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Cloud Computing for Higher Education Institutes: Architecture, Strategy and Recommendations for Effective Adaptation

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Abstract

Due to the prevailing financial crisis and the growing needs, higher education (HE) institutes are facing challenges in providing necessary IT support for educational, research and development activities. Cloud Computing (CC) environment can rescue HE institutes from the above mentioned challenges The HE institute must exploit the opportunities afforded by CC while minimizing the associated security risks to allow access to advanced IT infrastructure, data centers, and applications and protect sensitive information. In this paper, CC architecture for HE institute containing the various deployment models, Service Models and user domain is proposed. For smoothing the migration from traditional system to CC based system a five phase strategy is presented. We finally provide the recommendations for a successful and efficient migration from traditional to cloud based system.

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Keywords: Cloud Computing, Cloud Architecture, IaaS, PaaS, SaaS

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1. Introduction

The role of Higher education (HE) for overall development of society is dully acknowledged. The collaboration between universities, government and industry, researchers and students has proven their contribution to the transformation of society and the entire world economy [1]. During the last few years, the universities offering higher education are making transition to research universities [2,3] and these universities use IT infrastructure as foundation for their educational activities and Science research. With the evolution of technology, number of educational services migrates from traditional form to the online form. These educational services, requires an adequate IT infrastructure using the proper technologies, guaranteeing the access of large number of users, fast and secure service access.

The HE landscape around the world is in a constant state of flux and evolution, mainly as a result of significant challenges arising from efforts in adopting new and emerging technologies. It is increasingly acknowledged that using technology effectively in HE is essential for providing high quality education. The adaptation of new technology is very slow mainly due to the cost implication. The transformation requires massive funding and investment, which are difficult to come at the times of deep recession and depleted budget reserves of government and private institutions. The funding offered to HE institutes has sharply decreased in times of economic slowdown, leading to financial crisis in HE institutions. To address their financial shortfall, HE institutes are resorting to a variety of cost-cutting measures, including significant cuts to IT budgets.

In the past few years the concept of "Cloud Computing (CC)" has emerged as a viable and promising solution to the challenges associated with shrinking IT budgets and escalating IT needs. CC is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Users can access these resources from any computer with a high speed Internet connection while having no other connection to the hardware that holds the source software [4]. Because computation takes place on a remote server, the user's hardware and software requirements are much lower than they would be otherwise, reducing both cost and maintenance requirements [5]. For this reason, CC holds appeal for HE institutions seeking to reduce IT budgets.

Today's students do not know a world without the Internet. Through programs such as Facebook, Twitter, Gmail, and Flickr, students already are well versed and frequent consumers of cloud-based technologies [6]. Accordingly, they expect to have 24/7 access to digital technologies in their educational environment, including cloud technologies which support social media. In addition, research has demonstrated that cloud-based solutions can be very effective in supporting collaborative and cooperative learning as well as other socially oriented theories of teaching and learning [7]. With the opportunity to facilitate these student needs, coupled with the cost-savings,

educational institute administrators are asking IT leaders to provide the necessary training, support and resources to implement and support these cloud-based strategies. Acknowledging the need and potential leading IT providers are coming up with cloud based software for HE institutes. The cloud-computing market is projected to grow from $40.7B in 2011 to $240B in 2020 [8]. The trend in HE sector is clearly shifting towards cloud services adoption. According to a 2011 study by CDW, only 5% percent of U.S. college and university respondents were not considering a cloud migration. About 29% had developed a written strategic plan for the adoption of cloud computing, with 28 percent in the midst of implementation [9]. The Higher Education Funding Council for England has developed a new program that would invest up to £10 million in cloud computing and shared IT infrastructure for universities and colleges.

2. Benefits and Characteristics of Cloud Computing

The HE institution must weigh the pros and cons of trying new technologies, especially those having limited budgets. The benefits of cloud computing solutions over traditional technologies are:

- **Mobility:** Nowadays students extensively use mobile devices to access data. Students want to refer textbooks, syllabi and even do their homework online via their Smartphone, laptop or tablet. Cloud-based classroom applications are the best way to facilitate this exchange between student and faculty.
- **New Services**: Many colleges and universities today are starting to offer virtual classrooms via online learning and video conferencing. Cloud servers allow institutions to offer these innovative teaching methods that can be accessed by students from anywhere via tablets, computers or mobile devices.
- **Storage:** Scalable cloud storage offers colleges and universities the ability to quickly expand storage capabilities. HE institutions have huge data to contend with, including everything from student and faculty information to course material. This data can quickly overwhelm traditional on-site storage options. Additionally, if a natural disaster happens or if a server fails, colleges and universities can quickly lose data that may never be retrievable again. Cloud storage also offers business continuity and disaster recovery.
- **Efficiency:** Institutions of higher learning are looking for new ways to make their organizations more efficient. A *recent survey by Faronics*in their “State of the Cloud” report indicated that nearly 55% of institutions want increased efficiency and believe that cloud computing is the best way to make this happen[11].

There can be numerous definitions available on cloud computing. A comprehensive definition is given by National Institute of Standards and Technology states that “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [12]. From the definition we can say that cloud computing has following characteristics

- On-demand self-service.
- Broad network access.
- Resource pooling.
- Rapid elasticity.

3. Objectives of the Research

a) To propose the architecture for cloud in HE institute including various service and deployment models.

b) To propose strategy for effective implementation cloud environment in HE institute

c) To provide recommendations to HE institute for successfuland efficient migration of its traditional system to cloud based system.

4. Cloud Architecture for HE Institutes

For successfully migrating from the traditional system in the HE institute towards cloud-based architecture requires adequate thinking, well-defined strategy and properly framed architecture. This will help HE institute to overcome the challenges associated with cloud environment such as data privacy and protection issues, risk and non performance issues, organizational support and acceptance, network related issues, contractual and jurisdictional issues, etc. The cloud architecture for the HE institute will encompass three cloud service models, and four cloud deployment models. These models will be oriented towards satisfying the five essential characteristics that a typical cloud environment should possess.

5. Cloud Service Models

Service models describe what kind of services can be obtained from the cloud. Cloud service delivery is divided among three typical models and various derivative combinations. The three fundamental classifications shown in figure 1 are often referred to as the "SPI Model," where 'SPI' refers to Software, Platform or Infrastructure (as a Service), respectively. Depending on the model selected, the cloud provider delivers differentiated services. These services are generally classified according to the level of the IT architecture they reside on. The cloud provider determines how the service is offered within the agreed upon service level agreements (SLA), and how the services on underlying layers may be accessed. The following layers are differentiated [13]:

Applications: The applications used by a customer based on the agreement.

Runtime: The environment in which the particular application is running, including the runtime library of the application's requisite functions.

Middleware: The switching software and/or middleware serve as a communication with other applications,

databases and the operating system.

Operating System: The operating system (OS) provides and manages the system resources of the underneath hardware to the user.

Hardware: The hardware consists of the physical units, such as servers, CPU, storage, and the network. It may contain a virtualization layer that provides the virtualized infrastructure resources to the OS.

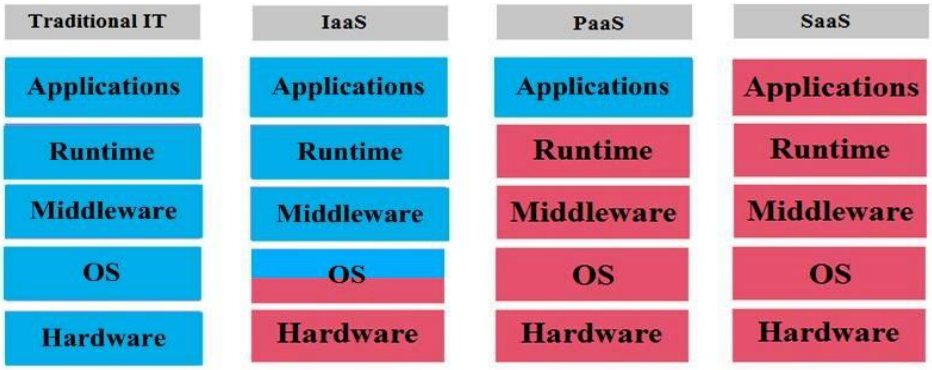

Figure 1: Service models for Cloud. Blue indicates as level owned and operated by the organization, and red indicates levels run and operated by the service provider.

a) **Infrastructure as a Service (IaaS):** It can be used to satisfy the infrastructure needs of the students, faculties or researcher globally or locally with some specific hardware configuration for a specific task. It provides a remote virtual hosting server for file storage, as it enables a user to save all of their file types in a virtual host and retrieve them from anywhere with an internet connection. Examples of IaaS are Google Compute Engine, Google Cloud Storage and Google Big Query.

b) **Platform as a Service (PaaS):** certain providers are opening up application platforms to permit customers to build their own application without the cost and complexity of buying and managing the underlying hardware and software layers. PaaS provides the entire infrastructure needed to run applications over the Internet, PaaS is based on a metering or subscription model so users only pay for what they use. Examples of PaaS are Google App Engine, Force.com and Heroku.

c) **Software as a Service (SaaS):** the application service provider is hosting the application which runs and interacts through web browser, hosted desktop or remote client. It eliminates the need to install and run the application on customer own computer and simplifying maintenance and support. Organizations that operate on SaaS are not burdened with the time-consuming and costly task of managing software updates, security patches and a host of other administrative duties for on-premise software solutions. SaaS ensures that these tasks are managed quickly, efficiently and affordably on the back-end.

6. Cloud Deployment Models

Regardless of the service model utilized (SaaS, PaaS, or IaaS) there are four deployment models for cloud services, with derivative variations that address specific requirements:

a) **Private cloud**: The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers. It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

b) **Community cloud**: The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

c) ***Public cloud****:* The cloud infrastructure is provisioned foropen use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

d) ***Hybrid cloud***: The cloud infrastructure is a composition oftwo or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds)"[14].

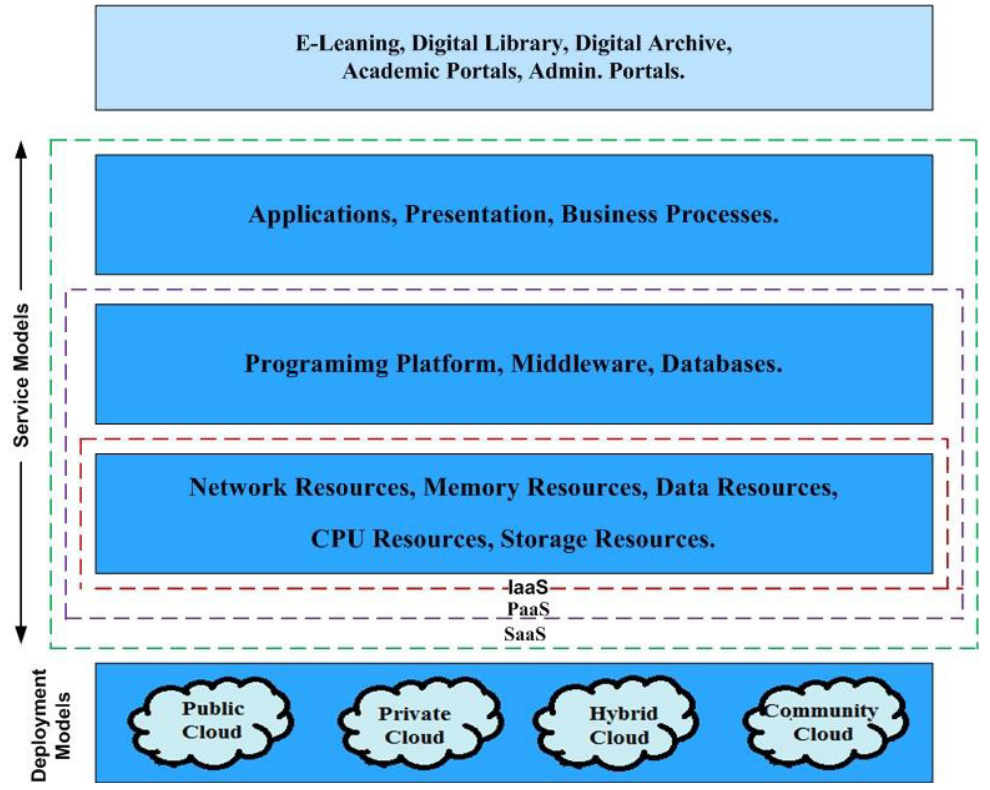

Figure 2: Architecture of Cloud environment for HE institutes.

In addition, it is possible to have derivative cloud deployment models emerging due to the maturation of market offerings and customer demand. For example, virtual private clouds —utilizes public cloud infrastructure in a private or semi-private manner and interconnects these resources to the internal resources of a consumers' data centre, usually via virtual private network (VPN) connectivity [15. The cloud system architecture design has clear implications on the future flexibility, security, and mobility of the resultant solution, as well as its collaborative capabilities. As a rule of thumb, parameterized solutions are less effective than de-perimeterized solutions in each of the four areas [15]. Outmost consideration should also be given while choosing between proprietary and open solutions.

7. Proposed Architecture for HE institutes:

We propose cloud based IT architecture for a HE as shown in figure 2. The IaaS is the foundation of all cloud services, with PaaS build upon IaaS, and followed by SaaS build upon PaaS as shown in the architectural diagram. A clear understanding of the relationships and dependencies between various CC models is important for understanding security risks. The capabilities and security risk are inherited from layer to layer. IaaS contains the infrastructure resource and the hardware platforms. IaaS provides the physical and logical connectivity between the hardware resources. IaaS contains a set of APIs which allow management and other forms of interaction with the infrastructure by consumers [15]. PaaS provides additional layer containing programming environment, middleware capabilities, database, messaging, and queuing. This allowscloud users/developers to build their applications on the cloud platform. The SaaS is build upon the underlying IaaS and PaaS stacks. SaaS provides the application level capabilities to users. It includes functions for presentation, application, and provides management capabilities. It should noted that there are significant trade-offs to each model in terms of integrated features, complexity vs. openness (extensibility), and security [15].

a) Strategy for Implementing Cloud environment in education

Moving towards the cloud needs a well defined strategy. It is important that it is aligned with the organization strategy. We propose a strategy as shown in figure 3 for successful cloud implementation involving five phases:

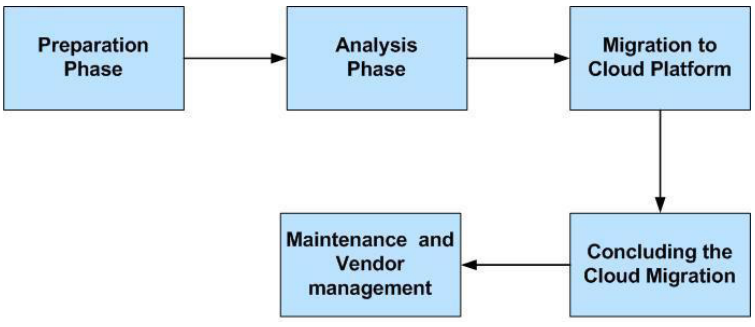

Figure 3: Five Phase Strategy for Transforming Higher Education through Cloud Computing.

Phase 1: Preparation Phase can be implemented in five steps.

Step 1:- Understanding the Cloud.

This step consists of developing the knowledge by participating in seminaries, conferences, discussions with the consultants, experts and Vendors.Success depends on the support by the institutes in terms of allocation of budgets for the research. It is also necessary to understand the functioning of cloud its benefits, the risks, and best practices.

Step 2:- Understanding the User Requirements.

As with all the software it is necessary to understand the user requirement here also. In this case one needs to understand the needs of the research faculty, staff, students, administrative department, the exam department and the network department within the institute.

Step 3:- Understanding the Project Feasibility.

It is necessary to understand the economic and technical feasibility of the new approach, thoroughly before going further for deployment.

Step 4:- Analyzing SWOT.

Step 5:- Analyzing the return on investment.

Phase 2:- Analysis Phase

Step 1:- Analysis of users, software and hardware requirements.

This phase may start from the categories of users who interact with the existing system and their requirements. The analysis of hardware and software from the perspective of cloud is done here.

Step 2:- Understanding the recent structure from IT perspective.

Here evaluation of the structure is done from point of view of IT requirements and usage. The services that needs migration and the services that needs to kept with the institute are decided.

Step 3: Setting up Benchmarks.

In this step benchmarks for security, legal compliance issues are set. The benchmarks are set up by comparing the internal practices of the organization as compared to the industry standards.

Step 4: Preparation for Roll out and adoption plan.

In this step before going for complete adoption of the cloud services, one has to decide whether to prototype the cloud services or whether to go for pilot projects.

Phase 3:- Migrating to the selected Cloud Platform

Step 1:- Selecting the Vendor based on set benchmarks.

The outsourcing strategies are decided and the benchmarks are developed in the second phase are used to evaluate the vendor ability to provide service. Special care has to be taken to ensure that there will be no affect the organization service delivery.

Step 2:- Integration of the new systems with the existing system.

In this step systems application integration is done to ensure that the candidate applications will be able to function with the internal applications that are not migrated to the cloud.

Step 3:- Contract development and signing of the contact.

The final step is contract development and signing that vendor that meets the user requirements for using cloud service. The transition to the cloud may be achieved gradually starting from testing a pilot project in cloud and the finalizing the application chosen for the cloud.

Phase 4:- Concluding the Cloud Migration

This phase can be implemented in six steps:

Step1: Discard or enhance the project to meet the user requirement.

Step2:- Put the Roll Out into practice.

Step 3:- Migrate the data and applications to cloud.

Step 4: -Support and provide adequate training to all users for successful migration.

Step5:- Monitor and control the project to ensure successful migration. Finally implement the operational cloud.

Phase 5: Contact Management, Vendor management, Ongoing maintenance and user support: Contact and vendor management should be planned and responsibilities should be assigned.

8. Recommendations for smoothening the transition of cloud computing

- Understand that adopting cloud services is just like adopting some form of outsourcing. The HE institution needs a properly framed outsourcing strategy to find the optimal balance between "do it yourself" and "hired hand" to truly leverage the cloud.
- Appoint an active vendor for cloud management. Make sure that the vendor has adequate staff that possesses legal and contracting skills to control your risk.
- Strengthen your integration skills. Develop a center of excellence for integration to ensure a flexible infrastructure.
- Identify the type of cloud computing that suits best for campus needs. Private clouds can be operated the

institution itself or by a third party, and hosted on campus or off-site. Community clouds have wider reach as it can be shared by several organizations. Public clouds are owned by a third party cloud providers and made available to the institute.

- Identify the opportunities and benefits associated with the migrating from traditional existing computing arrangements to cloud services. For example, migrating reduces server, licensing costs, and infrastructures requirements, while giving campus users the flexibility to access their applications and data from anywhere.
- Ascertain your IT infrastructure complements with that required for cloud-based services.
- Evaluate the costs, benefits, and risks of migrating to the cloud. For example, determine critical and sensitive data cannot be stored on a public cloud for legal or security reasons.
- Determine if institute possess the IT skills needed to manage a private cloud, or if it makes more sense to outsource.
- Prepare the institute network for cloud computing. The network has a critical role in making the cloud secure and delivers the expected performance.

9. Conclusion

Cloud computing is an emerging technology paradigm that promises to provide solution to the current financial crisis faced by HE institutes. The migration from traditional system towards CC would enable the HE institutions to cope with rapidly changing software and hardware needs at lower cost. It would help to standardize and update the educational content, and help enhanced collaboration between HE institutes. The HE institutes expect to cut 20% of their IT budget by moving most of its applications to the cloud. This presents a major shift in approach and provides a major opportunity to increase organizational efficiency, improve agility, and stimulate innovation. However, to support a smooth transition and optimal outcomes, HE institutes must first develop a comprehensive cloud-computing strategy that addresses the challenges unique to each institution. HE institutes are at the beginning of a transition period during which they face many challenges with respect to cloud adoption. In this paper, we have presented a five phase strategy for implementing cloud computing in higher education. We have also proposed a CC architecture for HE institute containing the various deployment models, Service Models and user domain. The correlation and dependencies between these models is elaborated. Finally, we provide a comprehensive list of recommendations for a successful and efficient migration from traditional to cloud based system for a HE institute.

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