Cloud Computing

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Cloud computing is currently being used by a large number of organizations. Many consider it a major development of the decade in computing. In this article we define cloud computing, various services available on the cloud infrastructure, and the different types of cloud. We then discuss the technological trends which have led to its emergence, its advantages and disadvantages, and the applications which are appropriate to outsource to a cloud computing service.

All of you have been using cloud computing services without being aware of it. Whenever you send an email using Gmail, Yahoo mail, or Hotmail, you are using the email software running on the computer infrastructure provided by Google, Yahoo, or Microsoft. These are 'free' cloud software services. The question which will now be uppermost in your mind would be 'what is cloud computing?' The term cloud computing is a jargon invented by computer professionals. I prefer the term computing utility [1] as this term reflects better the new model of 'pay for what you use' computing. However, the terminology cloud computing is universally used nowadays. (In fact, the phrase 'cloud' came from the common practice in the computer literature of enclosing a group of computers connected to the Internet in a cloud-like boundary (*Box* 1)). In essence computing is transitioning from an era of users owning computers to one in which users do not own computers but have access to computing hardware and software maintained by providers. Users access the computing facility they need using a browser running on a 'cloud access device' (*Box* 2) and pay only for what they use. In other words, computing is becoming a utility just like an electrical power utility or a telephone system. The fact that such a transition would be inevitable was foreseen by John McCarthy in 1961 (*Box* 3). However, it has taken over fifty years for computer and communication technologies to mature to realize his dream (*Box* 4).

Keywords
Cloud computing, services on a cloud, cloud types, computing utility, risks in using cloud computing.

Box 1. Origin of the Term 'Cloud Computing'

A Google search of 'cloud computing' resulted in 72,500,000 hits (on Oct.3, 2013). Obviously it is one of the hottest buzz words in computing. It is a metaphor for computers connected to the Internet which are usually enclosed in a cloud-like boundary in figures in early power point presentations. The terms became popular after it was used by Eric Schmidt (then Google CEO) in 2006 in an industry conference. A company called Net Centric (which is now defunct) applied for a trade mark for 'cloud computing' in 1999 for educational services. It was not approved[1]. According to an early Wikipedia entry (since removed) it was first used in an academic publication by Ramnath Chellappa of the Management Department of the University of Texas, Austin in 1997[2].

[1] Antonio Regalado, Who coined "Cloud Computing"? *MIT Technology Review*, USA, Oct. 2011.

[2] Ramnath Chellappa, *Intermediaries on Cloud Computing, INFORMS meeting*, Dallas, Texas, USA, 1997.

Box 2. Cloud Access Device

Servers in a cloud may be accessed by a PC, Laptop, Tablet, or even a Smart phone. One may ask whether there is an alternate device specially meant to access the services in a cloud mainly because when there is so much computing power available in the cloud why should an access device also need computing power. Further, PCs and their descendents have a bloated OS, take minutes to boot, become obsolete fast, need virus protection, and are expensive. A device called Thin Client[1] which is a terminal to access servers connected to a network has been used for over a decade. Thin clients have a good graphical user interface, are less expensive than PCs, do not become obsolete, and do not need virus protection. They are, however, not mobile. In 2011 Google designed a low-cost, mobile thin client-like device called Chromebook[2] to access the cloud. It has a Linux-based OS, built-in Chrome browser, has a media player, is virus proof, and boots in less than 10 seconds. It is manufactured by several competing manufacturers including Google. The main criticism of Chromebook is that it depends entirely on the cloud to do anything useful. If a Chromebook's communication with the cloud fails, it is almost useless.

[1] V Rajaraman, *Fundamentals of Computers*, 5th Edition, PHI Learning, New Delhi 2010.

[2] Chromebook, *Wikipedia*, 2013.

Box 3. John McCarthy's Memo

In 1957, John McCarthy was visiting the Massachusetts Institute of Technology and had started work on Artificial Intelligence. At that time MIT had an IBM 704 mainframe computer which was used in batch mode. One had to punch a deck of cards containing program and data, submit it to the computer centre, and wait for almost a day to get a print out with the results of computation. Often, after impatiently waiting for a day, a small syntax error in the program would lead to failure of the program. Normally three or four attempts were needed to obtain one useful result from the computer. McCarthy who had joined MIT in 1959, wrote in frustration, a note to the Director of the Computer Centre suggesting that teletypewriters from the offices of the faculty be connected to the computer permitting interactive time-shared use of the computer by several persons[1]. The idea

Box 3 *Continued...*

Box 3 *Continued*

was revolutionary. A number of changes in the hardware as well as the operating system were required. Fernando Corbató who was the Associate Director of the Computer Centre at MIT took up the challenge with his team and designed what is known as the Compatible Time Sharing System (CTSS). The system became operational in 1961. When a computer could be 'time shared, the next question was why not make computing a utility like a power utility. In a talk in 1961, during the centennial celebration of MIT, McCarthy stated that, "If the computers of the kind I have advocated become computers of the future then computers someday will be organized as a public utility just as a telephone system is a public utility. The computer utility could become the basis of a new and important industry."[2]

[1] John McCarthy, *Reminiscences on the history of time sharing*, *IEEE Annals of the History of Computing*, Vol.14, No.1, pp.19–24, 1992.
[2] Utility Computing, *Wikipedia*, 2013.

Before we proceed further we should formally define cloud computing and the services available in the 'cloud'.

Box 4. Cloud Computing History

1959 John McCarthy's note on the need to time-share computers.
1961 John McCarthy's talk suggesting that computers should become a utility similar to a telephone service[1] .
1966 Douglas Parkhill publishes a book titled *Challenges of the Computer Utility* [2].
1995 Amazon starts selling books using the World Wide Web.
1999 Salesforce.com provides a software service on the World Wide Web accessible on payment.
1999 Ian Foster and Carl Kesselman publish a book titled *The Grid: Blueprint for a new computing infrastructure* and develop Globus tool kit to create a computer grid.
2004 Google starts free email service.
2006 Amazon introduces pay for use computing (Amazon Web Services) and Elastic Cloud Computing (EC2).
2006 Google starts offering Google Apps with 2 GB free disk space on their infrastructure.
2010 Microsoft starts providing a cloud service called Azure.
2011 IBM offers smart cloud.

[1] Utility Computing, *Wikipedia*,2013.
[2] Douglas F Parkhill, *The Challenges of the Computing Utility*, Addison-Wesley, Reading MA, USA, 1966.

Cloud Computing – Definition

There are many definitions of cloud computing. We give below an adaptation of the definition proposed by the National Institute of Standards and Technology, USA [2]. We define cloud computing as a method of availing computing resources from a provider, on demand, by a customer using a computer connected to a network (usually the Internet). There are five major characteristics of a cloud computing model. They are:

Cloud computing is a method of availing computing resources from a provider, on demand, by a customer using a computer connected to the Internet.

- A customer can avail any contracted computing resource such as processing power, storage space, or application programs from a service provider without human interaction.
- The computing resources can be accessed anywhere, anytime with any standard device which can access the web.
- The computing resources of a provider are pooled to provide the contracted service. The pooled resources may be geographically distributed across multiple data centres. The computing resources of a provider are shared by several customers. The resources are dynamically assigned to customers depending on the demand. Usually a customer has no knowledge of the location of the resources which may be anywhere in the world.
- Computing resources may be availed elastically by customers. A customer may request more resources when needed and release them when not required. From a customer's point of view the resources are unlimited. The customer pays only for the total resources used.
- Cloud computing systems are adaptive systems. They automatically balance loads and optimize the use of resources. A user is permitted to monitor and control resource usage thereby providing transparency in bills.

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Unique Characteristics of Cloud Computing as a Utility

Existing utilities such as a power utility have six major characteristics:

- Investment in infrastructure is made by a provider who also maintains it.

Since application programs are offered as one of the services by providers, consultancy on applications should be given as part of the providers' service offering.

- The service offered by the infrastructure provider is shared by several customers.
- The service is provided to customers on-demand.
- The service is elastic and scalable. In other words, customers assume unlimited availability of the service on demand.
- A customer pays only for what is consumed.
- A specified *quality of service* is assured by the provider.

Cloud computing as a utility has five additional requirements due to the special nature of computing. They are [3]:

- The infrastructure should be dynamic and virtualized. In other words, the infrastructure should take different 'Avatars' depending on the users' applications and their special requirements.
- Since application programs are offered as one of the services by providers, consultancy on applications should be given as part of the providers' service offering. This is often not emphasized in most publications as a distinctive characteristic of a computing utility.
- A computing utility requires two-way interactions between providers' infrastructure and a customer to enable customers to debug programs and to avail consultancy in case providers' application programs are used. A two-way interaction is not needed in an electrical power utility.
- Security of customers' data and programs are the responsibility of providers.
- As the location of the computers and data stores of providers is international, there is no clarity on what laws apply if there is a dispute between a provider and a customer.

Services Available on a Cloud

There are several types of services available on a cloud. We describe below three major services [2].

***Infrastructure as a Service* (*IaaS*)**

In this type of service a provider maintains computer servers, storage servers, and communication infrastructure, that is, data centre services. A data centre includes secure building(s) where

the hardware is located, uninterrupted power supply, air-conditioning, access control, and uninterrupted communication facility to access the hardware. Customers may deploy and execute their own systems and application software. The responsibility of the provider is only provisioning of hardware components of appropriate capacity. As different customers may deploy their own operating systems and applications running on them, the servers are enveloped by a layer of software which makes them behave like the hardware system demanded by the user. This is called *virtualization*. As many users may be simultaneously accessing the servers and each one may be running a different OS, there is a need to support several virtual machines. This is done by yet another software called a *hypervisor* [4]. IaaS is said to be multi-tenanted as many independent users share the infrastructure. Normally IaaS companies provide an Application Programmer Interface (API) to customers to conveniently use the hardware. IaaS providers also sign a Service Level Agreement (SLA) with their customers (see *Box* 5). The oldest IaaS provider is Amazon whose service is called Elastic Computing Cloud (EC2). Some other IaaS providers are Rackspace, IBM (SmartCloud+). All these providers have a virtualized system to cater to the programming environment demanded by diverse users of their hardware.

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Box 5. Service Level Agreement

A Service Level Agreement (SLA) is a legal document signed by a service provider and its customer which specifies, among other things, the following:

- Guaranteed availability of the service without failure. In computing it is typically 99.99% availability in a month
- The time allowed for the provider to respond to a service request
- Guarantee that a customer's data will be secure and not shared with other customers
- Frequency of back up of customer's data
- Billing policy
- Notification of any significant adverse events
- Run time inspection policy
- How long the data will be kept after the termination of the contract
- Recovery plan if there is a disaster
- How disputes will be resolved

In PaaS the provider maintains, besides the hardware infrastructure, software infrastructure such as an operating system, programming languages, and application program development and deployment tools.

Platform as a Service (*PaaS*)

This service is built over IaaS. In this type of service the provider maintains, besides the hardware infrastructure, software infrastructure such as an operating system, programming languages, and application program development and deployment tools. In other words, the provider caters to customers' requests of any systems program development environment such as .NET of Microsoft or a UNIX programming environment on the computing infrastructure and provides them on demand. Examples are: PaaS provided by Microsoft called Windows Azure, Amazon's Web Services, IBM's SmartCloud, and App Engine provided by Google.

Software as a Service (*SaaS*)

In this case a software vendor creates application software which runs on the infrastructure installed by an IaaS provider or on servers maintained by the application vendor which are connected to the Internet. This application software can be used simultaneously by many customers (this is said to be a multi-tenanted model). The application is accessed by a customer from the web using an appropriate access device. One such commonly used service is the email application program as was pointed out earlier. There are also third party software applications available on the cloud to manage customer relations, file tax returns, manage sales- force, and a variety of other common applications such as word processing, spread sheet, and database management.

In SaaS a software vendor creates application software which runs on the infrastructure installed by an IaaS provider or on servers maintained by the application vendor which are connected to the Internet.

Cloud Types

There are also several types of clouds [2]. They are differentiated based on the way they are deployed and access provided to them. We list below four types of clouds.

Public Cloud: The computing infrastructure maintained by a provider is available to anyone. It is located usually in the provider's premises and controlled by the provider. As a consequence the infrastructure is shared simultaneously by many cus-

tomers. There are both free and paid public clouds. For example, Google provides free storage space, office software, and email on its public cloud. Amazon's EC2 is a paid public cloud.

Private Cloud: The computing infrastructure is available for the exclusive use of a single organization. It may be a physically distributed set of interconnected computing systems belonging to the organization accessible to its members from anywhere, for example, from the far-flung branches of the organization. The infrastructure itself may be owned and maintained by the organization, outsourced to a third party, or it may be a combination of both. For example, a large bank with several branches may inter-connect their computing facilities to form a private cloud or request an infrastructure provider to design and maintain a cloud service for their exclusive use.

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Community Cloud: The computing infrastructure is available for the exclusive use of a specific community of users with shared interests. For example, a group of universities may decide to cooperate and interconnect their computing infrastructure and create a community cloud which may be accessed by any of its members. The infrastructure of a community cloud may be owned and operated by each participating institution in-house or may be outsourced. The forerunner of the community cloud was called grid computing [5]. A comparison of grid computing and cloud computing may be found in [6].

Hybrid Cloud: The computing infrastructure is a combination of two or more distinct entities, namely, private cloud, public cloud or community cloud. Each entity remains distinct but they are bound together by standardized protocols that permit data and application portability. For example, an organization may decide to keep part of its applications which it considers sensitive in its private cloud and execute other less sensitive applications on a public cloud. As another example, an organization may normally use a private cloud but as application load suddenly increases it may use a public cloud to handle the extra load. This is called 'cloud bursting'.

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Emergence of Cloud Computing

Cloud computing has become a reality due to three independent factors. They are: rapid growth of computer and communication technologies, changes in management philosophy, and the availability of excess computing capacities with giant corporations such as Amazon and Google. The most important technological improvement which has given rise to cloud computing is the rapid increase in communication bandwidth at competitive cost. A report published by the International Telecommunication Union [7] in 2011 states that between 2006 and 2011, the communication bandwidth available in the world has increased eight-fold and the cost of using the bandwidth has halved between 2008 and 2011. What this implies is that customers can use a computer half way across the globe as if it is in the next room. Bandwidth increase enables one to transport inexpensively, massive amounts of data almost instantly to remote computers. It also enables interactive use of computers regardless of their location.

CPU speed has been doubling every 18 months at constant cost. Besides this, disk storage capacity has been doubling every 15 months, again with no increase in cost. Increase of CPU speed has enabled interactive use of computers by multiple users in a time-shared mode, each user being under the illusion that the entire CPU power is available to him or her. High CPU speed is necessary to encrypt (see *Box* 6) all data sent on public communication lines (which is essential to ensure security of users' data in

Box 6. What is Encryption?

Plain text (e.g., email) may be read by anyone who is able to access it. Encryption is the process of transforming plain text to coded text called cipher text using an algorithm which uses a secret key. A cipher text cannot be interpreted by anyone unless he or she knows the secret key. Authorized persons are given the secret key which enables them to transform the cipher text to plain text. Currently a standard algorithm known as the Advanced Encryption Standard (AES) is widely used. AES uses a secret binary key whose length varies between 64 and 256 bits. It is difficult to break AES encrypted code, particularly when it uses a 256 bit encryption key. More details about encryption may be found in [*].

* V Rajaraman, Electronic Commerce, Secure Messaging, *Resonance*, Vol.6, No.1, pp.8–17, 2001.

cloud computing) and decrypt the encrypted data at the receiving side. The increased disk capacity at no increase in cost has made it practical to store many programs and large databases of multiple users on the disks of large computers at remote locations.

Concurrently there have also been improvements in software systems. The first important development was the maturing of operating systems which allowed sharing of a computer by several users. The other major development was the development of virtual machine operating system by IBM in the mid 60s. The idea was to introduce a software layer on a computer's basic operating system so that it mimics the programming environment of another computer. In other words a computer A with its operating environment can be made to 'look and feel' to a programmer like another computer B with a different operating environment. As we mentioned earlier this is called virtualization. Virtualization is essential to allow multiple users with diverse applications requirements to use a group of servers available with a provider. In other words the computer infrastructure (servers, storage, and network) of a provider assumes many 'avatars' as demanded by different users. Further, these 'avatars' live simultaneously as there are many customers using the system at the same time. Complex virtualization software and software to manage multiple virtual machines, called a hypervisor, was developed by many companies during the last decade.

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In addition to advances in computer hardware, software, and communications, management philosophy has been changing in the last decade. Managers have been concerned about the mounting cost of the computing infrastructure in their organizations. All clerical operations are now computerized. Desktop computers have replaced typewriters and centralized computer servers are required to store databases of organizations and to process data. Each desktop computer requires licensed software such as office software whose cost adds up. A more disturbing aspect is the rapid obsolescence of computers requiring organizations to budget recurring capital expense almost every three years. The cost of specialized IT staff to maintain the hardware and software

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of the computing infrastructure is another irritant. It has been realized by the top management of organizations that computing is not the 'core activity' of their organizations; it is only a means to an end. Management trend currently is to 'outsource' non-core activities to service providers. Thus the availability of computing as a utility which allows organizations to pay service providers for what they use and eliminates the need to budget huge amounts to buy and maintain large computing infrastructure is a welcome development.

Amazon, an e-commerce company, started operations in 1995 selling books using the Internet infrastructure. It later expanded and started selling may other items to customers all over the world. Customers found e-buying convenient and Amazon's business expanded rapidly. Amazon had to establish computing and communication infrastructure to cater to the maximum demand including high demands which are seasonal, for example, during Christmas. The computing facility installed by Amazon was not fully utilized; there were long periods of very low utilization (less than 10%). Amazon saw a business opportunity to earn by selling the excess computing infrastructure it had built up. In 2006 Amazon floated a business called Amazon Web Services which sold computing infrastructure on demand using the Internet for communication [8].

Meanwhile Google became a very successful company providing free information search service on the Internet. To cater to an increasing worldwide clientele, Google had to maintain a large computing infrastructure and size it to cater to the maximum expected demand. It started, in 2004, a free email service for all its customers using this infrastructure and in 2006 expanded its offerings to include free office productivity applications (such as word processing) called Google Docs and gave all its users 2GB free disk space. Google also saw a business opportunity to sell their excess hardware capacity and in 2012, started Google compute engine as a paid cloud service.

Amazon saw a business opportunity to earn by selling the excess computing infrastructure it had built up.

Thus the emergence of low-cost broadband communications,

rapid increase of speed and storage capacity of computers at constant cost, the trend towards outsourcing non-core activities (which included computing), and the availability of computing infrastructure on the Internet on demand as a 'pay for what you use' service combined to make cloud computing a reality.

The emergence of low-cost broadband communications, rapid increase of speed and storage capacity of computers at constant cost, the trend towards outsourcing non-core activities, and the availability of computing infrastructure on the Internet on demand as a 'pay for what you use' service combined to make cloud computing a reality.

Advantages and Disadvantages of Cloud Computing

Based on our discussions we list below the advantages of cloud computing.

- Reduction in capital expense of organizations as they need not invest in large computer infrastructure and repeatedly invest as computers become obsolete.
- Availability of a host of software systems on a 'pay for what you use' basis.
- Elastic and scalable computing infrastructure available 'on-demand'. An organization can request more computing power as and when it is needed with an illusion of infinite availability of processor power and storage. This facility is a great advantage for 'start-up' companies which need not unnecessarily invest in huge infrastructure. As and when their business expands they can request more computing power from a provider and pay only for what they use.
- Assured Quality of Service based on Service Level Agreements (SLA) which organizations can sign with providers.
- A cloud service may be designed to be 'self-healing'. In other words if a server on which an application is running fails, the system can be designed to shift the application automatically to another server. This is possible in a cloud provider's infrastructure as the available hardware is abundant and the system is elastic. In theory this is possible but in practice programming such a self-healing system is not easy.
- Organizations can use a cloud infrastructure to automatically back up their important data. This will allow quick recovery if data is corrupted.
- Organizations can archive data which they require occasionally for legal purposes on cloud storage.
- Disaster recovery will be easy if crucial applications are run

Disaster recovery will be easy if crucial applications are run simultaneously on the infrastructure of a cloud provider located in different geographical areas (e.g., in different cities).

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You may wonder what the risks in using a cloud service are. Some of the perceived risks are listed below:

- Using a cloud crucially depends on un-interrupted communication with the cloud provider's infrastructure. Failure of communication will cut off a cloud service. It can be mitigated by providing a second independent (redundant) means of communication. For example, if one connection to the cloud uses fibre optic communication, another could be by wireless system such as WiMAX [5].
- Whenever data or program is sent on a publicly accessible communication system and data is stored in a shared disk system there is a danger of eavesdroppers tapping the communication line and stealing or corrupting data or stealing it from disk storage. To mitigate this, it is essential to use strong encryption of all data sent to the cloud on a communication system and also encrypt data before storing.
- Another risk is the deterioration of the quality of service of a cloud provider or a provider ceasing operations due to bankruptcy. In such a case organizations must have a backup plan to shift their applications to another provider. The main difficulty in doing this is the lack of standardization of cloud services provided by different vendors. Thus an organization must explore the availability of pairs of providers who follow similar standards so that extensive rewriting of software systems can be avoided.
- Complex legal problems may arise if providers' servers are in a foreign country and an organization's programs and data are corrupted or stolen. An organization must clarify what laws apply while signing the Service Level Agreement with a cloud services provider.
- A recent problem is the clandestine surveillance of data traffic on the Internet by the intelligence agencies of USA. and UK. As cloud providers' infrastructure is spread throughout the

Failure of communication will cut off a cloud service. It can be mitigated by providing a second independent (redundant) means of communication.

world it may not be wise to use those services, particularly if the data to be processed or the program is sensitive. Even strong encryption may be broken by these intelligence agencies as they have access to huge computing resources [9]. One may mitigate this by using only cloud providers in one's own country

Often security breaches are due to improper controls within the organization.

Applications Appropriate to Outsource to a Cloud

As we saw in the last section, the major reservation that organizations have about shifting all their application software to a cloud provider is due to concerns on security even though many experts feel that this is not as serious as it is made out to be [10]. Often security breaches are due to improper controls within the organization. Cloud providers' sole business is selling data processing services. Thus these providers employ very good professionals and follow best practices to ensure security. Decision makers, as of now, are cautious about handing over all their data processing to an outsider. We give the following guidelines on what applications can be outsourced to a cloud computing service provider.

- Routine operations such as payroll processing, order processing, sales analysis, etc.
- Hosting websites of organizations. Traffic to such websites is unpredictable and there may be surges in demand which is handled better by a cloud provider as the provider is better equipped to provision not only more computing resources on demand but also larger bandwidth to access the websites.
- Those which require high performance computing or specialized software not available in the organization. For example, an engineering company may have a specialized design problem which may require a high performance computer or a special application software package.
- Parallel computing, particularly tasks in which a program is executed in a large number of processors concurrently with multiple data sets to speed up computation. An example is to find the websites in which a specified set of keywords occur. The universe of websites may be partitioned into, say 1000 sets. Each set may be given to a computer with a program to search

Traffic to websites of organizations is unpredictable and there may be surges in demand which is handled better by a cloud provider as the provider is better equipped to provision not only more computing resources on demand but also larger bandwidth to access the websites.

if the keywords occur in them and note the URLs of the websites where they are found. All the 1000 computers search simultaneously and find the URLs. The results are combined to report all the URLs where the specified keywords occur. This speeds up the search almost thousandfold. An open source software suite called Hadoop MapReduce[11,12] has been developed for writing applications on the cloud that process petabytes of data in parallel, in a reliable fault-tolerant manner which in essence uses the above idea.

- Applications which are seasonal requiring large and fast computing for a short period, for example, processing results of an examination conducted during recruitment of staff once or twice a year.
- Archiving data to fulfill legal requirements and which are hardly used day to day. They may be encrypted and stored in a cloud provider's storage.

Conclusions

Cloud computing is here to stay. Some professionals consider it is as the biggest development of the decade in computing. Every organization including educational institutions should have a cloud strategy on how to make best use of this new facility. As we pointed out, using a cloud computing facility crucially depends on the availability of broadband communication. Broadband communication infrastructure spanning the entire country is vital if this technology is to be used widely. There are four major concerns which organizations have about shifting their applications to the cloud. They are:

Every organization including educational institutions should have a cloud strategy on how to make best use of this new facility.

1. Doubts about the security of their programs and data if it is outsourced to a cloud provider.
2. Difficulty of shifting their applications from a provider if the quality of its service deteriorates or the provider ceases operation.
3. Failure of communication to the cloud or failure of computing servers/storage maintained by a cloud vendor.
4. The distribution of the computers across national boundaries

of multinational cloud providers which may lead to intractable legal problems in case there are disputes. Surveillance by foreign intelligence agencies is a new threat.

With current technology some of these concerns are more psychological than real. As we pointed out, it is essential to encrypt data when they are sent to a cloud. Most often security breaches take place within an organization due to disgruntled employees or carelessness. Professional providers have better expertise to ensure security. The second concern is legitimate. At present there is no standard which is universally followed by vendors to promote inter-operability. It is expected that the technology will mature and lead to a computer utility in which providers adhere to a common standard. In such a case users interact with brokers of services rather than directly with individual providers. Brokers will have an arrangement with multiple service providers [1] to allow optimal use of services of the vendors and economical service to customers. To mitigate the third concern cloud users must arrange redundant communication lines to their providers. Providers normally have redundant servers and service failure is rare. The only solution to the last concern is either establishing an international organization for clouds such as the International Telecommunication Union governed by treaty or using only the cloud services of providers within one's own country.

It is expected that the technology will mature and lead to a computer utility in which providers adhere to a common standard.

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Suggested Reading

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