Cloud Computing for Higher Education: A Roadmap

Abstract—Advances in technology offers new opportunities in enhancing teaching and learning. The new technologies enable individuals to personalize the environment in which they work or learn, a range of tools to meet their interests and needs. In this paper, we try to explore the salient features of the nature and educational potential of ‘cloud computing’ (CC) in order to exploit the affordance of CC in teaching and learning in a higher education context. It is evident that cloud computing has a significant place in the higher education landscape both as a ubiquitous computing tool and a powerful platform. Although, the adoption of cloud computing promises various benefits to an organization, a successful adoption of cloud computing in an organization, particularly in educational institutes requires an understanding of different dynamics and expertise in diverse domains. This paper aims at a roadmap of Cloud Computing for Higher Education (CCHE) which provides with a number of steps for adopting cloud computing.

Keywords: Cloud computing, Migration, Roadmap

I. INTRODUCTION

Higher education (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. This is mainly as a result of a new genre of students with learning needs vastly different from their predecessors, and it is increasingly recognized that using technology effectively in higher education is essential to providing high quality education and preparing students for the challenges of the 21st century. Although the new technologies have the potential to play an important role in the development and emergence of education system, where control can shift from the teacher to an increasingly more autonomous learner, and to rescue the HE from this appalling situation, the change is very slow or not forthcoming at all for various reasons. It is becoming clear to many people, including students, that traditional methods are unable to address the needs of HE where the emphasis is on higher order learning experiences and outcomes demanded of a changing knowledge- and communication-based society [1]. It is hoped that this need can be effectively facilitated by adopting the benefits of cloud computing through innovative research approaches.

The concept of “computing in the cloud” is about the delivery of IT services that run in a web browser; the type of services ranges from adaptations of familiar tools such as email and personal finance to new offerings such as virtual worlds and social networks. Storage of digital data is an important service among these. Cloud computing is a computing platform that resides in a service provider’s large data centre[2] and is able to dynamically provide servers the ability to address a wide range of needs of clients[3]. The cloud is a metaphor for the internet. Some people call it the World Wide Computer. Technically, it is a computing paradigm in which tasks are assigned to a combination of connections, software and services accessed over a network [4]. This network of servers and connections is collectively known as the cloud. Computing at the scale [5][6] of the cloud allows users to access supercomputer-level power.

Instead of operating their own data centers, firms might rent computing power and storage capacity from a service provider, paying only for what they use, as they do with electricity or water. This paradigm has also been referred to as “utility computing,” in which computing capacity is treated like any other metered utility service—one pays only for what one uses [7].

The typical uses of cloud computing to academics are:

- It can be used as a personal workspace;
- A convenient tool to make teaching and learning interactive- has strong potential for social interactivity;
- Personal Learning Environments (PLEs) used by many people as an alternative to institutionally controlled Virtual Learning Environments (VLEs)/LMS with different personalized tools to meet their own personal needs and preferences; as teachers we are always learning;
- Provides opportunity for ubiquitous computing;
• No need for backing up everything to a thumb drive and transferring it from one device to another;
• No need to copy all stuff from one PC to another when buying a new one. It also means you can create a repository of information that stays with you and keeps growing as long as you want them;
• Provides large amounts of processing power comparable to supercomputer level;

II. THE TECHNOLOGICAL IMPACT OF CLOUD COMPUTING ON HIGHER EDUCATION

The cloud based education system requires the use and creation of knowledge in higher education as a decisive factor for social, economic, cultural and technological transformation. Achieving this goal necessarily involves the use of technology, which would allow knowledge transmission and create new areas for education, research and development.

The impact of cloud in education [8] has attracted researchers and countries attention all over the world, especially due to technological implications of and open access to knowledge. The general infrastructure for providing conceptual and operational integration of ICT [9] in all activity fields and daily life areas translates, in the case of higher education, into management, education and research [10]. Thus, the conceptual framework of integrating cloud computing in higher education is reflected in aspects concerning: policy, objectives and incentives; resources and facilities; computer resources; teaching and learning activities; processes of performance monitoring and evaluation as in “Fig.1”. The rapid evolution of technology provides many opportunities as in Table I [11], but it also creates tensions that are difficult to manage as well as changes that are often difficult to implement.

<table>
<thead>
<tr>
<th>Users</th>
<th>Cloud Computing Implications</th>
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<tbody>
<tr>
<td>Students</td>
<td>• Open, computer-based educational offers</td>
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<td></td>
<td>• Digital Learning Environment</td>
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<td>• Educational methods with personal portfolio</td>
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<td>• Web-based self-service</td>
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<td>• Intelligent environments of synchronous and social learning</td>
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<td>Teachers</td>
<td>• Computer-based, integrated and flexible teaching systems</td>
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<td></td>
<td>• Training facilities for educational innovation</td>
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<td>• Easy access to educational and research content</td>
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<td>• Blog Web sites for collaboration and knowledge building</td>
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<td>• Use of presentation software and of digital content</td>
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<tr>
<td>Researchers</td>
<td>• Collaboration and transparent sharing of research infrastructures</td>
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<td></td>
<td>• Access to digital data and information</td>
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<td>• Knowledge of the economic demands and carrying out research in accordance with these demands</td>
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III. CLOUD ADOPTION STRATEGY ROADMAP

Migrating towards cloud needs a well-defined strategy that supports Cloud Computing capabilities. Representing an important part of the organization IT strategy, migration must be aligned to this. The success of the strategy implementation depends on the existence of a service-oriented architecture [12] at the level of the institution that offers the necessary infrastructure for cloud implementation. Also, in order to have success, the cloud strategy must be aligned with the institutional strategy. Starting from the recent researches related to the transition to Cloud Computing- a migrating strategy towards cloud formed of the following stages has been suggested as in “Fig. 2”.

Figure 1. Conceptual Framework of Cloud Integration

Figure 2. Cloud Migration Roadmap
**A. Stage One**

This step consists of developing the knowledge by participating at seminars, conferences, discussions with the suppliers and consulting the most recent researches in the field. The success of the phase depends on the allocation of sufficient resources for research, for understanding how Cloud Computing functions in different organizational structures from universities and between institutions, the benefits and risks, policies and the best usage practices of Cloud Computing. As with all software projects, the initial stage of understanding users’ requirements in order to determine whether the project is feasible. It is at this stage that the initial requirements, feasibility and initial plan is to be developed. During this phase thought should be given to how the existing systems strengths and opportunities can be maximised, weaknesses and threats minimised, the impact to organisation culture, processes, and structure minimised, and the effect to SLAs [13], how return on investment and costs to adopting cloud computing can be managed and the usability and access to resources will be assured and maintained. Also the impact to organisational security policies, standards and legal and compliance issues in order to analyse the strengths, weakness, opportunities and threats of existing systems a SWOT matrix is useful. The detail of stage components are depicted in the “Fig. 3”.

**B. Stage Two.**

In this phase benchmarks for security, legal and compliance issues identified in the analysis phase are set. The benchmarks will reflect the internal organisational best practices, policies and standards to industry standards and best practices and how these can be achieved when moving to the cloud. The benchmarks will reflect the legal and compliance best practices that need to be maintained and achieved in the cloud environment. Financing and cost management plan is developed in this stage and how costs will be managed. The plan on how to ensure security compliance, legal and compliance to industry standards and regulation is laid down. In preparing the adoption or roll-out plan it is important at this stage to decide whether prototyping of the cloud services will be used and whether there will be pilot projects before full roll-out and identifying risks and how they are to be mitigated. Evaluating the present stage from the point of view of the IT needs, structure and usage that may be migrated or need to be maintained within the institution is taken care at this stage. With respect to the IT needs, their structure and usage, the analysis may start from the categories of users who interact with the present IT infrastructure and their necessities. The objective is to identify the emergent technologies, efficient from the point of view of costs [14] that satisfy the necessities of the students and university staff. The hardware and software needs shall then be analysed from the perspective of cloud models as in “Fig. 4”.
C. **Stage Three.**

This stage is a preparation phase for the actual migration of systems and/or applications selected to the cloud platform and infrastructure of choice. In this phase 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 and also with the cloud infrastructure of choice. Outsourcing strategies are decided upon and the benchmarks developed in the second stage are used to measure vendor ability to provide service that will not affect the organisation service delivery and business. The last thing in this stage is contract development and signing that meets the user requirements for using cloud services. The transition to cloud may be achieved gradually, starting from testing a pilot project in cloud and then externalizing the applications chosen for cloud. The maintenance of low costs for using the solution must be permanently taken into account.

D. **Stage Four.**

At this stage the migrating to the cloud concludes and migration can proceed. Either the project can be discarded or enhanced to meet the user requirements. Given the outcomes from the three previous phases, the roll-out plan can be put into practice. Applications and data migration can proceed. Support to users during the migration process is provided, and the monitoring and control of the project is maintained to ensure successful migration. The solution now should be fully operational in the cloud; however contract and vendor management, testing and maintenance, user support and review should be ongoing for several months subsequent to launch. The system metrics or benchmarks developed and set in stage 3 can be used as indicators of success and should be monitored Security standards compliance, SLAs, legal and compliance issues, IT governance best practices and cost management are desirable metrics. Also documentation of lessons learnt and best practices during the project should be documented and communicated to all stakeholders. The solution implementation may be done in iterative phases, through a continuous transition of the data, services and processes towards cloud. Data migration must be performed by keeping an optimum balance between the data accuracy, migration speed, non-functioning time and minimum costs as in “Fig. 5”.

IV. **ESSENTIAL CRITERIA FOR CLOUD SELECTION IN ROADMAP**

Drivers for considering cloud computing solutions for educational institutes should be identified in the context of the institutional strategy and how well they align. The main drivers for adoption of cloud computing within institutions are economic, relating to the reduction in funding and the need to increase competitiveness through better student and staff experiences. Some of the essential selection criteria is furnished below.

A. **Open, standards-based Functionality**

Platform as a Service (PaaS) offerings are sometimes based on proprietary languages and hosting providers. Educational Institutes should choose an open, Java-based framework for SaaS applications. An Institute can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service’s provider.

B. **Secured Access to resources**

A robust SaaS application requires secure data access to ensure each user/student/staff sees only data that belongs to their tenant. Best practice design gives each table a tenant identifier column and filters all queries using that identifier. Capabilities are available over the network and accessed through standard mechanisms that promote use by
heterogeneous thin or thick client platforms (e.g. mobile phones, laptops, and PDAs).

C. Resource pooling

The provider’s computing resources are pooled to serve multiple consumers like teachers and staff using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to academic demand. There is a sense of location independence in that the students generally have no control or knowledge over the exact location of the resources but may be able to specify location at a higher level of abstraction. Examples of resources include storage, processing, memory, network bandwidth and virtual machines.

D. Dynamic Backup and Recovery

Our proposed EsaaS (Education Software as a service) suggests to add student-specific data extensions without affecting the overall data schema [15]. Best practice designs include using a pre-allocated field in each table to hold custom XML data extensions or using name/value pair tables. ESaaS users are uneasy about entrusting all data and backups to a SaaS provider. When an application server fails, users should transparently failover. Similarly, when a database server fails, the application should failover to a backup server instance and restarts a new backup server.

E. Elastic Allocation

Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale up capacity. The capabilities can then be rapidly released when additional capacity is no longer required. End users have been trained by Web 2.0 applications like MyYahoo and FaceBook to expect that the application user interface will be under their control. A drag and drop framework for enabling end users to configure their own dashboards is essential for a competitive SaaS offering. The cloud architecture should include the capability to dynamically expanding and contracting the pool of application and data servers.

F. Measured service

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

V. STRATEGIC FOCUS TO THE ROADMAP AND FUTURE WORK

Successful adoption of cloud computing is key for realisation of benefits promised by cloud computing environment. As organisations are faced with the need for high processing capabilities, large storage capabilities, IT resource scalability and high availability, at the lowest possible cost, cloud computing becomes an attractive alternative[16]. However, the nature of cloud computing pose challenges to organisation as they consider it. Issues such as security, legal and regulatory compliance become more prevalent. The aim of the research was to investigate the challenges facing cloud computing adoption and synthesise a roadmap which will provide organisations with guidelines for successful cloud computing adoption by addressing the challenges identified.

The roadmap is an open framework that can be used in any organisation and for any cloud computing platform and infrastructure as guidance towards successful cloud computing adoption. The proposed roadmap was divided into four stages. These stages would help to analyse similar adoption process. Future work should also include assessment of the several issues proposed, such as planning and analysis phase that addresses the needs of newly established organisations, re-categorisation of the roadmap issues based on strategic focus. By using the developed roadmap, business and IT managers will have a better understanding of the different key issues facing cloud adoption and will provide them with a tool to guide the process of cloud computing adoption.

VI. CONCLUSION

Cloud computing promises a radical shift in the provisioning of computing resources within an organization. It is penetrating into various domains and environments, from theoretical computer science to economy, from marketing hype to educational curriculum and from R&D lab to enterprise IT infrastructure [17]. Educational 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 roadmap for cloud computing in higher education [18], with a focus on the adoption strategies. Following the steps described in the roadmap, successful cloud computing adoption can be achieved in
higher education. Our future work consists of validating the usability of the roadmap in general cases and providing the evaluation of cloud system adoption derived from the steps contained in the roadmap.

REFERENCE