A Cloud Computing Framework for Ethiopian Higher Education Institutions

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Abstract: Educational institutions throughout the World have become highly dependent on information technology for their teaching-learning, service delivery and business requirements. Procuring and maintaining a wide range of hardware and software require substantial, ongoing investment and the skills to support them. In the current financial crisis and being challenged by growing needs, universities are facing problems in providing necessary information technology (IT) support for educational, research and development activities. The objective of this paper is to find alternatives to the use of IT, while leading universities try improve agility and obtain savings.

The paper discusses the advantages of cloud computing for educational institutions, the limitations of current IT utilization in Ethiopian Higher Education institutions. It also discusses alternative solutions to solve the current IT utilizations limitations in Ethiopian Higher Education Institutions. The research finding shows that Cloud Computing is the better ICT utilization mechanism for Education institutions teaching-learning and service delivery requirements, for it enables wise and strategic use of technology which significantly reduces cost. Accordingly, when the Proposed Hybrid Cloud Computing model is implemented, it will have significant contribution to the country in different aspects.

Keywords: Cloud Computing, Higher Education Institutions

I. Introduction

The use of the Internet and Information and Communication Technologies (ICTs) to deliver educational resources is considered mainstream in the 21st century, yet in Higher Education (HE) in developing countries it is often seen as a luxury. This has far reaching effects on teachers, learners and educational institutions in these countries, which often include a lack of basic ICT infrastructure and limited or no support for the training of teachers and learners in the use of digital online information sources. It is increasingly accepted that in the future most information sources and desktop applications currently used will be mainly accessed through the Internet, now increasingly referred to as ‘the cloud’. This means that at higher education level ICTs should be adopted as a matter of urgency to enable teachers and learners to access this new direction in Internet technology and application delivery. Teachers and learners will no longer have to physically carry their documents and data around them; instead they will be able to access them in the ‘cloud’ anywhere, from any connected device.

In recent days, many research institutes are struggling to adapt Cloud Computing for solving problems that are continuously increasing computing and storage. There are three main factors that interests in Cloud Computing: rapid decrease in hardware cost and architecture and modern supercomputers consisting of hundreds of thousands of cores; the exponentially growing data size in scientific instrumentation/simulation and Internet publishing and archiving; and the wide-spread adoption of Services Computing and Web2.0 applications. The Cloud Computing trend of replacing software traditionally installed on campus computers with applications delivered via the internet is driven by aims of reducing Higher Education Institutions (HEIs) IT complexity and cost. Cloud Computing could be a technological innovation that both reduces IT costs for the HEIs and eliminates many of the time-related constraints for students, making learning tools accessible for a larger number of students. There are many benefits of cloud computing for educational institute and below are listed a few of them:

- With cloud computing, HEIs can open their technology infrastructures to businesses and industries for research advancements.
- The extended reach of cloud computing enables institutions to teach students in new, different ways and help them manage projects and massive workloads.
- When students enter the global workforce they will better understand the value of new technologies. Cloud computing allows students and teachers to use applications without installing them on their computers and also allows access to saved files from any computer with an Internet connection.
II. Statement Of The Problem

In Ethiopia different initiatives are working as part of a national capacity building program that includes schoolNet, WoredaNet that aims to provide connectivity and specialized applications for schools and for local governments.

The Ethiopian Education and Research Network (EthERNet) was launched in 2001 to build and deliver highly interconnected and high performance networks for Universities and other Educational and Research Institutions in Ethiopia. More specifically, EthERNet was aimed to build and deliver high performance networking that connected these institutions with each other and similar institutions in the world, and by doing this to enable them to share educational resources and collaborate both within Ethiopia and globally. Since its establishment EthERNet has provided services like datacenter, video conference, e-library and technical support. Even though EthERNet is providing different services to Ethiopian Education and research, it still needs integration of other services, and service delivery based on the new model of computing, which cloud based computing, for a better service delivery strategy and strategic utilization of resources.

For a particular IT service, a sufficient level of aggregation for efficiency cannot be achieved within one campus but, rather, must be achieved at a higher level of aggregation, beyond a single institution. Efficiencies may be realized in aggregating personnel, expertise, licensing, business continuity, and other benefits far beyond simply joining computer hardware. Hence the main concern of this paper will be finding solutions for the above aforementioned factors so that HEIs can get the advantages of ICT in efficient and affordable manner. Therefore, the research will intend to get answers for the following research questions.

- Is the current EHEIs ICT service delivery strategy efficient?
- Do we need to change the way we are currently deploying and using ICT in EHEIs?
- Could cloud computing be an answer for minimizing the aforementioned problems?

III. Cloud Computing For Ethiopian Higher Education

Ethiopia as a developing nation has suffered by limitation of educational budgets. HEIs are being built-in very high speed. Currently there are around 31 government owned universities and many private colleges. Without quality education establishing educational institutions by itself cannot give the solution we seek for economic development and poverty reduction through education. Education should be supported through up to date technologies and services. Ethiopian government has been investing millions of dollars every year to support education in higher education institutions with technology. However due to struggling economy it is not able to supply full ICT infrastructure requirements of all universities. Requirements can be solved using cloud computing strategy i.e. implementing a central Hybrid Cloud Computing infrastructure that can be used by all HEIs of Ethiopia. The proposed Ethiopian Universities Hybrid Cloud combines private and public clouds. The private cloud is implemented and managed by Ethiopian MOE in collaboration with higher education institutions. Every resource that can be shared by multiple universities will be placed at EUHC and then it will be available to all hosted universities. Example, it is true that Registrar System is required by every university, this means there is a need to buy the system for all 31 universities. If the registrar system for one university costs 4 million, as one of the interviewed ICT director told to the researcher then we can imagine how much cost we invest to deploy the system in all the 31 universities. But this cost can be significantly reduced by deploying a single copy of the Registrar System in to the proposed EUHC cloud. The proposed EUHC has an interface from its Ethiopian Universities Private Cloud(EUPC) to public Cloud Service Providers. Whenever some resources can’t be deployed into EUPC due to different factors then through the public interface it is possible to access the resource from other CSPs. By deploying Hybrid cloud computing model, the fear of privacy and other related security issues can be avoided, since critical and sensitive data could be owned by university members and responsible bodies from Ethiopian Ministry of Education.

IV. Related Works

Regarding benefits and challenges of adapting Cloud Computing for the universities, discussed the possible offerings that Cloud Computing could deliver, especially in Malaysian Universities. The 21st century students are not satisfied with the traditional learning process; thus, the researcher used Cloud Computing to enhance the learning environment by using Cloud Computing benefits in cooperation with the multimedia contents, and made the learning process highly interactive to meet student expectations. Discussed more than ten Cloud computing offerings, pointing out that the Cloud Computing users gain the illusion of resource availability as an infinite on-demand resource, which enables storage and huge amounts of information on the Cloud. In addition, the researcher stated that introducing the students to Cloud technology will prepare them to work in the industry since they gained the skill of dealing with new technology. Cloud Computing offers cost-effective solutions for Universities, staff, and students since all of the needed hardware and software are available via the Cloud, which makes their files highly portable, easy to share while computing power is easy to
manage. Additionally, claimed using Cloud Computing would improve collaboration and communication in the learning environments. On the other hand, he clearly stated that the Cloud Computing has some drawbacks: need for Internet connection and trust in the CSP service availability, privacy of the data, and security.

Built Open-source software (OSS) for e-learning based on Cloud Computing in China. The researchers proposed the EduCloud platform to launch their e-learning environment on a public Cloud, using IaaS and SaaS to overcome resource limitation and lack of e-learning scalability. The researchers constructed their solution using Hadoop with two interfaces which were mapper and reducer. EduCloud consists of a set of tools and technologies to build a virtual and personal learning environment; thus, it focuses on migration of the current application to a Cloud based one via the SaaS level, especially interactive and collaborative applications, such as Sakai and Moodle which are Course Management Systems (CMS).

V. Cloud-Based Services in Ethiopian Higher Education Institutions

5.1. Building the Framework

Cloud Computing technology for delivering different services such as e-learning environment, Class Room Management Systems, Enterprise Resource Planning Systems, researching and similar services will give more flexibilities and dynamic resource utilization which solves the scalability issues. Then the Virtual University Services on top of Cloud Computing layer helps to solve limitations of the current IT service deployment scenario. The next figure shows a general layout of the new Ethiopian Universities Cloud Ecosystem based on the cloud computing with an interface layer to control the user’s access to different services.

![Cloud-Based Virtual Services Architecture](image)

Figure 15. Cloud-Based Virtual Services Architecture

Applying the Cloud based architecture deployment of ICT infrastructure to Education System will result in adding the required service in the appropriate layer through the interface. Using this architecture will enhance the QoS for adding more students and more multimedia content. In addition, video streaming will be performed better when utilizing the Cloud infrastructure. Using Cloud-Based Service for Users not only demonstrates the benefit of the underlying infrastructure but also gains more and more solid base real world practical experiences and management skills by utilizing Cloud services.

Based on the identified services and selected Clouds, the researcher proposed a Cloud Computing framework Ecosystem for EHEIs. The teaching-learning components, infrastructure, and their Learning Management System (LMS) are called the “Virtual Teaching - Learning ecosystem”. The following figure shows the Ethiopian Universities Cloud framework.
The presented framework namely Ethiopian Universities Hybrid Cloud (EUHC) contains four layers (User Interface, SaaS, PaaS, and IaaS) and three modules (User log database, system security, and service management):

5.2. User Interface Layer:

The User Interface layer contains three important components:

- User Portals: provide an access path to specific web applications or services since everything is located on the web and can be accessed using a network connection.
- Service Catalog: contains different types of services with detailed information about the additional access information, such as what layer the service is located and who can access this specific service.
- Service Repository: composed of different services like softwares, courses content, etc. categorized and arranged depending on the service name and access level which may be in one of the three other layers (SaaS, PaaS, or IaaS).

5.3. SaaS Layer

This layer provides access to hosted programs-applications or tools on the Cloud. ERP systems, Classroom Management Systems, and other Application Softwares can be hosted at this layer. Using Microsoft Word or Microsoft Access, for example, as a hosted application on the Cloud by SkyDrive or Google Apps is considered as a component for this layer.

5.4. PaaS Layer:

This layer provides access to different platforms-programming language, distributed systems, net-centric systems and similar platforms. For example for students taking Distributed Systems, Building a distributed system or simulation needs control of the number and the IPs for the VMs with a platform to host the developed application. For the Information Systems Management and DB systems, they are able to build more sophisticated systems and distributed DBs using different tools to manage these systems and DBs. In the PaaS level, the user can access the VM level with some limitations, and with this access, they are able to control part of the networking issues, such as IPs and routing mechanism which help in teaching Net-Centric computing courses for the beginner. For the Computational Science course, they can build a temporary multiprocessing system using multiple VMs to solve an existing problem quickly and efficiently. Researchers and developers use SaaS for their work simply by connecting to the cloud.

5.5. IaaS Layer:

The IaaS level gives more flexibility when dealing with the Hardware layer but through the virtualization. Now, we have reached the point where we have to build the servers and set up their configurations. Additionally, the user can deal with the fine details of the virtualization with some limitation which makes the virtualization step set in this level. Additionally, the proposed framework has system security module for maintaining the security of the cloud, A Service management module for monitoring, scheduling and deployment of services and users log database module for tracking users access to the cloud.
VI. Implementation Proposal

The proposed framework will utilize the existing IT infrastructure for institutions which would adapt the framework namely, Ethiopian Universities Hybrid Cloud (EUHC) as illustrated above. In such a situation, the framework needs to deploy a hybrid Cloud model which combines the local infrastructure as a private Cloud with selected public Clouds.

This mashup process combines multiple services from different CSPs to serve students and other users from different universities to enhance the teaching-learning and service delivery. Hybrid Cloud is one of the Cloud Computing deployment models. It provides the ability to access, manage, and use third-party (vendors) resources from multiple CSPs and combines them within in-house infrastructure (private Cloud). Using such a model allowed us to avoid lock-in and was blocked with one CSP by allowing mix and match services from different CSPs. In addition, it will give us the ability to secure the institution’s critical application and data by hosting them on the private Cloud without having to expose them to a third-party. With a hybrid Cloud model, the institution has more control of their system since part of the infrastructure is under their control. For this model, the research needs software which manages the complexities and the heterogeneity of this distributed data centers. The framework’s candidate is an open-source project called OpenNebula which can support on-demand VMs provisioning, pre-configured, and manage groups of interconnected VMs; thus, OpenNebula enhances the integration of external providers (CSPs) to enable the selected model of deployment. Managing Cloud’s infrastructure is one of the top concerns in IaaS; consequently, the need for a virtual infrastructure manager was raised. Using OpenNebula gives the ability to manage the local infrastructure and establish the first step toward hybrid Cloud solution by interfacing with a remote Cloud site. OpenNebula’s main role is to manage the VMs. This management creates a life cycle for each VM. The life cycle starts from the resource selection stage which results in a feasible placement on the selected VM by the scheduler. The VM is placed on the target physical resource which is considered as resource preparation in the second stage. After the VM placement, the VM creation stage boots the VM by the resource hypervisor. In the middle of the process, for example, the VM could be migrated to more suitable resources in the VM migration to optimize power consumption. The Final stage is VM termination which shuts down the VM image. The following figure shows the architecture of OpenNebula:

Figure 17. OpenNebula virtual infrastructure engine components

The framework places as its base the hybrid Cloud. On top of OpenNebula, Aneka, Which is a platform for managing and programming applications that are built and deployed on the Cloud PaaS implementation solution, as the implementation model for the PaaS layer. Aneka provides software infrastructure for scaling applications using broad collection of APIs for the developers to design and implement applications. Aneka gives developers the ability to run their application on a local or remote distributed infrastructure which supports the hybrid Cloud deployment model. Transferring the current system or platform to be managed and accessible within Cloud technology is a very hard task. Therefore, it needs lots of planning, preparing, testing, and changing of the current layers and architecture of the platform to be compatible with the Cloud-based educational environment; furthermore, the need for a flexible, extensible, and accessible solution for developing and deploying the proposed framework is raised. The Aneka platform met the listed requirements mentioned above which made it one of the best solutions in our case. The Aneka platform provides a flexible and configurable platform which supports multiple programming languages and gives the ability to develop and deploy the applications either on private or public Clouds as the following figure shows:
Since Ethiopian Universities IT infrastructure is heterogeneous including their workstations and servers, Aneka is suitable to deal with such heterogeneity to maximize resource utilization in powerful manner as the following figure shows. Aneka was built on the service-oriented architecture which gave Aneka its extensibility to integrate different types of Clouds. The aneka framework architecture is shown below:

As shown in the above layers corresponding to the basic service layers of the Cloud Computing easily integrated with the external Cloud. Aneka enables the execution of the application on its runtime environment by using the underlying Cloud infrastructure for either private or public Clouds. It provides management tools; administrators can easily start, stop, and deploy any application. The Aneka platform contains three classes of services which characterize its middleware layer:

1. Execution Services: Their primary responsibility is scheduling and executing deployed applications.
2. Foundation Services: They represent the collection set of management services, such as metering applications and resource allocation and updating the service registry whenever needed.
3. Fabric Services: They present the lowest level of middleware services classes. They provide access to Cloud resource management to enable resource provisioning which will scale the allocated resources to the applications to achieve the required QoS.

The next figure shows an overview of the proposed Hybrid Cloud Computing model for Ethiopian Higher Education Institutions.

Figure 18. Typical Aneka Cloud deployment

Figure 19. Aneka framework architecture

Figure 20. An overview of a hybrid Cloud for Ethiopian HEIs
The figure above shows an overview of the selected Cloud and how the content could be arranged in the private Cloud. Within six steps, the user can use a resource and then release it; these steps are illustrated in the following points:

1- The user sends a request using the EUHC interface
2- The verification of the authorization level will be checked using the user profile private Cloud.
3- If the user is unauthorized to request such services, the system will reject the user's request; otherwise, the request will be sent to the virtual infrastructure manager (OpenNebula) to redirect the request to the appropriate location for either public or private Clouds.
4- The system will establish a connection between the requested service from the Cloud and the user.
5- As long as the user needs the resource and does not exceed the maximum usage period, the system synchronizes the service delivery between the user and the resource.
6- When the user is done and no longer needs the requested resource, the system will terminate the session and disconnect the user from the target Cloud.

To build a powerful hybrid Cloud solution which utilizes the current Ethiopian Universities IT infrastructure (private Cloud), the researcher proposed to use Aneka middleware on top of OpenNebula. The combination of these two open-sources provided a manageable hybrid Cloud for the institutions. This approach will utilize the universities IT infrastructure more efficiently, and it provided additional resources when the Universities’ IT infrastructure was at the peak time and could not provide all the requested resources, such as storage and computing power. The additional resources will be brought from the available public Clouds. Ethiopian Universities’ hybrid Cloud contains several components to deliver the requested service. There are three layers made up for the private EUHC with two modules to manage the user's access and the content delivery. EUHC’s private Cloud will have the ability to be connected to public Cloud at the peak time. In addition, the user can request any needed service from the public Cloud at any time, which results in EUHC hybrid Cloud. The following list describes EUHC hybrid Cloud components:

1- Infrastructure layer: The Ethiopian Universities IT Infrastructure will be placed at the bottom of this layer since Ethiopian Universities’ private Cloud would be built on top of the available infrastructure. Furthermore, these physical infrastructures will be virtualized using OpenNebula which plays a critical role in the infrastructure layer.
2- Platform layer: This layer will contain the Aneka platform which will work and manage the platform to enable development and deployment of applications and programs with the ability to access public Clouds resources and platforms. Moreover, it is would be connected to the Service Repository module to integrate the Aneka platform service with different services.
3- User Interface layer: This layer controls and is managed by the EUHC’s hybrid Cloud, identifying the access model which could be students, faculty, administrator, researchers or others which can be created by the system's administrator. The authorization and identification process will be done using the Users Logs module to verify the entered information. Then it forwards the users’ request to the appropriate component in the same layer. Furthermore, this layer has three other components: IaaS, PaaS, and SaaS. IaaS provides a resource from the Infrastructure layer. A middleware container is used to develop applications and give learners and educators the access to PaaS services provided by the PaaS component in the user Interface layer which provides an access to the Platform layer that contains the Aneka platform.
Lastly is the SaaS component which provides access to either the Platform layer so as to use one of the deployed applications or to public Clouds which may host an application used by system users, such as e-mail. There is a certain level of QoS which is granted by the provided SLA which includes detailed information about the services and available levels of resources to be accessed. This multi-layer in the EUHC hybrid Cloud architecture offers additional levels of security for the presented system.

4- Service Repository module: This consists of different services, e-learning systems content, such as database systems, Web file system, and so on.

5- Users Logs module: This is mainly responsible for checking the track of the authorizations users and its access mode which is selected in the User Interface layer. Users' information is stored in the Users Logs module, such as access modes, user account name, password, user type, and so on. Moreover, this module manages and supports resource utilization by recording the resource requirements and their status. The following figure is the proposed EUHC hybrid Cloud implementation architecture:

![EUHC Hybrid Cloud Implementation Architecture](image)

Figure 21. Ethiopian Universities proposed Hybrid Cloud Implementation Architecture

VII. Conclusion And Future Research Direction

Despite its critics and drawbacks, it seems that Cloud Computing is here to stay. Present economic situation will force more and more organizations to at least consider adopting a cloud solution. Universities have begun to adhere to this initiative and there are proofs that indicate significant decreasing of expenses due to the implementation of cloud solutions.

The aim of this work was to identify the particularities of using Cloud Computing within Higher Education in Ethiopia. Mainly, we have considered the risks and benefits of cloud architecture and proposed a Cloud Computing framework for EHEIs. And also the study presents a cloud adoption strategy proper for universities. This paper discusses different cloud topics like cloud deployment types, service delivery models and related concepts. It also discusses the benefits and limitations of cloud computing to higher education institutions. This research investigated the potential benefits of using Cloud Computing in teaching-learning environments to overcome the current learning and service delivery system limitations. The research shows that hybrid cloud computing is a better choice for deployment in the universities since it gives the combined benefit of private and public clouds. The proposed hybrid Cloud Computing would be used as a road map for further studies on the topic.

The proposed framework is just the roadmap for the implementation of a whole virtual cloud based teaching-learning and service delivery ecosystem. After the system is ready to use an independent study comparing the teaching-learning process and service delivery using the proposed framework with the original teaching-learning process and service delivery environment should be conducted. This framework can be tested in departmental level before fully implemented for all universities.

The research possibilities regarding Cloud Computing for educational purposes are immense since the technology is relatively new. Research in the education fields has much to be examined, but there is not yet a clear definition and standard for such technology. The movement will be rapid after the standardization. Here is a list of some of the future work to be done:

1) The proposed framework should be implemented at departmental level and tested with iterative feedback reflection from the users so that the proposed framework will be modified based on the feedback before the framework’s full implementation for all universities.

2) Compare the implementation of the framework on the public Cloud, private Cloud, and hybrid Cloud by highlighting the strengths and weaknesses of each Cloud architecture while considering the performance and security issues. In addition the comparison study may consider the cost, ease of learning, network latency, ease of use, and any other important measurements.
References


