A Framework for Migrating IT Based Services to Public Cloud: The Case of Higher Education Institution in Developing Nations

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Abstract: *The demand of educational institutions for high computing power significantly increased due to the expansion of use of digital technologies for sharing information and knowledge among the faculty, students and researchers as well as handling traditional business processes. Coping up with rapidly growing data processing requirements of the universities in developing nations through building their own in-house data center with maximum possible scalability, flexibility, reliability and accessibility became costly and complicated. Cloud computing is available as an option with on-demand computing power, quick implementation, quick and effective communication, low maintenance, fewer IT staff, and lower cost. But in the absence of an explicit strategy, the potential benefits of cloud computing models may be elusive. This paper' therefore, is aimed at exploring the strategy for Higher Education Institutions (HEIs) to migrate their IT services to public cloud. The results of this study can be of great interest for decision makers of HEIs to make the best possible decision by using the public cloud in their own context.*

Key words: Cloud computing, public cloud, migration, higher education, developing nations

1. Introduction

Higher education institutions play significant role for the overall development of the society and the economy. Universities have become more and more technology centric, significantly transforming the way information and knowledge is shared among the faculty, students and researchers; the way faculty and students interact as well as the mechanisms of handling traditional business processes (Quadri and Quadri, 2017). They are using IT infrastructure as foundation for their educational activities and scientific research and have transformed their educational services from traditional to the online form (Pardeshi, 2014). These changes demanded high computing power with maximum possible scalability, flexibility, reliability, accessibility and security which could be achieved by Cloud Computing (Quadri and Quadri, 2017). Huge investment is required to deploy state-of-the-art technology that supports the current growing need of higher education institutions (Pardeshi, 2014). Due to significant shortages of funding, HEIs are resorting to a variety of cost-cutting measures, including significant cuts to IT budgets (Ibid.)

The computing power provided by data centers built within the universities (private cloud) has become complicated and costly to keep up with the rapidly growing data processing requirements (Yang and Tate, 2012). The growth of cloud computing has become a solution to institutions with lack of adequate IT budget by offering on-demand computing power, quick implementation, low maintenance, fewer IT staff, and lower cost (Yang and Tate, 2012; Pardeshi, 2014). In the cloud computing model the hardware and software requirements and thus, cost and maintenance needs are significantly lower since computation takes place on a remote server (Pardeshi, 2014). Due to such growing potential of cloud computing for HEIs, cloud-computing market was projected to grow from $40.7 B in 2011 to $240B in 2020 (Ibid.)

Cloud computing has a significant place in the higher education landscape both as a ubiquitous computing tool and as a powerful platform. As HEIs 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 (Masud, et al., 2012). Cloud computing gives new perspectives for education in third world countries. Their main problems are related to poor government funding of the education sector, lack of buildings and infrastructure suitable for conducting higher education activities, high migration of qualified teachers, lack of educational materials (books, software, technical means) etc. (Hadzhikoleva, et al., 2018). In addition, due to the prevailing financial crisis and the growing needs, higher education institutes are facing challenges in providing necessary IT support for educational, research and development activities (Pardeshi, 2014). Currently, cloud usage has been shallow, narrow and vanishingly small in most developing economies mainly due to lack of infrastructures and economies of scale for a wide and deep adoption of the cloud (Kshetri, 2010). Note that while it took many years and large investments for the developed world to acquire infrastructure, data centers and customized application software, cloud computing has made it possible for organizations of developing world to access them more easily (Cleverley 2009 and Kshetri, 2010).

It is one of the opportunities that could be sought by educational establishments which are stranded by low budget and poor infrastructure and it can provide immense benefit to them due to its flexibility and pay-as-you-go cost structure (Sultan, 2010). Therefore, Higher Education Institutions of developing nations must exploit these opportunities afforded by cloud computing. But in the absence of an explicit strategy for adoption of cloud computing, the potential benefits of this infrastructure may be elusive. Prior studies also recommended that future research is required to examine cloud adoption decision processes of an organization in the developing world (Kshetri, 2010). This paper, therefore, aims at proposing an integrated framework that guides the practices of migrating to public cloud by Higher Education Institutions (HEIs) in developing nations. This study can be of a great interest for educational practitioners and institutions in order to identify opportunities to use the cloud in their own context.

2. Review of Literature

2.1 Cloud Computing: Definition, Service Layers and Models

Cloud Computing is defined as clusters of distributed computers (largely vast data centers and server farms) which provide on-demand resources and services over a networked medium or internet (Sultan, 2010). It is a new way of providing services over the internet that allow campus users to access a shared pool of configurable computing resources (e.g. servers, memory, networks, network bandwidth, storage, applications, development platforms, data and services) anywhere anytime (Quadri and Quadri, 2017; Yang and Tate, 2012). It is a pool of abstracted, highly scalable, and managed infrastructure capable of hosting end-customer applications and billed by consumption (Staten, 2008 as cited in Yang and Tate, 2012). It is also known as a "utility computing" where computing capacity is treated like any other metered utility service – one pays only for what one uses (Thomas, 2011).

There are three layers of services provided by cloud computing (Ibid.). The first layer is Infrastructure as a Service (IaaS) that provides hardware resources for processing, storage, etc. in a virtual, on demand manner via the Internet and rented as virtual machines on a perusal basis and can scale in and out dynamically, based on customer needs. Users have control over operating systems, storage and deployed applications rather than the cloud infrastructure. Examples are Amazon's EC2 (Elastic Cloud Computing) and S3 (Simple Storage Service) which provide computing and storage infrastructure for fee. The second layer is Platform as a Service (PaaS) which provides programming and execution environments to the user. PaaS user can create applications using programming languages and APIs supported by the provider, and then directly deploy the applications onto the provider's cloud infrastructure within a few clicks. Google's App Engine is a case in point. The third layer is Software as a Service (SaaS) which provides users with complete turnkey applications through the Internet including CRM and ERP (Leavitt, 2009 in Yang and Tate, 2012). Software or applications are hosted as services in the cloud and delivered via browsers once subscribed to by the user (Yang and Tate, 2012). This approach can eliminate the need to install, run, and maintain the application on local computers (Yang and Tate, 2012). Sales force.com's online CRM system is one of the typical example of SaaS.

The above cloud based services can be deployed through different models – public cloud (owned and operated by independent vendors and accessible to the general public); private cloud (maintained in-house and solely accessible to internal users within an organization); community cloud (shared by several organizations and supports a specific community that has shared concerns – e.g. security); and hybrid cloud (a combination of two or more types of clouds - private, community, or public) (Yang and Tate, 2012; Gonzalez-Martínez, et al., 2015).

2.2 Potential of Cloud Computing for Higher Education Institutions

Cloud computing has significant potential for educational researchers and educators to better understand and improve their practice in increasing the quality of their students' learning outcomes, and, thus, in advancing the teaching and learning process in a higher education context. Effective use of cloud infrastructure in higher education is essential to providing high quality education by allowing students to construct knowledge through actively engaging with their peers and instructors in rich learning environments (Thomas, 2011). A cloud-based classroom applications allow students and the faculty to exchange textbooks, syllabi, assignments, educational materials, multimedia resources and knowledge and students can use smartphone, laptop or tablet to access these electronic resources online (Pardeshi, 2014; Gonzalez-Martínez, et al., 2015). Universities may also introduce fully virtual classrooms via online learning and video conferencing with the support of huge and scalable cloud servers' capacity and with quick and economical access to various application platforms and resources (Quadri and Quadri, 2017).

Cloud computing platform support teachers to prepare teaching portfolio, making presentation on teaching to a local audience using presentation software and digital content, access educational and research content, apply computer-based integrated and flexible teaching systems, etc. (Hadzhikoleva, et al., 2018). It provides learners virtual learning environments with different personalized tools to meet their own personal needs and preferences. Cloud-based virtual learning environments such as Blackboard or Lessons LAMS are now offering outsourced cloud-based e-learning services, benefiting students from ubiquity, scalability and availability capabilities (Gonzalez-Martínez, et al., 2015). With the provision of unlimited storage resources that cloud computing provides students can use mobile learning (m-learning) services – use their mobile phones to access, accumulate, share, and synchronize learning contents (Ibid.)

Cloud computing provides an easy user-friendly environment/ platform for collaborative research by providing new forms of social networking and open access to information among virtual communities of educators, researchers and practitioners (Thomas, 2011). It facilitates collaborative setting of research themes, sharing of evolving data and ideas, reflecting on others' views and refining one's own ideas, storing and preserving data as well as presenting, publishing and disseminating research outputs (Thomas, 2011). Scientists can also easily collaborate both nationally and internationally by sharing supercomputers, library resources and digital repositories (Wheeler and Waggener, 2009).

Cloud models cut IT management cost by offering much cheaper ways to acquire and use IT services, while providing greater flexibility in maintaining security, reliability and compliance (Thomas, 2011). By its design, cloud computing is scalable, flexible and elastic – offering IT departments a way to easily increase capacity or add additional capabilities when necessary, without investing in new and expensive infrastructure, training new personnel, or licensing more software (Ibid.). The cost of maintenance, telecommunication services, power consumption to run hardware, cooling, fire suppression systems or space can significantly be minimized (Quadri and Quadri, 2017; Gonzalez-Martínez, et al., 2015). Software development cost can also be significantly reduced.

The pay-per-use model of cloud computing avoids the waste of under-utilized software, which is often used by just a few learners, even though multiple copies may have been licensed (Gonzalez-Martínez, et al., 2015). It also provides opportunity to use the latest software and hardware technologies without having to own them. This is so beneficial for educational institutions which are being challenged by low budget. In addition, the adoption of cloud computing helps academic institutions to focus more on their main goals which are related to teaching and learning with minimum expenditure (Mokhtar, et al., 2013). With cloud computing infrastructures Universities can protect their valuable data ranging from student and faculty information to course material from natural disasters (Pardeshi, 2014). Cloud-based Customer Relation Management (CRM) systems supports the relationship between the institution's administrative staff and the students (Gonzalez-Martínez, et al., 2015).

2.3 Challenges/Risks of Cloud Computing

Based on review of related studies, Gharehbagh (2015) identified the following challenges associated with cloud computing.

a) Security and Privacy: risks associated with cloud services include lack of reliability, unauthorized disclosure of information, data change, data deletion/loss, etc. Suggested security measures are implementation of powerful encryption techniques and fine grained authority determination for data security; proper designing of network to prevent leakage of sensitive information; and application of multi-tenancy features with clearly defined boundary for every user's data.

b) Compliance with Regulations: Achieving compliance with the industry rules (related to storage operations, maintenance, security and management of vital or critical data) for organizations like medical care providers, financial institutions, etc. is very expensive and time consuming. Choosing a safe and guaranteed cloud service provider is suggested as a solution.

c) *Vendor lock-in:* This hinders migration from one service provider to the other since service providers have different architectures. Choosing cloud service providers with low lock-in (who have well-defined infrastructure standards and implementation) is suggested as a solution.

d) Loss of Physical Control of Data: Losing physical control by users over their data and application leads to a number of concerns – legal concern that arise from storage of data in a single system and the risk of combining data owned by one organization with the other. Monitoring, correlating and analyzing the behavior of the infrastructure and events with the aim of detecting and responding to events in real-time basis is suggested as a solution. Keeping critical data within the organization (private cloud) is suggested as another resort. An example is students' records or accounts which can be maliciously or accidentally leaked or commercialized and, together with identity theft, may lead to cyber bullying or abuse (Gonzalez-Martínez, et al., 2015).

a) Complexity of Calculating the Total Cost of Ownership (TCO): This is mainly because of the new payment model of the cloud (payment according to usage/growth) and the changing nature of the cost of cloud which is drastic.

b) Performance and Uptime: Both have direct impact on profitability and enterprises are always worried about this aspect of cloud computing. One study indicated that 43.5% of IT managers around the world are concerned about the loss of revenue due to cloud service problems and nearly 80% are concerned about hidden costs such as damage to their brand, considering idle time and poor performance. It is also experienced that the cloud services are out of reach temporarily (several seconds/several hours) due to strikes or overload or permanently (being out of business or changes business). Selecting major cloud service providers is suggested as a solution since they are more reliable than small providers. High availability is one of the features that organizations consider when selecting cloud providers (e.g. availability of 99.99% - only for 4 minutes and some seconds in a month, or only about 50 minutes in one year).

c) Bandwidth: insufficient bandwidth may hinder the proper delivery of educational services since cloud computing is Internet based service.

In addition to the above challenges other authors also raised issues related to organizational support and acceptance; contractual and jurisdiction issues; vender's going out of business with no warning that may result in total loss of institutional data; changes in platform which break interfaces and make data inaccessible (Wheeler and Waggener, 2009; Pardeshi, 2014). In addition to the solutions suggested under each challenge, educating learners, teachers and administrators was also suggested as a means to make a safe use of cloud computing (Gonzalez-Martínez, et al., 2015). The authors emphasized that students should be trained on how to use cloud services securely, limiting the personal information provided and learning privacy best practices; practitioners should also be aware that many cloud applications were not originally designed for educational purposes and security issues were not primary objectives in the design process.

3. Strategies for Migrating to Cloud

Different authors have recommended strategies constituting steps to be followed in the cloud adoption process. Ksherti (2010) identified the following considerations during the process of adopting cloud computing.

- First, lack of awareness on cloud computing, even among large enterprises in the developing world is one of the problems that needs to be addressed in the cloud computing adoption process.
- Second, larger number of different ***uses*** (**width**) – e.g. greater number of employees in a company using the cloud for performing a particular function; and high amount of ***usage*** (**depth**) – e.g. frequency of software download from the cloud, amount of data stored on the cloud, etc. are required for ensuring higher cloud performance.
- Third, data privacy and security associated with unauthorized access and unauthorized use of information stored in the cloud is another concern that needs serious attention (Ibid.).
- Fourth, business models of cloud computing should focus on affordability which is quite important within the developing nation's context that constitute small-scale consumers (e.g. SMEs).
- Fifth, since the penetration of mobile phone in developing countries is higher than the PC penetration and the Internet bandwidth is very low,

mobile-based cloud presents an enormous potential to bridge the digital divide. Therefore, cloud related business models should give special attention to cellular technology and mobile internet access in the developing world. There are mobile-based cloud innovations such as China Mobile's Big Cloud platform and Sales force's "offline PDA" (Etengoff 2008 as cited in Kshetri, 2010).

- Sixth, cost comparison should be conducted between infrastructure costs of the systems in case of building data center and the cost of cloud service provider. The cost of a data center includes number of servers, server rack, shelf spares, backup systems (tape drive), network equipment, annual system support and maintenance including running costs of the system infrastructure. This is compared with the costs of cloud service provider – identifying option of using either small or large server instances depending on the amount of CPU power and RAM required.

Specific steps were recommended by Pardeshi (2014); Mircea & Andreescu (2011 as cited by Hadzhikoleva, et al., 2018) and (Mokhtar, et al., 2013). This paper integrates all the relevant steps recommended by these authors and suggest them as a framework to be followed by HEIs while deciding to adopt or to migrate to cloud.

Phase One: Preparation (Pardeshi, 2014; Mircea & Andreescu, 2011 as cited by Hadzhikoleva, et al., 2018; Mokhtar, et al., 2013).

- Under the preparation phase institutions need to develop the knowledge base about cloud computing and evaluate the present stage of the university from the point of view of the data, services, processes, IT needs, structure and usage. The requirements of instructors, researchers, students, administrators and IT staff should be analyzed. Awareness should be created about the functioning of cloud, its benefits, the risks, and best practices. The economic and technical feasibility of cloud computing approach and return on investment should be analyzed. Cost comparisons should be conducted based on the processes mentioned above and there is a need to ensure that migrating reduces server, licensing costs, and infrastructures requirements, while giving campus users the flexibility to access their applications and data from anywhere.
- There is also a need to determine that critical and sensitive data cannot be stored on a public cloud for legal or security reasons.

Phase Two – Analysis Phase (Pardeshi, 2014; Mircea & Andreescu, 2011 as cited by Hadzhikoleva, et al., 2018)

- This phase involves analysis of users, software and hardware requirements from the perspective of cloud; deciding the services to be migrated and kept within the institution; setting security benchmarks (internal practice Vs. industry standard); setting legal compliances; and deciding whether to prototype the cloud service or go for pilot projects.
- To what extent the current cloud computing supports the legacy systems (outdated systems but remains in use) and whether it is possible to migrate the legacy system to the cloud is one of the issues to be addressed (Zhao and Zhou, 2014).

Phase Three - Selecting Cloud Platform (Pardeshi, 2014; Mircea & Andreescu, 2011 as cited by Hadzhikoleva, et al., 2018; Mokhtar, et al., 2013)

- Activities involved in this phase include selection of vendor based on the benchmarks set and the problems planned to address; developing contract and signing as well as ensuring the interoperability between the systems to be migrated and the internal applications that are not migrated to the cloud.
- Selection of cloud computing solutions can be done through internal experiments or through review of the external success practices of cloud computing (Mokhtar, et al., 2013).
- Masud et al. (2012) recommended the following essential criteria for cloud selection:
    - Educational institutions should choose open, standards-based functionality. Server time and network storage should be provisioned as needed automatically without requiring human interaction with each service's provider.
    - There is a need to ensure that the platform provides secured access to resources (each user/student/staff sees only data that belongs to their tenant)
    - The cloud service provider should provide dynamic backup and recovery:- when a database server fails, the application should failover to a backup server instance and restarts a new backup server

- 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. The cloud architecture should include the capability to dynamically expanding and contracting the pool of application and data servers.
- Measured Service: Resource usage can be monitored, controlled, and reported on, providing transparency for both the provider and consumer of the service utilized.

Phase Four - Conduction of the Cloud Migration (Pardeshi, 2014; Mokhtar, et al., 2013)

- This phase involves migrating the data and applications to cloud, providing support and adequate training to all users, monitoring and controlling the project to ensure successful migration and finally implementing the operational cloud.

Phase Five: Monitoring and Optimization (Mokhtar, et al., 2013)

- Academic institutions should monitor the position after implementation from time to time and try to optimize the new position through; architectural reviews, security audits, cost-reduction exercises, process improvements, and tool customization

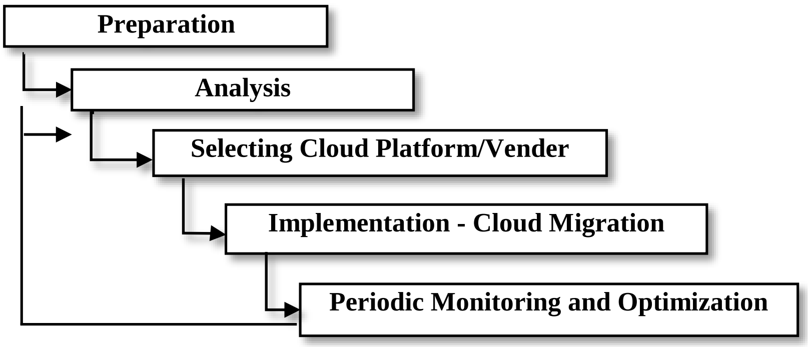

Fig. 1: Framework for Migrating to Cloud Computing

4. Other Options

Consortium sourcing has also become another option for providing cloud based services as opposed to commercial and institutional sourcing. One or more institutions become a direct service provider to other institutions on a cost-recovery basis. It could be a member funded activity with no profit premium or motive other than achieving scale to cover all operating costs. It is a non-for-profit model that allows the institutions to operate IT services by themselves. Such arrangements could involve IaaS and/or SaaS and support for instance, building centralized shared digital repository that can be joined by multiple libraries and establishing shared course management systems. In this model, institutions become both the means of supply and source of demand (Wheeler and Waggener, 2009).

Initiatives such as the Federal Cloud Computing Initiative also promote the use of cloud computing (Gonzalez-Martínez, et al., 2015). The Higher Education Funding Council for England has developed a new program that invested up to £10 million in cloud computing and shared IT infrastructure for universities and colleges (Pardeshi, 2014). National Research and Education Networks (NRENs) is also another prominent initiative which has been established in many African countries through partnership between the government supported partnerships among universities and research institutes (Foley, 2016).. The platform provides advanced information technology (IT) and communications services for connecting academic institutions to each other's networks, and to each other's resources, both nationally and globally with provision of very high bandwidth (Ibid.).

5. Conclusion and Future work

Instead of building costly and complicated in-house data center, cloud computing is available for educational institutions as an option with on-demand computing power, quick implementation, quick and effective communication, low maintenance, fewer IT staff, and lower cost. But cloud usage has been shallow, narrow and vanishingly small in most developing economies mainly due to lack of infrastructures and economies of scale for a wide and deep adoption of the cloud. Currently, due to the availability of cloud computing organizations of developing world which are stranded by low budget and poor infrastructure can access them more easily. But in the absence of an explicit strategy for adoption of cloud computing, the potential benefits of this infrastructure may be elusive. The aim of this study was, therefore, to propose an integrated framework that guides the practices of migrating to public cloud by Higher Education Institutions (HEIs) in developing nations based on review of relevant literature. The study reviewed major benefits of cloud computing to educational institutions including HLIs. It also reviewed major challenges – security and privacy, vendor lock-in, loss of physical control of data, complexity of calculating TCO, low performance and idle time and insufficient bandwidth. Finally strategies for migrating to cloud has been identified. The strategy/framework for migrating to cloud infrastructure constitute 5 key steps/phases including preparation, analysis, selecting cloud platform, conducting the cloud migration as well as monitoring and optimization.

Future research focus on examining empirically whether the strategies and processes of migration can be operationalized in both public and private HLIs given variations in current state of IT services, adaptive capabilities, technical expertise, levels of resources and institutional priority – cost reduction or efficiency.

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