PA Risk-Oriented Conservative Framework for Effective Deployment of Cloud-based e-Services in Higher Education

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***Abstract*—**Cloud Computing is irrefutably one of the greatest computing innovations in modern times. This utility-based platform promises to open up new opportunities in a wide range of computing domains, such as research, entrepreneurship, green computing, high performance computing, and pervasive intelligence among others. The basic tenet of this on-demand paradigm is to remove the burden where organizations would have to establish elaborate Information and Communication Technology data centers and instead offload part or all the elaborate Information and Communication Technology Infrastructure to a Cloud Solution Provider or through a third party for access across the Internet by hiring software, application platform as well as the ICT infrastructure. The uptake of this technology holds the promise of driving down cost while fostering innovation and promoting agility in running elaborate Information and Communication Technology departments. The constant need to store, update and manage on-site elaborate Information and Communication Technology infrastructures in academic institutions particularly institutions of higher learning for research and training activities is undoubtedly a costly exercise. For this reason, migration towards cloud services has and continues to be a running agenda in boardroom policies for these institutions. However, the full potential of this marvelous technology is yet to be realized in higher education due to deployment challenges. This paper reviews existing Cloud Computing deployment models and suggests a risk-based conservative approach for Cloud Computing uptake.

***Index Terms*—**Cloud Services; Cloud Computing; Utility Computing; Deployment Framework; Higher Education

I. INTRODUCTION

According to [4], Cloud Computing (CC) 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”. The key design goal is to establish a computing infrastructure capable of meeting almost all of the present and near-future requirements of a large computing utility. The resulting computing paradigm eliminates the need for businesses to maintain datacenters and instead hire the needed hardware, software and computing platforms in a pay-as-you-go manner directly from a cloud provider or through a broker.

It is a requirement that such systems run continuously and reliably in a way similar to utility-based services such as electricity and at the same time be capable of meeting extensive service demands. The benefit of a multiple access computing facility operated as a computer utility is that it broadens the horizon of computing potential in a convenient and cost-effective manner; which arguably would in turn stimulate growth in many areas society. Such benefits have been realized in diverse computing domains of e-commerce, search engines, high performance scientific computing and manufacturing [1].

Today, [2], many institutions of higher learning are progressively transferring research activities, e-learning and Enterprise Resource Planning (ERP) systems to the cloud as an alternative to the traditional server-based hosting techniques. In this case, integrating learning tools, materials, training content and services has resulted in an efficient and economical delivery of educational content in a conveniently scalable, cost-effective, configurable and easy to update computing ecosystem. Further, this location transparent approach in accessing computing resources has also greatly reduced management and maintenance activities of the virtual resources allowing users to create, disseminate, update and control applications without the worry of the underlying technological complexities [5].

Despite increased adoption of CC especially in the industry and service sectors, the paradigm comes with uncertainties and fears relating to control, performance, vendor lock, security, privacy, latency and reliability real. This has slowed down CC uptake especially in higher education where service delivery tops as compared to enterprises where profit is the key to organizational existence – making agility and risk taking feasible for enterprises [3] [7].

II. BACKGROUND

According to [14], there are a number of driving forces behind the current interest in CC in higher education

1. College and University ICT departments are struggling to deliver scalable, secure, reliable, and cost-effective technology services in a time of shrinking budgets and growing demands for increased operational efficiencies.
2. Students, faculty, and staff are using a rapidly changing array of consumer electronic devices, and they expect ready access and easy-to-use ICT resources.
3. Large commercial ICT organizations are gaining significant economies of scale - in their infrastructure and service-delivery capacities - that individual College and University ICT departments simply cannot match.
4. College and University Chief Information Officers (CIOs) are becoming intrigued by the possibility that some - and perhaps most - of the services currently managed by the central ICT department could be moved to the cloud.

A. Characteristics of the Cloud

Cloud Computing has several essential characteristics that make it unique from other innovations such as grid and high performance computing (HPC) [9].

On-demand self-service: The on-demand and unilateral self-provisioning of hardware or software computing resources such as CPU, OS, Memory, Storage, Network

Broad network access: The unrestricted access to compute services via standard methods over the Internet, via Smart Phones, thin clients, laptops, and standard desktop workstations

Resource pooling: The support to the use of hardware and software in a multi-tenant computing model while appearing to have infinite available capacity

Rapid elasticity: The on-demand ability to scale up or scale down access to resources

Measured service: The ability to provide usage metrics for the purpose of billing and chargeback; allowing consumers to pay only for what they consume

B. Cloud Services Models

Service models map the various consumer requirements to the CC resource. Traditionally, CC has been offered in three service models:

Software as a Service (SaaS): Applications delivered as a service to end users over the Internet

Platform as a Service (PaaS): Application development and deployment platform delivered as a service in the cloud

Infrastructure as a Service (IaaS): Server, storage and network hardware and associated software delivered as a service in the cloud

C. Deployment Models and Frameworks

The classical cloud computing paradigm considers the following deployment alternatives for cloud services for any organization:

Public cloud: Typically, available via the Internet for public use and may be accessed freely or via subscription pricing by individuals, institutions, private organizations and government agencies.

Private cloud: Typically, a dedicated cloud for exclusive use by a specific organization, institution or enterprise. It is invariably called an enterprise cloud which may be on-premise or off-premise hosted by a third-party provider.

Community cloud: An off-premise or on-premise alternative typically shared by various organizations in support of a specific community or community-based project.

Hybrid cloud: A selected mix of all other cloud models, or the use of technologies selected for their cloud capabilities integrated into traditional data centers.

D. Benefits of Cloud Computing

CC avails compute services anytime and anywhere to the users without accountability for the maintenance of applications or the worry service location in a convenient, cost-effective and reliable manner. Specifically, users of cloud computing gain in the following ways [8] [11] [13]:

Virtualization: Virtualization supports ease of use and reduction of overheads by hiding technological complexities of underlying infrastructure facilitating faster development, installation and upgrade of applications.

Infrastructure independency: Enables higher interoperability of applications and hence freedom of implementation since code does not depend on any specific platform.

Flexibility and Adaptability: By using virtualization, the underlying infrastructure can change more flexibly according to different conditions and requirements.

Location independence: services can be accessed independently of the physical location of the user and the resource.

Multi-tenancy: The location of code and data is principally unknown and the same resource may be assigned to multiple users.

Reduction of costs: The user of cloud services pays only for the resources used.

Elasticity and scalability of service: The users can at any time store data, with no limitation of space. The user's data store capacity is increased profoundly.

Availability and quality of service: The promise for CC is that cloud services are available 24/7 throughout the year

Support teaching and learning: The platform has significant impact on the teaching and learning whereby trainers could prepare their training materials anytime without application limitations

Reduction of maintenance and resource cost: By embracing CC technology, tertiary institutions can save greatly on administrative and maintenance costs

Ease of Implementation: Without purchasing the hardware, licenses software, or implementation services, any small college, training institute/college, and university can deploy CC quite easily.

E. Challenges in Cloud computing uptake in Higher Education

Despite the multiple promises offered by this great innovation, organizations and more so institutions of higher learning face grave challenges in the deployment of cloud services. Some of these challenges can easily affect the strategic position since they touch on core aspects of data privacy, security, latency, reliability, limited control and auditability [15].

Interoperability and portability: Institutions should have the flexibility of migrating in and out of the cloud and switching providers whenever they want, and there should be no lock-in period. CC should provide the capability to integrate smoothly with the on-premise IT.

Reliability and Availability: CSPs still lack round-the-clock service delivery; even in the presence of elaborate contractual guarantees

Security: The confidentiality and integrity of data offered by the cloud is often questioned and thereby many academic institutions are reluctant to embrace the idea of cloud computing. Moreover, there are concerns of whether CC can effectively handle regulations on privacy. Sometimes the physical location of clouds may span expansive geographical boundaries including continents

Lack of control: The users lack the freedom to physically own and control the data stored in cloud since they are left in the hand of the CSP or a third party.

Bandwidth: Since the cloud computing is an internet based service; it is quite challenging to effectively support compute intensive education research services such as HPC and big data analytics due to limited bandwidth.

Educational management rules: The control, monitoring and management are quite difficult with CC in relation to the traditional education that decision makers and management board are used to in relation to teaching, content and examination.

III. RELATED STUDY

Migrating towards the cloud needs a well-defined strategy that supports Cloud Computing capabilities. In order to have success, the cloud strategy must take into account the real needs of the institution and be aligned with the institutions strategy [6]. A number of models and frameworks have been invented and reported to this end.

A. 5-Stage Framework

In their research, [4], the authors express the experience of universities in attempts to migrate to the cloud and suggest a migrating strategy based on the following five stages:

1. Developing the knowledge base about Cloud Computing; by participating at seminaries, conferences, discussions with the suppliers and consulting the most recent researches in the field.
2. Evaluating the present stage of the university from the point of view of the IT needs, structure and usage; by understanding the university IT infrastructure, the data, services, processes and applications that may be migrated or need to be maintained within the university, so as to observe the security policy.
3. Experimenting the Cloud Computing solutions; the transition to cloud may be achieved gradually, starting from testing a pilot project in cloud and then externalizing the applications chosen for cloud.
4. Choosing the Cloud Computing solution; by identifying the data and applications, functions and main processes within the university and evaluating these elements according to criteria, such as mission, importance within the university, sensitivity, confidentiality, integrity, availability, in order to determine the candidate elements for cloud.
5. Implementation and management of the Cloud Computing solution.

B. Oracle's Private Cloud Model

The model is based on Oracle's belief that the greatest near and medium term opportunities for education rests with shared services models and private clouds, where like-minded education or research institutions can use a shared cloud infrastructure, or single institutions can take advantage of specific cloud technologies such as virtualization-enabled self-provisioning of application environments.

C. The 3-strategy Framework

In [11], the authors report a 3-dimensional framework in movement towards the cloud based on Technological, Organizational and Environment (TOE) framework for the Kenyan context.

The technological dimension comprises both the internal and external technologies relevant to the Institution. The organizational context comprises an institution's innovativeness, top management support, organizational culture, the quality of human resource, and size while the environmental context comprises factors of institutions surroundings, consisting of stakeholders such as sponsors, the government, the community, and competitive pressure.

D. IBM's 2-Dimensional framework

The two dimensions' framework reported in [4], is to be considered when developing a cloud computing strategy. The first dimension entails the determination of a cloud delivery model such as private, public or their sub-types and the second entails the mapping of a service type or types such as PaaS, SaaS and Iaas to the selected model.

IV. THE FRAMEWORK

The selection, adoption and implementation of cloud solutions have been on the increase with many institutions of higher learning especially in developing countries adopting the cloud computing offerings. For institutions without adequate computing resources this is a viable solution and is facilitated by existence of CSPs who provide cloud services for free or at discounted rates to educational institutions. According to [16], over 30 institutions across Africa have entered into partnerships which include grants, technical support, consulting, and training with Google to use Google cloud services.

The migration frameworks and models reported are too generic in nature and consider movement to the cloud a one-step activity. However, in the backdrop of potential of data corruption, questionable confidentiality and privacy as well as loss of control of key and sensitive institutional functions such as accounting, personnel and examinations, it is imperative that a thorough, well thought out and tested strategy be employed as the guiding principle for the movement towards the cloud.

The proposed framework encourages a thorough internal capacity and capability analysis in aspects such as available Cloud Computing expertise, availability of Internet bandwidth, financial resources for metered payments, information and data security concerns, data privacy and regulations, service and infrastructure readiness, licensing requirements, process requirements and memory locks, communication protocols , level of required controls and auditability among others for all the operational functions of the institution.

The initial phase may be guided by technology maturity and innovation frameworks such as Diffusion of Innovation (DOI), Technology, Organization and Environment (TOE), [11], and Information Technology (IT-CMF) [10]. Secondly, it proposes the generation of a prioritization list of operational functions in the desired order of migration to the cloud. In this case, less sensitive services such as student e-mail, research and e-learning would top the list while very sensitive services such as accounting and examinations would come last. Subsequently, for each of the functions in the list, starting at the head, a cyclic process of setting objectives; identifying constraints, alternatives and risks; assessment and resolution of risks; constructing prototyping and conducting pilot studies; verification and validation; integration and testing; adoption and deployment follows. This strategy is summarized in *Algorithm 1* and *Figure 1*

ALGORITHM 1: CONSERVATIVE CLOUD SERVICES DEPLOYMENT ALGORITHM

1. thorough internal capacity and capability analysis in aspects such as available CC expertise
2. Generation of a prioritization list of operational functions in the desired order of migration to the cloud
3. for each of the functions in the list, starting at the head

3.1 setting objectives;
3.2 identifying constraints, alternatives and risks;
3.3 assessment and resolution of risks;
3.4 constructing prototyping and conducting pilot studies;
3.5 verification and validation;
3.6 integration and testing;
3.7 adoption and deployment

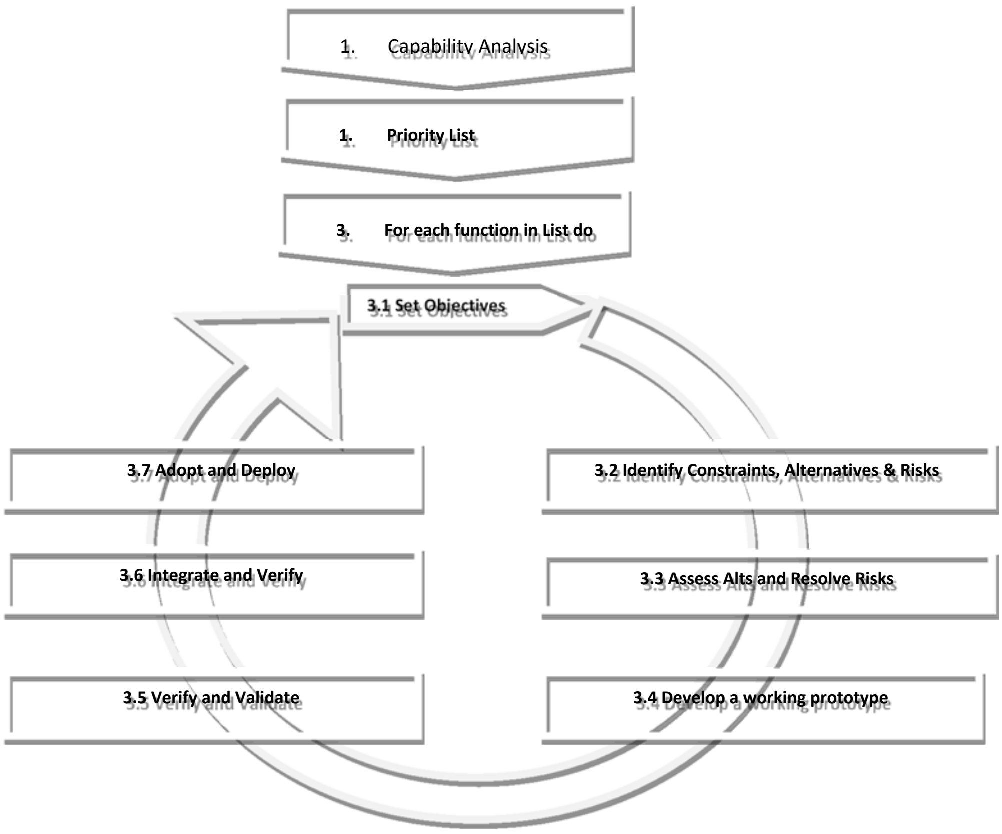

Fig. 1 Iterative Framework for Cloud Adoption in Higher Education

V. CONCLUSION

Cloud Computing marks a fundamental shift in computing in line with the movement from mainframes to client-server systems, with the ability to commoditize hardware and software and gain access via an on-demand and pay-as-you-use model. However, no institution should under-rate the stark realities of data integrity, security, privacy and control issues that may raise audit and administrative queries. For this reason, it is reasonable to take baby steps towards cloud computing, being sure of where we are at any time. The proposed approach could serve as a guide to this effect.

Although far from fully realized, the Cloud Computing philosophy is not far off and researchers need work tirelessly round the cloud to address issues of data privacy, security, confidentiality and integrity in order to assure consumers of desired levels of service quality and contractual Service Level Guarantees (SLAs). The proposed framework requires validation through an experiment and the results compared to existing frameworks. Further, extensive research is needed in control procedures for auditability of cloud services. This would most likely involve the use of artificial intelligence techniques to construct fool proof security and trust models.

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