing, backup and recovery in cases of failure makes the reputed cloud vendors highly reliable which often emerges as big worry in traditional computing. In cloud computing, subscribers no more need to plan for all of these complex tasks as vendors take care of those issues and they do it better.

3.6.8 Continuous Availability

Reputed cloud vendors assure almost 24×7 service availability. Statistics have shown that service uptime (delivered from reputed vendors) counted for a year generally doesn't go below 99.9%. Such guaranteed continuous availability of cloud service is a big enabler for any business.

3.6.9 Locational Independence/Convenience of Access

Cloud computing is available everywhere via Internet. Users can access it through any computing device like PCs, or portable computing devices like tablet, laptop or smart phone.

Only the thing required to avail cloud computing through those devices is the access to Internet, irrespective of geographic location or time zone.

Convenience of access and low investment make cloud computing the field with low barrier to entry.

3.6.10 High Resiliency

Resiliency is the ability of reducing the magnitude and/or period of disruptions caused by undesirable circumstances. Higher level of resiliency has great value in computing environment. Cloud computing is developed based on resilient computing infrastructure, and thus cloud services are more resilient to attacks and faults. Infrastructure resiliency is achieved through infrastructure redundancy combined with effective mechanism to anticipate, absorb and adapt. The cloud consumers can increase the reliability of their businesses by leveraging the resiliency of cloud-based IT resources.

3.6.11 Quick Deployment

Deployment time in cloud environment has significantly reduced than what is was in traditional computing environment. This is possible since resource provisioning is rapid and automatic in cloud environment. In a highly competitive market, the ability of quicker deployment gains significant business advantages.

Quicker system or application deployment attains business advantage in competitive market.

3.6.12 Automatic Software Updates

The issue of software upgrade incurs a lot of headache in traditional computing environment. New patches are released every now and then and users need to run those patches periodically. In cloud computing environment, this upgrade happens automatically. Cloud vendors always deliver the latest available version of any software (if not asked for otherwise). Upgraded environment gets available to users almost immediately after it releases, and whenever user logs in next time.

3.6.13 No License Procurement

Application license procurement needed separate budgetary arrangements in traditional computing. Moreover, unnecessary applications used to be provided with licensed packages. Cloud computing has eliminated that problem too. Here, users need not procure any periodic license for using applications; rather, they are allowed to pay (post-payment) according to their use of any software.

Software licensing is no more a concern for users in cloud computing.

3.6.14 Safety against Disaster

Breakdown of systems due to sudden technical failure or natural disaster is a major concern for users. Specially, any damage to physical storage devices may cause huge commercial loss. Cloud computing delivered by reputed vendors have robust recovery systems incorporated in their set up. Thus, systems and data remain more protected in cloud computing in terms of safety and security than previous ones.

3.6.15 Environment Friendly

Cloud computing promotes green computing. Proper utilization of resources minimizes overall electronic resource requirement, hence reduces generation of e-waste too. This is beneficial for environment as e-wastes are harmful for eco-system if not being processed properly. Apart from this, the reduced resource requirement results in lesser demand, hence production of computing resources. This decrease in e-production reduces carbon emissions and helps to decrease the overall carbon footprint.

Cloud computing is an eco-friendly computing approach.

This long list of benefits discussed above are represented in Figure 3.2. They give some idea about the usefulness of cloud computing and why so many people are excited about it.

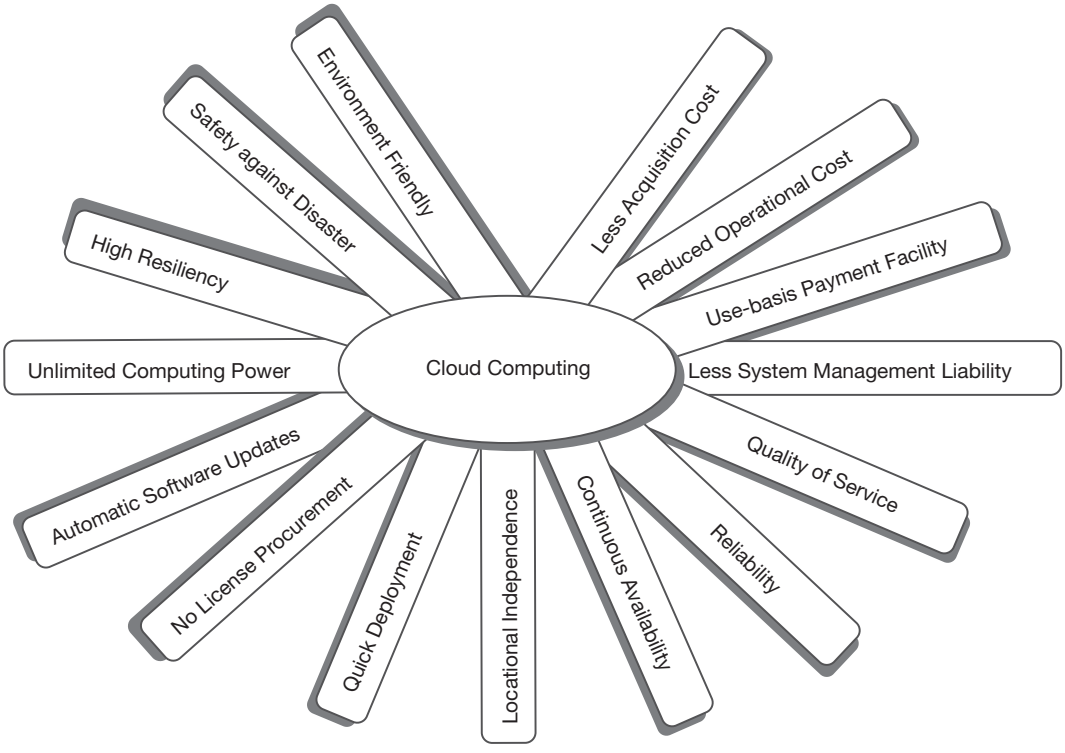

FIG 3.2: Advantages of cloud computing

3.7 CHALLENGES OF CLOUD COMPUTING

Cloud computing provides numerous benefits. But, like any new technology, this model of computing also brings some challenges with it. Following section focusses on those challenges. The promising part is that all of the concerned bodies including the cloud vendors are working rigorously to overcome these challenges.

3.7.1 Limited Portability between Cloud Providers

Cloud computing is at its early age and an overall standardization has not yet come up in the domain. Naturally different vendors are coming up with cloud computing facility for public use which is mostly proprietary to various extents. Applications developed on these proprietary clouds are difficult to move to other cloud platform due to *vendor lock-in*. This problem limits *portability* of applications. Hence, many times it becomes a challenge to move from one cloud provider to another. There various efforts are on to resolve this issue.

> *Presently, vendor lock-in problem limits portability of cloud applications.*

3.7.2 Inter-operability Problem

Interoperability is the ability of a system to work with other systems. The proprietary issue discussed above not only raises portability problem, it also restricts applications of two different clouds to interoperate with each other. This is known as the problem of interoperability. Applications of two different proprietary clouds do not interoperate since they follow different standards. Subscribers may find two different applications from two different cloud vendors suitable for their requirement. For example, some enterprise may like payroll management application of one cloud vendor while accounts management application of another. But it is difficult to establish link between these two applications if they are not interoperable. Efforts have been undertaken to solve this problem. Open standard application development (as discussed later) is a step towards that direction.

> *Use of proprietary technology restricts applications of two different cloud vendors to interoperate.*

3.7.3 Data Security

In cloud computing, users or enterprises need to store data outside their network boundary protected by firewalls. Thus the trust boundary of enterprises expands up to the external cloud. Security of users' data largely depends on the cloud vendors. This may introduce some extent of vulnerabilities to the security of data. Another concern arises when a cloud computing facility accessed by multiple parties causes overlapping of trust boundaries.

> *Building confidence among consumers about the security of user/enterprise data stored outside their own network boundary is a big challenge in cloud computing.*

3.7.4 Reduced Control over Governance

Cloud computing is built and governed by the policies of computing vendor or service provider. Consumers are relieved of the tiring responsibility of managing the computing system. While this turns out as a major benefit, the low control over the *governance* or authority of computing environment sometimes raises concerns among consumers who used to enjoy full control over self-owned traditional data centers. The main concern is regarding how a vendor operates the cloud. Although low but a certain degree of operational control is given to the subscribers depending on the type of service and service level agreement plays an important role in this regard.

> *Reduced control over cloud governance may sometime bother cloud computing subscribers.*

3.7.5 Multi-Regional Compliance and Legal Issues

Cloud computing vendors build data centers at locations of their convenience, both geographical and economical. A vendor may even have more than one data centers dispersed over multiple geographic locations. Since subscribers remotely access cloud computing over the Internet, they may not be aware of the actual location of the resources they consume. More importantly, the storage location of subscriber's data may not be within the country or region of the subscriber. This sometimes poses serious legal concerns.

The privacy or compliance rule generally differs across different legal jurisdictions. The rules for degree of disclosure of personal data to government agencies (in cases of some official investigations) differ from country to country, or even state to state within a country. Situation may arise where the law of the country of a cloud subscriber asks for some data to be disclosed where the law of hosting region of the cloud (that is the region/country of cloud data center) does not allow such disclosure.

Most regulatory frameworks recognize cloud consumer organizations responsible for the security, integrity, and storage of data even when in reality it is held by an external cloud vendors. In such scenario, resolving the multi-regional compliance and legal issues are soaring challenges before cloud computing.

> *Multi-regional legal issues raise concern over information privacy and compliance related problems in cloud computing.*

3.7.6 Bandwidth Cost

This one is not as significant as the other challenges discussed above. But it is a fact that while the pay-per-use model of cloud computing cuts down costs as subscribers only pay for the resources or services they use, the model brings some associated cost along with it. That is the cost of *network bandwidth* used to access the service.

In the current age of Internet, cost of bandwidth is very low at moderate speed of access. But more bandwidth can provide higher speed which is essential for high quality service. While low cost bandwidth may often fulfill requirements of general applications, data intensive applications (those deal with critical and huge volume of data sets) demand higher bandwidth which may add a little more in the total cost of computing.

Cost of network bandwidth is an additional expense in cloud computing.

3.8 HOW CLOUD COMPUTING ADDRESSES BUSINESS CHALLENGES

With a host of advantages, cloud computing has changed the way computing used to address business challenges in its way traditionally. Customers now get more flexible and robust computing environment that works in favour of businesses. Table 3.1 lists the cloud computing solutions to counter the common business challenges.

3.9 ETHICAL ISSUES IN CLOUD COMPUTING

Cloud computing implicates several ethical obligations. This is primarily caused by the fact that organizations work outside their trusted network boundary in cloud environment. Risk arises as controls are released to third party cloud vendors. The blurring network boundary raises confusion regarding accountability of participating parties.

The complicated structure of cloud may sometimes raise concern about the responsibility when some problems arise. Both the cloud computing vendors and the users must have clear ideas about their individual responsibilities. There are many instances where both parties need to work together to resolve issues.

Another important part of the ethical side falls on the cloud vendor's shoulders. This issue surfaces as cloud computing allows easy distribution of intellectual properties of other people. In cloud computing, users or enterprises have to rely their data upon cloud storages with the faith that security and privacy of information will be maintained by the cloud vendors. Cloud computing companies have total control over those data stored in their data centers. How they use those sensitive data depends on their moral. Any trusted cloud vendor must implement mechanism in order to provide unbreakable protection to its users' data.

Cloud computing philosophy is based upon a relationship of trustfulness between cloud computing vendor and its users.

Table 3.1 Cloud computing solutions to business challenges

Business Challenges	*Cloud Computing Solutions*
Budget	It provides flexibility by maximizing utilization of available budget with the scope for future growth
Business	It reduces time to market and provides scope for rapid business growth.
Mobility of users	It enables anywhere access from a variety of devices.
Flexibility	The agile nature of cloud computing enables easier and quick changes.
Scope of Growth	The scalable (or elastic) architecture enables rapid growth.
Availability	It provides almost 24 × 7 availability round the clock.
Recovery	It integrates reliable backup and disaster recovery mechanisms.

3.10 CLOUD COMPUTING: NETWORK AS COMPUTER

The cloud can be imagined as a huge network of computers. The details of this network remain hidden from the users. Users can log-in to the cloud from their individual computing devices (as shown in Figure 3.3), but they never know in which systems they are actually working. They even do not know where their data is stored. To the individual users, the cloud is seen as a single entity.

Cloud computing environment can be described by using Sun Microsystems's popular slogan during mid 1980s, which said "The network is the computer". This philosophy can generate higher computing power by combining power of multiple computers.

> *Computing cloud comprises of a vast network of computers but users visualize the entire thing as a single entity.*

3.11 ROLE OF WEB SERVICE

Cloud computing environment is built of heterogeneous computing systems spread over different geographic locations. Together they all act as a single system. One important thing to learn here is how applications running on those disparate systems communicate with each other. Answer to this is the web services.

A web service is the way of establishing communication between two software systems over the internetwork. Web services use standardized way of data exchange since different software systems might be built using different programming languages and run on different platforms. Thus, this standardization is very important so that communication remains independent of programming languages or platforms.

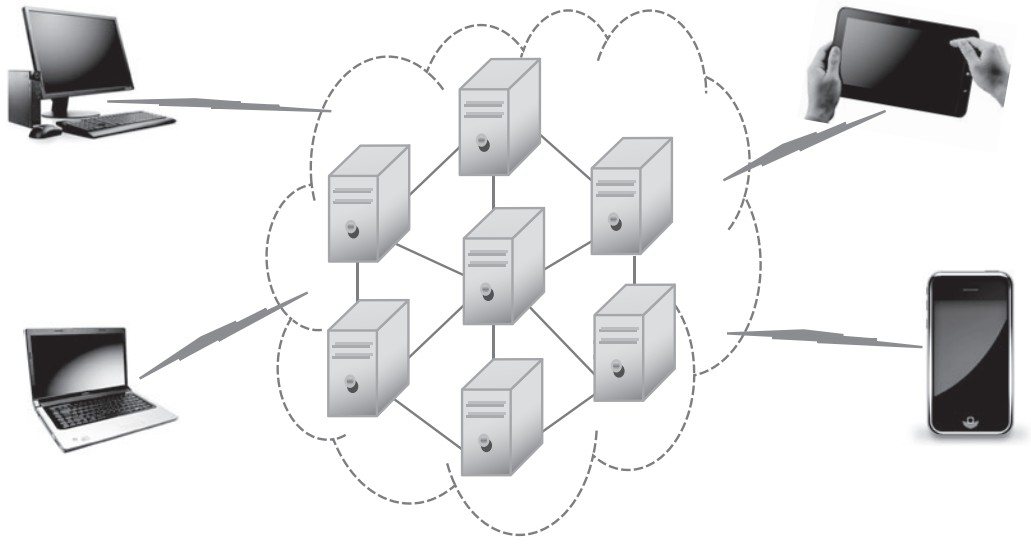

FIG 3.3: The cloud from the point of view of users

A critical aspect of cloud (or any other networked application) development is how processes/threads running on systems with different platform or architecture can communicate with each other.

3.11.1 Web Service

Web service describes the method of establishing communication between two web-based applications. World Wide Web Consortium (W3C) defines web services as "a software system designed to support interoperable machine-to-machine interaction over a network". Application of web services is an essential part of cloud computing development.

Web applications can communicate or publish their messages to the external world by using web services.

Web services are generally categorized into two different classes. Based on how the service is being implemented, a web service can either be

- Simple Access Object Protocol (SOAP) based, or
- Representational State Transfer (REST) compliant.

Both these approaches of web service development are computing architecture, platform and programming language independent.

3.11.1.1 SOAP-Based Web Services

SOAP-based web services use XML format for communicating messages among web applications as XML is an open format and recognized by all kind of applications. In this approach, HTTP or hyper-text transfer protocol is used for passing messages.

The SOAP is originally developed by Microsoft as older Remote Procedure Call (RPC)-based message passing technologies like DCOM (Distributed Component Object Model) or CORBA (Common Object Request Broker Architecture) did not work well with Internet. This was primarily because those technologies relied on *binary messaging*. On the other hand, the XML format of messaging performs well over Internet. The SOAP was accepted as standard when Microsoft submitted it to the Internet Engineering Task Force (IETF).

SOAP uses XML as messaging format and hyper-text transfer protocol (HTTP) for message passing among various web applications.

The rules of SOAP communications are described in Web Services Description Language (WSDL) format. The rules are stored in files with .wsdl extension.

3.11.1.2 REST: Compliant Web Services

REST represents a simpler way of communicating messages. SOAP is often considered as complex since creation of the XML structure is mandatory for passing message. In this respect, REST provides a light weight alternative. Instead of using XML to make a request,

REST relies on global identifier to locate the resources. Thus, a separate resource discovery mechanism is not needed. This 'representation' of paths of applications provides the additional power in REST.

The global identifier assigned to each resource makes the access method of the resources uniform. Any resource at a known address can be accessed by any application agents. REST allows many standard formats like XML, JavaScript Object Notation (JSON) or plain text as well as any other agreed upon formats for data exchange.

REST is an architecture style for designing networked applications. Here, simple HTTP is used to make calls between machines identified by their URLs (Uniform Resource Locators) which is simpler than other mechanisms like CORBA, DCOM or SOAP.

REST-compliant web services are known as REST ful.

3.11.1.3 SOAP versus REST

The differences between two types of web services have been summarized in Table 3.2.

Both SOAP and REST can be used for cloud computing development. The choice depends on the design and implementation requirements. Both the technologies have been used by different cloud players. But, gradually REST has gained preference over SOAP for its simplicity of use and ease of understanding. Thus, RESTful cloud APIs (Application Program Interfaces) are being more common in the market.

Both SOAP and RESTful web services can be used for developing cloud computing facilities.

Table 3.2 Differences between SOAP and REST

SOAP	*REST*
It is a message communication protocol that is used to build network application.	It is an architectural style for network application.
It uses XML for formatting message.	It uses simpler messaging formats like JSON. It also supports XML.
It requires the XML parsing.	Here, the XML parsing can be avoided by using JSON.
SOAP defines its own additional security over HTTPS.	It inherits security measures from the underlying transmission protocol as HTTPS.
It is a bit heavy.	It is lighter than SOAP and response time is better.
It is complex than REST.	It is simple to use and easy to understand.
It is recognized as a standard protocol.	It is not an standard, rather an architectural style.
SOAP uses services interfaces to expose the business logic.	REST uses Uniform Resource Identifier (URI) to expose business logic.
SOAP oriented development is faster since it is supported by many tools.	Development time is longer due to limited tool support.
It shows lesser flexibility in controlling resources.	It shows more flexibility in controlling resources.
It requires less knowledge in programming.	It requires rather greater knowledge in programming in comparison with SOAP system.

3.12 ROLE OF API

API (Application Program Interface) is a set of defined functions or methods which is used to compile the application. It defines the contract of communication or standard interface provided by software components for others (other software components) in order to interact with them.

APIs play important role in cloud computing. When some cloud services are released, corresponding APIs (referred as cloud API) are also released as they are critical for the usefulness and operational success of those services. Cloud services generally provide well-defined APIs for its consumers so that anyone can access and use the capabilities offered to develop application or service. Request for data or computation can be made to cloud services through cloud APIs. Cloud APIs expose their features via REST or SOAP.

For instances, the cloud APIs can be classified as IaaS (Infrastructure as a Service) API for resource configuration or workload management, PaaS (Platform as a Service) API to integrate with database service etc. and SaaS (Software as a Service) API to integrate with application services like ERP or CRM. Both vendor specific and cross platform APIs are available, but cross platform APIs are still not widespread in cloud computing arena and are available for specific functional areas only. APIs streamline the access of cloud services and enforce the adherence to compliance.

3.13 UBIQUITOUS CLOUD

The term 'ubiquitous' means as being everywhere. The idea of *ubiquitous computing* talks about making computing facility available everywhere and for all the time. The concept looks beyond personal computer like systems and involves creation of smart devices (any devices like fridge, car etc.) and connecting them to make the communication and exchange of data more efficient. The underlying technologies to support ubiquitous computing include embedded computing devices (electronic chips), networks and Internet among other things.

The *ubiquitous computing* paradigm is also known as *pervasive computing*. In comparison with desktop computing, interaction with computing environment in ubiquitous computing can happen using any devices having some computing capability of any form. Cloud computing further strengthens the idea of ubiquitous computing. *Ubiquitous cloud* refers to the use of computing resources spread over geographic locations from any place and any time.

> *Pervasive or ubiquitous means 'existing everywhere'.*

3.14 CONFUSION BETWEEN CLOUD AND INTERNET

Many people confuse Internet as cloud computing. Where however, the fact is that these two are different. The confusion arises because cloud computing is generally delivered via Internet. The actual fact is that earlier users used to access websites or web portals consisting of static and dynamic pages via Internet but now they access cloud computing too.

Cloud computing has its own characteristics. It follows utility service model and it is measurable where users can be billed as per use. More importantly, it can deliver both software and hardware to users over internetwork or Internet in special form called 'service'. Cloud computing does not mean simple static or dynamic web content; it is much more than that.

Cloud and Internet are not same. Internet is a means for accessing cloud.

SUMMARY

- Cloud computing developed following the utility service model. Salesforce.com first built and delivered enterprise application over Internet following utility model in 1999. Various other reputed computing firms like IBM, Amazon and others jumped into the development field of utility computing from the beginning of the current century.
- In utility computing model, the computing facility is delivered to users according to their demand and on payment basis. Payment is calculated as-per-usage basis. Under this model, the computing facility is built and managed by computing vendors.
- Utility computing model minimizes cost of computing for users as well as generates good business for vendors.
- The utility computing facilities became popular as 'cloud computing' around the year of 2006 after reputed computing firms like Microsoft and Amazon addressed it as 'cloud'.
- Cloud computing provides lots of benefits to its subscribers. It has very low initial investment compared to traditional computing, minimum system management headache, low operational cost, almost unlimited resource availability and reliable and robust service as provided by the reputed vendors.
- Cloud computing is also known as 'green computing' or 'eco-friendly' computing as it minimizes electronic resource wastage.
- Among the challenges of cloud computing the portability, interoperability, information security and privacy are some major concerns for subscribers.
- Roles of web services are very important in any web base development and so in cloud computing as well. A web service is the way of establishing communication between two software systems over the internetwork.
- Based on the implementation, web service can be divided into two categories: SOAP-based and REST-based. Among these two, earlier SOAP gained popularity among cloud vendors. But slowly they started to prefer REST since it is light-weight than SOAP.

REVIEW QUESTIONS

Justify the 'low initial investment' philosophy of cloud computing.

In cloud computing, cloud vendors develop and keep all facilities ready for its potential customers (the users). Vendors invest in large to develop the computing facilities those are essential to attract customers. Thus, investment of cloud computing vendors is very high in its initial phase.

Users on the other hand can avail those facilities on rent basis as per the requirement. They need not to procure resources or purchase software licenses any more. This reduces the initial investment of users radically. Thus, the low investment philosophy of cloud is true from users' perspective.

Why is cloud computing called variable cost computing model?

Cloud computing philosophy enables users to use computing resources on rent basis. Unlike traditional computing, users need not to invest huge capital at the beginning for developing computing infrastructure and can pay to the cloud vendors as per their usage of resources. Resource consumption is measured and billed. When use is higher, users pay accordingly and during low usage they pay less. This is why cloud computing is called a variable cost computing model.

What are the advantages of utility computing?

Utility computing brings many benefits to users. It eliminates the burden of huge initial investment from users. It allows them to pay as per their usage. Sharing of common resources among multiple users under one computing infrastructure reduces cost of computing also. Users can simply connect and use computing. In brief, users get tension-free computing facilities at much lower cost.

What is pervasive computing?

Pervasive computing refers to the computing environment having created through the use of embedded microprocessor that always remains connected with other devices via Internet. Devices those are part of pervasive computing can be anything from car, electric meter to human body. Such computing environment is generally built based on wireless communication technology, Internet and advanced electronic chips. Pervasive computing devices always remain connected.

Is it true that cloud computing ensures round the clock availability?

It can be said that cloud computing is available anywhere and anytime. But it is true that cloud computing vendors cannot generally deliver services with hundred percent service uptime assurance. Reputed cloud vendors guarantee more than 99.9% of service uptime, but till now it has not been possible for vendors to deliver 100% service uptime over a reasonable period of time. Anyway, despite of this, its service availability is still much better than the traditional computing scenario. And cloud users rarely suffer or can even feel the effect of the almost insignificant service downtime.

MULTIPLE CHOICE QUESTIONS

1. Utility model of computing is beneficial for
   - **a)** Users of computing
   - **b)** Vendors of computing
   - **c)** Both b and c
   - **d)** None
2. The term 'cloud computing' was first presented in its current meaning in the year of
   - **a)** 1999
   - **b)** 2006
   - **c)** 2008
   - **d)** 2010
3. Which among the following is/are feature(s) of utility service model?
   - **a)** Metering
   - **b)** Billing
   - **c)** On-demand service availability
   - **d)** All of these

4. Which among the following companies was first to successfully adopt utility computing model for enterprises?

a) Amazon
b) Salesforce.com
c) IBM
d) Google

5. Heterogeneous software applications communicate over the internet using

a) HTML
b) Message passing
c) Web services
d) None of these

6. Presently, the web services are categorized as

a) SOAP & REST
b) SOAP & RPC
c) REST & RMI
d) REST & CORBA

7. REST is considered as the light-weight alternative of SOAP since it can avoid

a) the use of global identifier for resources
b) the use of JSON for message passing
c) the use of XML for message passing
d) None of these

8. Use of REST-compliant web services results in longer development time than using of SOAP-based web services in cloud computing development. This statement is

a) True
b) False

9. REST is a/an

a) Message communication protocol
d) Architectural style
c) Web architecture
d) Cloud type

10. Which among the following is not a benefit of cloud computing?

a) Low initial investment
b) Fixed cost of computing
c) Access through internet
d) High-performance computing

11. Which among the following is not considered as an inherent nature of cloud computing?

a) Flexibility
b) Elasticity
c) Scalability
d) Portability