Optimising the Impact of NRENs on Africa's Research.

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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ......................................................................................... v

PART ONE: FOREWORD ....................................................................................... vii

PART TWO: PAPERS (a/z by 1st author) ............................................................... 1

Mobile Gateway for Open Education Resources (OER): A case with University of Swaziland libraries  John Paul ANBU K.1 and Jessie FURVIN 2 ................................................................. 3

Leveraging Inter-Institutional Connectivity to Facilitate Weather Data Transmission from Automatic Weather Stations in Uganda  Maximus BYAMUKAMA1, Mary NSABAGWA2, Julianne SANSA-OTIM2 ................................................................................................................. 9

How ICTs and Collaboration with NRENs are Changing the Face of Higher Education  Deirdre CARABINE ......................................................................................... 17

Low Altitude Remote Sensing and its Application in Precision Agriculture: A Case of Nzathu Farm in Traditional Authority Somba in Blantyre District, Malawi  Donnex CHILONGA1 and Manuel KISWISCH2 ........................................................................................................... 23

Towards parabiotic partnerships for access and discovery: Leveraging access to e-content within the framework of library consortia in Zimbabwe  Collence Tangaingenhamo CHISITA1, Alexander Madanha RUSERO2 ......................................................................................... 35

When is it an African NREN: Building a Vibrant and Sustainable National Research and Education Network in Africa  Benjamin A. ESHUN ........................................................................... 45

EOSC and the Free Riders  Margareth GFRERER1, Solomon MOGUS2 ............................................................................................................... 53

A Collaborative Research Review Platform for Enhancing Project Quality in Universities in Zimbabwe  Tatenda T. GOTORA1, Dr. Sindiso M. NLEYA2 ........................................................................... 63

Responding to the demands of big data scientific instruments through the development of an international software defined exchange point (SDX)  Julio IBARRA1, Jeronimo BEZERRA1, Luis Fernandez LOPEZ1,2, Heidi MORGAN, Donald COX4 ........................................................................... 73

Grid Computing, Compute and Data Storage Services  Jude Iyke NICHOLARS1, Jude NAMUKANGULA1 ........................................................................................................... 87

Securing Campus Wireless LANs  Joan MASAI1 and Maureen WANJA2 ............................................................. 95

Video- Conferencing for Outreach Communication Strategy to Enhance Academic Publishing and Research Communication in Africa  Wilson OKOKA1, Irene Judith NAGASHA2 ........................................................................................................... 101

The research performance and citation impact of Tanzanian scholars: a scientometric study  Raphael Zozimus SANGEDA1 and Edda Tandi LWOGA2 ........................................................................... 109

Design of an Executable Solutions Management Platform based on Virtual Machine Snapshots  Robert SHONIWA1, David FADARALIKI2, Monica CATHERINE S3, Tendai MARENGEREKE4 ........................................................................................................... 129

Improving Quality Education and Research Capacity through Advanced ICT Services: Lessons of NREN Implementation in Sierra Leone  Thomas SONGU1, Anne POWELL2, Boubakar BARRY3, Parminder BRAR4 ........................................................................... 139
Deploying Educational Roaming (eduroam) in a Rural Research Institution in Rakai, Uganda; Challenges and Lessons Learned  Lloyd SSENTONGO 1,2, Rodgers KIMERA 1,2, Ben KAKEETO 1,2, Moses MUBIRU 1,2, Brian K MOYER 1, Matthew ECONOMOU 3, Christopher J WHALEN 1,3, Michael TARTAKOVSKY 3 ................................................................. 151

Knowledge Intermediation Strategies: Novel Evidence from Canada  Namatié TRAORE 3 *, Nabil AMARA 1 ................................................................. 157

A Technical Evaluation of the Performance of Classical Artificial Intelligence (AI) And Methods Based on Computational Intelligence (CI) i.e Supervised Learning, Unsupervised Learning And Ensemble Algorithms In Intrusion Detection Systems  Kudakwashe ZVARESHE 1 Innocent MAPANGA 2 Prudence KADEBU 3 ................................................................. 181

PART THREE: Participant List ................................................................................................................................. 189
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We are also indebted to the Research and Education Network for Uganda (RENU), the host of UbuntuNet-Connect 2016 and all the staff at the organisation for the effort put towards ensuring that the conference was a success. Special mention should go to the CEO, Eng. Isaac Kasana and the technical staff for providing uninterrupted connectivity during the conference. UbuntuNet-Connect 2016 went down in history as the first ever UbuntuNet-Connect that to be streamed live, thanks to the dedication and commitment of the technical staff at RENU.

To the outgoing Board Chairperson of RENU, Prof. Michel Lejeune, Representatives from the European Union (EU) Delegation in Uganda and to the Belgian Ambassador to Uganda, His Excellency Hugo Verbist we also say a big “Thank You” for finding time from your busy schedules to attend UbuntuNet-Connect 2016.

We would be doing great injustice if we would not acknowledge the great role played by our sponsors who contributed in cash and in kind towards the conference. We express our gratitude to the European Commission (EC), The AfricaConnect Project, NetworkTheWorld (NTW), the Network Startup Resource Center (NSRC) SEACOM, the African Partnership for Chronic Disease Research (APCDR), Knowledge Consultng Limited (KCL) Internet Society (ISOC), the Internet Corporation for Assigned Names and Numbers (ICANN), FARO Technical Services, Bandwidth and Cloud Services Group, Soliton Telmec Ltd, the National Information Technology Authority of Uganda (NITA-U), the Uganda Communications Commission (UCC) and SPIDDAFRICA SOLUTION.

Thank You all; Together we succeeded!
PART ONE:
FOREWORD

Universities, institutions of higher learning and research centers all over the world are increasingly becoming under enormous pressure to change the, social and economic statuses of the communities they operate in and even beyond by way of new discoveries inventions and proposed new ways of doing things.

Elsewhere these institutions have taken the lead and have become driving forces of positive change. In Africa, these institutions are trying hard to take this particular role in their societies but are inadvertently being affected by a myriad of challenges to assume this position. One of the challenges is the lack of a united front which can help these institutions negotiate these challenges as a block.

Fortunately, the emergence of National Research and Education Networks (NRENs) on the African continent has provided the continent with a viable solution. Apart from proving universities, institutions of higher learning and research centers with affordable Internet connectivity, NRENs have the enviable position to influence and impact positively on research that is being carried out on the continent.

The theme for UbuntuNet-Connect 2016, “Optimising the Impact of NRENs on Africa’s Research,” sought to expound the several ways available in which Research and Education Networks can effectively contribute to ground breaking research.

From the papers that were presented at this conference to the dialogue that this theme initiated, it is apparent that our research and education institutions continue to work in silos thereby missing out of the benefit of the collective effort that can be brought forth by working with the NREN. In some cases, some of these institutions are hardly aware of the existence of the NREN in their countries.

From the conference, we also noted that there is a need for research institutions on the continent to come up with metrics that can help trace the scale at which the continent is doing research so that we are aware of the amount of contribution NRENs can make in scaling the same.

Lastly, we would like to thank all stakeholders and partners that contributed in one way or the other, to the success of the conference. As you will be reading, quoting and citing and sharing the proceedings, our focus has now shifted to Addis Ababa, Ethiopia, the venue for UbuntuNet-Connect 2017.

Dr. Pascal Andoh Hoba,
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PART TWO:
PAPERS (a/z by 1st author)
Mobile Gateway for Open Education Resources (OER): A case with University of Swaziland libraries

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Abstract

Open educational resources (OER) are free and openly licensed educational materials that can be used for teaching, learning, research, and other purposes. Around the globe there are a number of initiatives which are being experimented in the development of OER. This paper is a case study of the development of a gateway application for the OER material to enhance the teaching and research capability of the University of Swaziland. The development of the desktop OER gateway and the conversion of such a gateway into mobile application gateway are discussed in this paper.

Keywords: Open Educational Resources, OER; mobile application; Open Education, OER

Mobile gateway

1. Introduction

Open Education resources are described as educational resources which are available freely for research and education to be used and reused for the development of education by the wider educational community. William and Flora Hewlett Foundation defines OER as "teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge." (The William and Flora Hewlett Foundation, n.d.) Globally there are a number of initiatives to maximize the usage of these resources. UNESCO is the frontrunner in consolidating most of these initiatives. UNESCO announces that “universal access to high quality education is key to the building of peace, sustainable social and economic development, and intercultural dialogue. OER provide a strategic opportunity to improve the quality of education as well as facilitate policy dialogue, knowledge sharing and capacity building” (UNESCO, n.d.). In 2001 Massachusetts Institute of Technology (MIT) released all its courses on the internet for free access; since then there are a number of high quality educational resources that are made freely available in the internet (Blackall, 2008).

2. Open Access – the Genesis

The genesis of Open Access to Educational Resources can be attributed to the maturity of the Open Source movement which started in the early 80s mainly to counter the closed and proprietary software and operating systems environment. It gained its momentum and spread
its wings into a number of fields which had felt the monopoly of specific groups of people who made knowledge resources as money minting activities. In scholarly publication there was a great monopoly which restricted users to access quality scientific information mainly because of the monopoly of proprietary scholarly literature. These monopolies made sure that the journals were sold at very high price which only wealthier institutions could afford to buy. Thus an artificial digital divide was created among the haves and have-nots. The open education movement addressed this fundamental issue to curb this anomaly and to bring back education to the masses which resulted in the birth of Open Access movement. The Open Educational Resources are the offshoot of the Open Access movement which aims to provide open access to quality educational resources.

Keeping the anomaly of closed access to quality educational resources as the main agenda the Budapest Open Access Initiative (2002) (BOAI) in February 2002 highlighted the need to remove the barriers to educational resources and make it available free and open for all the people in the world. The BOAI particularly invited “governments, universities, libraries, journal editors, publishers, foundations, learned societies, professional associations, and individual scholars who share our vision to join us in the task of removing the barriers to open access and building a future in which research and education in every part of the world are that much more free to flourish”.

The following are some of the main players who endorsed the Open Access for further improving the access to educational resources.

- February 2002 -- Budapest Open Access Initiative
- June 20, 2003 -- Bethesda Statement on Open Access Publishing,  
  [http://legacy.earlham.edu/~peters/fos/bethesda.htm](http://legacy.earlham.edu/~peters/fos/bethesda.htm)
- October 22, 2003 -- Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities,  
- December 12, 2003 -- UN World Summit on the Information Society Declaration of Principles and Plan of Action,  
  [http://www.itu.int - Document 1](http://www.itu.int - Document 1)
- January 30, 2004 -- Organisation for Economic Co-operation and Development (OECD) Declaration on Access to Research Data From Public Funding,  
- February 24, 2004 -- The International Federation of Library Associations and Institutions (IFLA) released the IFLA Statement on Open Access to Scholarly Literature and Research Documentation,  
  [https://www.ifla.org/publications/ifla-statement-on-open-access-to-scholarly-literature-and-research-documentation](https://www.ifla.org/publications/ifla-statement-on-open-access-to-scholarly-literature-and-research-documentation)
- September 23, 2005 -- Salvador Declaration: Commitment to Equity,  

### 2.1 Open Education

From Open Access to educational resources a new concept called Open Education evolved. Open education is defined as:

“Open education is about sharing, reducing barriers and increasing access in education. It includes free and open access to platforms, tools and resources in education (such as learning
materials, course materials, videos of lectures, assessment tools, research, study groups, textbooks, etc.). Open education seeks to create a world in which the desire to learn is fully met by the opportunity to do so, where everyone, everywhere is able to access affordable, educationally and culturally appropriate opportunities to gain whatever knowledge or training they desire.” (What is Open Education, n.d.).

This noble global phenomena caught up with the imagination of the entire world and many countries started embracing the concept of Open Education as the way forward to make the society more meaningful especially if it has to be made well educated. Africa joined the bandwagon in September 2007 with its Cape Town declaration on Open Education. The crux of the declaration reads as

“We are on the cusp of a global revolution in teaching and learning. Educators worldwide are developing a vast pool of educational resources on the Internet, open and free for all to use. These educators are creating a world where each and every person on earth can access and contribute to the sum of all human knowledge....... It is built on the belief that everyone should have the freedom to use, customize, improve and redistribute educational resources without constraint. Educators, learners and others who share this belief are gathering together as part of a worldwide effort to make education both more accessible and more effective…..” (Cape Town Open Education Declaration, n.d.)

2.2 Open Educational Resources

Taking cue from the concept of Open Education many illustrious thinkers, scientists, educators and teachers started developing material which are called Open Educational Resources (OER). OERs are defined as “Digitized materials offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research” Contrary to the misunderstanding that OER is sub-standard educational material they are high-quality, free and open educational materials that offer opportunities for people anywhere in the world to share, use and reuse. Open Educational Resources (OER) are built on two convictions: that "knowledge is a public good" and that "the internet is a good way of sharing knowledge." (Open Educational Resources, 2015)

Walz, (2015) asserts that Open Educational Resources (OER) have saved students millions of dollars in textbook costs and greatly expanded access to a wide variety of educational materials for countless numbers of students and life-long learners. OER have also saved teachers time and effort by allowing them to reuse, modify, and build on materials developed by other teachers. The beauty of OER resources is the ability and flexibility built around it to reuse, modify and build on it to recreate new resources. The success of OER is mainly attributed to this great freedom which comes with Open Education.

3. OER and University of Swaziland a case study

University of Swaziland (UNISWA) was developed from the University of Botswana, Lesotho and Swaziland (UBLS) which had its headquarters in Lesotho between 1964 and 1975. First operated from 1975 as University College it gained university status in 1982. With 7 faculties and one institute of distance education which spans three sprawling campuses, UNISWA is the foremost institution of higher education in Swaziland. The total student enrolment in 2015 stands at 6305 and a teaching staff complement of 271 (University of Swaziland, 2015). In the year 2013 the Institute of Distance Education decided to introduced blended learning and encouraged the staff members to augment their courses with the creation of electronic learning support tools. In order to create a multimedia learning environment, the staff members were encouraged to use Open Educational Resources.
3.1 OER Usage and Challenges

With a number of initiatives in OER being practiced around the globe, the biggest challenge for the staff members to use the OER material is to identify the right resource for the right learning activity. In order to ease the access problems, the university library was approached to provide resource audit assistance to the staff members with special emphasis on OER. While providing user education on Open Educational Resources, it was evident that the staff are not able to use them properly because of their limited exposure to the resources and also because of the rapidity with which new resources arrive in the global OER scene. It was a big challenge to provide access to these resources through formal presentations since the availability and existence of these resources became numerous and varied in platforms.

3.2 OER Desktop Gateway

In order to streamline access to these resources, the University of Swaziland Library developed an Open Educational Resource Gateway. This gateway is available at http://www.library.uniswa.sz/oer. Figure 1 is a screen capture of the OER Gateway at the University of Swaziland library website.

![Desktop OER Gateway](image)

Figure 1. Desktop OER Gateway

The development of OER Gateway allowed the lecturers to freely use content from OER repositories and sources especially multimedia and images. The focus of the gateway is to provide a one-stop entry into the world of Open Educational Resources. An elaborate resource audit was conducted by analysing each and every OER and a comprehensive website was developed after months of research. The gateway was established with links to various repositories and OER projects around the globe. The OER Gateway provided an easy faceted menu based links to: Repositories
Courseware
Reference
Multimedia
and other OER Resources

4. OER Mobile Gateway

After months of using the desktop OER gateway it was felt that there were a number of limitations. First and foremost the mobility of the gateway was severely hampered, especially if the lecturers wanted to use the resources in the classroom situation and, if they wanted to use it along with the students, it was not possible since the interface is desktop. Time-critical mobile-specific features like push notices or location-based services could not be activated through desktop gateway. Looking at the limitations of a desktop gateway, this gateway was further developed into a mobile-based gateway application with push notices and location-based alert services and linking to real-time social network based OER network. The vision of this project is to further enhance into a mobile portal for OER. Currently the mobile app is in its testing stage. Figure 2 is a screen capture of the OER Mobile application.

Figure 2. OER Mobile Gateway

4.1 Advantages of Mobile OER Gateway:
The following are some of the major advantages of the mobile OER Gateway

- Push Notification as and when a new resource is added
- Connected to OER groups through Social Networking
- OER News updated periodically
- Location-based resource service
- All the mobile-compliant resources are identified and tagged
4.2 Challenges in the Mobile OER Gateway

The major challenge we face in the OER Gateway is the continuous updating of links and resources. While it was a desktop interface it was easy to update the links as and when it is updated or new links are found. With mobile Gateway each time an update is done it has to be compiled and resubmitted to the app store for re-download by the users. Another major challenge is the research on new and upcoming resources which keeps the developer very busy. The current application and the push notices are not based on any Selective Dissemination of Information type of an alert system. Such an exhaustive system requires a service of a portal which seems to be the future of this project.

5. Conclusion

Open Educational Resources are a big boon to the Social development and the sustainable development of any country since it augments the creation and development of human capital. Providing proper support to the creation of these resources, especially by creating appropriate support tools to enhance the usage of these resources, will result in better utilization of the resources and at the same time will improve the process of creating more resources. With Open Educational Resources it is not only about the free and open usage, it also provides a platform for collaboration. Creating support tools especially using mobile platforms will result in better utilization of these resources even when the users are on the go. This pilot project is an example of how support tools can enhance the resources for better utilization.

References


Leveraging Inter-Institutional Connectivity to Facilitate Weather Data Transmission from Automatic Weather Stations in Uganda

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Abstract

The use of Automatic Weather Stations (AWS) for Environment monitoring by the Uganda National Meteorological Authority has increased massively over the past 15 years. This increase is mainly due to the savings in time, energy and money that are usually accompanied by the use of Information Technology to replace manual organizational processes. These stations collect various weather data and automatically transmit this data to a central repository, usually a physical server in a relatively remote location. The transmission of this data, in Uganda, is achieved primary by GSM/GPRS over the backbone of one of the national service provider. While GPRS speeds are probably sufficient for the small amounts of data from these AWS, the consequence of this is a regular cost to the authority, not only in financial terms but also poor connectivity in remote areas, downtime and high power consumption.

Since universities in Uganda are spread across the country with considerable spatial separation, it is possible that the UNMA (Uganda National Meteorological Authority) could place a number of AWSs at these campuses and still cover many climatological zones and, equally importantly, benefit from transmitting the AWS data through the networks at these universities that have been set-up by the national NREN, RENU. Because this data volume is very low, the cost of such transmission would be almost zero and other advantages would be manifested, such as the very limited involvement in communication channel maintenance and a higher availability of power.

In this paper, we investigate the practical consequences that leveraging inter-institutional NREN connectivity would bring to a government authority like UNMA. We analyze the impact that this would have on the cost, operation and reliability of the whole AWS.

Keywords: Automatic Weather Station, NRENs, Weather, Gateway, Wireless
1. Introduction
1.1 Structure of an Automatic Weather Stations
In general, an AWS consists of several sensors, a central processing unit, a power source and a communication device. Figure 1 shows one possible set-up. The sensors measure various environmental parameters such as wind, temperature, solar insolation, humidity, wind speed, wind direction and others. The data from these sensors is read by the central processing unit and stored locally or transmitted to a remote location. The pair of the CPU and communication device is typically called the gateway. The communication device (sometimes called the uplink in this paper) enables radio telemetry and is responsible for transmitting data central repository, usually over the internet to server computer.

![Figure 1: Schematic of an Automatic Weather Station](image)

1.2 The State of Environment monitoring in Uganda
Automatic Weather stations in Uganda are run by several organizations. The mandate of weather data collection and dissemination for public use lies solely on UNMA. However, there are several other private organizations that man their own AWS, such as NARO (National Agricultural Research Organization).

Within the UNMA, AWS are characterized by poor lifetime usually due to vandalism, which is common in many developing countries (Rogers & Tsikunov, 2013) (Moura & de Rezende, 2008) (Japan Meteorological Agency), lack of maintenance due to insufficient funds or ignorance of the mode of operation and lack of skilled manpower to manage them. Of 37 stations installed as per October 2014, 6 stations were affected by various power and communication issues and 5 stations had been vandalized with the intention of stealing the solar panel (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016).

2. Problem Statement and Motivation
Automatic Weather Station data needs to reach the remote destination server promptly at the smallest possible cost. The current costs of GPRS connectivity are not regularly covered by UNMA due to the constant cost and the administrative procedures involved obtaining these funds. Further, cellular networks are very unreliable especially for 2G connectivity, which most AWS use. They suffer connection breakages and downtime.

Secondly, the gateway is the single most power hungry device in the whole AWS and this is majorly because of the uplink device. In our previous work, we have analysed the availability of a Raspberry Pi gateway connected to 12V battery sources and cellular connectivity. We
obtained a downtime of almost 12 hours every day due to lack of sufficient power at night. compared to powering it from the grid in which downtime less than a few minutes each day.

As such, remote measurement and communication reliability is an issue because of cost, downtime and power. The motivation for this work therefore comes from the need to re-engineer how these AWS can send out data packets to the remote destination effectively.

3. Collaborators and Funding

This work is being carried out under the WIMEA-ICT project, a beneficiary of funding from the Norwegian Agency for Development Cooperation (NORAD) under its NORHED (Norwegian Programme for Capacity Development in Higher Education and Research for Development) programme to enhance research capacity in institutions of higher learning in East Africa (Sciences, 2016).

WIMEA-ICT is being implemented by four academic institutions namely Makerere University (MAK), Dar es Salaam Institute of Technology (DIT), University of Bergen (UiB) and the University of Juba (UoJ), in collaboration with their respective National Meteorological services, and is aiming to improve weather information management through the use of suitable ICTs. The project intends to set up seventy (70) Automatic Weather Stations (AWS) in the three partner African countries. Of the 70 AWS, Uganda and Tanzania shall each receive 30 while South Sudan shall receive 10. Between October 2014 and January 2015, Uganda had 37 weather stations directly under UNMA (Uganda National Meteorological Authority) (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016). The project shall therefore contribute about 45% of the total number of weather stations.

While UNMA has the mandate to densify the network of AWSs in Uganda, one of the expected outcomes of the WIMEA-ICT project is to assist UNMA achieve that goal.

4. Related Work

The only similar work we found was from the WACREN proceedings in 2016 in which Pehrson, (2016), discusses the possible contributions of RENs in environment monitoring in Africa. It is mentioned that RENs can facilitate the deployment of access points to which remote wireless sensor network gateways can connect.

5. Methodology

5.1 Deployment strategy

In the deployment of AWS, several issues must be put into consideration to locate the ideal point of installation. We have devised a technique that involves a scientific approach of finding the intersection location at which several constraints are fulfilled (Nsabagwa, Byamukama, Sansa-Otim, & Okou, 2016). These are

- the climatological zones – geographical expanses of land that demarcate areas of similar weather patterns
- Internet availability
- Land ownership policies
- Security
- Power availability

In our analysis, we discovered that deploying AWS on university premises solved almost all of the constraints mentioned. In particular, the following were identified.
First, universities and other educational and research institutions usually have more reliable internet connectivity than their surroundings. In Uganda, this is especially so because most universities are connected to the network provided by the RENU.

Secondly, university land is usually managed by a single stakeholder—either government (for public institutions) or individual entities (for private institutions). As such, land ownership policies and the administrative process to acquire permission to install these devices are more straightforward.

Thirdly, these institutions have more intellectually cultivated mindsets. There is thus a lower probability of vandalism and security will be largely higher than the surroundings.

In addition, the availability of power is also a major requirement for any university to operate. This is one of the constraints whose achievement solves major obstacles in data transmission.

The issue that remains thus is that of climatological zones. For the analysis to be complete, we needed to compare the climatological zones and the locations of various universities.

Figure 2 shows the various climatological zones in Uganda and Fig. 3 shows the penetration of the RENU network and indicates that there is penetration of RENU in a number of climate zones in Uganda.

Fig. 4 shows the approximate location of various universities in Uganda. Coupled with the fact that RENU is the largest internet service provider to universities in Uganda, we concluded that the deployment technique of AWS at academic and research institutions in Uganda would represent the majority of the climate zones and thus have balanced distribution of these AWS.
Figure 4: University locations in Uganda

5.2 Cost Analysis

We now proceed to analyze the extra cost of establishing such a network, compared to the current cost. To analyze this, little or no fore knowledge of the current cost is necessary. The cost of running an AWS involves the initial cost of deployment, which applies for all cases, and the added cost of data transmission, and regular maintenance. The last cost is also independent of any other factors.

The cost of data transmission using a university network would be close to zero. This is because, compared to the university internet traffic, it is very small. As a reference, we take a sample station deployed at Makerere University. This is a weather station, designed by WIMEA-ICT from scratch. The data received by the CPU to send over the uplink is about 1000 bytes/minute. This amounts to 58kB each hour. In comparison, a typical university will pass through traffic of several hundred gigabytes of data each hour. There is no other immediate cost that we could identify in this set-up.

There are many benefits though that we identified, such as a higher probability of data reaching the destination, the possibility of Real-time data, the availability of reliable back-up at local university servers, the possibility of opening the data up to several mirrors, on-site power and a smaller probability of vandalism.

5.3 Network Architecture

The network architecture for an AWS benefitting from a RENU network would not be complicated. The first constraint that needs to be overcome is the last-mile solution—how the CPU gets the data to the university servers. We have experimented with WiFi and Ethernet at Makerere University and all have shown good reliability. WiFi may be necessary when the power connection point is far away from the Ethernet connection point. The extra reliability obtained from using optical fibre for the last mile is not sufficient to justify the cost of the civil works and other requirements such as technical network deployment labour. Once the connection is established, the next question is on the technique to access the data. There are two options: the data can remain on the local storage on the gateway CPU and accessed from there over TCP/IP or the data can be sent to local storage on the server. The latter option may be more optimal when speed of access of data from multiple clients is paramount. Lastly, the issue of centralization of data from multiple stations will be important for managers of AWS networks. There are many solutions to this. One rudimentary solution is to implement a
dedicated application that runs on one server at one institution that pulls data from the servers of other institutions regularly. If only the new data is requested, the data traffic will still be negligible.

Figure 5: AWS network architecture

6. Conclusion and Recommendations

In conclusion, it is clear that using existing networks managed by NRENs can greatly reduce the cost that meteorological authorities incur in keeping their automatic weather stations online, along with several other benefits.

Because the joining the NREN network is a very affordable option for the educational and other research institutions, NRENs like RENU can include contractual closes that mandate the universities to support research that needs very little bandwidth. It is a very small cost to the institutions but a very large saving for meteorological and research institutions.

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How ICTs and Collaboration with NRENs are Changing the Face of Higher Education

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Abstract
This paper presents a sustained argument for the university of today, and its academic and research staff, to make the best use of the facilities afforded by RENs to ensure that ICTs become the foundation for academic networking and collaboration. The paper examines the role of the REN and its changing goals, the challenges faced when using out-dated teaching methodologies in the classroom, and the role that RENs can play in networking or peering individuals, research communities, and institutions. I also make the case for a closer relationship between academic staff and their REN so that peering can become a seamless way to bring a nation’s teaching and research staff, and their institutions, together to bring universities fully into the technological world of the twenty-first century.

Keywords: ICTs in Higher Education, Academic Practices, Peering, Networking and Collaboration, RENs

1. Introduction
“Research and education networks (RENs) have been designed to meet the needs of some of the most demanding internet users in the country: scientists, academics and researchers in the nation's leading academic institutions. These networks are engineered to support high-quality services that remain consistent regardless of the number of users on the network.” (DiMaria, 2016).

This paper is concerned with the benefits of education institutions using ICTs maximally through their NRENs so that higher education in Africa can experience the transformation necessary to bring it into the twentieth-first century. Chiefly I want to explore the area of networking, and will be using the analogy of “peering” to bring out the benefits of networking and collaboration through RENs. I want to be clear from the outset that I am talking from the perspective of the end user, the academic who not only uses the commodity Internet, but is also a strong supporter of our local REN and is keen to see it play an expanded role in the education sector.

In this networked world where we are now seeing the growth of the Internet of People and Li-fi, the lonely academic in his / her ivory tower is a thing of the past. Networking, or “academic peering” is as inevitable as using a computer even though many academics still resist it. My central point here is that we ought to embrace it because academic peering can have numerous benefits: it can save human-power hours and cut costs, it can enhance content quality, it can expand audiences and bring the very best content to more students, and it can promote the development of critical minds that are creative and can think outside the traditional box. In other words, academic peering can promote the provision of education that is fit for today's purpose. And while this can start with individual academic staff or even a few institutions
coming together, in thinking the big picture, it can be achievable nationally and regionally by using our RENs to network institutions cheaply and efficiently.

The importance of RENs for academic research and teaching is indisputable. According to Tusubira (2011), RENs not only provide “dedicated high speed networks that enable access to online resources for students and researchers”, but also “support content-level collaboration in research and education.” “Support content-level collaboration”: this is precisely where we need to start our reflections. This shifts the burden of responsibility from the provider and enabler, the REN, to the end users who are the content creators, the academics and researchers. And this is, of course, fair. But as the old adages goes: horses can be brought to water but cannot be made to drink.

Listen to Rob Vietzke (vice president of network services at Internet2 in the US): “RENs typically comprise a group of engineers and entrepreneurs who helped build the network capability because it is additive. We are not marketing people and we're certainly not profit-driven people, so sometimes we miss the opportunities to market the great services that we're doing” (DiMaria: 2016). I am sure most of the REN people here will agree; this is where university networking comes in to play. RENs are the “enablers” in the sense that they are the backbone supporting our teaching and research efforts. We have come a long way since books and learning and research resources were stored in libraries, and RENs had no role. With the diversification and democratization of knowledge and learning materials, a country's teaching and research institutions now need their RENs to do what they are formed to do, that is: to be very specialised service providers that support research and education activities. And if RENs are truly to be enablers of research, this means that significant changes have to be implemented at the grassroots university level. My point? Enabling research networks achieve their self-imposed goals cannot be done solely by the REN.

2. The Challenges of Academic Practices in Institutions

Even with the best will in the world, there is a fundamental barrier in terms of transforming higher education, whether maximizing the use of RENs or not: our traditional academic practices. The presence of computers on campus, no matter how many, is not an indicator that the university and its community are ICT savvy: the hardware is simply a means to an end – because computers are about people when all is said and done. It is the Internet and the numerous apps and various software that are used to enhance the student learning process that are important. Throughout the region – with notably few exceptions – academic work practices appear to have remained more or less static over the past thirty years, and have remained largely unaffected by recent advances in ICTs. And while many academics have embraced Power Point Presentations and libraries have online catalogues and a growing number of e-books, few academics have moved beyond the “chalk ’n talk” methodology of teaching and simply use the PowerPoint presentation as a dust-free means to read notes in the classroom.¹

Given this framework of academic practice, creating challenging, learner-friendly, contextualized (given the fact that knowledge transfer remains largely a North to South process), and stimulating learning resources that are based on solid research is a huge challenge in the East Africa region. Despite the fact that the majority of new and emerging technologies are easy to use, the academic mind-set seems unable to embrace these and integrate them into teaching methodologies. While there is a number of reasons why many academic staff are stuck in the past (financial remuneration being perhaps the most important), other constraints play

¹ For a comprehensive survey of PPPs (and its criticisms) see Craig, Russell J. and Amernic, Joel H. (2006) ‘PowerPoint Presentation Technology and the Dynamics of Teaching’ Innovative Higher Education. 31 (3). http://www.springerlink.com/content/d07282073378x00l/ [accessed 24 October 2016].
their part in maintaining the traditional status quo. In the past, the lack of up-to-date academic resources left lecturers to rely on their own class notes and the meagre holdings in the university library. Today, yellowing notes are sometimes updated with some content downloaded from the Internet, but the Internet is a big, scary place, and the academic is used to his/her traditional comfort zones.

The good news is that we are being forced to change because student expectations and learning practices have changed. The serious-minded student will often explore a topic widely on Google and obtain good up-to-date resources. Scholars need to engage with that and begin exploring for themselves. In trawling the Internet for up-to-date information, academic staff can compile learning resources that are a mixture of their own notes, videos from the YouTube education channel, podcasts from universities world-wide, lectures online, and integrate these with discussions and interactive debates.

The world's foremost intellects in the university world have numerous videoed lectures uploaded to the Internet; we can easily use these to stimulate and broaden our students' learning experiences. We can listen to Amartya Sen on peace-building, Richard Branson on entrepreneurship, Stephen Hawking on the future of robotics, Amina Mama on feminism … all these are much more interesting than listening to one lecturer three times a week for a full semester. It simply takes a little creativity. But let me widen the net (so to speak): what about co-teaching? I teach in situ while my colleague's class can see the lecture while at a different location and then the next week we swap places. One course, two teachers, interested students, and more importantly, increased inter-university student interaction. This is the individual academic peering that is made possible through our RENs.

3. The Role of RENs and Peering

And the wonderful thing is that while this requires co-operation, none of it requires donor finance, much in the same way that we do not need a loan from the IMF to dig a vegetable garden! Individual academic peering and inter-university peering can, in my view, yield exponential results. And it is precisely because most African countries are resource constrained that we need to forge smaller, non-donor funded research and teaching communities and research groups. But these need not be local or even regional. Let us think the big picture: they can be global. Gone are the days when the department budget had to look for sufficient funds for guest lecturers from other universities: today, this is easily achieved with all parties in their own location using the video-conferencing facilities provided by our RENs.

I believe that peering in the research/academic world not only has intellectual but also (and this is increasingly important in today's world) economic benefits in many and various ways. My main point is that while the engineers work behind the scenes to provide the academic research world with better facilities and tools, the end users cannot now be passive receivers: the enablers need input from content providers. In order for a REN to be truly successful, the nuts and bolts parts, the backbone, must be enfleshed by local researchers and educators who realise the benefits of peering, of networking, or simply, of sharing knowledge.

In the pre-Internet pre-REN days, the knowledge and skills I gained were built upon the shoulders of those who have gone before me and those who laboriously published and disseminated their work. In this age, the knowledge I gain is not confined to the books I find in a library; the knowledge I have at my fingertips on my phone is truly vast and is constantly being generated and disseminated in the blink of an eye. For pen to print used to take up to a year; today I can publish online as the thoughts are formed in my head. Makerere lectures can be heard in Dar-es-salaam in real time; MIT gurus are on YouTube even before the whiteboard has been wiped clean!
The mind-boggling growth of ICTs, and the changing face of education that is concomitant with this growth makes academic peering even more important than in previous decades. But despite the uptake of ICTs in the higher education sector, and despite the earnest desire on the part of many vice chancellors and deans to create vibrant research communities and utilize their REN to the maximum, a fair number of academic staff needs to be coaxed on to the playing field. Way back in 2011 Louis Fox wrote: “a major challenge confronting African nations today is how to ensure that all colleges and universities, including those that have not traditionally benefited from expensive research infrastructure, can participate seamlessly in national and multinational e-science efforts that are cyber-infrastructure-enabled. The challenge begins with the need for ubiquitous deployment of advanced research and education networks.” (Fox: 2011) While it is indeed satisfying to be moving in the direction of advanced networks on the continent, we note that the game has more players now: engineers and academic staff and researchers!

As our local REN, puts it in their just-published newsletter outlining their development, growth, and future plans: “The third level envisaged is where transformation mostly happens and we shall refer to it as the level of deeper sharing of resources. The resources to be shared include: highly skilled human resource (such as academic staff, researchers and other specialists); high value research facilities (such as expensive lab equipment, high performance computer (HPC) facilities, massive research data); jointly utilised education content hosted by shared repositories which then facilitate multiple colleges collaborating to offer new or widely needed special programmes and regionally or globally distributed collaborating research teams.” (RENU: 2016) Breaking the barriers that prevent us from collaborating and sharing in academic teams may not be easy – at my university we have been trying with some limited success, but we shall keep on looking for ways to network and work together to change the face of higher education. Our RENs have done a wonderful job in enabling university peering. The future will be a joint initiative.

References


Biography

Irish academic and philosopher Deirdre Carabine has lived and taught in Uganda for twenty-three years. She has recently been founder Vice-Chancellor at the Virtual University of Uganda (VUU), the first fully online-only postgraduate university in Sub-Saharan Africa (founded 2011). Prior to that she set up International Health Sciences University in Kampala. She began her Africa adventure at the Uganda Martyrs University in 1993. Currently, she is Director of Programmes at the young VUU and, in that role, she is fully responsible for the university's Virtual Learning Environment. She is passionate about the use of ICTs for education and is a strong supporter of RENU.
Low Altitude Remote Sensing and its Application in Precision Agriculture: A Case of Nzathu Farm in Traditional Authority Somba in Blantyre District, Malawi

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Abstract

The practical application of Low Altitude Remote Sensing (LARS) in Precision Agriculture (PA) has tremendously gained ground recently. This is despite concerns about the viability of such systems for farmers related to the costs of both the system and the image processing software, technical expertise to operate the LARS and processing of the imagery itself, and timely delivery of information which is greatly compromised by not only the unstable and expensive internet facility but also local weather conditions such as wind and clouds. Using image analysis, this study illustrates the utilization of self-build unmanned aerial vehicle (UAV) in monitoring crop conditions in farmers’ fields in the area of Traditional Authority Somba in Blantyre district of Southern Malawi. It demonstrates that both optical and near-infrared imageries obtained from LARS can be used to monitor fertilizer trials, conduct crop investigation and mapping of field surface drainage.

Keywords: Low Altitude Remote Sensing, Unmanned Aerial Vehicle (UAV), Global Positioning System (GPS), Geographic Information Systems (GIS), Precision Agriculture, Soil fertility, Maize, Crop Monitoring, Somba, Blantyre, Malawi

1. Introduction

The practical application of Low Altitude Remote Sensing (LARS) technologies in Precision Agriculture (PA) has tremendously gained grounds recently. Considering the quest to match agricultural practice with crop and soil conditions, PA technologies are considered as one major direction in modern agriculture development. Among the myriad benefits of PA include increased crop yield and efficiency achieved by lowering the costs associated with fertilizer, pesticides, herbicides, and fungicides (i.e. apply only what is needed, and at the required location and time). Socio-economically, PA is beneficial since it reduces the transport of agriculture inputs on the air, soil and water (Zhang & Kovacs, 2012). Environmentally, PA minimizes over-application of inputs hence reduces the risk of pesticide and fertilizer runoff or leaching into environmentally sensitive areas such as water.

Presently, there is substantial progress in using Variable Rate Technologies (VRT) and Global Positioning Systems (GPS) to reduce the application of fertilizer, insecticides and fungicides.
Nevertheless, obtaining up-to-date data for crop and soil conditions (e.g., nutrient deficiency, water stress, pests, disease) for VRT remains a challenge (Flowers, Weisz, & White, 2005). Historically, zonal maps for VRT machines have for so long been created by applying yield maps from yield monitors (Diker, Heermann & Bordahl, 2004). However, these maps are considered unreliable and limited. This is because they are generally acquired once a year and often display a huge variation when observed (Blackmore, Godwin & Fountas, 2003). Moreover, these types of yield maps are only available after the season, and many harvesters are still not equipped with yield monitors.

Currently, the alternative to the scenario above is the utilization of remotely sensed imagery acquired during the growing season. Apart from deriving yield maps from them, such imagery could as well be used to extract timely information about crop condition for management purposes (Yang, Everitt, Qian, Luo & Chanussor, 2013). Specifically, information about soil and crop condition can be obtained from high spatial resolution satellite imagery. For example, in their study on Optimal geometric configuration and algorithms for LAI indirect estimates under row canopies of vineyards, Lopez-Lozano, Baret, de Cortazar-Atauri, Bertrand & Casterad (2009) successfully applied a variety of satellite data, including data from IKONOS, QuickBird, GeoEye-1 and WorldView-2 in crop yield predictions. However, weather conditions coupled with the satellites’ poor spatial and temporal resolution (i.e. highest spatial resolution for commercial satellite data e.g. WorldView-2 and GeoEye-1 is approximately 50 cm for the panchromatic band) restrict the image’s availability for these sensors. While the spatial resolution might be quite good, the limited spectral resolution of the panchromatic band might not be adequate to examine within-field variations of crop condition and yield (Zhang & Kovacs, 2012).

This therefore makes the utilization of airborne multispectral and hyperspectral sensors eminent for monitoring crop condition and yield. These sensors have a finer spatial resolution and real-time monitoring capability (Yang, Everitt, Bradford and Escobar, 2000, 2004, & 2004). It is propounded that aerial imagery is as effective as high resolution satellite imagery in monitoring spatial variation of crop condition and yield. Moreover, the development of Low Altitude Remote Sensing Systems (LARS) over the recent past makes its application for PA possible. Plausible breakthroughs can be identified as from 2000 where Inoue, Morinaga, and Tomita collected crop images using a Charge-Coupled Device (CCD) camera mounted on a blimp to measure biomass and Leaf Area Index (LAI) variation within rice and soybean fields (Flowers, Weisz, & White, 2005). The results showed that studying crop biological parameters can best be accomplished through the use of LARS images. Hunt et al. (2005) used a colour digital camera mounted on a radio controlled model aircraft to collect images of a corn field in order to examine the relationships among Normalized Green Ratio Difference Index (NGRDI), biomass and corn nitrogen status. Likewise, in 2008 they also assessed the relationships between LAI and Green Normalized Difference Vegetation Index (GNDVI) for a wheat field. In their recent research in 2010, Hunt et al. used a customized digital camera on-board a LARS to take high-resolution (i.e. 2.7 and 5.1 cm) color-infrared pictures of two winter wheat fields. Through assessing the spectral information with ground collected biophysical data these researchers demonstrated the scientific feasibility of applying LARS to monitor within-field crop variations (Zhang & Kovacs, 2012). In a similar fashion, Primicerio et al. (2012) used an ADC-lite camera on-board a UAV to acquire photos of a vineyard. They managed to convert digital numbers to reflectance and then calculated NDVI to display vineyard vigour.

A number of sensors and cameras are available for LARS. However, optical or infrared sensors are the most commonly used for crop monitoring whereas thermal infrared sensors have been shown to be valuable for monitoring soil moisture or stress (Ryo et al, 2007; Berni et al, 2009;
Zarco-Tejada et al, 2012). Zarco-Tejada et al, (2013) further demonstrated that hyperspectral sensors on board a UAV could as well be used to examine leaf carotenoid content.

The aforementioned studies demonstrate the scientific feasibility of LARS applications for crop monitoring. The spatial resolution limitation of satellite imagery is seen to be resolved by LARS. In spite of all this, LARS has its own challenges too. The small spatial coverage and the image processing of the LARS data are the most apparent challenges. Transportation regulations of some countries restrict the operating height of LARS. This means that a large number of images need to be collected for each field. Most importantly, it is difficult to mosaic the images. Hunt et al. (2008) found it difficult to calculate NDVI from a mosaic of LARS. This was because the same crop feature in several images could have different digital numbers as a result of changes in the incident angles and/or the atmospheric transmittance. Therefore, instead of focusing on a mosaic of images, most LARS investigations concentrate on each image separately (Primicerio et al, 2012).

Arguably, there seems to be varied messages about the practical applications of LARS for PA. While scientific research praises LARS for the capability to measure relationships between crop biomass and water stress using the digital numbers (or reflectance values) obtained from LARS imagery, suggesting a typical practical use for crop monitoring, such analyses unfortunately are done on each image separately. This suggests that it would be impractical for farmers with vast fields who may consequently require many images to monitor their fields (Berni et al., 2009; Swain et al., 2010). The situation is compounded by limited literature on applications of LARS for crop monitoring.

2. Study Area

The study was conducted in Traditional Authority Somba, in the outskirts of Malawi’s commercial city of Blantyre, on the trial farm of Nzathu Association, a GTZ funded project. The target crop was maize, Malawi’s main staple crop. Located at 15°40′S, 34°58′E and at an average altitude of 1039m, Blantyre has an annual mean temperature of 22.4°C and annual mean rainfall of 834mm. Generally, Malawi is a characteristic of a tropical wet and dry savanna climate. As a country whose economy heavily relies on agriculture, it is essential to monitor the field crop conditions in a timely fashion to maximize production. Normal growing season in Malawi is from November to April (Ngongondo et al. 2014). Permission to fly over the farm was granted by the association. The main objectives were to analyze fertilizer field trials, field tile drainage conditions, and crop damage from disease infestation. No permission was obtained from Malawi Government to fly the LARS over this area despite writing them for the same.
3. The Equipment and Methods employed

The UAV system used in this study weighed 3.4 kg and was developed by Manuel Kiewisch, a UAV technologist and research scientist of University of Technology, Germany. The Table below explains the component parts that the UAV consisted of.

<table>
<thead>
<tr>
<th>Component (brand name)</th>
<th>Function</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motors (AC 2836-358)</td>
<td>To provide lift and steering</td>
<td>Max. 880Kv (Rounds per minute per Volt)</td>
</tr>
<tr>
<td>Telemetry (Xbee Pro S1)</td>
<td>To enable wireless communication with PC</td>
<td>900 Mhz module, ca. 800m range</td>
</tr>
<tr>
<td>Frame (n.v.)</td>
<td>For stability and functional setup for the parts (anchorage)</td>
<td>Aluminium/glass fiber frame, ca. 50cm in diameter</td>
</tr>
<tr>
<td>Batteries (Turningy)</td>
<td>To provide power source for all energy consuming components</td>
<td>3S3P3 cells in series (3 cells in parallel), 3000 mAh (milli Ampere), 11.6 Volt</td>
</tr>
<tr>
<td>Chipset (Ardupilot Mega 2.0)</td>
<td>To enable communication between parts, steering, autopilot, and sensoric</td>
<td>Magentometer (stabilization in air), GPS (localization), Sonar (altitude measurement)</td>
</tr>
<tr>
<td>Remote Control (Spectrum DX7)</td>
<td>To enable manual control of the UAV</td>
<td>900 Mhz module, range ca. 800m, 7 channel setup</td>
</tr>
<tr>
<td>Camera (Canon PowerShot S95)</td>
<td>To record aerial optical ground information for remote mapping, study processes</td>
<td>10 Mega Pixels resolution, compact digital camera, ca. 260gr</td>
</tr>
</tbody>
</table>
The images, after capturing them using the PowerShot S95 camera, were stored directly on a flash card located in the camera. The PowerShot S95 camera has three bands: near infrared, red, and green. The flight altitude was set at 60 meters. Hence the camera had a spatial resolution of 5cm. Since the field had one crop only, the front overlap and side lap were 85% and 65% respectively. High overlapping flight path assists to improve the efficacy of post-flight mosaic processing.

Prior to each flight, a total of six Ground Control Points (GCP) were set up and dispersed throughout the field. The GCPs were mounted on a wood stake at a height of 1.5m. This was necessary for orthorectification and georeferencing of the final mosaic images. Locations of the GCPs were recorded using a Trimble GeoXH GPS. Each flight mission required a team of three people. One person operated the control unit for the planning and operation of the LARS, while the other two were responsible for flight observation (i.e. spotting potential hazards) and the distribution and collection of the GCPs. Each raw image was converted into a jpeg file and calibrated using Pixelwrench2 software. Pix4d Mapper (Pix4D, Switzerland) software was used to orthorectify and mosaic the optical infrared imagery and also to generate NDVI images of fields. A stratified random sample was used to statistically examine the differences in NDVI among the three fertilizer treatments.

4. Study Results and Discussion
4.1 Assessing fertilizer treatments using UAV imagery

The benefits of organic manure on soil quality and crop production cannot be overemphasized. Several studies have shown that adding compost increases crop production and improve soil fertility (Keener, Dick, & Hoitink, 2000).

4.1.1 Mosaicked image of maize field as captured by the UAV (taken on 8th December, 2015)

Figure 3 shows two mosaicked images of a maize field as captured by the UAV. Image 1 is a mosaicked infrared color composite image (NIR, red, green-no enhancement applied) while image 2 is a mosaicked NDVI image. Area marked A is area treated with organic fertilizer (9.37 L/ha), while area B is treated with both organic and chemical fertilizer (9.37 L/ha) and chemical fertilizer (185.53 kg/ha), and area C is treated with chemical fertilizer only (371.25 kg/ha). Area marked D shows an error in fertilizer application. Calculated final yields for the areas A, B and C were calculated at 1.23, 1.77 and 2.47 tons/ha, respectively.
4.1.2 Mosaicked image of maize field as captured by the UAV (taken on 20th January, 2016)

Figure 4 are two mosaicked images of a maize field as captured by the UAV. Image 1 is a mosaicked infrared color composite image (NIR, red, green-no enhancement applied) while image 2 is a mosaicked NDVI image. Area marked A is area treated with organic fertilizer, while area B is treated with both organic and chemical fertilizer, and area C is treated with chemical fertilizer only. Area marked D shows an error in fertilizer application. Calculated final yields for the areas A, B and C were calculated at 1.23, 1.77 and 2.47 tons/ha, respectively.

The first flight took place on 8th December 2015 when maize crop was about 35cm high. Figure 3 shows a great contrast between the area treated with organic fertilizer and that treated with chemical fertilizer. The former had the weakest vegetation vigor hence appears much darker in the infrared image. Its NDVI values are considerably lower than those of the chemical fertilizer treatment (i.e. P<0.001). There is no much difference between areas B and C (P=0.59). The variability within each treatment area could be attributed to differences in soil types, soil moisture content, or other factors. The NDVI difference between areas B and C is very apparent in images taken on 20th January 2016 (Figure 3) when the crop was at a later growth stage than one taken earlier on 8th December 2015. Major differences (i.e. P<0.001) were observed between treatments A and C, and B and C. While the differences between treatment areas A
and B were not statistically significant (P=0.07), the P values is really close to the critical value of 0.05. Therefore, a flight taken between these two dates would have provided better discrimination of the treatment areas.

4.2 Identifying area of lodging and insect infestation using UAV imagery

One typical pest that attacks maize in tropical and subtropical regions is armyworm. A warm, humid weather and heavy rainfall favor the proliferation of armyworm in such regions. It is estimated that, on average, one caterpillar needs 140 cm² of leaf area to develop through 6 instars. However, the 6th instar itself requires 77.2% of that leaf area (Sparks, 1979). Due to this scenario, Zhang & Kovacs (2012) explain that farmers may only recognize and report the armyworm infestation at this stage of growth. Following such infestation, the main midribs of the leaves remain intact while the succulent parts are completely consumed. This makes the leaf area of the field or parts of the field to drop considerably within a short period of time. With such damage, armyworm impacts can therefore be assessed using high resolution remotely sensed imagery. The expectation is that, due to the loss of flag leaves and increased exposure of the soil surface and shadows, there must be a decrease in reflectance in the NIR band while that of the red band should increase (Zhang & Kovacs 2012).

![Figure 5](image)

Figure 5

Another important damage common to many cereal crops, maize inclusive, is lodging, or stem breakage. Mostly, this is a result of stormy weather conditions coupled with inadequate standing power of the crop during certain growth stages (i.e. heavy seed heads). High nitrogen fertilization too may cause plants to be more susceptible to lodging. A combination of armyworm infestation and stormy weather conditions rendered the maize crop more susceptible to lodging. Therefore, lodged areas appear as a bright red tone in the infrared image. Since the lodged maize crop covers the bare soil, stronger reflectance is observed from the leaves and stalks in the IR band giving a large contrast between the lodged and non-lodged areas (Zhang & Kovacs, 2012).

![Figure 6](image)

Figure 6

Figure 7 shows two images of the maize field. To the left is a mosaicked infrared color composite non-enhanced image (NIR, red, green) whose plants are infested with both armyworm and lodging. To the right is the corresponding NDVI derived image. Area A shows
a healthy non-infested maize field, B is a section of the maize crop attacked by armyworm whereas C and D indicates sections of lodging and rock outcrop, respectively.

From the same images in Figure 7, stressed areas of the crop field were also identified. During the field walk, it was discovered that the maize crop on shallow soils, for example on and around rock outcrop, were dead. In the NIR, these crops are shown in a dark tone. Information gathered from such interpretation may be used to determine whether a farmer should invest in equipment to lift the lodged heads during harvesting. Based on such information, a determination may further be made as to what mechanism should be put in place to improve the fertility of the shallow soils.

4.3 Identifying field tile network using UAV imageries

At an average altitude of about 1039m above sea level, Blantyre has an undulating topography with clay as the main soil type (UN-Habitat, 2011). The combination of these two factors leads to drainage problems for local farmers. In a bid to reduce risk of crop failure due to excess water and maintain uniform crop production amidst climate variability (Zhang & Kovacs 2012), the use of field tile drainage system were adopted. Good drainage also reduces the frequency of pests and disease outbreak while ensuring that a farmer gets a modest return (Zucker & Brown, 1998). Once installed these drainage systems need to be monitored and maintained hence it is necessary for the farmer to know the exact location of the tiles.

The images for this task were collected on 17th March 2016, immediately after harvest. They were processed by applying linear enhancement and mosaicked. After analyzing the mosaicked images, locations of some of the tiles in the image were identified. A brighter tone with a linear-like feature represented the locations of the tiles. At the same time, well drained areas were drier hence looked brighter (see Figure 8). Further, some drainage problems such as excessive wetness were also identified. Worth noting here is that, just like Zhang & Kovacs (2012), interpretation was possible in the section where the soil was bare as opposed to the western part of the field. This was as a result of presence of remains of maize stalks which covered the ground.
5. Conclusion

This paper demonstrated the feasibility of applying UAV acquired images, both in optical and near-infrared, for monitoring crop conditions in precision agriculture. The results suggest that it is possible to acquire images and process them in a timely fashion for PA applications. However, high current costs and operational logistics have compromised the assimilation of its application. Nevertheless, it is anticipated that as the costs of LARS decrease and more experienced personnel available to acquire and process the data, the adoption of UAV systems will skyrocket.

References


Biography

Donnex Chilonga is a research scientist cum geographer with specialty in the utilization of space-based technology in solving current social problems. He has been teaching at University level since 2012. Throughout his 4-year span Donnex has built a reputation for developing space-based scientific models tailored for disaster management. Together with his colleagues in the Geography and Earth Science department of Mzuzu University, Donnex is a lead on building a model for communication for first responders in times of flooding in Malawi. Donnex’ academic background includes a PGD in Remote Sensing and GIS and BA (Geography) obtained from African Regional Centre for Space Science and Technology Education, Obafemi Awolowo University and Mzuzu University respectively. Currently he is an MSc student in GIS. His interest in environmental protection for equitable use saw Donnex obtaining a Diploma in Law from the University of Malawi.
Towards parabiotic partnerships for access and discovery: Leveraging access to e-content within the framework of library consortia in Zimbabwe

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Abstract
The age of intelligence presents library consortia in Zimbabwe with an opportunity to innovate, reinvent and re-profile in order to effectively disseminate research and scholarly communication as well as keep abreast of current technological development in ICTs. The survival of the library consortia is hinged upon renewal and reinvention through innovation and creativity and collaboration with National Research Networks to facilitate access to research and scholarly communication. This paper seeks to investigate the extent to which library consortia as part of the technological infrastructure can leverage strategic partnerships with NRENS for enhanced access and knowledge discovery. The paper will examine how partnerships with research networks and other key stakeholders can benefit resource sharing initiatives. It will explore the extent to which library consortia in Zimbabwe can use strategic partnerships to facilitate access to research and scholarly communication. The paper will find out the strategies that are in place to promote resource sharing, for example, collaboration between NRENS and library consortia and open access initiatives. The treatise will also seek to find out how library consortia can work with NRENS to enhance resource sharing and e-content licensing. The paper will examine how library consortia can utilize research networks to support self-determined learning (heutagogical) through provision for wider access to scholarly communication.

Keywords: Access to content; library consortia; partnerships and open access, NREN

1. Introduction
The dawn of the twenty–first century has seen academic libraries in Zimbabwe grappling with numerous challenges namely; growing needs of users, adapting to the proliferation of digital technologies, rising costs of subscriptions to scholarly journals and high costs of internet connectivity (Chisita, 2016, unpublished). Csajbéker and Vasas, L (2012) argue that librarians are oblivious of the fact that their organisations cannot overcome all existing, imminent and impending challenges independently and hence the need for collaboration and partnerships. The proliferation of library consortia has become a common feature of the progressive learning societies of the world. The development of library consortia and National Research Networks (NRENs) in Zimbabwe was spurred by the need to ensure reliable access to information in
response to the seismic shifts in the global information and technological landscape. The phenomenal rise of library consortia and research networks in Africa gives credence to Francis Bacon’s truism “knowledge is power” (Spedding, Ellis, & Heath, 1969, Vickers, 1992.). Access to information is critical because information /knowledge are referred to as “the thermonuclear competitive weapons of our time. Knowledge is more valuable and more powerful than natural resources, big factories or fat bankrolls. In industry after industry success comes to the companies that have the best information or wield it most effectively- not necessarily the companies with the most muscle” Stewart, 1997.)

The twenty first century calls for a fundamental rethink and a radical paradigm shift with regards to how academic and research institutions and Internet Service Providers (ISPs) will work together to enable affordable access to scholarly content as well coming up with innovative and practical strategies to support interdisciplinary and inter-institutional collaboration (Gibbons, 1994). Library policies and practices should enable resource sharing beyond national boundaries through optimum utilisation of ICTs infrastructure. The new mode of knowledge production and learning and research in the twenty-first century gives credence to the calls for radical inter-institutional and interdisciplinary collaboration (Gibbons, 2005).

Frodeman (2010.) quoted in Chisita and Abdullah (2012) posits that the second millennium has witnessed a transition from Kantian disciplinary to interdisciplinary or integrative knowledge production. The author states that the old model of knowledge production is no longer compatible with the technology-driven twenty first century characterised by the abundance of information and communication technologies, globalisation and accountability. The interdisciplinary and dynamic nature of librarianship renders it acquiescent to collaboration because of the of the dire need to keep up with current trends in the profession, for example, in the educational field , internationalization, standardization, technological progress, teaching methods ,research and development are critical issues (Chisita & Abdullah, 2012,).

Kunda and Khunga (2014) highlighting the need for Higher Education and Research institutions to move away from an anachronistic silo or exclusive modus operandi which is anathema to the current knowledge dispensation which calls for deep and wide collaboration. The authors highlighted the urgent need for educational institutions to share resources and build bigger networks that support collaborative research in Africa. The success of Higher Education is dependent upon extend of interconnectivity and access to information. However, the high costs of subscription to e-resources and Internet connectivity makes it cumbersome to share teaching and research resources.

2. Technology and NRENs

The propagation of ICTs has precipitated the metamorphosis of academic libraries from an exclusive to inclusive mode of operation premised on resource sharing through library consortia serviced by robust internet connectivity. Library cooperation can be enhanced through incorporating NRENs in the development matrix. NRENS have the capacity to build infrastructural capacity to enable effective and reliable internet access and inter-institutional connectivity. Library consortia can also utilise NRENs to develop and manage the infrastructure that enables global scientific collaboration and access to digital scholarship to enhance learning, teaching and research. Darch (2000) and Zeleza (1996) expressed a techno-pessimistic view on the possibilities of African librarians benefiting from affordable internet services because of the commercialisation of internet service by commercial internet service providers and lack of access to appropriate content reflecting the scholarly views of people from third world countries. Darch (2000.) urged techno pessimists to be guided by Gramsci’s
“pessimism of the intelligence, optimism of the will”. He highlighted the pressing need to direct collective attention towards the present as a basis for its radical transformation.

The emergence of NRENs in Africa serves as a magic formula for the democratisation of access to scholarly communication, hence the need to invest and support such innovations for the benefit of Africa. The strength of NRENs lies in their social capital through radical partnerships at regional and international level, the use of common standards and protocols in order to build a common gateway to support the information needs of researchers and scholars. NRENs serve as dedicated internet infrastructure and service provider for the benefit of research and academic institutions. Its secondary role allows it to extend its service to Communities of Interest (COI) and Communities of Practice (COP), government institutions and other key stakeholders.

3. Library Consortia in Zimbabwe

Globally, library consortia are the vanguard in promoting and facilitating access to scholarly communication for the benefit of their primary stakeholders namely; students and researchers and lecturing staff. Udoumoh and Okoro, (2007) describe academic libraries as the nerve centre of the university. The academic libraries are viewed as a central point of academic life and as an institution that brings people together to share epistemic experiences (Abram, 2008) In 1997, Rosenberg conducted a review of the state of university libraries in Africa. The authors review highlighted the extremely poor, though widely varying, situations at different universities, both financially and otherwise. Ojedokun, and Lumande, (2005) state that the political dispensation of successive governments in African countries has not been helpful because of its emphasis on forcing institutions to compete vis-a-vis dwindling funding and lack of infrastructure to support teaching, learning and research.

Zimbabwe is no exception to this development as evidenced by the formation of Zimbabwe University Library Consortium (ZULC) in 2002 and College and Research Libraries Consortium (CARLC) in 1999 to facilitate access to electronic journals in cost effective ways (Chisita, 2016).

The world over, modern forms of cooperation amongst academic libraries are buttressed by traditional forms of cooperation. However there is need for deep-seated collaborative initiatives that transcend traditional forms of cooperation based on Inter–library Loans (ILL) to networking for digitisation projects, shared subscriptions and storage. Anasi and Ali (2012) noted that cooperation among academic libraries in Africa was being affected by a number of factors including lack of funding, power surges, lack of common metadata standards, uneven development of libraries, poor bibliographic control, poor ICT infrastructure and lack of comprehension of the benefits that accrue from cooperation. NRENs provide the missing link that connects library consortia with other stakeholders including consortia, researchers and communities.

Partnerships and cooperation among libraries provides a stimulant for creative and innovative ideas to transform library services and products. Strategic partnership will determine the extent to which libraries are able to accomplish overall objectives. Dong et al., (2009:1) state that libraries enter into partnerships with other libraries in order to afford access to library resources at a time when budget continue to dwindle. Cost-benefit studies on the value of library consortia highlighted that cost savings and access to wider range of library resources were some of the advantages of collaboration (Scigliano, 2002).

4. Library consortia and NREN nexus
However, library consortia in developing countries need to build parabiotic relations with key stakeholders including NRENs and development partners. Such symbiotic relations will connect library consortia to NRENs that have the capacity build ICT infrastructure to enhance access to e-content. Accessing and using e-scholarly content is impossible without reliable and fast internet and good ICT facilities. Kotecha (2010) posits that the possibility of achieving reliable access to journals to support learning, teaching and research requires a series of layers, beginning with campus-level infrastructure and ICT human capital, national infrastructure (NRENs), regional interconnectivity between national networks, and connections to international networks. Echezona, and Ugwuanyi (2010) highlight the tremendous progress made by African libraries in establishing affordable Information and Communication Technology (ICTs) links to enhance Internet connectivity. Such progress is also attributed to the development of NRENs). NRENs play an important role in the development of network infrastructure to ensure reliable access to content. Network infrastructure is the critical structural capital that library consortia need to enable easier and affordable access to their institutional repositories and repositories of Electronic Thesis and Dissertations (ETD)

Harle, (2009) acknowledges the critical role of NRENs in developing the potential of high-speed cable connections for higher education and research. The author further notes that the needs of Higher Education and researchers have been downplayed by National frameworks within Africa which were designed for the commercial sector. Such frameworks are unaffordable for academic libraries since they are non-profit making organisations.

In 2014 The Zimbabwe Research and Education Network (ZIMREN) an Internet Service Provider (ISP) was launched with the main purpose of supporting research and educational institutions in Zimbabwe. ZIMREN also aims to provide for inter-institutional connectivity through an NREN that will be connected to the regional research education network (RREN) in Eastern and Southern Africa (UbuntuNet). ZIMREN was established as a result of the combined efforts of academic institutions under the auspices of Zimbabwe Universities Vice Chancellors Association (ZUVCA) with the technical support from UbuntuNet. While other countries within the region had managed to develop and operationalise their NRENS, Zimbabwe was still lagging behind by 2014 until the promulgation of ZIMREN. However, recent developments show that ZIMREN has been overtaken by the Zimbabwe Academic Research and Education Network (ZARNET) which recently joined UbuntuNet Alliance with effect from August, 2016.

The development of ZIMREN raised higher expectations of stakeholders since it promised to put in place a robust fibre-optic backbone dedicated to academic and research activities in institutions of higher learning (Chitanana,2014). The author conducted a study which explored the challenges and opportunities of developing ICT infrastructure to support learning and teaching in academic institutions. Furthermore the author highlighted the need for ZIMREN to use its collective bargaining power to negotiate improved bandwidth at a more affordable cost and to coordinate the development of national network infrastructures. In 2006, Chisenga bemoaned the high cost of internet connectivity “...Although Internet access is now widely available on the continent, the speed and reliability of Internet connections is a major challenge faced by most institutions...” (Chisenga, 2006)

Cooperation among libraries is not a new phenomenon but an ancient tradition dating back to inter-library loans (ILL) (Case, 2011). The author further argues that many libraries are beginning to comprehend that they are inseparable from the larger information system and that resource sharing is a critical component of the delivery of collections and services. Mulira (2010) points out that library resource sharing should be considered as a priority because of increasing costs of subscriptions to scholarly communication, dwindling budgets, growing
needs of users and the information explosion. Academic libraries are collaborating to realise economics of scale in acquisitions and access to high quality scholarly content. “Resource sharing has become a dynamic and increasingly strategic area of service that reflects a constantly changing information landscape and commitment libraries are making to empower their communities to discover and access information efficiently and effectively” (Bailey-Hainer, et.al).

Chiparaushe and Chisita (2016) point out that development of library consortia in Africa is a response to the desire to fulfil the aspirations of libraries by reaching out to many users and to be able to satisfy growing information needs of users vis-a-vis the information explosion. Libraries exist for a purpose and it is through an in-depth understanding of their mission and goals, that society can appreciate the great roles they play in socio-economic transformation of any society. The authors further argue that libraries should exploit the digital dispensation in order to realise their full potential through venturing into strategic partnership with regards to resource sharing and the production and licensing of e-content. However, it is through working with NRENs that library consortia can realise the goal of facilitating affordable access to e-content to support the learning, teaching and research activities.

5. Library consortia, NRENS and development partners

Library consortia in Zimbabwe also benefit from INASP initiatives in promoting access to e-resources and open access and capacity building in maintaining ICT infrastructure and licensing and negotiations for e-content. Burnet (2015) states that in 2013, INASP launched a new flagship programme, called “Strengthening Research and Knowledge Systems” (SRKS). The programme enables partner countries to access scholarly content in support of teaching, learning and research. INASP has been working with NRENS to build capacity amongst campus engineers in order to increase the reliability of networks as well as empowering staff to maintain research infrastructure (INASP, 2016). Furthermore, library consortia can also benefit from collaboration with NRENS to improve access to e-scholarly publications in academic institutions. A combination of the technical skills of NRENS and content knowledge of librarians and consortia is critical in mapping strategies to widen and deepen access to scholarly content in support of learning, teaching and research. The main objective for the INASP initiative was to build the capacity of NRENS and develop a sustainable model for continuous education and training for Higher Education with regards to developing campus infrastructure.

6. Leveraging access scholarly content: Open Access Initiatives

Library consortia should cooperate with NRENS to improve the visibility and accessibility of their ETD repositories which have now become the new medium for disseminating scholarly content (Gul, et al, 2015). Such technologies do not only enhance visibility of scholarly content but also knowledge discovery. Chisita and Chiparaushe (2016) note that ICTs are enabling enabled academic libraries to develop digital platforms for end users, and the public to connect each other. These platforms enable easier accessibility and discoverability of ETD content. Singh (2015) describes ETDs as rich and unique sources of information “…untapped and under-utilised asset…”

The Open Access culture has strongly gripped academic institutions in Zimbabwe because of the efforts and commitment of library consortia namely ZULC and CARLC. The proliferation of Institutional Repositories (IRs) and ETDs provide tangible evidence of the growing power of Open Access in Zimbabwe. ZULC has collaborated with Electronic Information for Libraries (EIFL) to promote Open Access among academic libraries in Zimbabwe. ZULC
adopted Open Access policies in 2013, following the successful ZULC and EIFL OA Advocacy Campaign “Say “No! To Secret Knowledge: Support OA”( EIFL, 2013). Currently, only eight academic institutions subscribing to ZULC and two affiliate members have their IRs enlisted on the OpenDOAR(2016) Library consortia should collaborate with NRENs to improve visibility and accessibility of their intellectual content. Chisita and Chiparaushe (2016) noted that the reason why some academic institutions were not listed on the OpenDOAR was because either their IRs were still in infant stage of development or they had not yet established one. Collaboration with NRENs can help in the development of infrastructure that support IR’s and ETDS. In 2015 there were two Zimbabwean academic journals from the University of Zimbabwe which were enlisted on the Directory of Open Access Resources.

The endorsement of Open Access policies by members of the Zimbabwe University Library Consortium (ZULC) has given credence to the importance of the Open Access Initiatives and accessibility of ETDS. The development marks a victorious start in the battle to conquer knowledge frontiers and reposition the country in the global information / knowledge landscape. However, academics are working with NRENs and other development partners to build a robust network that will facilitate easier and faster access to scholarly content. Furthermore, if the existing ETDS are not interconnected they will remain isolated islands of scholarly content because of lack of interoperability (Schöpfel & Prost). The authors highlighted the need to use ETDS as special vehicles for democratising access to scholarly communication. They also proposed a new non-anachronistic and non-elitist model for disseminating or sharing scholarly communication for the benefit of all. Library consortia can work with NRENs to build interconnected and interoperable systems or networks for the benefit of scholars, researchers and staff. ZIMREN and ZARNET has been working with ZULC and CARLC to promote and enhance access and sharing of digital content. Library consortia are digitising their local content and NRENs should support such initiatives through providing the critical infrastructure for hosting a central repository that provides nationwide access.

Such systems will improve discoverability and accessibility. The future trajectory of ETD envisages an open-access driven and interoperable global system for accessing and exchanging scholarly content to support learning, teaching and research (NLETID, 2016).

Chisita and Chiparaushe (2016) advocate for a creative library partnership model which allows the consortium to transcend beyond the traditional partnerships based on resource sharing only. Such a model of library partnership would be a multi-stakeholder partnership incorporating different types of libraries, government, artists, NRENs and the public for purposes of ensuring that the consortium achieves “high-impact” with “low-cost” tools (Chisita and Chiparaushe, 2016). Partnerships between library consortia, NRENs, RENs, development partners, ISPs, and other key stakeholders is critical in building a sustainable digital infrastructure that supports learning, teaching and research in Zimbabwe. Library consortia can benefit from the efforts of NRENs with regards to accessing high speed network connectivity to boost education and research areas in Zimbabwe.

The viability of NRENs is dependent upon their ability to innovate by collaborating with key stakeholders including library consortia, librarians, policy makers and users in order to provide quality service. Burnett (2015) urges NRENs to offer more in order to gain a competitive advantage over commercial ISPs. The author emphasises the provision of high quality service as one characteristic of a competitive NREN. Mutual beneficial partnerships with library consortia will help democratise access to education through supporting self directed learning.

The adoption and adaptation of critical institutions both private and public are no longer an institutional choice but a developmental trajectory necessity which is highly inevitable in order
to adapt to the modern trends in the realm of Information generation, transmission, storage and preservation. Parabiotic partnerships will unlock the logjams that have hindered partnerships for access and discovery hence leveraging access scholarly to e-content within the framework of library consortia in Zimbabwe. Through working with NRENS and other key stakeholders, library consortia in Zimbabwe can leverage their intellectual capital for the benefit of scholars and researchers irrespective of time and space. Such collaboration will usher in new egalitarian information dissemination models with regards to information discovery, delivery and uninterrupted access. Such initiatives should boost the quality of research and teaching in Higher education.

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When is it an African NREN: Building a Vibrant and Sustainable National Research and Education Network in Africa

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Abstract

A National Research and Education Network (NREN) is both: 1) a high performance communications network owned and operated for and by the education and research community of a country and; 2) the organization that operates that network, constituted as a consortium of members, a dedicated agency, a company, NGO, or other type of body. In World Bank partner countries an NREN may simply be a consortium of universities that organize themselves as a “buying club” in order to get a better price from Internet Service providers (ISPs), or it may be more sophisticated and be offering connectivity services to its members. (Case for NRENs 2009). Several countries around the world have adopted the NREN as the centerpiece of an advanced network for collaboration and communication between the Tertiary and Research Institutions within their country and to other parts of the world. (Ravinder 2008; C@ribNET 2010).

Around the time of GARNET's inception in 1995, the United States Congress took critical steps toward what was called then the National Public Network. The United States Senate and the House of Representatives moved toward enacting legislation to authorize their NREN (Kahn 1992). Yet in the context of Ghana and most other Africa Countries, the lacking of similar political strong intervention is what could have led to slow deployment of the NREN.

Poor Internet connectivity is one of the pertinent issues in the digital divide between developing and industrialized countries, hampering the transition to the global information society. Africa is currently the most under-served continent in terms of the information and communication technologies. Hence the collaboration amongst tertiary education institutes in Africa is imperative to make them key players in the enhancement of information and communication technologies for society (Ravinder 2008).

GARNET like most other African NRENs has gone through several iterations of starting and stopping, various Boards and memberships, and various models of operations, which did not make any significant process in providing a sustainable NREN. Current attempts to have a sustainable NREN have been directed towards providing technical and services oriented solutions by focusing on the business model and financial plan(caseformren.org). Beyond merely the technical aspects of scalability, our concerns lie in how to reproduce and translate the necessary learning processes alongside the spreading of artifacts, funding, and people. (Braa, Monteiro et al 2004).

A conscious effort has to be made using the theory of Information infrastructures to look at the collection of governance, policy, structures, people, procedures and technologies that
make up an NREN and its infrastructure in order to make it sustainable (Star and Ruhleder 1996). Without a conscious effort to achieve sustainable systems, initiatives from aid organisations, governments and NGOs are likely to replicate past outcomes of lengthy technology deployment and fast technology abandonment (Beardon et al. 2004).

In order to leapfrog NRENs into becoming a vibrant and sustainable, the practices that have worked elsewhere on the continent should be reinforced. There is no need to rebuild the same problems in the new networks we are building. Instead there is a need to make the NREN stronger by building an organization with and active and vibrant community. In order to achieve this, interventions would have to be taken in the areas of governance, policies, procedures as well as the products and services that the NRENs of today would be providing to its community of users and practitioners like Universities ICT Directors, Researchers, Academicians, Librarians and other stakeholders.

The presentation will propose key interventions that would be the set of actionable items for Governments, Donors agencies and other relevant stakeholders that are interested in either establishing or strengthen NRENs in Africa could use to ensure that they would be viable.

1. Background

A National Research and Education Network (NREN) is both; 1) a high performance communications network owned and operated for and by the education and research community of a country and 2) the organization that operates that network, constituted as a consortium of members, a dedicated agency, a company, NGO, or other type of body. In World Bank partner countries an NREN may simply be a consortium of universities that organize themselves as a “buying club” in order to get a better price from Internet Service providers (ISPs), or it may be more sophisticated and be offering connectivity services to its members (Dyer, 2009). Several countries around the world have adopted the NREN as the centerpiece of an advanced network for collaboration and communication between the Tertiary and Research Institutions within their country and to other parts of the world. (Ravinder 2008; CKLN 2010)

Hence it is important to note that the NREN is the organization that binds a community of Researchers, Academicians, Librarians, ICT Professionals and other stakeholders together. The NREN will meet the computer and communication needs of scientists, researchers, and educators; its implementation should also be used as an opportunity to extend the benefits of public networking technology to new groups of users. (M. Kapor and J. Berman, 1992)

Around the early 1990s, the United States Congress took critical steps toward what was called then the National Public Network. The United States Senate and the House of Representatives moved toward enacting legislation to authorize their NREN (Kahn 1992). Yet in the African context, the lacking of similar political strong intervention is what could have led to slow deployment of the NREN on the continent.

The building blocks of Research and Education Networks comprise of Universities and Research Institutions, NRENs and Regional RENs and each must be seen and operation as distinct and separate organizations. Even when working closely together there must be time-bound and specific and identifiable objectives. Most of the poor emergence of NRENs on the continent can be attributed the lack of clear distinction and separations of the functions of the NREN from that of the University, initiating organization, or Government Agency.
2. The African NREN Problem

Poor Internet connectivity is one of the pertinent issues in the digital divide between developing and industrialized countries, hampering the transition to the global information society. Africa is currently the most under-served continent in terms of the information and communication technologies. Hence the collaboration amongst tertiary education institutes in Africa is imperative to make them key players in the enhancement of information and communication technologies for society (Ravinder 2008).

The Association of African Universities (AAU) supported the need for the Internet connectivity by stating:” African universities and researchers are often working in a silo model, insulated from regional actors and drivers of funding and requirements. …” (AAU 2007). Under its Strategic Plan 2003-10 and following a very strong mandate issued by the 11th General Conference of the AAU held in Cape Town, South Africa, in February 2005, AAU had to establish the role as coordinator of the many ICT initiatives including the Research and Education Networking Unit (RENU) to act as a focal point in relation to the many initiatives in relation to Information and Communications Technologies (ICT) in education and research networking, currently under way in Africa (Source: www.aau.org/page/research-and-education-networking-unit).

It was the emergence of the RENU under the AAU that led to the

a) Memorandum of Understanding (MOU) Between UbuntuNet Alliance and the Association of African Universities (AAU),
b) Memorandum of Understanding (MOU) Between UbuntuNet Alliance and The West and Central African Research and Education Network (WACREN)
c) And the formation of the African Research and Education Network (AfREN) forum for discussions on issues of interest to the research and education networking (REN) community such as collaboration, advocacy and coordination of activities in Africa.

There is a traditional session on updates from the UbuntuNet Alliance (Eastern and Southern Africa), WACREN (West and Central Africa) and ASREN (Arab countries, including North Africa). (Source: http://wacren.net/en/events/afren-meeting-africa-internet-summit-ais)

The Arab States Research and Education Network (ASREN) is the association of the Arab region National Research and Education Networks (NRENs), as well as their strategic partners, that aims to implement, manage and extend sustainable Pan-Arab e-Infrastructures dedicated for the research and education communities and to boost scientific research and cooperation in member countries through the provision of world-class e-Infrastructures and e-services. (Source: http://www.asrenorg.net/)

UbuntuNet Alliance is the Regional Research and Education Network for Eastern and Southern Africa. It capitalizes on the emergence of optical fibre and other terrestrial infrastructure opportunities to establish a high speed research and education backbone, which interconnects all National Research and Education Networks (NRENs) in the region. (Source: ubuntunet.net)

West and Central African Research and Education Network (WACREN) is the promotion and establishment of interconnections between national research and education networks in West and Central Africa to form a regional research and education network, the interconnection of this network with other regional and continental networks, and the provision of services aiming at fostering collaboration between research and education institutions in the region as well as between them and peer institutions at continental and international levels (Source: wacren.net).
The academic and research institutions in Africa are yet to reap the full benefit of being members of a physical research and education network. The African Institutions are not benefiting from the economics of scale associated with bulk purchasing of Internet Services and do not have the networks that would enable the collaborations with their counterparts within the country, continent and beyond. This is making it very difficult for them to effectively conduct the core business of teaching, research and collaboration and play a vital role in the African higher education arena.

NRENs like most of ICT4D projects are donor-sponsored initiatives, host institutions are rarely sharing any cost of the project implementation and some people view the system “a free lunch”. However, while the system is delivered “for free” thanks to the donors, there are significant costs to the adopting country in lost opportunities, wasted energy, and loss of good-will when systems fail to deliver the expected outcomes. The challenge then is to overcome this mentality of accepting free donations without a proper assessment process, which has resulted in reduced commitment and ownership (da Silva et al 2013).

Common myths about NREN formations are as follows:

1. NREN issues are technical in nature and require Technical Interventions for them to be resolved.
2. There are various models and ownership structures for establishing NRENs and making them vibrant
3. NRENs are best formed by Champions from the most predominant University(s) in the country.
4. NRENs Boards must be representative in order to cater and protect the needs and interest of all stakeholders

This is however not uncommon with many of the NRENs on the African Continent and like the others are faced with the following issues:

1. Governance Structures that lacks the needed dynamism and strategy to resolve sustainability issues. The Governance structures must adapt like “chameleons” in an ever-changing administrative, environmental, financial and technological settings.
2. Lack of independent fulltime staff to implement and oversee operations and who will also responsible for the management of the services provided by an NREN. (casefornrens.org)
3. Lack of willingness to give up power/privileges and become more transparent: New Systems like NREN implementation may require a new order (Ciborra 2005) which can cause opposition, particularly when trying to achieve a more transparent process (da Silva et al 2013).
4. Competing interests— misalignments between personal or membership interests and the interest of the NREN, which would make an actor to behave in a manner detrimental to the NREN community (da Silva et al 2013).

3. Can there be a Sustainable African NREN?

African NRENs has gone through several iterations of starting and stopping, various Boards and memberships, and various models of operations, which did not make any significant process in providing a sustainable NREN. Current attempts to have a sustainable NREN have been directed towards providing technical and services oriented solutions by focusing on the business model and financial plan(casefornrens.org). Beyond merely the technical aspects of scalability, our concerns lie in how to reproduce and translate the necessary learning processes alongside the spreading of artifacts, funding, and people. (Braa, Monteiro et al 2004).
A conscious effort has to be made using the theory of Information infrastructures to look at the collection of governance, policy, structures, funding model, procedures and technologies that make up an NREN and its infrastructure in order to make it sustainable (Star & Ruhleder 1996). Without a conscious effort to achieve sustainable systems, initiatives from aid organisations, governments and NGOs are likely to replicate past outcomes of lengthy technology deployment and fast technology abandonment (Beardon et al. 2004).

Much of the Information Systems (IS) research during the last four decades or so focusing on the deployment and use of Information and Communication Technologies (ICTs) has argued for more active participation of the concerned users in various facets of systems design, development and use (Barki & Hartwick, 1994; Baroudi, Olson, & Ives, 1986; Fitzgerald, Russo, & Stolterman, 2002; Franz & Robey, 1986; Garrity, 1994; Hunton & Beeler, 1997; Ishman, Pegels, & Sanders, 2001; Mumford & Weir, 1979).

In order to leapfrog NRENs on the African continent into becoming a vibrant and sustainable NREN, the practices that have worked elsewhere on the continent should be reinforced. There is no need to rebuild the same problems in the new networks we are building. Instead there is a need to make the NREN stronger by building an organization with and active and vibrant community. In order to achieve this, interventions would have to be taken in the areas of governance, policies, procedures as well as the products and services that the NREN would be providing to its community of users and practitioners like Universities ICT Directors, Researchers, Academicians, Librarians and other stakeholders. All interventions and actions must lead to the “NREN sweet spot” in which there is strong support from the Government and membership (Dyer, 2009).

The selection of the mix of products and services would come at a time where the AfricaConnect2 project was about to take off. NRENs on the continent thru their RRENs stands to secure roughly 26.6M€ counter-part funding to afford equipment, connectivity, capacity building and other services. (Africaconnect2 (n.d.))

4. Developing an Action Research Approach for NREN

Action Research involves solving organizational problems through intervention while at the same time contributing to knowledge (Davison et al, 2004). Unlike much traditional academic research where the researcher decides on a problem and then negotiates access to a suitable research site, in Action Research the source of the problem and the initiative for seeking a solution may come from practitioners facing the problem who become in effect the client for the project. (Rose, S. et al 2015). Hence the author of this proposal will use several interventions and actions in order to determine which ones lead to the NREN becoming a vibrant and sustainable.

Research proceeds as a cycle of joint planning, action, observation and reflection, where the reflection phase paves the way for further cycles of planning, acting, observing and reflecting in a spiral of learning. (Rose, S. et al 2015). Hence the actions and interventions be replicated in two other NRENs in the West and Central African Region, namely the nascent Sierra Leone Research and Education Network (SLREN) and the Nigerian Research and Education Network (NgREN). This would ensure, the close relationship between knowledge acquisition and action; action research is ‘research in action rather than research about action’ (Coghlan & Brannick 2010).

Once the actions are taken to improve practice, the research generates new knowledge about how and why the improvements came about (Rose, S et al 2015). The new knowledge
generated could be used as the cornerstone to build vibrant and sustainable NRENs across the west and central regions of Africa and the continent as a whole.

As part of the action research approach suggested above, the following methods will be used: qualitative, cross-sectional and fieldwork involving several NRENs on the African continent but of particular interest would be the Ghanaian NREN, GARNET and others in the WACREN region. The study plans will be for the next 2 years and it will look at what interventions would have to be made in the areas of Governance structures and instruments, policies and procedures, programmes and activities, and the projects and services that the NREN would provide to its community. These interventions would then be recommended for replication in other NRENs in order to determine if it would produce similar results.

5. Making it work

By implementing the right actions focused at the governance, organizational structure and funding models as well as developing the right products and services that bring value to its memberships it would be possible to have a set of researched derived actions to make the African NREN vibrant and sustainable. By the end of the project, the researcher hopes to come out with a theory or blueprint about how NRENs should be formed in the African continent and what information infrastructures must be put in place in order to have a vibrant and sustainable NREN.

The key outcome of this project would be the set of actionable items for Governments, Donors agencies and other relevant stakeholders that are interested in either establishing or strengthen NRENs in Africa could use to ensure that they would be viable.

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Biography

Benjamin A. Eshun is currently the Head of ICT Services for Central University, the largest private University in Ghana. Under his watch, he is responsible for the sound ICT policies and sustainable strategies for their implementation that has radically transformed the ICT environment of the University. He is an NREN Evangelist and played a pivoting role in the development in the Ghanaian Academic and Research Network (GARNET), initiating action and support for the organization and the topology of the physical connections from various Development partners and several Public and Private ISPs. In conjunction with the Network Resource Startup Centre (NSRC) based in Oregon, USA planned and executed several training workshops for the Higher Education Institutions (HEI) community in Ghana in Campus Network Best Practices and Network Management and Monitoring.

He had previously worked over 10 years with the Association of African Universities (AAU) as the ICT Officer and in addition to several software development companies in Ghana. He also serves on the Board of Open Learning Exchange (OLE) Ghana an NGO working towards the fulfilment of the UN Millennium goal of attaining universal basic education for all. He has vast exposure to the state of ICT developments of universities on the International Academic arena and in the Africa continent in particular.

He holds a BSc. Computer Science and Physics and an Executive Masters Business Administration in Project Management from the University of Ghana, Legon. He is married to Esther, and together they have three children.
EOSC and the Free Riders

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Abstract

Big Data, Open Science and Technology are the topics on the agenda of the European Commission (EC) on one side and on the other side, ministries, research funding organizations, universities and public research institutions together with university libraries are bringing complaints about the access to scientific publications and research data also to the EC. Against these facts the EC has taken on the responsibility to realize the idea of Open Science and to favour the implementation of an European Open Science Cloud (EOSC), which “aims to develop a trusted, open environment for the scientific community for storing, sharing and reusing scientific data and results” (COM 2016). A High Level Expert Group (2016) has worked on the definition, the key trends in Open Science and the answer, how EOSC will be realized for the target group of European researchers and professionals in science and technology. The EOSC is an EU Member State Project. Non-European researchers can join the EOSC as free riders. Based on the findings of the HLEG this research will explore the question: What is the advantage for a research community from an emerging country to get a free rider position on the EOSC?

This research is primarily a literature review. Discussions with international researchers and Ethiopian university management presents insights about the advantages of a free ride position on the EOSC. An overview between the free rider problem as discussed in economic literature and the invitation to free ride on WIKIPEDIA and EOSC will conclude this research.

Keywords: Open Access, Open Science, 4th industrial revolution, free riding, innovation, Big Data

1. Background

The European Commission (EC) is discussing the 4th industrial revolution. In the European Open Science Cloud Workshop on June 29, 2016 on Governance and Funding, Andrus Ansip, the Vice President of the Single Market in the EC states, “[T]he industrial revolution of our time is digital. We need the right scale for technologies such as cloud computing, data-driven science and the internet of things to reach their full potential. The EU has this scale.” European Commission (2016) Guenther Herman Oettinger, EU Commissioner for Digital Economy and Market communicates the vision that the “European Cloud Initiative will unlock the value of big data by providing world-class supercomputing capability, high-speed connectivity and leading-edge data and software services for science, industry and the public sector.” European Commission (2016) Carlos Moedas, EU Commissioner for Research, Science and Innovation suggests that “[T]he European Open Science Cloud will make science more open, efficient and productive.” European Commission (2016) The expected outcome is seen in the European Open Science Cloud.
Data, Open Science and Technology are defined by the EC as the keys for the 4th industrial revolution and are packed in the European Open Science Cloud Initiative, which is built on the Digital Single Market (DSM) Strategy. “It aims to develop trusted, open environment for the scientific community for storing, sharing and reusing scientific data and results. … It aims to deploy the underpinning super-computing capacity, the fast connectivity and the high-capacity cloud solution. Focusing initially on the scientific community, the user base will be expanded to the public sector and to industry, creating solutions and technologies that will benefit all areas of the economy and society. (European Commission, 2016) As the target group of the EOSC EC has defined 1.7 million European Researchers and 70 million professionals in science and technology; additionally the higher education sector will have access to the EOSC from the beginning. Over time, the EOSC will be opened to government and business users.

The European Commission Directorate-General for Research and Innovation (RTD) sees the future of EU economic development in the “Open Access to Scientific Publication and Open Research Data” and promotes the dissemination of the original ideas in science and research into a functional system. The term Open Science has been introduced and enriched by the term ‘Open Access’ in the sense of Open Access to research data as the key for development and innovation. RTD’s Background Note highlights the benefits of the Open Access as improved scientific research, accelerated innovation and involved citizens and society. This all inclusive Open Access approach could result in an avalanche of information ‘Big Data’, which needs to be designed, collected, handled, stored, disseminated, mined and used. A Cloud, which combines data infrastructure, high-bandwidth networks and powerful computers will accommodate this ‘Big Data’.

A Commission High Level Expert Group (HLEG) has been assigned by the EC to work on the European Open Science Cloud (EOSC), its definition, the key trends in Open Science, and the answer how EOSC could be realized. Based on the findings of the HLEG this research will explore the answer to the question: What is the advantage for a research community from an emerging country to get a free rider position in the EOSC?

2. Methodology

This research aims to analyse the policy and governance recommendations provided by the HLEG and will elaborate on the example of Ethiopian research institutions and the Ethiopian Ministry of Education as the representative of all public Ethiopian Universities how to participate in the EOSC. Since Non-EU-Member States are not foreseen as partners in the EOSC they are pushed to take on a “free rider” position in order to participate and benefit from the EOSC. Discussions with researchers are used to structure the requirements of a successful free ride on EOSC and to overcome the general obstacles widely seen at Ethiopian universities.

3. Findings

Supporting arguments for Open Science come from different angles and have started already in 2012. For example, the Vice President of the European Commission responsible for the Digital Agenda mentioned that “Openness and sharing are not exclusive to the scientific community. … open data package … shows that there are benefits for web entrepreneurs, ordinary citizens, governments … But sharing data, and having the forum to openly use and build on what is shared are essential to science. They fuel the progress and practice of scientific discovery. According to Kroes (2012), “That’s why scientists have long sought out new tools and new ways to share their knowledge”

All European Academies (2013) (ALLEA) states in October 2013 that the traditional system for the publication and dissemination of scientific journals has shown some limits and
highlights on one side that in the scientific publishing sector is concentrated to some big players and on the other side to the fact that “public bodies which subsidise research have also to pay for permitting other researchers to access published research results.” University and research libraries are complaining about increasing prices for journals, while their budgets are static. Therefore, the libraries “have regularly cancelled serial subscriptions to accommodate price increases of the remaining current subscriptions. … [G]overnments, research funding bodies and research performing institutions world-wide have therefore developed open access policies to improve the access to the scientific publications resulting from the research they funded.” (Directorate-General for Research and Innovation (RTD) 2016)

Stakeholders such as ministries, research funding organisations, universities and public research institutions involve themselves in the definition and implementation of policies as well as in programmes, the production and dissemination of scientific results in order to widen the access to research results deriving from publicly funded research projects. At the supranational level organisations such as the Organisation for Economic Cooperation and Development (OECD), the European Union (EU) and the United Nations for Educational Scientific and Cultural Organisation (UNESCO) get engaged in defining agreements and setting the ground for Open Science. The EC has taken on the responsibility to bring the idea of Open Science into action and has started to coordinate the Open Science approach throughout the Member States. In a first step the EC intended to make publicly funded research (scientific publications and research data) openly accessible. The HLEG will advice the EC on the EOSC.

3.1 EOSC

Since the EOSC should not be understood as just the virtual cloud in a server room, the HLEG first defined the EOSC as “a supporting environment for Open Science and not an ‘Open Cloud’ for science. The EOSC aims to accelerate the transition to more effect Open Science and Open Innovation in a Digital Single Market by removing the technical, legislative and human barriers to the re-use of research data and tools, and by supporting access to services, systems and the flow of data across disciplinary, social and geographical borders.” Discussing the EOSC in the context of Open Science the HLEG refers to the EOSC as a need emerging from ‘conservative understanding of science to the current requirements’. This transition refers to the new modes of scholarly communication, modern rewards and recognition, increasing reliance on data experts, cross-disciplinary collaboration, fostering transition from science to innovation, etc.

In the frame of a “data-driven economy” (European Commission 2014) the term Big Data has been introduced and refers to large amounts of different types of data produced with high velocity from a high number of various types of source. In general, the importance of data is understood as the key for analyses that leads decisions making processes at all levels. Data analyses are guiding towards perceptions and knowledge, which are seen as source of innovation and employment. The Vice President of the European Commission responsible for the Digital Agenda justifies the EC lead in the Open Science discussion as “Big Data needs big collaboration”(Kroes 2012). In her speech, the Vice President made it clear that Open Science isn’t just about opening up data, but also about sharing research findings. In the Gremium of Open Science it is widely discussed to provide Open Access to peer-reviewed publications as well as to all research data that is funded by the public, to preserve data and to allow the re-use of scientific information. The HLEG sets out the data requirements for a successful EOSC as Findable, Accessible, Interoperable and Reusable (FAIR) and highlights the support through data related elements (software, standards, protocols, workflows) and the aspect of data management and long-term stewardship. The e-infrastructure necessary to handle Big Data and
to cooperate among EU partners has been organized by National Research and Education Networks (NRENs). The EU Member State NRENs cooperate under the umbrella of the GEANT University and Research Network.

The First Report and Recommendations of the HLEG (High Level Expert Group 2016) has structured the possible realization of the EOSC in to the sections of Policy, Governance and Implementation. For the sake of the elaboration of this research, the focus is brought just on Policy and Governance.

The HLEG comprises the Policy Recommendations into

P1. Take immediate, affirmative action on the EOSC in close concert with Member States
P2. Close discussion about the perceived need
P3. Build on existing capacity and expertise where possible
P4. Frame the EOSC as the EU contribution to an Internet of FAIR Data and Services underpinned with open protocols.

The Policy Recommendations address primarily to the EU Member States except P4, which opens the door for non-Europeans to participate in EOSC.

In terms of Governance Recommendations, the HLEG lists the following:

G1. Aim at the lightest possible, internationally effective governance
G2. Guidance only where guidance is due
G3. Define Rules of Engagement for service provision in the EOSC
G4. Federate the Gems (and Amplify Good Practice).

The governance recommendations could be understood as an invitation for Non-EU Member States to join the EOSC as free riders.

3.2 Free Riders

The economic literature mentions widely the problem of ‘Free Riding’, where a free rider is an individual that may be able to obtain the benefits of a good without contributing to the costs. The free rider discussion refers primarily to public goods, where the provider cannot exclude non-payers. But free riders also seen in cartels, where competitive producers restricting output and increasing price. In general, “[w]hen property rights are not clearly defined and enforced, the individual motivated by self-interest has an economic incentive to free ride at the expense of others in the group who attempt to promote self-interest through group behavior. … [I]n the case of collusive behavior to restrict competition, the free rider serves a beneficial role acting as an impediment to anti-competitive behavior.” (Pasour 1981)

With reference to the discussion about “The Trouble with ‘Free Riding’ (Lee 2008) it is demonstrated that free riding

1. not just refers to public goods;
2. does not request for government regulations;
3. is not necessarily a problem, but might also be a wishful situation to improve collective actions initiated by individuals;
4. attracts contributors and users (free riders).

Subsequently, the EOSC could take the Wikipedia success story as a best practice to make knowledge openly accessible. The major differences are seen in the following:

1. content refers to previously publicly funded projects;
2. dissemination of research findings for further exploitation;
3. acceleration of innovation processes through out all sectors by building on conducted research projects and their research data;
4. users and contributors to EOSC are primarily European researchers and professionals in science and technology, who are confronted in their daily life with research questions and hypotheses.

3.2.1 Free Riding on the EOSC
In the case of EOSC free riders demonstrate their self-interest on using research data and publication for continuous scientific/academic exploitation and education purposes and not for individual benefits as widely explored in economic literature. The objective of the free rider is to use research data for his/her own research projects as built on to accomplished research projects and to confront previously collected data with new assumptions, new research questions and hypotheses, in order to gain new (additional) perspectives and subsequently innovative ideas, which were not discovered under the initial research context.

Although there is a clear invitation to free ride on EOSC, there are clear limitations for becoming a free rider in the accessibility to the high-speed internet for the education and research sector; the so called national research and education networks (NREN). The access to NRENs (in Ethiopia the EthERNet) is the precondition to link with the Pan-European research and education network (GEANT) as the European knot for all European universities on one side and on the other side there is the accessibility to the e-infrastructure facilities at the workstation at the universities and research centres.

Since the term ‘free riding’ has a negative touch, but is understood as welcoming in the EOSC case, promotion has to reach out to research institutions from outside EU Member States. The invitation to free ride focuses on the exploitation of the research data and contribution to the findings communicated on the EOSC. University managements have to communicate the benefits of stepping in into a free rider position and have to promote the university’s strategy towards researchers and lecturers to encourage them to take on their individual free rider position on the EOSC.

Discussions with researchers showed that:
a) A successful free rider position on EOSC requires university internal:
   - Commitment to the understanding that research is important for the development of disciplines and the update of the lecture contents;
   - Understanding that economic growth and nation’s development depend on education and innovation. Universities and politics work together to set the framework for a smooth development;
   - Implementation of multi-disciplinary research teams: Positions of data experts/analysts as link between EOSC, IT-experts of the NREN and the researchers.

b) A series of obstacles universities face - for example in Ethiopia - needs to be overcome in order to accommodate an international research culture at the Campus so that facilities offered will be used. Some of those are the following:
   - Three-fold risks (human resource, time & money): the provided means to participate in the EOSC community won’t be taken; this leads to the capacity of the lecturers to participate in research; it needs also to become aware that many lecturers have long-term jobs besides their lecturing assignments, which are time consuming; the funding of research project is often insufficient that researchers/lecturers with a 2nd job
assignment will not risk losing their positions outside the universities for a short-term research project;

- Practice (client) oriented universities: most universities have the focus on teaching and not on research;
- Leadership issues: senior researchers and research assistants are not teamed up; in many universities the system to work in teams of senior and junior lecturers and researchers is not practiced;
- Lack of pro-active communication by national researchers towards the international research community: the researchers are used to be addressed by international researchers; they are not used to promote their own research project and research teams for international collaboration;
- Lack of confidence to approach international research communities: many researchers PhD degrees from Western universities are hesitating to approach their Western universities or doctor-fathers/-mothers for support in their research interests.

### 3.2.2 Advantages for ‘Free Riding’

In general, as a free rider, are searcher has the possibility to ‘slip-in’ into research projects and research communities.

More precisely, some of the advantages in a free ride on EOSC could be seen in the following non-exhaustive list:

1) Access to primary data collection that has been collected and funded by others;
2) Use, additional scrutiny, iteration and modelling of collected data with locally relevant assumptions might discover new insights and perceptions;
3) Access to international research communities with the same research interests;
4) Possibility to adjust research approaches from EU countries to make them fit to the local situation;
5) Each researcher - without big research budget - could find and excel in his/her niche at an international level;
6) Adjustments to research results published on the EOSC might lead to innovation and economic development in different local and national context;
7) Possibility of participating in high quality research at low costs;
8) Provision of a series of PhD topics;

### 4. Conclusion and Recommendation

The EOSC has means to disseminate research results and data as well as a source where researchers could find resources for further exploration and exploitation in different global contexts in order to accelerate innovation and development.

The EOSC enables accesses to researchers and professionals in science and technology in the following way:
Evaluating discussion with researchers and the WIKIPEDias success it is clearly stated that in the context of collective actions on the Internet have turned the free rider position from an economic problem to a wishful situation that moves away from the philosophy of public goods and government regulations.

Summarising the typical free ride discussion and comparing that with facts from WIKIPEDIA and EOSC brings out the following:

<table>
<thead>
<tr>
<th>Differentiations in:</th>
<th>Typical Free Ride</th>
<th>Wikipedia</th>
<th>EOSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kind of goods</td>
<td>Public goods (tangible and intangible)</td>
<td>Private good (intangible)</td>
<td>EU initiated good (intangible)</td>
</tr>
<tr>
<td>Remuneration</td>
<td>Tax, fee, fine, royalty</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Objective</td>
<td>To provide goods that would/are not be provided from the private sector</td>
<td>An online encyclopaedia project edited solely by experts, by providing additional draft articles and ideas for it.</td>
<td>To develop a trusted, open environment for the scientific community for storing, sharing and reusing scientific data and results.</td>
</tr>
<tr>
<td>Purpose</td>
<td>To provide services to the community for free or against levy or taxes based on the volume of consumption or social affordability</td>
<td>To feed the Nupedia project, which produces a free online encyclopaedia.</td>
<td>To make publicly funded research accessible for the global research community; To provide research data for further exploration and exploitation; To accelerate innovation providing access to research data from completed research projects to researchers and educators.</td>
</tr>
</tbody>
</table>
| Target group                  | Citizens of a nation                                 | Not defined by Wikipedia                            | - European researchers
- Professionals in science and technology |
| Free riders’ local characteristics | Nationals                                      | Citizens, who are using Wikipedia, but not contributing to its development. | Researchers form outside of EU Member States |

Figure 1: Accesses provided by EOSC
<table>
<thead>
<tr>
<th>Free riders’ consideration</th>
<th>To obtain the benefits of a good without contributing to the cost</th>
<th>To use and eventually to contribute to the overall result, if wished</th>
<th>- To use, model, iterate and exploit information provided on the EOSC; - To contribute to EOSC and the research community, if specific results for further research have been achieved.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>No exclusion</td>
<td>No exclusion if web- and computer facilities are available and accessible</td>
<td>Most likely just from the national education and research network (NREN)</td>
</tr>
</tbody>
</table>

In comparison the free rides on WIKIPEDIA run by itself, whereas EOSC will require facilitators to encourage university managements to provide the floor for possible free rides and to encourage researchers to join and contribute to the international research communities presenting their research data on EOSC. Allocating the advantages of free rides on EOSC depend very much on the framework set by the respective university management, which could accommodate the following:

- Information to researchers and lecturers about the applicability of Open Science, the access to EOSC and the potentials to cooperate with NRENs and GEANT;
- University administrations’ responsibility to promote the access to the high speed internet for research/study/teaching purposes;
- The active involvement of the triangle of the individual NREN, national Higher Education Facilitator and University present the frame that individual academics and students could participate in the EOSC.

The driving force of successful free rides are the self-interests of free ride researcher and their will to contribute to international research projects. The free ride on the EOSC is rather a gain than an economic problem as cited in literature. It will not cause damage to the genuine research team, because in general, once the data of the initial project has been published, the research project has been accomplished and the research team is - most likely – already in for the next project or is working on specific sequences of the original findings. Instead of bringing the research data in an archive the EOSC is promoting further exploration and exploitations.

The reuse, scrutiny and analyses of the provided data from a different cultural angle additional and new insights might be gained, which the previous research team has not thought of.

The free ride on EOSC could be seen as a win-win situation for the genuine research team in the same way as for the funding organization and the supporting private sector. A hierarchical approach could structure the free ride participants in three levels: the ground layers (genuine research team), the explorers and exploiter (free riders) and those commercializing the results (funding organisations and respectively the private sector).

The visualization of the cooperation hierarchy between the immediate research team, the mediate research team and the commercialiser lets assume that there is a gaining position for all parties. The mediate research team is not considered to lower the share of the immediate research team rather it will add to the ground layers’ results, what the immediate research team was not able to add. The share of the commercialiser gets increased by the contribution of the mediate research team.
The cooperation between the immediate (genuine) and mediate (free rider) research teams should become the common code of contact among them that an active exchange of thoughts could take place. Communication about the modelling, iterating and working process on the provided research data and newly found insights and perception could be discussed prior the free riders feed back their ‘manipulated’ research to the EOSC for the wider discussion in the global research community.

Overall, the global data stewardship and the creation of a global level playing field in scientific data sharing and data-driven science as mentioned in The European Open Science Cloud Workshop in June 2016 presents a clear invitation to a long-term free rider position but also to contributions, if the reuse, iteration and modelling of data led to specific results.

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Abstract
Software project quality in Zimbabwean universities has greatly depreciated due to exhaustion of many Information Technology (IT)-related topics and an infested reliance on the copy-paste philosophy from past researches online without acknowledgement. Over the years most graduates may possibly have been able to get away with project recycling in fulfilling their IT studies in Institutions of Higher Education. Despite the vast improvements in Information Communication Technologies (ICTs) and a plethora of scholarly research material on the internet, this has had a significant impact on production of novel research by students due to skyrocketing plagiarism cases. This research seeks to analyze the current project reviewing process in universities to unearth the drawbacks and to explore other tested interactive platforms which have been used in some institutions like the ECLIPSE-based platform and CPECAEE platform. By so doing the researchers of this paper will go on to postulate the design model of a web based interactive platform which adopts social networking and virtual school framework. The platform is meant to improve project quality through cultivating a spirit of team work in carrying out research work in universities and help grow the potential for start-up initiatives while students are still at college.

Keywords: Higher Education, Software project quality, Collaboration, Interactive platform, Zimbabwe.

1. Introduction
Zimbabwe universities offer diverse IT related programs ranging from a generalized computer science field to specializations like software engineering and information security. All these programmes demand a capstone project submission which is proving to be hard for many students. This has influenced open access platform initiatives by most higher education institute libraries so as to act as a leeway to research papers for local and well renowned journals although internet connectivity remains expensive for some upcoming institutes Mapito N., (2016). The Chinamasa (2014) study revealed that the availability of internet in universities...
has provided access to the global community which in a way provides students with a means to plagiarize work from other scholars or actually buy project write ups online. Using all the thirteen university institutions in Zimbabwe (both state and non-state) as the study population, a random sample of four universities (31%) comprising three state universities and a private university was used for the study. The three state universities include the Harare Institute of Technology (HIT), Midlands State University (MSU), National University of Science and Technology (NUST) and the private Women University (WUN). A questionnaire was used as an instrument for data gathering. An analysis of the responses to the questionnaire reveals that among other challenges faced by students, coming up with a project topic is not an easy task. Consequently project recycling is rife as no centralized repository exists linking all the universities since one project in one institute can simply be used in another as the documentation is not archived digitally. Chinamasa (2014) goes on to reiterate that despite most recent efforts by some universities to submit the thesis on anti-plagiarism software like Ephorus, Viper and Turnitin some still find a way to submit copy pasted researches especially in undergraduate studies. Moreover this is not only compromising innovation but the standards of education nationwide as some of the graduates go into industry with lack of expertise to carry out research and some have their brilliant ideas stolen by clever students. Biased assessment and lack of expertise in certain fields by project supervisors has additionally contributed to suppressed creativity and nurturing of brilliant ideas proposed by learners as discovered by the researchers. Henceforth project quality for current and future students in today’s universities is under threat. However, despite these challenges some state universities such as HIT, MSU and NUST have adapted E-learning platforms such as Moodle, Changamire and Sakai which are in part, an important step towards collaborative research. According to Taufer et.al, (2007), within a collaborative research environment, a myriad of challenges present themselves with respect to the storage, organization, sharing and communication of information within and across groups. Clearly, with regards to software projects at undergraduate level in the universities, a collaborative research platform will be an important step towards improving not only the quality of the software projects and innovation, but also of the graduates from these universities. Moreover, Taufer et.al, (2007) suggests that the challenges inherent in getting a research group to work together can be addressed in part by collaborative, web-enabled, electronic tools that facilitate the management communication and organization associated with a research project. To the best of our knowledge, no such efforts have been reported in literature with specific reference to Zimbabwe universities. To this end, with specific reference to software projects, our contribution is as follows; firstly we propose the creation of a platform which provides a discussion forum as a way of enhancing collaboration and review. This platform we believe will provide an interactive and reference platform for students as well as researchers. Secondly within the platform, the creation of a centralized project repository that will facilitate and allow rating of research work. Subsequently, students will be able to post and review projects at any university in Zimbabwe as long as they are subscripted and have privileges. Thirdly, a national software project framework for universities in Zimbabwe is proposed. This we believe, will provide better supervision and evaluation as many lecturers and evaluators will be involved in the process. The rest of the paper is organized as follows: Section 2 will focus on the related work of approved interactive platforms and subsequently analyze the current project reviewing system in section 3. We go on to propose a design model for project assessment with a design solution in Section 4. We then conclude our work in Section 5 and, ultimately provide recommendations and suggestions for future work in Section 6.
2. Related Work

Many definitions have been postulated by various scholars in relation to software projects. Pressman. (2010) strongly believes five main activities are necessary for any given software project to be successful which are; communication, planning, modeling, construction, and deployment. Furthermore (Pressman, .2010 and Sommerville, 2007)go on to indicate that a project needs to be managed well if it is to succeed using standard proven software engineering methodologies through use of a well organised team. (Ambati, and Kishore2004) give a comprehensive definition applicable in the academic sector by stressing on the software projects being carried out by a team whether students or researchers in institutions of higher learning. Also (Ambati,. & Kishore, 2004)highlights the team is guided by a team leader who can be staff member or senior researcher in formulating a large scale software systems and most of the projects will be well funded as long as one institution acts as the command centre. However (Ambati, & Kishore, S.P., 2004)illustrates that the nature of operation is changing as there are now intra-country, inter-region and global communities which are now collaborating in software development as influenced by technological improvements. As a means to simplify projects they are broken down into small tasks which are assigned to groups or individuals as per area of interest but still there are trivial issues which arise in collaboration, communication and controlling project creep as noted by (Ambati, & Kishore, 2004) and (Bouillon, Krinke. & Lukosch 2005) especially when sparsely distributed researchers are involved.

2.1 Collaboration Interactive Platforms

Many researchers have over time tried to address issues to do with collaboration and the advent of virtual schools was a great innovation as a means to enhancing effective distance learning as noted by (Clark, & Begre, 2005). Moreover they strongly believe that improvements in computer conferencing, computer based instruction, e-learning systems and the Web evolution have significantly influenced the establishment of virtual schools. These form of online platforms can be accessed at the comfort of one’s home and they have had successful stories in catering for the less privileged societies through Florida and University of California virtual school initiatives as stated by (Clark, T. and Begre, Z., 2005)in USA. (Bouillon., Krinke & Lukosch, 2005) subsequently attempt to tackle the collaboration challenge by designing an Eclipse-based platform which comprises two components CURE and Code-Beamer. The former was meant to provide the standard cooperation platform to be used for interaction by Fern Universities distance learning students and the latter was a project management solution. The platform enables students to work in groups in developing software engineering projects while interacting using wiki, mail, chat and group calendar which have been integrated in the eclipse environment. Code-Beamer is a server-based development tool which was used to provide project monitoring abilities and task allocation for the project team by attaching the plug-in, various trackers were made available in eclipse (Bouillon, Krinke, & Lukosch,. , 2005). Most importantly the Eclipse-based platform supports distributed software development and Bani-Salameh et.al, (2014) reiterates software developers have adopted the social interaction in their distributed development process. Farhan, Muhammad,, Anwar, & Mohsin (2011), report another collaborative CPECAEE platform. This kind of platform is an open source form of collaborative platform for universities initiated in the virtual university set up in Pakistan with the key drive to encourage students to participate in extra curricula activities. The study carried out by Farhan, Muhammad, Anwar, & Mohsin (2011) and Lukosch, (2005) research work, in terms of the availing an e-learning collaborative platform for learners by integrating CPECAEE with the robust Virtual University Learning Management Systems (VULMS). This will give students room to get access to all course material and instructors similar to Coursera (http://www.coursera.com) which is currently offering virtual learning to students and
professionals all over the world. In addition, Farhan, Muhammad., Anwar, & Mohsin (2011) discuss the importance of having an open source style collaborative platform for universities so that every student can learn practical and working methodology related to the software project. Both Bouillon, Krinke, & Lukosch., (2005) and Farhan, Muhammad., Anwar, & Mohsin (2011) emphasise the need for a supervisor for the students and use of a transparent grading system for the projects or group activities although not much in terms of providing peer reviews amongst the researchers not being in existence. In the quest for software project quality, Storey, Treude, van Deursen, & Cheng, (2010 ) note that today’s generation of software developers including university students have adopted the social networks as a form of platform for interacting with other software professionals and get to have access to fully fledged development tools with trackers on these web portals. Moreover Storey, Singer, Cleary, Figueira Filho, & Zagalsky, (2014) additional observations wherein they propose that social media in software engineering is contributing to a paradigm shift in three significant ways ranging from

- The rise of the social programmer that actively participates in online development communities;
- A rapid increase in the creation and discussion of technologies and crowd sourced content; and
- The formation of ecosystems around content, technology, media, and developers.

The researchers strongly propose integrating virtual school interactive framework (Ambati& Kishore, 2004), social media in software development using concepts of Storey, Treude., van Deursen, & Cheng (2010) and Bani-Salameh., Alwidian., Hammad., & Wedyan (2014). with the aspect of having peer reviews is key to production of software projects of high quality.

3. Analysis
3.1 Analysis of Current System

From the investigations done by the researchers in the current university set up they decided to make observations in four different universities in Zimbabwe and had assistance from students. They found out the current software project supervision and assessment process is manually done although some lecturers have incorporated use of Whatsapp and email as a way to keep in touch with students. The student initially has to identify a research area or problem and write a proposal which he or she has to take to a potential supervisor in the respective department for guidance. The feedback will then aid the student to come up with a suitable topic and to fine tune the project proposal after thorough investigations. The project co-ordinator has the responsibility to attend to student project related queries and provide required project guidelines while also informing the scheduled review dates. The first review date is for project proposal, this will encompass a panel of lecturers (mostly 3 individuals) gathered to assess the student project ideas, reject or accept them and try to assist students to refine their scope as indicated by Mapito, (2016). Furthermore Mapito, (2016) goes on to indicate It is at this juncture that the students will be given supervisors based on their areas of interest and usually the minimum ratio of student to lecturer supervision is 5:1 due to the increased universities enrolment. Although supervisors make aggressive efforts to cater for the large pool of students by creating social media project communities and email groups some still have a tendency of not seeking any form of guidance. When the proposal has been accepted the next phase will be project progress review involving continuous assessment of how much the learners have been able to do. The number of progress reviews will vary from each university like at HIT a
minimum of two are done in computer science related projects per semester. While at MSU and NUST they can be done at least one a semester. Usually evaluators for the project reviews are selected from the department and for the final presentation lecturers from other departments are invited. The reviews will seek to assess the problem being addressed, the software engineering methodologies used and the innovation improvised. The prototypes developed will also be evaluated at a separate review date and varies with each institute mandate. Students are encouraged to constantly liaise with their academic supervisors and produce documentation for each finished phase till project completion. However, most students don’t follow this advice and end up just copying past work so as to complete the projects in time for the final presentations due to limited time, many other courses they are studied and limited resources (Mapito, 2016).

![Figure 1: Current Project Reviewing and Assessment Process Data Flow Diagram (DFD)](image)

### 3.2 Drawbacks of Current Project Reviewing and Assessment Process
- Requires more effort and time from both student and supervisor
- Too much project recycling and data redundancy
- Project archive is usually a room full of paper reports and is not secure
- Poor data disaster recovery facility
- Feedback time from supervisor is long
- Biased criticism by evaluators and supervisors.
3.3 Proposed Solution Uses Cases

Figure 2: Use Case showing interaction between Student and Supervisor with System

Figure 2 above is showing the intended actions that the student will perform on the system like creating a discussion or topic, uploading a document, commenting and rating a project. Also depicts the supervisor actions like providing feedback and rating a project. As a security measure the uploaded document can only be downloaded by other students or lecturers upon the uploader’s approval thus giving access rights to owner.

Figure 3: Use Case showing interaction between Student, Evaluator and Project Co-ordinator

Figure 3 above shows the reviewer actions which can be carried out by a student, a lecturer or external evaluator who can comment and rate a project affecting the final project mark evaluation. The project coordinator can also post updates and respond to student queries on the platform.
4. Proposed Solution Design

The system data flow has been illustrated in figure 4 above and will be made available to four main users’ namely students, lecturers, evaluators and project co-ordinator. Before the various users can get access to the system they need to be registered by the administrator. The design model suggests that students initiate the discussion forum by creating a project topic and receive critics from any interested reviewers in the form of comments. The deliberation goes on till the student has a finite topic and has enough information to write a proposal using the institute guidelines provided by the project co-ordinator. The platform will allow the student to upload their proposal documentation which can be evaluated online and graded if accepted. The student gets to pick a supervisor(s) or vice versa through the co-ordinator according to the lecturer’s interest. The student and supervisor get to interact till the project is completed on the platform but other interested reviews are free to pass comments at each stage if given permission by the concerned topic creator. At each phase a report is uploaded which has to be accessed by authorized participants. Students with similar research areas get to interact on how best to create diversion there by enhancing collaboration and cooperation. This platform will also have independent evaluators thereby reducing bias and making the assessment transparent as other students get to be involved in the evaluation of their peers. Students get access to more material to reference their researches on and can even get advice on how to publish their work on the platform. The documentations will be stored at a central location and data backup will be performed regularly the system administrator (Mapito, 2016).
Figure 5 shows the proposed software architecture adopting a client-server architecture Pressman R. (2010) comprising of the client or user, Open Source softwares Apache web server and MySQL database thereby adopted (Ambati, V. & Kishore, S.P., 2004) and (Farhan, M., Muhammad, S.S., Anwar, M. & Mohsin, A.Q.) open style principles. The web server will enable development and deployment of the interactive platform on the web while storing the application web pages. The database server is going to be responsible for storing the user information and securing of the data.

Figure 6 shows the main modules to be implemented on the platform and the relationships amongst the objects to be developed using classes in PHP.
5. Conclusion

Project recycling and the diminishing originality in software projects in Higher Education is a cause of concern. The research established that the root of the problem lies in lack of creativity by students, adherence to the copy-paste philosophy from online material, restricted supervision, biased assessment and no centralized repository to try to curb inter-university project duplications. The proposed solution made the project reviewing process digitally interactive by Killen, (n.d.), promotes collaboration and helps reduce evaluation bias due to the fact that power has also been given to the students and external evaluators. Use of social media interaction on the platform will be familiar to most learners hence meant to increase more student participation as emphasized by Farhan, Muhammad, Anwar, & Mohsin, (2011). Much of the project will be kept digitally and can be referenced by any student from the centralized repository. The evaluation and supervision is done online thereby making the process easier to be done anytime and anywhere where internet existence (Clark, & Berge, 2005). Implementation of the interactive platform has created a more effective and efficient communication channel between students and lecturers while also promoting innovation (Mapito, 2016). Project quality will be improved as a result as learners get feedback from a diverse pool of individuals and get advice on how to publish their work.

6. Recommendation and Future work

The researchers would further develop an automated document reviewing section on the collaborative platform using concepts borrowed from other anti-plagiarism tools like Ephorus, Viper and Turnitin Software while allowing custom made parameters defined by the institute or body of exam. The platform will need to be extended to the mobile devices as the era of mobility is upon us and integration with a software development environment (Storey, Treude, van Deursen, & Cheng, L.T., 2010). A lot needs to be done in ensuring security as the document is uploaded to the review portal and offering a second authentication mechanism so as to reduce the cases of mistaken identity or hacker’s abuse as suggested by Mapito, (2016).

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Responding to the demands of big data scientific instruments through the development of an international software defined exchange point (SDX)

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Abstract

Science is being conducted in an era of information abundance. The rate at which science data is generated is increasing, both in volume and variety. This phenomenon is transforming how science is thought of and practiced. This transformation is being shaped by new scientific instruments that are being designed and deployed that will dramatically increase the need for large, real-time data transfers among scientists throughout the world. One such instrument is the Square Kilometer Array (SKA) being built in South Africa that will transmit approximately 160Gbps of data from each radio dish to a central processor.

This paper describes a collaborative effort to respond to the demands of big data scientific instruments through the development of an international software defined exchange point (SDX) that will meet the network provisioning needs for science applications. This paper discusses the challenges of end-to-end path provisioning across multiple research and education networks using OpenFlow/SDN technologies. Furthermore, it refers to the AtlanticWave-SDX, a project at Florida International University and the Georgia Institute of Technology, funded by the US National Science Foundation (NSF), along with support from Brazil’s NREN, Rede Nacional de Ensino e Pesquisa (RNP), and the Academic Network of Sao Paulo (ANSP). Future work explores the feasibility of establishing an SDX in West Africa, in collaboration with regional African RENs, based on the planned availability of submarine cable spectrum for use by research and education communities.

Keywords: Software-Defined Networking; Software-Defined Exchange; Science Data Applications, Big Data

1. Introduction

New scientific instruments are being developed in the southern hemisphere that will increase the need for large, real-time data transfers among scientists throughout the world. The Large Synoptic Survey Telescope (LSST) being built in Chile will produce 6.4 GB images that must be transferred to the U.S. in 5 seconds. The Square Kilometer Array (SKA) in South Africa will transmit approximately 160 Gbps (Gigabits per second) of data from each radio dish to a central processor. A Science Data Processor (SDP) receives data streams potentially as high as...
3 Tbps (Terabits per second). The SDP is responsible for producing ready-for-science data products, which are then distributed to regional science centers for analysis.

Simultaneously, a parallel activity is the construction of new fiber-optic submarine cable systems in the South Atlantic, directly linking South America and Africa along the southern hemisphere. The South Atlantic Cable System (SACS) links Fortaleza, Brazil to Luanda, Angola. SACS is under construction and is scheduled to be ready for service by third quarter 2018. The South Atlantic Inter Link (SAIL), formerly CBCS, links Fortaleza, Brazil to Kribi, Cameroon. SAIL is scheduled to be ready for service in 2018.

Currently, most science data flows from Africa’s southern hemisphere, destined to either Europe or the Americas, are transported north to either London or Amsterdam. Science applications that are delay sensitive are impacted, because of network latency, caused by distances across continents and oceans, and the number of network segments, involving multiple academic networks along the path, operated by different organizations. These new submarine cables will enable the construction of new network paths to potentially link the research and education communities in the southern hemisphere of Africa to Brazil, and other nations in South America, North and Central America, and the Caribbean. This is significant to big-data-generating science instruments like LSST and SKA that require large capacity bandwidth for high-throughput applications, and lower latency for delay-sensitive applications.

The network requirements for the SKA are significant. SKA literature refers to the following four types of network services (Ref): Science Data, Sync and Timing, Non-science data, and External connections. The network service for Science Data is required to provide high-throughput network transport, in order to move thousands of Gigabits of data per second. The network service for Sync and Timing requires low latency, high priority and low bandwidth. The network service for Non-science data is expected to carry a variety of network traffic types: Live observation critical data; testing, diagnostic and commissioning data; monitoring and control information; and general-purpose communications traffic (e.g., IP telephony). Finally, the network service for External connections will be required to support multiple 100G connections to external networks.

To achieve the aforementioned requirements, the end-to-end network path should provide high resilience, low delay, multiple paths, high bandwidth and an efficient control plane to act in all status changes (i.e., port status, devices outages, etc). Traditional networks possess limitations, such as sub-optimal resource utilization, forwarding based on destination MAC or IP address, etc. The operational complexity of managing different administrative domains, topologies, link technologies, devices, and requirements is challenging when using traditional network operations methodologies for provisioning, monitoring and operating networks. The AtlanticWave-SDX project aims to develop a capability to support applications, such as the LSST and the SKA, that have intensive network resource requirements.

The end-to-end path for the LSST will be composed of different academic networks, some of them supporting SDN and network programmability. Having information about network resources and control for programmability will enable LSST and SKA applications to react to network conditions in a more efficient way, sometimes even anticipating issues. For example, a link that will flap might be detected when a CRC/loss number increases. With network programmability, SKA applications will be able to provision multiple paths dynamically and on demand, apply QoS and prioritization policies, and manipulate flows at multiple levels. Using information made available by all network devices on the path, SKA applications will
be able to select the preferred paths from among several choices for sending its traffic from South Africa to the regional science centers around the world.

The end-to-end network path for SKA science flows will most likely be provided by multiple academic networks, in multiple countries, and in most cases, these networks are interconnected at academic exchange points. To achieve end-to-end programmability and control, all academic exchange points along the path must support network-aware applications. Fortunately, exposing network control capabilities to applications within a single SDN domain is now feasible and many academic networks (e.g., AmLight, Internet2, and ESnet) provide this capability today. This is not the case for applications that must span multiple domains. Most of the current Academic Exchange Points are still using traditional methodologies for forwarding (e.g., IP or MAC-based forwarding) and control (e.g., a NOC team controlling network devices through SSH and/or SNMP).

An academic exchange point supporting network-aware application features is called a Software-Defined Exchange, and it is considered the next step in the network evolution following the SDN line of thinking. This SDX must be open, programmable and resilient. All its external interfaces must also be secure and standard to support different kinds of network-aware applications.

The remainder of this paper is organized as follows. Section 2 presents background information and a literature review of previous SDX proposals. Section 3 describes the AtlanticWave-SDX architecture. In Section 4, a policy API is presented followed by a description of security challenges and how the AtlanticWave-SDX intends to respond to these challenges are in section 5. Finally, conclusions and next steps are presented in Section 6.

2. Background

Currently, there is no single, agreed upon definition of what a Software Defined Exchange (SDX) means. The spectrum of definitions ranges from Networking Exchanges to Cloud Service Exchanges, both capable of orchestrating resources across independent administrative domains. Moreover, below the SDX definition for networks, we can have: (1) Layer-3 SDXs that provide connectivity and routing between Autonomous Systems (AS) as in the case of an Internet Exchange Point (IXP); (2) Layer-2 SDXs for multi-domain Ethernet circuits; and (3) SDN SDXs to interconnect SDN islands. Likewise, the Cloud Service SDX provides access to compute and storage resources. In the next sections, we provide examples of recent Layer-3, Layer-2 and SDN SDXs, as those are more relevant to the AtlanticWave-SDX project; Cloud Service Exchanges could be seen as Federated Clouds or Hybrid Clouds. In Figure 1, we show a taxonomy for the Network Exchanges we consider in this paper, and examples under each category.

3. Layer 3 SDX

A Layer-3 SDX provides connectivity between different Autonomous Systems. The main characteristic of a Layer-e SDX is that a BGP process is required to handle the exchange of BGP routes. The minimum additional requirements are a SDN fabric and a SDN controller to install flows between the participants. It is desirable that the SDX has a Policy Manager to enrich the policies beyond what can be defined with BGP. Some examples of Layer-3 SDXs are SDN-IP (Lin et al 2013), Cardigan (Stringer et al 2013; 2014) and SDX (Gupta et al, 2014), which are described in more detail next.
(Lin et al. 2013) proposed a solution to enable BGP peering between SDN and non-SDN Autonomous Systems. To achieve BGP peering, the centralized SDN control plane integrates a BGP process; turning the entire SDN AS into a single BGP router from the point of view of its peers. The solution was developed as an application in the ONOS controller, and tested using an emulated Mininet topology. Experiments tested how the number of Routing Information Base (RIB) entries affected the memory incremental cost. The authors concluded that SDN-IP could scale up to 10,000 RIB entries, processing 100 RIB updates per second.

Cardigan (Stringer et al 2013; 2014) described a distributed router based on RouteFlow and a mesh of OpenFlow switches that are represented as a single logical switch. The goal is to implement a SDN-based distributed routing fabric. Cardigan’s datapath works in a full-mesh, like routers’ line cards and fabric cross-connects using proactive flow installation. Cardigan was deployed connecting the Research and Education Advanced Network of New Zealand (REANNZ) to the Wellington Internet Exchange (WIX), handling 1134 flows with a TCP performance of 800Mbps approximately.

Gupta et al (2014) proposed the design, implementation and evaluation of SDX, to improve the network management capabilities of BGP participants in an Internet Exchange Point (IXP). The main idea behind SDX is to present a virtual SDX switch to each BGP participant, so they can realize high level tasks such as: application-specific peering, inbound traffic engineering, wide-area load balancing, and redirection through middle boxes all while ensuring isolation between the policies. For this solution, each participant sends its policies to the SDX controller; then the SDX engine compiles the individual policies and installs a single set of policies on the SDX switch. The authors claim that just adding a SDN switch and controller to an IXP, as in the previous examples, is not enough to realize a SDX. The first version of this SDX was
implemented using Pyretic (Reich et al 2013) running on a POX controller, an enhanced version is being implemented using Pyretic and a Ryu controller (Ryu, 2015).

4. Layer 2 SDX

A Layer-2 SDX allows operators to create multi-domain circuits; typically using Layer-2 technologies like Ethernet VLANs. This scenario is mainly used in Research & Education Networks such as Internet2 and ESnet. For instance, Internet2's Advanced Layer 2 Service (AL2S, 2015) allows network operators to create their own Layer 2 circuits in the Internet2 AL2S backbone connection two or more endpoints. Similarly, the On-demand Secure Circuits and Advance Reservation System (OSCARS, 2015) accomplishes the same goal in the Department of Energy’s high-performance science network ESnet.

5. SDN SDX

The design objective of the SDN SDX is to interconnect SDN islands managed by different domains. The WE-Bridge (Lin et al, 2015) is a mechanism to enable different SDN administrative domains to peer and cooperate. WE-Bridge itself is not an inter-domain routing protocol, but a platform to exchange basic network information between different domains. The main goal is to improve inter-domain routing by announcing domain-views containing rich/fine-granularity information/policies, to enable various inter-domain innovations based on network information. This solution includes a network view virtualization, and a virtual network format and distribution using JSON. The peer relationships are established through a peer-to-peer control plane and a modified version of Link Layer Discovery Protocol (LLDP) to connect domain border switches. Contrary to the peer-to-peer approach used by the WE-Bridge, Mambretti et al. (2014a, 2014b) proposed a centralized Path Controller to manage the resources of federated controller in order to interconnect federated SDN islands.

Similar approaches are the Service Provider SDN (SP-SDN) (Kempf et al, 2014) and MEF’s Lifecycle Service Orchestration (MEF, 2015). Both proposals envision a service orchestration layer on top on the SDN control layer, which span different administrative domains. Some application examples presented in these projects are: elastic WAN, network slices on-demand, VPN circuits on-demand, and end-to-end Network-as-a-Service.

6. SDX Characteristics

As we have seen, a SDX could exchange BGP routes, Layer-2 circuits, computing and storage capacity. More generally, an important characteristic of an SDX is its ability to exchange networking, computing or storage resources in a common point, between independent administrative domains. Furthermore, the capability to apply richer policies to the exchange of these resources is another important characteristic of the SDX. Finally, in terms of security, strong isolation of constituent data and control interfaces is a desirable characteristic of a SDX.

7. Architecture

The AtlanticWave-SDX project is working to extend the SDX concept to a production deployment of a multi-domain international SDX involving initially three academic exchange points, which include SouthernLight (São Paulo/Brazil); AMPATH (Miami/USA) and SoX
AtlanticWave-SDX will provide application users with an end-to-end service that supports the traffic policy requirements of the application across multiple Autonomous

Figure 2: AtlanticWave-SDX network architecture

8. Systems and physical exchanges.

There are several alternatives for providing such an end-to-end capability. Figure 2 shows the proposed topology with three options of deployment. Option 1 assumes a single SDX controller that manages multiple IXP switch fabrics. While this approach is the simplest technical option, it is not ultimately viable in a distributed, multi-party environment. Option 2 introduces an intermediate slice manager, such as FlowVisor (Sherwood et al 2009) or Flowspace Firewall (FlowSpace Firewall, 2015), which allows individual controllers to be handed a slice of the network resources to be managed while isolating those resources from others. Option 3 creates a hierarchy of controllers with a local controller at each exchange being managed by a separate higher-level controller. We expect Option 2 to be the most practical approach for the near term and intend to focus here for the initial implementation and deployment. In this work, we are extending our previous work (Gupta et al 2014) in SDX design to include both lower layer concepts (e.g. VLAN stitching) and upper layer concepts (e.g., application-based routing, load balancing, QoS, etc). We are designing and implementing a software toolkit with APIs for application developers to tell the controller what demand they will introduce, at what times, and with what performance requirements, so the controller can plan/schedule the use of resources with prior knowledge of "when" and "what". The software developed in this project will be based on the SDX controller presented in Gupta et al (2014) and available from GitHub (Ryu, 2015).
This software is being actively used and extended, including ongoing work to deploy it on GENI (Berman et al 2014). The AtlanticWave-SDX project includes significant effort in “hardening” this software to make it production-ready and in extending it beyond the current Pyretic-based policy language to include programmable APIs for developers that support the specific application use cases identified here.

9. Towards a Policy API for SDX

Before talking about SDX policies, it is necessary to know what kind of applications can be deployed in an SDX. In Gupta et al (2014) the authors proposed four applications: application-specific peering, inbound traffic engineering, wide-area load balancing and redirection through middle boxes. In general, the four applications match fields of the TCP/IP header and apply actions accordingly. However, in Big Data science network service requirements, such as for LSST and SKA, the application needs to comply with certain latency and bandwidth requirements. These requirements cannot be defined using only fields of the TCP/IP header or the network topology status; the SDX controller requires external information sources such as SNMP, sFlow or perfSONAR (perfSONAR, 2015) measurements.

Taking into account the conditions described previously, there are several candidates for a Policy API for SDX. In Gupta et al (2014), the authors opted for Pyretic, a high level programming language for SDN. Similarly, the ONOS controller introduced the concept of intents for network policy specification (ONOS 2015). On the other hand, WE-Bridge (Lin et al, 2015) proposed JSON as its policy API. Other valid contenders for a Policy API are RESTful and XML interfaces. To illustrate what SDX policies would look like, we present three examples: application specific peering, on-demand circuit provisioning and bandwidth calendaring.

10. Application Specific Peering

Consider three Autonomous Systems (A, B and C) connected to an SDX. Both B and C are advertising the same IP prefix to SDX’s Route Server (See Figure 3). SDX’s Route Server decides which is the best BGP path for these prefixes and advertises it to A.

In this example (Coursera 2015), routes advertised by B are preferred over C, for instance, because of the AS-path length. For example, A might want its traffic destined for port 80 (dstport 80) to go to B, while traffic destined for port 4321 or port 4322 to go to C. This policy could be implemented as follows:

```java
if (dstport == 80)
    forward to B
else if (dstport == 4321 ||
    dstport == 4322)
    forward to C
```

Figure 3
This may be implemented in Pyretic as follows:

\[
\text{match}(\text{dstport} = 80) \rightarrow \text{fwd}(B) + \text{match}(\text{dstport}=4321/4322) \rightarrow \text{fwd}(C).
\]

11. On-Demand Virtual Circuit Provisioning

This application provides the capability of provisioning virtual circuits on demand like Internet2’s ADVANCED LAYER 2 SYSTEM and ESnet’s OSCARS. However, the SDX controller could take advantage of Network Measurement Systems, such as perfSONAR, to define Service Level Agreement (SLA) compliance and elastic WAN services, enriching the policies. In this scenario the SDX policy might look like:

\[
\begin{align*}
\text{if} & \quad (\text{current\_latency} > \text{SLA\_latency}) \\
\text{secondary} & = \text{findSecondaryPath}() \\
\text{while} & \quad (\text{current\_latency} > \text{SLA\_latency}) \\
\text{LoadBalance} & (\text{primary}, \text{secondary})
\end{align*}
\]

The while loop represents a dynamic policy. This behavior could be represented using Pyretic Dynamic Policies, ONOS Intents, an active polling mechanism, or a reactive triggered signal coming from the Network Monitoring System (NMS) (e.g. SNMP Traps). Another option is to use state machines as proposed by Kim et al. in Kinetic (Kim et al). The ideal scenario will be as follows: (1) The application sets an SLA (i.e. latency less than 10ms and packet loss lower than 2%); (2) the SDX controller sets an alert in the monitoring system to receive notification via SNMP traps or JSON messages; (3) whenever the SDX controller receives an alert, it will reconfigure the network fabric.

12. Bandwidth Calendaring

As proposed in Kempf et al (2014), bandwidth calendaring will allow the SDX to reserve bandwidth for particular times. This is particularly relevant for the LSST because images are going to be sent each night. However, the circuits used could be in different time zones, making the reservation a more interesting problem. A possible representation of the policy is:

\[
\begin{align*}
\text{scheduled\_time} & = 21:00:00 \text{ GMT -5} \\
\text{if} & \quad (\text{current\_time} == \text{scheduled\_time}) \{ \\
\text{BW} & = 90 \quad // \text{Bandwidth in Mbps} \\
\text{t} & = 60 \quad // \text{Reservation time} \\
\text{OnDemandVC} & (\text{BW}, \text{t})
\end{align*}
\]

Once again, Pyretic Dynamic Policies, ONOS Intents, or Kinetic style state machines are the candidates for implementation.
13. Security Concerns for SDX

Whenever new components are introduced in a network architecture, we also introduce new vulnerabilities; SDX is no exception. Considering the three types of SDX, we could say that the Layer-3 SDX will inherit all BGP vulnerabilities, the Layer-2 SDX will carry the same vulnerabilities of a shared Ethernet domain, and finally the SDN SDX will also introduce controller vulnerabilities. Such threats include DDoS attacks, attack inflation, exploitation of logically centralized controllers, compromised controllers (affecting the entire network), malicious controller applications, and negative impacts on recovery speeds (Kreutz et al 2015). Moreover, SDX introduces its own vulnerabilities as the SDX controller is a middle man that every participant has to trust, and there is a possibility that some participants will declare policies that interfere with the proper function of other participants. As a result, a trust relationship must be established between the applications loaded on the controller and the devices the controller manages (Shin et al 2014), (SDX Central 2015).

The security issues with BGP are: prefix hijacking, TCP specific attacks, and manipulation of BGP attributes. Prefix hijacking occurs when an AS mistakenly or maliciously announces a prefix that has not been assigned to it. Some common TCP attacks are eavesdrop, man-in-the-middle, and DDoS (which can cause route flapping). Controllers are even more susceptible to TCP-based attacks since few controllers actually use secure TCP connections (Kreutz et al 2015). Surprisingly, we observe that this issue occurs in spite of the OpenFlow protocol (McKeown et al 2008) allowing for an SSL secure channel between controller and switch. Already, several solutions (i.e., Resource Public Key Infrastructure or RPKI (Bailey et al 2014) and Secure BGP or S-BGP (Boldyreva et al 2012) have been proposed to make BGP more secure and eliminate prefix hijacking. In consideration of these security requirements, Bailey et al. (2014) combined RPKI and CARDIGAN to enforce the consistency of BGP announcements with its forwarding rules. Subsequently, mechanisms must also be developed to establish trust between controllers in order to ensure proper forwarding or detect malicious elements before a misconfiguration can occur and damage the network (FlowSpace Firewall 2015). Equally important is the need for fast recovery after a link failure to mitigate packet loss and time sensitive science data flows, such as the 17 second intervals required for the LSST telescope. This requires that mechanisms be incorporated throughout the network to notify the SDX controller of failures, so it can flush its flow entries and select new routes (Sharma et al 2011).

Concerning Layer-2 SDXs, LAN switches must be securely configured since switches in a shared Ethernet network are more vulnerable to malicious packets. A few examples of layer-2 attacks include MAC flooding, VLAN hopping, man-in-the-middle (via MAC address spoofing), and hijacking (Altunbasak et al 2005). Unfortunately, with SDN, detecting and mitigating these attacks now becomes the responsibility of the network controller. While we are working on methods for detecting rogue DHCP servers and spoofed MAC addresses within the SDN framework, such methods require additional compute resources from SDN controllers and may raise scalability concerns (Giotis et al 2014).

Finally, from the Policy perspective, we would like for the policies of each SDX participant to only affect its own policy space. As a consequence, strong isolation is one of the main security requirements. Furthermore, each SDX controller becomes the middle man that every participant has to trust. Thus, the controller functionality is a potential point of failure. For these reasons, controller resiliency and policy verification are desirable. Other countermeasures should include access control, attack detection, event filtering, firewall and IDPS, flow aggregation, forensics support, packet dropping, rate limiting, and shorter timeouts (Shin et al
Regrettably, most of these countermeasures are not yet fully supported and work is ongoing to implement them (Kreutz et al 2015; SDX Central 2015).

14. Conclusions and Next Steps

While an exact definition for a Software Defined Exchange (SDX) has yet to reach a consensus, astronomy projects, such as LSST and SKA with data-intensive high-throughput network requirements, present important use cases for furthering the development of SDX. In this paper, we discussed the AtlanticWave-SDX project’s goals, design, policy API, and security concerns. Once complete, the AtlanticWave-SDX will provide for an international long-haul network interconnecting Chile to the U.S., and potentially Africa, in the future. Additionally, with network programmability, applications of astronomical instruments will be able to provision multiple paths dynamically and on demand, apply QoS, prioritize policies, and manipulate flows at multiple levels. Furthermore, by using information made available by all network devices along the path, these applications will be empowered to choose preferred paths from multiple transit options between the northern and southern hemispheres.

Acknowledgments

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References


Biographies

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**Heidi L. Morgan, PhD.** is Senior Computer Scientist, Information Sciences Institute (ISI), University of Southern California (USC), and Research Scientist Associate, Center for Internet Augmented Research and Assessment (CIARA) at Florida International University. She is a Co-PI for several NSF funded projects including SwitchOn – Exploring and Strengthening US-Brazil Collaborations in Future Internet Research (switchon.ampath.net), Americas Lightpaths: Increasing the Rate of Discovery and Enhancing Education across the Americas (amlight.net) and the AMPATH International Exchange Point in Miami. Heidi enjoys working to advance research and education networking initiatives in the Caribbean, Mexico, Central and South America and collaborating with likeminded professionals in the US and around the world.

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Grid Computing, Compute and Data Storage Services

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Abstract

The development of grid computing is a cutting-edge technology that brings a number of benefits for many Universities and Research Institutions around the world. Grid computing enables Universities and Research Institutions manage Information Technology resources in a centralized multi-core architecture, irrespective of their location in the world. It enables them to solve their ever increasing computing and storage problems. Universities and Research Institutions would undoubtedly enhance the quality of their output, while reducing costs by sharing resources through Grid technology. A number of Universities and Research Institutions believe that grid computing has the capacity to improve research work and other University operations, especially among the growing Institutions in Africa. Nevertheless, many African Universities and Research institutions have not yet embraced and adopted the use of Grid Computing Technology. Accordingly, there is a need for an extensive study in the adoption methods of this technology, especially among NREN member institutions in Sub-Saharan Africa. Study on such Information Technology solutions are needed to align academic processes to improve the utilization of grid computing and reduce the cost of computer hardware and increase in computing power. To examine this, the researchers will adopt a comparative research design to evaluate several related cases and NRENs operations within the region and Uganda in particular. These cases will provide the researchers with a clear difference, the benefits, the implementation method and the challenges of adopting grid computing technology. Subsequently, the NRENs would make use of these results to adopt such technologies.

Keyword: Grid Computing.

1. Introduction

Grid computing has become crucial in distributed computing, specifically among university research, (Xhafa & Abraham, 2010). Grid computing provides a degree of service and resource sharing that will go beyond even the internet as they will not only change the method which data is accessed, also how this information is created, used and also kept. Grid computing focuses on making sure that all resources are available on a regular basis, (Zhang, Chen, Zhang & Huo, 2010). Many huge firms such as Boeing are presently using grid computing to improve their operations. Nonetheless, future grids will permit universities and also organizations to benefit from computing since using grid computing improves effectiveness as well as reducing business costs and will be a catalyst for economic expansion and organization growth, benefiting markets across numerous sectors and university resources sharing and also research, (Moreno-Vozmediano, Montero & Llorente, 2013).
The current grid computer model highlights the sharing of computational cycles as well as is tailored to compute-intensive and parallelizable applications, (Avram, 2014). As this version develops, it will certainly enable university systems to share other resources, such as storage, data and computer software. This evolution will certainly increase the requirement for high bandwidth interactions throughout the grid and also enhance its importance as a possible source of development. Grids create a dispersed network of computers that share sources over a heterogeneous collection of systems, merging resources to ensure that numerous computer systems can share work and comfortably access remote resources. There is a clear need for grid computer in medicine layout, geophysical prospecting as well as mechanical engineering in universities as Grid computing utilizes the idle time of hundreds or thousands of web servers that could be leased to any person who requires massive processing power, (Tian, & Fang, 2014).

Nonetheless, the needed communication framework to support large-scale grid computing in African universities and particularly in the sub-Saharan Africa has actually not yet been established (Bothun, 2016). Security is a prime problem; it might be difficult to persuade people to invest in a technology that seems to provide outsiders with access to their servers. However, there is need to note that network restrictions will not interfere with the capability of users to access computational power, yet these restrictions will be a constricting factor in the advancement of complete resource-sharing models. The broad adoption of grid computing in universities depends on solving technical and economic problems, including end-to-end safety. One more challenge is postured by the typical business software program, which is not tailored to support the grid version. It is vital for grids to have interoperability standards that fit elements from different vendors. However, XML is starting to play a vital role in solving this issue, (Dean, et al., 2012).

Many managers in organizations and academicians in universities are not knowledgeable about the advantages and characteristic of reducing the expense using Grid computing (Bothun, 2016). Information technology companies aspire to motivate educational institutions to adopt the use of grid computing; for instance, Pharmaceutical giant Novartis has actually linked nearly 3,000 of its scientists’ desktop computers in a grid that provides more than 5 teraflops of computing power. This allows their scientists examine bigger information sets with higher precision and to target new issues (Aher, 2012). Bank One is utilizing grid middleware innovation to disperse risk-analytics processing. It aims to cut hardware expenses while increasing the performance of analytics for its interest-rate derivatives trading business. Johnson & Johnson uses grid innovation to run powerful applications that design scientific trials of pharmaceuticals. Entelos, a biotechnology company in California, uses a grid structure to speed the procedure of drug discovery. It can run simulations in a matter of hours or days with its network. A variety of innovation companies have actually made possible platforms for educational use within grid computing and offer global forums for educators, scientists and Information Technology specialists from education industry to pursue grid computing initiatives, establish abilities and share finest practices for decreasing operating costs while enhancing quality and access to education, (Rittinghouse & Ransome, 2016)

2. Statement of the problem

In an enterprise, servers typically sit idle, with just 10% to 20% of servers storage and computing power utilized, (Lee & Zomaya, 2012). Computer resources are even less utilized about 1% or 2% of these resources are used on average. This suggests that grid computing can leverage substantial amounts of idle business resources.
Therefore, there is need to study how Grid computing can be adopted by the NRENs that are endeavoring to meet the global competition with renowned institutions around the globe

3. Main objective

To develop a suitable Grid Computing Model that could be adopted by the NRENs in the Region and Uganda in Particular for more effective and efficient academic and research activities among its members that would stand the tests of time.

4. Specific objectives

i. To study the existing grid technology usage among the NRENs in Uganda and collect requirements for a suitable model for improving research and academic activities.

ii. To design a suitable grid computing model for improving research and academic activities among NRENs in Uganda.

iii. To implement a prototype of the developed model.

iv. To test and validate the developed prototype

5. The concept of grid computing

Grid computing is a computer network in which each computer's resources are shared with every other computer in the system. Processing power, memory and data storage are all community resources that authorized users can tap into and leverage for specific tasks. A grid computing system can be as simple as a collection of similar computers running on the same operating system or as complex as inter-networked systems comprised of every computer platform you can think of. (http://computer.howstuffworks.com/)
6. Grid computing architecture

The Grid Computing Architecture consists of

6.1 User

The users could be any individual devices connected to the grid server through guided/unguided media, and these devices must house a collection of computer software program referred to as middleware. The essences of having the middleware in place are to allow different computers to run a process or application across the entire network of devices. Actually, the Middleware is perceived as the workhorse of the grid network. Communication in any grid network may not happen without this middleware. However, the challenge is that there’s no standard format for middleware.

6.2 Grid Server

There must be at least a mainframe computer system, i.e. a server, which handles all the administrative duties for the entire Grid network. In other words, this mainframe computer may be called a control node. However, different applications and Web servers in the Grid network, no matter the media connection type, provides specific services to this Grid server,

6.3 Grid Clients

This tier consists of interconnection of computers running special grid computing network software. These computers act both as a point of interface for the user and as the resources the
system will tap into for different applications. Grid computing systems can either include homogeneous system i.e. several computers of the same make running on the uniform operating system or heterogeneous system i.e. different computers running on various different types of operating systems. It will also be very important to note that the interconnectivity of these Grid clients could be done through the use of guided or unguided media technology.

7. Methodology

This research will adopt an integrative model of both qualitative and quantitative methods. An analytical research design will be done to evaluate several related cases and comparative design to NRENs operations within the region and Uganda. These cases will provide the researchers with clear business requirements; these will be used for analysis and design of a suitable Grid computing model for the NRENs using a UML notation and this model will be implemented using Network simulation tools, such as NS2 or OMNet++, and to test and validate the operation of the prototype.

8. Conclusion

Grid computing is a brand-new approach to producing a solution for old issues. This technology offers lots of advantages to business, industries and universities. Many substantial Information Technology companies establish new Grid-based applications and construct new Grid facilities. The majority of the research in literature focused on advantages, chances, downsides, risks and configuration of Grid computing for enterprises. Having gone through these, we can confidently establish that Grid Computing can also be utilized by all the NREN member Universities in the East African region and beyond. Furthermore, the use of Grid Computing in universities has many benefits such as accessing the file storages, e-mails, databases, educational resources, research study applications and tools anywhere for professors, administrators, personnel, students and other users in university, on demand, to mention but just a few. Therefore, there is need to study how Grid computing can be adopted by the NRENs in the pursuit of meeting some of the goals of the UbuntuNet Alliance. In addition, study on such Information Technology solutions are needed, in order to leverage by aligning most academic processes with information technology to improve the utilization of grid computing and reduce the cost of computer hardware and increase in computing power.

9. Proposed Budget

The summary of the proposed budget presented on the next page contains five main spending categories. First, the research team (see Professional Honoraria) is composed of a Systems/Analyst (SA). The SA will assist with analysis, coordinate the research and write the majority of the document and as well will be responsible for leading the research and writing all relevant part of the report. The SA will also advise on methodology and provide recommendations. Additionally, it will be necessary to hire a Network administrator and a Full Stack systems programmer who will be contracted for advising on the technicalities and implementation of the proposed Grid Computing Model.

The second part of the budget is attributed to data collection efforts within the five main areas of research – Data collection, Analysis, Design, Implementation, and Testing. This section is calculated in accordance to the necessity. The travel related expenses considers four round trips to and from Morocco, Tanzania, Kenya, and various districts in Uganda between February 2017 and October 2017, the trip to Morocco will be for learning experience as well as other contingencies which may not have been covered
in the budget, there will also be a trip. Subsequently, a prototype Grid model will be ready for presentation in the UbuntuNet Connect conference by November 2017. (Annex 1)

References


Websites:

http://computer.howstuffworks.com/
## Annex

### Annex 1 Research Proposed Budget

<table>
<thead>
<tr>
<th>Cost (US$)</th>
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</thead>
<tbody>
<tr>
<td>1. Professional Honoraria</td>
</tr>
<tr>
<td>Systems Analyst</td>
</tr>
<tr>
<td>Network Administrator</td>
</tr>
<tr>
<td>Full Stack Systems Programmer</td>
</tr>
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<td>Sub total</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost (US$)</th>
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<tbody>
<tr>
<td>2. Data collection</td>
</tr>
<tr>
<td>Data collection will require a total of 990 “research assistant hours (RAH)” at $8.00 per hour. The project will gather and analyze data in the following countries in the East African region</td>
</tr>
<tr>
<td>i. Uganda</td>
</tr>
<tr>
<td>390 RAH to gather data from around 50 Campuses and carry out analysis</td>
</tr>
<tr>
<td>ii. Kenya</td>
</tr>
<tr>
<td>400 RAH to gather data from around 57 Universities and carry out analysis</td>
</tr>
<tr>
<td>iii. Tanzania</td>
</tr>
<tr>
<td>200 RAH to gather data from around 27 institutions and carry out analysis</td>
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<tr>
<td>Sub total</td>
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<table>
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<tr>
<th>Cost (US$)</th>
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<tbody>
<tr>
<td>3. Travel Related Expenses</td>
</tr>
<tr>
<td>Two round trip tickets to/from Uganda and Kenya for two people @ $500 each person</td>
</tr>
<tr>
<td>Lodging expenses, meals and per diem@$2800 (14 day, $200 per day for each person)</td>
</tr>
<tr>
<td>Two round trip tickets to/from Uganda and Tanzania for two people @ $560 each person</td>
</tr>
<tr>
<td>Lodging expenses, meals and per diem@$2800 (7 day, $200 per day for each person)</td>
</tr>
<tr>
<td>One round trip tickets to/from Uganda and Kenya for one person @ $2721 Plus</td>
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<tr>
<td>Lodging expenses, meals and per diem@$1400 (7 day, $200 per day)</td>
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<td>Sub total</td>
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</table>

<table>
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<tr>
<th>Cost (US$)</th>
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</thead>
<tbody>
<tr>
<td>4. Technology Cost</td>
</tr>
<tr>
<td>i. Softwares:</td>
</tr>
<tr>
<td>OMNeT++ (stands for Objective Modular Network Testbed in C++)</td>
</tr>
<tr>
<td>UML (stands for Unified Modeling Language)</td>
</tr>
<tr>
<td>ii. Hardware:</td>
</tr>
<tr>
<td>Two PCs, a Printer and other Scholastic materials</td>
</tr>
<tr>
<td>Sub total</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Contingencies</td>
</tr>
</tbody>
</table>

| Total Proposed Budget ($) | 51281 |
Securing Campus Wireless LANs

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Abstract
Most KENET member institutions of higher learning have deployed a campus WLAN. The campus WLAN is deployed in areas across campus where most students have access, including lecture halls, hostels and social areas. However, the campus WLAN is not secure and in most campuses is open (not secured) or uses a shared secret. Some universities have used mac address authentication on a campus WLAN, a solution that does not scale and mac addresses can be easily spoofed.
KENET has deployed campus WLANs in over 25 member institutions campuses. This paper will document the lessons learned from previous WLAN deployments focusing on campus WLAN design, autonomous versus lightweight access points, WLAN security, 802.1x, AAA and migrating to eduroam.

Keywords: campus WLAN, eduroam, Authentication, challenges, AAA, BYOD, network monitoring, open source tools, access points

1. Introduction
Kenya Education Network, (KENET), is the National Research and Education Network (NREN) of Kenya. KENET provides affordable and low-congestion Internet services to educational institutions in Kenya. KENET is licensed by the Communications Authority of Kenya (CA) as a not-for-profit operator serving the education and research institutions. KENET provides affordable, cost-effective and low-congestion Internet bandwidth to member institutions in Kenya. Bundled with the Internet connectivity, KENET provides to its members Shared service such as web-hosting, training and capacity building, and VPNs. KENET also provides Research services such as Identity provision, digital certificates, web conferencing and eduroam.

KENET has deployed safe and secure campus WLANs in over 25 member institutions. The solution seeks to provide end-to-end security, protecting WLAN endpoints, infrastructure and client communications.

2. WLAN Design Considerations
This section discusses some items that should be considered when designing wireless networks.

a) Site survey
Site surveys should be performed in order to determine the optimal access point for the
location and to identify the possible access point locations to minimize interference while maximizing the range.

b) Regulatory domains

Devices that operate in the unlicensed band do not require a formal licencing process by the end user. However, equipment designed for operating 802.11 in the ISM bands is obligated to follow government regulations for the region it is to be used. WLAN devices must comply with the specifications of the relevant governing regulatory body within the country.

c) Capacity

Capacity here does not refer to the bandwidth, but rather the ability of the WLAN to provide reliable and available connectivity to the clients in the coverage area. During design, the number of eventual clients and the application traffic requirements needs to be anticipated – this will influence the number of access points to be deployed.

d) Infrastructure

The wired LAN infrastructure needs to be able to support the traffic generated by the wireless devices. The available bandwidth needs to be sufficient to support the clients. KENET deploys eduroam on a separate VLAN. This allows for flexibility when applying policy to the different network segments.

e) Power

Power requirements of the access points and for the client devices needs to be taken into consideration. If access points support Power over Ethernet, make provision for PoE switches. Otherwise use the power injectors.

f) Monitoring

Monitor the wireless infrastructure nodes to ensure that any downtimes are promptly resolved. Inter-switch trunk links and ports connecting to access points should be monitored for clear visibility of traffic consumption.

3. WLAN Security Mechanisms

The main issue with wireless communication is unauthorized access to network traffic, by sniffing the network. Unlike the wired networks, where a hacker would need to be physically located at the premises, with a wireless network, the intruder can access the network from a location outside the building.

The most common security mechanisms for WLAN networks are:

I. Open authentication with no encryption

Open authentication provides no way for the access point to determine whether the client is valid. It is therefore an insecure way to deploy WLANs and is not recommended.

II. Wi-Fi Protected Access (WPA)

WPA uses Temporal Key Integrity Protocol (TKIP) for encryption and dynamic encryption key generation with either a pre-shared key or a RADIUS/802.1x-based authentication. WPA provides more robust security to WEP.
III. Wi-Fi Protected Access 2 (WPA2)

WPA2 provides certification in both Enterprise and Personal classifications. The Enterprise classification requires support for a RADIUS/802.1x-based and EAP for authentication. Personal classification requires only a common key shared by the client and the AP. WPA2 uses Advanced Encryption Standard (AES) and TKIP for encryption.

4. 802.1x

IEEE 802.1x is a standard for authentication on wireless and wired networks. It provides WLANs with strong, mutual authentication between a client and an authentication server. It also provides dynamic per-user encryption keys, removing the administrative burden and security issues surrounding static encryption keys.

With 802.1x, the authentication credentials are encrypted then transmitted over the wireless network. TKIP or AES are used for the encryption.

After mutual authentication has been successfully completed, the client and RADIUS server each derive the same encryption key, which is used to encrypt all data exchanged, resulting in a per-user encrypted session.

802.1x has three layers:
1. The supplicant software which runs on the client device
2. The authenticator which is the access point in WLANs
3. The authentication server which is the RADIUS server

5. eduroam

5.1 What is eduroam

eduroam stands for education roaming. eduroam is a safe and secure service that employs WPA2 Enterprise security mechanism, with AES and TKIP encryption and 802.1x and EAP for authenticated access to the network. The eduroam service was developed for the international education and research community, offering wireless internet access without the need of multiple logins and passwords, in a safe, fast and simple way.

5.2 eduroam Topology and Requirements

KENET has deployed safe and secure campus WLANs in over 25 member institutions. The solution seeks to provide end-to-end security, protecting WLAN endpoints, infrastructure and client communications.
The WLAN topology is made up of the following components;

1. Access points and wireless LAN controller
2. WLAN clients with 802.1X supplicant software
3. RADIUS protocol carrying extensible authentication protocol (EAP) packets between client and the authentication server
4. Authentication server (Authentication, Authorization and Accounting (AAA) server)

KENET deploys eduroam on a separate VLAN. This makes it easier offers flexibility in applying policies to the various segments of the LAN.

5.3 Previous eduroam Projects

In the year 2013, KENET received funding under the KTCIP/Kenya ICT Board infrastructure grant and successfully implemented WLANs in ten member institution campuses. Most of the institutions did not have proper campus WLANs at the time and the project was designed as a template on how to deploy WLANs for the institutions to build upon. Each campus was allocate a Cisco 5508 wireless LAN controller, a server, Cisco 1552e outdoor access points and Cisco 3500 indoor access points.

KENET deployed more WLANs in 2014 and 2016. The 2014 project targeted nine campuses, deploying a Hp Unified solution. In 2016, WLANs were deployed in seven campuses, using Ubiquiti Unifi access points.
Conclusion
The WLAN deployments implemented by KENET have not gone without challenges. Some of the challenges faced include theft of access points and challenges in updating the database of users for each campus. eduroam was successfully implemented in the campuses of various Universities. Students, staff and researchers have access to safe and secure Internet.

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Biographies
Joan Masai is a Network Administrator at KENET. She has been working at KENET since 2012, working at on network operations, network development and campus network direct engineering support. She holds a Bachelor of Science in Networks and Communication Systems from the University of Eastern Africa, Baraton. She is a member of the IETF Africa chapter. Her current interests are in the areas of Network Security and Cloud computing.
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Video-Conferencing for Outreach Communication Strategy to Enhance Academic Publishing and Research Communication in Africa

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Abstract

The paper presents the effectiveness of video-conferencing community outreach projects in enhancing research ethics communication for public awareness in Uganda. It sets out to establish how vital the practice of research ethics in cross-cultural environment was in enhancing the smooth tripartite interactions among the researchers, communities and host institutions. The objectives were to: get an overview of community outreach research ethical issues and communication strategies; establish researchers’ outreach methods (approaches); identify the ethical challenges facing inter-cultural research in the country; assess the key enablers of community research ethics; and discover creative methods of infusing ethics in a cross-cultural community research. This review was conducted by sourcing documents, current literature and news bulletins, online search engines, through discussion with key informants, documents from Ugandan government specifically the ministries or national as well as international bodies, and lessons learned from research ethical practice. The findings were generally disappointing, contrary to the widely issued guidelines. There are rampant unresolved ethical issues that are worsened by communication gaps; field ethical challenges include: wrong attitudes, behaviour, methodology, perceptions, communication strategies, and cultural illiteracy; commonalities of outreach themes, agreements, modalities, methods, target communities, networks, and funding sources; many absentee field researchers and fictitious research sites; and weak ethics culture. Ethical issues are prompted by flouting guidelines, weak or lack of capacity, experience, integrity, professionalism, communication skills, or ignorance. There are multiple gaps in university coordination, concepts, methods, planning, budgeting, and implementation leading to project failures, budget overruns, conflicts, and disincentives. Community participation ensures trust, effective communication, and social acceptance. Inter-cultural community involvement promotes ethical research good practice among the researchers themselves on one hand, and the inter-cultural demographics plus the host institutions, on the other. Outreaches are critical for achieving early adoption and widespread diffusion of research ethics and culture in communities. They should be well planned, implemented, monitored, and evaluated for enhanced participation, transparency, empowerment, mutual trust, sustainability, and gender equality to achieve SDGs in Uganda.

Keywords: NRENS, video-conferencing, outreach communication, research communication, gender equality
1. Introduction

The paper presents the effectiveness of video-conferencing community outreach projects in enhancing research ethics communication for public awareness in Uganda. It set out to establish how vital the practice of research ethics in a cross-cultural environment was in enhancing the smooth tripartite interactions among the researchers, communities, and host institutions. Outreach activities are critical for making the relevance of university education and research a reality to the local communities in African countries like Uganda (AICAD, 2011). It is imperative that all Uganda universities plan, develop, implement, monitor, and evaluate the effectiveness of outreach policies, programmes, projects, and activities from the 2015 MDGs to 2030 SDGs (Okaka, 2015). The principal issues are: community outreach research issues and communication strategies; researchers’ outreach methods or approaches; quality assurance (QA) challenges facing higher education institutions (HEIs) in view of the SDGs especially achieving SDG 4 progress on universal access to quality education for all. Policy makers as well as the public devote considerable attention to the outcomes of higher education (Okaka 2009, 4). For some aspects of higher education outputs and outcomes, such as the type and number of degrees awarded, the research outputs produced or the labour-market returns to higher education studies, numerous indicators exist at both national and international levels (OECD 2007). For example, the key issues of university and higher education in Tanzania largely revolve around the following (Msolla 2000, 5): financing, expansion and access, quality assurance and relevance, information and communication technology (ICT), building a skilled human capital, and research. Infrastructure services for ODEL QA outreach services.

However, quality assurance and relevance calls for improving accessibility to higher and technical education must go in tandem with quality assurance for the education being provided for (Msolla 2008). There has been some feeling among members of the public #that the quality of education, both at school and University levels is declining (Msolla 2000). The decline is in part attributable to laxity in the enforcement of the known quality control measures, and in part due to lack of a national qualifications framework (NQF).

Likewise, a report at the first European forum for quality assurance in Munich said that the development of a quality culture demands: open, active commitment to quality at all levels; willingness to engage in self-evaluation; a firm regulatory framework; clarity and consistency of procedures; responsibilities for quality control and quality assurance; emphasis on obtaining feedback; commitment to identifying and disseminating good practice, as well as prompt managerial action to redress problems (Newton, 2006).

In addition, it states that quality as a transformation evolves through: development or empowerment of student by learning process; institutional changes enabling better learning or research; accreditation that explores value-added elements to widening access; external examination of research degrees to evaluate transformation; principal evaluation mechanism for improvement audit, as well as forward-looking and agenda-setting. ODEL offers the prospects (Okaka & Nagasha, 2016.).

2. Problem Statement

Although university - community video conferencing (meeting) technology provides multiple research, policy, and publications communication benefits and opportunities for sustainable development goals (SDGs) in Africa (UN, 2015), its adoption or diffusion is still wanting due to lack of awareness. In addition, a government–commissioned study has described
productivity of Ugandan PhD holders as ‘dismal,’ (GoU, 2013). AICAD research project and community outreach evaluators found that most AICAD/JICA funded projects which were implemented by AICAD member university researchers from Uganda were generally less effective and very unsuccessful in their community outreach operations (AICAD, 2012).

3. Methodology

This review was conducted by sourcing documents, current literature and news bulletins, online search engines, through policy analysis as well as discussion with:

- Key informants;
- Communication theories and best practice;
- Documents from Ugandan government specifically the ministries of education;
- Finance through the Uganda National Council of Science and Technology;
- International, regional, and UN development / specialized organizations;
- Lessons learned from research ethical practice.

4. Video Conferencing Issues and Quality Assurance at Higher Education Institutions

The current status is still very disappointing as community outreach video conferencing policies are lacking in most universities. Video conferencing can fill the multiple gaps like wrong: attitudes, behaviour, methodology, project perceptions, communication strategies, and cross-cultural interactions; there were common field research themes, agreements, modalities, methods (surveys, clinical trials, experiments, labs, pilots), communities, networks, and funding sources; too many absentee field researchers; fictitious research sites; group conflicts, and weak research ethics culture, lack of capacity, experience, ICT infrastructure, facilities, networking, and effective communication strategies.

QA is an imperative for effective university strategic planning, implementation, monitoring, and evaluation of research outreach policies, programmes, projects, and activities for the SDGs with a focus on SDG 4 on quality education for all. Ineffective outreaches have failed to bring change among the beneficiaries; weak or lacking teaching, learning, as well as outreach output indicators. Most HEIs are still afflicted by inadequate funding of strategic plans; insufficient ICT facilities (for teaching, learning, research, and ODEL), poor QA, low research culture, and lack of research outputs communication strategies (Okaka, 2016). At the institutional level, specific analysis needs to be made from the following perspectives: the programs, student assessment, quality of the staff, students admission, facilities and infrastructure (IUCEA/DAAD 2010, 4).

There are multiple gaps in university coordination, concepts, methods, planning, budgeting, and implementation leading to project failures, budget overruns, conflicts, and disincentives; video conferencing outreach activities use a variety of methods such as: community media literacy (including radio, TV, internet, mobile phones, newspapers, ICTs), school curricula, presentations, public meetings and focus groups, surveys, promotional posters and brochures, contests and special events, telecenters, community centers, internship placements, distance learning, virtual field trips, arts, and field labs. Prior idea of levels or nature of change one wants to effect (knowledge, attitudes, and practice) is vital for effective planning, implementation, and evaluation of outreach activities for the target video conferencing community audience.

The following aspects for the assessment of the quality of IUCEA member institutions: requirements set by the stakeholders; philosophy, mission, and vision of the institution; policy plan; governance; human resources; funding and financial management; educational activities;
research; community outreach; benchmarking; quality assurance; achievements (outcomes); and satisfaction of the stakeholders (IUCEA & DAAD, 2010). In most HEIs, the expected and actual input indicators, research indicators, teaching and learning indicators, internal service indicators, and output indicators are quite unsatisfactory to the society.

Recent studies have found that most university graduates in the sub-region (67% from Uganda), lack employable skills on one hand; while on the other hand, the productivity of most of the Ugandan PhD holders who are living and working in the country, has been described as dismal, for a variety of practical reasons (Okaka & Nagasha, 2016). Institutions rarely collect, analyze, and use vital information to manage their activities.

HEIs in Uganda in particular, have rarely published full, impartial, and objective information (quantitative/qualitative) about their programmes and awards offered. Most institutions are yet to launch a structured monitoring system to collect information about the quality of their activities including (IUCEA & DAAD, 2010): student evaluations; student progress system; structured feedback from the labour market; and structured feedback from the alumni. Besides, higher education has already developed its own approach to quality assurance during a period of internal quality assurance (IQA) progress.

Some of the common key university-challenges facing internal QA system include:

1. Lack of quality assurance awareness.
2. Resistance against (due to misperceptions).
3. Resistance of staff because they feel threatened.
4. There is not enough knowledge on QA available in the universities.
5. There is resistance as QA is seen as time consuming and costly (additional workload).
6. It is difficult to (specifically) define quality; so QA indicators are not always clear;
7. The purpose of QA and the added value are not always clear
8. Poor communication between the staff and the institutions’ management.

Most of the findings were generally disappointing, contrary to the widely issued guidelines by the IUCEA and NCHE (Okaka & Nagasha 2016). There are unresolved ethical issues that are worsened by communication gaps challenges include: wrong attitudes, behaviour, methodology, perceptions, communication strategies, and cultural illiteracy; commonalities of outreach themes, agreements, modalities, methods, target communities, networks, and funding sources; many absentee field researchers and fictitious research sites; many absentee field researchers and fictitious research sites; and weak ethics culture. Ethical issues are prompted by flouting ethical guidelines, weak or lack of capacity, experience, integrity, professionalism, communication skills, or ignorance. There are multiple gaps in university IQA coordination, concepts, methods, planning, budgeting, and implementation leading to project failures, budget overruns, conflicts, and disincentives. One of the neglected areas in university courses is gender mainstreaming.

As a result, the IUCEA (2015) introduced a specific thematic cluster on gender. The principal objective is to provide a framework for a course that equips students with knowledge and skills to apply gender perspectives to all aspects of life. The expected student learning outputs and outcomes include the abilities to:

- Demonstrate knowledge and understanding of gender concepts and their importance to personal and societal development;
- Use technological tools and methods for gender disaggregated data and empirical evidence in addressing gender issues;
• Demonstrate critical understanding and ability to share gender knowledge and skills as change agents in society;
• Underscore the significance of women’s empowerment by recognizing sexist bias, gender imbalance;
• Distortions and trivialization of women’s contribution to mainstream development;
• Appreciate the importance of strategic alliances between men and women in addressing gender inequalities;
• Describe strategies for addressing gender inequalities;
• Demonstrate an understanding of the value of gender equitable access to, and control of resources;
• Apply knowledge and skills acquired to mainstream gender in their respective disciplines as well as social and professional lives;
• Demonstrate understanding of national, regional and international frameworks for gender equality and women’s empowerment.

QA does best through local community - private – public – partnerships (CPPP) that in turn thrive on outreach communication strategies. For example, Kyambogo University strategic plan (KYU 2014) has identified among its focal areas for academic and research development initiatives, Open, Distance, and E-Learning capacity building as well as strengthening. This entails among others, procuring adequate computer labs, computers, and ICT compliant teaching and learning infrastructure to facilitate OPDEL with quality online courses or programmes. Department of Distance Education has produced initial modules for distance learning programmes that were advertised using brochures and principally the internet. Its principal objective is to increase accessibility to education through open, distance, and e-Learning courses.

5. Conclusion and Recommendations

Community participation ensures trust, effective communication, and social acceptance of the innovations. Inter-cultural community involvement promotes ethical research good practice among the researchers themselves on one hand, and inter-cultural demographics plus the host institutions, on the other benefit from video conferencing.

Video community outreaches are critical for achieving early adoption diffusion of research ethics and culture in communities. Video conferencing should be well planned, implemented, monitored, and evaluated for enhanced participation, transparency, empowerment, mutual trust, sustainability, and gender equality to achieve 2030 SDGs progress in Uganda and the rest of the African countries. Most university outreaches are hindered by weak institutional capacity, low staff morale, wrong approaches, uncoordinated planning and implementation, weak north-south cooperation funding gaps, staff development, PPP gaps, lack of strategic planning, bureaucracy, poor timing, ethics, and disincentives.

The prevalent low or poor quality standards of teaching and learning out-puts in the sub-regional HEIs, demand unprecedented levels of investments in quality assurance policy networking, enhanced capacity building, practical university-community-public private partnerships (UCPPP), South-South and North-South collaborations communication coordination, gender mainstreaming, ICT access and effective deployment, ethics, attitudinal, behaviour, management, and strategic IQA .policy change. The QA institutions like the IUCEA, NCHE, and universities or the higher education institutions are still heavily underfunded and under too well resourced to fully perform their regulatory mandates for QA.
Effective video conferencing outreach policy will fast-track Africa’s long—term 7 dreams for via ICT—led research and publications dissemination: a prosperous Africa with inclusive and sustainable development; an integrated, united continent with Pan-Africanism for renaissance; good governance, democracy, human rights, justice, and the rule of law; a peaceful and secure Africa; a strong cultural identity, common heritage, values, and ethics; Africa where development is people-driven; and a united Africa with global influence.

- Video conferencing technology is viable, accessible, affordable, cost cutting, time saving, interactive, efficient, effective, flexible, and vital.
- conferencing can be moderated to benefit the deaf by signers.
- Video conferencing propels public, private, and community partnerships.
- Video conferencing promotes gender equality for inclusive education.

5.1 Recommendations for Research and Practice

- Enhance video conference funding for climate change research and policy dissemination projects.
- Strengthen South-South, North-South collaboration, ICT access, research culture, local capacity building, and community outreach
- Recording video - conferences made available in a variety of ways like CDs, DVDs, streaming video.
- Improving distance education, other applications like meetings, academic, dissertation or thesis defences, telemedicine, palliative care, as well as online conferences.
- Enhance outreach programs like: industrial training (IT), school and college practice, community practice, distance learning, open education for good relationships among all stakeholders.
- Software for local translations
- Electronic dictionaries and guides
- ICT literacy for children & women
- Innovative video conferencing outreach awareness campaign as regular institutional education, research, publications, training, and dissemination programs

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Tanzania.
The research performance and citation impact of Tanzanian scholars: a scientometric study

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Abstract

Purpose: A scientometric analysis was conducted to map the research performance and citation impact of Tanzania scholars from 1991 to 2015. The study analyzed the growth of the Tanzanians’ scholarly literature; ascertained the year-wise distribution of publications, subject-wise distribution of publications; determined the authorship pattern and degree of collaboration; and analyzed the citation impact. Scientometric analysis is a type of quantitative methods used in evaluating research productivity of individuals. Data for research productivity of all Tanzania scholars were obtained using the SCOPUS database. For the Tanzanians’ scholars, a total of 12,379 articles were published from 34 academic and research institutions from 1991 to 2015. Most Tanzanian scholars had published journal articles (n=10392, 83.9%), which was followed by review articles and conference papers. The top three universities with high cumulative number of publications were Muhimbili University of Health and Allied Sciences (MUHAS) (n=2009, 16.2 %), University of Dar es Salaam (n=1880, 15.2%) and Sokoine University of Agriculture (n=1571, 12.7%). The three universities alternated the first three ranks over the period of 25 years. The top five subjects where Tanzanians scholars published were related to medicine (n=6868, 25.0%), agricultural and biological sciences (n=5260, 19.2 %), immunology and microbiology (n=2781, 10.1%), environmental sciences (n=2309, 8.4%), and biochemistry, genetics and molecular biology (n=1853, 6.8%). Forty two percent of all publications were co-authored with researchers from the United States of America and the United Kingdom each contributing almost equally. Kenya is the third collaborating country contributing to 870 publications (7.0%). The maximum number of citations received in a single publication was 1914. The study findings call for scholars to recognize the importance of publishing in visible journals in order to receive large citation counts. Institutions are urged to employ scientometrics in evaluating the research performance of their scholars since such techniques take into account a combination of several measures. These findings suggest that many factors should be considered in combination when evaluating researchers’ productivity and impact. For Tanzania to achieve its sustainable goals it and progress from a low- to a middle-income country, it needs to involve its researchers, policy-makers and providers such as the health care providers to collaborate in efforts to bridge the gaps between research, policy and practice.
Keywords: scientometrics; research productivity; research performance; research publications; citation impact; Tanzania.

1. Introduction

Science, technology and research are widely acknowledged as important components in achieving sustainable economic development goals (Confraria & Godinho 2015; Toivanen & Ponomariov 2011; Inglesi-Lotz & Pouris 2013; Guindon et al. 2010; Lavis et al. 2010). Parallel to this movement, the United Nations Sustainable Development Goals emphasized the critical role of improving science, technology and research cooperation as a specific goal, and as a means of implementing a number of thematic goals (United Nations 2015). Universities and research institutions play a key role in building a strong public sector of research and development of a country or region, and their capacity is critical for national system of innovation (Kotecha et al. 2011). However, there have been inadequate efforts to improve science, technology and research activities in Africa, despite the movement from agriculture-dominated economies to a research and knowledge-based future (Schemm 2013). To achieve the Vision 2025, Tanzania created in 1999 the Development Vision 2025 which aims at propelling Tanzania from a least developed country to a middle income country with a high level of human development and whose economy is diversified and semi-industrialized. The country need to embrace science and technology and innovation. This implies priority on science and technology and innovations to raise productivity in agriculture with priority to value addition by moving up the value chain in agriculture and promoting linkages with other sectors (The Citizen Magazine 2016; The United Republic of Tanzania 2010).

Scientometrics is used to analyze the research productivity and citation impact of researchers work in their discipline, institutions or region. It is important in informing policies and decisions regarding country or regional development trends. Most universities and research institutions in sub-Saharan Africa have a weak research infrastructure, capacity and funding which affects their contribution to the world’s knowledge production and development through research activities (Abrahams et al. 2009; Pouris 2015; Toivanen & Ponomariov 2011; Kotecha et al. 2011). Lack of access to international and local research outputs, and poor visibility of Africa’s research outputs contribute to low research productivity (Nature 2015; Abrahams et al. 2009). Most of the African scholars “publish in journals that are not counted by the Index” (Nature 2015:1). Africa faces many challenges of which investments in science, technology and research could assist to improve their economic base. Understanding the nature and dynamics of research performance of a specific country is important for building and integrating the national innovation system (Toivanen & Ponomariov 2011).

The African scientific outputs have been growing at a rapid rate than the world average, although the share of the Africa’s scientific output at the global level has remained low (Godinho 2013; Confraria & Godinho 2015; Schemm 2013). For instance, Schemm (2013) reported that the share of Africa’s research outputs to the world increased from 1.2% in 1996 to around 2.3% in 2012, although the contribution of Africa to the global research outputs and impact still remains small. According to Onyancha (2016), sub-Saharan Africa contributes a “mere 0.03% of the global research data as compared to an average of 1.4% of the world’s research articles”. Confraria and Godinho (2014) also reported that the Africa’s research outputs have increased in recent years to a level above the world average, although the continent’s productivity in relation to population is well below world average. The rapid developments of technology, open access movement and other initiatives such as research for
life programmes have immensely contributed to the growth of African research outputs (Schemm 2013).

The level of collaborative research activities in Africa is substantially higher as compared to the rest of the world, although the intra-Africa collaboration is still low (Onyancha & Maluleka 2011; Nature 2015; Confraria & Godinho 2015). For instance, a recent Nature report revealed that “Africa led the world in collaborations in 2014 articles in the Index” (Nature 2015:1). About 70% of Africa’s research output was generated through international collaborative research in the 2014 Nature Index (Nature 2015). Pouris and Ho (2014) also found that the internationally collaborative articles grew by 66%—almost twice the growth of the single-country articles in Africa. However, scholars found that the research collaborations within African countries are still low, when compared with extra-Africa collaborations (Onyancha & Maluleka 2011; Nature 2015; Confraria & Godinho 2015). Further, the research collaboration of the top publishing African countries is dominated by a few external partners, mainly the US, UK and France (Confraria & Godinho 2014: 1260).

Evidence also shows that the research output in Tanzania is considerably less than other countries in the African region (Pouris 2010; Boshoff 2010; Abrahams et al. 2009; Confraria & Godinho 2015; Onyancha 2016; Godinho 2013). For instance, Abrahams, Burke, and Mouton (2009) found that Tanzania total publications according to Information Sciences Institute (ISI) were 4,815 out of the 95,711 papers in 14 countries in the Southern African Development Community (SADC) during the period of 1990 to 2007. In another study, Pouris (2010) reported that South Africa published almost 14 times more publications than the second country in the list-Tanzania, with a total of 4184 publications from 1994 to 2008. A recent study reported that Tanzania total publications were 2,354, which was twelve times more publications produced by South African scholars during the period 2007–2011 (Pouris & Ho 2014). Further, the African science is dominated by a few countries. For instance, South Africa accounted for 64% of the region's 2014 WFC, followed by Egypt, Kenya, Algeria and Tunisia (Nature 2015). Another research also reported almost similar findings that the leading countries in terms of research outputs were South Africa, Egypt, Tunisia and Nigeria (Confraria & Godinho 2015). It is therefore important to have a complete picture of research productivity of a certain region or country in order to determine gaps critical for socio-economic development.

When searching the literature on research productivity and impact in Tanzania, we found few African studies, which had included Tanzania in their analysis (Abrahams et al. 2009; Confraria & Godinho 2015; Pouris 2010; Pouris & Ho 2014; Onyancha 2016; Boshoff 2010). Other Tanzanian’s studies either focused on the research productivity and impact of a specific institution or discipline, or profession (Lwoga & Sife 2013; Lwoga & Sife 2014; Sife & Bernard 2016; Sife et al. 2013; Sife et al. 2014). Although few studies analysis (Abrahams et al. 2009; Confraria & Godinho 2015; Pouris 2010; Pouris & Ho 2014; Onyancha 2016; Boshoff 2010) have investigated Tanzanians research productivity, there is still no comprehensive study that has been conducted to examine the patterns and impact of research performance among the Tanzanian scholars.

This study reports findings of a scientometric study of research productivity and impact in Tanzania scholars from 1991 to 2015. The broader aim of the paper is to provide empirical findings to inform multi-sectoral policies, programmes, capacity, and financing issues related to improving research performance across the country. The study seeks to answer the following research questions:

1. What is the growth of the Tanzanians’ scholarly literature?
2. What is the year-wise and subject-wise distribution of publications”
3. What is the authorship pattern among Tanzania scholars?
4. What is the pattern of collaboration in knowledge production in Tanzania?
5. What is the citation impact of Tanzania scholars?

The scientometric approach was conducted to assess the extent and impact of research performance among Tanzanian’s scholars. Scientometrics is the “statistical analysis of research pattern” (Ramkumar 2016). Scientometric is important for measuring research productivity and quality, specializations, collaborative networks, patterns of scientific communications (Perron et al. 2016). It allows a wide range of metrics to be conducted, including comparisons of different disciplines, institutions, countries, changes over time etc. (Pouris 2012). Scientometric can inform decisions related to policy, resource apportionment, and understanding the socio-economic impact of research (Perron et al. 2016).

2. Methodology

Data was extracted from the SCOPUS (Elsevier 2016) database, because it indexes quality research outputs and it provides adequate coverage of African research (Fari & Ocholla 2016; Onyancha & Ocholla 2009). The list of the Tanzanian universities was acquired from the Tanzania Commission for Universities (TCU) website. The list of the research institutions was acquired from the Tanzania Commission for Science and Technology (COSTECH) website. The data was extracted and downloaded from SCOPUS by using institutional affiliation as the search term. The study created the search query with the specific names of the different search phrases (i.e. AFFIL (“name of the university”) AND (LIMIT-TO (AFFILCOUNTRY,”Tanzania”))). Thereafter, in order to identify a wide range of research institutions, we used truncated queries with terms that are broadly used to name research-based institutes in the country, such as science-, technology-, research, center, etc., (i.e. AFFIL(“sci* ”) AND (LIMIT-TO(AFFILCOUNTRY,”Tanzania”))). Both specific and truncated queries were restricted to the year between 1991 and 2015 covering journals, book series, and conference proceedings, while excluding editorials, erratum, letters, and notes. Through descriptive bibliometrics or publication count, domestically and internationally co-authored papers were identified for co-authorship analysis.

From the list of aggregated authors and affiliations, we identified the authors’ affiliations and countries from the fields of affiliation and corresponding address. Multinational collaboration was determined by author’s affiliation was located outside Tanzania. The names of affiliations and countries that were not well formatted were reconstructed from the author’s address. Besides, some institution such as the Muhimbili University of Health and Allied Sciences changed its names during the study period. Other institutions changed their several affiliates. We therefore manually reprocessed the author’s affiliation to reflect the historical changes of names. The data cleaning and splitting of authors was aided by Python version 2.7 scripts (https://www.python.org/) which re-organized the data and stored it to a MySQL® version 5.5 (https://www.mysql.com/) database. The final data cleaning was finalized using Microsoft Excel® version 2010 (https://products.office.com/en-us/excel).

A total of 16,662 articles were identified when search term included was Tanzania. In order to confirm that these articles were published by the Tanzanian scholars, we added all the Tanzanian institutions found by the search term so that the researchers in the affiliations of authors, and excluded articles that were not published by authors in country, which had been
accidentally included in the original set. A total of 12,379 articles published by Tanzanian scholars were finally analyzed.

3. Results

![Figure 1: Annual increase of research articles in Tanzania from 1991 to 2015. The articles increased exponentially to a total of 12,379, the highest number of publication (1307) was in 2015.](image)

There was a more than 12.5 fold increase in number if articles per year from 105 in the year 1991 to 1,327 articles in the year 2015, a 92% increase in publications. Years after 2000 saw rapid growth in annual publication turnover for example the number of articles doubled in 4 years from 235 in 2000 to 456 publications in 2005.
Eighty four percent of all publications were research articles, followed by reviews and conference presentation contributed 4.7% each, of all articles published between 1991 and 2015.
Figure 3: Overall Institution publication rank in the study period 1991-2015

The leading Institutions with cumulative total 500 or more articles during the 25 years were the Muhimbili University of Health and Allied Science (MUHAS) with 2009(16.2%) publications in the study period. This was followed by University of Dar es Salaam (UDSM) and Sokoine University of Agriculture (SUA) with 1880(15.2%) and 1571(12.7%), respectively. Next was National Institute for Medical Research (NIMR), Kilimanjaro Christian Medical Centre (KCMC) and Ifakara Health Institute (IHI). There is dominance of medical research literature among Tanzania researchers as most of these institutions conduct medical research with exception of UDSM and SUA. The first three overall ranking institutions when have alternated their rank positions over the years as depicted in Figure.
In 2015 SUA was leading with 183 articles compared to UDSM and MUHAS which produced 178 and 168 publications, respectively.
Figure 5: Journal sources for Tanzanian Scholars top 27 journals 50 publications or more

The leading journals are in the field of medical sciences
The medicine subject category contributed 25% of publications followed by agricultural and biological sciences 19% and Immunology and Microbiology 10%. Pharmacology, toxicology and pharmaceutics contributed the least at only 2% of all articles published in the years 1991 to 2015.
Table 1: Journal ranking with respect to total citations, total number of publications and average citation per publication

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<th>Total publications</th>
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<th>Average Citation</th>
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<td>1.</td>
<td>Lancet</td>
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<td>2.</td>
<td>Malaria Journal</td>
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<td>New England Journal of Medicine</td>
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<td>4.</td>
<td>Tropical Medicine and International Health</td>
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<td>PLoS ONE</td>
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<td>6.</td>
<td>American Journal of Tropical Medicine and Hygiene</td>
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<td>AIDS</td>
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<td>Nature</td>
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<td>9</td>
<td>Transactions of the Royal Society of Tropical Medicine and Hygiene</td>
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<td>27.45</td>
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<td>14</td>
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<tr>
<td>19</td>
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<td>102</td>
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<tr>
<td>20</td>
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<td>267</td>
<td>108</td>
<td>2</td>
<td>968</td>
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<tr>
<td>22</td>
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<tr>
<td>23</td>
<td>Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science</td>
<td>105</td>
<td>255</td>
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<td>2222</td>
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</table>

The Lancet journal is leading with total of 10,354 (5.5%) citations followed by Malaria journal and New England Journal of Medicine with 3.2% and 2.9%, respectively of all citations. The journals show variation in ranking based on number of articles, citation, and average number of citations per publication in that journal.
**Table 2**: Highly cited articles. Six papers each with more than 500 citations had a total of 5285 (2.8%) citation out of 186,777 citations from all Tanzanian publications in the study period. Includes first author and first Tanzanian author in the list, the institution of the Tanzanian author is indicated.

<table>
<thead>
<tr>
<th>Sno</th>
<th>Publication</th>
<th>Number of citations</th>
<th>Tanzania Institution</th>
</tr>
</thead>
</table>
Figure 7: Top 20 most prolific authors in Tanzania

Top 20 prolific authors in Tanzania published 2207 (17.8%) of all publications and included many from the field of health sciences.
Table 3: Top collaborating countries in published literature during 1991 to 2015

<table>
<thead>
<tr>
<th>Sno</th>
<th>Country</th>
<th>Number of articles</th>
<th>% of all articles</th>
<th>Sno</th>
<th>Country</th>
<th>Number of articles</th>
<th>% of all articles</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>United States</td>
<td>2673</td>
<td>21.6%</td>
<td>17</td>
<td>Italy</td>
<td>294</td>
<td>2.4%</td>
</tr>
<tr>
<td>2</td>
<td>United Kingdom</td>
<td>2496</td>
<td>20.2%</td>
<td>18</td>
<td>Nigeria</td>
<td>236</td>
<td>1.9%</td>
</tr>
<tr>
<td>3</td>
<td>Kenya</td>
<td>870</td>
<td>7.0%</td>
<td>19</td>
<td>Ghana</td>
<td>219</td>
<td>1.8%</td>
</tr>
<tr>
<td>4</td>
<td>The Netherlands</td>
<td>752</td>
<td>6.1%</td>
<td>20</td>
<td>Zambia</td>
<td>211</td>
<td>1.7%</td>
</tr>
<tr>
<td>5</td>
<td>Switzerland</td>
<td>741</td>
<td>6.0%</td>
<td>21</td>
<td>Spain</td>
<td>205</td>
<td>1.7%</td>
</tr>
<tr>
<td>6</td>
<td>South Africa</td>
<td>724</td>
<td>5.8%</td>
<td>22</td>
<td>India</td>
<td>200</td>
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</tr>
<tr>
<td>7</td>
<td>Sweden</td>
<td>715</td>
<td>5.8%</td>
<td>23</td>
<td>Malawi</td>
<td>193</td>
<td>1.6%</td>
</tr>
<tr>
<td>8</td>
<td>Germany</td>
<td>661</td>
<td>5.3%</td>
<td>24</td>
<td>Ethiopia</td>
<td>182</td>
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<tr>
<td>9</td>
<td>Denmark</td>
<td>627</td>
<td>5.1%</td>
<td>25</td>
<td>Zimbabwe</td>
<td>169</td>
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<tr>
<td>10</td>
<td>Norway</td>
<td>576</td>
<td>4.7%</td>
<td>26</td>
<td>Austria</td>
<td>155</td>
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<tr>
<td>11</td>
<td>Uganda</td>
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<tr>
<td>12</td>
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<td>472</td>
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<td>28</td>
<td>China</td>
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<td>13</td>
<td>Canada</td>
<td>364</td>
<td>2.9%</td>
<td>29</td>
<td>Finland</td>
<td>134</td>
<td>1.1%</td>
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<tr>
<td>14</td>
<td>Japan</td>
<td>326</td>
<td>2.6%</td>
<td>30</td>
<td>Mozambique</td>
<td>130</td>
<td>1.1%</td>
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<tr>
<td>15</td>
<td>Australia</td>
<td>314</td>
<td>2.5%</td>
<td>31</td>
<td>Brazil</td>
<td>127</td>
<td>1.0%</td>
</tr>
<tr>
<td>16</td>
<td>France</td>
<td>305</td>
<td>2.5%</td>
<td>32</td>
<td>South Korea</td>
<td>125</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

There was a high level of collaboration with 9075 (73%) publications co-authored with international scholars. The top collaboration countries were the United States and the United Kingdom contributing 21.6% and 20.2% of all collaborations with Tanzania. The top African collaborator is the East African Neighbor Kenya which ranked 3rd contributing 7% of collaborations with Tanzania.
4. Discussion

The use of Scientometrics can be helpful for countries to make informed political decisions with regards to achieving sustainable development goals. This is due to the fact that, the scientific research and scientific publication are requirements for the creation of the necessary long-term potential for sustainable economic development (Confraria & Godinho 2015).

4.1 Growth

Our study reveals an exponential growth of articles spanning over 25 years; between the year 1991 and 2015. The propensity to publish in the Tanzania has risen particularly fast since 2004-2008, suggesting that a possible take-off of Tanzania science similar to trend observed sub-Saharan Africa (Confraria & Godinho 2015; Breugelmans et al. 2015; Pouris & Ho 2014). This period was also marked by establishment of new private and public universities in Tanzania. Increase in number of publications from 2004 also observed by others in Africa (Breugelmans et al. 2015) and may be due to presence of collaborations some of which marked by the presence of medical and Tropical research centers focusing in in poverty diseases priority in East Africa (Breugelmans et al. 2015). Notable apparent productivity of African science, as measured by publications to gross domestic product, has risen in recent years to a level above the world average, however, it is argued that looking at the equivalent ratio after it has been normalized by population, there is still a huge gap to overcome (Confraria & Godinho 2015). One needs to analyze the growth rate with respect to the country population and the number of researchers in a given institution.

4.2 Subject’s category

The research on medical sciences appears to be leading in Tanzania. Medicine was the top subject, followed by Agriculture and Biological Sciences and immunology and Microbiology. This is in concordance other studies show that Africa’s research outputs are highly represented in the fields of health sciences which is similar to the coverage of world’s publications (Confraria & Godinho 2015; Abrahams et al. 2009). The high contribution of research publications in health-related sciences, such as medicine and immunology and microbiology, may stem from research work on tropical diseases and specific health problems, as well as from

Authorship patterns chart:

Figure 7: Authorship patterns of Tanzania scholars between the years 1991 to 2015. Ninety percent of articles were multi-authored papers of these 49% by six or more authors.
the location of international medical research centers in Africa, and the visible presence of international cooperation between Tanzanian researchers and those overseas (Confraria & Godinho 2015; Gondwe 2010). Accordingly, a number of health institutions including Medical universities and medical research institutions appear to rank high in the list of contributors of science in Tanzania, in our analysis. The prosperity of health related research may also be due to increase of funding in these areas by organizations such as SIDA, The European & Developing Countries Clinical Trials Partnership (EDCTP), Wellcome-Trust, National Institute for Health among others (Breugelmans et al. 2015). The ranking of Agricultural Sciences seems reasonable, given the needs of the Tanzania to depend on Agriculture the trend and the significance applies to African countries (Confraria & Godinho 2015; Abrahams et al. 2009). Therefore, scientific specialization, in Tanzania is not quite different from the overall Africa’s specialization in areas of medical research and Agriculture. However, compared to the world patterns, Agricultural Sciences are relatively more important in Africa (Godinho 2013).

4.3 Authorship

Authorship pattern in Tanzania is dominated by multi-authors in 90.3% of the publications indicating a high degree of collaboration among Tanzanian scholars. Furthermore, collaboration between Tanzania and international researchers is quite high at 73%. In other studies, it was noted that collaborative patterns among African scholars are substantially higher than in the rest of the world (Pouris & Ho 2014). Tanzania Scientists that collaborate with peers in Europe and US are likely to receive more scholarly impact as reflected in their citation impact (Confraria & Godinho 2015; Breugelmans et al. 2015). Papers that had more citation impact were mostly those that were coauthored in collaboration with international researchers.

4.4 Institutional ranking

The most prolific institution in the 25 years period covered by the analysis is Muhimbili University of Health and Allied Sciences (MUHAS) who produced a volume of 2009 (16.2%) of all publications. The top 3 institutions alternatively exchanged first to third rank. In 2015 the leading institution was SUA followed by UDSM and MUHAS. This results coincide with web ranking of Tanzania University in 2016 (Anon 2016).

4.5 Prolific authors

The top 20 scholars comprise mostly researchers in the field of health. The list includes both Tanzanian native scholars and foreign scholars working in Tanzania.

4.6 High impact journals and article

Top ranking journals with regard to citations were the high impact journals such as Lancet and New England journal of medicine. Malaria journal, an open access journal ranked second in both number of articles and citations rank. Medical researchers in this area should consider the journal to boost their impact and visibility. One local journal the Tanzanian Journal of Health research ranked third in number of articles however the journal ranked poorly in average number of citations with each article receiving less than 2 citations. This implies that Tanzania authors need to publish in journals that are widely visible (e-journals & open access journals) and that Tanzania need to establish local online journals and improve visibility to boost the number of citations.

4.7 Implication for practice and policy

For Tanzania to achieve its sustainable goals it and progress from a low- to a middle-income country, it needs to involve its researchers, policy-makers and providers such as the health care
providers to collaborate in efforts to bridge the gaps between research, policy and practice. However, the government needs to adopt a model to fund Tanzania research institutions and increase budget support for research to more than the current 1%.

4.8 Study limitations

We used Elsevier’s Scopus (Elsevier 2016) database to analyze research impact of Tanzanian scholars over other online databases alternatives such Thomson’s Reuters Web of Science (WOS) database. Scopus covers about 20000 journals compared to 13000 by WOS (Mongeon & Paul-Hus 2016). Moreover, the database is updated on daily basis rather than weekly. This gives opportunity to get more dependable amount of publications. WOS data has limitation with English-language journals is very comprehensive, one limitation of the Web of Science is that coverage of non-English-language journals is less extensive, although this has recently increased with the inclusion of French and Portuguese journals in particular. Scopus reported a higher citation rate for health relevant articles compared with the Web of Science possibly due to the fact that Scopus abstracts more from biomedical journals WOS. Thus implies that this kind results need to be interpreted with caution when another compared with data from other databases. However, when pharmacy and pharmacology journal research was analyzed from both Scopus and WOS there the two databases differed in the number of articles within a tolerable margin of deviation for most journals (Gorraiz & Schloegl 2008).

Another potential limitation of our analysis is the method used to assign papers to organization. Authors often report their affiliations in different ways for different publications, so we used an algorithm to unify these affiliations, but some authors who published in foreign countries may have been discounted in the analysis. Moreover, scientists from foreign countries working in Tanzania were also counted as Tanzanian scholars.

5. Conclusion

The citation impact of research publications from Tanzania increased exponentially from 1991 to 2015; collaborative research had a higher impact and was more highly cited than non-collaborative research. We expect the observed trends to continue as suggested by the number of recent, high impact relevant papers that has been published in this period. In the future, scientometric study should be conducted to benchmarks Tanzania with neighboring African countries to compare their profiles with respect to achieving common developmental goals. Collaboration with external partners and publishing boost scholars’ impact. However, Tanzania needs to increase collaboration with other African countries on common issues related to economic growth and sustainable development.

References

analysis'. *Scientometrics*, 102(2) pp.1241–1268.


**Biography**

![Dr. Raphael Zozimus SANGEDA](image)

**Dr. Raphael Zozimus SANGEDA** is a lecturer in the department of Pharmaceutical Microbiology at the Muhimbili University of Health and Allied Science (MUHAS), in Tanzania. He is member of the H3ABionet - A Pan Africa Bioinformatics Network.

His research interest includes Scientometric studies to explore scholarly research performance; Bioinformatics particularly Genome wide association studies (GWAS) in investigating the Genetic epidemiology of Human Immunodeficiency Virus, Hepatitis B virus and Hepatitis C virus infections in individuals with Sickle Cell Disease; Creating and managing electronic databases and the Case Report Forms (CRF) for data capture and managing HIV epidemiological-clinical databases.
Design of an Executable Solutions Management Platform based on Virtual Machine Snapshots

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Abstract

Annually, dozens of software solutions are developed by students as part of the mandatory requirements for them to be awarded their respective degree qualifications. However, most of these potentially groundbreaking solutions tend to be stored away and forgotten upon completion. This then gives rise to the current predicament where universities produce multiple graduates but do not yield a proportional number of usable innovative software solutions. The aim of this paper is to design a platform that enables the storage, indexing, retrieval and execution of these developed solutions. This will be done through the design of a user-friendly interface as the front end, a database of virtual machine snapshots for each executable system running at the backend and a querying engine to interface the two. This will go far in ultimately aiding universities to become recognized hubs of innovative and marketable technologies.

Keywords: Virtualization, projects repository, virtual machine snapshots, information retrieval

1. Introduction

Cloud computing has ushered in a lot of revelations in e-learning. Many universities and colleges to date have managed to create repositories for past exams, lecture notes, project documentations and theoretic assignments (DSpace). (Ramshirish et al. 2006) This development facilitates for students to reference to past educational materials and analyze the trends a particular course has been following over the years.

However, since much progress has been made in digitizing and centralizing these materials, little or no progress has been made in centralizing student projects in executable form. Study (with a bias towards Information and Communication Technology) has shown that, student projects (mainly software based projects) are handed over and stored in CD format after completion. Some of the products will not conform to the expectations of project submission i.e. no environment setup to run the project, students submitting only the source code only not the executables etc. To that cause, current students cannot allude to past projects for the purposes of research, literature review and improvements on these projects as there is no proper evidence of existence of such projects.
These challenges necessitated for the development of a cloud based platform to allow improvement and modification of past projects. The researchers propose to develop a centralized repository of projects in executable form. The repository has a backend running on a cloud platform. Every student project being an individual Virtual Machine, snapshot taken in the executable format of the project with the virtual machine environment tailored for each project. Front end access for the purposes of uploading, installation and viewing is done via a web GUI.

2. Literature Review

2.1 Definitions

Mell et al (2009) defines Cloud computing (hereinafter: CC) as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”

Virtualization is one of prerequisites for the realization of CC (Dong et al. 2009), the concept of virtualization, is essentially method of dividing a single machine into smaller virtual machines by running multiple operating systems and giving the impression to an end user that his or her job was running on a separate, dedicated machine.

2.2 Challenges

The concept of automation when it comes to student-developed projects or programs is not a new one. In the past, it has been focused on a number of aspects including the grading of student programs (Jones 2001). The problem was rooted in the management of large classes of students who were taking a programming course. Jones goes on to give a detailed report in the paper on how the automation of grading student programs impacted both the author and the performance of the students. Not only did automation of a typically manual task save time, but it also improved the fairness of the grading process too. This effectively led to the overall improvement of student-developed programs.

There were some shortcomings however which included the instructor having to spend more time preparing assignments that met the specifications of the testing system and also developing the grading program (Jones 2001). This basically proves that automation of student-developed products will most probably lead to an improvement not only to the faculty members who are supposed to evaluate the projects but to the students as well. Examiners will be better able to review and properly analyze student projects through the use of this platform as opposed to the old model of relying on student project demonstrations on a once-off final presentation.

For our use case most student projects are very volatile and require very specific hardware to successfully execute. In the University we face the challenges of student project being hard to replicate or reconfigure once projects have been submitted, which counteracts the purpose reproducible research in higher education.

Previously E-learning research focused on the reuse of learning material, but not on IT infrastructure, services and applications. Many universities’ ICT driven policies focus on traditional Learning Management System, such as BlackBoard, Moodle etc.
2.3 Related Work

Boettiger (2015) explores common reasons that code developed for one research project cannot be successfully executed or extended by subsequent researchers, he further summaries the challenges as a result of: (i) Problems of dependencies in code (ii) Imprecise documentation (iii) software updates (iv) Barriers to adoption and reuse in existing solutions to solve said problems. He goes further to highlight the current paradigms on solving the issue of reproducible research as workflow systems and virtual machines.

Dong et al. (2009) propose the BlueSky cloud framework which allows use of cloud computing as a base for modern e-Learning applications, within it physical machines are virtualized and allocated on-demand.

CloudIA (Sulistio et al., 2009) a system developed within Hochschule Furtwangen University is a comprehensive private cloud solution infrastructure that provides IaaS, SaaS, PaaS with respect to requirements and needs of e-Learning and collaboration. The IaaS system enables the creation of a VM by choosing a base image and post-installing software packages selected by the user on the fly. CloudIA’s implementation model can be utilized to realize our needs. Vouk, et al also propose a similar solution where students are offered predefined VMs.

<table>
<thead>
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<th>Table 1: Overview of research on private cloud in University Setting</th>
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<tr>
<td>Paper</td>
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<td>------------------------</td>
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<td>Liang et al (2011)</td>
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</table>

The private cloud serves as a real world test-bed for deployments, benefiting students, researchers and faculty as well as providing needed relief for currently strained education budgets. (Mircea et al, 2011) A private cloud model enables educational institutions to have a complete control of identity management, services, data security, applications, and resources.

By leveraging CC, we aim to provide students with the appropriate tools for application development, reuse and archival purposes of student projects. Given the survey of literature related to our problem, a private cloud solution would enhance realization of research and educational reproducibility of students’ projects. Table 1 gives an overview of our research on private cloud in a university setting.
3. Design
3.1 Architecture Design

The full architecture design of the platform is illustrated in Fig 1. Considering its design from a basic point of view, it is comprised of four main components. These are the web interface, the database querying module, the database itself as well as the server on which everything is housed.

The web interface acts as a front-end where the user enters commands for processing. These are then fed to the database querying module which is effectively an interface between the database itself and the web interface.

The database is basically comprised of three main tables; the Projects table, the Virtual Machines (VM) table and the VM snapshots (Kalmbach et al 2015) table. The projects table contains all the projects available on the platform. The VM table contains all the Virtual Machines on the platform as well as the operating system running on each VM, the number of snapshots associated with it and so on. The VM snapshots table is comprised of the titles of the projects running on the snapshots, the configurations, installed applications/add-ons and other hardware and software specifications associated with the snapshot. A snapshot can have more than one project running on it. Also, a virtual machine can have more than one snapshot associated with it (Pearce et al. 2013). However, a project can only be run/stored in one snapshot.

The database, the various virtual machines as well as the snapshots will all be stored on a server. It is imperative that this server is of a very high quality since it is the backbone of the whole platform. Understandably, due to the growth in popularity of distributed computing as a concept, future developments of the platform may result in there being more than just one server as the backbone. However, for demonstration purposes for this design, the aspect of distributed computing was not taken into consideration.
3.2 Submission Module

The operation of the submission process where a student uploads and installs their project onto the platform is illustrated in Fig 2. The student, upon completion of the project, is then asked to use the platform and upload/install their project. The student logs into the platform and is then prompted to select the operating system on which they developed their project.

As shown in Fig 1, the platform will accommodate more than one operating system including Windows, Android as well as some distributions of Linux. The student selects the operating system they used and then they proceed to outline the specifications that their project needs to operate ideally. These can be programs such as the Microsoft Visual C++ runtime libraries or a flavor of Microsoft SQL Server to mention a few examples for Windows. In addition to that, the student also states how much memory and hard disk space their project will require.

This captured information is then used when parsing through the Snapshots table to see if there is any (VM + snapshot) instance available that meets the criteria highlighted in the student’s specifications. If one is found, the system then checks if there is enough space to accommodate the student project. If there is, that snapshot is loaded and the student is given permission to upload and install their project onto the snapshot. However, if there is no VM + snapshot instance that meets the requirements, then a new snapshot is created that allows the student to install and configure their project as they see fit.

After the installation is completed, the student is then prompted to commit the changes they have made to the snapshot. The snapshot is then immediately saved and the Projects, Snapshots, and VMs tables in the database are updated accordingly.
3.3 Retrieval Module

This is with respect to a scenario where the user of the platform would like to retrieve and view/use a student project that has already been uploaded and installed onto the platform. Fig 3 highlights the flow of this process in the form of a diagram. The user logs onto the platform and then proceeds to enter the title of the project they would like to view. Alternative methods of selection include entering keywords such as “inventory management” which would lead to the displaying of some student projects that dealt with the various facets of inventory management.

![Diagram showing the retrieval process]

After entering the name of the project, a search is then done in the Projects table of the database. If the project does not exist, an error message informing that to the user is then displayed. However, if the project does exist, then the selected virtual machine running the project is loaded. It is then followed by the loading of the VM snapshot and then the automatic launching of the project for use or testing by the user.

4. Discussion

The design of this prototype is mainly based on the concept of snapshots in virtual machines. A snapshot has the capacity to capture the state of memory as well as the hard disk’s and the state of various devices on a selected virtual machine. The virtual machine in question may either be shut down or running when the snapshot is captured or restored. The snapshot then goes on to record the state differences between the original state of the virtual machine and the time when the snapshot was taken.

Due to this capability, snapshots that would have been captured earlier can then be restored very quickly. This would also mean a lot more space and time is saved as compared to the alternative of installing every project on a completely new virtual machine which would inevitably hog resources on the host machine. In addition to that, using snapshots also adds another identifier to the set of projects in that groups of projects can be referenced using the snapshot as a grouping characteristic/identifier.

An alternative to the use of snapshots would have been to install all the student projects with an operating system in common onto one virtual machine. This would have involved installing all add-ons and additional software onto one VM and ensuring that its specifications accommodated...
The projects with the highest requirements. Granted, this would save a lot of space as compared to the concept of using snapshots, but the challenges faced would ultimately outweigh the benefits. This is because it would result in a single point of failure for all projects. This means that in the event that the VM crashes, this would negatively affect all the functioning of the projects housed on that VM. This goes on to highlight the benefit of having multiple snapshots of VMs as opposed to having just one VM for everything.

Another problem that would be faced if the single VM approach is used is regarding backward compatibility and selection of the ideal add-on/program version that can accommodate all the student projects installed on a single operating system. Say, one project requires Add-on version 1.1 while another requires Add-on version 3.2. If version 3.2 has no backward compatibility with 1.1 this would mean that any project that runs on version 1.1 will not be able to run successfully. The solution to this would ideally be to install projects 1 and 2 on two different machines.

This problem is resolved by the use of snapshots in that each snapshot can be set up to have all the necessary requirements pre-installed without worrying about compatibility with the requirements of other projects.

In order to accommodate most, if not all the student projects to allow them to be placed on the platform, the most common operating systems were used in the design of the prototype. These included Windows 7 and 8, Linux Ubuntu 14.10 as well as Android Kit Kat version 4.4. Other operating systems such as the various Linux distros and Mac OS flavors were not included but may be added in future as the platform has the capacity to accommodate more VMs.

There are a number of other benefits that are associated with the implementation of this platform as well. One of them is that the installation of multiple projects on a single snapshot also allows efficient usage of space. Also, in the long run, it will not only help ensure only working prototypes are submitted by students, but it will also allow individual modules of previous student projects (possibly from a preceding academic year) to be used as case studies in Secure Programming or security courses in the degree programme’s curriculum. To add to that, this will allow there to be more diversity in project ideas by students since there will be a common repository to reference and evaluate the originality of a project proposal before it is even started.

5. Conclusion

Considering the volumes of student projects generated per year at any university, the number of business solutions, patentable and innovative projects the university in question will produce should be equally huge in number. However, that is not the case since in many cases there is no standard system or platform is in place to harness all these generated products and ideas for further improvement. The platform being suggested in this paper proposes to solve that challenge. This is done through the implementation of cloud computing concepts in order to not only better manage resources and components associated with the platform but to also use them efficiently. Ultimately, this will lead to the production of more unique and innovative student projects and also allow for the progressive improvement of previous student projects to come up with more industry-ready solutions and systems in the long run.
6. Future Work

6.1 Containerization vs Virtualization

Whilst virtual machines provide a readily available solution without a steep learning curve, current trends are moving towards the use of containers with cloud computing. Solutions such as Docker provide a novel remedy to our problems, the main challenges pose are the learning curves. Other universities are using containers to provision assignments and enable uniform platforms for computer science related practical courses. We aim to integrate both virtualization and containers with our infrastructure (Scheepers 2014).

6.2 HitCloud

We aim to develop further on our solution to provide a fully-fledged private cloud infrastructure (HitCloud) based on existing resources which offers IaaS, SaaS and PaaS within the learning environment.

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**Biographies**

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Improving Quality Education and Research Capacity through Advanced ICT Services: Lessons of NREN Implementation in Sierra Leone

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Abstract

Sierra Leone is just 12 years from a devastating conflict and still suffers from serious gaps in its infrastructure. The average adult has had just 3.3 years of schooling, and adult literacy rates are around 43%. Among its six million people, 60% live below the national poverty line. While there are many needs in Sierra Leone, previous experience has shown that universities can play a key role in social and economic development. To achieve this, universities need adequate Information and Communication Technology (ICT) facilities, sufficient collections of educational online resources, and with so much now online - reliable internet connections. This paper outlines ongoing work to support Sierra Leone as the country develop its higher education and research capacity to tackle development challenges. The paper provide guidelines to government, institutions, and development partners on how to approach the provision of advanced ICT services to the higher education and research community in Sierra Leone. The paper describes the proposed ICT services and expected beneficiaries. The timing is appropriate as it coincide with the rollout of fibre optic connectivity to universities and schools in Sierra Leone. The premise of the report that the organization of ICT services and connectivity for higher education and research institutions is best provided by a dedicated organization called the National Research and Education Network (NREN) is based on international best practice and the current plans of the stakeholders in the region. Finally, the paper discusses the lessons learnt from collaborations with development partners to improve research capacity and access to research resources and the establishment of a vibrant National Research and Education Network for national development in Sierra Leone.

Keywords: Connectivity, Information and Communication Technology, Fibre Optic, Higher Education, Research and Education Network, Online Resources, Quality Education, Sierra Leone

1. Introduction

The term Information and Communication Technologies (ICTs) is used to refer to hardware, software, networks and media for collection, storage, processing, transmission and presentation of information in the formats of voice, data, text and images (World Bank ICT Glossary Guide). As such, the nature of ICTs is diverse, ranging from telephones, radios and TVs to more
complex technologies such as Internet technologies, mobile telephony, computers and databases. This diversity means that they can be used by people with varying degrees of skills, although the current trends towards sophisticated applications are more and more demanding on the end user. A primary purpose of ICTs is to provide an enabling environment for the generation of ideas, their dissemination and use. Through ICTs, the diffusion and sharing of knowledge is enabled through open access to information and better coordination of knowledge. ICTs facilitate the creation of networks locally, regionally and globally, leading to collaborative and interdisciplinary approaches to problem-solving and research diversification through shared knowledge-bases, online forums and collaborative spaces.

Throughout the globe there has been a fast-growing trend for universities to organize their Internet access and connectivity to each other through centralized organizations called National Research and Education Networks (NRENs). About a hundred countries in the world have adopted the NREN as the centrepiece of their information and communication technology (ICT) plan for tertiary education institutions and for connecting research institutes and other institutions such as schools and hospitals. Within each continent, continental level Research and Education Networks (REns) have been set up to implement and operate the regional networks that interconnect the NRENs. It also connects to each other, making researchers interconnected as part of a global research and education community. These include GÉANT in Europe; Canary in Canada; Internet 2 & NLR in the USA; CLARÁ in South America. Similar regional RENs exist in the former USSR; Asia. In Africa, the UbuntuNet Alliance covers the Eastern and Southern belts and the West & Central Africa Research & Education Networks (WACREN) for the West and Central Africa region.

Implementing NRENs has proved to be the most promising option for African Universities and Research Institutions. However, setting up an NREN in Sub Saharan African country has its own challenges. The challenge of African countries include lack of access to the fibre optic broadband thus making Internet cost high ranging from US $3000-$4500 per 1 Mbps; need to negotiate with other countries for connectivity; expensive rates charged by local service providers for local transit; expensive set up costs and unwillingness for local Universities and Research Institutions to participate and provide the seed funds. The lack of interconnectivity among existing institutions in Africa has further hindered collaborative research. Most institutions have made little progress in terms of research outputs and receiving research grants because of expensive Internet bandwidth costs that makes it difficult to share teaching and research resources.

This study will examined the potential for using ICT to support the improvement and transformation of the education sector in Sierra Leone, with the aim – requested in its terms of reference – of raising awareness and stimulating action, especially among Sierra Leone governments and development partners. It identifies specific opportunities and challenges, and recommends areas of intervention for governments, educational institutions, the private sector and NGOs, and development partners.

2. Methodology

The methodology for this study has included desk research, questionnaires and interviews carried out with selected experts and stakeholders. The researchers will adopt the survey method for the study. Seven (7) tertiary institutions in Sierra Leone will be surveyed. Questionnaire will be the main data collection instrument which will be purposefully sent to senior administrators, academic/educators, ICT staff and librarians in all the tertiary institutions in the country. Data will be collected between September 2016 and November 2016 and the main distribution of the questionnaire will be through the electronic mail and hand delivery.
The tertiary Institutions that surveyed include Njala University (NU), University of Sierra Leone (USL), the Milton Margai College and Science and technology (MMCST), University of Makeni (UNMAK), Eastern Polytechnic and Ernest Bai Koroma University of Science & Technology (EBKUST). The sample size will be made up of 500 students from all the institutions, 50 lecturers, 10 ICT personnel and 20 university administrators. The analysis of data was done at the end of the data collection. The responses will be grouped and categorized on the basis of information provided. The analysis was done using Microsoft Excel or SPSS.

Additional information for this research was gathered through the following means:

- Interviews with NREN managers, and regional Research and Education Network (REN) Chief Executive Officers (CEOs) at UbuntuNet 2015 Conference in Maputo, Mozambique
- Further networks and discussions for Sierra Leone joining the WACREN community continued in March 2016 in Dakar, Senegal: WACREN 2016 Conference
- SLREN stakeholder workshop in Njala University in April 2016.
- Searches through NREN and regional REN websites where they existed, and through PowerPoint presentations from conferences.
- Information from WACREN, UbuntuNet, INASP, AfricaConnect, World Bank 2016 report on NRENS in Africa, reports from GARNET and websites and interactions with key players.

3. Background

In 2013, representatives from a key development partner, the International Network for the Availability of Scientific Publications (INASP) visited Sierra Leone to begin the project planning process to improve quality education, strengthen research capacity and access to research resources. They gained a first-hand understanding of the situation and met key people in the higher education and research system. They found that there were challenges of poor infrastructure in institutions: leaking roofs, unpaid bills, no internet connection and limited broadband infrastructure nationally. However, they also found that there were people working in the sector with a high level of motivation and commitment to improve standards of education and research. These people and institutions were keen to work with INASP and it seemed the time was right to begin work in Sierra Leone.

With support from INASP, WACREN and key stakeholders in the Sierra Leone research and education community, Ministries, Departments and Agencies, telecom providers, donor agencies and colleagues from Liberia gathered in Njala University, Sierra Leone in April 2016 for a stakeholder workshop to discuss the establishment of the SLREN. The successful event led to the adoption of the “Njala Declaration” to establish and develop the Sierra Leone Research and Education Network (SLREN). An interim Steering Committee was established with the mandate to operationalise the SLREN. The SLREN was officially inaugurated in July 2016 to oversee the establishment of a vibrant NREN in Sierra Leone.

The SLREN operates as a non-profit making organisation and draws its legal mandate from the Universities Act 2005 and the Corporate Affairs Commission Act No. 5 2009 Company Limited by Guarantee without a Share. The SLREN’s vision is to develop and leverage high quality information & communications infrastructure and services for the Sierra Leone research and higher education community for national development. SLREN mission is to develop an advanced network infrastructure services, promote collaboration among the national research and education communities and build the capacity of the RENs community. The objective of SLREN is to promote the establishment of interconnections between national research and education communities using advanced technologies available, connect this network with other...
regional and continental networks, and provide services aimed at fostering collaboration between research and education institutions in Sierra Leone and the sub-region.

The timing is appropriate as it coincides with the rollout of fibre optic connectivity to universities and schools in Sierra Leone by early 2017. The international fibre connectivity landing station in Sierra Leone during 2011, connected to the submarine fiber optic cable - laid down on behalf of the Africa Connect Europe (ACE) consortium, will radically improve Sierra Leone’s operating environment, including bringing down the price of bandwidth. There is optimism in the higher education and research community that the landing of the fibre cable will transform internet connectivity in the country (Reuters, 2011) This development will make it far more feasible to establish REN infrastructure in the future. At the moment, however, with the REN infrastructure still forthcoming, universities have limited Internet connectivity, where most are able to use it only for administrative purposes, with students left to find Internet access outside the institution, typically at cyber cafes. Finally, bandwidth costs remain high in Sierra Leone where coverage of the ISPs is limited and many organizations still depend on VSAT technology for connectivity. The paper discusses the lessons learnt from strengthening research capacity, availability of research resources and the establishment of a vibrant NREN for national development in Sierra Leone.

4. Challenges in Research & Higher Education

Sierra Leone is among the world’s poorest countries and endured a long civil war from 1991-2002 that devastated the country, including its educational infrastructure. More recently, the most widespread epidemic of Ebola Virus Disease (EVD) in history began in Guinea in 2013 and spread to Liberia and Sierra Leone. The country has received considerable attention around the world in recent years due to the most widespread epidemic of EVD and the devastating effects of the Ebola virus outbreak. The outbreak continued for over two years, resulting in significant loss of life and social disruption across the West Africa region. (European Centre for Disease Prevention and Control, 2016)

In August 2014, World Health Organisation declared the Ebola epidemic in West Africa a Public Health Emergency of international concern. According to the UNICEF, over 5 million children and university students were denied access to education in Guinea, Liberia and Sierra Leone as schools and universities did not re-open for nearly one academic year as a result of the EVD outbreak. Before the Ebola outbreak only 74% of children of school going-age were in primary school in Sierra Leone. The impact of prolonged school and university closures in a country with some of the lowest education indicators in the world is dire and the outbreak had negative consequences on the availability of teachers and teaching and learning materials; the safety of school and university premises; and the vulnerability of girls and women. (Global Education Cluster 2015) The psychological well-being of children and youth was also impacted by school and university closures because school and university provide a sense of stability and hope, helping to mitigate the psychosocial impact of a crisis. Thousands of children and youth lost their parents and caregivers, which increased the risk of homelessness, neglect and malnutrition. The temporary closure of universities and restrictions on movement of people halted much of the work of development partner’s projects to strengthen quality education and the foundation to access and production of research. However, it also highlighted the vital need for access to high-quality research resources to help equip researchers and policymakers to tackle their countries’ needs.

According to the African Development Bank report (2011), Sierra Leone has one of the slowest and lowest rates of internet penetration and usage in the world (African Development Bank, 2011)). The civil conflict in the 1990s, suggest that Sierra Leone missed out in the first phase of the submarine fibre cable laid along the West African coast in the mid-1990s. In 2009
however, the government of Sierra Leone developed and adopted an ICT policy in line with 2007 ICT policy of the Economic Community of West Africa States – ECOWAS (Government of Sierra Leone, 2009). Among other provisions, the ICT policy set itself the objectives of: a) improving the education system through the use of ICT to promote e-learning, and b) to subsidise access for high-speed internet subscribers in schools and higher education institutions across the country (Ibid). The objective was to multiply, by ‘seven-fold, the ICT penetration rate from the current low level of 0.27 percent to 2 percent by 2015’ (African Development Bank, 2011) This will be achieved by establishing a landing station in Sierra Leone, connected to the submarine fiber optic cable - laid down on behalf of the Africa Connect Europe (ACE) consortium - and building a terrestrial backbone that delivers broadband internet connectivity service deep into rural areas of Sierra Leone (Ibid). In October 2011, the ACE submarine cable was landed in Sierra Leonean’s capital - Freetown - admits jubilation and optimism that the landing of the cable will revolutionise internet connectivity in the country (Reuters, 2011). Over three years since the submarine cable was landed, internet penetration still remain lows at around 1.3 percent. way below the low-income countries’ average of 6.2 percent, with a connectivity bandwidth of 1,994 bps per internet user, compared to an average of 9,141 bps for low-income countries (The Economist Intelligence Unit, 2014:9-10).

The poor internet connection has negative impact on the already ailing research and higher education landscape in Sierra Leone. None of the higher education institutions in Sierra Leone is current using advanced internet-based online learning platforms- considered the norms in Europe and America - such as Moodle and blackboard. The majority of the staff and students of higher education institution in Sierra Leone lack basic technologies and communication networks such as institutional emails and internal network communication systems, with top university professors and administrators using yahoo and Gmail addresses. The disconnection of Sierra Leone from the global network has resulted in:

- Inadequate flow of educational and research content to schools, colleges and universities,
- Inadequate research activities and an underdeveloped research infrastructure,
- Lack of technical expertise and visionary capability that has curtailed competitiveness,
- Limited interaction between academic and research community, industry and government,
- Limited regional cooperation and collaboration in sharing knowledge between researchers, teachers and educators

The ‘digital divide’ of access to technology for Sierra Leone - especially in urban areas - seems to improving. But the gap remains widest in poor, rural, and isolated communities in the poorest communities. Schools and universities in Sierra Leone are far behind in terms of skills and abilities to access and to benefit from technology. These institutions have grossly inadequate educational infrastructure. This limits the ability of students and teachers to access electronic and other media resources available for learning and teaching. This challenge, combined with the lack of exposure to alternative learning resources, keeps the pass rates of children in these rural areas below their urban counterparts. In remote communities, even the teachers face daunting challenges related to isolation from their peers and a lack of teaching resources. Enhancing access to ICT through the provision of advanced ICT in education in the remote and hard to reach research and educational institutions in Sierra Leone will contribute to improving quality teaching and learning for better learning outcomes. There is the realisation that Higher Education Institutions should drive the process of generating knowledge for national development. There is also the realisation that without basic research
infrastructure in ICTs, the evaluation of a knowledge economy necessary for sustained social
development will be impossible.

5. **Practical steps for improving quality education and research capacities**

Noting the realities of the in-country challenges relating to infrastructure and connectivity, INASP staff, working with Research4Life, decided to begin the project through raising awareness of the online research materials already available through Research4Life, open access and INASP’s own programme. INASP was delighted to be approached by Miriam Conteh-Morgan, a Sierra Leonean librarian, who was appointed by her institution, the University of Sierra Leone, as project lead. ICT Director, Thomas Songu, was appointed as lead by Njala University. These two representatives have been vital to the success of the project; their commitment, collaboration and work ethic have continued to drive activities forward. It has proved invaluable to have two team members representing different sections of information provision and different institutions. They have been able to bring a more holistic approach to planning and overcoming challenges, as well as combining their shared networks and having a vision to extend the project to other institutions. The project plan was developed in consultation with Miriam, Thomas and their two universities; ensuring that plans were appropriate, inclusive, needs-focused and feasible.

6. **Building relationships – mobilization and collaboration for access**

We began in May 2014 by organizing a symposium for leaders in research and academia who discussed both the barriers and opportunities to supporting access to online research. This event provided a forum for consultation with in-country experts, as well as a chance to explain the project and get high-level buy-in. Priorities identified during the symposium aligned with the recommendations of Sierra Leone’s Government Agenda for Prosperity, including the need for improvements to: ICT infrastructure, education quality and power supply. There was a clear commitment to supporting the improvement of essential infrastructure as well as to recognize and support the role of librarians. Keen to ensure that we provided some practical support early on, the symposium was followed immediately by a workshop for library and IT staff to introduce some of the practical aspects of managing access to online resources. As a result of this workshop, the two groups formed a liaison committee with a view to founding a library consortium.

7. **Use of research: creating a skilled pool of researchers and journal editors**

There is a relatively low level of research activity in Sierra Leone, particularly of that which reaches academic journals. However, there are pockets of activity producing quality research. This includes research about the agricultural sector, particularly led by the Sierra Leone Agricultural Research Institute. The important research being done in Sierra Leone rarely becomes part of the global body of scientific knowledge because of a lack of skills for negotiating the complicated process of publishing. INASP has learned that, for impact, the improvement of access needs to be accompanied by skills training for researchers and journal editors in writing, research communication and publishing. INASP has tools to address these issues, particularly the AuthorAID initiative. This helps researchers in developing countries to publish and communicate their work, often by offering online courses to researchers. In this case, in response to the poor access to internet around the country, INASP adapted its online courses to develop courses that could be downloaded and used offline, such as ‘Planning and Communicating Research.’ This proved to be especially relevant later during the Ebola outbreak where people needed to avoid travel or large gatherings, and institutions were closed.
A researcher at Njala University applied for and won an AuthorAID grant to run a proposal writing course which resulted in the formation of eight thematic research groups.

The second phase of the project began in September 2015 and will run until March 2018. Three components of the national research system will be addressed: electronic resource access and use; campus networking; and improving the visibility of research through journal publishing. Despite the setbacks resulting in time lost, and the poor ICT infrastructure, those working on the project are optimistic for its success. The project leads are committed and active, the two institutions are collaborating well, both librarians and ICT staff are already represented in the library liaison committee, strong regional links have been forged with peers in Ghana and INASP publishers have extended free access to online literature available through our access programme to the country. We will explore the way forward below.

8. Electronic resources access and use Expansion to other institutions

A strong national library consortium can support a country to provide access to resources. A consortium can be a central manager and support for those offering and managing information access at member institutions across the country. It can strengthen buying power, enabling institutions of all sizes and budgets to access information. Negotiating as a larger body can also be more effective than as a single institution. Members can share skills and knowledge and work together to create a stronger information provision service. Having formed a liaison committee, the next step for USL and Njala was to engage with other institutions to take steps towards forming a library consortium. During March 2016 the committee has begun to initiate contact with academic leadership of several institutions to introduce the project. They will be looking to engage ICT and library staff from potential members in order to take a holistic approach to improving and managing access. This will develop during the coming months and years and it will be interesting to see how partnerships and cooperation strengthen the activities and what different stakeholders will contribute.

9. E-resource management and awareness raising

Institutions and staff need to be able to manage their online resources effectively in order to offer a good service to researchers. They need to be able to select the most appropriate resources and then ensure that users are aware of what is available, and are able to access them easily and simply in order to make full use of that which they are providing. A further training workshop on electronic resource management for librarians and a training workshop on search skills will be held for faculty staff, both in the first half of 2017. These workshops will use the training materials developed for the May 2014 events, which aimed to promote the availability of electronic resources (negotiated-for free access by INASP, open access or through Research4Life) in institutions across Sierra Leone.

10. Symposia for academic leadership

These symposia will bring together senior faculty and library staff to discuss the project. They will build upon the Phase one symposium, looking in more detail at how activities can support research, teaching and learning in Sierra Leone. They will introduce new institutions to the liaison committee and the benefits of a library consortium. Several half day symposia and training events will take place between March and May 2017 which will be facilitated by the liaison committee.
11. National ICT infrastructure and campus networking

The building of Sierra Leone’s ICT infrastructure was hampered and delayed by the long civil war. Where there currently is internet connectivity, and when access becomes more widespread, institutions will need to keep up with the technology. They will need skilled engineers and ICT professionals to configure campus networks, and ensure campus-wide access. Institutions will need their own infrastructure in order to make use of that which is available externally.

12. National Research and Education Networks

In November 2015, INASP supported Thomas Songu to participate in the UbuntuNet-Connect conference in Maputo, Mozambique. The UbuntuNet Alliance works in eastern and southern Africa aiming to secure and support National Research and Education Networks (NRENs) to develop efficient ICT systems. NRENs are not-for-profit, specialized internet service providers dedicated to supporting the needs of research and education communities within countries. They work closely with research centres and institutions to provide the most appropriate services. This conference gave Thomas the opportunity to meet with other NRENs supported by INASP – in Tanzania, Zambia and Uganda, and explore what might be possible in Sierra Leone. This gave him the impetus to join the West and Central African NREN network, WACREN. A committee has been convened to establish a Sierra Leone NREN in order to support institutions around the country. The ICT Director has reported a great depth of learning and inspiration attributable to this trip. To support this, Thomas and the committee have arranged two conferences, with financial support from INASP, bringing together key stakeholders in Sierra Leone (including Vice Chancellors, Principals, senior academics, researchers, ICT professionals and campus engineers) and WACREN. The events were the first step towards mapping out the establishment of a Sierra Leone NREN and the potential for that to join WACREN. Once the national infrastructure is in place for our partner universities, USL and Njala, to connect to high speed internet (hopefully by early 2017) they plan to work with a Ghanaian expert to configure their networks. This will build the Sierra Leonean links with Ghana and within the region.

13. Journal publishing, journal quality and visibility of research Journal editors

As mentioned above, important research is being undertaken in Sierra Leone, but researchers often find no outlet for their work. The institutions wish to revive those journals that, due to the war and then the Ebola virus, have ceased to operate and need support to start publishing again. INASP hopes that, by supporting the building of skills and brokering relationships, Sierra Leonean journals can eventually be hosted on African Journals Online (AJOL) – an INASP founded project now independently and locally run. In collaboration with AJOL, a training workshop on journal publishing and journal quality took place in February 2016. INASP sponsored eight editorial team members from Sierra Leonean journals, those both in operation and in the latter stages of development, to attend the AJOL workshop which took place in Accra, Ghana. Early in the project, connections with Ghanaian institutions were made, and Ghanaian colleagues and practices have been both helpful and influential.

Many reports and grey literature produced in Sierra Leone risk being lost due to difficulties in publication and a lack of institutional or national repositories. This means important knowledge is not being shared, or used and could potentially be duplicated. This literature needs to be kept, and needs to be shared, either institutionally or nationally; even internationally. The creation of a Sierra Leone platform using journals online software may be a way to increase the visibility
of research coming out of Sierra Leone. INASP could sponsor a Ghanaian expert to assist in the development and configuration of such a system as well as facilitating a mentorship initiative to support ongoing work and development.

Putting learning to use as well as providing support to Sierra Leone, the project was also an opportunity for INASP to explore work in a new country, and in particular a country where IT facilities and broadband infrastructure are limited. Since beginning work in Sierra Leone, and learning from our experience there, INASP has been investigating needs in other countries where ongoing or relatively recent conflicts have damaged infrastructure, strained resources and made day-to-day work much more challenging.

As a next step, in 2017 the SLREN and INASP plan to commission institutional studies of the research and knowledge systems in other universities and research institutions in Sierra Leone. Undertaken by local analysts, these will provide rich accounts of how research is done in the country, how it connects to practice and policy, and the overall state of the system. To test the waters – and to get an initial reading of the suitability of online support – we also targeted researchers in neighbouring countries of Guinea, Ghana, and Liberia when advertising INASP’s recent online course in research writing.

14. Conclusion

This paper explores the underlying contributions that a National Research and Education Network can provide to Sierra Leone’s economic development, specifically human resource capacity in the technology and technical fields. Taking a comparative study of tertiary and research institutions in Sierra Leone, this research inquiry identifies the NREN’s ability to facilitate a sector wide ICT capacity building strategy for higher education and research institutions, national and international university partnerships for distance learning and exchange program-based training programs, and train the trainer programs on advanced ICT infrastructure development within national institutions as key areas where it can support national level human resource capacity growth.

The study highlighted that a vital importance to the sustainability and success of NREN implementation is the identification and involvement of dynamic and committed people, including early engagements with NREN stakeholders and change agents. Strategically, the rationale of establishing the NREN should focuses on both the value for money argument where the Network would provide more affordable bandwidth and the availability through demand aggregation and leveraging member institutions’ collective purchasing power. Given the opportunity of laying and maintaining the fibre-optic communication infrastructure, priority should now be given to ICT infrastructure development and knowledge transfer and training programmes and value added services building on the bandwidth provision. SLREN must therefore embark on awareness raising and technical skill development at the university level and within the NREN administrative organization. Yet while it needs its own set of capacity programmes to function effectively, SLREN can play as a coordinator and facilitator for this and other national-level skill training and knowledge transfer initiatives.

Moving forward, Sierra Leone’s experience demonstrates that an NREN can build communities of practice along with, and even prior to its work implementing the physical infrastructure. Involving university-based ICT directors in key decision-making demonstrates how both government-led and private entity-driven NREN governance models can effectively incorporate member interests and concerns. As the NREN in the country continues to expand in different ways, it might be prudent to consider how some of the value added services that make an NREN so unique can be utilized by universities to better support the development of a domestic skilled talent pool.
With regard to funding, it is general practice for operational expenses of SLREN will be covered by fees and service charges from their members, while the government would cover major capital expenses for initial setup and later upgrades (with possible donor support). One option, of many, is to offer SLREN capabilities as a consultative service, which could generate additional revenue streams to be reinvested back to support the project’s sustainability. In the interspace linking the higher education and ICT sectors, the SLREN’s organizational structure and network-based value-added services can act as source of common ground and mutual gain-driven collaboration member institutions. Particularly in the context of recently fragile or post-conflict states, the cases looked at for this inquiry shed light on how an NREN can be used to grow research and education and technology-based ecosystems growing the ability of local populations to populate and sustain their countries’ economy long-term.

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Biography

Mr. Thomas Songu is an Information and Communication Technology (ICT) professional with over 20+ years implementation experience in strategic management of ICTs spanning the education, finance, media, defence, telecomm, mining and pharmaceutical industries at national and international levels. His considerable involvement in the development and implementation of strategic ICT projects has given him substantial experience in ICT infrastructure management for global public and private sector organizations. Thomas is currently working as the Director of ICT, Njala University. He is also a founding member and CEO of the Sierra Leone Research and Education Network (SLREN). Thomas has recently worked as ICT Expert, through the International Organization for Migration (IOM) funded project in the area of ICT Capacity Building in tertiary education to Sierra Leone. He has also previously worked as ICT Consultant for leading global organisations, including the UK Home Office, Computer Sciences Corporation (CSC), Siemens, T-Systems, Credit Suisse, Barclays, mainly in the UK, USA, France, Spain, Germany, Portugal, the Netherlands, and the United Arab Emirates (UAE). Thomas previous qualifications are a Bachelor of Science degree (BSc.) in Education with major in Mathematics and minor in Economics from Njala University, Sierra Leone, and a Master degree of Science (MSc.) in Information Systems Management, from London South Bank University, United Kingdom. Thomas is currently a PhD reader at Njala University. His research topic focuses on leveraging ICT in development to improve quality education and research capacities in developing countries.
Deploying Educational Roaming (eduroam) in a Rural Research Institution in Rakai, Uganda; Challenges and Lessons Learned

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Abstract

The NIAID International Center for Excellence in Research (ICER) in Uganda, RHSP (Rakai Health Sciences Program) recently deployed the eduroam service at the laboratories and offices in the village of Kalisizo and the main offices at Entebbe. Eduroam is a global framework to allow academics and researchers to have wireless access from any participating institution. An acronym for educational roaming, eduroam is a user friendly solution that provides a common WiFi network (SSID) at all participating universities and research organizations. Unlike the typical model of “guest” networks, this system provides a real identity to which network administrators and security staff can map both traffic and activity. There are clearly defined structures in place for reporting inappropriate activity to the home institution. The deployment of eduroam by the Office of Cyber Infrastructure and Computational Biology at the Ugandan ICER faced challenges and taught the team a number of lessons. The implementation began May 2016 in a test environment and was one of the first organizations to do so in Uganda. We share our experience in as far as challenges and lessons learnt.

Keywords: eduroam, RENU, GEANT, NAPTR, NREN, RADIUS server,
1. Background

All national roaming authentication traffic is aggregated into a national proxy server and all international roaming traffic is aggregated into a set of international proxy servers. This model works under most circumstances though there are drawbacks in efficiency and a lack of flexibility when it comes to routing realms which do not fit into the national aggregation model because they do not use the national ccTLD (country code Top Level Domain such as .us, .uk, .ug, .ml) ending of their federation (e.g. realms in ".net", ".org", etc.). Such was the case for the RHSP which uses rhsp.org. Dynamic Discovery places routing hints towards the responsible authentication server or national proxy into DNS, making routing more efficient. As an IdP (Identity provider), the RHSP IT staff had to ensure our realm is dynamically discoverable by adding a single resource record into our domain’s DNS zone. While adding this DNS record is optional, it has advantages in that it reduces the time it takes to authenticate users when roaming internationally, so eduroam operations recommend to add these records if your national federation supports dynamic discovery protocol.

Figure: 1 Eduroam radius hierarchy
2. How eduroam wireless infrastructure works

The guest user LLOYD from the institution RHSP wants to use institution A's eduroam wireless network. LLOYD will provide his credentials to the authenticator (here the wireless Access Point of institution A). The credentials are constituted by a username and a realm; it looks like an email address. (That is: lloyd@rhsp.org)

The AP asks institution A’s RADIUS server if LLOYD can access the network using the provided credentials. The RADIUS server notices that the realm is not one it can serve itself. It will then forward the request to the national top level RADIUS proxy server. If the realm belongs to a national institution, then the national top level RADIUS proxy forwards the request to the institution serving the realm. If this is not the case, the national RADIUS server will forward the request to the European top level RADIUS server that will forward the request to the appropriate national proxy RADIUS.

In this case, the request is sent to the institution RADIUS server at RHSP. User LLOYD is given access to the WiFi network.
3. Resolving National roaming issues by Adding Dynamic Discovery hints

to determine which discovery target name they had on their national RAIDUS proxy server. The target name entered at RENU had to be the same as the value in our DNS entry. Added Dynamic Discovery hints to our DNS zone of record type Network Authority PoinTeR (NAPTR) and this entry enabled RHSP users roam at eduroam participating institutions in Uganda.

3.1 How NATPR works

NAPTR record is a generic entry to any kind of service. It specifies which service a particular NAPTR entry is for, how that service is handled and who is handling it. It also provides basic failover and load-balancing mechanisms; there can be multiple NAPTR entries for the same service, with different priority and different weighting.

4. Resolving international roaming issues by adding an exemption for rhsp.org at the European Top Level radius server

Because RHSP does not use the Country code Top Level Domain(.ug) ending its federation, the European Top Level Radius (ETLR) Servers did not know how to route traffic for rhsp.org user accounts roaming outside Uganda. Through the Uganda National NREN (National Research and Educational Network) RENU, we did request GEANT (pan-European data network for the research and education community) to put an exemption at their ETLR servers so that international roaming traffic for rhsp.org users is routed back to the Ugandan national NREN which is then routed back to RHSP to authenticate user credentials before the roaming user gets access to internet.

5. Testing

Eduroam was tested to be working at the locations below using rhsp.org login credentials.
Acknowledgements

The authors wish to acknowledge the following for their efforts towards the success of this project.
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Knowledge Intermediation Strategies: Novel Evidence from Canada

Namatié TRAORÉ, Nabil AMARA

Abstract

This study investigates i) difference in knowledge intermediation strategies among knowledge and technology transfer organizations (KTTOs) and ii) the factors that explain such differences. It uses data from 212 Canadian KTTOs. When knowledge delivery and integration capabilities dimensions of knowledge intermediation are simultaneously accounted for, four categories of KTTOs emerge, namely, 1) knowledge stores; 2) knowledge match providers; 3) knowledge integrators and; 4) knowledge brokers. This heterogeneity results in a differentiation in KTTOs' service delivery strategies. A high absorptive capacity and an effective customer knowledge management strategy are conducive to richer service content and custom-made solutions. Larger knowledge intermediaries suffer from internal organizational stickiness that prevents them from delivering custom-made services. KTTOs with a low degree of formalization and centralization in decision-making are likely to adopt intermediation strategies aimed at reaching the largest possible number of users. Some managerial and public policy implications are drawn.

Keywords: Knowledge intermediaries; Service delivery richness spectrum; Typology of KTTOs; Survey; Canada; Multinomial Logit Model.

1. Introduction

As national systems of innovation (SNI) become more complex, both the geographic and cognitive distances between new knowledge users and innovators increase. These, coupled with the variety of knowledge sources and the diversity of the needs and wants of new knowledge customers, have resulted in the emergence of a new breed of players, broadly known as knowledge intermediaries or knowledge and technology transfer organizations (KTTOs). Their specific role is to articulate the supply of and the demand for new knowledge and ideas. The importance of their role have been extensively studied (Gibbert et al. 2002; Szulanski, 1996; Howells, 2006; Muscio, 2010; Siegel et al., 2007; Hassik, 1997; Huysman et al., 2004; Klerkx and Leewis, 2008; Vos, 2005; Cochoom et al., 1991; Bessant & Rush, 1995; Shohet & Prevezer, 1996). However, a review of this extensive literature shows that little attention has been paid to i) the types of KTTOs; ii) the strategies they use in deciding on the ways in which they acquire, transform and ultimately deliver knowledge to their clients. In addition, these prior studies do not concern themselves with the factors that explain differences in KTTOs' intermediation strategies (Szulanski, 1996; Meyer, 2010; Howells, 2006; Callon, 1980; 1994; Cash, 2001; 2014; Bessant & Rush, 1995; Hoppe and Ozdenoren, 2005; Howells, 2006; Landry et al., 2013; Lomas, 2007; 2000; Blondel, 2006; Meyer, 2010). This study builds
on and extends results from these previous studies. Its central question is what intermediation strategies KTTOs adopt and why? In response, it thus investigates the following key research questions: 1) How can the integration and the delivery dimensions of knowledge brokering activities be accounted for so as to establish a typology of KTTOs to highlight differences in their knowledge intermediation strategies?; 2) What factors/determinants underline these differences in strategies?; and 3) what are the implications of these findings both from a managerial and a public policy points of view and for future research on knowledge intermediation? The paper grounds theoretically itself into the resource-base theory of the firm (Bower, 1970) and adapts and enhances the Service delivery richness spectrum (SDRS) (Simard, 2008). On the empirical ground, unlike many prior studies that relied on either case studies or a given type of KTTO, (Sieg et al. 2010; Cilio, 2005; Diaz-Puente et al., 2009; Rasmussen et al. 2006; Janis, 2003; Hanel, 2006; Hewitt-Dundas, 2012; McAdam et al. 2012) and a limited number of services (Debackere & Veugelers, 2005; Agrawal, 2001; Jensen et al. 2003; Siegel et al. 2003; 2000; 2007), this study uses data from 212 Canadian KTTOs comprised of 4 types of intermediaries, namely, university technology transfer offices (UTTO); community colleges technology transfer offices (CCTOs); not-for-profit knowledge and technology transfer offices (NPO); and public research organizations (PRO). These 212 KTTOs offer 24 different services, a much larger set of services than that found in most empirical studies.

The remaining of the paper is organized as follows. Section 2 presents the SDRS and reviews the factors that may cause KTTOs to choose a given intermediation strategy instead of another. It also sets the study hypotheses. Section 3 describes the methodology of the research. This is followed by a presentation of the theoretical model in section 4. The empirical part of the paper focuses on the presentation of the regression models and their results in section 5. Section 6 summarizes these results and draws some managerial and public policy implications of these results.

2. The Service delivery richness spectrum (SDRS) framework and knowledge/technology intermediation

The Service delivery richness spectrum (SDRS) framework was developed by Natural Resources Canada (NRCan) (Simard, 2006; Simard, 2008) to gain a better "understanding of how government departments develop and provide science-based services". It is based on the idea that as knowledge is created and flows from creators to users, it goes through a number of stages including the transformation/translation stage, the combination/integration stage, the transfer stage and ultimately the utilization stage. As such, the transmission spectrum goes from the "reach" zone where the audience is much wider, to the "rich" zone where the audience has specific technical/specialized knowledge and needs. We adapt and enhance this framework in two ways: first, we extend it to the case of other types of KTTOs to investigate and better understand the factors explaining the "positioning and distribution of their mix of services to various users along the delivery richness spectrum" (Natural Resources Canada, 2006; Simard, 2008). More specifically, we integrate the delivery and integration capabilities of KTTOs to establish a typology and highlight different intermediation strategies. Second, we investigate the factors that cause any given KTTO to position itself either into the "reach" zone of the delivery spectrum or into the "rich" delivery zone. Below, we present these factors successively using as background the resource-based theory of the firm. They are operationalized in Appendix A along with their descriptive statistics.
2.1 Richness service delivery capabilities

This factor refers to the degree of customization of the services offered by a given KTTO. It is measured at three different customization levels: i) KTTO offers non-customized services; ii) when mixed services are offered and iii) when fully-customized services are provided. We contend that given their limited resources, in the process of articulating and translating both the supply of and the demand for knowledge, KTTOs try to identify solutions to problems by combining/recombining new and old ideas to create new knowledge (Coppolino & Abbate, 2012; Colombo et al., 2014; (Gwinner et al., 2005; Vargo, 2008; Teece, 2009; 1998)). This may result in custom-made solutions that are effective, convenient and affordable for their client firms. However, since most KTTOs are small or medium-sized with limited financial and managerial expertise and resources, a fully-customized solution may be difficult to achieve. A possible compromise is to offer services that provide a lesser level of customization by positioning oneself in the "reach" universe of service delivery.

**Hypothesis 1**: The higher the degree of customization of solutions offered by a KTTO, the higher the likelihood its mix of services will be in the rich zone of the delivery spectrum.

2.2 Service delivery reachness capabilities

The service delivery reachness capabilities are measured by a KTTO's innovativeness. It takes the value of 1 if the KTTO offered new or significantly improved services to its clients during the 3 years preceding the survey and 0, otherwise. As KTTOs attempt to reach a wider and more diversified clientele, they will have to offer their clientele an ever increasing number of new and/or significantly improved products/services. Thus, one would expect that the more innovative a KTTO, the greater its service delivery capabilities and the larger the audiences it may reach and deliver services to. In fact, such a KTTO is more likely to be more flexible and to think outside the box when identifying and assessing its customers' needs, and identifying the knowledge to adequately satisfy these needs (Szulanski, 1996; Simard, 2006; Salomann et al., 2005; Gebert et al., 2003).

**Hypothesis 2**: The more innovative a KTTO, the higher the likelihood its mix of services will be in the reach zone of the delivery spectrum.

2.3 Revenue generation capabilities

The survival of KTTOs as economic units depends largely, among other things, on the revenues they generate from their activities. The willingness of firms to pay for the services they acquire from KTTOs measures, at least in part, the value created. Thus, KTTOs must incorporate customers' wants and needs into the development of their services so as to generate maximum profits/revenues (Simard, 2006; Salomann et al., 2005; Gebert et al., 2003). This value, i.e., the cost to client firms, is likely to increase as the level of customization of services increases. Put differently, the type and the amount of services offered by KTTOs will be positively associated with higher or moderate revenue streams from client firms.

**Hypothesis 3**: KTTOs with smaller amounts of revenues are more likely than others to offer services in the reach zone of the delivery spectrum.

2.4 Absorptive capabilities

As convincingly argued by Klerkx and Leeuwis (2008), the adequate articulation of demand and supply of innovation is critically important as most of KTTOs' clients are SMEs which may experience difficulties in clearly stating their needs due to the lack of managerial, financial and technical expertise. Thus, KTTOs need sufficient absorptive capabilities (Cohen and
Levinthal, 1990; Zahra and George, 2002) to intermediate effectively and to lessen the uncertainty related to new knowledge acquisition, transfer and utilization (Klerkx and Leeuwis, 2008; Hoppe and Ozdenoren, 2005). A key resource needed by KTTOs in this respect are their employees, in particular, employees with scientific and business expertise (Gwinner et al., 2005; Neu & Brown, 2005; Walsh et al., 2008). A scientific background is necessary for understanding the underlying science and technology issues involved in the services being provided. Likewise, a training in business helps KTTOs’ employees understand the business issues involved in knowledge and technology transfer, and to develop and provide the business components of knowledge and technology transfer services. Overall, the larger the number of these two types of employees within a given KTTO, the more it will be able to offer increasingly more refined services (Kuhlthau, 1991; Simard, 2006).

**Hypothesis 4**: The number of employees with specialized technical, financial and managerial skills will positively impact on a KTTO’s ability to deliver services in the rich zone of the service delivery spectrum.

### 2.5 Information management capabilities

Information management capabilities include the information generation and search/finding capabilities as well as information/storage and diffusion capabilities. We contend that the information search process (ISP) in the form of using general sources of information such as libraries and the Internet coupled with the ability to search specialized databases are all critical to the effectiveness of service delivery process (Landry et al. 2013; Kuhlthau, 1991; Taylor, 1986; Wilson, 1981). This process also includes putting in place both an effective information retrieval strategy and a rigorous customer knowledge management (CKM) strategy geared toward making "knowledge for, from and about customers" works so as to create an effective customer relationship (CRM) strategy and higher-value customer services (Bose & Sugumaran, 2003; Davenport et al., 2001; Salomann et al., 2005; Gibbert et al., 2002; Davenport & Klahr, 1998; Thomke & von Hippel, 2002; von Hippel, 1977; Woodruff, 1997).

**Hypothesis 5**: An increased use of general as well as technical resources for information retrieval and customer knowledge management by KTTOs will positively impact on their capabilities to deliver services in the rich zone.

### 2.6 Network brokering capabilities

These network capabilities are operationalized by using indicators of the strength of the relationships forged by KTTOs (Hansen, 1999; Gwinner et al., 2005) as well as the importance of market, institutional, and information networks. KTTOs facilitate the linking of "innovation seekers" and "innovation solvers" (Coppolino and Abbate, 2012) and are thus able to establish effective communication channels between "the know-how, the know-why, the know-when and the know-who". For an effective service delivery process, they have to manage many types of networks, including social, industrial, scientific and technological networks (Bidault and Fischer, 1994; Chesbrough, 2003; Fleming and Waguespack, 2007; Meyer, 2010; Lomas, 2007; 1997; Blondel, 2006; Kash & Rycott, 2000; Darroch & McNaughton, 2002; Tether, 2002; Romijn & Albaladejo, 2002). Participation in such networks allows KTTOs to identify and acquire ideas and information that complement and validate their in-house knowledge, thus contributing to increasing the likelihood of success of their service delivery projects (Malecki & Tootle, 1996; Bougrain & Haudeville, 2002; , 2006; Cooke and Wills, 1999).

**Hypothesis 6**: Increased KTTOs' network brokering capabilities will positively impact on their ability to deliver services in the rich zone.
2.7 Control variables: size and types of organizations

2.7.1 Size

Based on the review of the relevant literature, two control variables were introduced into this study, namely, the size and the types of KTTOs. A KTTO's size as measured by the number of employees accounts for the impact of resource availability on knowledge delivery services (Amara et al. 2013; Tether, 2002; Landry et al., 2002; Koberg et al., 2003; Becheikh et al., 2006; Schartinger et al., 2002). Larger KTTOs are likely to have more in-house technical and financial resources as well as managerial expertise to offer their clients custom-made solutions. However, in contrast to their smaller counterparts, they may lack the necessary flexibility to respond in a timely manner to rapidly changing customer needs and Wants due to internal stickiness arising from the "not-invented-here" (NIH) syndrome (Hayes & Clark, 1985; Szulanski, 1996; Katz and Allen, 1982) and their heavy tendency of relying on "core competencies" (Nelson, 1993; Traoré, 2004). We expected the negative impact of NIH syndrome to outweigh the positive impact of resource availability.

Hypothesis 7: A KTTO's size is negatively related to its ability to deliver services in the rich zone of the delivery spectrum.

2.7.2 Types of KTTOs

The type of KTTO accounts for any differences in the service delivery pattern stemming from differences in managerial philosophy and motives, as well as the environment in which the KTTO operates. Browne (2005) showed that organizations with lower degrees of formalization and centralization are more likely to be successful in transferring knowledge. Barnard et al. (2001), Landry et al. (2013); Landry et al. (2011); and Lloyd et al. (1997) also showed that other elements of organizational context as they relate to senior management willingness to engage in knowledge intermediation service delivery, do impact on the level and the type of service delivered. We therefore expect that KTTOs with lesser degrees of centralization and formalization, namely, UTTOs and NPOs, may have lesser constraining mandates in terms of performance goals and objectives and are therefore more likely to service a much larger clientele base and thus position themselves in the reach zone of the service delivery spectrum.

Hypothesis 8: UTTOs and NPOs are more likely than their counterparts to deliver services in the reach zone of the delivery spectrum.

3. Methodology: Questionnaire development and data collection

KTTOs in the study were identified by i) consulting the available listings of UTTOs and CTTOs and ii) by relying on the web sites of various Canadian and provincial government agencies to develop a list for PROs and NPOs. A snowball strategy, using references to other web sites, was also used to identify additional organizations. In the end, after excluding all those organizations that did not offer any knowledge and technology intermediation services to firms, a final population of 263 was obtained. A questionnaire developed with help from an advisory committee of the CEOs and Executive Directors of nine KTTOs was administered by a survey firm with extensive background in survey administration. By February 21, 2009, 212 interviews were completed. The response rate is thus 80.6% (212/263 organizations). This is a large enough number of organizations to capture the heterogeneity in intermediation organizations so as to develop a reliable taxonomy and investigate the factors influencing the differences in knowledge delivery strategy among KTTOs. Finally, to test for non-response bias in our sample, an analysis of early versus late respondents’ answers to key variables of the study was also performed. The rationale for comparing early and late respondents is the assumption that late respondents are good proxies for non-respondents (Miller and Smith,
1983; Radhakrishna and Doamekpor, 2008). More specifically, we performed a comparison between the first and last 10% of respondents (the latter being used as a proxy for the non-respondents) based on five explanatory variables used in the econometric models, namely, KTTO’s size, market network index, institutional network index, information network index, and strength of ties index. An independent-sample T-test was run and used for the comparison. The results indicate that, on average, the early respondents sub-sample does not differ from the late respondents sub-sample, suggesting that non-respondents are similar to late respondents, and thus non-response bias is not a concern in our sample.

4. Theoretical model: Typology of KTTOs and Model's variables

As stated earlier, the typology of the KTTOs is based on the combination of two service delivery dimensions, namely, 1) knowledge transfer capacity (knowledge delivery capacity); and 2) knowledge integration capacity (knowledge integration capacity) (Table 1). The results of the Principal Component Factors Analysis (PCFA) to test for uni-dimensionality indicated that one factor explained 51.87% of the original variance of the knowledge delivery index, with an initial Eigenvalue of 2.59. Likewise, one factor explained 80.05% of the original variance with an initial Eigenvalue of 2.50. The scores of Cronbach’s $\alpha$ for reliability were .755 for the five items knowledge delivery capability index, and .793 for the four items of the knowledge integration capacity index. These values indicate that the items composing the two indices are reliable (Nunnally & Bernstein, 1994; DeVon et al., 2007). Using these two indices, we derived the typology of the KTTOs in two steps. First, the medians of the two indices were calculated. As can be seen in Table 1, the medians are equal to 16 and 14 for the index of knowledge delivery capacity and the index of knowledge integration capacity, respectively. Second, the four KTTOs configurations, used as dependent variables in our models, were derived by crossing the two indices as shown in Figure 1 and obtained as follows:

- **Knowledge stores**: (low knowledge delivery capacity and low knowledge integration capacity): index of knowledge delivery capacity $\leq 16$ and index of knowledge integration capacity $\leq 14$.

- **Knowledge match providers**: (high knowledge delivery capacity and low knowledge integration capacity): index of knowledge delivery capacity $>16$ and index of knowledge integration capacity $\leq 14$.

- **Knowledge integrators**: (low knowledge delivery capacity and high knowledge integration capacity): index of knowledge delivery capacity $\leq 16$ and index of knowledge integration capacity $>14$.

- **Knowledge brokers**: (high knowledge delivery capacity and high knowledge integration capacity): index of knowledge delivery capacity $>16$ and index of knowledge integration capacity $>14$.
Figure 1: Typology of KTTOs with regard to their Knowledge delivery and knowledge integration capacities
Table 1: Operational Definitions of the Four profiles of Service Delivery Richness Spectrum of Knowledge Transfer Through Services Provided to Private Firms: Configurations Are Built Using Two Indices

<table>
<thead>
<tr>
<th>KNOWLEDGE DELIVERY CAPACITY</th>
<th>The sum on a 5-point scale, ranging from 1 (Never) to 5 (Very often), of the scores for items corresponding to respondents’ answers regarding five aspects of knowledge transfer capacity through distribution of services to clients:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Seeking new geographic markets;</td>
</tr>
<tr>
<td></td>
<td>• Extending current services to new categories of clients; developing new services;</td>
</tr>
<tr>
<td></td>
<td>• Developing new services;</td>
</tr>
<tr>
<td></td>
<td>• Developing and exploiting niches or specialized markets;</td>
</tr>
<tr>
<td></td>
<td>• Providing customer-specific services (customizing services, delivery methods, after-sale services, etc.).</td>
</tr>
<tr>
<td>Median</td>
<td>16.00</td>
</tr>
<tr>
<td>Mean</td>
<td>15.39</td>
</tr>
<tr>
<td>Std</td>
<td>4.26</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>25.0</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>2.59</td>
</tr>
<tr>
<td>Variance Explained</td>
<td>51.87%</td>
</tr>
<tr>
<td>Cronbach’s $\alpha$</td>
<td>.755</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KNOWLEDGE INTEGRATION CAPACITY</th>
<th>The sum on a 5-point scale, ranging from 1 (Never) to 5 (Very often), of the scores for items corresponding to respondents’ answers regarding four aspects of knowledge integration capacity:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Using and updating databases of scientific information;</td>
</tr>
<tr>
<td></td>
<td>• Developing measures favoring knowledge sharing between your employees;</td>
</tr>
<tr>
<td></td>
<td>• Capturing and using knowledge obtained from other industry sources (e.g., industry associations, competitors, clients and suppliers);</td>
</tr>
<tr>
<td></td>
<td>• Capturing and using knowledge obtained from public research institutions including universities and government laboratories</td>
</tr>
<tr>
<td>Median</td>
<td>14.00</td>
</tr>
<tr>
<td>Mean</td>
<td>13.58</td>
</tr>
<tr>
<td>Std</td>
<td>3.63</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>20.00</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>2.50</td>
</tr>
<tr>
<td>Variance Explained</td>
<td>62.51%</td>
</tr>
<tr>
<td>Cronbach’s $\alpha$</td>
<td>.793</td>
</tr>
</tbody>
</table>

4.1 Specification of the independent variables

The independent variables considered in this study were grouped into the 7 categories defined in section 2 and their descriptive statistics are presented in Appendix A. The reliability test for the nine multi-scale independent variables, namely, LnTIES, MARKET, INSTIT, INFOR, GENFIND, STOSPRE, LnENG, LnMNG, and LnSize, was performed by running a principal components factor analysis (PCFA) (Ahire & Devaray, 2001). The values of Cronbach’s $\alpha$ indicate that each index is reliable (see Appendix A). To test for the multicollinearity between the continuous explanatory variables in the model, we first, estimated both their pair-wise correlation coefficients and their tolerance statistic values. All the estimated values were much higher than .2, indicating that there is no multicollinearity issue (Menard, 1995; Field, 2006).

5. Empirical models and results

5.1 Empirical Models

Five situations were deemed relevant to the identification of the factors explaining differences in knowledge intermediation strategies: 1) adopting a knowledge broker strategy rather than a knowledge store strategy; 2) adopting a knowledge broker strategy rather than a knowledge match provider strategy; 3) adopting a knowledge broker strategy rather than a knowledge integrator strategy; 4) adopting a knowledge match provider strategy rather than a knowledge store strategy; and 5) adopting a knowledge integrator strategy rather than a knowledge store strategy. A multinomial Logit regression was estimated to ascertain the first three situations, while two bivariate logit regressions for the latter two options. For the multinomial logit regression model, the four alternative profiles are 1, 2, 3 and 4 as presented in Figure 1 with
profile 4 being the reference category. For the two binary logit models, the alternative strategies/profiles are 2, 3 and 4. The probability of choosing any given profile \( k \) (with \( k = 1; 2; 3; 4 \)) is given by:

\[
\text{Prob}_{ik} = \frac{e^{\beta_k X_i}}{1 + \sum_{k=1}^{4} e^{\beta_k X_i}}
\]

(1)

where \( X_i \) is the matrix of the profiles' attributes and \( \beta_k \) is an \( m \times 1 \) vector of parameters to be estimated. As a consequence, the multinomial model is expressed in logarithmic form as:

\[
\ln \left( \frac{\text{Prob}_{i1}}{\text{Prob}_{i4}} \right) = (\beta_1 - \beta_4) X_i = \beta_1 X_i
\]

(2)

\[
\ln \left( \frac{\text{Prob}_{i2}}{\text{Prob}_{i4}} \right) = (\beta_2 - \beta_4) X_i = \beta_2 X_i
\]

\[
\ln \left( \frac{\text{Prob}_{i3}}{\text{Prob}_{i4}} \right) = (\beta_3 - \beta_4) X_i = \beta_3 X_i
\]

### 5.2 Regression Results

As shown in Panel A of Table 2, all the models are significant at the 1% level: The multinomial model has a very good predictive power, with 60.5% of correct predictions. The value of the Nagelkerke \( R^2 \) is .598, and the computed value of the likelihood ratio (i.e., 167.17) is much larger than the critical value of the chi-squared statistic at the 1 percent level, with 63 degrees of freedom. Consequently, the model is significant at the 1 percent level. Similarly, the computed value of the Chi-square statistics for each of the two Logit regression models is greater than its critical values (i.e., 38.93) with 21 degrees of freedom at the 1% level. The two equations have good predictive powers, with 80.7% and 81.0% of overall correct predictions, respectively. Finally, the value of Nagelkerke pseudo \( R^2 \) is .534 for the first binary Logit regression model and .499 for the second model.

Results show that hypothesis 1 is supported as higher degrees of service customization lead to KTTOs being in the rich delivery zone. In fact, developing non-customized solutions for client firms (NOCUST) or developing mixed solutions (MIXED), rather than customized solutions (CUST) have a significant and negative impact on the likelihood that KTTOs adopt a profile of knowledge broker rather than one of knowledge match provider. Contrary to our prior expectations, hypothesis 2 is not supported. In fact, innovative KTTOs are more likely to deliver services in the rich zone as increased innovativeness is found to increase the likelihood of being a knowledge broker rather than a knowledge store, knowledge match provider, or a knowledge integrator. KTTOs that generated no revenues (NOREV) or moderate revenues (MODREV) from sale of services to firms are less likely to adopt a profile of knowledge broker rather than one of a knowledge store. Moreover, KTTOs that generated no revenues (NOREV) as opposed to more sizeable revenues are less likely to adopt a profile of a knowledge broker rather than one of a knowledge integrator. Put differently, increased revenue
generation capabilities increases both knowledge delivery and integration capabilities and increase the chances that knowledge integrating KTTOs become knowledge brokers. Thus hypothesis 3 is supported.

As for the absorptive capability variables, an increase in the number of employees with scientific or engineering training (LnENG) increases the likelihood that KTTOs be knowledge brokers rather than knowledge match providers, whereas an increase in the number of employees with management training (LnMNG) increases the likelihood that KTTOs be knowledge brokers rather than knowledge integrators and offer services in the rich zone of the delivery spectrum. These results lend support to hypothesis 4. Likewise, for the Information management capability variables, generation and finding of knowledge (GENFIND) has a significant and positive impact on the likelihood that a given KTTO adopts a profile of knowledge broker rather than one of a knowledge store, or one of a knowledge match provider, whereas storing and spreading knowledge (STOPRE) has a significant and positive impact on the likelihood that KTTOs adopt a profile of knowledge broker rather than one of a knowledge integrator. Thus, stronger knowledge search and retrieval capabilities increase the chances that KTTOs with knowledge store, knowledge match provider and knowledge integrator profiles better process knowledge for, from and about customers and ultimately allow them to deliver more refined and higher-value services and increases their likelihood of adopting a knowledge broker profile. Likewise, increased knowledge storage and diffusion/dissemination capacity will increase the probability for KTTOs with strong integration capacities (knowledge integrators) to strengthen their delivery capabilities and become knowledge brokers. In summary, hypothesis 5 is supported by the results. Hypothesis 6 is partially support. In fact, all the indicators of the network brokering activities, except for the strength of ties between KTTOs and their clients (LnTIES) lead to intermediation service delivery in the rich zone of the spectrum. As shown by the results, LnTIES has a significant and negative impact on the likelihood that KTTOs adopt a knowledge broker profile rather than a knowledge match provider or knowledge integrator profiles. In contrast, the market network index (MARKET) has a significant and positive impact on the likelihood that KTTOs be knowledge brokers rather than knowledge stores or knowledge integrators, whereas institutional networks (INSTIT) and information networks (INFOR) have significantly positive impacts on the likelihood that KTTOs be knowledge brokers rather than knowledge match providers. Thus, increased KTTOs brokering activities with regard to the cognitive distance with their customers and their leadership in different networks including market, information and institutional networks are conducive to higher level of customization of knowledge intermediation services).

Finally, for the control variables, the results show that an increase in the KTTO’s size (LnSIZE) decreases its likelihood of being a knowledge broker rather than a knowledge store. Thus, larger KTTOs are less likely to provide custom-made services than their smaller counterparts and therefore are more likely to deliver services in the reach zone. This result suggests that organizational stickiness prevail in knowledge intermediation among the KTTOs surveyed and lends support to hypothesis 7. Likewise, with regard to the types of KTTOs, the results show that being Not-for-profit Organizations (NPOs) or University Technology Transfer Offices (UTTOs) rather than Public Research Offices (PROs) or CTOs, decreases the likelihood that KTTOs be knowledge brokers rather than knowledge stores. Since NPOs and UTTOs are likely to be subjected to a lower degree of centralisation and formalization than other types of KTTOs, these results support the contention that such organizations are more successful in delivering knowledge intermediation services in the reach zone of the delivery spectrum that are geared toward a wider clientele base (Browne, 2005). Thus, hypothesis 8 is support.
Table 2. Results of the regression models

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>PANEL A: Multinomial Logit Estimation</th>
<th>PANEL B: Binary Logit Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[Knowledge store to Knowledge broker]</td>
<td>[Knowledge match provider to Knowledge broker]</td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td>-5.977</td>
<td>.013</td>
</tr>
<tr>
<td><strong>RICHNESS SERVICE DELIVERY CAPABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Customized solutions [NOCUST]</td>
<td>.845</td>
<td>.234</td>
</tr>
<tr>
<td>Mixed solutions [MIXED]</td>
<td>-.361</td>
<td>.693</td>
</tr>
<tr>
<td>Customized Solutions [CUST]</td>
<td>Benchmark</td>
<td>Benchmark</td>
</tr>
<tr>
<td><strong>REVENUE GENERATION CAPABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No revenues from sale of services [NOREV]</td>
<td>-1.322 **</td>
<td>.049</td>
</tr>
<tr>
<td>Moderate revenues from sale of services [MODREV]</td>
<td>-1.446 *</td>
<td>.061</td>
</tr>
<tr>
<td>Important Revenues from Sale of Services [IMPREV]</td>
<td>Benchmark</td>
<td>Benchmark</td>
</tr>
<tr>
<td><strong>ABSORPTIVE CAPABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of employees with scientific or engineering training [LnENG]*</td>
<td>-.024</td>
<td>.492</td>
</tr>
<tr>
<td>Number of employees with management training [LnMNG]*</td>
<td>.465</td>
<td>.150</td>
</tr>
<tr>
<td><strong>INFORMATION MANAGEMENT CAPABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation &amp; finding of knowledge [GENFIND]</td>
<td>1.580 ***</td>
<td>.001</td>
</tr>
<tr>
<td>Storing &amp; Spreading of knowledge [STOPRE]</td>
<td>.369</td>
<td>.185</td>
</tr>
<tr>
<td><strong>NETWORK BROKERING CAPABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength of ties [TIES]</td>
<td>-.567</td>
<td>.287</td>
</tr>
<tr>
<td>Market networks [MARKET]</td>
<td>.205 **</td>
<td>.037</td>
</tr>
<tr>
<td>Institutional networks [INSTIT]</td>
<td>.080</td>
<td>.185</td>
</tr>
<tr>
<td>Information networks [INFOR]</td>
<td>.024</td>
<td>.430</td>
</tr>
</tbody>
</table>
**SERVICE DELIVERY REACHNESS CAPABILITIES:**

- **Innovative KTTO [INNOV] (YES=1)**
  - 1.036 ** .047
  - 2.426 ** .003
  - 1.202 ** .039

Table 2. Results of the regression models (Continued)

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>PANEL A: Multinomial Logit Estimation</th>
<th>PANEL B: Binary Logit Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[Knowledge store to Knowledge broker]</td>
<td>[Knowledge match provider to Knowledge broker]</td>
</tr>
<tr>
<td><strong>CONTROL VARIABLES:</strong></td>
<td>Coeff. (β)</td>
<td>P-value</td>
</tr>
<tr>
<td>Size [LnSIZE] *</td>
<td>-.673 ** .035</td>
<td>-.073 .431</td>
</tr>
<tr>
<td>Types of organizations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College technological transfer office [CTTO]</td>
<td>-2.675 .342</td>
<td>1.045 .272</td>
</tr>
<tr>
<td>Not-for-profit organization [NPO]</td>
<td>-3.711 *** .008</td>
<td>.386 .405</td>
</tr>
<tr>
<td>Public Research Organization [PRO]</td>
<td>Benchmark</td>
<td>Benchmark</td>
</tr>
<tr>
<td>Number of cases: (Total = 212)</td>
<td>78/52</td>
<td>41/52</td>
</tr>
<tr>
<td>Chi-square (d.f.):</td>
<td>167.17 (63)</td>
<td></td>
</tr>
<tr>
<td>Nagelkerke R² (Pseudo R Square):</td>
<td>.598</td>
<td></td>
</tr>
<tr>
<td>Percentage of correct predictions:</td>
<td>60.5%</td>
<td></td>
</tr>
</tbody>
</table>

*, ** and *** indicate that the coefficient is significant, respectively, at the 10%, 5% and 1% thresholds.

*Ln indicates a logarithmic transformation.
6. Summary, managerial and public policy implications

The central research question of the study was how do KTTOs actually combine and manage their internal and external resources and capabilities to deliver services to customers with substantial differences in terms of needs, desires and wants? Our results show that when knowledge delivery and knowledge integration are simultaneously accounted for, 4 types of KTTOs emerge, namely, 1) knowledge stores with limited knowledge delivery and integration capabilities; 2) knowledge match providers with extensive delivery capabilities but limited integration capabilities; 3) knowledge integrators with limited delivery capabilities but extensive integration capacities and 4) knowledge brokers with extensive delivery and integration capabilities. Factors that are conducive to a richer service content and custom-made solutions include i) increased innovativeness; ii) increased absorptive capacity; iii) stronger information search and storage capabilities and; iv) shorter cognitive distance with customers; v) increased networking capabilities. Likewise, managing knowledge from, for and about customers is an effective value-creating intermediation strategy as it leads to a higher level of service customization. Larger firms suffer from internal organizational stickiness that prevents them from delivering custom-made services. As well, NPOs and UTTOs are more likely than others to adopt an intermediation strategy geared toward reaching the largest possible number of users.

These results suggest that for KTTOs’ intermediation strategies to be effective, their managers need to i) adapt their positioning and distribution of mix of services to various users and ii) assess their knowledge delivery and integration capabilities by taking into account both their internal and external resource endowments. From a public policy perspective, this suggests that to promote more effective innovation diffusion/dissemination throughout the knowledge value-chain, decision-makers should no longer rely solely on the linear model of innovation diffusion. Rather, they should recognize KTTOs as an integral part of the national innovation system and use them as knowledge service delivery channels to reach different audiences. The results also suggest that managers of larger KTTOs will be more successful if they concentrate on providing more general types of intermediation services. The same holds for managers of less centralized and less formalized KTTOs such as university technology transfer offices (UTTOS) and not-for-profit organizations (NPOs). Thus, public policies aimed at reaching the greatest possible number of knowledge/technology users will be more effective if resources are provided to larger KTTOs and/or to UTTOs and NPOs to support their implementation. In contrast, resources should go to smaller KTTOs for services aimed at fulfilling specific clients’ needs or at reaching specific audiences. Furthermore, public policies aimed at enhancing the role of knowledge intermediaries, if geared toward i) increasing KTTOs’ access to more highly qualified workers such as engineers, scientists and management experts and/or ii) increasing KTTOs' information management capabilities, are likely to be successful as both of these factors lead to higher value services. Finally, the results suggest that KTTOs' managers can increase their revenues by improving both their service delivery and integration capabilities through greater service customization.

Some limitations of our study are worth mentioning. The study is about Canadian KTTOs This provides an opportunity for a comparative empirical study with for example some OECD countries with similar challenges in terms of the complexity of the innovation systems and knowledge markets. Moreover, as a cross-sectional study, it cannot capture the dynamics of knowledge intermediation. For example, any given KTTO may choose at any time to move along the knowledge delivery spectrum. This could not be accounted for in our model. In addition, we introduced into our models the types of KTTOs (UTTOS, NPOs, PROs and CTTOs) to account for differences in knowledge delivery strategies stemming from differences in managerial philosophy and motives. We were able to make only general statements in
regards to the impact of such factors. Given the results suggesting that such differences may in fact play an important role in defining the position and the mix of services provided by KTTOs, further research is warranted to further investigate this issue. In spite of these limitations, the results of this study have enhanced our understanding of the knowledge intermediation process from both a theoretical and an empirical points of view.

References


Landry, R., Amara, N. & Jbilou, J. (2011) 'Evidence on the roles of knowledge brokers in health service organizations', working paper, Department of Management, Laval University, Faculty of Business,


Simard, A., (2006) 'Knowledge markets: More than providers and users' Ottawa, Canada : Natural Resources Canada, Knowledge Strategies Division


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### Appendix A. Definitions of independent variables and descriptive statistics

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sub-items</th>
<th>Mean (SD)</th>
<th>Percentage (Number)</th>
<th>Cronbach’s alpha [Unidimensional alpha]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RICHNES SERVICE DELIVERY CAPABILITIES</strong></td>
<td>Three dichotomous variables constructed with respect to the responses of the organization to the following question: Which of the following statements best describes the services you offered to private firms over the last three years?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-customized solutions (NOCUST): (Mainly basic research &amp; Almost only basic research=1; Else=0)</td>
<td>19.3 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed solutions (MIXED): (Half-customized solutions and half-basic research=1; Else=0)</td>
<td>38.7 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Customized solutions (CUST): (Almost only customized solutions &amp; Mainly customized solutions=1; Else=0)</td>
<td>42.0 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CUST is the reference category.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REVENUE GENERATION CAPABILITIES</strong></td>
<td>Three dichotomous variables constructed with respect to the responses of the organization to the following question: Please estimate (as best you can) the percentage of sale of services in your organization’s total budget over the last three years?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-revenue from sale of services (NOREV): (0% of organization’s total budget from sale of services=1; Else=0)</td>
<td>47.6 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate revenue from sale of services (MODREV): (from 1% to 25% of organization’s total budget from sale of services=1; Else=0)</td>
<td>24.1 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Important revenue from sale of services (IMPREV): (more than 25% of organization’s total budget from sale of services=1; Else=0)</td>
<td>28.3 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IMPREV is the reference category.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SERVICE DELIVERY REACHNES S CAPABILITIES [INNOV]</strong></td>
<td>Dichotomous variable indicating whether the KTTO has offered, over the last three years preceding the survey, to private firms, any new or significantly improved services?</td>
<td></td>
<td></td>
<td>73.1 %</td>
</tr>
</tbody>
</table>
**NETWORK BROKERING CAPABILITIES:**

<table>
<thead>
<tr>
<th>Strength of ties with clients [LnTIES]</th>
<th>Industry</th>
<th>1.82</th>
<th>.692</th>
</tr>
</thead>
<tbody>
<tr>
<td>measured as a weighted index on a 5-point Likert scale (1 = Very close: practically like being in the same work group; 2 = Somewhat close: like discussing and solving problems together; 3 = Somewhat distant: like with people that you do not know well; 4 = Distant: like a working group with which you can only have a quick exchange of information; 5 = Very distant: practically like with people that you do not know at all) describing the working relationship between organizations and their clients in the following sectors.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public sector organizations, government departments/agencies, universities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Market networks [MARKET]</th>
<th>Suppliers of equipment, materials, components, or software</th>
<th>2.99</th>
<th>.744</th>
</tr>
</thead>
<tbody>
<tr>
<td>measured as a weighted index on a Likert scale of frequency ranging from 1 = Never to 5 = Very often of the use of the organization, over the last three years preceding the survey, to rate the degree of frequency of use of the following four information sources for the development and improvement of services offered to private firms:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clients or customers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitors or other organizations in your sector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institutional networks [INSTIT]</td>
<td>Measured as a weighted index on a Likert scale of frequency ranging from 1 = Never to 5 = Very often of the use of the organization, over the last three years preceding the survey, to rate the degree of frequency of use of the following six information sources for the development and improvement of services offered to private firms:</td>
<td>Universities or other higher education institutions</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colleges/technical institutes</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Federal government research laboratories</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Provincial government research laboratories</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private non-profit research laboratories</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patent databases</td>
<td></td>
</tr>
<tr>
<td>Information networks [INFOR]</td>
<td>Measured as a weighted index on a Likert scale of frequency ranging from 1 = Never to 5 = Very often of the use of the organization, over the last three years preceding the survey, to rate the degree of frequency of use of the following four information sources for the development and improvement of services offered to private firms:</td>
<td>Conferences, fairs, exhibitions</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scientific journals and trade/technical publications</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Investors (banks, venture capitalists, etc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry associations</td>
<td></td>
</tr>
</tbody>
</table>
Appendix A (Continued). Definitions of independent variables and descriptive statistics

**INFORMATION MANAGEMENT CAPABILITIES:**

| Generation & Finding of knowledge [GENFIND] | Measured as a weighted index on a Likert scale of frequency ranging from 1 = *Never* to 5 = *Very often* of the use by the organizations, over the last three years preceding the survey, of the following five tools for the development and improvement of their services offered to private firms: | Data mining/ text retrieval software | 2.28 | .770 |
| | | Expert or decision support software | (.98) |
| | | Automatic e-mail alerts | |
| | | Intelligent agent or artificial intelligence mind/knowledge mapping software | |
| Storing & Spreading of knowledge [STOSPRE] | Measured as a weighted index on a Likert scale of frequency ranging from 1 = *Never* to 5 = *Very often* of the use by the organizations, over the last three years preceding the survey, of the following four tools for the development and improvement of their services offered to private firms: | Content/document management software | 2.86 | .738 |
| | | Intranet or enterprise information portal | (.95) |
| | | Knowledge repository or digital archive | |
| | | Workflow/process management software | |

**ABSORPTIVE CAPABILITIES:**

| Employees with scientific or engineering training [LnSCENGI N] | Measured as number of employees with scientific or engineering training. This variable was matched with the normal distribution using a logarithmic transformation | 26.19 | (55.27) |
| | | | |
| Employees with business training [LnMNG] | Measured as number of employees with business training. This variable was matched with the normal distribution using a logarithmic transformation | 4.87 | (8.47) |

**CONTROL VARIABLES:**

| Size of KTTOs [LnSIZE] | Measured by the total number of full-time employees (equivalent full time) in 2008. This variable was matched with the normal distribution using a logarithmic transformation | 46.57 | (85.68) |
A series of dichotomous variables indicating the types of organization. The organizations are regrouped in four types:

- Not-for-profit organization (NPO) 36.3%
- College technological transfer office (CTTO) 25.5%
- University technological transfer office (UTTO) %
- Public research organization (PRO) 19.8%

The reference category is Public Research Organization (PRO) 18.4%

*The unidimensionality of constructs with multiple item scales was assessed by conducting a principal components factor analysis for each construct (PCFA). The results of these analyses indicate that the unidimensionality criterion was satisfied*

**Biography:**

**Namatié Traoré, Ph.D**

Dr. Namatié Traoré is a Visiting Professor with the Telfer School of Management and a former Fulbright Fellow.

He is a former Senior Manager with the Canadian Public Service where he was Director of the Economic and Industry Analysis Division at Agriculture and Agri-Food Canada (AAFC); Director of Canada’s agricultural statistics program at Statistics Canada; and Chief Economist at the Canadian Food Inspection Agency (CFIA).

He has published in such journals as the Journal of Business Research; Research Policy; Industry and Innovation; Higher Education; Science Communication; International Journal of Biotechnology;

His research interests are in Entrepreneurship, Innovation and Knowledge creation and dissemination.
A Technical Evaluation of the Performance of Classical Artificial Intelligence (AI) and Methods Based on Computational Intelligence (CI) i.e Supervised Learning, Unsupervised Learning And Ensemble Algorithms In Intrusion Detection Systems

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Abstract

The emergence of new technologies in this dynamic information era has caused a tremendous increase in the rate at which data is being generated through interactive applications thereby increasing the movement of information and data on communication networks as individuals, organizations and business interact on a daily basis. Big Data is flooding our networks and storage devices stimulating a cause for concern in terms of processing, storage, access and security of large blocks of data in most networks. The facilitation of online research services is always under the risk of intruders and malicious activity. Most techniques used in today's Intrusion Detection Systems are not able to deal with the dynamic and complex nature of cyber-attacks on computer networks. Over the years, Intrusion Detection Systems have been developed by many researchers to detect intrusions aimed at networks as well as standalone devices which are based on machine learning algorithms, neural networks, statistical methods etc. In this paper, we study several such schemes and compare their performance. The experiments are done using WEKA (Waikato Environment for Knowledge Analysis) and one of the most popular Intrusion Detection Systems datasets which is NSL-KDD99 so as to analyse the consistency of each algorithm. We divide the schemes into methods based on classical artificial intelligence (AI) and methods based on computational intelligence (CI) i.e supervised learning, unsupervised learning, ensemble and immune algorithms. We explain how various characteristics of CI techniques can be used to build efficient IDS. This paper will further evaluate the performance of the algorithms using the following parameters: accuracy, detection rate and false alarm.

Keywords: Big Data, Intrusion Detection, NSL - KDD99, Machine Learning, Neural Networks, WEKA
1. Introduction

The current advances in Information and Communication Technologies the world over have brought significant benefits to individuals and businesses. Conversely, this has substantially increased the threat landscape in as far as security of systems is concerned. No matter how much security controls are present in a particular system, intrusions are imminent (Ibrahim et al, 2013) thus creating need for intrusion detection. This is largely because security is based on rules and configurations that are set by the owners or users of a product. Mistakes can happen and loopholes always create opportunities which intruders exploit. It is imperative to seek out ways to detect intrusions in a system in order to avert or reduce the impact of an attack. An Intrusion Detection Systems (IDS) is a software that monitors a single or a network of computers for malicious activities (attacks) that are aimed at stealing or censoring information or corrupting network protocols (Kemmerer & Vigna, 2002). IDSs are also defined as special-purpose devices to detect anomalies and attacks in the network. Anomaly detection and misuse detection are two approaches to IDSs (Tavallaee et al 2009). The former is popularly applied for research purposes while the latter is targeted for commercial products. In either case, the IDS can identify an attack. Intrusion Detection is regarded as the second line of defence. Various techniques and methods are applied in IDSs. In this work we look at two broad categories i.e. Classical Artificial Intelligence methods and Computational Intelligence methods with respect to IDSs. We carry out several experiments on various algorithms in each category. Classical Artificial Intelligence methods include techniques such as Multilayer Perceptron, Voted-Perceptron and CHIRP. Computational Intelligence methods include Naive Bayes, Adaboost, Random Forest etc. These techniques perform best under different scenarios. Thus, they differ in their accuracy in detection, false positive rates and efficiency.

The rest of the paper is organized as follows: section II presents some related work on Intrusion Detection Systems (IDSs) and relevant techniques from literature. Section III explores the different types of IDSs. Section IV provides an analysis of the schemes for intrusion detection systems. Section V. discusses experimental results and lastly the conclusion and future are given in section VI.

2. Related Work

The success of a technique in detecting an intrusion hinges largely on the quality of the data on which it is trained. There are a few datasets that are commonly used for evaluating performance of techniques applied in IDSs. KDD99 is a dataset prepared in (Stolfo et al, 2000) from data generated in the DARPA’98 IDS evaluation (Lippmann, et al 2000) It has shortcomings of redundant records and high level of difficulty (Tavallaee et al 2009). Learning algorithms trained on the dataset give results that are inclined towards frequent records over less frequent records which usually show anomalies. This makes the results obtained from experiments done on this dataset very much unreliable. NSL-KDD datasets is an improvement of the KDD99 dataset (Tavallaee et al 2009) as a way to overcome the challenges imposed by the KDD99 dataset. All redundant records are removed in both the test and training sets. The difficulty in the dataset is also reduced as the number of selected records from each difficulty level group is inversely proportional to the percentage of records in the original KDD data set. The number of records in both the training and test set are reasonable thus allowing running of all records rather than a sample of records to yield consistent and comparable results.

The input features used in IDS is also another factor that is of importance. According to Chae et al. (2013), if the correct features are used, the IDS becomes more computationally efficient and effective. They evaluate the performance of standard feature selection methods and go on to propose a new feature selection method using the Attribute Ratio (AR) which is calculated by mean and frequency of features.
The area of Intrusion Detection research has greatly matured as evidenced by the expanse of techniques that have been applied on relevant datasets in various experiments in a bid to enhance intrusion detection capability. Ibrahim et. al analysed the performance of Self Organization Map (SOM) an Artificial Neural Network, in an Intrusion Detection System (Ibrahim et al, 2013). The IDS consists of three modules, for database creation, preprocessing and detection of attack. This is applied to KDD99 and NSL-KDD datasets. In this work SOM is found to perform better than other techniques applied on KDD99 over on the NSL-KDD datasets with a detection rate of 92.37% and 75.49% respectively.

Revathi.&. Malathi (2013) make an analysis of algorithms for Intrusion Detection applied on the NSL-KDD dataset. Experiments are performed using Machine Learning algorithms which are SVM, J48, Random forest, CART and Naive Bayes algorithms. This is done using a dataset with 41 features and also a dataset of 15 features reduced using the CFS subset technique for dimensionality reduction. In both cases, Random Forest algorithm shows the highest accuracy rate of 99.1% and 99.8% respectively for a normal attack. AdaBoost-based algorithm with decision stumps used as weak classifier is used for intrusion detection in Weiming Hu et al (2008). The algorithm is tested on Knowledge Discovery and Data Mining CUP 1999 data set. The algorithm is found to have a high running speed, low false-alarm and high detection rates of about 0.307% and 90.04% respectively on the test set. Pachghare, & Kulkarni (2011) et al. makes a comparative analysis of various decision tree based algorithms such as J48, Random Forest, Random Tree, NB Tree, LAD Tree etc. In this analysis J48 Graft gives the best results compared to the other types of decision trees.

Hybrid Intrusion Detection Systems have been proposed in a number of researches. These combine strengths of different algorithms so as to improve existing techniques. In Zhang and Zulkernine, (2006) an approach is proposed that combines the benefits of misuse and anomaly detection. Most Intrusion detection techniques are usually based on either misuse detection or anomaly detection, not both. Random Forests algorithm is used in the misuse detection to detect known intrusions while outlier detection also provisioned by the random forests algorithm is used in detection of unknown intrusions. The misuse detection performs well for known intrusions. However, outlier detection in Random Forest algorithm is found not to perform very accurately as it results in many false positives.

A model based on a combination of Hidden Markov Model (HMM) and Rough Set Reduction is proposed and applied in Anomaly Detection (Zihui Che & Xueyun Ji, 2010). The HMM and rough set based approach can identify misuse and malicious intrusion by means of attributes reduction.

3. Types of Intrusion Detection Systems

The major classifications of intrusion detection systems are active and passive IDSs. An active Intrusion Detection Systems (IDS) is sometimes referred to as an Intrusion Detection and Prevention System (IDPS). It is designed in such a way that malicious traffic will be dropped without external intervention. The IDPS has the advantage of providing real-time remedial solution in response to an intrusion. A passive IDS on the other hand does not provide any solution in the wake of an attack. Rather, it only monitors and analyzes network traffic activity and alert an operator to the possible attack. Table 1 shows some types of IDSs.
### Table 1: Types of Intrusion Detection Systems

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Intrusion Detection System (NIDS)</td>
<td>Network Based-Network IDSs (NIDS) are placed in key areas of network infrastructure and monitors the traffic as it flows to other host.</td>
</tr>
<tr>
<td>The Host Intrusion Detection System</td>
<td>Host Based-Intrusion Detection System is installed on a host in the network.</td>
</tr>
<tr>
<td>Stack Based IDS</td>
<td>Stack based IDS is latest technology, which works by integrating closely with the TCP/IP stack, allowing packets to be observed as they make their way way up the OSI layers.</td>
</tr>
<tr>
<td>Signature Based IDS</td>
<td>Signature-Based IDS use a rule set to identify intrusions by looking out for patterns specific to known and documented attacks.</td>
</tr>
<tr>
<td>Anomaly Based IDS</td>
<td>Anomaly-Based IDS analyses ongoing traffic, activity, transactions and behavior in order to identify intrusions by detecting anomalies.</td>
</tr>
<tr>
<td>Network behavior anomaly detection (NBAD)</td>
<td>Network behavior anomaly detection (NBAD) is the monitoring of the network for any anomalous behaviour in traffic flow.</td>
</tr>
</tbody>
</table>

### 4. Schemes for Intrusion Detection Systems

#### 4.1 Classical Artificial Intelligence Methods

Multi-Layer perceptron (MLP) is a feedforward neural network which maps a set of inputs to a set of outputs with multiple layers between them. The flow of data happens in forward direction from input to output layer. Training of MLP is done with the backpropagation learning algorithm. MLP goes beyond merely classifying an event as an attack or normal traffic but also it can be used to classify many different types of attacks. (Frank, 1994). It is widely used for classification, pattern recognition and prediction. Multi-Layer Perceptron can solve problems which are not linearly separable.

#### 4.2 Voted Perceptron

The Voted perceptron is an improvement of the classical perceptron algorithm which uses kernel functions which gives an improvement in performance, both in test accuracy and in computation time. A list of all prediction vectors that are generated after each and every mistake in prediction is maintained during training. For each such vector, the number of iterations it “survives” until the next mistake is made is counted which is referred to as the “weight” of the prediction vector. A prediction is then calculated by a weighted majority vote derived from binary prediction of each one of the prediction vectors (Freund & Schapire, 1998).
4.2 CHIRP

CHIRP classifier, is an iterative sequence of three stages (projecting, binning, and covering) that are designed to deal with the curse of dimensionality, computational complexity, and nonlinearily separable (Wilkinson, 2011) CHIRP is a nonparametric, ensemble classifier works on any data set, thus it is suitable for diverse data sets regardless of unavailability of prior knowledge of the structure of the data set.

5. Computational Intelligence

5.1 Random Forest

Random Forest is an ensemble learning method used for solving both regression and classification problems. It can be applied for dimensionality reduction, resolving missing values, outliers and other tasks in data exploration. It is a result of combination of weak models to form a more efficient model. Random Forest generates several classification trees to form a forest. Each tree places a vote for classifying an object (Zhang & Zulkernine, 2008)

5.2 Real Adaboost

Adaboost is an ensemble technique which assists in combining a number of “weak classifiers” into a solitary “strong classifier”. A weak classifier is one that performs poorly, but performs much better than random guessing. A perfect example can be seen in the classification of sexes using height. One could say anyone over 5’ 9” is a male while anyone below that height maybe classified as a female. This method can lead to a lot of misclassifications but the accuracy will still be greater than 50%.

5.3 SVM

It is a machine learning algorithm that is used for classification and regression. It is based on the idea of a decision plane that separates members belonging to different classes. Each data item is plotted as a point in n-dimensional space with the value of each of the n features being the value of a particular coordinate. SVM aims to produce a model which predicts target value of data instances in the testing set with only the attributes given (Vidhyaa, 2013) Naïve Bayes

It is a classification technique that is based on Bayes' Theorem with an assumption of independence between predictors/features. In simple terms, a Naive Bayes classifier assumes that the presence of a particular feature in a class is unrelated to the presence of any other feature. For example, a fruit may be considered to be an apple if it is red, round, and about 3 inches in diameter. Even if these features depend on each other or upon the existence of the other features, a Naive Bayes classifier would consider all of these properties to independently contribute to the probability that this fruit is an apple. This indeed is a strong assumption but it results in a fast and effective method. Naïve Bayes algorithm has been successfully applied to spam filtering and document classification.

6. EXPERIMENTS AND RESULTS

All experiments were done using WEKA (Waikato Environment for Knowledge Analysis). “WEKA is a collection of machine learning algorithms for data mining tasks” (Weka3, n.d.) It is an Open Source software providing an extensive set of tools for data preprocessing, association rules, classification, regression, clustering and visualisation. The training dataset used is NSL-KDD dataset which contains 42829 instances with several types of attacks. The testing dataset consisted of 22544 instances. Figure 1 shows the steps that are followed in the classification process. Table 2 shows the results from the experiments that were performed by
applying the various algorithms on the datasets. Analysis is done based on build time, test time and true positives.

![Figure 1: Classification Process](image)

Table 2: Experiment Results

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Build Time</th>
<th>Test Time</th>
<th>True Positives</th>
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<tbody>
<tr>
<td>MLP</td>
<td>7695.915 app 2.1 hrs</td>
<td>1.31</td>
<td>77.71</td>
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<tr>
<td>Chirp</td>
<td>429,725 app 7.15mins</td>
<td>0.495</td>
<td>76.8808</td>
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<tr>
<td>Voted Perceptron</td>
<td>19.435</td>
<td>54.115</td>
<td>41.1595</td>
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<tr>
<td>Random Forest</td>
<td>80.395</td>
<td>0.835</td>
<td>80.4516</td>
</tr>
<tr>
<td>Real Adaboost</td>
<td>8.715</td>
<td>0.145</td>
<td>80.4205</td>
</tr>
<tr>
<td>Bagging</td>
<td>41.695</td>
<td>0.155</td>
<td>82.6295</td>
</tr>
<tr>
<td>SVM</td>
<td>21873.475 app 6hrs</td>
<td>396.585 app 6mins</td>
<td>72.3518</td>
</tr>
<tr>
<td>Naive Bayes</td>
<td>0.795</td>
<td>0.965</td>
<td>76.1178</td>
</tr>
<tr>
<td>Ensemble Selection</td>
<td>106.335 app 1.7mins</td>
<td>4.02</td>
<td>84.3018</td>
</tr>
</tbody>
</table>

which denote the accuracy of the algorithm in detecting intrusions. The results displayed by the table indicate that ensemble selection offers the highest detection rate with an accuracy of 84% albeit with a higher build time and test time. Bagging performed very well with a lower build time and test time. All the methods falling under Computational Intelligence performed very well. On the other hand Classic Artificial Intelligence methods ie. MLP, CHIRP and Voted-Perceptron were outperformed by CI methods.

7. CONCLUSION

The results of the experiments show us that Ensemble Selection is a much better technique compared to the other algorithms as it yielded more true positives and a higher precision and recall value. The Voted Perceptron yielded the worst results meaning that it may not be the best algorithm to use for intrusion detection. Computational Intelligence methods outperformed Classic Artificial Intelligence methods. We will analyse the performance of Immune algorithms. In our future work, we will use the winning Algorithm to design a prototype.
References


## PART THREE: Participant List

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