A Technical Feasibility for Adoption of Cloud Computing in King Abdulaziz University, Saudi Arabia

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Abstract: ***The current study focuses on how cloud computing, private cloud in particular, is influencing educational institutions worldwide. Although commercial enterprises are in the process of using cloud computing yet most of the educational organizations are still running the traditional client server model. This model caused many problems to different educational institutions. After studying the literature, the author discovers that the technical feasibility for private cloud adoption in an educational institution has not been comprehensively conducted in previous studies. The current study tries to narrow this gap via carrying out six steps before the adoption of cloud computing and three steps after the adoption. The results attained before the adoption show a significant underutilization of compute resources in client server model and poor average availability, performance and response time for the PMS application hosted at that model. However, the outcomes accomplished after the adoption indicate a substantial boost in several areas of private cloud assessment. These outcomes are measured by systems' outstanding availability, performance and response time in Aziz Admissions Portal assessment. Also some top users were interviewed to measure the performance and satisfaction level. Finally, it can be concluded that private cloud computing helped KAU to overcome difficulties faced in the previous model and helped to improve the performance tremendously.***

Keywords: Cloud Computing, Client Server Model, Private Cloud Model, Technical Feasibility

1. Introduction

Cloud computing is commonly everything one does with his or her computer, like saving files or using office word or excel online over the Internet. The visible form of data in the cloud sailing out through the Internet and maybe reached via whatever computing machine linked to the World Wide Web is the actual driver to form cloud computing phrase. Yet, one would ask: why care about cloud if our PCs at home and work can cater such services? Cloud computing is made for tomorrow, when everyone would operate many types of compute machines, like personal and portable computers, smartphone, or pad. The goal is to allow access to the data and services one needs from everywhere via any machine linked to the World Wide Web. Moreover, cloud computing is inexpensive for enterprises. A company does not need to procure a central storage hardware, for instance, or hire computer professional to maintain it if storage as a service is leased from one of the cloud service providers. Indeed, there are some disadvantages for cloud computing; for example, private data might be exposed when put into the cloud which includes a lot of concern about privacy and trust. The case is still debatable when it comes to cloud computing drawbacks. In addition, cloud services are still at early phase in comparison to counterparts on a personal computer or portable device. On the other hand, everyone will adopt cloud computing sooner or later.

Cloud computing has recently achieved broad recognition and acceptance from Information Technology (IT) firms and academic communities. It is an improved computing pattern catering instant computing resources from a combined pool of assets; it does also support the payment plan known as pay-as you-go. Cloud customers can rent compute resources, like processing power, desk spaces, memory, network or even an application as they demand. They are, moreover, able to lower or elevate their usage of rented resources; hence, they only pay for what they utilize [1] [2]. In fact, cloud computing is very much like the power links which grant electricity as a service that is charged to consumers based on the quantity spent and provided in several abstraction tiers [6]. Several explanations do exist for cloud computing which differ from author to author; for example, Gartner et al. [3] has clarified cloud computing as: "A style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies". The illustration indicates the flexible and expandable nature of cloud computing.The phrase elastic implies that computing assets, given to users, could be increased and decreased based on the necessities of the workload in cloud computing. The afterward definition was given by Forrester Research [4] as "A standardized IT capability (services, software, or infrastructure) delivered via Internet technologies in a pay-per-use, self-service way." The Institute of Standards and Technology (NIST) explains cloud computing as "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" [2]; such definition is literally catching further recognition within Information Technology industry nowadays. A third description, which includes all cloud computing unique qualities, is: "Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically re- configured to adjust to a variable load (scale), allow- ing also for an optimum resource utilization. This pool of resources is typically exploited by a pay- per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLAs" [5]. Cloud computing mainly has three layers which are:

1) The infrastructure layer, which indicates the requisite level of cloud setups, composed of storage, virtual machines (VMs) and network, is the first tier of cloud system [6].
2) The platform layer, which eliminates the difficulties of building and handling the infrastructure tier from cloud users to easily develop, roll out and manage apps, is the second level of cloud system [6].
3) The software layer, which points out an advanced payment based software paradigm accommodated in cloud setups and reached through the World Wide Web, is the third tier of cloud system [6].

Figure 1.1 shows examples of services that can be leased from each principal layer of cloud computing, such as a compute resource out of the infrastructure layer, a database engine out of the platform layer and a finance app out of the software layer.

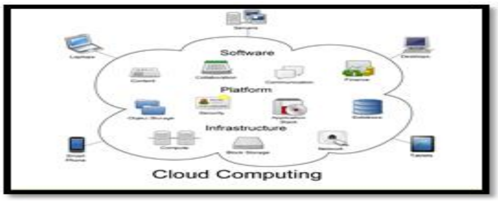

Figure 1.1: Services that can be leased in each of the three Principal Layer of Cloud Computing [7].

1.1 Objectives and Importance of the Study

Inspired by the technology of cloud computing spreading worldwide, this research paper will focus on how cloud computing, private cloud in particular, is influencing educational institutions worldwide. The Objectives include:
1) Identify factors favorable to KAU for adoption of cloud computing.
2) Improve computing resources efficiency.
3) Lower IT cost per unit, project or product.

Cloud computing is a popular subject that is crucial in all fields of life, especially in universities. The research paper will help decision makers in Saudi universities explore how cloud computing, private cloud in particular, enhances processes efficiency, reduces costs, and minimizes time needed to provide better services to the students. This will indeed improve the university image; and thus, grant it a competitive advantage among other universities in Saudi Arabia. Moreover, this research will open many chances for future studies on improving IT usage in Saudi universities and could allow more collaboration between universities worldwide, which can give more chances to work globally.

2. Literature Survey

Cloud computing, an improved computing pattern catering several benefits in comparison to current scattered designs, has recently attained broad usage. Some of its benefit are flexible assets control, low cost and simple failure control etc. Even though cloud computing is nearly a contemporary computing pattern, the point behind it, as a computing utility, goes back to the year 1961 when John McCarthy, a great establisher in the area of artificial intelligence, said that "If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility... The computer utility could become the basis of a new and important industry" [14]. Basically, catering computing assets as a service to cloud users as electricity companies do supply electricity to their subscribers is mainly what cloud computing is implementing. The cloud user, in this computing utility pattern, receives a service when he or she needs and gets charged based on pay-as-you-go notion. Hence, this implies that cloud users only pay for what they utilize.

It required very lengthy years in the history of computing for the perception of cloud computing to evolve into a fact. Mainframes, large high speed Central Processing Unit (CPU), back in 1970s provided consolidated joint compute assets that can be accessed via dump terminals [12] [15]. After that, catered services were provided via isolated and dedicated servers that are linked with personal computers by local area networks (LANs). Then, the emergence of the Internet helped this network based computing pattern evolve so that connected users can have access to the catered services. Several initial means of services like electronic mail and search engines were provided due to high speed Internet and large capacity networks [12].

Hosting services for web pages were commenced by major and minor Internet service providers. For example, Salesforce.com [16] and Amazon.com [17] are one of the several enterprises providing such services via Internet. The phrase cloud computing came up nearly in 2006 via the start of Amazons Elastic Compute Cloud (EC2) [18] and afterward Google App Engine [19] as commercial offerings. While this improved type of computing is leading, unique designs of applications like web 2.0 positioned for social media as Facebook, service oriented workflows like MapReduce [20] have appeared.

2.1 Principal Layers of Cloud Computing

The three principal layers, that were briefly explained earlier, are clarified in details in the afterward three points:

2.1.1 Infrastructure as a Service (IaaS)

According to ProfitBricks website, cloud computing foundation is the Infrastructure as a Service (IaaS). Instead of buying or renting an area in a costly data center, work force, property, and all the requirement to implement and manage storage, servers, and networks, users can simply lease a virtual area, that can be accessed via Internet, in one of the data centers of IaaS suppliers. IaaS suppliers cater consumers the needed resources like processing power (cores), storage in a form of disk space, random access memory (RAM) and network to build a virtual server and the management interface that automatizes them; it is the responsibility of IaaS suppliers to maintain and manage the physical hardware of the servers, virtualization tier and the network to guarantee that catered cloud assets are accurately running and delivering the IaaS [21]. On the other hand, IaaS user has to procure, setup, and handle the upper layers of the cloud that are operating systems, middleware, software and applications [22].

2.1.2 Platform as a Service (PaaS)

Platform as a Service (PaaS) carries applications through the Internet. Cloud suppliers, in the PaaS design, supply the software gadget and hardware, required for the application evolution, to consumers as a service. The hosting and the management of the supplied software and hardware is granted by the cloud suppliers' infrastructure; hence, PaaS consumers focus on developing and running application rather than worrying about hosting and maintaining software and hardware. They only need to access PaaS supplier service portal via any web viewing software mediator and start using the platform [23]. "Common PaaS vendors include Salesforce.com's Force.com, which provides an enterprise customer relationship management (CRM) platform. PaaS platforms for software development and management include Appear IQ, Mendix, Amazon Web Services (AWS) Elastic Beanstalk, Google App Engine and Heroku" [24].

2.1.3 Software as a Service (SaaS)

Software as a Service (SaaS) is an allocation paradigm program carrying applications to SaaS users by SaaS suppliers over secure Internet connections. SaaS is gradually turning into a common allocation paradigm as a core technology supporting service oriented architecture (SOA) and web services through the aid of high capacity and speed transmission of data worldwide [25]. For SaaS, the core infrastructure, middleware, computer program, database and information are entirely hosted in the supplier data center and managed by a service agreement. This assures that the leased service is efficient and effective, along with helping the enterprise be in business with marginal initial charge [26].

2.2 Cloud Computing Service Deployment

Aside from the allocation model implemented; for example, IaaS, PaaS and SaaS, There are four service deployment types for cloud computing. Deployment models might have unique products that handle distinct particular demand or circumstance. Public, private, hybrid and community are the main distribution patterns of cloud computing [27].

Figure 2.1: Public Cloud assets are accessible to everyone [28].

2.2.1 Public Cloud

It is believed that cloud suppliers cater all cloud assets like CPU, RAM, storage, network, software, application and many others then make them accessible to everyone. Some of these services are carted at no cost whereas some of which are carted based on how much is utilized from the plan. Advantages of public cloud are minimal capex since cloud assets are provided by the supplier, ability to extend to meet the demand and avoid any wasted resources since payment is based on how much consumed. Amazon Elastic Compute Cloud (EC2) and Windows Azure Services Platform are some of public cloud instances [29]. Figure 2.1 shows how Public Cloud assets are accessible by everyone.

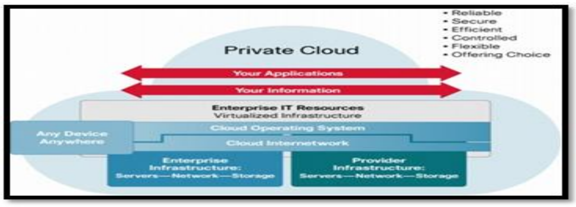

Figure 2.2: Private Cloud Service Layers in the Enterprise [30].

2.2.2 Private Cloud

Irshad et al. [27] believe that private cloud is an alternative distribution paradigm for cloud services. Assets in this paradigm are fully dedicated for organization; thus, no anonymous organization can participate in those assets which can be hosted in the enterprise headquarter or outside. It is top for companies with active random computing requirements which need continuous management over their compute resources [31]. Information Technology associations state their worries regarding serious matters, like security, happening through broad public cloud computing enforcement. Such kinds of anxieties arise from the reality of storing the datum of clients off their sites; truly, the data could exist within unspecified site [10]. Moreover, such joint computing resources are not appropriate for every enterprise especially ones having extremely important and vital systems and worries of security [31]. The uppermost level of dominance across efficiency, dependability and protection is provided by private cloud [32]. For instance, The Hochschule Furtwangen University (HFU) has a private cloud infrastructure setup, known as Cloud Infrastructure and Application (CloudIA). The setup aim is to develop, based on a request, IAAS and run electronic education [8]. Figure 2.2 explains private cloud service layers in the enterprise

Figure 2.3: Hybrid Cloud Setup between Private Cloud and Public Cloud [33].

2.2.3 Hybrid Cloud

As the name indicates, it is an implementation pattern that integrates various clouds [34]. Hybrid cloud is a mixture of a private cloud setup hosted locally within an organization data center and public cloud setup leased from one of the providers of public cloud accompanied by adaptation between the two podiums. Through enabling production capacities towards running among hosted private cloud in addition to leased public cloud, hybrid cloud setup empower enterprises with superior elasticity and additional implementation alternatives. For instance, an organization can run its critical business applications on its hosted private cloud setup and have its development and testing environments run on a leased public cloud setup, like Google Compute Engine. Amazon Web Services (AWS) is used to orchestrate the links between private and public cloud. Thus, organizations with active or variable workloads can exceptionally value hybrid cloud capabilities to meet their computing demands [35]. Figure 2.3 demos how hybrid cloud is built with a secure connection using IPsec VPN between private cloud setup in an enterprise and public cloud on the Internet.

Figure 2.4: Different Associations Participation in Community Cloud (sharing same compute interests) [36].

2.2.4 Community Cloud

According to Gartner et al. [37], "Community cloud computing refers to a shared cloud computing service environment that is targeted to a limited set of organizations or employees (such as banks or heads of trading firms). The organizing principle for the community will vary, but the members of the community generally share similar security, privacy, performance and compliance requirements. Community members may wish to invoke a mechanism that is often run by themselves (not just the provider) to review those seeking entry into the community." Figure 2.4 demonstrates how numerous associations, having the same compute interests, are participating in community cloud.

2.3Virtualization

Virtualization, offered by Hyper-V [38], Xen [39], VMware [40] or KVM [41], is an empowering technology in cloud computing. Virtualization technologies give the opportunity to contain the entire software stack, the operating system to applications, in a package which can be named as Virtual Machine (VM). In addition, Virtual Machine Monitor (VMM), known as Hypervisor in Xen expression, is capable of controlling physical machine assets in way that enables operating many VMs on one real machine. As the operating system kernel acts for the functions of an application, the VMM does for the VMs [12].

2.4 Cloud Computing in Education

The significance of cloud computing is proven in the annual Horizon Reports 2010, 2011, 2012 and 2013, that demonstrate evolving technologies in the US and Australia [42] [43] [44] [45]. Countries like China [46], Germany [8], and Sweden [47]; moreover, are evaluating the modern technology in education. A huge sum of researches suggest cloud computing infrastructure in education particularly for colleges and universities [48]. Further researches debate and examine various podiums of learning management such as Moodle and Blackboard [49]. From experiential data aspect, Leaders in cloud services have issued several case studies to shed the light on how they can offer services that aid cloud computing in schools [48]. Cloud computing, from the teaching side, is incorporated by schools in the core curriculum of courses, like English, History, Science [42] [43] or teaching of particular expertise, like photo or video editing [43]. Several universities, at post-secondary class, have altered their core curriculum to include cloud computing [48]. On the other hand, aside from informal or casual clues, facts on the awareness of stockholders or the motives pushing towards cloud computing acceptance or refusal in education are confined. Nearly all researches follow various kinds of innovation diffusion theories, like Technology Acceptance Model (TAM) or Theory of Planned Behavior (TPB), that help study the acceptance attitude of instructors and learners. However, those researches focus on studying cloud computing acceptance at the post-secondary grade ignoring the study of problems from management point of view [48] [50] [51]. Tan and Kim, employing the Expectation Disconfirmation Theory (EDT) in a different study which aimed attention at Google Docs, study the intent of MBA students to utilize application from the cloud [51]. Bhattacherjee and Park, employing migration theory in a long research, study university students posture and conduct use towards Google Apps in South Korea [50].

In the CDW Corporations annual report [53], A review of one thousand two hundred and forty two IT decision makers discovered the fact that the sum of institutions of higher education planning or adopting cloud computing has been growing when relating it to the annual report of year two thousand and eleven. Causes behind this rise are: fifty five percent boost in competence, forty nine percent elaboration in motility, thirty two percent evolution in the capability to devise, thirty one percent growth in IT team availability for other projects, twenty one percent decrease in IT operational expenditure and twenty four percent raise in the capability to propose state-of-the-art products and services. The CDW report, moreover, disclosed that cloud computing is being implemented or maintained at forty three percent of establishments of higher education. A ten percent growth in the percentage of cloud computing implementation or maintainability in establishments of higher education if we relate it to thirty four percent in year 2011. After all, the CDW discovered that schools were shifting to certain cloud computing applications with various percentages, such as: processing power with twenty five percent, storage with thirty one percent and messaging /conferencing and collaboration with twenty nine percent [54]. Classical software are substituted by institutions of higher education with cloud computing technology which can deliver services and applications via World Wide Web. Causes towards cloud computing adoption are directed by the drop in IT charges, decrease in systems complication and the chance to obtain graceful and elastic services. According to Katz et al. [55] who explained the most popular characteristics cloud computing presents to institutions of higher education, "The prospect of a maturing cloud of on-demand infrastructure, application, and support services is important as a possible means of

- driving down the capital and total costs of IT in higher education;
- facilitating the transparent matching of IT demand, costs, and funding;

- scaling IT;
- fostering future IT standardization; acceleration time to market by reducing IT supply bottlenecks;
- countering or channeling the ad hoc consumerization of enterprise IT services;
- increasing access to scarce IT talent;
- creating a pathway to a five-9s and 24 x 7 x 365 environment;
- enabling the sourcing of cycles and storage powered by renewable energy; and
- increasing interoperability between disjointed technologies between institutions."

According to Mr. Cearley, VP & Gartner Associate, "Cloud is the new style of elastically scalable, self-service computing, and both internal applications and external applications will be built on this new style" [56]. Cloud computing is deliberated in three out of ten topmost tactical technology tendencies for the year two thousand and fourteen as stated by Gartner [69].

2.4.1 Cloud Computing in the U.S. Education

Several educational establishments in the United States of America are in progress to implement cloud computing, like the University of California, Washington State University, the University of Washington and many others [54]. For instance, a course, in the University of California at Berkley was transferred from IT division to Amazon Web services, a cloud computing supplier, due to the fact that the course needed massive number of servers [51]. Cloud computing supports schools to help them concentrate on their core business in innovations and research, instead of wasting time and assets on complicated IT setups and systems [54]. One of the effective instances of cloud computing in the United States of America is the North Carolina State University virtual computing lab [57]. The setup of the virtual computing lab was implemented by further schools and utilized for students from lower grades because the project is considerably prosperous [58]. Reduction in charges and IT complication were achieved by North Carolina State University; it decreased the number of employees from fifteen to three through subcontracting several locally developed services to the cloud [54]. Numerous universities, which are impressed by the smart features of cloud computing, are adopting and taking complete use of this technology. A numeral of academic and formal firms in the U.S. have acknowledged cloud computing power to enhance efficacy, price and suitability for the academic sections. For instance, cloud computing was discovered by The University of California (UC) at Berkeley as alluring to employ in a class uniquely aiming for installing and evolving SaaS applications. UC transferred its course from the university data center to the cloud via the granted aid of Amazon Web Services (AWS). The power to get a massive number of servers required for the course in a short time is one of the major causes that was cited [59][60]. Schools, furthermore, appear to have accepted the notion of cloud computing. For instance, Kentucky's Pike County region inserted the cloud into schoolhouses, having around ten thousands and two hundred students. Cloud computing is used to convert one thousand and four hundred outdated PCs, which were prepared to be casted aside, into completely working VMs [61]. The total cost of ownership (TCO) over a five year time for the hosted virtual computer solution is approximated by Pike County to be lower than one half of price of supporting onsite PCs. Pike County bypassed the extra fare of infrastructure and manpower to manage the servers through hosting PCs in IBM data center [62]. Efficacy was accomplished by Washington State University through the adoption of virtualization, one of the cloud computing enablers [68].

2.4.2 Cloud Computing in the UK Education

Cloud computing is likewise discovering its path in United Kingdom education. Google Apps are used by a numeral of universities in England; the Royal College of Art (RCA), University of Westminster and many others are examples. The price and the common call from students giving up the unstable locally hosted email systems, were the major elements that influenced this shift [64]. Sultan did a research about the University of Westminster (UOW). It, having beyond twenty two thousand students, is one of the academic institutions in England to accept cloud computing. When student email service started to appear obsolete, consideration in cloud computing commenced. A problem, spotlighted through a study, displayed that ninety six percent of students were configuring their emails to immediately pass on received emails to their email accounts hosted at exterior providers. UOW began to seek for different alternative to solve this problem. The alternative was the education version of Google Apps that can supply the entire campus with complimentary emails with seven point three gigabyte of storage space and other services. The price of Google Mail usage was exactly nothing. An approximate calculation for allocating the same disk space on locally hosted systems would require UOW to pay about one million British pound regarding system setup, updates, manpower, certificates of use, disk space, servers and continuous maintenance. Nevertheless, OUW obsolete email system, running on Microsoft Exchange, continues to exist as the formal employee email system. This was clearly a wise resolution by UOW that was worried about lawful dilemma of relocating the guardianship of their datum to an outsider off their premises [59].

2.4.3 Cloud Computing in the African Education

Google has effectively aimed at the East African academic mart; a numeral of East African institutions of education, like the Kenyan Methodist University, the University of Mauritius and many others have agreed with the huge cloud supplier to supply Google cloud services to their students, such as Google Docs and several other offered services. World Bank aided mentioned east African institutions of education to uphold bandwidth in universities [59]. Cloud computing was utilized as well by several universities in impoverished African states, like Nairobi, Ethiopia and Rwanda [63]. Ethiopia provides two hundred and fifty thousand portable computers to its school teachers with Microsoft aid; the whole portable computers are operating on Azure cloud platform. Teachers will be able to load the curriculum, stay informed about academic register and safely transport student datum over the education system with no further charge for H.W* and S.W* support to be connected [65]. The capability of cloud computing to assist the educational system in Africa, through IT charge cut and helping education to be more efficacious than before, is extremely robust and enabler agent for education improvement in this immature continent [59].

2.4.4 Cloud Computing in the Saudi Arabian Education

In Saudi Arabia, cloud computing is yet in the initial phases of usage. Though, a growing sum of IT firms in Saudi Arabia show case in adopting cloud computing. IDC showed in a report that entire expenditure on cloud distribution in Saudi Arabia has improved thirty four point eighty six percent in year two thousand and twelve, with extended period of time expenditure to stretch at a CAGR* of forty nine point seven percent between years two thousands and twelve and two thousand and sixteen. Furthermore, even though enterprises in Saudi Arabia generally favored to run their IT tasks on the inside of their data centers, some enterprises are giving attention to subcontracting standards and increasingly making use of hosting and managed services. The rising approval of subcontracting is considered to be the first stage to advance to a paradigm built on cloud [66]. According to Alhazzani, two hundred professors were examined at King Saud University to locate cloud computing features and detriments within education as well as study the spread of cloud computing toolkits use among professors. Results showed that fifty-six point seven present of the respondents are aware of cloud computing notion, six point seven percent were unbiased on cloud computing notion and three point three percent were highly aware of cloud computing notion. The whole sample consented that cloud computing notion made applications accessible everywhere all the time. The respondents, furthermore, consented on cloud computing ease of use and economical price in maintenance. The results by Alhazzani showed as well a consent through the respondents on the cloud computing detriments regarding the worries about storing data in servers outside their control. A lot of the respondents were worried as well about publication politics and rights of property, and on the constancy and security of critical datum. Executive, infrastructure, and financial limitations were moreover causing worries for the respondents. At the end, the results of the research pointed out that great number of the respondents (ninety six point seven percent) consented that cloud computing is indeed a big stage for the growth of universities in Saudi Arabia [67]. Finite studies regarding cloud computing in Saudi Arabia were issued. A study built on the Technology Acceptance Model (TAM), showed great degree of consumers' acknowledgement of cloud computing in KSA*. The study; however, did not assign the status of consumers examined in companies and if their opinion was founded on individual or enterprise cloud applications [68].

2.5Literature Review Gap

It is discovered from the comprehensive literature that the technical feasibility for adoption of cloud computing, private cloud in particular has not been comprehensively conducted by researchers in their previous studies on educational institutions. The researcher tries to narrow this gap in the literature.

3. Problem Definition

Although commercial enterprises are in the process of using cloud computing yet educational organizations, such as universities are still running the traditional client – centric models which are personal computing model (data and software resources are hosted in a local computer) and client server computing model (data and software resources are hosted in organization's servers). Doelitzscher et al. [8] believe that "In a typical university scenario, PC labs and servers are under-utilized during the night and semester breaks. In addition, these resources are on high demand mainly towards the end of a semester". The client server computing model has several limitations; for example, the massive numeral of underused servers is a significant issues in several information technology firms [9]. There are many reasons for server sprawl to become a showstopper in many data centers; one of these reasons is vendor obligation to operate its apps within a segregated server. Another cause is OS diversity in that a DB* could operate better on UNIX or Linux and an email system might need Windows OS*. A third reason is consolidation and possession of different integrating ventures that can result in a massive set of servers, one server to run a solo function [10]. According to Nguni et al. [11], "The consequences of improper resource management may result into underutilized and wastage of resources which may also result into poor service delivery in these data centers. Resources like; CPU, memory, Hard disk and servers need to be well identified and managed." Figures 3.1 and 3.2 show the risk of over- provisioning which leads to underutilization of available assets and heavy penalty for under- provisioning which can lead to losing revenue if the business demands are higher than the available capacity of compute resources or losing customers if their needs are not always fulfilled by the available capacity of compute resources.

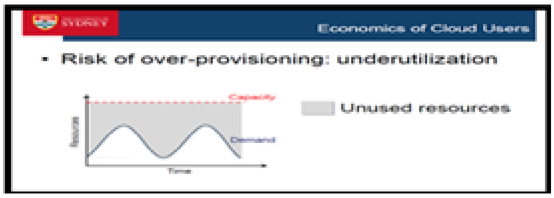

Figure 3.1: Risk of Over- Provisioning: Underutilization [10].

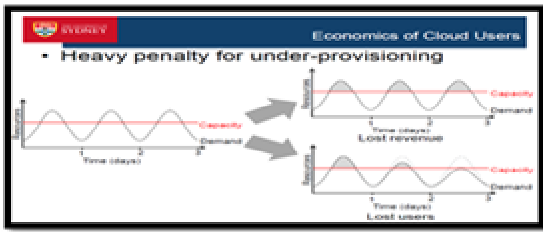

Figure 3.2: Heavy Penalty for Under- Provisioning [10].

Figure 3.3 shows over 5K servers average CPU utilization over 6 months period at Google. The CPU usage turns to vary between 10 and 50 percent. When those servers were examined over longer time intervals [12] [9].

*H.W = Hardware. *S.W= Software.*CAGR = Compound Annual Growth Rate. *KSA = Saudi Arabia. DB= Database. OS= Operating System.

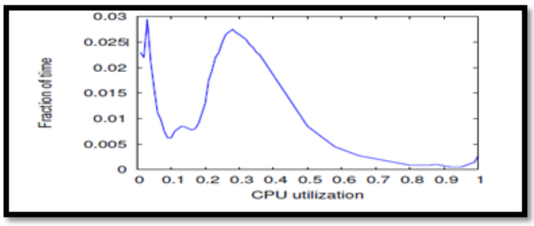

Figure 3.3: Average CPU utilization of more than 5K Servers during a period of 6 months (source: The Case for Energy-Proportional Computing [13]).

As a result, universities, running the traditional computing are suffering from many issues such as:

1) Lack of required computing resources due over-provisioning or under-provisioning.
2) Huge efforts wasted on managing complexities of infrastructure, platform, and software.
3) Lack of scalability that limits the business from scaling up or scaling down.
4) IT cost per unit, project or product is annually inflating.

King Abdulaziz University (KAU) is running the client server model, where data and software resources are hosted in KAU data center servers and it is experiencing the above mentioned problems.

4. Methodology

The building blocks of the methodology implemented are divided into two main segments: segment one involves the steps taken before the adoption of private cloud at KAU whereas segment two comprises the steps following the adoption of private cloud at KAU.

4.1 Prior to the adoption of Cloud Computing

The six following points describe in details the steps taken before the adoption of private cloud all the way till the private cloud setup is completed. The steps are:

1) Client Server Model Assessment.
2) Client Server Model Assessment Output.
3) Cloud Computing Adoption Options.
4) Technology Vendors Evaluation.
5) Technology Vendor Selection.
6) Private Cloud Solution and Implementation Architecture.

4.1.1 Client Server Model Assessment

This assessment is split to 2 phases; in phase one, quantitative data are acquired from 191 hosts running client server model using VMware Capacity Planner tool. In stage two, quantitative data are obtained from Performance Management System Portal (PMS), which is hosted in 4 hosts running the client server model using Business Service Management (BSM) tool.

4.1.1.1 Stage One: Client Server Model Characteristics and Utilization Metrics Assessment

In this stage, the assessment measures client server model and acquires quantitative data from 191 hosts using VMware Capacity Planner tool to get the system characteristics and utilization metrics to determine if workloads could be virtualized or not. The tool provides a quick and accurate virtualization analysis. The 191 hosts are monitored for 24 weeks to collect data during the busy days of the academic semester as well as the days off; after that, the data collected are tabulated and cleansed; the outputs are presented in a table format which is divided into capacity and utilization sections. Then, graphs are plotted from the tabulated and cleansed data and displayed under results section; finally, the researcher analyzes the data to get the outcomes ready to be compared later with the data collected from private cloud model characteristics and utilization metrics.

4.1.1.2 Stage Two: PMS Portal Availability, Performance and Response Time Metrics Assessment

In stage two, the assessment evaluates PMS Portal, which is hosted at 4 servers running client server model and used by Admissions business owners during the Admissions period to make different decisions that have to do with Admissions, and acquires quantitative data from the 4 servers using BSM tool, which supplies information and applicable observations to handle the performance of KAU apps, servers, storage and networks. The tool is used to get the availability, performance and response time metrics of PMS portal during KAU admissions period for the year 2017; the data collection covers from June 5, 2017 till August 31, 2017. After data are collected, they are tabulated and cleansed; then, the outputs are presented in one table. Finally, the data are analyzed to get the outcomes ready to be compared later with the data collected from Aziz Admissions Portal hosted at private cloud model.

4.1.2 Client Server Model Assessment Output

The assessment output is divided in two outcomes; the first of which is related to data collected from VMware Capacity Planner tool to get client server model characteristics and utilization metrics assessment results, while the second one is related to the data assembled from BSM tool to have PMS Portal availability, performance and response time metrics assessment outcomes. Both of which are detailed in results and discussion section.

4.1.3 Cloud Computing Adoption Options

After KAU has decided to go with cloud computing, it was realized that cloud computing has many deployment models to consider; KAU had to examine the deployment models, which are public, hybrid, community and private cloud deployment models, to make its decision. Based on the Saudi Cabinet Decision No. 81, which states the rules and regulations of data hosting, it is mandatory on all government sectors to keep their data hosting within the Saudi Arabian borders [70] [71]; as a result, public, hybrid and community cloud computing deployment models were not options for KAU. This is because data hosting in public cloud is outside the Saudi Arabian borders; moreover, data hosting in hybrid cloud is partially outside the Saudi Arabian borders; add to that, KAU does not originally have a private cloud setup which is a prerequisite to go with hybrid cloud; in addition, the maturity level of community cloud within Saudi Arabia is still in the first stages. Consequently, KAU decided to adopt private cloud since the data will be kept within the Saudi Arabian borders.

4.1.4 Technology Vendors Evaluation

Five well established cloud solution providers in the market approached KAU to present their solution architecture for private cloud and implementation stages; the five were IBM, DELL, EMC, CISCO and HP. Based on the technical presentations held at KAU, each of them were fulfilling KAU technical requirements and specifications detailed in the request for proposal (RFP) officially announced for private cloud setup by KAU Contracts and Procurement Management.

4.1.5 Technology Vendor Selection

The selection was finalized based on the governmental procurement law which grant the tender to a technology solution vendor via a certified local Saudi enterprise passing through the official tendering channels if and only if the technical requirements and specifications detailed in the RFP requested are 100 % met with the least reasonable price to deliver the solution on ground. HP met the requirements and won the bid; thus, it was the technology solution vendor selected.

4.1.6 Private Cloud Solution and Implementation Architecture.

After HP met the procurement selection criteria; the project of KAU transformation from client server model to private cloud model started. The high available solution is built across two data centers that are located within KAU campus. The solution is built using two storages with metro cluster setup. The solution is a set of services and products that facilitates building and managing assigned work to KAU IT medium. It unifies the whole advantages and agility of cloud computing, safety and dependability that firm requirements to proceed with assurance. Cloud service automation (CSA) manages the cloud infrastructure using operation orchestration (OO) as the source engine for all the workflows and automation to build the IaaS, PaaS and SaaS. The automated life cycle values are attained via CSA portal which helps manage cloud services through a built-in graphical service designer, that easily and quickly, designs new cloud services. The use of Data Protector Software, StoreOnce virtual tape library (VTL) and Catalyst Deduplication Stores disk backup devices in the solution, increases the backup reliability, reduces the backup and restore time and enables KAU to store more backup with less capacity using the advanced de-duplication technology available in the StoreOnce. Figure 4.1 explains a high level view of KAU private cloud installed at the two data centers.

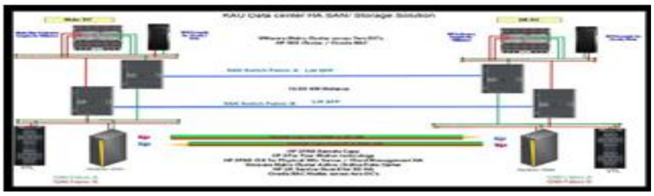

Figure 4.1: High Level View of KAU Private Cloud at the two Data Centers.

4.1.6.1 Servers & Blades Infrastructure

Site One has eight C7000 blade enclosures with fully redundant power fans and management modules. Each enclosure can take maximum of 16 half height servers or maximum of 8 full height servers. The total number of physical blade host servers in site one is 67 blade servers (60 half height blade servers and 7 full height ones). 3 physical management servers for CMS*, vCenter and SQL database are added with private cloud setup. **Site two** has six C7000 blade enclosures with fully redundant power fans and management modules. Each enclosure can take maximum of 16 half height servers or maximum of 8 full height servers. The total number of blade physical host servers in site two is 59 blade servers (48 half height blade servers, 9 full height ones). Two management servers for OneView management are added with private cloud setup. **Site three** has the Quorum Witness server located at KAU medical college.

4.1.6.1.1Servers' Pools Distribution

The cloud solution has 20 VMware clusters, 8 clusters are running as metro cluster where each metro cluster has from 8 to 12 hosts. The other 12 clusters are configured as local clusters with 2 to 9 hosts per cluster. All clusters are distributed among the two sites. Each cluster has distributed resource scheduler (DRS) enabled to balance the computing workloads with obtainable assets in the virtual environment. DRS is configured so that all pools of resources are increased, decreased or adjusted in a cluster. It rearranges VMs between physical servers if one or further VM workload intensely alters. Once the workload reduces, several physical servers are powered-down to consolidate workload.

4.1.6.2 3PAR Storage & SAN Switches

For best performance, fiber channel storage area network is implemented in the private cloud solution. For metro cluster hosts, OS boots from local HDDs; whereas local clusters hosts boot from SAN storage. All VMs, residing in 3PAR storage, have logical unit numbers (LUNs). There are two 3PAR storages in the cloud solution; one in each site with 8 x 8 GB replication links using dark fiber connecting sites 1 & 2. For metro-clusters to properly work, LUNs are presented to all hosts in a cluster in both sites; each LUN has its own replicated LUN with the same LUN ID and WWN and is presented to all cluster hosts for high availability in case of any failure. Thus, data are always available. Thin provisioning is used in the private cloud solution to permit a volume to be built and obtained as a LUN to a host. It also powers the dedicate-on-write approach method to save disk space; as a result, KAU would buy storage capacity if only requires. From the SAN switches side, the solution contains two SAN switches fabrics "A" and "B" in site one and site two where a cascade connection between the two sites exists using dark fiber links.

4.1.6.3 VMware Components

VMware vSphere Metro-Cluster is one of the core components in private cloud solution that has been built crosswise data centers one and two. VMware High (HA), which is implemented to provide recovery of VMs in the event of an ESXi host failure, is another core component in private cloud solution.

*CMS= Center Management Server.

4.1.6.3.1 VMware Metro Cluster

The use of VMware Metro Cluster is to provide high availability of and recovery for VMs across the two sites. VMware Metro Cluster is very dependent on the 3PAR storage and peer persistence license on both sites. VMware vSphere Metro Storage Cluster (vMSC), as a proven design for extended stretched storage cluster architecture, is implemented across KAU two data centers to keep and maintain data availability. Figure 4.2 shows peer persistence setup in KAU cloud solution.

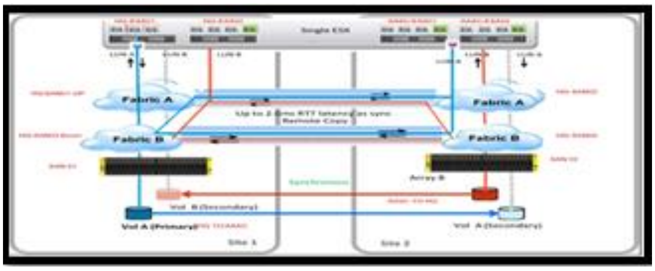

Figure 4.2: Peer Persistence Setup.

4.1.6.3.2 VM distribution in the Metro Cluster

KAU private cloud setup has 8 metro clusters to fulfil different business requirements; two of which serve quality in DMZ environment; another two work for server farm environment; two serve the DMZ environment; while the last two serve quality in server farm environment. One of the 8 metro clusters is selected to demo the VM distribution based on the application running on VMs. Table 4.1 demonstrates VM distribution in DMZ1-M metro cluster. For example, VMs (ADM1 through ADM10 were built to serve critical applications for admissions, are equally distributed among DMZ1-M metro cluster; this metro cluster has two host server groups; one group is in site1 having 4 physical host servers (S1-DMZ1-M-esx01, S1-DMZ1-M-esx02, S1-DMZ1-M-esx03, S1-DMZ1-M-esx04; the other group is in site2 having 4 physical host servers (S2-DMZ1-M-esx05, S2-DMZ1-M-esx06, S2-DMZ1-M-esx07, S2-DMZ1-M-esx08).

Table 4.1: Sample for VM distribution in DMZ1-M metro cluster.

Host Group 1	VMs	Host Group 2	VMs
	ADM1		ADM6
S1-DMZ1-M-esx01	ADM2	S2-DMZ1-M-esx05	ADM7
S1-DMZ1-M-esx02	ADM3	S2-DMZ1-M-esx06	ADM8
S1-DMZ1-M-esx03	ADM4	S2-DMZ1-M-esx07	ADM9
S1-DMZ1-M-esx04	ADM5	S2-DMZ1-M-esx08	ADM10

4.1.6.3.3 Virtual Machine Availability

VMware HA is implemented to provide recovery of VMs in the event of an ESXi host failure. If an ESXi host fails for any reason, the VMs running on that host will restart on another one in the same cluster within very short time. While there would be a service interruption perceptible by users in the event of an ESX host failure, the impact is minimized by the automatic restarting of these virtual machines on other hosts via HA feature in each cluster.

4.1.6.4 Cloud Service Automation (CSA)

CSA is a XaaS solution and a key differentiator in the private cloud solution which is built on converged infrastructure technologies. It manages the cloud infrastructure using the OO as the source engine for all the workflows and automation to build thousand out-of-the-box automated IT tasks flows, such as opening a change request ticket, workflow approval, deploy VM servers, hotfix installation, etc. These flows are customized only one time by the system experts; and then, they can be replicated as many times as necessary via requesting them inside the service catalog; this improves the operational efficiency via avoiding human errors, reducing deploying time and manual repetitive tasks. The automated life cycle values are attained via CSA portal which helps manage cloud services through a built-in graphical service designer, that easily and quickly designs new cloud services.

4.1.6.5 Data Protector Backup Solution

The backup solution is based on the Data Protector Software, StoreOnce virtual tape library and Catalyst Deduplication Stores. The backup for production and non-production environments is performed on the StoreOnce VTL and Catalyst and controlled by Data Protector Software. The use of them increases the backup reliability, reduces the backup and restore time and enables KAU to store more backup with less capacity using the advanced de-duplication technology that is available in the StoreOnce.

4.2 Post the adoption of Cloud Computing

This stage has three steps: the first one is gathering data from KAU private cloud model to measure how existing workloads at KAU are preforming using VMware vRealize Operations Manager tool; the second one is conducting interviews with candidates from three different categories to have their feedback statements regarding two topics which are: hosting different KAU business apps at client server and private cloud models and administering and managing client server and private cloud models. The third one is collecting data from Aziz Admissions Portal to measure the availability, performance and response time of the portal during Admissions period in the year 2017, which is hosted at KAU private cloud, using BSM tool.

4.2.1 Step One: KAU Private Cloud Model Characteristics and Utilization Metrics Assessment

In this stage, the assessment measures the model and acquires quantitative data from 75 physical active hosts and 543 VMs using VMware vRealize Operations Manager tool to measure servers' characteristics and utilization metrics to determine how existing workloads are preforming. The tool provides a quick and accurate analysis and gathers inventory and performance data. The 75 physical active hosts and 543 VMs are monitored for 24 weeks to collect data during the busy days of the academic semester as well as the days off; after that, the data collected are tabulated and cleansed; the outputs are presented in two table formats; one for the active physical server hosts and one for the running virtual machines in the private cloud setup. Then, graphs are plotted from the tabulated and cleansed data and displayed under results section; finally, the researcher analyzes the data to get the outcomes ready to be compared later with the data collected from client server model characteristics and utilization metrics.

4.2.2 Step Two: Interviewing Several Candidates from Three Different Categories

In **category one**, 4 nominees are interviewed; 2 of them are business owners from KAU who are: the Dean of Admissions and Registration and the Vice Dean for Development in the Deanship of Admissions and Registration; the 3rd and 4th candidates are two chief programmers from Academic Applications Management at Deanship of IT. The interviews' goal for the formerly mentioned candidates is to have their feedback statements regarding Aziz Admissions Portal availability, performance and response time after being hosted at KAU private cloud. In **category two**, 4 nominees are interviewed; 2 are principal programmers from Financial and Administrative Applications Management at Deanship of IT; the 3rd and 4th candidates are two primary programmers from University Portal Applications Management at Deanship of IT. The interviews' objective for the previously mentioned nominees is to have their feedback statements regarding Anjez and KAU Portals availability and performance while mentioned portals were hosted in the client server model and after those portals are hosted at KAU private cloud. In **category three**, 4 nominees, who are engineers and private cloud architects from Servers Management at Deanship of IT, are interviewed. The interviews' goal for the previously mentioned candidates is to have their feedback statements regarding the scalability, flexibility and operations efforts of client server model and of KAU private cloud.

4.2.3 Step Three: Aziz Admissions Portal Availability, Performance and Response Time Metrics Assessment

The assessment evaluates Aziz Admissions Portal for the year 2017, which is hosted at 10 VMs in KAU private cloud, and acquires quantitative data from the VMs using BSM tool; the tool is used to get the availability, performance and response time metrics of the portal during admissions period; the data collection covers from June 5, 2017 till August 31, 2017.After data are collected, they are tabulated and cleansed; then, the outputs are presented in one table. Finally, the data are analyzed to get the outcomes ready to be compared later with the data collected from PMS Portal hosted at the client server model.

4.2.3.1 Admissions Milestone One Assessment

June 5, 2017 was the 1st day at which the actual admissions activities started on Aziz Admissions Portal; the data collection covers 24 hours of June 5, 2017; the metrics include number of user logins to the Aziz Admissions Portal, total action hits on the portal, average admissions apps availability and performance percentages, average total time, average server time, average network time and client time measured in seconds.

4.2.3.2 Admissions Milestone Two Assessment

July 9, 2017 was the 1st day at which confirming the Admissions Requests began on Aziz Admissions Portal; the data collection covers 24 hours of July 9, 2017; the metrics include the same ones collected in milestone one.

4.2.3.3 Admissions Milestone Three Assessment

Milestone three had three rounds; **round one** was on July 24, 2017 at which the 1st day of Admissions Results started on Aziz Admissions Portal; the data collection covers 24 hours of July 24, 2017; the metrics include the same ones collected in milestone one and two; **round two** was on July 29, 2017 at which the 2nd round of Admissions results began on Aziz Admissions Portal; the data collection covers 24 hours of July 29, 2017; the metrics also include the same ones collected in milestone one and two; **round three** was on August 2, 2017 at which the 3rd round of Admissions results startedon Aziz Admissions Portal; the data collection covers 24 hours of August 2, 2017; the metrics also include the same ones collected in milestone one and two.

5. Results & Discussion

The results attained out of the methodology followed throughout this research work and related discussion are delineated in the following two parts.

5.1 Results

The results achieved are divided into two sections; section one covers the outcomes attained before the adoption of KAU private cloud while section two includes the results achieved after the adoption of KAU private cloud.

5.1.1 Prior to the adoption of Private Cloud

The results of the data studied and analyzed before the adoption of private cloud are divided in two units; unit one details the results of client server model while unit two specifics the outcomes of PMS Portal availability, performance and response time during Admissions period (June 5, 2017 – August 31, 2017).

5.1.1.1 Client Server Model Characteristics and Utilization Metrics Assessment Results

The outcome of the assessment shows that the sum of physical hosts is 191 servers; the total socket count of CPU is 449 sockets; the total number of cores is 449 cores; the total speed of processing power in (GHz) is 511; the total CPU capacity is 1228 (GHz); the overall capacity of memory is 714 (GB); the full volume of disk space is 43948 (GB); the overall CPU usage is 39 (GHz); the overall average of CPU utilization is 3.1572 %; the overall usage of memory is 244.6 (GB) ; the total the median of memory usage is 34.26 %; the total use of disk space is 26784 (GB); the mean use of disk space is 61 %. Figures 5.1 through 5.3 display utilization versus capacity of CPU, memory and disk respectfully for the client server computing model.

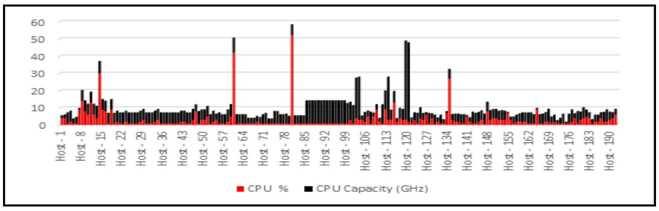

Figure 5.1: CPU Utilization vs CPU Capacity at the Client Server Model.

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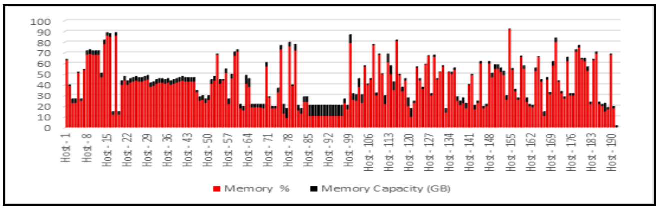

Figure 5.2: Memory Utilization vs Memory Capacity at the Client Server Model.

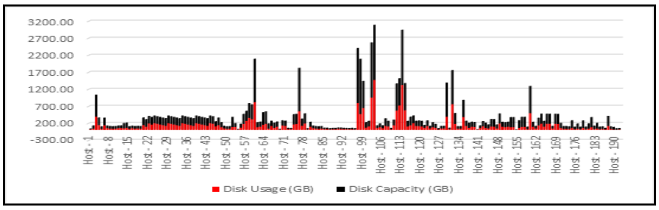

Figure 5.3: Disk Utilization vs Disk Capacity at the Client Server Model.

5.1.1.2 PMS Portal Availability, Performance and Response Time during Admissions Period Assessment Results (June 5, 2017 - August 31, 2017)

The outcome of the assessment shows that the average availability and performance of the 4 servers were 83.56 % and 81.47 % respectfully. It is also noted that the total action hits on the portal was 12,392 hit; the average admissions apps availability and performance were 83.56 % and 81.47 % respectfully. The average total time, server time, network time and client time were 2.26, 2.13, 0.04, and 0.46 seconds respectfully; the maximum average total time reached was 3.60 seconds whereas the minimum was 1.78 seconds. Figures 5.4 through 5.6 demo the total action hits, average PMS apps availability and performance percentages and average PMS apps response time measured in seconds respectfully for PMS Portal from date June 5, 2017 till August 31, 2017.

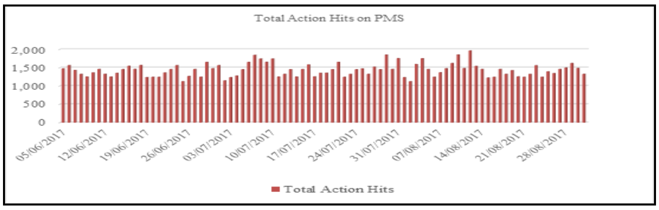

Figure 5.4: Total Action Hits on PMS Portal.

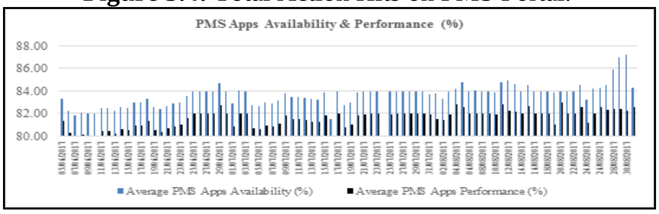

Figure 5.5: Average PMS Apps Availability and Performance running on PMS Portal.

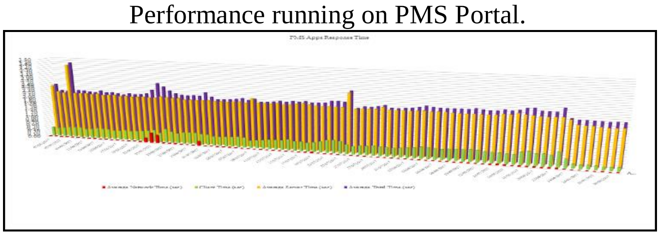

Figure 5.6: PMS Portal Average Response Time.

5.1.2 Post the adoption of private cloud

The outcomes of the three steps taken after the adoption of private cloud are detailed in the afterward three points.

5.1.2.1 Step One: KAU Private Cloud Characteristics and Utilization Metrics Assessment Results

The result of the assessment done for the physical layer of the solution displays that only 75 active physical hosts were monitored, due to license limitation in the tool used to fetch data; the total socket count of the CPU is 178 sockets; the total number of cores is 1872 cores; the sum of virtual machines provisioned is 543 VMs; the total speed of processing power is 163 (GHz); the total CPU capacity in (GHz) is 4169; the overall capacity of memory is 32827 (GB); the full volume of disk space is 2598290 (GB); the aggregate utilization of the CPU capacity is 1783 (GHz); the cumulative use of memory is 17099 (GB); the total use of disk space is 1230773.27 (GB); the overall average of CPU utilization indicates a 43 %. In addition, the inclusive median of memory is 52.1 %; the average consumption of disk space is 47.3686 %. Figures 5.7, 5.8 and 5.9 display the usage versus capacity of CPU, memory and disk respectfully for the 75 hosts.

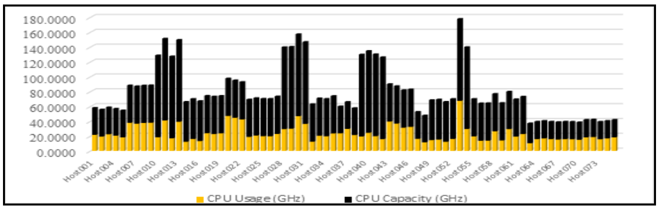

Figure 5.7: CPU Usage vs CPU Capacity for the 75 Hosts.

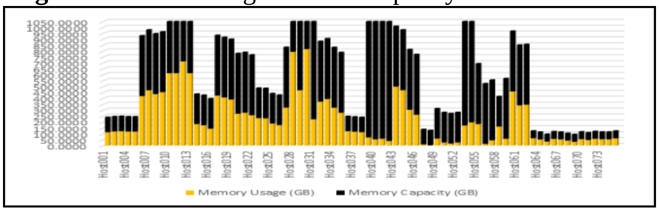

Figure 5.8: Memory Usage vs Memory Capacity for the 75 Hosts.

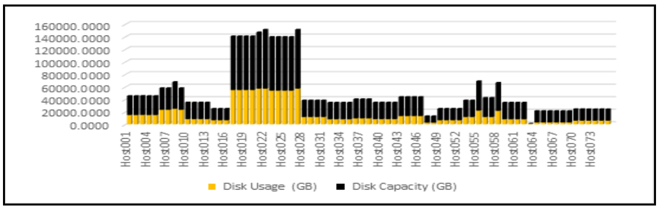

Figure 5.9: Disk Usage vs Disk Capacity for the 75 Hosts.

The outcome of the assessment completed for the virtual layer on the solution indicates that the sum of virtual machines is 543 VMs; the overall sum of cores is 3614 cores; the overall speed of processing power is 1662 (GHz); the total CPU capacity in (GHz) is 9656; the overall capacity of memory is 9007 (GB); the full volume of disk space is 223302 (GB); the aggregate utilization of the CPU capacity is 5634 (GHz); the cumulative use of memory is 6461 (GB); the total use of disk space is 200930 (GB); the average CPU utilization indicates a 58 %. Furthermore, the inclusive median of memory is 72 %; the average consumption of disk space is 90 %. Figures 5.10, 5.11 and 5.12 show usage versus capacity of CPU, memory and disk respectfully for the 543 VMs.

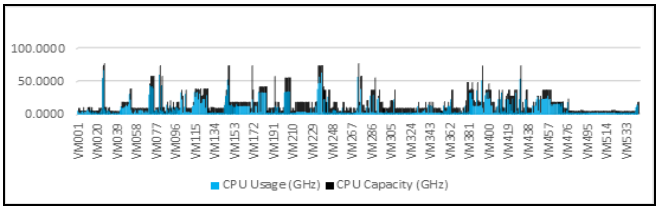

Figure 5.10: CPU Usage vs CPU Capacity for the 543 VMs.

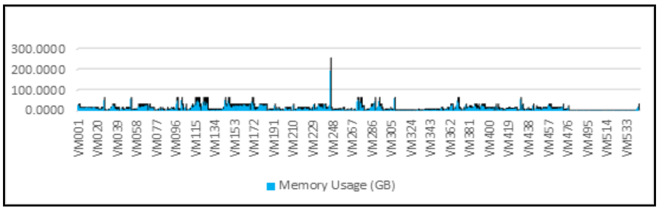

Figure 5.11: Memory Usage vs Memory Capacity for the 543 VMs.

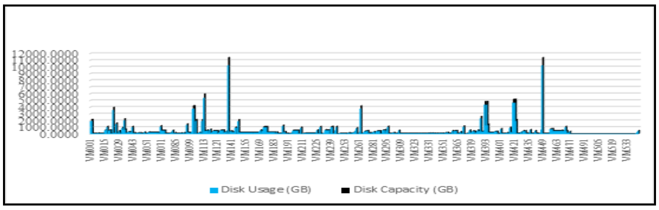

Figure 5.12: Disk Usage vs Disk Capacity for the 543 VMs.

5.1.2.2 Step Two: Interviewing Several Candidates from Three Different Categories Results

The 1st **interview**, in **category one**, was accomplished with their Excellences Dr. Abed Al Mashaikhi, Dean of Admissions and Registration and Dr. Aiiad Albeshri, Vice Dean for Development at the Deanship of Admissions and Registration. They both were pleased with service level catered by the Deanship of IT to support KAU Admissions 2017; they described the infrastructure of computing power consisted of 10 VMs hosted in KAU private cloud as a solid base for a smooth and non-disruptive electronic Admissions; they also characterized the 24 * 7 support team monitoring Admissions computing power as the technical backstage team that is not seen by the public; yet, it is an important element in strengthening the solid base of Admissions computing power. They were delighted that Aziz Admissions Portal hosted at KAU private cloud was able to score an average of 99.41 % of availability and 99.15 % of performance throughout the Admissions period. They ended the interview by saying “We look forward to experience the same solid base infrastructure if not better in next KAU Admissions year.”

The 2nd **interview**, in **category one**, was done with both chief programmers, Eng. Faisal Al Ahmadi, Academic Application Management Manager and Eng. Mohammad Al Muflihi, Academic Application Management Deputy Manager. They both believe that after hosting Aziz Admissions Portal along with its applications in KAU private cloud, the availability and performance of admissions services have become very reliable since both chief programmers have experienced many outages in the old Admissions Portal due to hardware failures when the portal used to run at the client server model; they believe that the negatives of the old setup, such as the lack of required computing resources due over-provisioning or under-provisioning and many others have almost disappeared after moving Aziz Admissions portal and its applications to KAU private cloud. They both concluded the interview by saying: “Thank you for KAU private cloud efficacy and effectiveness which have help us focus more on enhancing the Admissions business.”

The 1st **interview**, in **category two**, was achieved with both Eng. Abdulrahman Alaidaroos, Financial and Administrative Applications Management Manager and Eng. MohannadHarbi, Financial and Administrative Applications Management Deputy Manager. They mutually assured that Anjez Portal along with its applications availability and performance have improved after being hosted in KAU private cloud; they mentioned that many of the Anjez Portal halts, that used to be experienced in the client server model due to the inability to extend the servers hardware recourses during peak hours, are almost gone after moving the portal to KAU private cloud. Finally, they concluded the interview by stating: “We have no doubt that KAU private cloud setup today is elastic enough to meet the future of Financial and Administrative Applications Management needs”.

The 2nd **interview**, in **category two**, was finished both Eng. Mohammed Aboelseoud, University Portal Applications Management Manager and Eng. Momen Obeid, University Portal Applications Management Deputy Manager, they believe that KAU portal along with its applications availability and performance have become much better after being hosted in KAU private cloud; they consider that the scalability and the flexibility of allocating the required compute power, memory and disk space, when required, for the portal have become very handy compared to the complexity of assigning the same in the old KAU setup. They were very pleased with the short time of recovery catered by the private cloud setup during several cases in which a restore for some files was necessary. They both concluded the interview by saying “We are favoring KAU private cloud setup for its advantages that positively aiding our service delivery in the University Portal Applications Management.”

The **only interview**, in **category three**, was completed with Eng. Fahad Abuladil, Servers Management Deputy Manager and a private cloud architect at Deanship of IT, Eng. Hosam Alsouier, a private cloud architect, at Servers Management, Deanship of IT, Eng. Mohammad Bingursain, a private cloud architect at Servers Management, Deanship of IT and Eng. Ziyad Alashhab, a lecturer and private cloud architect at Servers Management, Deanship of IT. They trust that the Server Management team was almost exhausted in following and fixing hardware failures in the client server model since the number of servers was vast compared to the number of available team members; Thus, there was always a need to hire more manpower recourses to follow up and fix issues of such setup; they also mentioned that the time taken in installing, configuring and patching servers in the old KAU setup was lengthy which could take up to 3 to 4 hours per server since the process is sequential and can involve human errors. On the other hand, the 4 nominees assured that most of the troubles faced in managing the old KAU setup were almost cured after adopting private cloud;

they consider that the results attained after the adoption are: considerable improvement in quality and reliability of the service deployment and reduction in service delivery time from days to minutes. They all concluded the interview by saying: “Private cloud has changed our delivery of services from ordinary engineers managing traditional server environment to architects orchestrating compute recourses to meet KAU business.”

5.1.2.3 Step Three: Aziz Admissions Portal Availability and Performance Metrics Assessment Results (June 5 – August 31, 2017)

The aftermath of the assessment presents that 10 VMs were hosting Aziz Admissions Portal from June 5, 2017 to August 31, 2017; the average availability and performance of those VMs were 99.41 % and 99.15 respectfully. It is also noted that the number of user logins metric acquired from the Admissions database was 2,073,896 login; the total action hits on the portal was 6,999,083 hit; the average admissions apps availability and performance were 99.41 % and 99.15 % respectfully. The average total time, server time, network time and client time were 0.74, 0.19, 0.04, and 0.51 seconds respectfully; the maximum average total time reached 2.10 seconds whereas the minimum was 0.28 of a second. It is also noted that there are three milestones in KAU Admissions which are apparent in the large numbers of user logins and total action hits on the portal; those milestones are explained in points 5.1.2.3.1 through 5.1.2.3.3. Figures 5.13 through 5.16 demo the total number of user logins, total action hits, average admissions apps availability and performance in percentage and average admissions apps response time measured in seconds respectfully for KAU Admissions from June 5, 2017 till August 31, 2017.

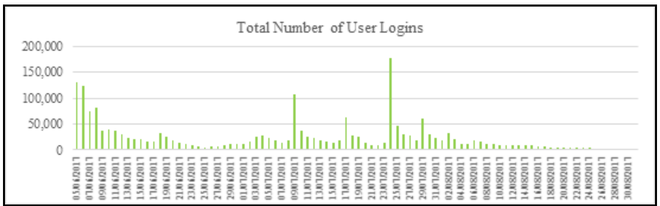

Figure 5.13: Total Number of User Logins in Aziz Admissions Portal (June 5 - August 31, 2017).

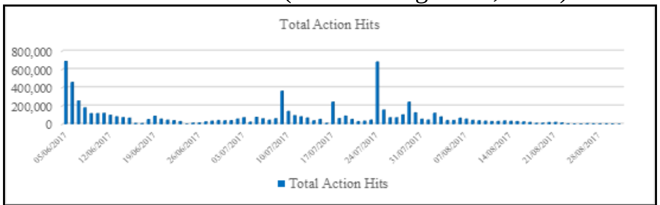

Figure 5.14: Total Action Hits on Aziz Admissions Portal (June 5 - August 31, 2017).

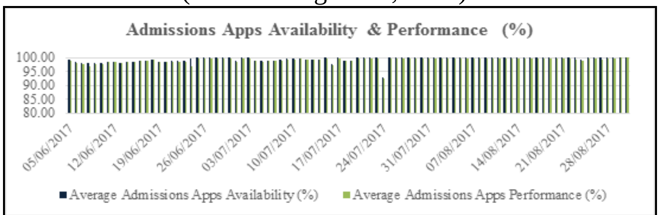

Figure 5.15: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (June 5 - August 31, 2017).

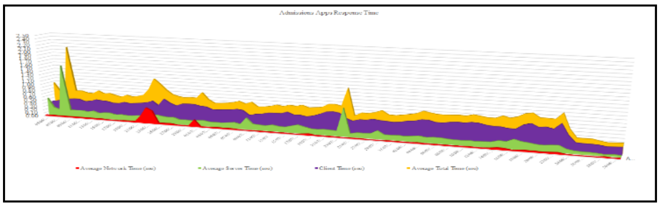

Figure 5.16: Aziz Admissions Portal Average Response Time (June 5 - August 31, 2017).

5.1.2.3.1 Admissions Milestone One Assessment Results (June 5, 2017)

It is noted particularly in the data gathered for June 5, 2017 that they are missing the number of user logins metric from 12:00 AM to 11:59 AM since Aziz Admissions portal was opened on 12:00 PM. The total number of user logins was 131,505 login; the total action hits on the portal was 688,168 hit; the average admissions apps availability and performance were 99.34 % and 98.98 % respectfully. The average total time, server time, network time and client time were 0.96, 0.53, 0.03, and 0.39 seconds respectfully; the maximum average total time reached was 2.08 seconds whereas the minimum was 0.25 of a second. Figures 5.17 through 5.20 demonstrate the total number of user logins, total action hits, average admissions apps availability and performance percentages and average admissions apps response time measured in seconds respectfully for KAU Admissions on June 5, 2017 over 24 hours.

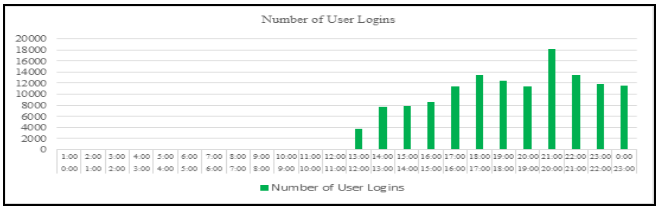

Figure 5.17: Total Number of User Logins in Aziz Admissions Portal (June 5, 2017).

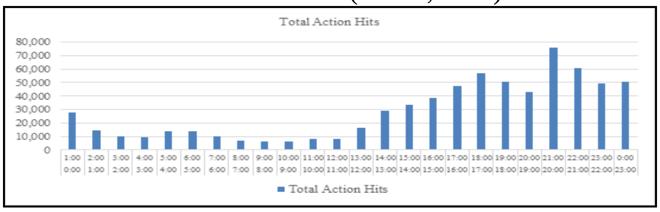

Figure 5.18: Total Action Hits on Aziz Admissions Portal (June 5, 2017).

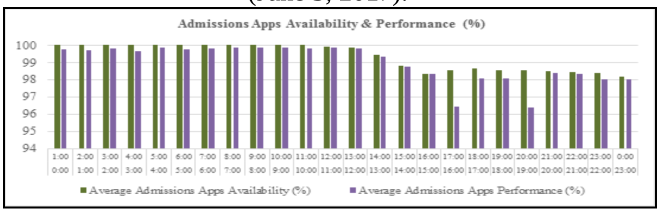

Figure 5.19: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (July 5, 2017).

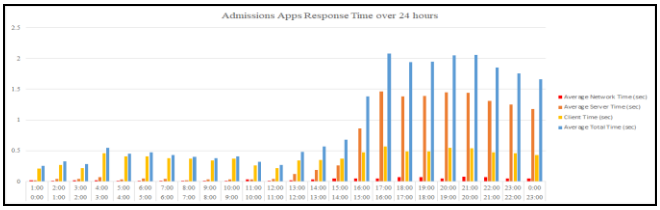

Figure 5.20: Aziz Admissions Portal Average Response Time (June 5, 2017).

5.1.2.3.2 Admissions Milestone Two Assessment Results (July 9, 2017)

For July 9, 2017, the total number of user logins was 106,956 login; the total action hits was 362,289 hit; the average admissions apps availability and performance were 99.80 % and 99.35 % respectfully. The average total time, server time, network time and client time were 0.75, 0.35, 0.01, and 0.39 seconds respectfully; the maximum average total time reached was 2.88 seconds whereas the minimum was 0.52 of a second. Figures 5.21 through 5.24 show the total number of user logins, total action hits, average admissions apps availability and performance percentages and average admissions apps response time measured in seconds respectfully for KAU Admissions on July 9, 2017 over 24 hours.

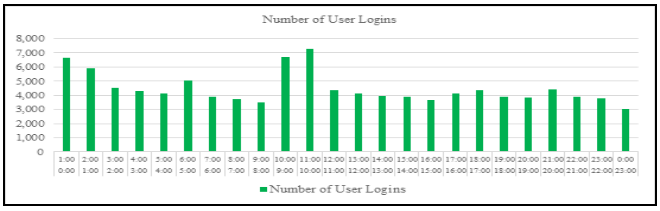

Figure 5.21: Total Number of User Logins in Aziz Admissions Portal (July 9, 2017).

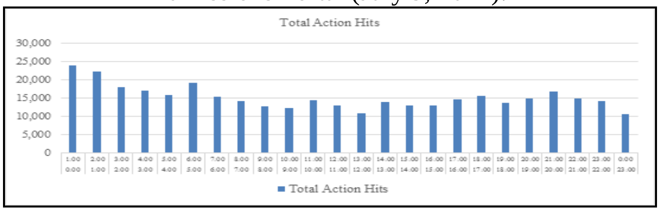

Figure 5.22: Total Action Hits on Aziz Admissions Portal (July 9, 2017).

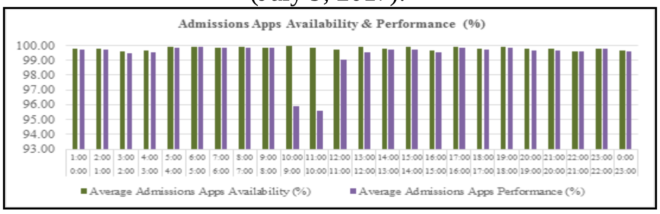

Figure 5.23: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (July 9, 2017).

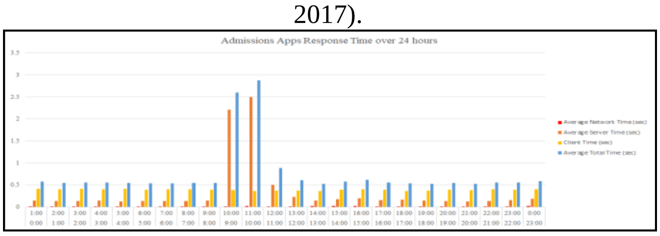

Figure 5.24: Aziz Admissions Portal Average Response Time (July 9, 2017).

5.1.2.3.3 Admissions Milestone Three (Round One) Assessment Results (July 24, 2017)

For July 24, 2017, the total number of user logins was 176,918 login; the total action hits was 681,256 hit; the average admissions apps availability and performance were 92.81 % and 92.22 % respectfully. The average total time, server time, network time and client time were 1.34, 0.83, 0.01, and 0.49 seconds respectfully; the maximum average total time reached was 4.19 seconds whereas the minimum was 0.51 of a second. Figures 5.25 through 5.28 demonstrate the total number of user logins, total action hits, average admissions apps availability and performance percentages and average admissions apps response time measured in seconds respectfully for KAU Admissions on July 24, 2017 over 24 hours.

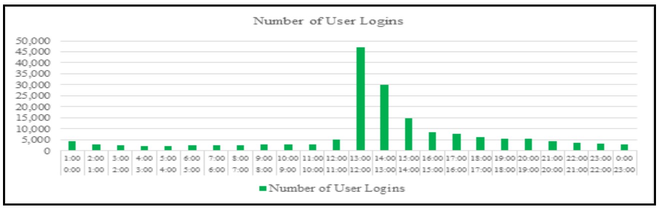

Figure 5.25: Total Number of User Logins in Aziz Admissions Portal (July 24, 2017).

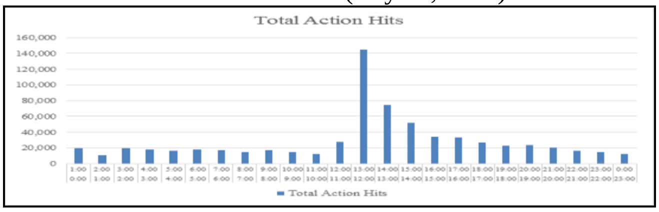

Figure 5.26: Total Action Hits on Aziz Admissions Portal (July 24, 2017).

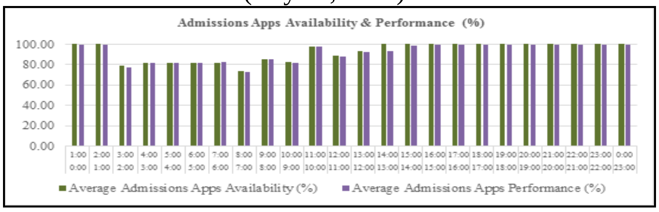

Figure 5.27: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (July 24, 2017).

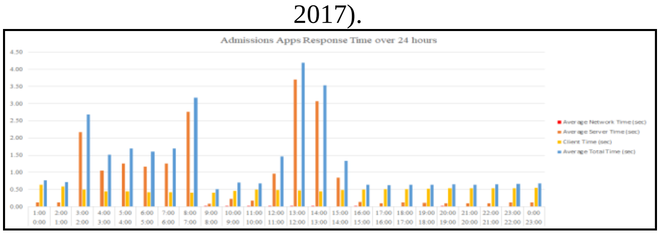

Figure 5.28: Aziz Admissions Portal Average Response Time (July 24, 2017).

5.1.2.3.4 Admissions Milestone Three (Round Two) Assessment Results (July 29 2017)

For July 29, 2017, the total number of user logins was 59,566 login; the total action hits was 241,761 hit; the average admissions apps availability and performance were 99.99 % and 99.53 % respectfully. The average total time, server time, network time and client time were 0.75, 0.25, 0.01, and 0.50 seconds respectfully; the maximum average total time reached was 3.47 seconds whereas the minimum was 0.52 of a second. Figures 5.29 through 5.32 demonstrate the total number of user logins, total action hits, average admissions apps availability and performance percentages and average admissions apps response time measured in seconds respectfully for KAU Admissions on July 29, 2017 over 24 hours.

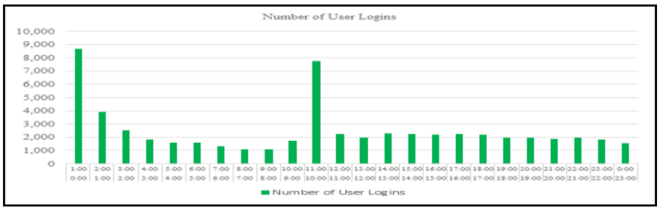

Figure 5.29: Total Number of User Logins in Aziz Admissions Portal (July 29, 2017).

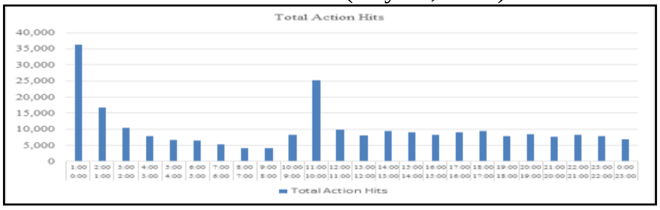

Figure 5.30: Total Action Hits on Aziz Admissions Portal (July 29, 2017).

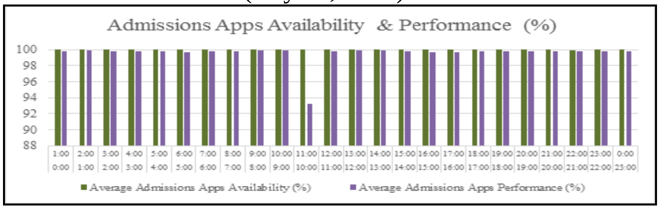

Figure 5.31: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (July 29, 2017).

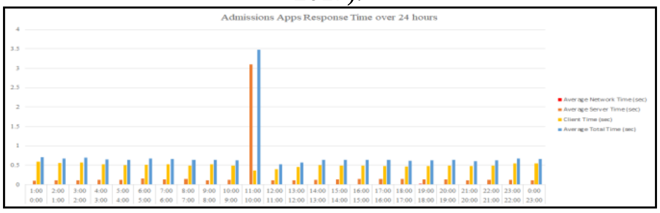

Figure 5.32: Aziz Admissions Portal average response time (July 29, 2017).

5.1.2.3.5 Admissions Milestone Three (Round Three) Assessment Results (August 2, 2017)

For August 2, 2017, the total number of user logins was 33,086 login; the total action hits was 121,409 hit; the average admissions apps availability and performance were 99.99 % and 99.77 % respectfully. The average total time, server time, network time and client time were 0.69, 0.14, 0.02, and 0.53 seconds respectfully; the maximum average total time reached was 0.74 of a second whereas the minimum was 0.61 of a second. Figures 5.33 through 5.36 demo the total number of user logins, total action hits, average admissions apps availability and performance percentages and average admissions apps response time measured in seconds respectfully for KAU Admissions on August 2, 2017 over 24 hours.

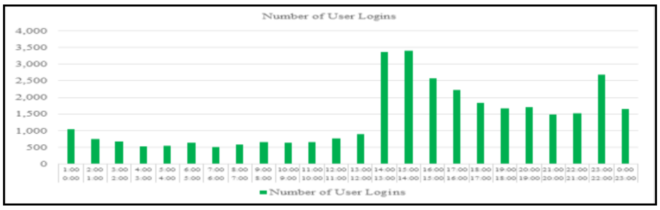

Figure 5.33: Total Number of User Logins in Aziz Admissions Portal (August 2, 2017).

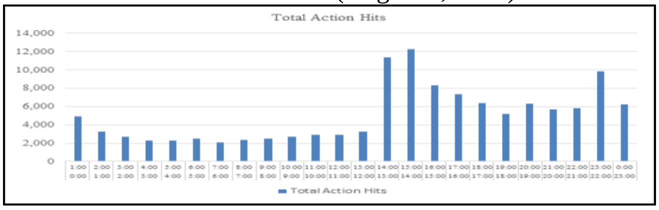

Figure 5.34: Total Action Hits on Aziz Admissions Portal (August 2, 2017).

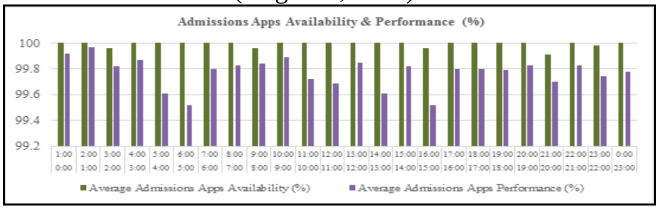

Figure 5.35: Average Admissions Apps Availability and Performance running at Aziz Admissions Portal (August 2, 2017).

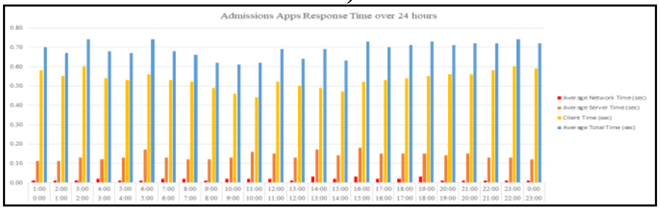

Figure 5.36: Aziz Admissions Portal Average Response Time (August 2, 2017).

5.2 Discussion

The discussion of the results is divided into two sections; section one covers the debate of outcomes attained before the adoption of KAU private cloud; section two includes the debate of the outcomes achieved after the adoption of KAU private cloud.

5.2.1 Prior to the adoption of Private Cloud

The debate of the outcomes reached before the adoption of private cloud at KAU is split in two units; unit one includes the outcomes of client server model characteristics and utilization metrics assessment while unit two comprises PMS Portal availability, performance and response time metrics assessment.

5.2.1.1 The Discussion of Client Server Model Characteristics and Utilization Metrics Assessment Results

Client server model show a significant underutilization of CPU capacity with semi reasonable use of memory and disk space. However, the resources of CPU, memory and disk space, in this model, were isolated assets and cannot be shared; as a result, such resources were running to cater KAU computing needs; yet, they operated in silos. An opportunity to implement vitalization in KAU computing environment apparently exists after assessment since vitalization is a kay element in KAU private cloud. In addition, it is anticipated that virtualization would help KAU consolidate a considerable number of existing and expected future workloads, thereby increasing average system utilization and lowering the overall hardware footprint and associated costs. As a result, KAU started to think about adopting cloud computing.

5.2.1.2 The discussion of PMS Portal Availability, Performance and Response Time Metrics Assessment Results

The results of the assessment completed for PMS portal show poor average availability (83.56 %) and performance (81.47 %) for the 4 physical servers running client server model if compared to the average availability (99.41%) and performance (99.15 %) of the 10 VMs assigned for the Aziz Admissions Portal running at KAU private cloud. The difference noted in the average availability, performance and response time between the old and new models of computing at KAU positively reflect the efficiency and effectiveness of the new computing pattern.

5.2.2 Post the adoption of Private Cloud

The results achieved out of the 3 steps taken after the adoption of KAU private cloud are discussed in the following points.

5.2.2.1 Step One: The Discussion of KAU Private Cloud Characteristics and Utilization Metrics Assessment Results

The outcome indicates a substantial boost in several areas and a considerable saving in some others when comparing the 191 hosts of client server model to the 75 hosts of private cloud model. A 39 % of saving is noted in the number of servers used in the study of private cloud model compared to those studied in the client server model; a 40 % of saving is observed in the number of CPU socket used in the private cloud model contrary to the ones used in the client server pattern; a 417 % of boost in the number of cores offered in private cloud model in contrast to the one catered by the client server model; a 32 % of saving is noticed in the total speed of processing power per CPUs in the private cloud model compared to speed of CPUs in the client server pattern; a 340 % of improvement in the CPU capacity is noted in the private cloud model contrary to the CPU capacity of the client server model; a 4598 % of enhancement in the memory and a 5912 % of enrichment in the disk space in the private cloud model are observed in contrast to the ones in the client server model; a 4600 % of boost in the CPU usage in the private cloud model is noticed compared to the CPU usage in the client server pattern; a 6991 % of increase in the memory use and a 4595 % of growth in the disk space utilization in the private cloud model contrary to the ones in the client server model. Table 5.1 summarizes the outcome of the comparison done between the 191 hosts in the client server model and 75 hosts in private cloud model.

Table 5.1: Comparison between the 191 Hosts of Client Server Model and 75 Hosts of Private Cloud Model.

Model / (%)/ Status	Physical Hosts	CPU Socket Count	No. of Cores	No .of VMs	Speed per CPU (GHz)	CPU Capacity (GHz)	Memory Capacity (GB)	Disk Capacity (GB)	CPU Usage (GHz)	Memory Usage (GB)	Disk Usage (GB)
Private Cloud Model	75	178	1872	543	163	4169	32827	2598290	1783	17099	1230773
Client/Server Model	191	449	449	0	511	1228	714	43948	39	245	26784
Percentage (%)	39	40	417		32	340	4598	5912	4600	6991	4595
Status	Saving	Saving	Boost	Boost	Saving	Boost	Boost	Boost	Boost	Boost	Boost

The result also indicates a considerable increase in many areas when comparing between the 75 hosts and 543 VMs in the private cloud model; a 724 % of increase in the number of virtual servers catered is noticed as an over commitment over the actual 75 physical hosts with a pool of shared resources; a 193 % of boost in the number of cores offered is noted as an over commitment over the actual number of cores in 75 physical hosts allowing more cores to be distributed among VMs; a 1020 % increase in the speed of processing power of CPUs is observed as an over commitment over the actual speed of processing power of CPUs in 75 physical hosts; a 232 % of enhancement in the CPU capacity is noted as an over commitment over the actual CPU capacity in the 75 physical hosts catering more CPU power; a 27 % of improvement in the memory capacity is noticed as an over commitment over the actual memory size in 75 physical hosts fulfilling more in memory computing needs if required; a 9 % of boost in the disk size is perceived as an over commitment over the actual disk size in the 75 physical hosts providing more space for storing data; a 316 % of increase in CPU utilization is recognized as an over commitment over the actual CPU use in the 75 physical hosts allowing more room for computing power to be offered; a 38 % of enhancement of memory use is noted as an over commitment over the actual memory usage in the 75 physical hosts catering more memory to utilize; a 16 % of enrichment in the disk usage is noticed as an over commitment over the actual disk utilization in the 75 physical hosts giving more space to store. Table 5.2 sums up the result of the comparison done between the 75 hosts and 543 VMs the private cloud model.

Table 5.2: Comparison between the 75 Hosts and 543 VMs in the Private Cloud Model.

Private Cloud Model /(%)/ Status	Servers	No. of Cores	Speed per CPU (GHz)	CPU Capacity (GHz)	Memory Capacity (GB)	Disk Capacity (GB)	CPU Usage (GHz)	Memory Usage (GB)	Disk Usage (GB)
Virtual Machines	543	3614	1662	9656	9007	223302	5634	6461	200930
Physical Hosts	75	1872	163	4169	32827	2598290	1783	17099	1230773
Percentage %	724	193	1020	232	27	9	316	38	16
Status	Boost	Boost	Boost	Boost	Boost	Boost	Boost	Boost	Boost

5.2.2.2 Step Two: The Discussion of Interviewing Several Candidates from Three Different Categories Results

The feedback statements communicated during the 1st interview, in category one, demo that both candidates are really satisfied with the Aziz Portal hosting in KAU private cloud; their positive feedback statements were supported by the real metrics numbers of Aziz Admissions Portal reflecting how reliable and stable the infrastructure was during the Admissions period of year 2017. The 2nd interview, in category one, was also indicating excellent feedback statements about Aziz Admissions Portal availability, performance and response time which revealed how efficacious and trustworthy KAU private cloud was performing during 2017 Admissions. It is obvious from the 1st interview, in category two, that the problems, which used to be faced while Anjez Portal was running in the old KAU setup, were vanished after moving the portal to private cloud; candidates' feedback statements specified the fact that they are glad and confident that KAU private cloud will meet Financial and Administrative Applications Management tomorrow's requirements based on the substantial quality of transition noted in Anjez Portal availability, performance and response time. Similarly, it is apparent from conclusions of the 2nd interview, in category two, that both candidates are satisfied about hosting KAU portal in private cloud setup; the main points highlighted during the interview regarding the positive characteristics and features of KAU private cloud indicate that the solution helps them improve their working experience; the concern mentioned during the interview that had to do with DB performance in the virtual environment could be checked by KAU private cloud architects for further examination. The feedback statements communicated during the only interview, in category three, specify the fact that the team used to suffer from client server model issues; moreover, private cloud is currently helping them recover from those issues and leverage the quality of service delivery they offer.

5.2.2.3 Step Three: The Discussion of Aziz Admissions Portal Availability and Performance Metrics Assessment Results (June 5 -August 31)

The benchmarks of 99.41 % of average availability and 99.15 % of average performance for the 10 VMs hosting Aziz Admissions Portal from June 5 to August 31, 2017 emphasize how established KAU private cloud setup was in providing the necessary compute assets to present top notch Admissions services. The marks of 99.41 % of average availability and 99.15 % of average performance for Admissions applications that were catering different admissions services show a second benchmark for KAU private cloud efficiency. A third measure for the efficiency of KAU private cloud setup is the average total time taken by Admissions applications (0.74 of a second) along with average server time (0.19 of a second) to serve admissions services; this mark affirms how rapid and capable KAU private cloud was in fulfilling the needed compute resources for the Admissions apps to handle students applying to KAU. A fourth indicator for both stability and efficiency of KAU private cloud setup during the same period of Admissions is the ability to handle 2,073,896 users' login with 6,999,083 action hit to the portal.

5.2.2.3.1 The Discussion of Admissions Milestone One Assessment Results

June 5, 2017 was the 1st day of Admissions and considered as the start of Admissions milestone one in which an average of 99.34 % of availability and 99.98 % of performance marks for Admissions 10 VMs; these marks underline how established KAU private cloud setup was in delivering the necessary compute assets to serve and handle 131505 users' login with 688168 action hit on the portal during the 1st day of Admissions. Another criterion for the efficiency of KAU private cloud is the average total time taken by Admissions applications (0.96 of a second) along with average server time (0.53 of a second) to serve Admissions services. This criterion confirms how rapid and capable KAU private cloud was in catering computing power for Admissions apps on the 1st day of Admissions.

5.2.2.3.2 The Discussion of Admissions Milestone Two Assessment Results

July 9, 2017 was the 1st day of confirming Admissions requests and considered as the start of Admissions milestone two in which an average of 99.80 % of availability and 99.35 % of performance measures for Admissions 10 VMs; these measures assert how trustworthy KAU private cloud setup was in offering the needed compute resources to serve and manage 106956 users' login with 362289 action hits on the portal during the 1st day of confirming Admissions requests. Another mark for the efficacy of KAU private cloud setup is the average total time taken by Admissions applications (0.75 of a second) along with average server time (0.35 of a second) to serve admissions services. This mark asserts how prompt and competent KAU private cloud setup was in fulfilling the processing power for Admissions apps on the 1st day of confirming Admissions requests.

5.2.2.3.3 The Discussion of Admissions Milestone Three (Round One) Assessment Results (July 24, 2017)

July 24, 2017 was 1st day of round one of Admissions results and considered as Admissions milestone three, in which an average of 92.81 % of availability and 92.22 % of performance criteria for Admissions; those criteria confirm a slight degrade in the availability and performance of Admissions Application if compared to the 1st day of round two of Admissions results and 1st day of round three of Admissions results; 176918 users' login with 681256 action hit on the portal during the 1st day of round one of Admissions results are considered as an indicator of vast numbers of students accessing the portal; yet, the portal was up serving with no halts and a small drop in efficacy. The average total time taken by Admissions applications (1.34 seconds) along with average server time (0.83 of a second) to serve admissions services show a mark of latency if compared to the 1st day of round two of Admissions results and 1st day of round three of Admissions results. The reason behind the slight degrade in the availability and performance of Admissions Application and latency in average total time taken by Admissions applications, as clarified by chief programmers, Eng. Faisal Al Ahmadi, Academic Application Management Manager and Eng. Mohammad Al Muflihi, Academic Application Management Deputy Manager, was because of some issues faced in the web services, that connect Admissions applications running behind the portal to many external entities outside KAU LAN to complete the admissions processes for each student applicant to increase data accuracy.

5.2.2.3.4 The Discussion of Admissions Milestone Three (Round Two) Assessment Results (July 29, 2017)

July 29, 2017 was 1st day of round two of Admissions results in milestone three, in which an average of 99.99 % of availability and 99.53 % of performance indicators for

Admissions confirm how reliable KAU private cloud setup was in catering the needed compute assets to serve and handle 59566 users' login with 241761 action hit on the portal during the 1st day of round two of Admissions results. Another criterion for the efficacy of KAU private cloud setup is the average total time taken by Admissions applications (0.75 of a second) along with average server time (0.25 of a second) to serve admissions services. This criterion underlines how rapid and eligible KAU private cloud setup was on the 1st day of round two of Admissions results.

5.2.2.3.5 The Discussion of Admissions Milestone Three (Round Three) Assessment Results (August 2, 2017)

August 2, 2017 was 1st day of round three of Admissions results in milestone three, in which an average of 99.99 % of availability and 99.77 % of performance benchmarks for Admissions confirm how dependable KAU private cloud setup was in providing the needed compute assets to serve and handle 33086 users' login with 121409 action hit on the portal during the 1st day of round three of Admissions results. Another measure for the efficacy of KAU private cloud setup is the average total time taken by Admissions applications (0.69 of a second) along with average server time (0.14 of a second) to serve admissions services. This measure emphasizes how quick and fit KAU private cloud setup was in catering computing power for Admissions apps on the 1st day of round three of Admissions results.

6. Conclusion

Cloud computing, private cloud in particular, has a positive impact on KAU; the effective impact of private cloud adoption assisted in achieving the objectives of this research; the favorable factors to KAU for adoption of cloud computing, such as legal issues, risks, security issues and many others, were highlighted throughout the research work. The results detailed under section 5.1 demonstrated the improvement of computing resources efficiency and the reduction of IT cost per unit, project or product. In fact, KAU has been undertaking many initiatives to improve its infrastructure to move from the client server model environment to private cloud infrastructure. The initiatives resulted in KAU achieving its core objective of high available private cloud setup for core KAU IT services. Private cloud setup help KAU create a high available data centers with scalable infrastructure to support the growth of the university and deliver new added value services with a reduction in operating costs via automating processes fulfilled by CSA. The outcomes of KAU private cloud adoption, which match the expected results, if not exceed them are:

1) Spectacular improvement in quality and reliability of the service deployment.
2) Service delivery time is reduced from days to minutes.
3) Process standardization across private cloud setup using CSA.
4) The ability to quickly adopt any new e-services in the private cloud infrastructure.
5) Increase in staff efficiency via automating the processes of provisioning the infrastructure to avoid human error happening with repetitive tasks and improve in implementation time.
6) Increase in user satisfaction accomplished via CSA deployment agility, automating services and standards enforcement.
7) Reduction in costs through reducing working hours consumed in deploying, managing and improving business service environment.

It can be concluded, based on the results formerly discussed, that following KAU adoption of private cloud resulted in moving all its production, test and development environments to private cloud computing setup, difficulties detailed in problem statement are addressed as follows: KAU has controlled the lack of required computing resources due over-provisioning or under-provisioning through private cloud setup which has the capability to manage computing resources via a pool of shared resources; as a result, servers are not operating in silos anymore. Moreover, it has contained the huge efforts wasted on managing complexities of infrastructure, platform, and software via private cloud solution which has increased staff efficiency through automating the provisioning of infrastructure, platform, and software using CSA. In addition, it has governed the lack of scalability that limits the business from scaling up or scaling down by the scalable private cloud infrastructure setup in which service delivery time is reduced from days to minutes to support the business demands and the growth of the university. Furthermore, KAU is managing IT cost per unit, project or product annual inflation via CSA capabilities which improve operational efficiency through eliminating repetitive tasks, avoiding human errors, improving implementation time and reducing working hours consumed in deploying managing and improving service delivery.

7. Future Scope

Further studies can be done in keeping track of the ongoing developments of cloud computing technology to maintain topnotch service delivery to enhance KAU competitive advantage among other universities; developing plans appropriately elastic to adapt alters needed by private cloud technology adoption; conducting awareness sessions to students, professors and employees are essential to explain what cloud computing is and how it enhances IT services at the campus; moving to hybrid cloud computing setup to put KAU non-sensitive and public applications on public cloud while keeping sensitive application on premise to keep the privacy and safety of data.

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