Adopting Cloud IaaS Architecture for Ethiopian e-Government Services

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Abstract

Government organizations delivering e-government services should look for better vehicles to decrease Information and Communication Technology budgets, and at the same time provide agile e-services to organizations and citizens. The paradigm of cloud computing services such as Infrastructure as a Service, Platform as a Service and Software as a Service offer means for governments to address issues of budget constraints and agility of service.

Infrastructure as a Service is one of the three main categories of cloud computing services. In a private cloud model, government organizations with similar business process can utilize resources of data center with relatively lower cost using a cloud Infrastructure as a Service. This paper investigates how to give efficient and cost effective e-Government services by adopting cloud Infrastructure as a Service architecture in a developing economy, Ethiopia, to gain a deeper insight into a research question: How can we provide cloud Infrastructure as a Service using few Data Centers in Ethiopia?

To answer the above question, exhaustive literature review on technologies that are the keystones to adopt and implement cloud Infrastructure as a Service architecture has been carried out. Assessments of some regional data centers, national data center and government offices that are connected to Ethiopian government private cloud, WoredaNet, have been done. The study specifically focused on those sectors that have automated their business process and have Management Information Systems application deployed in regional Data Center. Comparative analysis between the results of the survey and cloud Infrastructure as a Service architecture requirements was done.

We, therefore, adopted Cisco cloud Infrastructure as a Service architecture to enhance the current WoredaNet architecture for better and cost effective e-government services, particularly storage and computing power, from the regional Data Center.

We have analyzed the results of our testing that it can be scaled up to Wide Area Network like Ethiopian government private cloud, WoredaNet. We concluded that with limited number of servers we can solve storage and computing power problems of government organizations.

Keywords: Cloud Computing; Data Center; E-Government; Infrastructure as a Service; Virtualization

1. Introduction

The flow of information is essential for effective governance and managing the day-to-day business of government services for citizens. E-Government creates opportunities to reduce the costs of providing information and services to the public. It is the use of Information and Communication Technology that have the ability to transform relations with citizens, businesses, and different levels of government. Some of the e-government applications fall under the following categories [1].

- G2G (Government to Government): Administration, Inter-government enterprise, Control, monitor and distribution
- G2C (Government to Consumer): Registration/Land/Revenue Services, Hospital services, Agricultural services
- G2B (Government to Business): Tenders (e-tenders), Contract Management, Tax, etc.

E-government applications rely on Data Centers. Data Center is an essential corporate asset that connects all servers, applications and storage services. Therefore, Data Center is a key component that needs to be planned and managed carefully to meet the growing performance demands of users and applications [2].

Cloud computing is a promising technology model that is changing the way government organizations consume Information and Communications Technology (ICT), and how they deploy and deliver services to citizens and stakeholders. In addition, cloud architectures can benefit governments to reduce duplicate efforts and increase effective utilization of Data Center resources [3]. As it is described in [4], governments that adopt cloud computing strategy believe that "If the goal of e-Governance is to be achieved, it can do so by leveraging cloud infrastructure without having to purchase significant hardware, lowering both time and cost barriers in Data Centers". It is also indicated in [5] that E-Governance with cloud computing offers integration management with automated problem resolution, manages security end to end, and helps budget based on actual usage of data.

There are three main cloud services provided according to the demands of ICT customers. Firstly, Software as a Service (SaaS) provides access to complete applications as a service. Secondly, Platform as a Service (PaaS) provides a platform to develop other applications. Finally, Infrastructure as a Service (IaaS) provides an environment for deploying, running and managing virtual machines and storage services. The three cloud computing services can be viewed as a stack in Figure 1 [6].

Figure 1: Cloud Computing Service Layer

IaaS (Infrastructure as a Service) refers to computing infrastructure comprising of networking, hardware, virtualized operating systems and software servers offered as a service. At its core, Infrastructure as a Service is a way for organizations to get the hardware, storage, networking and other services they need to run their operations without worrying about buying, managing or maintaining the equipment [7].

1.1 Research Background

The Ethiopian Government has recognized the power of ICT in national development plan and had launched an e-government initiative in 2005. One of the e-government initiatives is establishing government cloud, called WoredaNet ICT Network, in which all public sectors in the country are to be connected to get e-Services from National Data Center.

Based on this initiative, there is 1 National Data Center and 9 Regional Data Centers in the country. The National Data Center is connected to the Regional Data Centers and to all Woredas that have WoredaNet ICT Network in the country. Currently, over 630 Woredas (districts) are connected; some government ministries and some regional bureaus that are connected to the WoredaNet are getting Internet and video conferencing services. The Ethiopian government cloud, WoredaNet, architecture is shown in Figure 2 [8].

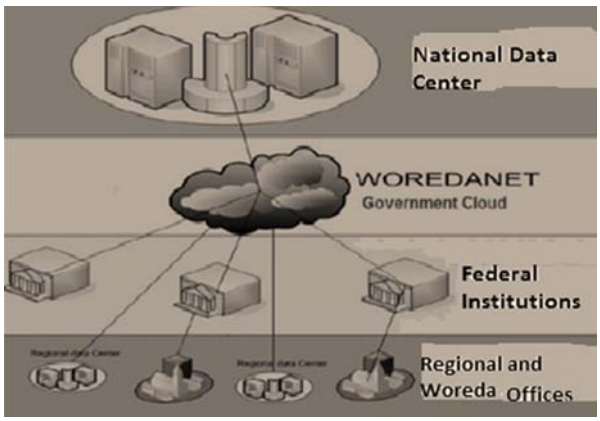

Figure 2: Ethiopian Government Cloud

1.2 Problems with Current e-Government Services

In Oromia region about 22 regional bureaus have conducted BPR (Business Process and Reengineering) study of their respective businesses and developed MIS applications since 2008, where each of them developed sector specific applications and databases. They require independent storage and computing power which is expensive to purchase for each of these regional bureaus. As the need of automating the manual business process increases within public sectors of the country, it requires huge amount of storage space and computing power. Therefore, the main purpose of this paper is to answer the research question: How can we provide Infrastructure as a Service using few Data Centers in Ethiopia?

To answer the above question, exhaustive literature review on cloud computing and some of its key benefits, particularly Infrastructure as a Service conceptual architecture, cloud IaaS architecture of different vendors and some of the parameters to adopt cloud Infrastructure as a Service architecture has been carried out. This study also identified technologies that are the keystones to adopt cloud Infrastructure as a Service architecture.

Assessments of some regional data centers, national data center and government bureaus that are connected WoredaNet have been done. As a result, primary data collection was done based on questionnaires developed to answer the research question and distributed to a total of 81 individuals (8 Federal IT experts, 7 regional IT heads and 66 regional IT Experts). About 64 respondents filled the questionnaires and based on their responses, comparative analysis between the results of the survey and cloud Infrastructure as Service architecture requirements was done.

The rest of the paper is organized as follows: Section 2 presents related work. The adopted cloud IaaS architecture is described in Section 3. Section 4 presents discussion. Section 5 concludes the work and points out future works.

2. Related Work

Shared hosting is the prominent hosting option for most businesses and government organizations in Ethiopia [9]. The principle of this hosting option comes from the fact that ethio-telecom is sharing the resources of a single server with many other users. However, in this hosting option there is a performance problem, and in addition resources of a data center such as storage and computing power are not provided as a service on demand.

Lowering costs is a major driver for adopting the cloud IaaS architecture. There are some core characteristics which describe what IaaS is. IaaS is generally accepted to comply with the following [7]:

- Resources are distributed as a service
- Allows for dynamic scaling
- Has a variable cost, utility pricing model
- Includes multiple users on a single piece of hardware

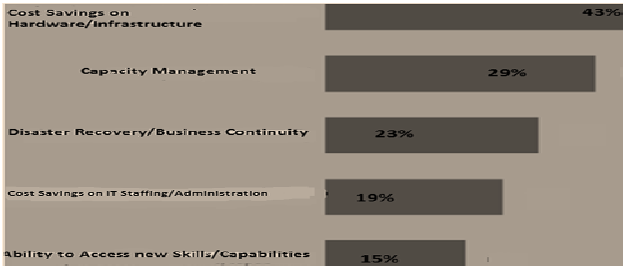

Figure 3: Top Five Motivations to Use IaaS

A survey conducted in [10] illustrates the top five motivations specified by respondents as reasons to use IaaS where cost savings is a key objective. The survey conducted is described in Figure 3.

IaaS provides simple provisioning of processing, storage, networks, and other fundamental computing resources over a network.

Table 1: Comparison of IaaS with other IT services options

Factor	*IaaS*	*Managed Services*	*Conventional Data Center*
Provisioning	On-demand, instant	On-demand, days to weeks	Weeks to months
Scaling	Instantly up or down	Weeks to months, up or down	Months, up only
Charges	No upfront, "pay as you consume"	Upfront fees, minimum term commitment, fixed monthly fees	Capital-equipment purchase or lease, maintenance charges, plus bandwidth utilization fees
Self-service?	Yes, via desktop console	No	Not automated

As it is compared in table 1 [10], IaaS service option is better provisioning option than other IT service options.

Cloud IaaS architecture designed by different vendors such as Cisco, IBM, Oracle and HP are discussed. Cisco is an enabler of the IaaS layer and provides specific services in the Software and Platform as a Service Layers. The Cisco cloud IaaS architecture [11] enables virtualized and on demand cloud services from a data center. IBM cloud IaaS architecture [12] also enables service based, scalable and elastic, shared and Internet based cloud services. Oracle Optimized solution for cloud IaaS [13] encompasses the compute node, storage infrastructure, network devices, virtualization software, operating systems, and management software to provide cloud services. HP Cloud System described [14] enables enterprises and service providers to build and manage services across private, public, and hybrid cloud environments with ease, reducing complexity and fostering business growth.

In this study, a thorough literature review of factors and opportunities to be considered for adopting Cloud IaaS architecture was conducted. Analyzing these factors and measuring their significance will help to choose which cloud IaaS architecture to adopt within government data center. The most powerful attribute of cloud IaaS architecture is the speed and simplicity with which pools of infrastructure resources can be fixed and flexibly configured and reconfigured to match infrastructure requirements. Therefore, factors to be considered to adopt cloud IaaS architecture are ranked to indicate their level of significance. Each factor is given low - for low significant factor, medium - for medium significant factor and high - for highly significant factor.

These factors are used for comparing and analyzing the different vendors' IaaS cloud architectures. A cloud IaaS architecture that considers factors that are highly significant were chosen and adopted in Oromia Regional government data center context.

Table 2: Factors and their level of significance

Factor	*Significance*
Bandwidth	High
Cost	High
Performance	High
Scalability	High
Security	Medium
management	Medium
Integration with other Services	Low
Standardization issue	Low
Ease of Use	Low

Based on factors and their level of significance in Table 2, for adopting cloud IaaS architecture in Oromia regional data Center context, Table 3 summarizes the comparison of the different vendors' cloud IaaS architectures.

Table 3: Comparison of vendors' cloud IaaS Architecture

Cloud IaaS Architecture	*Parameter for Adopting Cloud IaaS architecture in Oromia Regional Data Center*								
	Bandwidth Requirement	*Cost*	*Performance*	*Scalability*	*Security*	*Management*	*Integration*	*Standardization*	*Ease of Use*
IBM [12]	High	expensive	Greater latency	license	OK	Separate	OK	Vendor Lock in	complex
HP [15]	High	expensive	Greater latency	license	OK	Separate	OK	Vendor Lock in	complex
Oracle [13]	High	expensive	Greater latency	license	OK	Separate	OK	Vendor Lock in	complex
Cisco [11]	High	Less expensive	Lower latency	No license	OK	Unified	OK	Open	simple

Table 3 shows comparison of different cloud IaaS architectures based on factors to be considered before adopting the architecture. These factors are used for comparing and analyzing the different vendors' cloud IaaS architectures.

Different countries adopted cloud IaaS architecture. The Chinese University of Hong Kong transforms their IT infrastructure with Cisco Data Center .The University centralized and virtualized its information technology resources by deploying Cisco cloud IaaS architecture with its Unified Computing System [15]. Based on IBM cloud IaaS architecture, Vietnam Technology and Telecommunication (VNTT) offers cloud IaaS mainly the server or storage capacity and system capability for its clients, which are mainly for small and medium size enterprises. In collaboration with VMware Company, IBM has built a data center in South Africa, Johannesburg, to offer cloud services [16].

We had conducted literature review on the approaches that exist to adopt Cloud IaaS architecture. According to the comparison in Table 2, factors that are significant to adopt cloud IaaS architecture were clearly shown. Vendors' cloud IaaS architectures that considers these significant factors were compared. From the table, Cisco cloud IaaS architecture satisfies more than 66% of the factors that are significant to adopt cloud IaaS architecture. Therefore, It is preferable than other vendors' cloud IaaS architecture and adopted in Oromia regional data center.

3. The Proposed Solution

We have adopted Cisco cloud IaaS architecture based on the existing Ethiopian government private cloud, WoredaNet. In order to perform the adoption, the research first compares the different cloud IaaS architectures disused in the literature review with existing components in Oromia regional data center and identifies components of virtualization technology and defines their functionalities. Secondly, testing and demonstrations of Cisco cloud IaaS architecture in a small scale was carried out. Finally, by scaling up the adopted Cisco cloud IaaS architecture we propose the result to be implemented for Ethiopian e-government services.

3.1 Identifying Components of Cisco Cloud IaaS Architecture

Components in Cisco cloud IaaS architecture discussed in the literature review are identified and compared with Oromia Regional Data Center equipments to carry out the testing. The components are identified and compared as follows.

- *Application Software*: A client software ,XenCenter is to be installed on desktop/laptop computers.
- *Virtual Machine:* XenServer 6.1 host is to be installed on a physical server.
- *VMSwitch*: it is a built-in virtual switch which helps as a load balancer..
- *Storage and SAN*: it is a blade of servers or single server with SAN (Storage Area Network).

- *Compute, Access, Aggregation, Core, Peering*: are servers in rack, access switches, core switches, and routers respectively.
- *Backbone*: There is a WoredaNet Internet in National Data Center and Regional Data Centers.

Therefore, many of the components in Cisco cloud IaaS architecture are found in Oromia RDC.

3.2 Oromia Regional Data Center Services Scenario

Regional bureaus, zone and Woreda/district government offices are connected to regional data center and national data center via WoredaNet. These government offices are getting intranet services (e-mail, portal, MIS, Video Conference) from the Data Center through http://ip_address and then authenticated by their username and password.

3.3 Equipments that are found in Oromia Regional Data Center

1. Cisco Routers that are used to connect the data center to WoredaNet
2. Firewall to keep security
3. Cisco 6500 series, Core Switches are used to route packets among internal VLANs
4. Cisco 3560 series access switches
5. Video conference cameras and plasma displays
6. Server Farms are connected to SAN (Storage Area Network) through Veritas Net Backup Server
7. Veritas Net Backup Server is installed a software that manages all Severs and SAN arrays
   - It creates backup scheduling
   - Manage client computers
   - Manage SAN (Disk and Tape arrays)

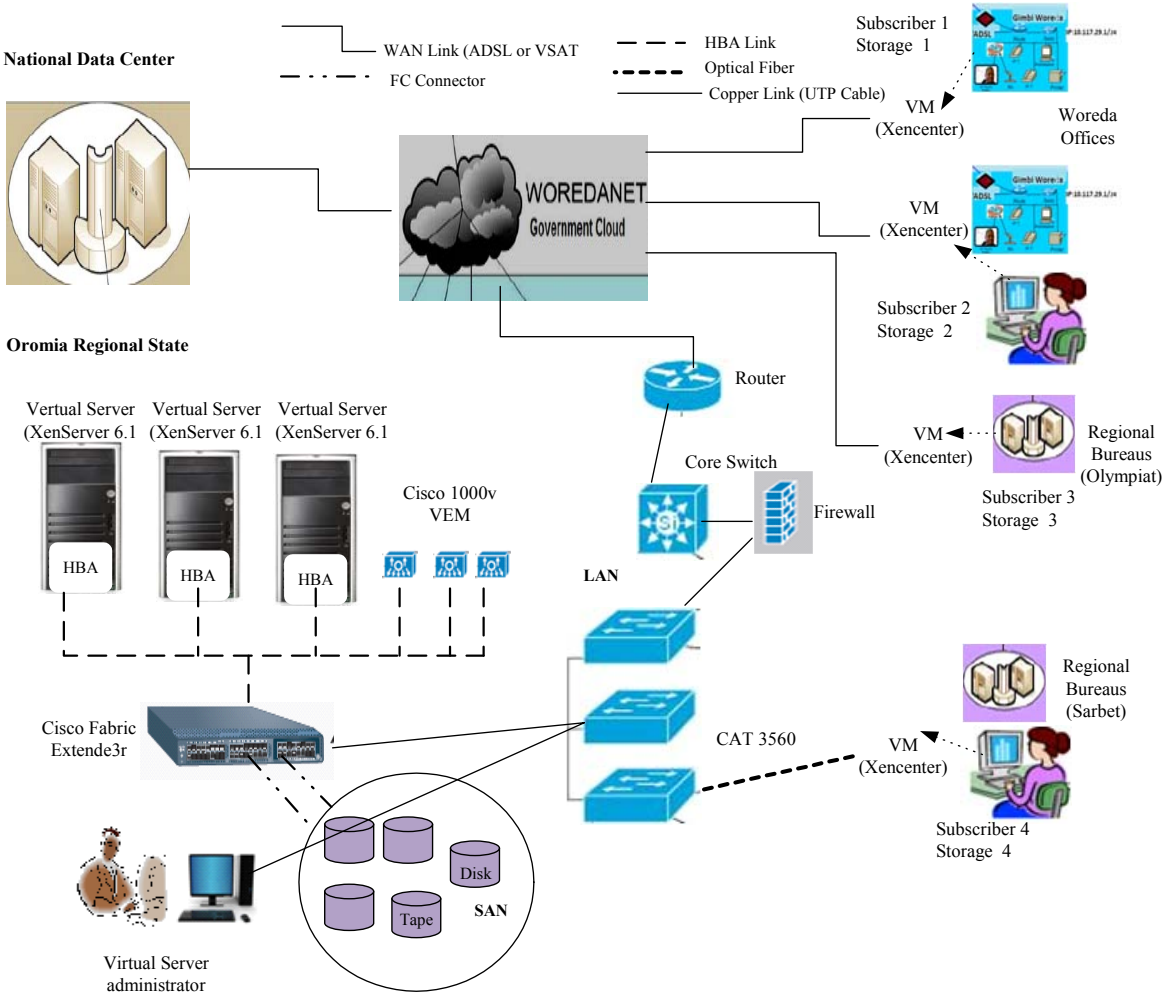

Figure 4: The Adopted Cisco Cloud IaaS Architecture

3.4 Description of the Adopted Architecture

Figure 4 shows an overview of the adopted Cisco cloud IaaS architecture and how the subscribers/users from regional bureaus, zones and Woreda sector offices could access server resources within Oromia Regional Data Center via WoredaNet. The number of servers is decreased from 7 to 3 in a new adopted architecture. The physical servers installed XenServer 6.1; it can run 500 virtual machines. This shows the 3 physical servers can run 1500 virtual machines which justify about 1500 users can connect and access the resources of the physical servers. Within six steps, the user can use a resource and then release it.

1. The user sends a request using the XenCenter.
2. User's verification using the built-in Active Directory feature in XenServer 6.1.
3. The user's request will be sent to the virtual infrastructure manager, XenServer 6.1.
4. The system will establish a connection between the requested service from the Cloud and the user.
5. The system synchronizes the service delivery between the user and the resource.
6. When the user is done, the system will terminate the session and disconnect the user from the cloud service.

Access to storage is done as follows [17]:

In the XenServer 6.1 Storage Repository, Virtual Disk Images are created as a storage abstraction of objects that can be presented to a Virtual Machine.

The Oromia ICT Development Agency director and two data center administrators validated the adopted Cisco Cloud IaaS architecture from its contribution to enhance the current data center services.

3.5 Contribution of the Adopted Cisco Cloud IaaS Architecture

The adopted Cisco Cloud IaaS architectures deliver a comprehensive solution for storage and computing power requirements of government organizations who have automated their business process. The key contributions of the adopted architecture include:

1. Cost Reduction: Few servers can serve for storage and computing power requirements.
2. Scalability: In case new server is added, more clients can be added to the data center.
3. Ease of Use: Using the management console, XenCenter, any network administrator with Microsoft Active Directory knowledge can manage resources of servers.
4. Performance: XenServer 6.1 has a feature of live migration of virtual machines between pools of servers.

4. Discussion

In this paper, the critical role of ICT in e-governance, limitations of the current ICT service delivery from regional data centers, and identification of better ICT service delivery technologies such as cloud IaaS architecture have been studied. After identifying the requirements and limitations, the research showed that Cloud IaaS architecture can overcome most of these limitations and fill the gap of storage requirements to improve e-government service delivery. Cloud IaaS architectures of different vendors and their components have been compared. From the different Cloud IaaS architectures, Cisco cloud IaaS architecture is chosen and adopted in Oromia regional data center. Cisco cloud IaaS architecture is chosen based on factors and parameters that are more significant to consider in adoption of cloud service architecture in the Ethiopian context. Open source virtualization tools, XenServer 6.1 and XenCenter have been used for the implementation and testing of the adopted Cloud IaaS architecture in small scale LAN environment.

5. Conclusion and Future Work

In this paper, we have adopted Cisco cloud IaaS architecture for Ethiopian e-government services. Through this work, we demonstrated the usefulness and effectiveness of services provided by Cisco IaaS cloud architecture. The testing of the adopted architecture in a small scale at one regional data center verified that the adopted Cisco cloud IaaS

architecture can scale up to large scale, at national level.

The study is limited to cloud IaaS architecture adoption in private cloud model. The study focused on government Data Centers that are already connected with WoredaNet. The adopted Cisco cloud IaaS architecture is a road map to adopt and implement other cloud computing services.

Future research should focus on adopting and implementing other cloud computing services beyond IaaS such as SaaS, PaaS and XaaS (Everything as a Service) in Ethiopian data centers. It should also focus on the impact of adopting cloud computing in developing economies such as Africa in general and Ethiopia in particular.

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