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Cloud Computing in Higher Education in India

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Abstract: Cloud computing comprises of cooperation and coordination of different computing services to provide very high computing power for acquisition and analysis of wide spread out sources of data. It greatly helps in lowering the cost while maximizing the ability to process the required information. With cloud computing universities and other institutions can better manage their labs, research facilities, classrooms and libraries, etc. The students and teachers can benefit far better from it in individual and collaborative work because of easy access features provided by the cloud. This paper reviews the growth of cloud computing, its benefits and problem, features of common cloud computing services, and the various issues to be considered in selecting the most appropriate cloud computing service for academic institutions. The paper also discusses the importance of virtualization in growth of cloud computing.

Keywords: Cloud Computing, Higher Education, Information Technology, Virtualization

I. INTRODUCTION

Prof. John McCarthy (1961) coined the term cloud computing to highlight the concept of coordination of various computing platforms in retrieval of information from an ever widening area of information database [1]. Possibly it was so named because the widely scattered sources of data simulate the appearance of smaller areas as circles from a distance, and many circles combining and overlapping each other resemble the appearance of a cloud. Also, the network had earlier been represented as a collection of overlapping circles appearing like a cloud. Also has the feature of constantly changing, enlarging and diversifying as clouds do.

The term cloud serves not simply to highlight something new in some area; it involves designing of intricate newer software and principles for interaction and retrieval of information over a much wider area, to improve its efficiency, and to take care of security concerns with future growth in mind.

True to the imagination of McCarthy [1] cloud computing has received acceptance at a pace not commonly observed before. It has great potential in teaching and research which rest on exchange and retrieval of information and of educational management at each level; more so in apex educational institutions [2]. It is for these reasons that cloud computing is being rapidly adopted in by the universities. Surveys in 2016 reported a marked increase in cloud computing in India. Investment in the field of Information Technology grew by almost six percent in the year 2015-2016, which comes to an investment of about $71 Billion [3]. From the current trend of acceptance it appears that surveys for 2017 will see exponential growth in this field, and more and more universities are likely to opt for and greatly augment their facilities of cloud computing for administrative and educational purposes.

Though Information technology has become indispensable in all advanced seats of learning, an initial survey carried out by us in central universities has revealed inadequate knowledge and understanding about the scope, difficulties and problems in cloud computing. Also there is a need to have better knowledge about the essential features to be considered while evaluating selection of the type of cloud computing considering the requirements and available resources.

A few investigators have studied the state of cloud computing in some central universities, it was observed that most of the libraries were using cloud computing in some form or the other depending on available finances and personal preferences [4]. However majority of librarians were skeptical about the security problems. In another study the same author examined the prospects of cloud computing in Banaras Hindu University library system, and the problems being faced by them. The study found that Banaras Hindu University library staff is ready to work in cloud environment [5]. A survey on cloud computing in India covered the history of its development and some essential technical background, but main attention was given to public governance and army cloud [6]. Though there are several studies on the use of cloud computing services in libraries but the study on cloud computing services for the whole institution including the teachers and the students are very few. Therefore there is a need to re-examine the whole issue with special reference to teaching and research in various aspect of higher education, including arts, science, social science, medicine, engineering and other specialties. Also there is a need to incorporate cloud computing as short term course with an interdisciplinary approach to impart knowledge in different aspects of cloud computing.

This paper reviews the studies that have examined the scope of cloud computing for universities. A survey done in Ming Chuan University of Taiwan has reported that students and teachers agree with the fact that the cloud has improved the IT standard of the organization [7]. More advance researches can be done in universities with the help of the collaboration feature offered by cloud. Cloud computing facilitates have led to better management of institution's resources, thereby reducing the investment cost [8].Cloud computing technology has the potential to offer a greener future by reducing energy consumption. Further, the

Universities having their own internal clouds can provide services which will eventually benefit the students better [9].

In this regard a survey of students was also carried out to access their attitude towards cloud services and their knowledge about the features cloud computing provides to fulfil their requirements. A broad format to work out the various features of cloud computing has been drawn on the basis of the response of the students. Convenience sampling was conducted on the target population. The sample size for study was taken as 107. A five point Likert scale questionnaire was administered on the sample and the results were analyzed and it was found that students have a positive approach towards cloud adoption (Unpublished personal data).

II. SIGNIFICANT MILESTONES

The significant milestones in the development of cloud computing have been summarized in Table 1. It is obvious that development from 1960 through 2006 were primarily related to gradual development in Information Technology. Interest in clouding computing picked up from 2008, but the subsequent period showed rapid advancement and use of cloud computing in management, teaching and research.

Table1: Milestones in Cloud Computing

YEAR	*DEVELOPMENT*	*CONTRIBUTION*	*CHALLENGES*	*FUTURE SCOPE*
1960	Time sharing systems	Allowed integration of tasks from different locations With single mainframe system	Complex hardware and operating system specifications were the challenges	Query and response system
1966	Development of Computers, Notebooks, Servers, Telecom, Software by Compaq	Quality solutions by compatible products.	Coping up with new evolving technologies.	More efficient products.
1970	Full time sharing solutions	Less waiting time	More resources occupied than required.	Efficient resource utilization; decreased waiting time
1977	ARPANET (Advanced Research Projects Agency Network)	Foundation of internet by use of TCP/IP protocol for the first time.	Supported communication only within a network.	Protocols developed for communication between different networks.
1981	CSNET (Computer Science Network)	Took networking to a higher level.	It was an extension to networking system	Resulted in Worldwide spread of internet
1990	Virtual private networks	Distributed computing	High security concerns when connected to a VPN via mobile.	Better and more efficient algorithms available
2000	Cloud computing	Higher speed software, platform and other infrastructure	Better security; availability of large number of extensions	Improved features lead to greater acceptance
2006	Amazon	Introduction the concept of Elastic Compute Cloud		
2008	*NASA's Open Nebula*	*A European Commission funded project*	*First open source software*	*Creating private clouds, hybrid clouds, and federation clouds*
	IROMS	European Commission funded project	A landmark in real-time cloud environment	
	Google App Engine beta (April 2008)			
	Gartner (mid-2008)	an American research and advisory firm	Relationship among consumers, users and	Resulted in differential growth of

		providing information technology	sellers of IT services	IT products in different areas
	Microsoft Azure (announced in October 2008)			
2010	Microsoft Windows Azure (released on 1st February 2010)			
	Rackspace Hosting and NASA launched Open Stack) (July 2010)	Open source cloud software	Possible to run cloud services on standard hardware.	This was a great step in cost curtailment
2011	IBM Smart Cloud (March 1, 2011)	Developed to support Smarter Planet	Cloud computing is a critical part of the various components of Smarter Computing foundation	
2012	Google Compute Engine (May 2012)	Released in Preview		
	Oracle Cloud (7th June 2012) announced	It was the first cloud to provide access to an integrated IT solutions between Applications (SaaS; PaaS)-Platforms (PaaS) and Infrastructure layers (IaaS)		
2013	Google Compute Engine (December 2013)	Released as General Availability		
2014	Microsoft Azure (released on 25th March 2014)			

Table 2: Definitions of cloud computing

III. CLOUD COMPUTING TECHNOLOGY

National Institute of Standards and Technology (NIST) [10] has listed the following formats for cloud computing:

Three service format:

1. Software as a service (SaaS): The required hardware, networking software and operating system are provided by the service.
2. Platform as a service (PaaS): Operating system, networking software and hardware is provided by the service provider, while the client has to manage its required software and applications.
3. Infrastructure as a service (IaaS): Only the hardware and network are provided by the service. The users have to manage for their operating system, software and applications.

Four deployment format:

1. Public cloud: It is designed for use of general public. All the services are offered over the internet and are owned and operated by the cloud provider.
2. Private cloud: As against the public cloud this service is designed for the specific organizations. After installation, the set-up is managed either by the organization itself or by a third party to be appointed by the organization.
3. Community cloud: In this service, a few organizations come together to share the cloud facility. Like the private cloud, this service has to be maintained and operated by the organization itself or by a third party to be appointed by the organization.
4. Hybrid cloud: In this system part of cloud facility is obtained from public cloud and part from private cloud.

Five essential characteristics:

1. On-demand self-service: In this set up the resources are provided to the user on demand. The user has option to manage these computing resources.
2. Resource pooling: In this setup, the resources made available from a shared pool of data.
3. Broad network access: In this set up services are available over internet and/or over a private network.
4. Rapid elasticity: In this set up extent of services can be scaled as per the requirement in what is called as horizontal or vertical scaling technique.
5. Measured service: This setup is something like metered services. The user pays only for the extent he uses the services.

A. Definitions

Cloud computing may be differently defined based on the basis of technology, structure, function, organization, and other features. Some of the famous definitions are summarized in the following table.

S.NO.	*AUTHOR*	*YEAR*	*DEFINITION*
1	Mell and Grance [10]	2011	Enabling on demand network access to a shared pool of configurable computing resources
2	Mell and Grance [10] Voorsluys, Broburg and Buyya [11]	2011	A technology which can be understood as a cluster of three fundamental models: Infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS)
3	Bhanti, Lehri and Kumar [8]	2011	A technology which enables application access to Internet connected device present at distant datacenter.
4	Dangare and Indi [12]	2014	Cloud computing is defined as a path to get to the storage space and the resources which are available over a network. The computing power we get through cloud computing is provided on demand.

B. Benefits of cloud computing

Cloud computing has several advantages. With cloud computing it is possible to quickly and reliably retrieve, combine and analyze information from wide spread out sites. These are summarized in the Table 3.

Table 3. Advantages of cloud computing

S.NO.	*AUTHOR*	*YEAR*	*BENEFITS*
1.	Hiltz and Wellman [13]	1997	1. Mastery of course material 2. Accessibility 3. Group activities 4. Collaborative learning
2.	Papa, Perugini & Spedaletti [14]	1998	1. Reduction of IT budgets in schools
3.	Wen Lung et.al. [7]	2012	1. Supports both virtual and traditional classrooms 2. Assists both teacher and students in improving their performance
4.	Kumar and Murthy [9]	2013	1. Reduce information and Technology Costs 2. Provide better student services 3. Access to a database offering wide variety of academic resource. 4. Access to applications from anywhere 5. Reduce hardware, power and management costs
5.	Bulla, Hunshal & Mehta [15]	2015	1. Increases computing power. 2. Versatility 3. High extendibility 4. On demand service 5. Extremely inexpensive 6. Pre-built solutions and services

C. Cloud Services and Deployment Models

The institution needs to have a clear idea about the service they have to use depending on the scope of these services to suit their requirement (when to use SaaS, PaaS, and IaaS). This can be understood by the applicability of different services in cloud computing. The scope of different services is shown in Table 4.

Table 4. Comparison of features of the three cloud service platforms

On-demand self service	*Resource pooling*	*Broad network access*	*Rapid elasticity*	*Measured service*	*Services*	*Private*	*Hybrid*	*Public*	*Community*
+	+	+	+	+	SaaS (Software as a service)	+	-	+	+

+	+	+	+	+	PaaS (Platform as a service)	-	+	+	+
+	+	+	+	+	IaaS (Infrastructure as a service)	+	+	-	+

There are five ingredients of essential service. Though all the services incorporate these features but their efficiency may vary in different areas. Further, all types of clouds are not covered by all services. Therefore, the institutions planning to avail of cloud computing service should carefully evaluate the various features and options extended by these services prior to taking final decision to hire them.

IV. VIRTUALIZATION IN CLOUD COMPUTING

Creation of something which is not real but behaves like the real thing is called virtualization. Oxford dictionary defines virtual in computing as creating something not physically existing as such but made by software to appear to do so. In other words virtualization is creating a software-based representation of something physical. Virtualization can be made to represent servers, storage, and networks. This can help to greatly reduce the cost of any set-up. Several hardware and software are required to communicate with different clouds through LAN and internet.

Use of virtualization helps to do away with extra hardware that would have otherwise been required to perform additional work. The other benefits of virtualization include reduction of capital and operation costs, minimization or elimination of downtime of the physical set-up, increased efficiency and responsiveness. The whole set-up runs faster, data management becomes easier, etc. The concept of virtualization came up in 1960s.

Virtualization software was initially designed to logically divide the computer storage and interacting devices. With further advancement the meaning and scope of virtualization has drastically changed. It is now possible quite safely and effectively to improve and enhance the efficiency of the cloud computing set-up. It is also a green technology in that it does not use physical resources to the extent it would have been required without the process of virtualization. It can greatly help to improve the cloud infrastructure of academic institutions (Fig. 1).

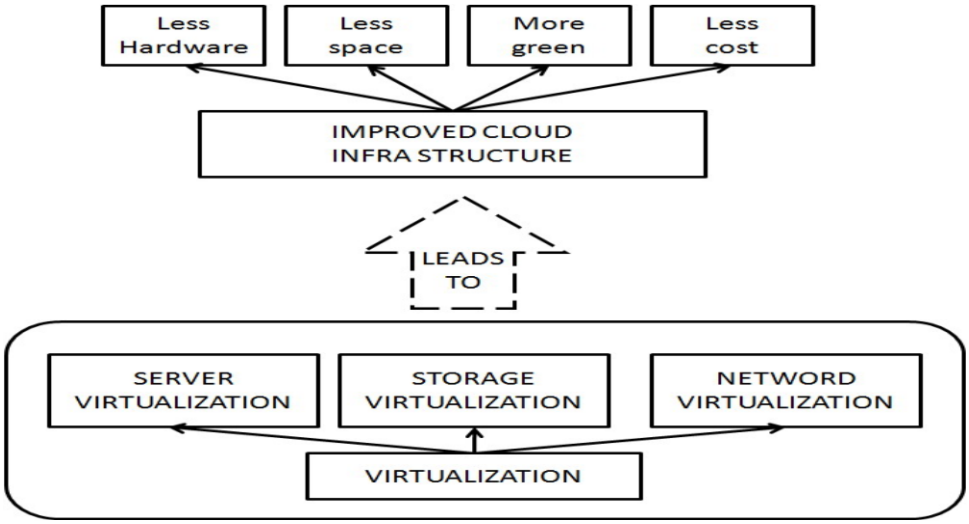

Fig. 1 Virtualization

Table 5. The following table illustrates virtualization in detail.

WITHOUT VIRTUALIZATION	*WITH VIRTUALIZATION*
Components are: physical hardware, an operating system and various applications installed on that operating system.	Components are: physical hardware, hypervisor, operating system instances and a management software.
Only one operating system can be installed on one physical hardware.	Various operating systems can be installed on one physical hardware.
Operating system is tied with the physical hardware so if anything goes wrong with the hardware the operating system halts.	The operating system instances are installed over the hypervisor which makes it a more robust environment.
Simple architecture which is easy to handle but more chances of interruptions which may lead to failure.	Complex architecture which needs advance knowledge but the interruptions can be managed easily through migration.

V. ORGANIZATIONS AND SCOPE OF CLOUD AND FOG COMPUTING

The concept of cloud computing was introduced to get the benefit of information available worldwide more efficiently at a reduced cost. However, the wider approach led to several security and privacy problems. This led to the development of the concept of Fog computing.

In Fog computing the area of interaction was greatly restricted by specifying the participating database services.

The possibility of security breach was thus minimized at the cost of wider area of approach available in cloud computing. However, a provision was made to allow interaction between Fog and Cloud services when necessary.
Wider scope of information from cloud computing, this type of computing has great potential for use in education, administration and in several other areas.

Fog computing provides sufficient information for most purposes. However it may sometimes be necessary to gather more information by use of cloud computing services. Therefore a link has been provided for interaction of the two types of computing under such circumstances.

The pattern of flow and use of information through LAN, internet, Fog computing and Cloud computing is shown in the Fig 2.

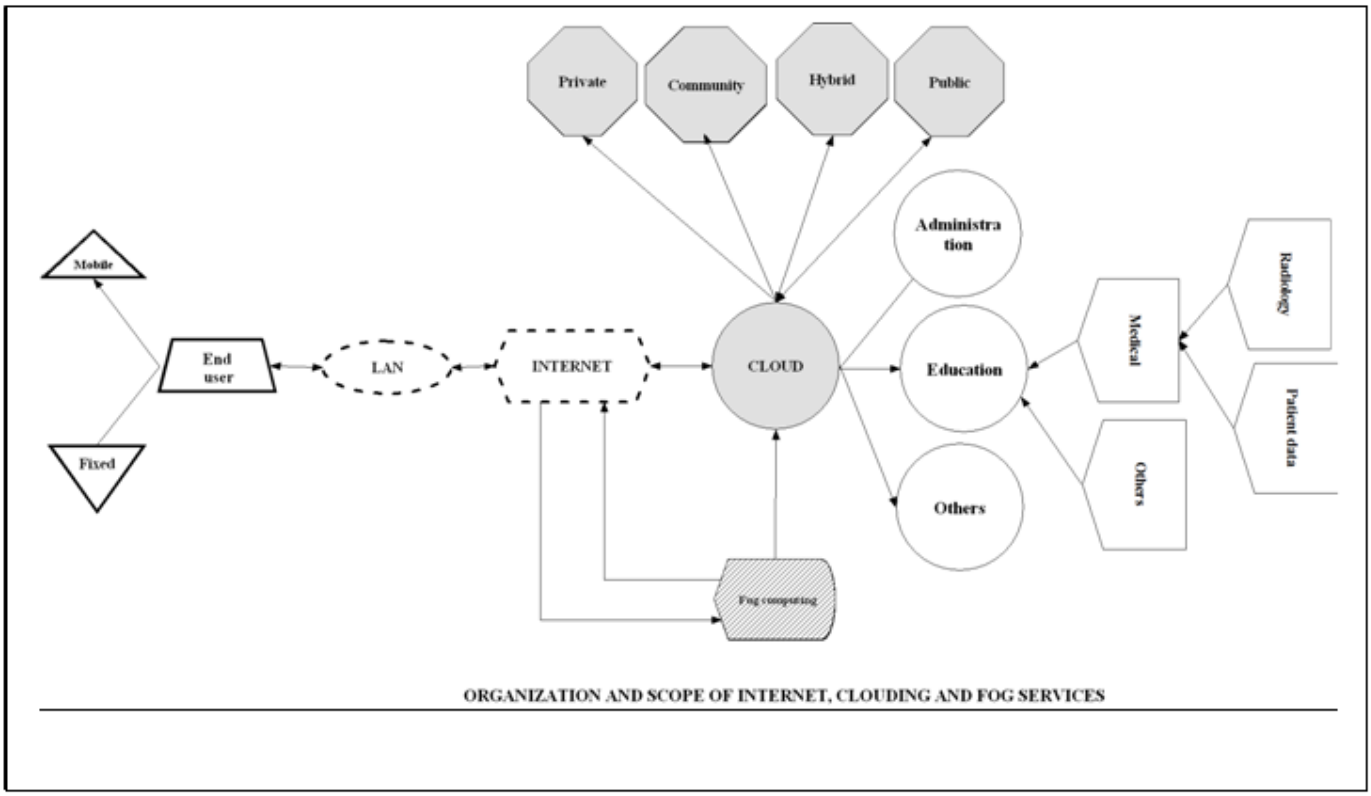

Fig. 2: Interrelationship and scope of Cloud and Fog computing

VI. FEATURES OF FAMOUS CLOUD SERVICES

The essential features required of a cloud computing service include convenience and reliability of use. Further, they must be user friendly and cost effective. Table 6 compares the features of famous cloud computing services which will enable the institutions deciding to hire them for selecting the service most suitable to their requirement.

Table 6: Comparison of essential features of the famous service providers

S.No.	*PARAMETER*	*AMAZON CLOUD*	*IBM CLOUD*	*MICROSOFT AZURE CLOUD*	*GOOGLE CLOUD*
1.	Goal	Provision of resources as per the requirement of the client.	Provision of highly scalable and distributed computing environment.	High speed computing for less money.	Providing for simultaneous working of different services simultaneously.
2.	Types of services offered	SaaS, PaaS, IaaS	SaaS, PaaS, IaaS	PaaS, IaaS	PaaS, IaaS

3.	Benefits	Provide high durable storage at low cost on demand. Efficient databases and resource management tools.	Good data analytics solutions. Services as per the choice of user. Hybridization benefits.	The resources can be scaled as per the requirement. Flexibility Less cost Joint cloud benefits.	High secure environment, reliable data storage & computing solutions
4.	Facilities	Compute, storage, databases, networking, developer tools, security, analytics, IOT, mobile and enterprise applications	Compute, storage, databases, and tools	Compute, storage, mobile, data management, messaging, media services, CDN, developer, management and machine learning	Compute, storage and databases, networking, big data, machine learning, management tools, developer tools and security
5.	Computing method	Virtual Machine as Amazon's Elastic Compute Cloud (EC2)	Total management responsibility of IBM	Virtual machine system similar to Amazon Machine Image (AMI)	Virtual machines on Google Platform using Google Compute Service.
6.	Big data analysis	Analyzed with the Elastic Map Reduce.	A set of tools offered to analyze big data.	Cortana is used for big data analytics.	Dataproc, Managed by the service provider.
7.	Mobile services	Mobile hub portal to develop applications for mobile.	Bluemix to incorporate feature for mobile applications.	Mobile application services are a part of Azure service suit.	Firebase platform available for mobile services.
8.	Networking	Virtual Private Cloud (VPC) which promotes remote networks.	Resources available as per the requirement over the network.	Virtual Network (VNET) allows virtual machine isolation.	Every instance of Google compute engine corresponds to a single network.
9.	Internet of Things (IoT)	IoT solutions provided by Amazon.	IoT devices can be developed using the fully managed services provided by IBM cloud.	IoT Hub is IoT solution managed by Azure.	IoT supported by Google through Pub/Sub.
10.	Communication service provided by	Amazon EC2	Web sphere, Info sphere, Warehouse, Lotus live Connections	Lync online Exchange online	Google wave Google groups Gmail
11.	Interactive modeling tools	Amazon cloud front	Info sphere warehouse	System management server, Hyper V	Sketch up
12.	Web traffic monitoring	Amazon Cloud Watch	Tivoli live monitoring services	System center server management suites	Google analytics
13.	Support for control systems and error tracking	AWS cloud trail	Cognos connection	System management server	Google code
14.	Pricing	Number of hours of use	Customized discounting pricing / fixed monthly billing.	Number of minutes of use, & short term commitments with discounts.	Sustained use Pricing (Discounts are offered for long use in a month)

VII. COST OF CLOUD COMPUTING IN INDIA

The investment cost for obtaining cloud services mainly depends on type of hardware, area of the cloud to be covered and length of maintenance contract. The cost does not vary much between small and large number of users, rather it may be slightly higher for smaller number of users.

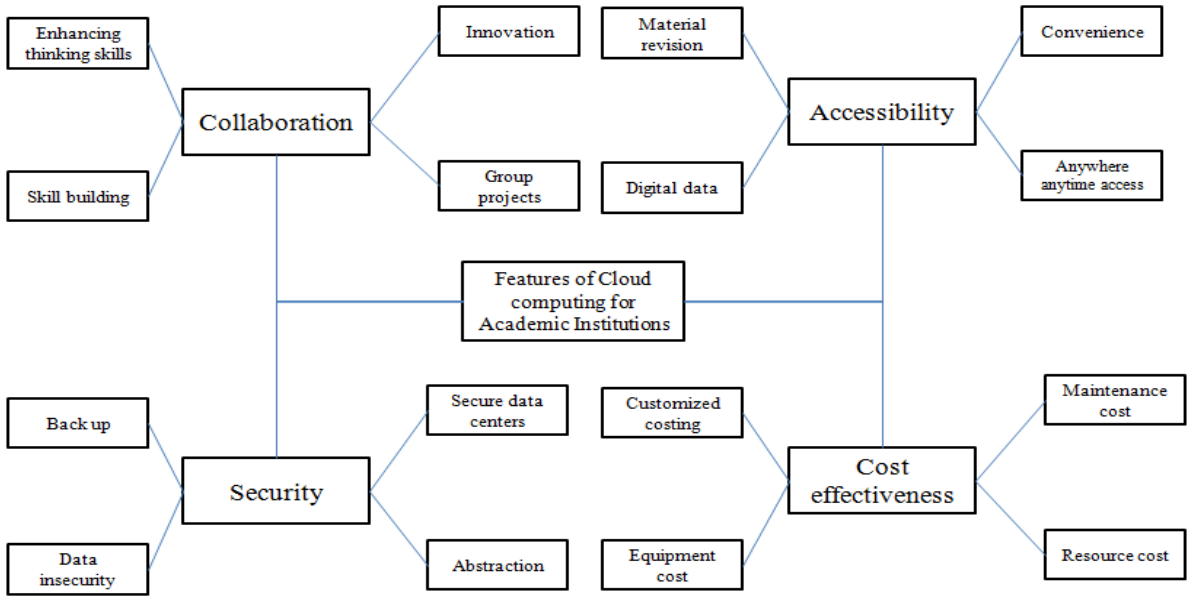

Fig. 3: Dimensions of Cloud Computing for Academic Institutions

For example the cost is approximately Rs. 18000/- per month for small users (up to 25 users) and Rs. 17000/- per month for large institutions (up to 10,000 users) such as Universities and other large institutions. Cloud service providers also offer structured and scalable resources and pricing to allow users to obtain cloud services as per the available resources and requirements. Figure 3 summarizes the various issues to be examined while evaluating the cost of obtaining cloud facility

CONCLUSION AND FUTURE SCOPE

Though cloud services are used quite often there is inadequate knowledge about the different ingredients of cloud computing among students as well as in administration. The cloud computing has much more to offer than what it is being used for in institutions of higher learning. Further work needs to be done on proper planning in selecting the type of cloud service most suited to individual institution's needs. There is a special need to formulate guidelines for selecting cloud computing facility for institutions of higher as well as for institutions of lower education in order to derive maximum benefit from these services and cost curtailment. This will be possible with a larger survey of various educational institutions and discussion at a higher forum to be especially constituted for this purpose.

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