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# A Study of Cloud Computing in the University Enterprise

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## Abstract

***The demand for computing resources in the university is on the increase on daily basis and the traditional method of acquiring computing resources may no longer meet up with the present demand. This is as a result of high level of researches being carried out by the universities. The 21st century universities are now seen as the centre and base of education, research and development for the society. The university community now has to deal with a large number of people including staff, students and researchers working together on voluminous large amount of data. This actually requires very high computing resources that can only be gotten easily through cloud computing. In this paper, we have taken a close look at exploring the benefits of cloud computing and study the adoption and usage of cloud services in the University Enterprise. We establish a theoretical background to cloud computing and its associated services including rigorous analysis of the latest research on Cloud Computing as an alternative to IT provision, management and security and discuss the benefits of cloud computing in the university enterprise. We also assess the trend of adoption and usage of cloud services in the university enterprise.***

## Keywords

***Cloud Computing, University enterprise, SaaS, IaaS, PaaS.***

## 1. Introduction

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
The term "cloud" is analogical to "Internet". The term "Cloud Computing" is based on cloud drawings that were used in the past to represent telephone networks and now to depict Internet in Cloud computing is Internet based computing where virtual shared servers provide software, infrastructure, platform, devices and other resources, hosting to customers on a pay-as-you-use basis. All information that a digitized system has to offer is provided as a service in the cloud computing model. Users can access these services available on the "Internet cloud" without having any previous know-how on managing the resources involved. Thus, users can concentrate more on their core business processes rather than spending time and gaining knowledge on resources needed to manage their business processes.

The underlying concept of cloud computing dates back to the 1950s: when large-scale mainframe became available in academia and corporations, accessible via thin clients/terminal computers. According to Christopher [1], because it was costly to buy a mainframe, it became important to find ways to get the greatest return on the investment in them, allowing multiple users to share both the physical access to the computer from multiple terminals as well as to share the CPU time, eliminating periods of inactivity, which became known in the industry as timesharing.

The National Institute of Science and Technology (NIST) in the US, stated that Cloud computing relies on sharing of resources to achieve coherence and economies of scale similar to a utility (like the electricity grid) over a network (typically the Internet). Also, at the foundation of cloud computing is the broader concept of converged infrastructure and shared services.

Cloud computing customers do not own the physical infrastructure; rather they rent the usage from a third-party provider. They consume resources as a service and pay only for resources that they use. Most cloud computing infrastructures consist of services delivered through common centres and built on servers. Sharing resources amongst users can improve, as servers are not unnecessarily left idle,

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which can reduce costs significantly while increasing the speed of application development.

Cloud and cloud-like solutions appear to be widespread and growing in higher education, though in relatively focused areas, such as student e-mail. E-mail notwithstanding, higher education institutions are more likely to obtain new services from the cloud than to transition established services that have long been operated by the campus. Many colleges and universities see pockets of cloud service usage in other areas, often led by individual faculty or students looking for the added flexibility and convenience that the cloud can provide.

However,with such an exponential increase in data traffic, university IT teams will need to spend an ever-increasing share of their time simply preparing to handle projected capacity requirements. Year over year, the challenge of long-term scalability will only become more acute. And with university IT budgets sometimes falling behind the pace of change, schools need to find smart, secure ways to meet growing demand while controlling costs.

## 2. Overview of Cloud Computing

Cloud computing, according to academicroom.com is the delivery of computing and storage capacity as a service to a community of end recipients. The name comes from the use of a cloud shaped symbol (US Patent) as an abstraction for the complex infrastructure it contains in system diagrams. Cloud computing entrusts services with a user's data, software and computation over a network.

The origin of the expression 'cloud computing' is obscure, but it appears to have been derived from the practice of using drawings of stylized clouds to denote networks in diagrams of computing and communications systems. The term came into popular use in 2008, though the practice of providing remote access to computing functions through networks dates back to the mainframe timesharing systems of the 1960s and 1970s. In his book written in 1966, 'The Challenge of the Computer Utility', the Canadian electrical engineer, Douglas F. Parkhill predicted that the computer industry would come to resemble a public utility "in which many remotely located users are connected via communication links to a central computing facility" [20].

For decades, efforts to create large scale computer utilities were frustrated by constraints on the capacity of telecommunications networks such as the telephone system. It was cheaper and easier for companies and other organizations to store data and run applications on private computing systems maintained within their own facilities.

The constraints on network capacity began to be removed in the 1990s when telecommunications companies invested in high capacity fiber-optic networks in response to the rapidly growing use of the Internet as a shared network for exchanging information. In the late 1990s, a number of companies, called application service providers (ASPs), were founded to supply computer applications to companies over the Internet. Most of the early ASPs failed, but their model of supplying applications remotely became popular a decade later, when it was renamed cloud computing. The telecommunications companies who previously offered primarily dedicated point-to-point data circuits, began offering virtual private network (VPN) services with comparable quality of service but at a much lower cost. By switching traffic to balance utilization as they saw fit, they were able to utilize their overall network bandwidth more effectively. The cloud symbol was used to denote the demarcation point between that which was the responsibility of the provider and that which was the responsibility of the users. Cloud computing extends this boundary to cover servers as well as the network infrastructure (Internet Engineering Task Force, 1993).

Early pioneers of cloud computing include Salesforce.com, which supplies a popular business application for managing sales and marketing efforts; Google, Inc., which in addition to its search engine supplies an array of applications, known as Google Apps, to consumers and businesses; Amazon Web Services, a division of online retailer Amazon.com, which offers access to its computing system to Website developers and other companies and individuals. Cloud computing also underpins popular social networks and other online media sites such as Facebook, MySpace, and Twitter. Traditional software companies, including Microsoft Corporation, Apple Inc., Intuit Inc., and Oracle Corporation, have also introduced cloud applications.
As computers became more prevalent, scientists and technologists explored ways to make large-scale computing power available to more users through

time sharing, experimenting with algorithms to provide the optimal use of the infrastructure, platform and applications with prioritized access to the CPU and efficiency for the end users [2].

**Cloud services**

There are three types of cloud computing services, namely:

- Infrastructure/Hardware as a Service (IaaS/HaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)

**Infrastructure-as-a-Service (IaaS)**

According to the online reference Wikipedia, Infrastructure-as-a-Service (IaaS) is the delivery of computer infrastructure (typically a platform virtualization environment) as a service. IaaS leverages significant technology, services, and data center investments to deliver IT as a service to customers. In this most basic cloud service model, cloud providers offer computers, as physical or more often as virtual machines, and other resources.

The virtual machines are run as guests by a hypervisor, such as Xen or KVM. Management of pools of hypervisors by the cloud operational support system leads to the ability to scale to support large numbers of virtual machines. Other resources in IaaS clouds as declared by Alex, Harm, QiangGuo and GuoNing [3] include images in a virtual machine image library, raw (block) and file based storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles.

Simplified statements of work and à la carte service-level choices make it easy to tailor a solution to a customer's specific application requirements. IaaS providers manage the transition and hosting of selected applications on their infrastructure. Customers maintain ownership and management of their application(s) while off-loading hosting operations and infrastructure management to the IaaS provider. Provider-owned implementations typically include the following layered components:

Computer hardware (typically set up as a grid for massive horizontal scalability)

Computer network (including routers, firewalls, load balancing, etc.)

Internet connectivity (often on OC 192 backbones)

Platform virtualization environment for running client-specified virtual machines

Service-level agreements

Utility computing billing

Rather than purchasing data centre space, servers, software, network equipment, etc., IaaS customers essentially rent those resources as a fully outsourced service. Usually, the service is billed on a monthly basis, just like a utility company bills customers. The customer is charged only for resources consumed. The chief benefits of using this type of outsourced service include:

Ready access to a preconfigured environment that is generally ITIL-based (The Information Technology Infrastructure Library [ITIL] is a customized framework of best practices designed to promote quality computing services in the IT sector.)

Use of the latest technology for infrastructure equipment

Secured, "sand-boxed" (protected and insulated) computing platforms that are usually security monitored for breaches

Reduced risk by having off-site resources maintained by third parties

Ability to manage service-demand peaks and valleys

Lower costs that allow expensing service costs instead of making capital investments

Reduced time, cost, and complexity in adding new features or capabilities

A classic example is Amazon's Elastic Compute Cloud (Amazon EC2) which is a web service that provides resizable computing capacity in the cloud. It is designed to make web-scale computing easier for developers and offers many advantages to customers.

Amazon EC2 presents a true virtual computing environment, allowing clients to use a web-based interface to obtain and manage services needed to launch one or more instances of a variety of operating systems (OSs). Clients can load the OS environments with their customized applications.

They can manage their network's access permissions and run as many or as few systems as needed. In order to use Amazon EC2, clients first need to create an Amazon Machine Image (AMI). This image contains the applications, libraries, data, and associated configuration settings used in the virtual computing environment. Amazon EC2 offers the use of preconfigured images built with templates to get up and running immediately. Once users have defined and configured their AMI, they use the Amazon EC2 tools provided for storing the AMI by uploading the AMI into Amazon S3. AmazonS3 is a repository that provides safe, reliable, and fast access to a client AMI. Before clients can use the AMI, they

must use the Amazon EC2 web service to configure security and network access.
During configuration, users choose which instance type(s) and operating system they want to use. Available instance types come in two distinct categories, Standard or High-CPU instances. Most applications are best suited for Standard instances, which come in small, large, and extra-large instance platforms. High-CPU instances have proportionally more CPU resources than random-access memory (RAM) and are well suited for compute-intensive applications. With the High-CPU instances, there are medium and extra-large platforms to choose from. After determining which instance to use, clients can start, terminate, and monitor as many instances of their AMI as needed by using web service Application Programming Interfaces(APIs) or a wide variety of other management tools that are provided with the service. Users are able to choose whether they want to run in multiple locations, use static IP endpoints, or attach persistent block storage to any of their instances, and they pay only for resources actually consumed. They can also choose from a library of globally available AMIs that provides useful instances. For example, if all that is needed is a basic Linux server, clients can choose one of the standard Linux distributions AMIs [4].

**Platform-as-a-Service (PaaS)**
Cloud computing has evolved to include platforms for building and running custom web-based applications, a concept known as Platform-as-a-Service. PaaS is an outgrowth of the SaaS application delivery model. PaaS services allow users to focus on innovation rather than complex infrastructure. Organizations can redirect a significant portion of their budgets to creating applications that provide real business value instead of worrying about all the infrastructure issues in a roll-your-own delivery model. The PaaS model is thus driving a new era of mass innovation. Now, developers around the world can access unlimited computing power. Anyone with an Internet connection can build powerful applications and easily deploy them to users globally, the cycle of building and delivering web applications and services are entirely available from the Internet, all with no software downloads or installation for developers, IT managers, or end users. Unlike the IaaS model, where developers may create a specific operating system instance with home grown applications running, PaaS developers are concerned only with web-based development and generally do not care what operating system is used. PaaS services allow users to focus on innovation rather than complex infrastructure. Organizations can redirect a significant portion of their budgets to creating applications that provide real business value instead of worrying about all the infrastructure issues in a roll-your-own delivery model. The PaaS model is thus driving a new era of mass innovation. Now, developers around the world can access unlimited computing power.
PaaS provides the entire infrastructure needed to run applications over the Internet. Such is the case with companies such as Amazon.com, eBay, Google, iTunes, and YouTube. The new cloud model has made it possible to deliver such new capabilities to new markets via the web browsers. PaaS is based on a metering or subscription model, so users pay only for what they use. PaaS offerings include workflow facilities for application design, application development, testing, deployment, and hosting, as well as application services such as virtual offices, team collaboration, database integration, security, scalability, storage, persistence, state management, dashboard instrumentation, etc. [5].

**Software-as-a-Service (SaaS)**
The traditional model of software distribution, in which software is purchased for and installed on personal computers, is sometimes referred to as Software-as-a-Product. Software-as-a-Service is a software distribution model in which applications are hosted by a vendor or service provider and made available to customers over a network, typically the Internet. SaaS is becoming an increasingly prevalent delivery model as underlying technologies that support web services and service-oriented architecture (SOA) mature and new developmental approaches become popular.

Ken [6] and Rajani [7] suggested that Software-as-a Service also requires users to rent application software and databases. SaaS is also often associated with a pay-as-you-go subscription licensing model. Meanwhile, broadband service has become increasingly available to support user access from more areas around the world. The huge strides made by Internet Service Providers (ISPs) to increase bandwidth, and the constant introduction of ever more powerful microprocessors coupled with inexpensive data storage devices, is providing a huge platform for designing, deploying, and using software across all areas of business and personal computing. SaaS applications also must be able to interact with other data and other applications in an equally wide variety of environments and platforms. SaaS is closely related to other service delivery models we have described. Research firm IDC identifies two slightly different delivery models for SaaS. The hosted application management model is similar to an Application Service Provider (ASP) model.

SaaS is most often implemented to provide business software functionality to enterprise customers at a low cost while allowing those customers to obtain the same benefits of commercially licensed, internally operated software without the associated complexity of installation, management, support, licensing, and high initial cost. Most customers have little interest in the how or why of software implementation, deployment, etc., but all have a need to use software in their work. Many types of software are well suited to the SaaS model (e.g., accounting, customer relationship management, email software, human resources, IT security, IT service management, videoconferencing, web analytics, and web content management). The distinction between SaaS and earlier applications delivered over the Internet is that SaaS solutions were developed specifically to work within a web browser. The architecture of SaaS-based applications is specifically designed to support many concurrent users (multi tenancy) at once. This is a big difference from the traditional client/server or application service provider (ASP)-based solutions that cater to a contained audience. SaaS providers, on the other hand, leverage enormous economies of scale in the deployment, management, support, and maintenance of their offerings. Examples of SaaS include: Google Apps, Quickbooks Online and Salesforce.com.

**Deployment of Cloud services**

There are four (4) types of cloud services deployments namely: Public cloud, Private cloud, Community cloud and Hybrid cloud.

Public cloud: Public cloud applications, storage, and other resources are made available to the general public by a service provider. These services are free or offered on a pay-per-use model. Generally, public cloud service providers like Amazon AWS, Microsoft and Google own and operate the infrastructure and offer access only via Internet (direct connectivity is not offered).

Private cloud: Private cloud is cloud infrastructure operated solely for a single organization, whether managed internally or by a third party and hosted internally or externally. Undertaking a private cloud project requires a significant level and degree of engagement to virtualize the business environment, and it will require the organization to re-evaluate decisions about existing resources. When it is done right, it can have a positive impact on a business, but every one of the steps in the project raises security issues that must be addressed in order to avoid serious vulnerabilities.They have attracted criticism because users "still have to buy, build, and manage them" and thus do not benefit from less hands-on management, essentially "[lacking] the economic model that makes cloud computing such an intriguing concept".Community cloud: Community cloud shares infrastructure between several organizations from a specific community with common concerns (security, compliance, jurisdiction, etc.), whether managed internally or by a third party and hosted internally or externally. The costs are spread over fewer users than a public cloud (but more than a private cloud), so only some of the cost savings potential of cloud computing are realized.

Hybrid cloud: Hybrid cloud is a composition of two or more clouds (private, community or public) that remain unique entities but are bound together, offering the benefits of multiple deployment models.

By utilizing "hybrid cloud" architecture, companies and individuals are able to obtain degrees of fault tolerance combined with locally immediate usability without dependency on internet connectivity. Hybrid Cloud architecture requires both on premises resources and offsite (remote) server based cloud infrastructure. According to Alan [8], Hybrid clouds lack the flexibility, security and certainty of in-house applications. Hybrid cloud provides the flexibility of in house applications with the fault tolerance and scalability of cloud based services. Figure 2.1 below shows the various types of cloud services and deployments.

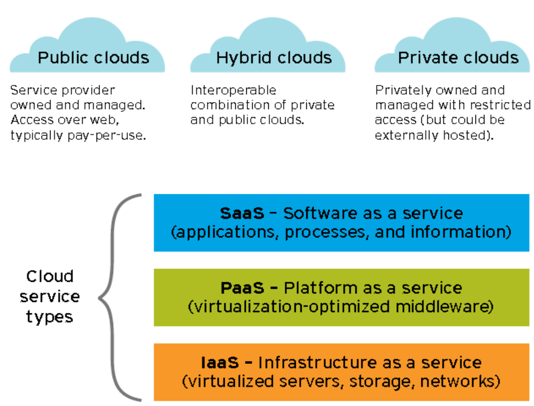


**Figure 1: Cloud Taxonomy [18]**

**Cloud Engineering and security Issues**

Cloud engineering is the application of engineering disciplines to cloud computing. It brings a systematic approach to the high level concerns of commercialization, standardization, and governance in conceiving, developing, operating and maintaining cloud computing systems. It is a multidisciplinary method encompassing contributions from diverse areas such as systems, software, web, performance, information, security, platform, risk, and quality engineering.

The cloud model has been criticized by privacy advocates for the greater ease in which the companies hosting the cloud services control, thus, can monitor at will, lawfully or unlawfully, the communication and data stored between the user and the host company. Cauley [9] stated clearly, instances such as the secret NSA program, working with AT&T, and Verizon, which recorded over 10 million phone calls between American citizens, causing uncertainty among privacy advocates, and the greater powers it gives to telecommunication companies to monitor user activity. Using a cloud service provider (CSP) can complicate privacy of data because of the extent to which virtualization for cloud processing (virtual machines) and cloud storage are used to implement cloud service [10]. The point is that CSP operations, customer or tenant data may not remain on the same system, or in the same data centre or even within the same provider's cloud. This can lead to legal concerns over jurisdiction. While there have been efforts (such as USEU Safe Harbour) to "harmonize" the legal environment, providers such as Amazon still cater to major markets (typically the United States and the European Union) by deploying local infrastructure and allowing customers to select "availability zones." Cloud computing poses privacy concerns because the service provider may access the data that is on the cloud at any point in time. They could accidentally or deliberately alter or even delete information.

Zissis and Lekkas [11] also established that as cloud computing is achieving increased popularity, concerns are being voiced about the security issues introduced through adoption of this new model. The effectiveness and efficiency of traditional protection mechanisms are being reconsidered as the characteristics of this innovative deployment model can differ widely from those of traditional architectures. Winkler [12] concluded that an alternative perspective on the topic of cloud security is that this is but another, although quite broad, case of "applied security" and that similar security principles that apply in shared multiuser mainframe security models apply with cloud security.

The relative security of cloud computing services is a contentious issue that may be delaying its adoption. Physical control of the Private Cloud equipment is more secure than having the equipment off site and under someone else’s control. Physical control and the ability to visually inspect the data links and access ports is required in order to ensure data links are not compromised. Issues barring the adoption of cloud computing are due in large part to the private and public sectors' unease surrounding the external management of security based services. Security issues have been categorized into sensitive data access, data segregation, privacy, bug exploitation, recovery, accountability, malicious insiders, management console security, account control, and multi-tenancy issues. Solutions to various cloud security issues vary, from cryptography, particularly public key infrastructure (PKI), to the use of multiple cloud providers, standardization of APIs, and improving virtual machine support and legal support [13]. Cloud computing offers many benefits but it also vulnerable to threats. As the uses of cloud computing increase, it is highly likely that more criminals will try to find new ways to exploit vulnerabilities in the system. There are many underlying challenges and risks in cloud computing that increase the threat of data being compromised. However, these security concerns must be addressed in order to establish trust in cloud computing technology.

Urquhart [14] observed that although, cloud computing is often assumed to be a form of "green computing", there is no published study to substantiate this assumption. In areas where climate favours natural cooling and renewable electricity is readily available, the environmental effects will be more moderate. (The same holds true for "traditional" data centres.) Thus countries with favourable conditions, such as Finland, Sweden and Switzerland, are trying to attract cloud computing data centres. Many of the underlying technologies such as grid computing, peer-to-peer computing have a direct contribution to cloud computing. In order to understand what type of components exist in a cloud, we first need to enumerate the typical components of an application development. The components excluding human resources are i) infrastructure resources ii) software resources, iii) application resources and iv) business processes [15]. In the cloud computing paradigm, all of the above components are treated as services and are in the "cloud".

## 3. Existing University Enterprises implementing Cloud computing

Currently, there are many practices and examples regarding the use of cloud computing in the higher institutions. For instance, in Commonwealth, many colleges and universities had collaborated at the formation of Virginia Virtual Computing Lab [16] This allowed institutions both to cut down IT expenses (by reducing the necessities of licensing and software updating) and to maintain its own data centers, as well as to improve IT resources for researches and students. By including the cloud services, North Carolina State University achieved a substantially decrease of expenses with software licensing and at the same time to reduce the campus IT staff from 15 to 3 employees with full working schedule [16].

Another example is Kuali Ready [17], a community-source project chartered to provide a business continuity planning service and it is also an example of higher education institutions organizing themselves to provide cloud services. Kuali Ready is a good early example of some key principles that are emerging to guide cloud developments.

Also in another university enterprise illustrated in figure 2 below, the university is divided into 3 campuses namely; Bekitas, Ayazagba and Davutpaza, the three campuses are connected to the university community cloud system and in each campuses the end users that are mainly staff and student connect directly to the university cloud system.

From the student's part, all that is needed to acquire and use the IaaS Cloud Computing solutions is a credit card (or other payment method) and an Internet connection robust enough to support the Cloud service. These two requirements are deceptively simple.

The institution however will be providing the back-bone of the Cloud service which entails server, storage, and network facility. It would be necessary to note that the school already has a server and network facility in place. Though the cloud service would need a special dedicated server, it would still interact with the existing servers. The storage facility that will be needed to complete the service is however not present in the school but would have to be introduced in order to complete the service [17].

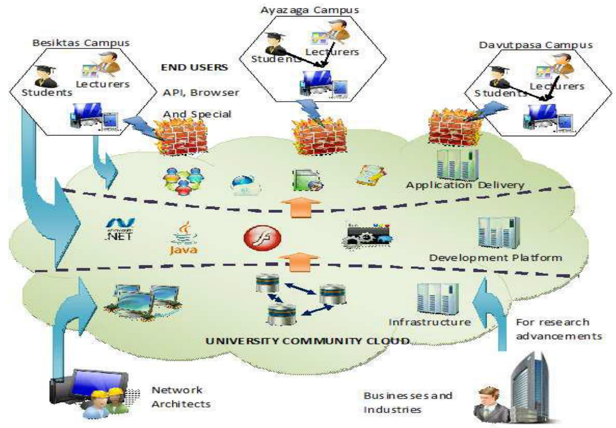


**Figure 2: University Cloud Schematic Diagram [19]**

## 4. Some University Enterprise Models

A typical model of cloud computing as illustrated in the figure below is absolved into the university enterprise. The cloud clients this time around are the student, administrative staff, teaching staff and the researchers. The layout of the cloud system can be categorized into 3 namely:

SaaS: provides the necessary software needed in the university enterprise such as Google Apps, Microsoft live@edu, Business Productivity, Campus EAI etc

Paas: provides the platform; the execution runtime, database, web server, the development tools etc

Iaas: provides the infrastructure such as Microsoft, Education ERP.net, Amazon S3 etc

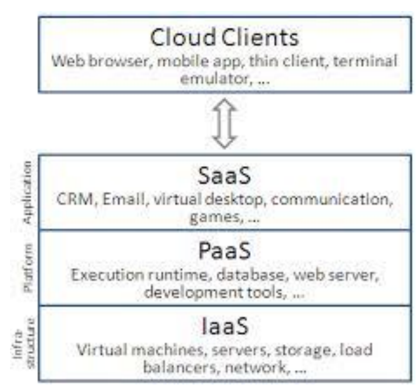


**Figure 3: Cloud computing layers [17]**

The teaching staff shall benefit of support in preparing their teaching portfolio (presentations of lessons, conferences, articles, etc.), in teaching practice (methods and teaching techniques, study materials, feedback) and in evaluating (methods and techniques of evaluation and management of the results). Researchers will benefit from the advantage of using the latest technologies, experimenting the results and communication, while paying for using this services. In the university enterprise: the student, administrative staff, teaching staff and the researchers will be able to access all the three categories of the cloud system.

The diagram in the figure 4 below is a simplified structure of the main users of IT services in the university. The main users according to include the students administrative staff, lecturers, researchers and developers.

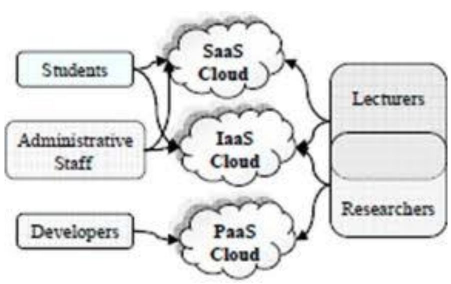


**Figure 4: Simplified structure of the Main Users of IT Services in a Typical University Now Using the Services of Cloud Computing [17]**

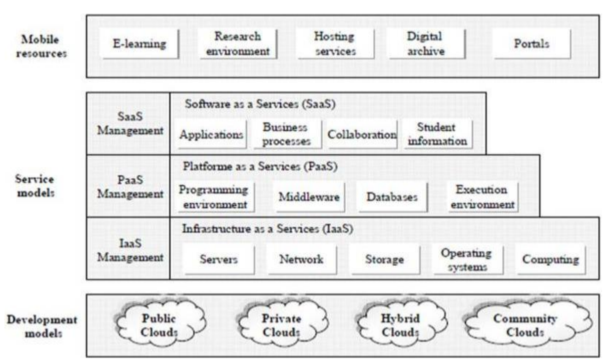


**Figure 5: Cloud Architecture for University [17]**

Figure 5 above is an advanced model of cloud architecture for university. It is adapted from cloud computing layers for the university. Each layer provides services that are needed in the university.

In its broadest usage, the term *cloud computing* refers to the delivery of scalable IT resources over the Internet, as opposed to hosting and operating those resources locally, such as on a college or university network. Those resources can include applications and services, as well as the infrastructure on which they operate.

## 5. Conclusion

Cloud computing is a recent development that provides easy access to high performance computing resources and storage infrastructure through web services. Cloud computing delivers the potential for efficiency, cost savings and improved performance to governments, organizations, private and individual users. It also offers a unique opportunity to developing countries to get closer to developed countries through the use of shared facilities. Developing countries like Nigeria can take the benefits of0nstitutions, among the drivers that are encouraging more institutions to contemplate cloud services are budget pressures, calls for increased reliability of and access to IT systems, and the need for institutions to provide timely access to the latest IT functionality. Cloud computing is not a revolution but an evolution that has been ongoing for well over a decade, if not since the very beginning of electronic computing. The cloud is simply an architectural model that employs many of the same components used in datacenters around the world today in a more flexible, responsive, and efficient way. The primary difference is in how these components are tied together with a dynamic control plane.

However, Cloud computing is a recent technology with lots of issues to be considered. It has some technical issues which include scalability, elasticity, data handling mechanism, reliability, license software, ownership, performance, system development and management. Also, on-technical issues such as legal and economic aspects.
This study is an initial step which can provide the basis for the deeper research on the deployment of cloud computing for the Institution's Research Community and the advanced degree students working in the field of Cloud Computing.

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