NRENs Cloud Infrastructure Framework (NRENs-CLIF): Case Study of SADC Region

Nalina SURESH[1], Jameson MBALE[2]

[1]*University of Namibia, P/B 13301, Windhoek, Namibia, email:* nsuresh@unam.na

[2]*Copperbelt University, Box 21692, Kitwe, Zambia, email:* jameson.mbale@cbu.ac.zm

Abstract

Recently, the appealing features of cloud computing have been driving its integration into the ICT component of the education sector. In view of this, the NRENS in developed countries are adopting Cloud computing as its technology support and provider of solutions that are very effective in facilitating collaborative research and learning among member institutions. In addition, the developed world opted for this technology because of its flexibility to pay-as-you-go combined with an on-demand scalable model which is changing the NREN computing model and driving them to adopt it. However, very little if nothing has been done particularly the NRENs in the SADC region. It is against this background that NRENs Cloud Infrastructure Framework (NRENs-CLIF) was conceived to build a Cloud computing infrastructure framework suitable for the SADC NRENs. The NRENs-CLIF would build an Inter Cloud Infrastructure system that would envision the transitions every NREN into Cloud system and make them interoperable to each other. The study emphasizes that the SADC NRENs need to join NRENs-CLIF to ensure that resource sharing and collaboration among these NRENs becomes a success.

Keywords: NRENs-CLIF, NRENs, SADC, collaboration

1. Introduction

The evolution of Cloud computing for Information Technology (IT) or computational resources provisioning has led to a significant shift in the IT industry and prompted interest from different organizations, institutions and users to take its advantage. Hence in this study NRENs Cloud Infrastructure Framework has been introduced and abbreviated as NRENs-CLIF.

1.1 Statement of the Problem

The NRENs in developed countries are moving towards Cloud computing technology. According to Thorsteinsson et al. (2010), cloud-based solutions can be very effective in supporting collaborative and cooperative learning. Katz (2009) stated that many NRENs in the developed countries are joining Cloud-based services to stay organized and connected. Despite the fact that Cloud computing has a huge potential, in SADC there has not been dedicated research nor initiatives on Cloud computing issues so far. This is supported by Mbale (2013), who stated that very little effort had been made especially in developing countries regarding the utilization of Cloud computing. He further emphasized that in view of the current state of SADC NRENs there is a need to overhaul a major part of their current infrastructures to be compliant and embrace this upcoming Cloud technology. Therefore, this work introduces NRENs-CLIF, which would assess the prevailing status of SADC NRENs non-Cloud based technology and further determine the best possible approaches of transforming the current infrastructures into Cloud model. The study also seeks to investigate the security risks, challenges and opportunities of moving organizational data into the Cloud in the SADC NRENs perspective. The study aim to address the following critical research questions:

How can the SADC NRENs resources be utilized to establish institutional Cloud infrastructure and connectivity to facilitate research collaboration?

- What are the resources that can be used to establish institutional Cloud infrastructure in the SADC NRENs?
- What Cloud Service Architecture is suitable for interconnection of NRENs in the SADC region?
- What are the challenges faced by SADC NRENs with regards to establishing institutional Cloud services?

1.2 Organisation of the Paper

The paper is organised in the following parts: Section 1 introduces the highlights of the NRENs-CLIF and the reason of undertaking this work. Similar work done by other scholars concerning the NRENs utilising Cloud technology is discussed in Section 2. The NRENs-CLIF architecture is illustrated in Section 3, explaining the functions of each component. The discussion and findings of the research are presented in Section 4. Section 5 summarises the functions and benefits of the NRENs-CLIF model.

2. Literature Review

Some of the NRENs both in the developed and third world that are striving to embrace the Cloud technologies are discussed. According to Koukis (2012), reported that Greek Research Educational Network (GRNET) deployed Software as a Service (SaaS) platform in which end users could deploy services by configuring only the parameters related to their institutions. He further, highlighted that, it is expected that the transfer of physical machines to virtual ones will save tremendous amounts of investment in future, which is the highest priority of the Greek Government.

Wind (2011), pointed out that GRNET through Okeanos project was to deliver a production quality IaaS and to offer virtual computing resources at a pay-per-use fee. Though cautiously, he explained that Okeanos was currently in alpha testing phase, he pointed out that it (Okeanos) offered its user's access to Virtual Machines, Virtual Ethernets, Virtual Disks, and Virtual Firewalls through a simple web-based Graphical User Interface (GUI).

Pol and Dijkstra (2009), narrated that the Netherlands Research Educational Network, SURFnet has embraced Cloud computing. They further stated that in SURFnet all generic IT services in higher education and research is provided by Public Cloud.

Luo et al. (2011) discussed the Malaysian Research and Education Network (MYREN) that offered the basic SaaS services through Servers running on open source platform. They further stated that MYREN Cloud was planning to deploy Compute-as-a-service (CaaS) for future releases, though they observed that security issues in MYREN still needed to be addressed for reliable operation. They also reported that MYREN had a Cloud portal used to connect to its member institutions into the Cloud. Salmon (2009), narrated that JANET was looking forward to creating bandwidth on demand service and making it into public service creating EU NRENs secured, standard and infrastructure intensive capable platform better than the commercial network available in UK.

3. The NRENs-CLIF Model

The NRENs-CLIF Architecture demonstrated in Figure 1 is a heterogeneous framework which is both multi domain as well as multi Cloud provider in nature. It has the ability to host specific systems. It has also the capacity to manage, monitor and maintain some of critical systems that are actually necessary to ensure reliability and fault tolerant. The architecture has been categorised into models or logical groupings and has been decomposed into their functionality and the way they will actually integrate with entire end to end system.

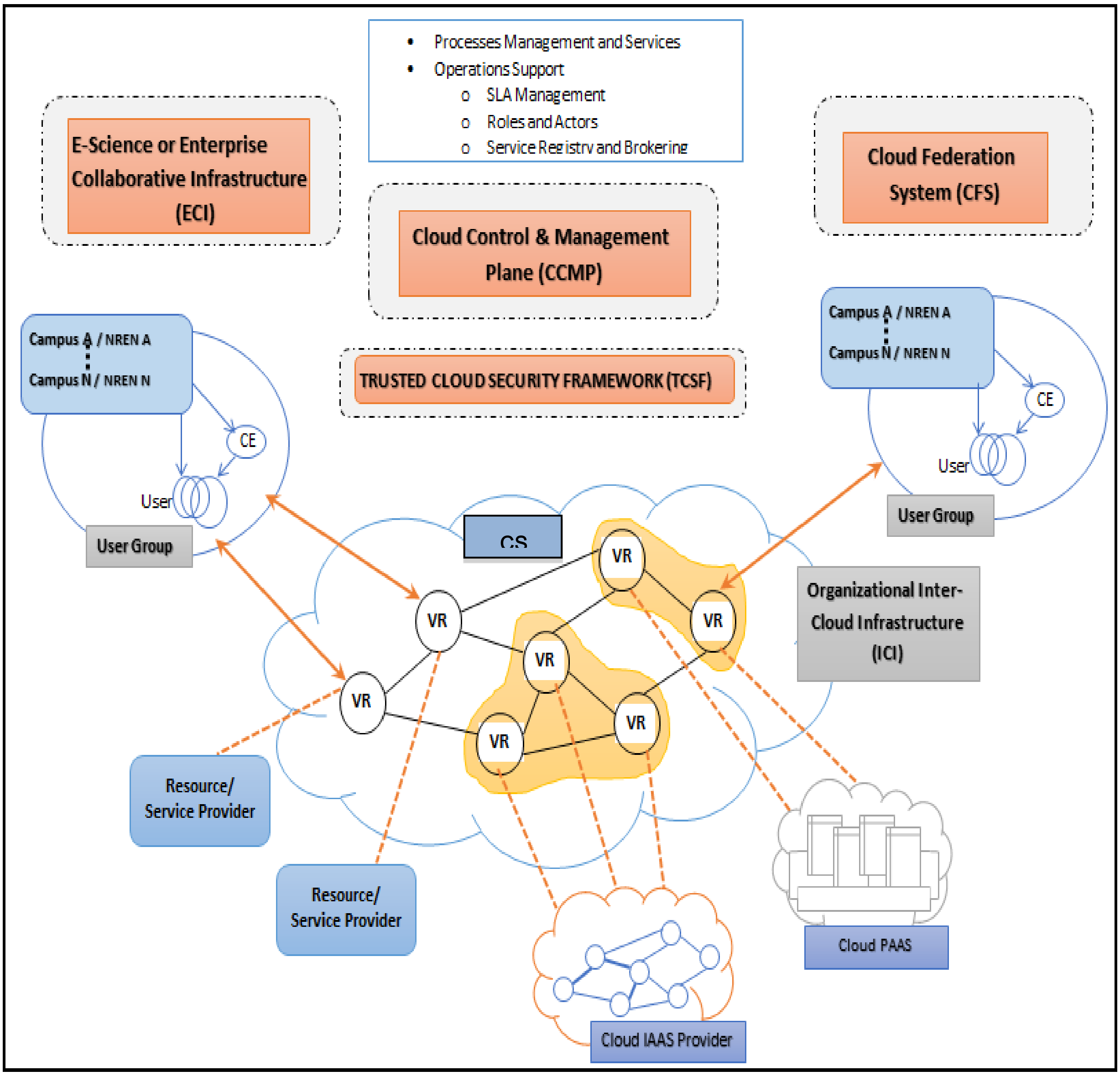
Processes Management and Services
Operations Support
SLA Management
Roles and Actors
Service Registry and Brokering
E-Science or Enterprise Collaborative Infrastructure (ECI)
Cloud Control & Management Plane (CCMP)
Cloud Federation System (CFS)
TRUSTED CLOUD SECURITY FRAMEWORK (TCSF)
Campus A / NREN A
Campus N / NREN N
CE
User
User Group
Campus A / NREN A
Campus N / NREN N
CE
User
User Group
CS
VR
VR
VR
VR
VR
VR
VR
Organizational Inter-Cloud Infrastructure (ICI)
Resource/ Service Provider
Resource/ Service Provider
Cloud PAAS
Cloud IAAS Provider

Figure 1. NRENs-CLIF Architecture

The NRENs-CLIF is made of two operational components: the Main and Supporting architectural components.

3.1 The Main Architectural Component

The Main Architectural component is comprised of the following functional parts: Cloud Control & Management Plan (CCMP), Cloud Federation System (CFS), e-Service or Enterprise Collaboration Infrastructure (ECI) and Trusted Cloud Security Framework (TCSF).

3.1.1 Cloud Control & Management Plan (CCMP)

CCMP is an isolated system component associated on top of CSM. The CCMP integrates all the Inter Cloud application system with the infrastructure control and management system. It provides logical and functional interface between different cloud service layers running in different cloud domains. In addition, it provides single control and management domain to heterogeneous inter-cloud infrastructure for the standardisation of interlayer interfaces.

Other functions of the CCMP are: to support messaging, monitor all physical and virtual infrastructural resource. To configure hardware, software, virtual resources, session management, and synchronisation of the distributed heterogeneous cloud platforms.

The CCMP has the following four internal functional components: Cloud Resource Manager, Network Infrastructure Manager, Virtual Infrastructure Composition and Orchestration, and Services / Infrastructure Lifecycle Management. The Network Infrastructure Manager takes care of all the network resources that are available to CCMP. The Cloud Resource Manager specifically controls the resources provided by infrastructure as-a-service (IasS) and platform as-a-service (PaaS) domain(s). Whilst the Virtual Infrastructure Composition and Orchestration provides access to virtual resources (VRs) and group them to make communication between them possible. The Services and Infrastructure Lifecycle Management creates and initialises virtual machines (VM), to make them operational and terminate their resources.

In addition to the above expressed internal functional components, the CCMP has the following interface(s): the inter-cross-layer control/signaling which manages communication in the domains; the monitoring, which provides VR capabilities such monitoring all physical and virtual infrastructural resources; the location, which manages location of VRs from either service or resource provider; the topology, it is an aware infrastructure management which recognizes the type of topology for the VRs; and configuration and protocol management, which configures VRs for different domains.

3.1.2 Cloud Federation System (CFS)

CFS provides interaction between completely two different domains either operational or administrative. Hence, the NRENs-CLIF will exploit the CFS's architect to create interaction, interoperation and logical structures among multiple domains. So, it can be extended to provide any kind of services on any domains with a NRENs-CLIF membership. That's, it will be able to access the resource or services of secondary Cloud system from primary Cloud systems. It is important at this juncture that operational and administrative controls be in place to forward services, user credentials, authentication credentials, keys from one Cloud system to another system.

CFS communicate between completely different Cloud computing systems by providing single sign on capabilities for privileged users who can access services from two different Cloud system. In such scenario additional infrastructure may be required to interconnect two completely different Cloud systems, but they could be part of the same service delivery infrastructure.

As mentioned above, CFS tries to integrate multiple Cloud systems that are independent from each other and able to provide independent services and resources to one another and this integration is possible using federation infrastructure. So, associated with CFS a number of functional components were required for integration. Apart from each of these functional components to communicate with each other will require specific protocols and interfaces that are discussed below:

Service brokers: help to communicate different services to different parts of this Cloud system. That's, one service from one Cloud could be forwarded to another Cloud system.

Trust broker: brokering trust information, communication protocol, encryption information, key management but to mention a few.

Registry services and discovery services: maintain list of all the services and resources provided by specific independent Cloud systems. They also provide interface(s) for discovering such services.

Identity provider: federates identity information of different users among Cloud domains. That's, different and independent Cloud system should be able to recognize and federate the same identity information of different users among Cloud domains. Such a scenario, require federated attribute authority which will have common understanding of user credentials and user related information associated with all of these Cloud systems.

Policy authority: is in charge of enforcing common policy to all of these inter Cloud systems.

Inter Cloud GW system: is associated with performing translational capabilities. It automatically translates appropriate request query, protocols, messaging, and communication signaling. That's, making request/query send by one Cloud domain understandable to another domain. It also performs data format translation among Cloud domains.

3.1.3 e-Science or enterprise collaborative infrastructure (ECI)

ECI is specialized infrastructure which includes dedicated transport network and has the capabilities of provisioning resources and specific services on-demand. Such services could be utilized by University, research and educational networks. For instance, in Figure 1, to cite an example, two campuses A and B have different user groups. Both campuses can collaborate jointly on scientific experimentation project using ECI infrastructure. The ECI has the ability to support large scale scientific projects infrastructure which could support specific areas or domains of research like particle physics, and bio-informatics. Other specific examples of these fields are: genome research, electromagnetic, geographical mapping, satellite based systems but to mention a few. In fact, the ECI's research oriented infrastructure could also be targeted towards large scale project such as space exploration projects, protocol engineering, understanding network dynamics, and traffic engineering.

3.1.4 Trusted Cloud Security Framework (TCSF)

TCSF is a cross functional entity and it involves interaction with multiple layers in the protocol architecture. It will provide a basis for all secure operations between each and every component that is present in NRENs-CLIF architecture. It will take care of integration with multiple Cloud layers and secure every layer independently. TCSF Interface is implemented for different layers and it creates encapsulation for the entire CSM. TCSF will not only ensure security operations are being performed but also incorporates some security controls to ensure that when interacting with third party system or external Cloud through the CFS, even those are secured and performed as desired.

3.2 The Supporting Architectural Component

The supporting architecture component has the following parts: Cloud Services model (CSM), Virtual Resources (VR), and Inter-Cloud Infrastructure (ICI).

3.2.1 A Cloud Services Model (CSM)

A CSM is the central component of NRENs-CLIF architecture. The CSM framework for interCloud infrastructure is incorporated in NRENs-CLIF with regard to the choice of Cloud service delivery models over this community Cloud as shown in Figure 1. The CSM oversees the complete operations of: CCMP, CFS, ECI and TCSF. CSM will be associated with multi provider infrastructure operation, routine operations, work flows, SLA management, and monitoring whether meeting the targets or not. CSM has its own set of well-defined user roles and responsibility that would be working in resource operation and management framework. CSM roles are owned by management or operational entity or by an entity which actually owns that particular Cloud computing system through ownership or a particular stake holding.

The CSM is split up into six (6) horizontal layers or planes that are defined to group related functionalities performing cross functional operations, management, controls and security. These layers are: first, the Physical Platform, which includes different physical resources such as storage, computing and networking. Second, is the Cloud Virtualization Layer, which customises all non-hardware resources that could be completely virtualized and would have to interact with physical, lower or second structures interacting with upper layers and so on. Third is the Cloud Virtual Resource / Orchestration Layer, which combines multiple virtual machine resources (VRs) grouped into logical entities. These groups of VRs could be utilised to perform or deliver a particular type of service. Fourth, the Cloud Service Delivery Layer, which is associated with different service delivery models, that include either pure IasS on virtualized platform, or PaaS to IaaS interface interconnecting. Fifth, is the Access/Delivery Infrastructure Hosting, whose functions are to provide access to cloud services/resources and interconnect multiple cloud domains that would help deliver services to end user. Sixth, are the User/Customer Side Resources and Services that are located in and provided by the customer's enterprise or campus network to support their integration with the Cloud based infrastructure.

3.2.2 Virtual Resources (VRs)

The Virtual Resources (VRs) provide specialised functions such as filtering, visualization, data processing, but to mention a few. The VRs resource could be software, platform or an API. These virtual resources could also be grouped together to create a complete service.

3.2.3 Inter Cloud Infrastructure (ICI)

ICI allows campus or NRENs to access the central Cloud in this case the CSM. From Figure 1, an example can be cited taking campuses A and B, where they have different user groups that are required to collaborate among each other. These campuses are performing jointly on scientific experimentation, and associated with this they have dedicate scientific infrastructure.

4. Discussions and Findings

The study revealed that (85%) of the NRENs have not implemented Cloud technology as illustrated in Figure 2.

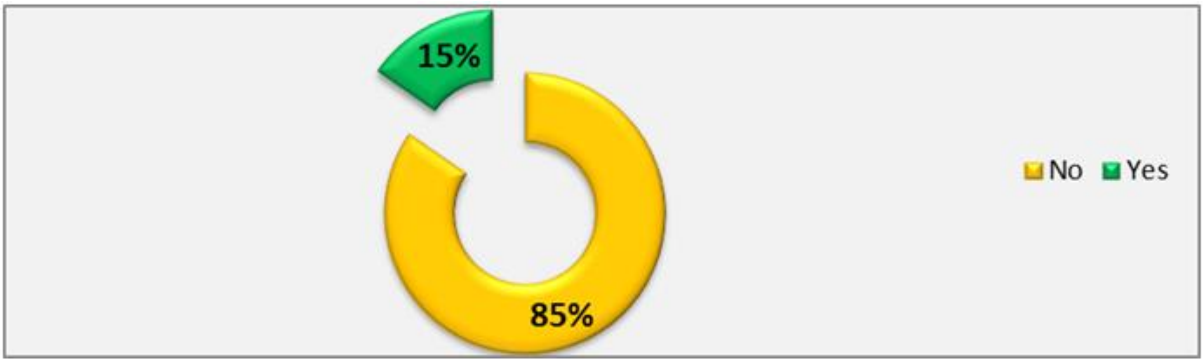

Figure 2. NRENs on Cloud

However 75% respondents indicated that their NRENs utilizes Virtualization technology(s) as shown in Figure 3.

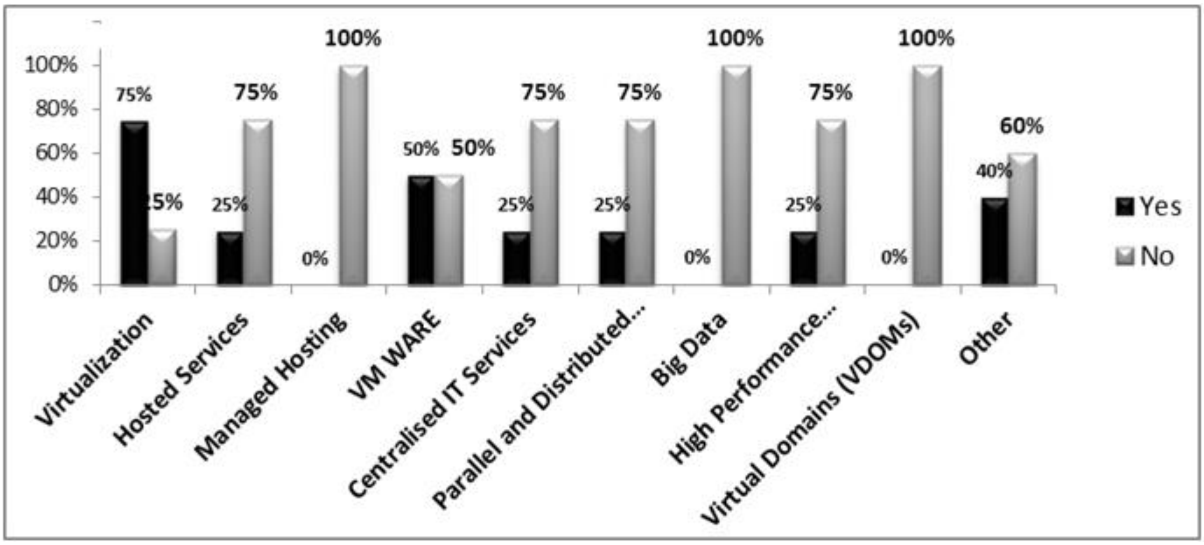

Figure 3. IT Infrastructure/Technologies

The researchers further observed that NRENs that were not on Cloud showed 77% of willingness to deploy Cloud Computing technology as presented in Figure 4.

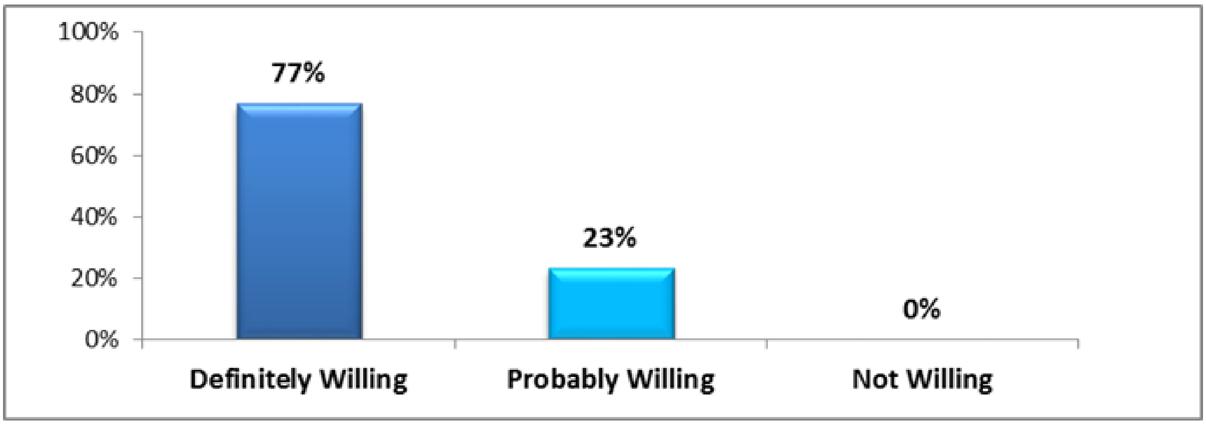

Figure 4. NRENs Willingness to Deploy Cloud Computing Technology

Hence these NRENs that had already deployed some virtualization technologies display much better preparedness and they would be able to adopt Cloud computing system much faster.

4.1 Reasons and Steps for NRENs to Adopt Cloud

In addition, the study revealed that some NRENs that are not on Cloud reasoned out that strict regulations and lack of technologies were the factors hindering the adaptation of Cloud as shown in Figure 5.

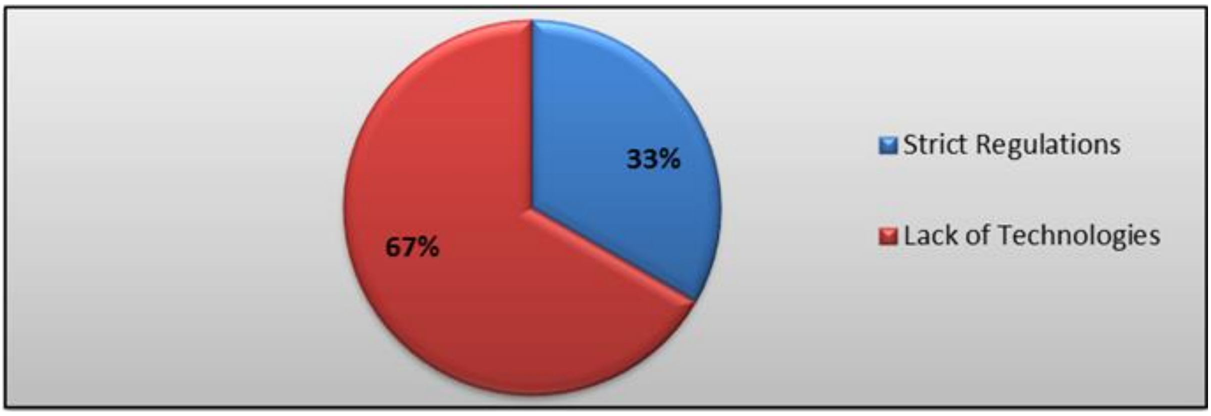

Figure 5. Reasons Why NRENs Have Not Adopted Cloud Computing Technology

The above illustrated reasons would hinder the NREN organizations preparedness for technology infrastructure towards Cloud computing. Steps such as upgrading the non-Cloud IT infrastructure, collaborating with other NRENs to simplify compliance requirements, relaxing of restrictions on data crossing the borders, establishing political support for Cloud initiatives, having strong guarantees in contracts and SLA’s to mention a few would be done in consultations with IT industry. Also, cloud users and international standard bodies, will clarify the rules by which organisations must operate and enable them move forward.

4.2 Benefits and Purpose that NRENs Use Cloud Computing

An interesting finding on this study was that NRENs explore Cloud services to improve communication, collaboration, exchanging data more efficiently, for standardised shared platform and to run enterprise software applications, within and among outside NRENs as shown in Figure 6.

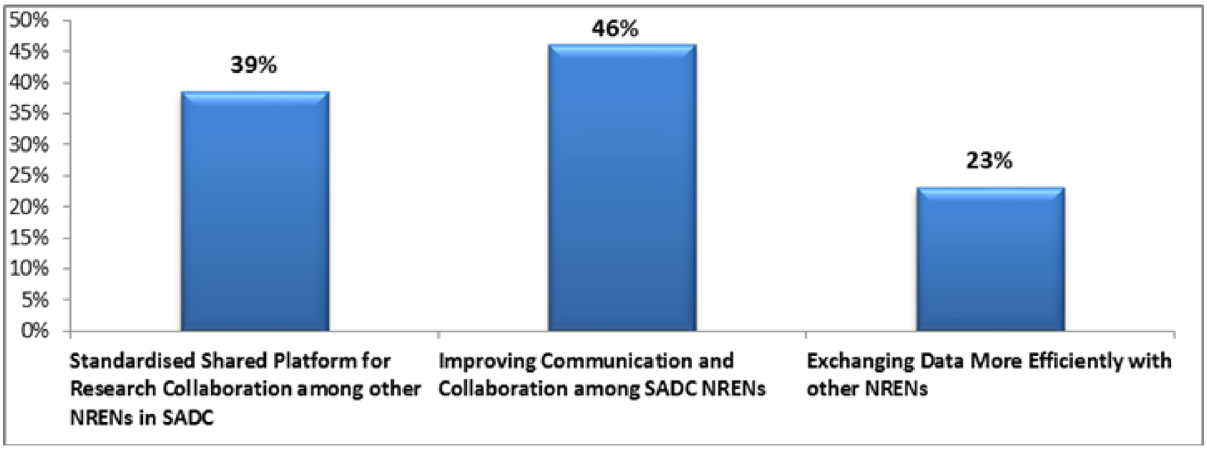

Figure 6. Benefits of Cloud Services in NREN

4.3 Rate of Challenges/Issues of the Cloud Computing on-Demand Model

The study revealed that 85% of the NRENs have not implemented Cloud technology as illustrated in Figure 7.

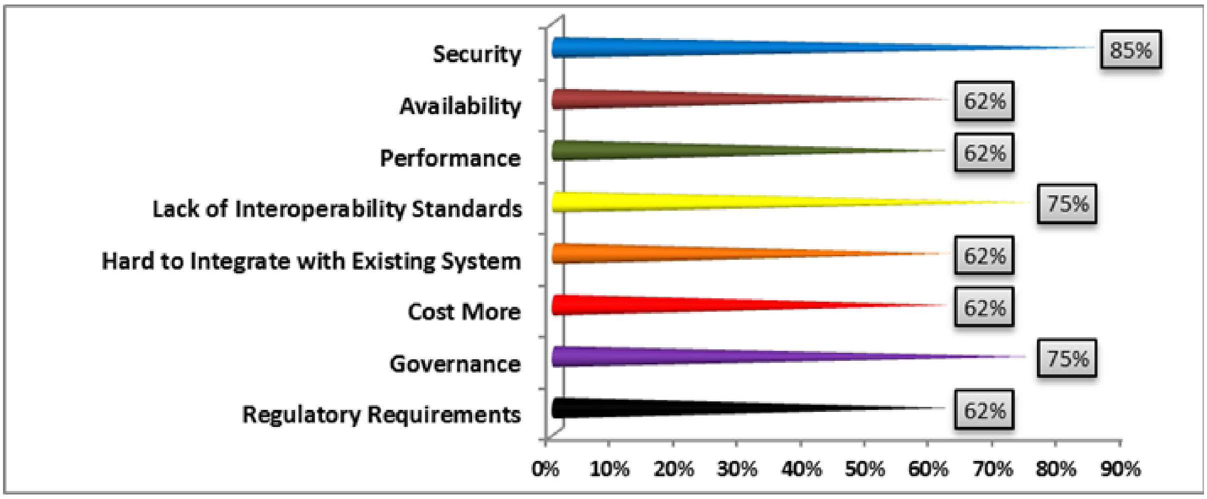

Figure 7. Challenges/Issues of the Cloud Computing

The reasons illustrated in the figure are associated with the factors or challenges such as security, availability, integrity, performance, cost, interoperability, governance but to mention a few. The survey conducted, as depicted from graph outlines the perceived challenges and issues associated with cloud computing and on-demand computing models from a total of thirteen (13) NREN respondents.

The study also revealed that majority of the respondents felt that these very challenges had played a major role in slowing down its acceptance. From these statistics, one can deduce that SADC NRENs are actually inclined and taking active initiative towards Cloud implementation.

Figure 8 shows among the targeted respondents who answered this question and (100%) voiced that they deployed Private Cloud model which should not have been the case as they are using the services rendered by google drive, google App, drop box, Gmail and many other services from different CSP.

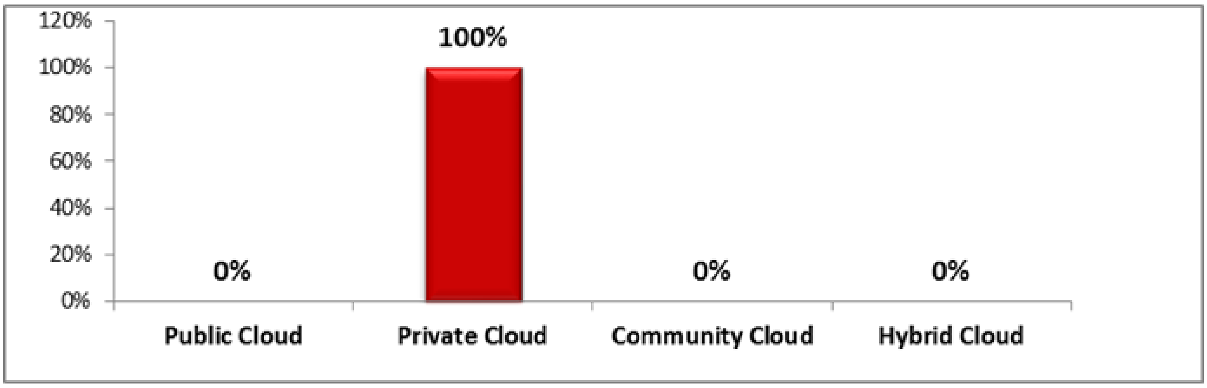

Figure 8. Cloud Models Deployment by NRENs

Figure 9 interprets that among all the targeted respondents, who answered this question, 67% asserted that the reason for their NRENs not being embraced Cloud, was lack of technologies and rest 33% reasoned as strict regulations. Whereas as lack of political will, management support and stakeholders cooperation were voiced at 0%.

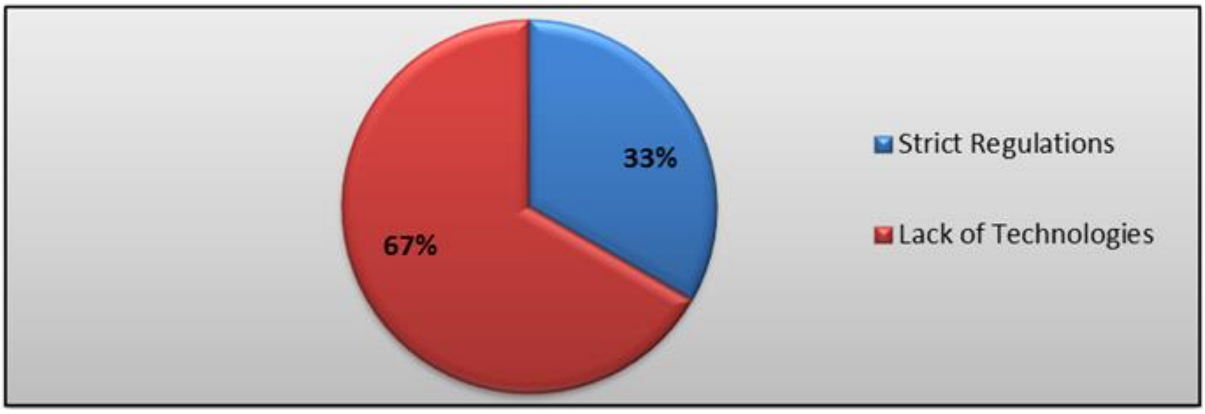

Figure 9. Reasons Why NRENs Have Not Adopted Cloud Computing Technology

Figure 10a shows category 1 which deals with the steps to be taken by NRENs that speed up NRENs adoption to Cloud computing. The figure below displays that the highest priority is given to the step for collaboration with other NRENs to simplify the complexity of the compliance requirements stood at 61%. Both stronger executive and political support for Cloud computing initiatives and establishing or enforce technical standards for Cloud-related technologies stood at 39% and none (0%) for loosen restrictions on customer or employee data crossing borders.

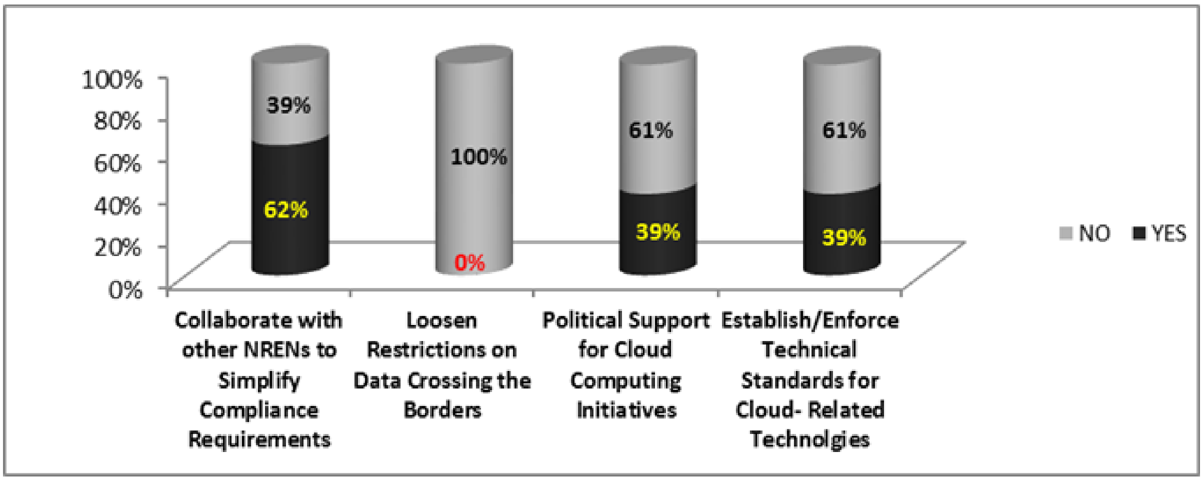

Figure 10a. Steps to be Taken by NRENs to Adopt Cloud Computing

Figure 10b shows category 2 which deals with the factors that would speed up NRENs adoption of Cloud computing. From the figure below, it is evident that factors such as stronger executive support for Cloud computing initiatives, effective governance practices for making decisions on Cloud computing and growing availability of Cloud services from well-known IT vendors and service were all rated at 39%. Furthermore, replacing and interoperating the non-Cloud based IT systems with Cloud-based ones and stronger guarantees or protections in contracts and Service Level Agreements (SLA's) were rated at 46%.

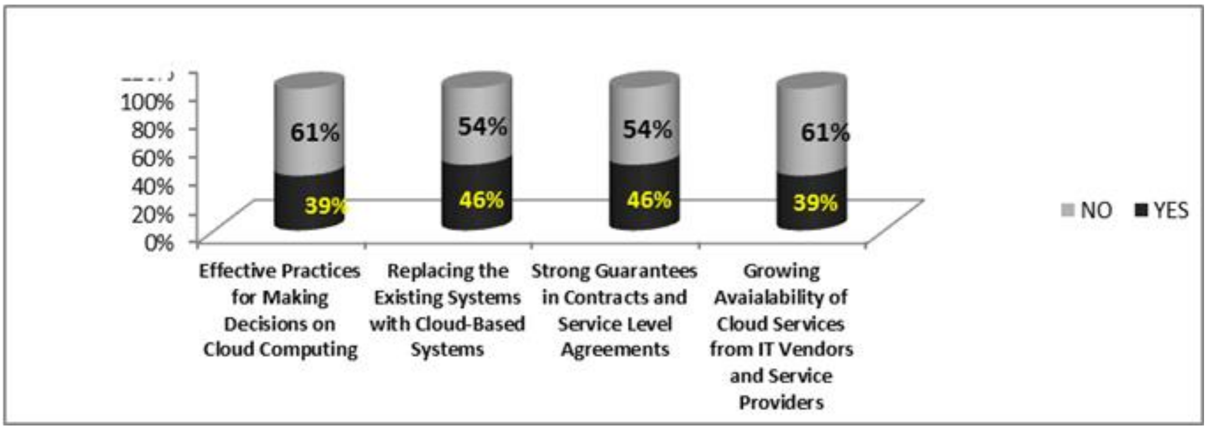

Figure 10b. Factors to be Taken by NRENs to Adopt Cloud Computing

The following discussion is categorized into two sub-categories namely the benefits and purpose of employing Cloud services in NRENs. Each category was posed to the targeted respondents and was asked to rate and the results are depicted as illustrated below:

Figure 11a shows category 1 which is the benefits of Cloud services. About 39% were in favour of providing standardised shared platform for research collaboration, 46% ranked for improving communication and collaboration among other NRENs in SADC and its users and 23% rated for exchanging data more efficiently with outside organization.

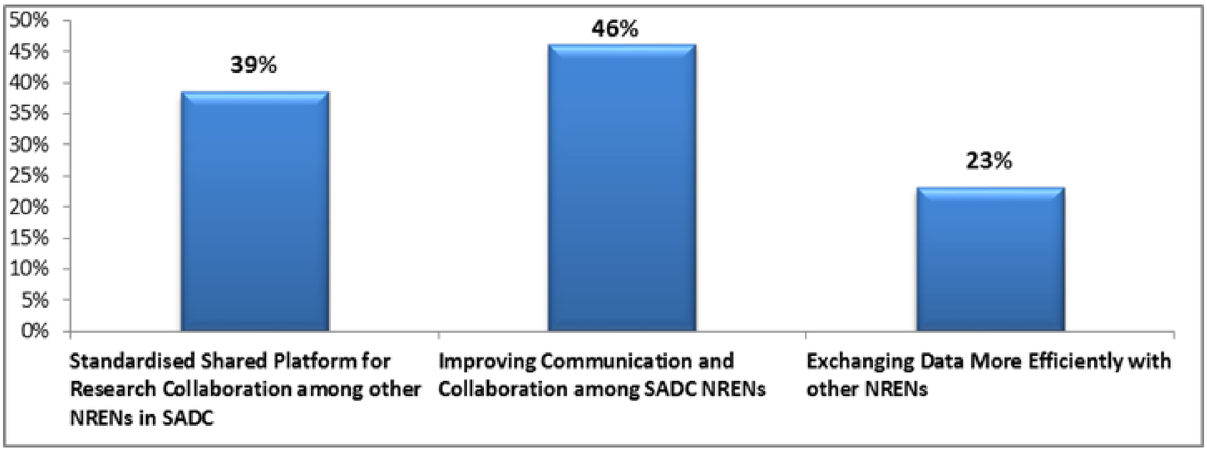

Figure 11a. Benefits of Cloud Services in NRENs

Figure 11b shows category 2 which is the purpose of using Cloud services, 62% indicated that Cloud computing for backing up data, 46% use for processing and storing applications, 69% use for running enterprise applications, 39% use for developing and testing software and 8% claimed they use Cloud computing for other purposes.

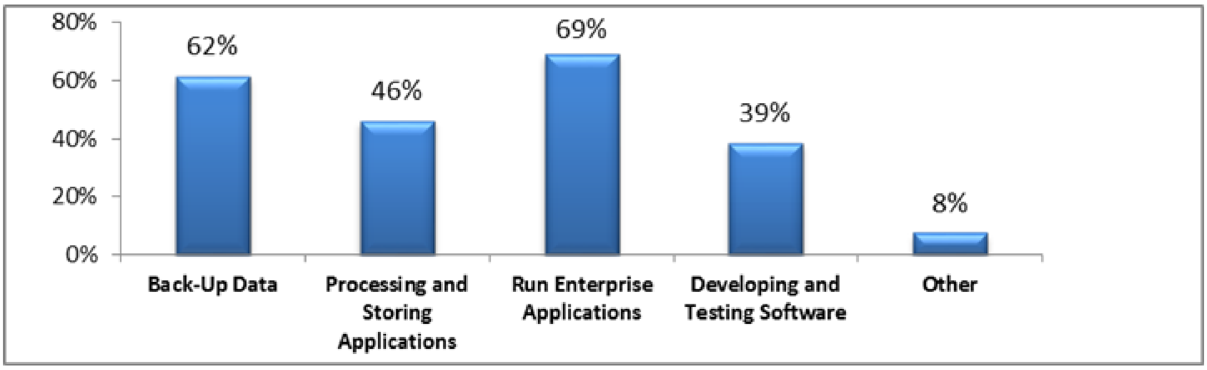

Figure 11b. Purpose of Cloud Services in NRENs

5. Conclusion

This research aims at transforming the existing SADC NRENs traditional IT infrastructure to Cloud infrastructure. In addition it allows creating a common infrastructure to provide all the services through NRENs-CLIF model and ensure interoperability between different NRENs. The conclusion is discussed in relationship to the research questions.

5.1 Research Question One: "What are the resources that can be used to establish institutional Cloud infrastructure in the SADC NRENs?"

From the data analysis discussed earlier, the first research question aimed at identifying the resources that are essential for establishing institutional Cloud infrastructure in the SADC NRENs. The study identified the necessary resources (see Figure 10a and 10b) that directly affect the successful implementation of NREN. These are: minimum threshold level of technological infrastructure, human resources, internet connectivity, security and frameworks. Others are SLA's, political will, funding and economic reasons. Hence the introduction of NREN-CLIF would transform the SADC NRENs from non-Cloud based technology to Cloud based one and further determine the best possible approaches of transforming the current infrastructures into Cloud model.

5.2 Research Question Two: "What Cloud Service Architecture is suitable for interconnection of NRENs in the SADC region?"

The second research question aimed at ascertaining what Cloud architecture was suitable for interconnection of NRENs in the SADC region. In the study (see Figure 3), it was found that some of NRENs used Virtualization in their hosted service environment. This technology is one of the key drivers of Cloud system and therefore these NRENs are in much better position to adopt Cloud computing technology faster. In this light the NREN-CLIF could consider developing a unified platform that was tailor-made to cater for SADC NRENs.

5.3 Research Question Three: "What are the challenges faced by SADC NRENs with regards to establishing institutional Cloud services?"

The third research question aimed at looking at the challenges faced by SADC NRENs with regards to establishing institutional Cloud services. In answering this question, the study identified various challenges such as security, interoperability, policies and so on. There is a need to address these challenges, otherwise this would reduce the willingness of NRENs to embrace Cloud computing technology and hence the reason that they are not becoming member institution of NRENs-CLIF. Therefore, these challenges would be addressed by incorporating components like TCSF, CSM, CCMP and CFS associated with the NRENs-CLIF architecture. The support and facilities provided by NRENs-CLIF would make the transition easier and also increases the NRENs' willingness to embrace it when finally implemented.

References

Katz, R. N., Goldstein, P. J. & Yanosky, R. (2009).'Demystifying cloud computing for higher education', *EDUCAUSE Centre for Applied Research Bulletin*, Issue 19, pp. 1-13

Koukis (2012*), Greek Research Education Network* (GRNET).

Luo, S., Lin, Z., Chen, X., Yang, Z., and Chen, J. (2011). 'Virtualization security for cloud computing service'. In: *Cloud and Service Computing (CSC), International Conference* pp. 174–179. IEEE.

Mbale, J., Kauna, M., & Victor, H. (2013). 'Examining ubiquitous security. Capital issues in implementing a campus-system-as-a-service (CSaaS) model in the cloud computing age: Case study sub-Saharan region.' *International Research Journal of Computer Science and Information Systems (IRJCSIS)*, 2(2), pp.18-24.

Salmon, D. (2009). 'Prospects for a future Janet.' In: *8th International e-VLBI Workshop*, 1p. 48.

Thorsteinsson, G., Page, T., & Niculescu, A. (2010). 'Using virtual reality for developing design communication'. *Journal of Informatics and Control*, 19(2), pp. 93-106.

Van der Pol, R. and Dijkstra, F. (2013). Network and capacity planning in SURFnet http://tnc2009.terena.org/core/getfile582a.pdf?file_id=41

Wind. S (2011). Open source cloud computing management platforms: Introduction, comparison, and recommendations for implementation. In: *Open Systems (ICOS)*, 2011 IEEE Conference on, pp. 175-179. IEEE.