UbuntuNet-Connect 2011

Proceedings and Report of the 4th UbuntuNet Alliance Annual Conference

theme: access for success

November 23-25, 2011
Safari Park Hotel
Nairobi, Kenya

ISSN 2223-7062
Proceedings Editors:

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Key title: Proceedings and report of the 4th UbuntuNet Alliance annual conference

IDRC funded CORENA Project number 105717 provided funding in support of the conference
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INTRODUCTION

“Access for Success” was the theme for the 4th UbuntuNet-Connect Conference, held in at the Safari Park Hotel, Nairobi, Kenya in November 2011 and successfully hosted by KENET, the Kenyan Academic and Research Network. The field of Academic and Research Networking evolving rapidly and in Africa, this is receiving considerable attention.

UbuntuNet-Connect is the series of annual conferences organized by UbuntuNet Alliance that track the progress in the area. The first was held in Lilongwe, Malawi in November 2008, the second in Kampala, Uganda in November 2009. The third conference, UbuntuNet-Connect 2010, was held at 17 - 18 November 2010 at Kopanong Hotel, Johannesburg, South Africa.

For various reasons this fourth volume of UbuntuNet-Connect Proceedings has been delayed at the editorial stage and has some formatting inconsistencies. Some abstracts only have been included as the full papers were not forthcoming or the paper has been published elsewhere. We apologise for this. However it was felt, for the sake of the authors, that it was important to publish the volume.

Fuller details and presentations may be found on the UbuntuNet Alliance website: http://www.ubuntunet.net/uc2011_program

Group Photo of some of the Participants at UbuntuNet-Connect 2011
The Impact of Improved Access and Connectivity on Intellectual Property Output: Baseline Report

Francis F Tusubira¹, Ali Ndiwalana², Solomon Dindi³, Harriet Obbo⁴

1. Introduction

“...when countries lose their base for academic excellence – through out-dated policies, neglected institutions, the exodus of their best graduates or woefully inadequate investment in research – their competitiveness in the global knowledge society will dwindle and eventually disappear”⁵.

We open with this quote because it paints a stark but correct picture of what is happening in many African countries, providing a starting point for this discussion.

The intellectual property output of African universities and research institutions and their contribution to national human development is not commensurate with their human resource. The institutions also have very limited visibility at the global level, leading to loss of competitiveness of the institutions, and consequently the competitiveness of their home countries. While this is the result of many factors, we posit that the current isolation of Africa-based researchers from the global information infrastructure (GII) is a major contributing factor, and that the reduction of such isolation will lead to increased intellectual property output.

During 2009, the UbuntuNet Alliance initiated research aimed at examining this hypothesis by tracking researcher behaviour over a period of at least five years. The actual baseline data collection started during 2010, running into mid 2011. In this paper we report on this baseline study that was designed to benchmark the status of access and connectivity as well as intellectual property output, all measured at the institutional level. Based on the findings of the baseline research, we also make action recommendations to universities that are aimed at creating the kind of research environment where improved access and connectivity would boost research output.

We start with a background section that provides the context for this on-going research, specifically discussing what makes up the research environment in a university, in recognition of the fact that there are several other elements that will influence the quality and quantity of intellectual property output. We then describe and explain the research

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design, followed by a presentation, analysis, and discussion of the baseline study results. This is followed by a summary of our preliminary findings and action recommendations for universities in Africa.

2. Background

2.1 Isolation of the Africa-based researcher from the GII

By 2006, with the exception of mainly South Africa and Senegal, universities and research institution in sub-Saharan Africa were accessing the Internet via commercial Internet service providers delivering services via VSAT. Data compiled during that year showed that the member countries of the UbuntuNet Alliance were paying a total of USD1.2 million for an overall total of about 700Mbps per month. At that time, this amount of money would have procured 60Gbps if spent by universities to pay for bandwidth in the USA. Figure 1 gives the typical Internet access cost scenario across Africa as published during 2006.

![Price per Mb, ranked in ascending order](source: Balancing Act African Satellite Markets Report 2006)

Source: Balancing Act

Figure 1: Typical Internet costs across Africa (published 2006)

The isolation of Africa-based researchers from the GII is, in other words, not due to lack of funds, but due to distorted markets resulting largely from poor policy and regulation – there is no other reason for explaining such a wide variance of pricing across a delivery platform whose actual cost of delivery across Africa is location independent. The combination of the growth of NRENs in Africa; increased supply of competitive marine fibre landing on the continent; and improved regulation is leading to very sharp reduction in prices\(^6\),\(^7\) even


if, at close to USD1,000 per Mbps per month for most universities in the region, the prices are still very high compared to the rest of the academic and research world.

It must be pointed out that access is not simply about Internet connectivity. It also includes campus readiness to connect to the Internet and provide sufficient access devices to faculty and students. The Kenyan NREN—Kenya Education Network (KENET) has conducted two studies, the E-readiness survey in 2006 and the East African Accession Project in between 2008 and 2010.

KENET used the E-readiness survey (2006)\(^8\) that covered 25 member institutions (17 universities and 8 tertiary institutions) to assess the level of preparedness of member institutions to use ICT for teaching, learning, research, and management. Although it included both a hard-facts questionnaire for institutional data and a perceptions questionnaire for students and staff, the main goal was to influence institutional ICT strategy development through providing a diagnostic e-readiness framework that enables an institution to work through a four-stage process towards better e-readiness. To assess e-readiness, the survey used 17 indicators grouped into five categories—network access, networked campus, networked learning, networked society and institutional ICT strategy.

In the East African Accession survey\(^9\), KENET went beyond its borders to include universities in Burundi (5), Kenya (17), Rwanda (7), Tanzania (9) and Uganda (10) by working with NRENs in those countries.

A major finding in both studies was that the overwhelming majority of academic institutions at tertiary and university level were not ready to participate in the GII, even if cheap high capacity connectivity was to be provided to them. An internal survey\(^10\) by the Research and Education Network of Uganda, RENU, conducted three years later also revealed that only one institution, Makerere University, was ready \((at \ the \ time)\) to take in 100Mbps of Internet connectivity.

The UbuntuNet Alliance, working with NRENs, focuses on the removal of isolation of the Africa-based researcher by creating and enabling easy access to both online resources (materials) and online collaboration opportunities (people). The Alliance and almost all NRENs in Africa are still at a formative stage, and require both government and development partner support to get them to the same level of service delivery as NRENs around the more developed countries. There are however competing demands on both these sources of funding, and the Alliance therefore set out to make an evidence-based case for investment by African governments into NRENs and the required connectivity by demonstrating the impact of increased access and connectivity on intellectual property output.

2.2 Intellectual Property Output and the Research Environment

We use the phrase “intellectual property output” in this paper to include all scholarly publications and patents. Scholarly communication includes peer reviewed journal papers, conference paper, and non-peer reviewed academic publications. Several authors have


\(^{9}\) EA Accession Project findings on E-Readiness of Higher Education Institutions in East Africa, [http://kenet.or.ke/eready/index.php](http://kenet.or.ke/eready/index.php)

\(^{10}\) RENU Internal documents
highlighted the challenge of limited intellectual output from African universities, in most cases with specific reference to scholarly publications, which manifests itself in the triple challenges of quality, quantity, and visibility. For example, in their paper, Adams et al\textsuperscript{11}, using data from the Thomson Reuters Web of Science\textsuperscript{12}, show that from 1999 to 2008, the entire African continent had 27,600 scientific papers published, while the Netherlands alone had 27,000 during the same period. When one factors out countries in North Africa along with the Republic of South Africa, the number drops to less than 8,000.

The challenges of quantity and quality are compounded by poor visibility. Non profit initiatives like African Journals Online\textsuperscript{13} were set up to ensure the greater visibility and easier accessibility of African scholarly output to both Africa and the rest of the world. The Scholarly Communication in Africa Programme, SCAP\textsuperscript{14}, is one of the responses to the challenge of visibility. SCAP is “aimed at increasing the visibility and developmental impact of a spectrum of research outputs from universities in Southern Africa”. Despite being region specific, the online discussions, findings, and recommendations have relevance to the rest of Africa.

On a global scale, patents registered by African countries are almost insignificant. The 2011 statistics from the World Intellectual Property Organisation\textsuperscript{15}, WIPO, show that out of 1,414 (2008 data) patents in force as registered by the African Regional Intellectual Property Office, only 113 were from African countries, the bulk of these (98) being from South Africa. The same report has South Africa (2010 data) with 6,530 reported patents in force, including 820 from South Africa and only 8 from the rest of Africa. To provide a sense of the current imbalance, of the 6,530 patents cited above, 1,939; 702; and 493 patents were from the USA, Germany, and UK respectively. Continental statistics have been used to make the point: global statistics push Africa below the significant level.

The national research system of any country, as well as specific institutional organisational factors of say a university, have a direct and high impact on intellectual property output\textsuperscript{16}. Based on an analysis of 63 agricultural research organisations in Ghana and Nigeria, Ragasa\textsuperscript{17}, makes the clear case that organisational factors impact the productivity of scientists, while at the same time giving a comprehensive review of papers that have looked at factors that impact on researcher output. Our focus in this discussion is the institutional research environment. The objective is not to carry out an analysis of the environment, but rather to place access and connectivity as one of the elements within the larger context of the research environment. It also provides an important starting point for tracing the thread of impact of access and connectivity. We recognise the fact that if the other factors in the

\textsuperscript{12} http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science/
\textsuperscript{13} http://www.ajol.info/
\textsuperscript{14} http://www.scaprogramme.org.za/
\textsuperscript{16} Two key references, both books containing related articles from various authors are noted here. One is “Higher Education, Research, and Innovation: Changing Dynamics” edited by V. Lynn Meek, Ulrich Teichler, and Mary-Louise Kearney. International Centre for Higher Education Research Kassel, 2009; and the other is “The Road to Academic Excellence: The Making of World-Class Research Universities”, edited by Altbach, P.G. and Jamil Salmi, J. The World Bank, 2011.
\textsuperscript{17} Ragasa, C., “Do Organizational Factors Affect Individual Scientist’s Productivity? A Comparative and Multilevel Analysis of Nigeria and Ghana Agricultural Research Systems”, International Food Policy Research Institute, 2010
research environment are not right, connectivity and access alone would still make some difference, but the synergy would be lost as would be the real value of such access.

Figure 2 illustrates the theoretical concept used in this paper. A researcher, with a given set of attributes (level of qualification, discipline, research competence, ICT literacy, information literacy, teaching competence, gender) gets immersed in the research environment of a university. This environment will then shape the researcher’s behaviour, stimulating them to conduct research and generate intellectual property output. Conversely, the environment, if not conducive to research, can instead discourage a researcher from conducting research.

![Figure 2: Concept of the relationship between the researcher, researcher behaviour (ICT specific) and the research environment](image)

In the university environment, we note the following key organisational factors that define the research environment:

i. Research Policy—spelling out the policy objectives and strategy. The policy should cover the organisational positioning and governance of research within the university; principles and methods/processes for identification of research priorities; research capacity development; research funding targets; incentives to promote research (such as research-related promotion; output oriented research funding; recognitions; etc.); research dissemination and exploitation; balancing time allocation between teaching and research; etc.

ii. Intellectual Property Policy—addressing approaches to ownership and rights of the institutions vis-à-vis the researchers; and types of copyright that will apply and how; etc.
iii. Library Resources—supporting the teaching and research processes, especially those accessible online;
iv. Research Funding (within the broader context of institutional budget guidelines);
v. Industry and Commercial linkages (also relates to the level of maturity within the industrial and commercial enterprises);
vi. Laboratories and Equipment;
    vii. Connectivity and Access;
    viii. Graduate Programmes;
    ix. Linkages (institutional, national, regional, global)
x. Institutional Research Culture.

This illustration focuses on the specific behaviour we have assumed would be shaped by access and broadband connectivity to the global research and education environment, namely:

i. Time spent online
    ii. How the time online is used
    iii. The relative amount of time spent on research
    iv. Active involvement in collaborative activities (internal and external)
    v. Publication culture

This behaviour leads to two specific outputs: publications, and patents. What happens next will then condition the researcher in a way that either reinforces or weakens positive aspects of researcher behaviour. If the incentives (as captured in the research policy) reinforce the positive behaviour, the researcher becomes more conscious of the shortcomings in the research environment and will push for improvement. Where the environment is responsive to such pushing, a virtuous cycle will be created and overall research output will be increased.

The following suppositions, not illustrated in Figure 2 (and not addressed in this research) need to be noted:

    i. The actual fact of publication reinforces a good research culture because it leads to satisfaction and a feeling of confidence.
    ii. Where there is positive reinforcement, the researcher will work on improving their attributes especially where the environment supports or enables this: holders of master’s degrees will join PhD research programmes, and PhD holders will seek post-doctoral research opportunities as well as other ways of improving their research capacity.
    iii. Experienced researchers, if immersed in a poor research environment, will immediately start to push for improvement. If they fail, they will either leave or degrade.

It should also be noted that while we have included National Development in our model, the real connection is not as simplistic as it appears: there are many other factors not discussed in this paper that will determine whether or not intellectual output will positively impact on national development. This aspect will be expanded on and examined during the next round of data collection.
2.3 The Specific Role of Access and Connectivity

We submit that access and connectivity boost a good research environment in various ways. The first one that has been very important to universities in developing countries is access to online resources, both the scholarly databases and the more general online publications. The second one is enabling collaboration – within the university and nationally, regionally, and globally. This permits the researcher to join (or re-join) the global discourse in their areas of specialisation, to stay up to date, and be challenged by the work and progress of peers. A very important aspect of this is direct inclusion and access to the dedicated resources in the global research and education community, achieved when national research and education networks (NRENs) are established. Thirdly, it enables access to and use of advanced applications, including direct learning and research tools (for example grid computing; online labs or i-labs) and tools that support effective interaction (for example video-conferencing applications). Finally, access and connectivity enable the institution to have online visibility for its programmes, and its intellectual property output, increasing the chances of attracting good students as well as high calibre researchers.

Looking at all the factors that define the research environment, and taking into account the typical pace of change of major policies in universities, it is reasonable to expect that access and connectivity is the only one that will change rapidly over the five year period starting 2010 because it is strongly driven by external factors, providing a window of opportunity for monitoring impact while the other factors remain on a path of gradual change.

3. Methodology

Our methodology is based on the UbuntuNet Alliance Monitoring and Evaluation Strategy. During this exercise, the team identified the basic elements of a program theory, which included both an action and a change theory to help facilitate their work. The action theory captures the efforts of the Alliance and key partners in translating available resources to produce the programme deliverables, while the change theory captures the anticipated changes in the target audience as a consequence of these deliverables. The target beneficiaries are Africa-based researchers in this scenario; the leverage mechanism is the presence of reliable, efficient, affordable and sufficient Internet bandwidth on the continent that is likely to contribute towards a positive outcome—their improved intellectual property output at the global level along with its resulting benefits. All of this takes into account the ecological context bound to influence the outcome, of which higher education institutions where these researchers are based is just a part. Others include the national telecoms policy and regulatory regimes, national and regional fibre rollouts, research funding initiatives, etc.

Using a multi-stage process, we created two survey instruments for the baseline study. The institutional tool collected various types of data about higher education institutions that were NREN members in participating countries, aimed at capturing data about the research environment. Multiple administrative personnel (ICT Support; Library; Research

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18 UbuntuNet Alliance. Consolidating Research and Education Networking in Africa (CORENA) Monitoring and Evaluation Strategy. UbuntuNet Alliance, 2009, can be obtained on request from info@ubuntunet.net
Divisions; Administration) at each institution completed this instrument. The individual tool collected individual researcher perceptions about how their institutional environment supported or stifled their research activities, and also solicited data based on which the researcher behaviour could be inferred.

The resulting instruments were structured and included either single-option or multi-option variables. A 5-point Likert scale was used for responses, and an “other” option provided wherever necessary to capture responses that did not match the structured options. The instruments were self-administered, under the management of a researcher or the NREN CEO in each of the countries that participated.

By the deadline, UA had received returns from five member NRENs out of the eight that had agreed to participate in the survey: the challenge in all cases was the lack of response from both institutions and researchers. Only Ethiopia, Malawi, and Uganda returned sufficient numbers of the individual questionnaires from a sufficient number of universities to assure statistical representation. These three countries were therefore carried forward for the current focus of baseline analysis, with the plan to add more countries during the second round of surveys. All institutional questionnaires from all the countries (Ethiopia, Malawi, Rwanda, Uganda, and Zambia) were however carried into the institutional analysis.

3.1 Individual returns
Valid returns were obtained from 271 academic staff of universities: Malawi (66), Ethiopia (140), and Uganda (65). The following major categories, each broken down into sub-categories, were examined through this instrument:

i. Demographic characteristics: gender, age, academic rank; qualification; duration of employment by current institution; main employment assignments;
ii. Research policy: existence and satisfaction;
iii. Sources of research funds;
iv. Library: resources and satisfaction;
v. Laboratories and equipment: sufficiency and satisfaction;
vi. Computers: access, ownership, usage, and applications used;
vii. Internet: access, quality, utilisation;
viii. Conduct of research: individual leadership, volume, time allocation, collaboration;
ix. Research output: type, where published, attitude to creative commons;
x. Barriers to, and motivation for research

3.2 Institutional returns
Returns were received from a total of 16 institutions: Malawi (3), Ethiopia (5), Uganda (2), Rwanda (3) and Zambia (3). The institutional returns covered the following major categories:

i. ICT in the Institution: ICT support unit, Internet and email access, ICT in education functions, ICT in research, ICT curricula, data and network security
ii. Library: Automation, access to online resources, user training (information literacy);
iii. Research and intellectual property: documentation, dissemination, commercialisation;
iv. Research support services.

4. Analysis of Survey Returns and Findings

In this section, we present the analysis of the returns as well as the findings. The individual and institutional surveys are separately treated in two parts, and the third part examines the cross-relationships.

4.1 Analysis of Individual Returns

4.1.1 Demographic characteristics

The demographic characteristics of the sample for the individual survey are summarised in Table 1.

Table 1: Demographic characteristics of respondents

<table>
<thead>
<tr>
<th>Rank</th>
<th>Attribute</th>
<th>Frequency</th>
<th>% -share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>53</td>
<td>19.6%</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>214</td>
<td>79.0%</td>
</tr>
<tr>
<td>Missing data</td>
<td></td>
<td>4</td>
<td>1.5%</td>
</tr>
<tr>
<td>Cumulatively</td>
<td></td>
<td>271</td>
<td>100.0%</td>
</tr>
<tr>
<td>Age</td>
<td>Younger than 22</td>
<td>6</td>
<td>2.2%</td>
</tr>
<tr>
<td></td>
<td>22-32</td>
<td>82</td>
<td>30.3%</td>
</tr>
<tr>
<td></td>
<td>33-43</td>
<td>109</td>
<td>40.2%</td>
</tr>
<tr>
<td></td>
<td>44-54</td>
<td>51</td>
<td>18.8%</td>
</tr>
<tr>
<td></td>
<td>55-65</td>
<td>19</td>
<td>7.0%</td>
</tr>
<tr>
<td></td>
<td>Older than 65</td>
<td>3</td>
<td>1.1%</td>
</tr>
<tr>
<td>Missing data</td>
<td></td>
<td>1</td>
<td>0.4%</td>
</tr>
<tr>
<td>Cumulatively</td>
<td></td>
<td>270</td>
<td>100.0%</td>
</tr>
<tr>
<td>Highest degree attained</td>
<td>Bachelors</td>
<td>34</td>
<td>12.5%</td>
</tr>
<tr>
<td></td>
<td>Masters</td>
<td>166</td>
<td>61.3%</td>
</tr>
<tr>
<td></td>
<td>PhD</td>
<td>70</td>
<td>25.8%</td>
</tr>
<tr>
<td>Missing data</td>
<td></td>
<td>1</td>
<td>0.4%</td>
</tr>
<tr>
<td>Cumulatively</td>
<td></td>
<td>270</td>
<td>100.0%</td>
</tr>
<tr>
<td>Academic rank</td>
<td>Professor</td>
<td>7</td>
<td>2.6%</td>
</tr>
<tr>
<td></td>
<td>Ass. Professor</td>
<td>48</td>
<td>17.7%</td>
</tr>
<tr>
<td></td>
<td>Senior Lecturer</td>
<td>38</td>
<td>14.0%</td>
</tr>
<tr>
<td></td>
<td>Lecturer</td>
<td>130</td>
<td>48.0%</td>
</tr>
<tr>
<td></td>
<td>Assistant Lecturer</td>
<td>18</td>
<td>6.6%</td>
</tr>
<tr>
<td></td>
<td>Tutor</td>
<td>6</td>
<td>2.2%</td>
</tr>
<tr>
<td></td>
<td>Research Associate</td>
<td>2</td>
<td>0.7%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>12</td>
<td>4.4%</td>
</tr>
<tr>
<td>Missing data</td>
<td></td>
<td>10</td>
<td>3.7%</td>
</tr>
<tr>
<td>Cumulatively</td>
<td></td>
<td>271</td>
<td>100.0%</td>
</tr>
<tr>
<td>Duration at current</td>
<td>Less than 1 year ago</td>
<td>45</td>
<td>16.6%</td>
</tr>
<tr>
<td>academic rank (years)</td>
<td>1-5 years ago</td>
<td>155</td>
<td>57.2%</td>
</tr>
<tr>
<td></td>
<td>6-10 years ago</td>
<td>41</td>
<td>15.1%</td>
</tr>
<tr>
<td></td>
<td>11-15 years ago</td>
<td>9</td>
<td>3.3%</td>
</tr>
<tr>
<td>Missing data</td>
<td></td>
<td>13</td>
<td>4.8%</td>
</tr>
<tr>
<td>Cumulatively</td>
<td></td>
<td>8</td>
<td>3.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>271</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
The sample had 271 respondents, 79% of whom were male, a very typical situation. More than 72% were below 44 years of age and only 8% were above 55 years. While this could mean that the more senior members could have been reluctant to complete the questionnaire, direct knowledge of the situation in countries like Uganda points to the reality that senior academics, who are normally experienced in research and the research leaders, are leaving the universities earlier in life. These do not necessarily leave the countries but are absorbed into high-level jobs within government, governmental agencies, and the private sector.

61% of the respondents had a Masters qualification and only 26% a PhD qualification, another challenge to research capacity. The main assignments of almost all respondents were teaching and research.

4.1.2 Research policy: existence and satisfaction

While we did not specifically look into the content of research policies, 84% of the respondents confirmed that their institutions had research and publication policies. However, of these, 49% indicated that they were not satisfied with their institutional research and publication policies. The actual content of research policies will be examined in some depth during the next round of surveys in order to get better insights into the internal institutional arrangements.

4.1.3 Sources of research funding

Typically, most respondents (54%) got their research funding from their institutions as indicated in Figure 3. While this would normally be a positive indicator, it should be noted that research budgets in these institutions are meagre. International development agencies and charitable foundations, from which a total of 48% get their funding, spend much more in real terms than the local institutions. The result is that the local research agendas are often driven by considerations that are not cognisant of the needs of African countries, are largely managed outside of the developing countries and lack sustainability beyond the foreign support. A rather high proportion of research funding seemed to come from the personal resources of researchers (23%), raising the question of how academics in African universities, who are widely reported as severely underpaid, are able to fund their own research. This will be also examined in the next round of inquiry as this research progresses.

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It emerged that the heavy users of the library resources – using them on a daily basis – use mainly electronic access, pointing to the importance of e-services in libraries. The majority of those who visit the libraries physically tend to do so only once a month (very likely linked to the lending period and number of allowed items). Usage of e-access is still very limited, which is consistent with some of the observations by both Afeworki\(^ {21} \) and Harle\(^ {22} \). On the other hand there are very few users satisfied with the quality of library e-services as can be seen in Figure 4. In many of the universities, the services were reported not to be available.

**Figure 3: Typical sources of funding for research projects amongst respondents**

**4.1.4 Library: resources and satisfaction**

**Figure 4: Level of satisfaction with library e-services**

**4.1.5 Laboratories and equipment**


\(^ {22} \) Harle, J., "Digital resources for research: a review of access and use in African universities". Issues paper prepared as part of an ACU study of Arcadia, June 2009. www.acu.ac.uk/publication/download?id=173
The majority of the respondents pointed to insufficiency or lack of laboratories and equipment as one of the two biggest barriers to research. This is a challenge that would hit especially the science-based disciplines, keeping researchers out of a lot of the front line research.

### 4.1.6 Computers

Almost 96% of the respondents confirmed having access to a computer/laptop at work. Institutions owned 89% of these computers, pointing to the very low level of ownership of computers. Computers are primarily used for research and teaching, both taking up 62% in almost equal measure as highlighted in Figure 5.

![Figure 5: Use of computers/laptops for various functions](image)

Respondents use different software applications to support their research activities (Figure 6). Word processing, presentation and spreadsheet applications dominate. However, at the time of data collection, none of the institutions had any form of educational volume licensing with vendors as a way to help bring down the cost of accessing software, although they reportedly provided most of the software (73%). This was a rather surprising finding, considering the increasingly high penetration of computers, the high cost of software, and funding challenges of universities in the region.

Surprisingly, the majority do not use modelling and simulation applications, both important to advanced research. This in itself points to the level of most of the research currently conducted.
4.1.7 Internet: access, quality, utilisation

Most respondents (77%) indicated that their institutions had a campus network, which they used to access the Internet. Among those with access, 73% access the Internet using a computer/laptop in their office, and 20% shared a computer in a lab or Internet café at the institution. Only 36% of respondents had Internet access at home.

Despite the clearly limited bandwidth available to universities and the generally poor quality of service, only 46% rated the speed of Internet access as slow or very slow; and only 37% had concerns about reliability. This could be because most respondents have not experienced faster speeds or better quality of service, or because they do not use any bandwidth-intensive application or downloads. As can be seen in Figure 7, use of the Internet is still dominated by non-research activities.

Lack of internet access at home combined with limited ownership of computers discussed earlier will limit the amount of time academics can use to access online resources, especially taking into account time demands by other assignments during office hours.

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**Figure 6: Relevance of different software to research (ranked)**
4.1.8 Conduct of research

Figure 8 summarises the percentage time spent by respondents on different activities. It is evident that teaching related activities take up most of the time, with only 18.7% of the time allocated to research. While 90% of the respondents felt they were giving enough time to teaching, 70% felt they were not giving enough time to research. This challenge has also been noted by Sawyerr\textsuperscript{23}.

About 50% of the respondents only handle one project at a time, which they also lead. A decreasingly smaller percentage handles up to five projects and beyond; these would be the more senior members of staff (professorial levels) who normally have other academic staff reporting to them.

The majority of collaboration activities involve research projects that also lead to joint authoring. Collaboration networks however tend to be generally local, with most researchers focusing on others in their specialisation, in their discipline, in their faculty/school/college, in their institution or in their country. Only 33% of the respondents had collaboration beyond national borders. Cross-disciplinary research, one of the hallmarks of the knowledge society, still remains very limited, with only 24% of the respondents working with researchers from other disciplines.

Figure 8: Percentage of respondent time spent on different activities (ranked, weekly)

In their analysis of research within the University of Stellenbosch, Pauw and Imbayarwo\textsuperscript{24} highlight the importance of networks to research output, and illustrate the extensive collaborative networks of this university.

Responses indicated that where there is collaboration, the commonest tools are either mailing lists or various online platforms. This underscores the importance of access and connectivity to research collaboration.

4.1.9 Research output


\textsuperscript{24} Pauw, C., and Imbayarwo, T., “Tracking Research Collaboration and Research Output in Africa: A Case Study of Stellenbosch University”. African Science Trackers & Stellenbosch University, 2010
The commonest form of research output is a journal article, closely followed by a conference publication. Books, chapters in books, and technical reports are also at a significant level. What is however especially worrying was the number of respondents who reported no output at all. Figure 9, showing the number of respondents (out of the 271) who had not generated any item of research output in the different categories during the previous year, underline this major challenge. There was only one patent during a period of five years among all the institutions surveyed.

Ordinarily, an institution should have more conference publications as researchers share their findings in more timely and regular conferences compared to journals that should have longer peer reviews and lead times. The fact that more researchers had journal publications compared to conference proceedings during the year might be an indication of researchers responding to institutional promotion policies as opposed to nurturing their research ideas into agendas.

The choice of publication channel is heavily dominated by funding limitations, visibility within the discipline, promotion policies, and ease and clarity of the submission process. Electronic publishing, which would be comparatively cheap, is very limited. Outside other barriers to this, it is very easy to link it to the promotion policies in universities that do not recognise such publications as significant. Most respondents (88%) support open access repositories and 90% would be happy to share their publications free of charge.

The majority of respondents (70%) ranked both lack of sufficient time for research and inadequate research facilities/laboratories as the major barriers to research, followed by a heavy teaching load, lack of incentives, and inadequate remuneration (Figure 10). It is clear, considering this finding alongside how respondents spend their time (See Figure 8)

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25 The reference to lower cost does not ignore the reality of cost and the other challenges around electronic publishing. See e.g. Crampton, M. and Hulley, F., “Online Access to the Research Output from and about Africa through Database Aggregation and Full Text Linking”, 2004, NISC Pty Ltd, Grahamstown, South Africa.
that institutions need to critically rethink how best to allocate time for research activities amongst staff expected to both teach and undertake research.

![Figure 10: Biggest obstacles to undertaking research (multiple selections, ranked, no. of respondents)](image)

When it comes to motivation for research, figuring out ways to recognize research output (promotions, awards, research funding that is not tied to specific areas, etc.) seems more important than increased remuneration to incentivize research activity as revealed in Figure 11. This echoes findings by Ragasa in the study of research organisations in Ghana and Nigeria.

![Figure 11: Motivations for research (multiple selections, ranked, no. of respondents)](image)

### 4.2 Institutional survey

#### 4.2.1 ICT in the Institution

Higher education institutions play a critical role in the life of researchers by providing the first-level of support in an enabling environment. In all but 4 of the 16 institutions surveyed, there were more non-academic than academic staff, perhaps indicating a lack of focus on their core mission, and limited or ineffective computerisation in the administrative aspects of universities. This is not what would be expected in a situation where 15 institutions reported integrating ICT within their educational functions and 12 within research as highlighted in Figure 12.

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26 Ragasa, C., op cit
More institutions (12) are adopting a centralised method of information resources/assets management as they increasingly rely on ICT by setting up a unit solely charged with this responsibility. The institutional policy environments however still have to catch up as summarised in Figure 13. Institutions are still struggling to develop and implement good and responsive ICT policies and many are yet to think beyond the now and start planning for the inevitable disasters that can occur within the digital realm.

Internet access is still limited, with only seven of the institutions reporting access through fibre networks. Download capacities ranged from 512kbps to 40 Mbps, and upload capacities from 512kbps to 10 Mbps. Downlink/uplink asymmetry that characterises most Africa institutions is a reflection of the imbalance in intellectual property, with Africa running a very large deficit. All institutions reported having an institutional website, with 10 of these locally hosted within institutional networks and 6 with local ISPs. Local hosting within institution, while it appears good, has serious drawbacks in a situation where bandwidth is constrained (in this compounded by the smaller uplink pipe). First, all who want to access the website and related resources share the limited expensive bandwidth, constraining it further. Second slow access speed means that the institution is invisible to the world and loses competitiveness. Third is the reality that most of the campuses do not have 24x7 data centres.
To support education, 12 institutions reported using Moodle as their eLearning platform of choice. In addition to the advantages of being an open source platform, it provides an opportunity to share digital content at an institutional level and a potential collaboration area around which NREN activity could be structured.

4.2.2 Library

All institutions have institutional libraries, but with varying capacity to deliver on their mandate. The first challenge for many libraries is competent leadership - one library reported that they do not have a head. The second challenge is limited computerisation: only 4 libraries reported having an ICT budget and if it was not donor-funded, then it was really low. Despite the poor funding, libraries have moved to automate key core functions like the OPAC and issue desk as indicated in Figure 14.

Information literacy is a challenge that can slow down researchers, and libraries in Africa normally take a lead in developing this among researchers. 5 institutions reported offering no training whatsoever, 8 reported offering in-class training, but in a sporadic manner and only one institution reported taking advantage of the internet to offer such training to researchers using online techniques.

![Figure 14: Selection of core library functions that have been automated](image)

While libraries reported using email to provide regular updates and library information to researchers, their adoption of technology appears to be greatly driven by the large global suppliers and publishers that they interact with through the adoption of electronic processes, rather than by internal strategies and plans.

4.2.3 Research and intellectual property

Documentation of research outputs and dissemination across participating institutions is still very poor. 12 institutions did not have adequate knowledge about recent publications by their own staff, 10 institutions did not know of any recent research recognitions and 5 reported neither. In such an environment, where keeping track of research activity is still a challenge, one can argue that commercialization of any research outputs must still be far off. As such, it is not surprising that only one institution reported a patent being filed by a researcher during the last 5 years.

Having a good and up to date research database is absolutely crucial in the current environment if universities are to track research, collaboration, and take informed policy
and strategic decisions about research: Most universities in the region appear to be steering research totally blindly. The kind of information-rich analysis conducted for example by Pauw and Imbayarwo should be routine for universities in the region.

4.2.4 Research support services

While research support facilities across institutions are improving as indicated in Figure 15, the lack of research funding is still a big hurdle. Institutions seem to lack the necessary funding to nurture and reward research activity. Instead, research is primarily funded by international entities.

![Figure 15: Access to different research support services across participating institutions](image)

4.3 Impact of access and connectivity on intellectual property output

While this paper primarily presents the baseline study that was aimed at establishing the current status of the research environment, researcher behaviour, and researcher output, we have included this section as a preliminary examination of the relationship between connectivity and intellectual property output. In doing so, we underscore the fact that since there are many other factors that are components of the overall research environment (see Section 2.2), what is presented here should not be interpreted as conclusive findings: the research environment varies widely from institution to institution, making the interpretation of statistical correlation of impact of connectivity on research output with only one set of data both difficult and inaccurate. This will however be possible for each institution when a time series (surveys over the planned five years) of the data sets is generated, and some of the issues that have emerged from this study are examined further.

4.3.1 Comparison of connectivity

We need to reduce the varying levels of external bandwidth delivered to institutions to a common denominator before examining the relationship between connectivity and per capita intellectual property output. Possibilities include bandwidth per connected computer or number of network points; bandwidth per member of staff or per student, and bandwidth per user (staff plus students).

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27 Pauw, C., and Imbayarwo, T., op cit
Bandwidth per connected computer and bandwidth per network point is illustrated in Figure 16 for the institutions surveyed. The former is higher in institutions where the number of computers is still limited (many unused network points), and the latter higher where there is comparatively high usage of wireless access. Institutions 4 and 12 are EthERNet members that had just upgraded their bandwidth but were yet to acquire sufficient computers to support their user base (staff and students). Makerere University in Uganda (16), which had the highest bandwidth also had the highest number of computers.

It should be noted from Figure 16 that all the respondent institutions have a bandwidth per connected computer that is less than 25kbps. Many have only about 10kbps per connected computer. Even if one takes into account diversity (not every user demanding bandwidth at the same time), this is extremely low by international standards and emphasizes the continuing challenge of insufficient bandwidth.

![Bandwidth verses networked-devices and LAN-points across participating institutions](image)

In situations where there is a very high user to available computers ratio, the bandwidth per networked computer might be high, but sharing of access means that actual time online for each user is constrained. It therefore provides a more balanced view of access if the comparator is bandwidth per user, enabling comparison across institutions of varying sizes with varying levels of connectivity. This is illustrated in Figure 17. From this, the institutions with the highest connectivity are respondent 6, the Kigali Institute of Science and Technology (KIST) with 28 Mbps for 233 Academic staff and 3000 students; and respondent 15, Uganda Christian University (UCU) with 32 Mbps for 166 staff and 7800 students.

4.3.2 Linking per capita intellectual property output to bandwidth

Intellectual property output per capita (publications in the last five years) is still very low amongst participating institutions as summarised in Figure 18: on average, none of the
institutions has produced at least one publication per staff member over the last five years, underscoring the poor research performance of African researchers and institutions.

The highest per capita output is from respondents 6, 12 and 16. This is consistent with Figure 17, with the exception of responded 15, the Kigali Institute of Science and Technology that has the highest connectivity but no research output. This is not really surprising: KIST was established as a technical institute, not as a university. While it is apparent that institutions that have the highest connectivity also have the highest research output, we emphasize that this does not validate our claim at this point: it only gives an indication that there is a relationship between the two.

Figure 17: Bandwidth versus number of academic staff and students across participating institutions

Figure 18: Research per capita (ratio of academic staff to research output) across institutions

5. Summary: Challenges and Opportunities
We recognise that improving connectivity and access will not have the expected level of impact on research output unless some of the key challenges identified by this baseline survey are addressed. In this section that is aimed primarily at African institutions, we highlight what we consider key challenges as identified in the findings, and make some suggestions about how these can be converted to opportunities for improving the quantity and quality of research.

Applicability needs to be qualified: we have not, at this point in time, carried out tests of statistical validity, or indeed the level of depth of statistical analysis that would be required for conclusive and generalisable findings. These challenges and opportunities are therefore specific to the institutions and to some extent the countries examined, but they do provide lessons for other institutions and countries.

i. The departure of experienced researchers from universities into the public and private sector reduces research leadership as well as the opportunities for developing research capacity. The limited number of PhDs among the remaining young population of lecturers compounds the situation. On the other hand, the young population of lecturers can be an opportunity for the universities if it is properly channelled, especially when combined with steps to improve the overall research environment as discussed further below.

ii. There are very limited local budgets for research, a finding that echoes results from other sources. Some of the sources cited in this paper state that this results in research and research agendas that are driven from outside the countries, and not necessarily aligned to the research priorities of these countries. The opportunity for universities facing this challenge is making convincing cases about institutional and national priorities so that funding can be re-focused by development partners to these priorities; and making evidence based arguments (based on survey findings that are more country specific) to national funding sources so that research funding can be increased. Universities must learn to research their research environment, activities, and outputs.

iii. Online library services and resources have become increasingly available to African universities. There is however dissatisfaction among the majority of users regarding the quality of e-services provided by libraries. Leadership is still a challenge for many libraries. It is within the institutional capacity of universities to address these challenges, based on recognition of the importance of online services and competent library staff to the growth of research. The second aspect is objectively examining causes of user dissatisfaction (as opposed to a typical defensive reaction) so that users can increasingly drive services delivery (pull) rather than librarians (push). This should go hand in hand with concerted training for researchers in information literacy so that online research time is more productive.

iv. Laboratories that can support research are insufficient and lack equipment. This is a challenge especially for science-based disciplines. Realism must recognise the fact that advanced research equipment, along with the capacity to maintain and sustain it, can only come in the medium to long term. Connectivity however introduces the opportunity of accessing remote laboratories, especially
taking into account the fact that modern research equipment is largely computer driven. This should be combined with specific training in modelling and simulation; an area, which will reinforce advanced research.

v. Access by academic staff to computers, more than 90% of them owned by the institutions, is close to 100%. Internet penetration in universities in our sample has also increased, even if tends to be generally low speed with most universities providing less than 10kilobits per second per capita. Internet access is however heavily dominated by non-research activities. This increasingly high penetration of access and connectivity is an opportunity that still has to be harnessed for productive research. A key factor in doing this will be the incentives tied to research. As noted, the survey revealed that 49% of the researchers are not satisfied with the research and publication policies of their institutions, pointing to an area where changes are likely to have significant impact.

vi. Where there is a strong research culture that needs to be nurtured, the ability to access the Internet for research related purposes has to be a daily 24-hour reality for academic staff. The finding that most researchers have access at their places of work but do not own computers is a gap that needs to be addressed. The approaches used by countries like South Africa and Kenya to provide laptops for teachers\(^{28}\) can be easily replicated at university level, the driving requirement in this case being increased research output.

vii. Research in the knowledge economy is increasingly defined by interdisciplinary research as well as research collaboration beyond departmental, institutional, and national borders. The survey findings have revealed that this is still very limited. Research incentives targeted at stimulating interdisciplinary research and collaboration could have a positive impact on this.

viii. Research output, currently, largely journal papers, is still very limited. Universities need to seize on the willingness of researchers to share their research outputs freely as established by this survey to exploit online publishing where the ground is more level for institutions from developing countries. It should be especially noted that cost related to publishing was established as a barrier.

ix. The majority of staff devotes almost all their time to teaching, mainly due to teaching overload. Until institutions achieve a proper balance between time allocation for teaching and research, research output will remain limited. In Norway, for example, the general guideline is that staff should spend 50% of their time on research and 50% on teaching\(^{29}\). In many cases, this could be just


\(^{29}\) [http://www.eui.eu/ProgrammesAndFellowships/AcademicCareersObservatory/AcademicCareersbyCountry/Norway.aspx](http://www.eui.eu/ProgrammesAndFellowships/AcademicCareersObservatory/AcademicCareersbyCountry/Norway.aspx)
a case of diverting budgets from bloated administration (as established, 75% of the institutions surveyed have more non-academic than academic staff) to support to the core missions of the universities, enabling the hiring of more academics. Limited computerisation of administrative functions could be one of the factors leading to the staff being dominated by non-core functions: This needs to addressed hand in hand with effective business-process re-design that would lead to a reduction in the number of administrative and support staff.

x. The failure to track research and research data is a major challenge across all the institutions surveyed. Most institutions do not have data about themselves, and where efforts have been made to collect the data, it is not well managed, severely reducing its utility. In addition to this, failure to put any such data online reduces visibility. The implication of this is that the institutions cannot make evidence-based policy and strategy decisions aimed at increasing research output. This is an area of action that should be an easy win for any institution.

xi. While the extent of data, and the ability to which it can be used to give meaningful correlations is still limited, it has emerged in this baseline survey that there might be a correlation between per capita internet bandwidth and per capita research output. In depth statistical analysis as a time-series of data is collected will examine this.

6. Conclusion

This paper has established the baseline for the periodic surveys that will be carried out as we establish our main hypothesis, and has also identified the necessary areas of interventions by the majority of African institutions if access and connectivity are to have the expected high impact on intellectual property output. The baseline analysis has also identified gaps and limitations in the instruments used that will be addressed in subsequent surveys.

While we underscore the fact that it is a preliminary finding, the analysis of the baseline data has also shown that those institutions in our sample that have higher per capita connectivity also have higher per capita intellectual property output, pointing to a possible correlation. In-depth statistical analysis based on future surveys will examine this further as we build up the evidence-based case for improving the connectivity of universities and research institutions.
Widening the number of e-Infrastructure users with Science Gateways and Identity Federations

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Abstract

Grid infrastructures are being built in several areas of the world but, despite the huge investments made by the European Commission and by other funding agencies, both at national and international level, the total number of users is in the order of magnitude $O(10^4)$, much less than $O(10^7)$ which is the order of magnitude of the number of users of the international research and education networks (e. g., GÉANT in Europe) that have been funded more or less the same level of Grids. The reasons for this are the complexity for non-IT-expert users of the Grid security, based on a Public Key Infrastructure, the little adoption of standards to let different middleware be interoperable among each other, and the lack of general frameworks to build easily customizable high-level user interfaces.

In the recent past, interesting developments have been independently carried out by the Grid community with the Science Gateways and by the National Research and Education Networks with the Identity Federations to ease, from one side, the access and use of Grid infrastructures and, from the other side, to increase the number of users authorised to access network-based services.

A Science Gateway is a “community-developed set of tools, applications, and data that is integrated via a portal or a suite of applications, usually in a graphical user interface, that is further customized to meet the needs of a specific community.”

Identity federation is “federating an entity's identity to facilitate single sign-on or cross-domain single sign-on. It is an approach of authenticating a user across multiple sites within a company (intranet) or across independent and disparate domains (extranet) using open standards.” Identity Federations have the aim of setting up and supporting a common framework for different organisations to manage accesses to on-line resources. They are already established in many countries and currently gather a number of people which is in the order of $O(10^7)$.

In this presentation we intend to show the work done at INFN and Consorzio COMETA in Italy to develop a framework to easily and quickly build Science Gateways which can be configured as Service Providers of Identity Federations and then potentially accessible by huge numbers of users. The framework makes use of the Simple API for Grid Applications (SAGA) standard, defined by the Open Grid Forum, to perform middleware-independent

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job and data management. The architecture of the framework will be presented together with a few use cases belonging to different domains, including cultural heritage and e-collaboration. The advantages to create Identity Federations and Science Gateways in Africa will also be outlined.
Fostering a Secure Framework for National Research and Education Network

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Abstract
In the context of management of network services, widespread deployment and security problems requiring considerable human efforts and involvement, secure and distributed management mechanism become a central concern. Considering both National and International indicators, there is a big inadequacy on secured networks in the developing countries compared to other countries. This important problem will definitely affect the collaborative efforts in research and education networking in Africa. In order to see to the improvement towards emerging networks and collaboration in Africa, the paper proposes a framework not exploited through the collaborative research and educational network by malicious interference of the shared resources. The paper tends to bridge the gap of insufficient ICT infrastructures using minimal hardware that demonstrated it can be used for building higher level security protocols. In order to tolerate the failure and provide uninterrupted services to network components, the work examined the behaviour and fault tolerance of the proposed framework.

Keywords: Security, Education, Network, Research.

1. Introduction
This paper examines the security concerns and novel secured framework on deployment of National Research and Education Network (NREN) that is not exploited by malicious interference of shared resources. A Research and Education Network (REN) is an association of institutions that is focused on conducting research and educational instructions, with the aim of institutional collaboration for the purpose of maximising scarce resources, proffering solutions and improving infrastructure for the realisation of their organisational objectives [1]. The need for interconnectivity and interoperability does not imply that security issues should be compromised. Different user communities require different levels of security. Each network on which the national information infrastructure is built must have a number of security procedures implemented that will prevent unauthorized access to the network and the systems that comprise it [2]. Network technologies and services are now regarded as essential to support distributed research
communities around the world. The development of these services however is in its infancy and the services will continue to evolve over the years in Africa.

The current network is characterized by its increasing distribution, its dynamic nature, and the complexity of its resources, due to the increasing requirement of different services [3]. Emphasis should be geared towards using frameworks that are developed on minimal hardware pushing some of the resources to be managed by fewer secure managed devices. Network management essentially involves monitoring and controlling the devices connected in a network by collecting and analyzing data from the devices [4]. The current trend is to deploy mobile agents to manage such large heterogeneous networks like NREN. Mobile agents are special software objects that have the unique ability to transport itself from one system in a network to another in the same network [5].

The approach is to automate the resource sharing and collaboration using secure mobile-agent resource transfer (SMART) protocol architecture for NREN simply called SMARTREN.

The paper explores the fostering of a security framework in NREN most especially situated in Africa. The novel method is to explore the use of proposed mobile agent protocol to create a robust NREN services. The remainder of the paper is organised into five sections. In the first section, we review related technology and REN, highlighting some issues of current approaches, particularly for existing NREN and national environments. In the second section, we summarise the research design employed for the study. In the third section, we provide a holistic security issues resolved in the study. The fourth section provides analysis and discussion of the key challenges faced by NREN new secure protocol. Fifth, conclusions are drawn, research limitations discussed, and future research directions proposed.

2. Related Network and NREN Technologies

It is critical to recognize that even in the present Internet, it has been possible to accommodate a remarkable amalgam of private enterprise, academic institutions, government and military facilities. Indeed, the very ability to accept such a diverse constituency turns on the increasing freedom of the so-called intermediate-level networks to accept an unrestricted set of users [6]. The Internet services do serve the public but extremely vulnerable to mass attacks, although the linkages between the Internet and the public make the system extremely accessible to a very wide variety of users. It will be important to keep in mind that, over time, an increasing number of institutional users will support local area networks and will want to gain access to NREN by that means.

Osazuwa [1], mentioned some NRENs that are presently sharing contents between members and provide their clients with research networks and Internet without necessarily providing a robust and secured networks using minimal hardware solutions. South African
National Research Network (SANReN) provides connectivity to the world's research networks as well as commodity Internet access. TENET (Tertiary Education and Research Network of South Africa) is actively engaged in the construction of Access Networks connected to the SANReN network; provides Internet and information technology services, involving inter-alia, high-speed Internet access; inter-campus connectivity; ancillary operational functions in support of service delivery and the provision of other value-added services as may be needed from time to time in support of higher education and research in South Africa. National LambdaRail (NLR) advanced optical network infrastructure supports many of the world's most demanding scientific and network research projects. The Ghanaian Academic and Research (GARNET), is assisting to fulfil a very crucial need for research and education within Ghana by providing services aimed at fostering collaboration among research and educational institutions in the region as well as between them and peer institutions worldwide [7]. The Belgian Research and Education Network (BELNET) supplies Internet access with very high bandwidth to Belgian educational institutions, research centres and government services. Research and Education Network for Uganda (RENU) has been supporting teaching and learning, as well supporting advanced research within members and also nurtured local content networks. West and Central African Research and Education Network (WACREN) is charged with the responsibility for providing necessary assistance for the formation and sustenance of NRENs in the region. WACREN supports the development of properly structured campus networks such as NREN basic building blocks, and provides models and templates for NREN's in capacity building, organisational structure, financing access to bandwidth, business analysis and strategic plans [8].

The needs and benefits of these technologies do not imply that security issues should be compromised. Different NRENs require different levels of security but there must be a common ground in proffering platform independent secure protocol on which the national information infrastructure is built that will prevent unauthorized access to the network.

3. SMARTREN Architecture

The proposed flexible architecture, Secure Mobile Agent Resource Transfer (SMART) REN framework, is a hybrid model, which has features of secure mobile agent protocol as well as Simple Network Management Protocol (SNMP). The architecture forms a layer over the conventional SNMP based management that ensures the advantages of SNMP are not lost and also serves the purpose of managing legacy SNMP based systems. SMARTREN gives the Network Operating Centre (NOC) for stationed REN the flexibility of using SNMP model or SMARTREN depending on the resource sharing activity that is involved. This architecture has many advantages over the existing architectures. Some of the advantages are stated below:

- The repetitive request/response handshake is eliminated
• Reduces design risk by allowing decisions about the location of the code pushed towards the end of the development effort
• Resolves problems created by intermitted or unreliable network connections
• Real time notifications
• Parallel executions (or load balancing) where large computations are divided amongst processing resources which maintains minimal hardware usage.
• Offers an alternative to or complementing SNMP security in network management system

In the proposed architecture the REN station assumes responsibilities of their clients. All managed nodes are servers, which have mobile agent environment and respond to SNMP queries from mobile agents when they visit the context servers and manipulate data locally. When the client in the SMARTREN needs access to data in a network-connected device, it does not talk directly to the server over the network but dispatches a mobile agent to the server’s machine. On arriving at the servers’ machine, the mobile agent makes its request and return to the management station with the results. The architecture provides Java-compliant interfaces to network management services. Aglet Software Development Kit (ASDK) is the agent development environment to be used because of its modular structure, easy-to-use API for programming of mobile agents and excellent documentation. To interact with the SNMP agent, we use AdventNet SNMP [9]. It provides a set of Java tools for creating cross platform Java and Web-based SNMP network management applications. AdventNet provides a set of classes, which could be used to facilitate communication between managed device (a device with SNMP agent like Routers), and an SNMP manager or management application.

The SMARTREN architecture consists of the following major components:

• Management application (MAP)
• Mobile Agent Execution Environment (MAEE)
• Secure Mobile Agent Producer (SMAP)
• Mobile Agents (MA)
• Modified Multi-signcryption protocol (MMSP)

In the SMARTREN architecture, the mobile agents are provided with the list of nodes to be managed, SNMP statistics of interest and Health functions [10] defined by the user. The mobile agent development environment is the Aglet Software Developer Kit (ASDK), which provides a modular structure, easy-to-use API for programming of mobile agents and excellent documentation.

Figure 1 shows the hybrid model of SMARTREN and architecture for Resource Transfer using secure mobile agents. The REN administrator/manager is given the flexibility of deciding whether to use SNMPv3 or mobile agents. Every mobile agent enabled network device has to offer a mobile agent context server. The mobile agents hosted in the context
servers communicate with the local SNMP agent via SNMP based management applications.

Figure 1: Hybrid SMARTREN Model

Keys:
GUI – Graphical user Interface
CNMP – Conventional Network Management Protocol
MIB – Management Information Base
MN_i – Managed Nodes (i.e. Network Devices) where i = 1 to n

The Aglet Server (Tahiti) runs on every network device as the context server for incoming mobile agents. The agents are subject to security policies that are contained in the Modified Multi-signcryption protocol (MMSP) designed in this work. The arriving agents are authenticated and there after communicate with SNMP agent via UDP packets. The advantage of this process is that no actual traffic is generated at all since the sockets are directed towards the ‘loopback’ device. At the end of the mobile agent task on the station, it dispatches itself to the next destination on its itinerary. Finally, the agent is disposed of at the end of its tasks.
An attacker may tamper with the agent (aglet) state and must be protected against an eavesdropping attack as it will contain sensitive administrative information. Hence, the agent data state are protected in order to provide authentication and confidentiality using the protocol described in subsequent sections.

3.1 Security Issues

Despite the attraction of mobile agent technology, security is still a major concern. Security is an even more important issue when the critical data is carried by a mobile agent ([11], [12]). Indeed, while agents can be used to extract data for query purposes, the agents are prone to attack and hence the security of data in the agent is of prime concern [13]. One important issue is the malicious agent problem, where an agent that executes on a host attacks other agents or local resources. A second security concern is the malicious host problem [14]. An agent is under complete control of its host, which may steal or modify agent information or even destroy the agent. The solution is to prevent the information from being disclosed to a host using robust secure protocol.

Most of the research work into security is concentrating on the malicious agent issue, by advancing techniques that isolate the execution of agent from the rest of the system. However isolating on its own is only a first step for security. A security framework for agent architecture must furnish further properties. It is important that agent that visits a trustworthy host must be able to authenticate the information that it furnishes. Again, a host that sends an agent out must possess ways to ensure that agent gets to their destinations unaltered [15].

The fact that SNMP uses the unreliable, connectionless UDP rather than reliable, connection-oriented TCP reduces its security. An attacker can masquerade as a management station or a network device and send out malicious UDP packets to the well-known SNMP ports (161, 162) or corrupting ongoing SNMP request-response sessions [16].

The core of our secure agent system builds a protocol that is called Multi-signcryption protocol that provides user authentication, integrity and confidentiality for the agent transactions and Agent Transfer Protocol (ATP) over the network. The multi-signcryption protocol is a cryptographic method that fulfills both the functions of secure encryption and digital multi-signature for multi-users, at a cost smaller than that required by multi-signature-then-encryption ([17]; [13], [18]).

In [17], the author proposed a multi-signcryption protocol which combined a multi-signature with the encryption function. However, since their protocol can not provide message confidentiality, it cannot prevent a malicious attacker from obtaining the information in the messages. Pang [13] proposed a modified multi-signcryption protocol to achieve message confidentiality. However, since their protocol fixes the order of multi-
signers beforehand, it does not satisfy the need for order flexibility. Moreover, it cannot provide non-repudiation. Seo [18] analyzed the weaknesses of these previous multi-signcryption protocols and proposed a new multi-signcryption protocol. Their protocol provides not only message confidentiality, non-repudiation and order flexibility but also other requirements for secure and flexible multi-signcryption. It is believed to be more efficient. Therefore, in this work, we adapt modified Seo multi-signcryption protocol referred to in this work as MMSP and use it to design our secure mobile agent protocol.

3.1.1 Initialization and notations

Let $p$, $q$ be sufficient large primes with $p = 2q + 1$, and let $G \in Z_p^*$ have order $q$. Each managed node $MN_0$, $MN_1$, ..., $MN_n$ generates a pair of asymmetric key pairs $(x_i, y_i)$, where $x_i \in Z_p^*$ and $y_i = g^{x_i} \mod p$, and publishes the public key $y_i$ along with its identity information $ID_i$ through a Certificate Authority (CA). The MA itinerary (itireq corresponds to $M_0$) represents the original itinerary used to query or collect information from other managed nodes. Other notations used are stated below:

- $MN_i$: the $i$-th network gateway which belongs to the $i$-th managed node
- SMARTREN: the management center of an apartment complex
- NET: the network environment
- $E_{a,b}$: an elliptic curve over a finite field $GF(p^m)$, either with $p \geq 2^{150}$, $m = 1$ or $p = 2$, $m \geq 150$ ($E_{a,b}$: $y^2 = x^3 + ax + b(p > 3)$, $E_{a,b}$: $y^2 + xy = x^3 + ax^2 + b(p = 2)$, $4a^3 + 27b^2 \neq 0 \pmod p$)
- $q$: a large prime number whose size is approximately of $|p^m|$  
- $G$: a point with order $q$ which is chosen randomly from the points on $E_{a,b}$
- $ENC_{K}(\cdot), DEC_{K}(\cdot)$: the encryption and decryption algorithms of a private key cipher system with the key $K$
- $H(\cdot), hash(\cdot)$: a one-way hash function
- $x_i$: the secret key of the $i$-th manager who uses the $MN_i$, $x_i \in \mathbb{Z} \setminus \{1, \ldots, q - 1\}$
- $Y_i$: the public key of the $i$-th manager who uses the $MN_i$, $Y_i = x_iG$
- $\|$: denotes concatenation

3.1.2 Basic solution

In this section, we present a basic solution for secure network management services by applying an EC based signature protocol to SNMP based Context Servers (CS). We append the EC-DSS (Elliptic Curve based Digital Standard Signature) scheme [19] to the existing Network Management System (NMS) for user authentication and integrity of data. We assume that the existing NMS already establishes a common secret key $K_i$ between $MN_i$ and the Aglet (Tahiti) server of the Managed Nodes, and provides confidentiality through a private key cipher algorithm with $K_i$. Our basic solution is as follows.
EC-DSS Generation and Encryption phase

1. MN\textsubscript{i} generates a signature on the itinerary data M\textsubscript{i} as follows:
   a. MN\textsubscript{i} chooses random k\textsubscript{i} \in R [1, ..., q − 1], and computes r\textsubscript{i} = k\textsubscript{i}G (mod q)
   b. MN\textsubscript{i} computes s\textsubscript{i} = (H(M\textsubscript{i}) + r\textsubscript{i}x\textsubscript{i}) \cdot k\textsubscript{i}^{-1} (mod q)
2. MN\textsubscript{i} encrypts M\textsubscript{i} with K\textsubscript{i}, i.e., it generates C\textsubscript{i} = ENC\textsubscript{K_i}(M\textsubscript{i}).
3. MN\textsubscript{i} sends (r\textsubscript{i}, s\textsubscript{i}, C\textsubscript{i}, ID\textsubscript{i}) to the SMARTREN.

EC-DSS Verification and Decryption phase

1. After the CS receives (r\textsubscript{1}, s\textsubscript{1}, C\textsubscript{1}, ID\textsubscript{1}), (r\textsubscript{2}, s\textsubscript{2}, C\textsubscript{2}, ID\textsubscript{2}), ..., (r\textsubscript{n}, s\textsubscript{n}, C\textsubscript{n}, ID\textsubscript{n}) from network gateways, it decrypts the C\textsubscript{i} and obtains the itinerary data M\textsubscript{i} of MN\textsubscript{i}.
2. CS verifies the signature (r\textsubscript{i}, s\textsubscript{i}) of MN\textsubscript{i} as follows:
   (a) CS computes r\textsubscript{i}' = (H(M\textsubscript{i})G + r\textsubscript{i}Y\textsubscript{i}) \cdot s\textsubscript{i}^{-1} (mod q).
   (b) CS checks r\textsubscript{i} = r\textsubscript{i}'.

4.0 SMARTREN Protocol Using EC Multi-signcryption

In this section, we used a secure mobile agent protocol for network management services in network environments. Our protocol consists of four procedures such as registration procedure, mobile agent creation procedure, mobile agent execution procedure, and mobile agent arrival procedure. It provides confidentiality and integrity for the itinerary data, and user authentication using EC Multi-Signcryption. An overview of the proposed security model of the SMARTREN protocol is shown in Figure 2.
4.1 Certification procedure

In this procedure, each manager $U_i(1 \leq i \leq n)$ registers his own public key and address at the management center, SMARTREN.

1. $U_i$ gives his public key certificate and address information to the SMARTREN.
2. After the SMARTREN checks $U_i$’s identity and address, it stores $U_i$’s identity $ID_i$, public key $Y_i$, address, and $MN_i$ information in the database of the CA (Certification Authority).

4.2 Preparation and creation procedure

In this procedure, the SMARTREN calls a mobile agent MA and determines the migration path of MA, $MA_{route} = MN_1||MN_2||...||MN_n$. Then it creates itinerary request message $itireq$, and generates a signature on $itireq$ as follows:

1. SMARTREN chooses random number $k_C \in \mathbb{R}[1, \ldots, q-1]$ and computes $R_C = k_CG$.
2. SMARTREN computes $r_C = H(itireq||ID_C||R_C) \pmod{q}$ and $s_C = (x_C + r_C) \cdot k_C^{-1} \pmod{q}$.

SMARTREN gives $itireq$, $MA_{route}$, and signature, $(ID_C, r_C, s_C)$ to the MA, and the MA migrates to the first manager’s network gateway, $MN_1$ with them.

4.3 Execution procedure

1. After the MA has migrated to $MN_i(1 \leq i \leq n)$, $MN_i$ checks the $itireq$ and $MA_{route}$.
2. $MN_i$ verifies the SMARTREN’s signature and generates the EC Multi-Signcryption on its itinerary data, $M_i$ as follows:

[ Verification phase of the SMARTREN’s signature]

(a) $MN_i$ computes $R’_C = s_C^{-1} \cdot (Y_C + r_CG) = s_C^{-1} \cdot (x_C + r_C)G = k_CG$.
(b) $MN_i$ checks whether $H(itireq||ID_C||R’_C) \pmod{q} = r_C$, or not. If the equation holds, then it performs the following EC Multi-Signcryption phase. Otherwise, it reports the failure to the SMARTREN.

[ EC Multi-Signcryption phase]
(a) MNi chooses \( k_i \in R \{1, ..., q - 1\} \), and computes a session key \( K_i = \text{hash}(k_i \cdot Y_C) = \text{hash}(k_i \cdot x_CG) \) by using the SMARTREN’s public key and \( k_i \).

(b) MNi computes the signature \( r_i = H(M_i||ID_i||K_i) + r_{i-1} \pmod q \) and \( s_i = (x_i + r_i) \cdot k_i^{-1} \pmod q \) by using received \( r_{i-1} \) from MA. And, it generates \( C_i = \text{ENC}_{K_i}(ID_i||M_i) \) by encrypting \( (ID_i, M_i) \) with \( K_i \). The EC Multi-Signcryption message is composed of the multi-signature \( (r_i, s_i) \) and the cipher text \( C_i \). \( (r_i, s_i) \) are for user authentication and the integrity of \( M_i \), and \( C_i \) is for the confidentiality of \( M_i \).

3. MN1 gives the EC Multi-Signcryption message \( (ID_1, r_1, s_1, C_1) \) to the MA. Here, \( r_1(1 \leq i \leq n) \) is connected to \( r_{i-1} \). So, if the SMARTREN knows only \( r_n \) of the last signer, MNn, then it can compute \( r_i \) of the previous signers, MNi(1 \leq i \leq n-1). Therefore, the MA removes \( r_{i-1} \) from \( (ID_1, s_1, C_1), ..., (ID_{i-2}, s_{i-2}, C_{i-2}), (ID_{i-1}, r_{i-1}, s_{i-1}, C_{i-1}) \), and it stores \( (ID_i, r_i, s_i, C_i) \).

4. If \( i = n \), then MA migrates from the MNn to the SMARTREN. Otherwise, the MA migrates from the MNi to MNi+1.

4.4 Arrival Procedure

After the MA finishes the travels of the migration path MA_route, it arrives at the SMARTREN.

1. MA gives \( (ID_1, s_1, C_1), ..., (ID_{n-1}, s_{n-1}, C_{n-1}) \), and \( (ID_n, r_n, s_n, C_n) \) to the SMARTREN.

2. SMARTREN performs the following EC Multi-UnSigncryption to verify and decrypt the EC Multi-Signcryption message.

[EC Multi-UnSigncryption phase]

(a) For \( i = n, ..., 3, 2, 1 \), SMARTREN computes the session key \( K_i' \) using its private key \( x_C \), MNi’s public key \( Y_i \), and \( (r_i, s_i) \).

i. SMARTREN computes \( u_i = x_C \cdot s_i^{-1} \pmod q \) and \( K_i' = \text{hash}(u_i \cdot r_iG + u_iY_i) = \text{hash}(r_i + x_i) \cdot u_iG) = \text{hash}(x_Ck_iG). \)

If \( K_i' = K_n \), then the SMARTREN can decrypt \( C_i \). And it can obtain the itinerary data \( M_i \) and \( ID_i \) of the MNi.

ii. SMARTREN computes \( r_{i-1} = r_i - H(M_i||ID_i||K_i') \pmod q \). If the signature, \( r_{i-1} \), is recovered then the SMARTREN lets \( i = i - 1 \) and performs steps i and ii again.

(b) If the verification is finished correctly then the SMARTREN can confirm its own signature, \( r_C (= r_0) \).

3. If the EC Multi-UnSigncryption phase is performed successfully and all itinerary data \( M_1, ..., M_n \) of MN1, ..., MNn are decrypted, then the SMARTREN stores \( M_1, ..., M_n \).

4. SMARTREN terminates the MA’s execution.

5. Analysis of the SMARTREN Protocol

In this section, we analyze the security of our mobile agent protocol according to the security requirements of message confidentiality, message integrity, user authentication,
non-repudiation, and robustness. Then we analyze the efficiency of our protocol in comparison with the basic solution.

5.1 Security Analysis

1. **Message Confidentiality**: Message confidentiality means that it is computationally infeasible for a malicious attacker to gain any partial information on the content of the EC Multi-Signcryption message. In our protocol, if an attacker intercepts the mobile agent, MA, and searches the data in MA, then he can obtain the EC Multi-Signcryption messages \((ID_1, s_1, C_1), (ID_2, s_2, C_2), ..., (ID_n, s_n, C_n)\) of the itinerary data \(M_1, M_2, ..., M_n\). And the attacker can compute \(s_i^{-1} \cdot (r_i \cdot G + Y_i) = k_i G (1 \leq i \leq n)\) from the EC Multi-Signcryption messages. But, since the attacker cannot know SMARTREN’s private key, \(x_C\), he cannot compute session keys due to the difficulty of the elliptic curve discrete logarithm problem [19]. Therefore, it is computationally infeasible for the attacker to gain any information of the itinerary data, \(M_1, M_2, ..., M_n\). Our protocol provides confidentiality for the itinerary data.

2. **Message Integrity**: Message integrity means that the communicated EC Multi-Signcryption messages cannot be manipulated by unauthorized attackers without being detected. Assume that a malicious attacker modifies \(MN_i\)’s itinerary data and tries to forge \(MN_i\)’s \((1 \leq i \leq n)\) EC Multi-Signcryption message, \((ID_i, r_i, s_i, C_i)\). The attacker can create the forged itinerary data \(M_i'\) by modifying \(M_i\) of \(MN_i\). And then, he chooses \(k_i' \in_R [1, ..., q - 1]\) and can compute the session key \(K_i' = \text{hash}(k_i' \cdot Y_C) = \text{hash}(k_i' \cdot x_C G)\) by using the SMARTREN’s public key and \(k_i'\). Moreover, the attacker can use the \(r_{i-1}\) by eavesdropping on the MA, and he can generate signature \(r_i' = H(M_i' \parallel ID_i \parallel K_i') + r_{i-1} \pmod{q}\). But, since the attacker cannot know the \(U_i\)’s (managers’) private key \(x_i\), he cannot compute \(s_i' = (x_i + r_i') \cdot k_i'^{-1} \pmod{q}\). Even if he chooses a random \(x_i'\) and computes \(s_i'' = (x_i' + r_i') \cdot k_i'^{-1} \pmod{q}\), the SMARTREN can verify that \(s_i''\) is forged signature in the EC Multi-UnSigncryption phase. Therefore, the attacker cannot modify the itinerary data and cannot forge the EC Multi-Signcryption message. So, our protocol provides integrity for the itinerary data.

3. **User Authentication**: User authentication means the process whereby one party is assured of the identity of the second party involved in a protocol, and of whether the second party has actually participated. In our protocol, the SMARTREN can confirm the identity of the Administrator, \(U_i\), through the \(ID_i\) included in the EC Multi-Signcryption message. In the EC Multi-UnSigncryption phase, the SMARTREN can assure that \(U_i\) actually participated. So, our protocol provides user authentication.

4. **Non-repudiation**: Non-repudiation means that neither Administrators nor the SMARTREN can falsely deny later the fact that he generated an EC Multi-Signcryption message. In our protocol, non-repudiation is provided as follows. Since each EC Multi-Signcryption message includes the administrator \(U_i\)’s \((1 \leq i \leq n)\) private key, \(x_i\), anyone
who does not know $x_i$ cannot generate an EC Multi-Signcryption message instead of $U_i$. Therefore, if $MN_i$ of $U_i$ generates the EC Multi-Signcryption, he cannot falsely deny later the fact that he generated it.

5. **Robustness**: Robustness means that if the signature verification on a message fails, then it prevents such unauthentic messages from damaging a receiver. In our protocol, after the SMARTREN receives the EC Multi-Signcryption message from the MA, if the verification of $K_i^* = \text{hash}(x_C \cdot s_i^{-1} \cdot r_iG + x_C \cdot s_i^{-1} \cdot Y_i) = \text{hash}(x_ck_iG)$ fails, then the SMARTREN cannot compute the session key, $K_i$. So, since it cannot decrypt the cipher text $C_i$, it can prevent damage by an unauthentic message or malicious code in the MA. Therefore, our protocol provides robustness.

5.2 **Efficiency Analysis**

We evaluate our protocol from a point of view of network and communication overhead, and compare our protocol with the basic solution. We use the number of point multiple and modular multiplication to measure the computational cost, and the communicated message size to measure the communication overhead.

For convenience, we assume the following conditions:

1. we denote the number of managed node gateways by $n$ and the message size by $|M|$ bits;
2. the size of $q$ is set to 160 bits;
3. the output size of the cryptographic hash functions is 160 bits.

In the basic solution, since all $MN_i$s transmit EC Multi-Signcryption messages $(ID_i, r_i, s_i, C_i)(1 \leq i \leq n)$ to the Aglet (Tahiti) Server of the SMARTREN at the same time, a network bottleneck can be happened. The total communication overhead of the basic solution is $n \cdot |M| + n \cdot |q| + n \cdot |H(.)| = n \cdot (|M| + 320)$. But, in our protocol, the total EC Multi-Signcryption messages from $MN_1$ to $MN_n$ are $(ID_1, s_1, C_1), \ldots, (ID_{n-1}, s_{n-1}, C_{n-1}), (ID_n, r_n, s_n, C_n)$, and the communication overhead is $n \cdot |M| + (n + 1) \cdot |q| = n \cdot (|M| + 160) + 160$. So, when compared with the basic solution, our protocol reduces the communication overhead to, at most, 50%. The amount of EC Multi-Signcryption messages to be stored in the Aglet (Tahiti) Server can also be reduced to, at most, 50%. Moreover, since the MA migrates autonomously and transfers EC Multi-Signcryption messages either between $MN_i$ and $MN_{i+1}$ or between $MN_i$ and the Aglet (Tahiti) Server, the total remote interaction and network traffic can be reduced between them.

In the network overhead cost of our protocol and the basic solution, the point multiple is 1 for $MN_i(1 \leq i \leq n)$ and 2$n$ for the Aglet (Tahiti) Server. In the case of 160-bit modular multiplication, our protocol is 1 for $MN_i(1 \leq i \leq n)$ and 2$n$ for the Aglet (Tahiti) Server, but the basic solution is 2 for $MN_i(1 \leq i \leq n)$ and n for the Aglet (Tahiti) Server.
We have, so far, assumed that the same secret key $K_i$ established previously between the $MN_i (1 \leq i \leq n)$ and the Aglet (Tahiti) Server in the basic solution, and evaluated the efficiency of the basic solution without computational and communication costs for key establishment. However, key establishment is complex; it results in heavy network and communication overhead. If the secret key is fixed in the basic solution, “key freshness” cannot be provided. If the basic solution simply refreshes the secret key periodically, then it can provide “key freshness.” But it has another security problem, i.e. it cannot provide “forward secrecy” or “backward secrecy”, and it is not secure against “known-key attack” [19]. Therefore, if we add a key establishment phase to the basic solution for overcoming these security problems, then the computational cost and communication overhead of the basic solution increase, and the efficiency decreases.

Unlike the basic solution, our protocol does not need a key establishment phase. So, our protocol is more efficient than the basic solution.

5.3 Scalability

We compared two different solutions for sending itinerary data on managed elements to test network overhead imposed by the SMARTREN. SMARTREN is compared to the centralized SNMP using AdventNet SNMP. The topology used on this experiment consists of one management station and three managed nodes (DemoREN: RENa; RENb; RENc) interconnected through a 100Mbps Ethernet LAN. All machines run Windows or Linux. The daemon snmpd, which is included in the Linux, is an SNMP agent that responds to SNMP request packets.

In order to evaluate the performance, we alternately repeat the elements using the itinerary {RENa, RENb, RENc, RENa, etc.}. The SMARTREN approach fetches the SNMP table and does some filtering based on the user’s requirement. The SMNP is implemented using AdventNet SNMP package. The manager sends SNMP UDP packets to a SNMP agent that responds to the REN manager. The manager sends requests to all elements to be managed; one after the other. Thus, a new request is started after receiving the response from the previous one, until the last node receives a request and sends the response to the manager.

The response time of SMARTREN is measured as the mean time of the MA launching time and returning time. The centralized SNMP approach is measured as the mean time of the first GET message was sent out and the last result fetched back.

The following table listed the testing result:
### Table 1: Response Time of SNMP and SMARTREN

<table>
<thead>
<tr>
<th></th>
<th>Centralized SNMP Approach</th>
<th>SMARTREN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 host</td>
<td>0.69 Seconds</td>
<td>0.71 Seconds</td>
</tr>
<tr>
<td>2 hosts</td>
<td>0.9 Seconds</td>
<td>0.95 Seconds</td>
</tr>
<tr>
<td>4 hosts</td>
<td>1.2 Seconds</td>
<td>1.24 Seconds</td>
</tr>
<tr>
<td>30 hosts</td>
<td>4.9 Seconds</td>
<td>4.89 Seconds</td>
</tr>
</tbody>
</table>

From the table 1, the SNMP is a bit less when the hosts are small in performing the tasks. This is due to the fact that the SMARTREN is built on better architecture for handling mobility.

Regarding the health function computation, the SMARTREN daemon agent transfer less number of messages comparing to the SNMP method as shown in table 2. Thus, the total message size is reduced and the bandwidth is saved.

### Table 2: Communication Overhead of SNMP and SMARTREN Daemon Agent

<table>
<thead>
<tr>
<th></th>
<th>SNMP</th>
<th>SMARTREN Daemon Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Messages</td>
<td>Total Message Size</td>
</tr>
<tr>
<td>Interface utilization</td>
<td>4</td>
<td>364Byte</td>
</tr>
<tr>
<td>Interface Accuracy</td>
<td>3</td>
<td>275Byte</td>
</tr>
<tr>
<td>IP Discard Rate</td>
<td>5</td>
<td>458Byte</td>
</tr>
</tbody>
</table>

### Conclusion

This work has presented a framework to design a hybrid model based on secure mobile agent protocol and SNMP strategies. The work gives REN administrators flexibility of using any of the two approaches to exploit mobile agent technology in sharing resources.
The results show that as the managed nodes increases, the proposed techniques perform better than conventional approach. On this note, this paper has demonstrated that it is possible to develop a secure mobile agent NREN management system using Java components and cryptography. To this end, the paper has presented reasonable detail on design level view.

References


Biographies

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Visibility: towards a communication Strategy for UbuntuNet Alliance

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Abstract

This paper describes the role of communication in an organisation, with specific focus on UbuntuNet Alliance. It examines the various tools that the Alliance has used over the past 5 years to communicate with stakeholders; and the current consultative efforts to develop a Communication Strategy. The paper also examines the stage of development and uptake of communication tools in the member NRENs.

Organisations have objectives that define their existence and what they aim to achieve. They also have strategies that guide how the objectives will be achieve and tools used to achieve them. To ensure that there is proper and effective coordination and the surrounding community is well informed and aware of the activities of the organisation, communication is paramount. Effective communication requires effective strategies complete with coherent plan of actions.

Soon after the idea of establishing UbuntuNet Alliance was conceived, and the Founding Board of Directors in place, three mailing lists were set up at the Royal Institute of Technology (KTH) in Sweden. One was for the Founding Board, the second for established and emerging NRENs and the third was for the broader UbuntuNet Community. The NRENs list soon included key contacts in East and Southern Africa, while the Community list grew at a high rate as more people worldwide interested in research and education networking in general and in Africa were added to it.

The website, launched in March 2006 received visits from across the world. In May 2008, when NUANCE, the electronic Newsletter of UbuntuNet Alliance: Network, Collaboration, Education was launched, the Community list morphed into the NUANCE distribution list. Fliers and brochures describing the Alliance were also distributed by hand at events across the region.

Today, the communications landscape has changed and social networking tools are dominating in passing short messages to audiences. While communicating with stakeholders, gaps have been identified as some communities still do not know research and education networking and UbuntuNet Alliance as an organisation. This has challenged the Alliance to develop a thoughtful and comprehensive communication strategy, which will lead the communication and dissemination activities to propel successful change and ensuring the involvement and understanding of all stakeholders.
The Communication Strategy identifies 13 target audiences that UbuntuNet Alliance must reach out to. Seven channels of communication have been laid out and 12 tools will be used to reach the audience. The increasing role of social networking media has been recognised and appropriate tools will be incorporated. The communication strategy will lessen the barriers between its existing member NRENs and the research and education community they serve.

**Key words:** Communication Strategy, Communication channels, Feedback, social media, NREN

1. **Introduction**

UbuntuNet Alliance posits communication, dissemination and outreach as important tools for its development as well as for the general understanding of academic networking in Africa. Effective and strategic use of such tools has the potential to enhance the impact of UbuntuNet Alliance’s activities and image among all stakeholders. Since the establishment of the Alliance in 2005, a significant amount of effort has been put in achieving and maintaining a well informed community. Central in these efforts was the website and email lists for communicating with member NRENs and the general community. A major step was taken three years ago when the e-newsletter, NUANCE was introduced in May 2008. The number of subscribers has been increasing steadily over the years. Fliers, brochures, posters, emails, conferences and meetings have also been used to reach out to member NRENs as well as to all stakeholders.

Recently, however, it has been observed that there is a low level of understanding of general research and education activities, especially among prospective infrastructure users, policy makers, regulators and telecom providers in the region. There is an increase in activities in UbuntuNet Alliance as the organisation increases its operations and more services are delivered to the community. A well informed community of stakeholders is a key to the success of the Alliance. It has become obvious that a more focused communication strategy is of paramount importance to achieve sustained progress. A strategic and formalized communication and outreach process will ensure proactive and thorough dissemination of information. This will help to maintain broad support for UbuntuNet Alliance activities as well as deepen the general understanding of research and education networking among governments, regulators, private sector, researchers and the general public in Africa. The Alliance Communication Strategy has been developed to achieve this.

2. **The Nature of UbuntuNet Alliance**

UbuntuNet Alliance as a regional organisation aims at providing regional connectivity for the research and education community in eastern and southern Africa through NRENs. The NRENs are the ones that coordinate research and education networking activities at national level in their respective countries. They relate directly with the user community – the researchers, lecturers and students – which are the ultimate beneficiaries of the Alliance.
The Alliance’s regional nature means that it needs to interact with different telecommunication and connectivity providers, governments, regulators, and many other stakeholders – all in different environments. They all must have a clear understanding of the role of the Alliance in facilitating communications for scientific and research collaboration. So far, the Alliance has maintained a well-informed community of NRENs and is in constant touch with them. Contact is also made with Regulators and Governments. However, for the picture and cycle to be complete, all stakeholders must be reached. As the network rolls out and services are becoming available to the users, it is increasingly crucial that the end-users and all other stakeholders know what UbuntuNet Alliance is about.

3. Communications to date

3.1 The current status of UbuntuNet Alliance’s communication

Over the years of its existence, UbuntuNet Alliance has made tremendous efforts to build and maintain communication with the member NRENs and the community at large. Different tools and channels are used to reach out. Currently the following are used:

- **Mailing lists**, to communicate internally and with member; NRENs. The lists were launched almost immediately after the establishment of the UbuntuNet Alliance in 2005. Currently there are 5 mailing lists: for the Board, NREN CEOs, NREN CTOs, NREN community, and the one for the newsletter.
- The **website** is updated regularly and is used to reach out to the general audience. It was launched in March 2006 and now receives an average of 2000 visits a month. It provides up to date information about the Alliance, events and activities happening with the NRENs community.
- **NUANCE**, the monthly electronic newsletter was launched in May 2008 and is one of the major tools used to reach out to the community. It carries articles and stories from and about African NRENs; from other regions and general research and education networking.. The newsletter is sent to about 1500 recipients by email and many more access the web version. In April 2011, the French version of the newsletter was launched and analytics indicate that about one-third of web readers read the French NUANCE. Translations are available up to September 2010.
- **Fliers, brochures and posters** are also used to disseminate quick information. These printed tools have proved to be very useful at conferences and meetings and have been handed out to people. People take them home and to their offices and can refer to them anytime they need. These tools are updated regularly whenever there is an event.
- **Word of mouth** stands out and shows commitment. At the UbuntuNet Secretariat in Lilongwe (Malawi) people frequently walk in to find out what the Alliance does. Printed material (e.g. fliers, brochures) are always available to increase the understanding of the people.
- **Presentations** are made at conferences and meetings. The Alliance receives invitations to make presentations at conferences. Such opportunities help in spreading the word about. Often, one or two comes to the presenter for more information after the presentation.
• **Mass media** communication such as newspapers is not left out. The Alliance has made some progress in working with the media houses for features. A number of articles have appeared in print as well as online media. One of such appeared in one of Malawi’s daily papers, The Nation, after the AfricaConnect project kicked off. The press release of the AfricaConnect project appeared in tens of websites and generated a lot of interest from all over the globe. Occasionally, NUANCE articles are picked by other recognised online news services such as Balancing-Act Africa.

The Communication and Dissemination Intern stationed at the Secretariat in Lilongwe pulls together all the activities.

3.1.1 Challenges faced

The dissemination and communication activities put in place have achieved a great deal of result. At international level, among peer organisations, among development partners, etc UbuntuNet Alliance is known as a partner and a key player in Africa. However, some challenges have been met, most important being two as follows:

• In producing NUANCE, one of the aims has been to showcase what member NRENs are doing as a way of increasing awareness. To achieve this, regular input from the NRENs is required, however this has not been easy as NREN people are busy with other activities.
• The second challenge has been to grow to the readership of NUANCE. Currently, as indicated earlier on, NUANCE is distributed by email to about 1500 readers. This number has been reached primarily through conferences and meetings. It is not easy to grow readers and keep them happy with good content. Once in a while;

3.2 Gaps identified

Three major gaps have been identified while carrying out communication and dissemination activities for UbuntuNet Alliance. These are:

• While major efforts have been put in place, it has been noticed that there are some quarters that still do not know about research and education networking, NRENs and the Alliance.
• There is a broad range of stakeholders that the Alliance must address and each has different needs.
• The landscape is changing as social networking tools appear to be prominent.

These gaps are the reasons why UbuntuNet Alliance decided to develop a Communication Strategy. The aim is to increase and sustain awareness among all stakeholders.

4. **Towards a communication strategy**

Development of the Communication Strategy for UbuntuNet Alliance started early in 2011. Through the strategy the Alliance aims at increasing awareness and knowledge about UbuntuNet Alliance as an organisation and its services among all stakeholders. The Communication Strategy is also designed to enhance understanding of research and
education networking and its associated activities among all stakeholders starting with students on to the policy maker in the region.

The following are anticipated as outcomes Communication Strategy:

- The profile of UbuntuNet Alliance raised and maintained in Africa and beyond;
- UbuntuNet Alliance perceived as a competent and trusted regional research and education network in the membership region that effectively supports and adds value to NRENs without competing with them;
- Enhanced understanding of and support for research and education networking activities among stakeholders.

4.1 Target Audiences

Hovland in the ODI Planning tools [1] on How to write a communication strategy writes that when designing a communication strategy it is very essential to consider the target audience. It is paramount to identify those audiences with whom you need to communicate to achieve your organisational objectives. The communication strategy process for UbuntuNet Alliance therefore identified 13 target audiences and designed key messages for each. According to Newman [2], key messages are essential tools in all communications work. Key messages are the core of your writing. Key messages open the door to direct communication with your audience, because they bridge what your audience already knows and where you are trying to take them.

The 13 identified audiences are as follows:

1. Member NREN personnel
2. Researchers in research and higher education institutions
3. Professor and lecturers
4. Students
5. Administrator of Universities and Research Centre administrators
6. Member NREN personnel
7. Development partners
8. National Communications Regulators
9. Telecommunication companies
10. Policy makers in government ministries
11. Reporters in Media houses
12. Regional economic bodies
13. Broader (Global) REN community

These audiences will be targeted with dissemination material throughout the implementation of the communication strategy. The strategy takes a holistic approach to communications and dissemination so as not to leave out any category of stakeholders. The Strategy recognises the role of NRENs in that they are the ones that directly interact with most of the target audiences.

4.1.1 The tools and channels of communication
To reach out to the community of stakeholders, the Communication Strategy lists eleven tools that will be used to disseminate information to the target audiences.

1. Newsletter (NUANCE)
2. Fliers
3. Posters
4. Press releases
5. Brochures
6. Reports
7. Maps
8. Case studies
9. Presentations
10. Mailing list
11. Website and Social media

The above tools will reach the audience using the following channels/ media

- Mailing list
- Social networks ( Picasa, Twitter, Facebook)
- Website
- TV and Radio
- Conferences
- Face to face meetings
- Newspapers(print and electronic)

Where necessary, databases of contacts (those already there will be enhanced) will be kept and maintained to ensure that the audience is thoroughly reached. The databases will be updated regularly

4.2 Feedback, monitoring and evaluation

The Communication Strategy recognises the role of feedback in the process of communication and dissemination. Feedback received from the audience will be processed and allowed back into the communications cycle as input.

The various tools and channels will be monitored and evaluated for effectiveness. The key messages will be vetted properly before release.

5. Recommendation for NRENs.

In Sub-Saharan Africa, NRENs have boomed over the past year although KENET and TENET existed years before. The NRENs are all making progress in one of the other and are at different stages of development. A quick run through of the NRENs in terms of communication shows that little is being made to address the knowledge gaps that exist between them and their respective communities at national level. This could explain why
there are still many people even in universities that do not know anything about their local NREN, UbuntuNet Alliance and general research and education networking.

The Table below shows that out of the 13 member NRENs of UbuntuNet Alliance, 9 have websites. Of these nine, only four maintain a website that reflects the full variety of what the NREN does. Michelle Willmers of the University of Capetown (a follower of @UbuntuNet on Twitter) wrote to Margaret in an email,

“my perspective is that it is imperative that African ICT managers in the research arena start to take into account that dissemination is a new core function of the researcher and of the institution; and that no serious research endeavour can be undertaken without a communication strategy. Added to this, new developments in all other areas can have impact in terms of their capacity to supplement, link to and measure new expanded, technologically-driven scholarly communication practice.”

<table>
<thead>
<tr>
<th>NREN</th>
<th>Website</th>
<th>Active</th>
<th>Newsletter</th>
<th>Twitter</th>
<th>Facebook</th>
</tr>
</thead>
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<td>not sure</td>
</tr>
<tr>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
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<td>no</td>
<td>no</td>
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<td>no</td>
<td>not sure</td>
<td>not sure</td>
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<tr>
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<td>no</td>
<td>Not sure</td>
<td>yes</td>
</tr>
<tr>
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<td>no</td>
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<tr>
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<td>no</td>
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</tr>
</tbody>
</table>

Table 1.0

NRENs must position Communication and Dissemination as part of their core activities. A simple communication strategy that maps the target audience develops key messages for each of them and identifies tools and channels would achieve a great deal of the awareness that NRENs need to generate support.

Maria-Jose Lopez, the Public Relations and Communications Manager for CLARA shared with UbuntuNet Alliance that Latin American NRENs have each a person responsible for PR and Communications. These PR people have a network in the framework of CLARA where they share experiences and keep their stakeholders informed at all times.

Above all, NRENs should embrace the social media like Facebook, Picasa, Twitter and also establish good relationship with the media houses existing in their community since this can help in publicising their events whenever they have organised one.

6. Conclusion
It is important for organizations to streamline communication and dissemination within their activities. For the UbuntuNet Alliance, the success of the communication strategy will depend on the NRENs. There is the need for the NRENs to work with the Alliance and ensure that all stakeholders are aware of research and education networking activities.

7. References


Further Reading


[7] The Economic and Social Research Council (ESRC)’ How to write a communications strategy; http://www.esrcsocietytoday.ac.uk/ESRCinfoCenter/Support/Communications%5FToolkit/
Biography

Rose Chisowa is the Communication and Dissemination Intern of the UbuntuNet Alliance based at the Secretariat in Lilongwe. Her duties include being responsible for the monthly online newsletter NUANCE, day-to-day management of the UbuntuNet Alliance website, including updating and ongoing monitoring, assist in events organization and administration within the framework of the UbuntuNet Alliance projects and many more duties. Prior to joining the UbuntuNet Alliance, Rose worked with other organisations in the department of Communication. Rose has contributed highly in the development of the UbuntuNet Alliance communication strategy. In addition to that she has also worked hard on the production of advocacy and communication materials like the Annual Report, Television documentary, fliers and brochures. Rose graduated from the University of Malawi with a Bachelor of Arts in Journalism.
Access to Global Research Information: Collaborating for Research – the Arcadia study

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Abstract

Access to global research information is essential for the advancement of knowledge. Over the last decade, institutions of higher learning in East and Central Africa have greatly benefited from various support programmes that have focused on enhancing access to research information by researchers as well as providing support in other areas like training as well as ICT support. It is also observed that in majority of these countries, efforts have been made to create collaboration forums to facilitate sharing of resources.

These efforts have created a situation whereby availability of quality research information can no longer be considered a major hindrance to research efforts. The issue of availability of subscription and other free online resources has been well addressed over the last couple of years. Internet connectivity has been improving with the connection of the region to high speed broadband networks. Though the perception of researchers in most of these institutions is that access to global research information is poor, this situation is not replicated on the ground.

This paper aims at presenting findings of a study undertaken in 2009/2010 by the Association of Commonwealth Universities on behalf of Arcadia exploring the issues of availability, access and use of online journals in select Universities across four countries in East and Central Africa. The interrelationship of technology, awareness, skills and campus networks and their impact on strengthening of access to research information is presented.

Keywords: Global research; electronic journals; access

Abstract only: full paper not available
Synergizing E-infrastructures Initiatives to Foster e-Research in Higher Education Institutions in Africa

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Abstract

It is expected that improved connectivity will enable African Tertiary education and research institutions to generate a proportionate amount of intellectual property goods to achieve parity with the rest of the world. Nevertheless, this vision can only be attained through intensive collaborative activities. The emergence of large-scale e-infrastructure projects in Africa reflects a trend toward more complex configurations of scientific collaboration. This paper investigates the concepts of synergizing which denote the active processes of creating and managing relationships among people, organizations, and technologies in the creation of e-infrastructure. The paper also explores how embeddedness is not only an important result of infrastructure development, but is also a precursor that can act as both a constraint and a resource for development activities. The researchers are more interested with the process of creating and maintaining productive socio-technical relationships, which they refer to as synergizing. Human infrastructure posits that complex infrastructures come about through complex interactions among networks, place-based organizations, groups, and consortia. Through a multiple case study approach and integrated literature survey, the research examines how two e-infrastructure initiatives; UNESCO-HP brain gain and HP catalyst projects attempts to make use of these concepts to foster e-research and draws specific lessons for African HEIs. The study revealed that the two dominant e-research projects have adopted approaches that favor synergizing and embeddedness in e-research however despite funding of 24 projects in 21 HEIs, visibility of Africa in e-research world map is still wanting.

Keywords

E-research, e-infrastructure, synergizing, embeddedness, higher education institutions (HEIs),

ICT Indicators in Higher Education: 
Towards an E-readiness Assessment Model

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Abstract

The potential for information and communications technology (ICT) to transform teaching, learning, research and management in higher education has been the subject of many articles and reports [1]. Higher education institutions in developing economies are at different stages of adoption ICTs for education and management. For institutions that are in the early stages of the ICT adoption, there are no appropriate models or frameworks that are being used to assess their state of readiness to use ICTs in education and to develop appropriate institutional ICT strategies aligned to the institutional strategies. In addition, the few existing models can only be used for qualitative assessment without explicit and measurable indicators and targets. In other words, the indicators they use do not have quantitative targets that could be used for benchmarking and quantitative assessment of ICT strategies. This paper describes a model that overcomes this limitation by developing indicators with quantifiable targets. The proposed e-readiness assessment model contains 17 indicators grouped into five categories of network access, networked campus, networked learning, networked society and institutional ICT strategy. The model defines over 88 sub-indicators of the 17 indicators based on both hard facts and perception data. The model has also developed a staging framework with quantifiable targets for staging each of the 17 indicators and sub-indicators on scale of 1 to 4, where 1 is the lowest stage of preparedness and the 4 the highest stage of preparedness. Since collecting perception data based statistically significant is expensive, the researchers propose that institutions could integrate a sub-set of six sub-indicators into their strategic ICT plans in order to improve the integration of ICT in education. This framework has been tested in two separate e-readiness assessments of universities in Eastern Africa [2, 3]. This paper argues that the model is a good starting point for empirical studies on the assessment of the integration of ICT in higher education institutions and invites practitioners to adopt the indicators, modifying where necessary, to guide integration of ICT into higher education and to develop roadmaps for accession to higher stages of e-readiness for higher education institutions. Finally, the paper recommends further research to establish relationships between the indicators and sub-indicators and quality of higher education and to derive an ICT readiness index for higher education institutions.

1. Introduction

The potential for ICT to transform teaching, learning, research and management in higher education has been the subject of many articles and reports [1]. In the developed economies, Higher Education (HE) institutions in the developed world have automated
Information and communication technologies (ICT) could be used in education to improve administrative efficiency and to enhance teaching and learning. ICTs also allow both students and lecturers to participate in global research and education networks that support access to knowledge and collaborative projects. Thus, the use of ICTs in higher education institutions has the potential to enhance the quality of teaching and learning, increase the research productivity of the faculty and students, and improve the management and effectiveness of institutions. Additionally, ICT usage by students in higher education institutions develops the future workforce to effectively participate in the increasingly networked world and the emerging knowledge economy [4,5]. Graduates of higher education institutions will also occupy leadership positions in government, business, and society in the future and therefore will play a critical role in the transformation of a country like Kenya to an information society.

In order to achieve this goal of transforming the teaching, learning, research and management of higher education institutions using ICT, the institutions must achieve a minimum level of e-readiness. E-readiness of the institutions is a measure of the potential for the institutions to participate in the networked world of higher education and research. However, most of the higher education institutions have not yet assessed their level of e-readiness due to both lack of contextually appropriate assessment frameworks and the fact that leadership of higher education institutions are not yet convinced that ICT is strategically important or even essential in higher education [2].

This paper develops a simple model of assessing e-readiness of higher education institutions in countries with low levels of ICT diffusion [2,3]. The model uses indicators that are understandable by leadership of higher education institutions and that could be integrated into the institutional ICT strategies to measure the degree of adoption of ICT. The model defines 17 indicators and over 88 sub-indicators that could be used to measure e-readiness of higher education institutions. The model has been used successfully for e-readiness assessment of higher education institutions in Kenya [2] and in the five East African countries of Burundi, Kenya, Rwanda, Tanzania and Uganda [3]. It has also been used to develop accession roadmaps for ten universities in the five East African countries. The authors’ experience in using the tool has demonstrated that the tool is valuable for communicating with policy makers and leadership in the higher education and has resulted in higher stages of readiness for universities that have adopted the strategic indicators and sub-indicators in monitoring their ICT strategy implementation.

This paper first reviews e-readiness assessment frameworks and indicators for ICTs in higher education. It then describes the proposed e-readiness assessment model. The paper ends by providing conclusions on the model developed and making recommendations for adoption of the model and for the use of the indicators to guide integration of ICT into higher education and increase e-readiness of HEIs. It also recommends further research in refining the model.
2. E-readiness assessment frameworks and ICT in HE indicators

2.1 Concept of e-readiness

In general, e-readiness can be defined as the preparedness of a nation or community to participate in the information and knowledge society [6, 7]. It is often measured by judging the relative advancement of the most important areas for the adoption of the ICTs and their applications [8]. Researchers at the Center for International Development at Harvard University [6] described ‘e-ready’ society as:

“One that has the necessary physical infrastructure (high bandwidth, reliability, and affordable prices) has integrated current ICTs throughout businesses (commerce, local ICT sector), communities (local content, organizations online, ICTs used in everyday life, ICTs taught in schools), and the government (e-government)”.

The World Bank Information for Development Program [9] defined e-readiness for a state as:

“The preparedness of states to provide governance equitably and cost effectively and the capacity to reflect in the degree of integration the deprived segments of society attain application of ICT as an e-governance tool. Apart from this the ability of the state to provide business, the capacity to participate in the provincial level digital economy and further networking with national level digital economy”.

In the realm of higher education, Machado [10] conceptualizes e-readiness as

“the ability of HEIs and the capacity of institutional stakeholders (managers, key ICT persons, teachers and students) to generate (e-) learning opportunities by facilitating computer-based technologies – in short, how e-ready a HEI is to benefit from educational technology (or e-learning)”

This paper adopted the CID definition of e-readiness which has also been successfully used to develop the World Economic Forum’s Networked Readiness Index [11].

A higher education e-readiness model should therefore enable HE institutions to gauge their readiness to take advantage of the opportunities afforded ICTs. There are two main purposes for e-readiness assessment:

a. Diagnostic assessment as part of ICT strategic planning for a country, community or institution. This is the purpose of the AAU or CID assessment methodologies [1, 6]

b. Assessment for the purposes of ranking e-readiness and therefore comparing countries, communities or institutions. For example, the World Economic Forum networked readiness index is used to compare countries [11]

The model described in this paper has been derived from the CID and AAU assessment models and is therefore diagnostic. Its purpose was to be used in ICT strategic planning and evaluation of the effectiveness of institutional ICT strategies. In the following section, we
briefly review the three main e-readiness assessment models that motivated the development of our framework, namely, the CID assessment tool [6], the Networked Readiness Index methodology [11], and the Association of African Universities (AAU) assessment tools [1].

2.2 E-readiness diagnostic assessment frameworks

CID e-readiness tool

The CID e-readiness tool was titled, “Readiness for the Networked World – A Guide for developing countries” [6]. It was developed by the Information Technology Group at the Center for International Development (CID), Harvard University. This paper describes how the tool was modified and extended for use by the higher education community.

The CID e-readiness tool defined 19 indicators of the degree of e-readiness of a community or country. The 19 indicators were split into five main categories as follows:

(i) **Network access** category that measures readiness of the ICT infrastructure. It defined six indicators, namely – information infrastructure, Internet availability, Internet affordability, network speed and quality, hardware and software, and service and support. These indicators therefore measured the availability, cost, and quality of ICT networks and services

(ii) **Networked economy** category that measures the use of ICT by businesses and the government for commerce (B2C or B2B) and the availability of the human capital used to support the services. It has four indicators, namely, ICT employment opportunities, B2C electronic commerce, B2B electronic commerce and e-government. These indicators therefore measure how businesses and governments using ICTs to interact with the public and with each other.

(iii) **Networked learning** category of indicators measure the level of access to ICT by educational institutions, and the utilization of ICT in teaching and learning, and availability of ICT training programs. It has three indicators, namely, schools access to ICTs, enhancing education with ICTs, and developing the ICT workforce. These address the questions of how educational systems integrate ICTs into their processes to improve learning and how the educational institutions are preparing the ICT workforce.

(iv) **Networked society** category measures the degree to which people and organizations are using ICT. It has four indicators, namely, people and organizations online, locally relevant content, ICT in everyday life, and ICTs in the workplace. The indicators here address the questions: of the extent individuals in the community are using ICT at work and in their

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31 [http://www.readinessguide.org](http://www.readinessguide.org)
personal lives and the availability of significant employment opportunities for those with ICT skills.

(v) **Network policy** category of indicators are used to assess the ICT policies and/or legislation and the success or failure of the regulatory environment in a particular community. It has two indicators, namely, telecommunications regulation, and ICT trade policy. These indicators therefore here address the question of the extent to which the policy environment promotes or hinders the growth of ICT adaptation and use.

In e-readiness assessment of using the CID tool, each of the 19 indicators would be staged on a scale of 1 to 4, where 1 represents unprepared and 4 represents the highest state of readiness in that particular indicator. The final results could then be presented as a radar diagram for the 19 indicators.

**Networked Readiness Index**

The Networked Readiness Index (NRI) is defined as “the degree of preparedness of a nation or community to participate in and benefit from ICT developments” [11]. The Index is a composite of three sub-indexes, namely, the *environment* for ICT offered by a given country or community; the *readiness* of the community’s key stakeholders (individuals, businesses, and governments) to use ICT; and finally, the *usage* of ICT amongst these stakeholders. Figure 1 shows how the sub-indexes are used to derive the NRI.

**Figure 1: Network readiness index framework**

![Diagram of the Networked Readiness Index](source: WEF Global IT Report 2003-2004)

The NRI has been designed as a macro-level tool for policymakers and global leaders. The index signals broad trends, flags opportunities and deficits, and makes a unique contribution to the understanding of how nations are performing relative to one another with regard to their participation in the Networked World [12]. It influences decisions such as investors’ choice of a destination, effective Internet regulation or stimulation, as well as identification of investment opportunities.
The NRI was derived from the CID tool but uses a modified set of 48 indicators to measure the nine categories of indicators shown in Figure 1. The indicators are derived from both hard facts data and perceptions data obtained by surveying senior government and business executives. The values of the indicators were then mapped into a scale of 1 to 7 and then statistically used to derive the index. Although the framework proposed in this paper does not calculate an index, it defines quantitative values or ranges of values for each of the sub-indicators used to measure e-readiness.

**The Association of African Universities (AAU) Institutional Self-assessment Guidelines**

The Association of African Universities (AAU) developed a framework to assess ICT maturity of the member African universities in the year 2000 [1]. This framework was aimed at assessing the situation with regard to a university’s capacity to use ICT in education and for internal administrative efficiency [1]. The Association identified nine assessment areas and relevant sets of variables for each area, as outlined below.

a) **Planning and monitoring tools** - measured using the availability of university strategic plan, derived information policy plan, derived information master plan, and derived information project plans indicators.

b) **Application of ICT in teaching and learning** - measured using the indicators of teaching objective for using ICT, professional development of academic staff, technology access and usage patterns of academic staff, and technology access and usage patterns of students.

c) **Application of ICT in research** - measures the research objective of academic staff and students for using ICT.

d) **Application of ICT in academic information services (library)** – measures the extent of access to online public access catalogue, services in academic information management, and training in academic information management.

e) **Application of ICT in administration and management** – measures the extent of ICT application for administration and management functions.

f) **ICT infrastructure** – measures the type of infrastructure as well as accessibility and usage patterns.

g) **ICT organizational (support) infrastructure** – measures staff responsibilities in technical as well as functional areas.

h) **ICT financing** – measures the funding for ICT internally and via fundraising; with distinction within budget votes or budget line items.

i) **Training, research and development in ICT** – measures the training for ICT human resources development (workforce and leaders).

The above e-readiness frameworks suffer from three key limitations. Both CID assessment tool and the NRI methodology have often been used to measure the readiness of countries or states as the smallest community. That is, they have not been used for institutional assessment of e-readiness and therefore do not render themselves readily useable for higher education community and institutions. The model proposed in this paper focuses exclusively on higher education institutions. The NRI methodology assumes that hard facts data are available from credible sources like the World Bank, UNESCO, and ITU. This is not the case for most higher education institutions in sub-Saharan Africa in general and in Kenya in particular. In addition, the indicators used to derive the index are irrelevant for...
institutions and communities that are in early stages of ICT adoption. For example, institutional ICT strategy indicators are often missing from all the frameworks yet they are critical for institutional adoption of ICT [3].

Moreover, the values or range of values for the indicators appropriate for a developing country like Kenya are very different from those in a developed country like Finland. For example, stage 4 for the sub-indicator Internet bandwidth per 1000 students used in Kenya was only 5 Mb/s and above (high) for Kenya while it would be 1 Gb/s in developed countries.

The AAU model that was specifically developed for institutional assessment defines only a qualitative staging framework. The researchers were not aware of the use of the model in any university in Kenya or East Africa. The model proposed in this paper has a staging framework with quantifiable targets for each indicator, which is useful for developing roadmaps for accession to higher stages of readiness. Thus, the framework proposed in this paper, and described in the next section has borrowed from the CID, NRI, and AAU assessment methodologies but has different variables and indicators.

3. Proposed e-readiness assessment model and ICT in HE indicators

The AAU assessment model has not been used to assess the e-readiness of Kenyan universities and the authors are not aware of any African university in Africa that has adopted the model for self-assessment as envisaged by the AAU. The NRI on the other hand has been published annually since the year 2002 World Economic Forum for an increasing number of countries where data is available (see http://www.weforum.org). It works best for developed or developing countries where all of the data is available and collected by credible institutions such as the World Bank, National Statistical bodies or the regulators. Most of the data required to assess readiness in East African universities is actually not available from any public sources. Huang [13] acknowledges there are differences between developed and developing economies with respect to e-readiness assessment models for e-business implementation.

Although the 19 indicators by the CID [6] could have been adopted for use in the model proposed in this paper, many of the indicators were not relevant for a higher education institution. We therefore modified the CID tool by eliminating indicators that were not relevant and developed quantitatively measurable sub-indicators that could be staged on a linear scale of 1 to 4. For example, ICT Trade Policy, Telecommunications Regulation and Networked Economy indicators defined in the CID tool were not relevant e-readiness assessment of higher education institutions. Apart from eliminating some of the 19 indicators, we introduced six new indicators and defined two new categories. The two new Networked Learning indicators (i.e., ICT Research and Innovation and ICTs in Libraries) were motivated by the guidelines for institutional self-assessment guidelines developed by the Association for African Universities [1].

The final model contained 17 indicators classified into five categories, namely:
i. **Network access** (information infrastructure, Internet availability, Internet affordability, network speed and quality)

ii. **Networked campus** (network environment, e-campus)

iii. **Networked learning** (enhancing education with ICTs, ICTs in libraries, ICT research and innovation, developing ICT workforce)

iv. **Networked society** (people and organizations online, locally relevant content, ICTs in everyday life, ICT in workplace)

v. **Institutional ICT strategy** (ICT strategy alignment, ICT financing, ICT human capacity)

Each of the indicators was derived from sub-indicators. About 88 sub-indicators have been defined in this model. Similar to the CID assessment model, each of the indicators was to be staged on a scale of 1 to 4, with 1 being unprepared and 4 the highest state of ICT readiness for a typical higher education (HE) institution. The institutional ICT strategy category and the networked campus categories were not defined in the original CID assessment framework. In addition, the indicators and sub-indicators are now specific to higher education institutions in a typical developing country.

The researchers developed new quantitative criteria for staging that was considered appropriate for typical HE institutions at early stages of adoption of ICT in education. For example, one of the sub-indicators defined in the framework was the number of networked computers per 100 students. The framework defined stage 1 to be range less than five PCs per 100 students while stage 4 was 50 PCs per 100 students. The stages therefore represent a value judgment based on the experience of researchers in the Kenyan higher education ICT environment, situational data collected from higher education institutions and trends in learning environments at institutions in middle-income countries [10]. These criteria were set as minimalist standards for increasing the ICT readiness and usage in the different institutions. It is therefore possible for different institutions to set higher standards in their corporate and ICT strategic plans.

Figure 2 below shows what we refer to as the ICT in Higher Education E-readiness Assessment Model (HEAM).
The individual elements of the model are described below. The staging framework was used in the November 2007 to assess 25 Higher Education (HE) institutions in Kenya [2] and in November 2008 to assess 50 East African Universities [3]. The framework was also used for assessment of 10 EA universities in November 2010 but the networked society indicators that are based on perception data. Thus, the tool has been tested at least three times and in each case used to communicate strategic ICT issues with the senior institutional leadership. The researchers have observed that accession to higher stages of readiness in all indicators is heavily dependent on a Chief Executive Officer (e.g., Vice Chancellor) becoming the champion for ICT adoption and usage. This is consistent with leadership requirements for any organizational change management effort, including ICT adoption and usage. We note that the staging framework is largely a moving target as it is context sensitive and the context is constantly changing. For example, the actual relationship between an ICT variable (e.g., bandwidth per 1000 students) and the staging depends on the sophistication and availability of Internet bandwidth in a particular region or country.

Although the model proposed in this paper was developed specifically for assessment of higher education institutions in Kenya, it has been used effectively in other EA universities.
We therefore believe that it could be applicable in other institutions in sub-Saharan African countries. This is because it has been shown that there is a strong correlation between the ICT Opportunity Index introduced by ITU and the economic classification of countries introduced by the World Bank [18]. For example, countries classified as high average income countries by the World Bank are also ranked among the top 29 in the ITU ICT Opportunity index (14]. Similarly, the bottom low average (< US$ 800 GDP per capita) were also ranked among the bottom 121-183 countries in the ICT opportunity index. Kenya and most of the countries in sub-Saharan Africa are in the low average category and we expect the state of readiness of the higher education institutions to be in the same category. However, it is possible for a university to be an ICT early adopter island with the right leadership. The researchers have observed that rural universities are able to achieve the same level of e-readiness comparable urban universities.

In the following sections, we describe the indicators and sub-indicators defined for each of the five categories of indicators.

### 3.1 Network Access

We adopted the first four indicators of the Network Access category of the CID tool, namely:

(a) Information infrastructure (in the campus)
(b) Internet availability (by the higher education institutions)
(c) Internet affordability (by the institutions)
(d) Network speed and quality (as perceived by users on campus)

We then developed a set of sub-indicators for each indicator guided by our experience and knowledge of what is relevant in the local context. Table 1 shows the indicators and the sub-indicators in this category of indicators and the main purpose for the indicators.
Table 1 – Network access indicators and sub-indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key Sub-indicators</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA1 - Information infrastructure</td>
<td>♦ NA1.1 - Telephone internal teledensity ♦ NA1.2 - Telephone external teledensity</td>
<td>The sub-indicators measure access to telephone services by staff of an institution</td>
</tr>
<tr>
<td>NA2 - Internet availability</td>
<td>♦ NA2.1 - Uplink bandwidth per 1,000 students ♦ NA2.2 - Download bandwidth per 1,000 students ♦ NA2.3 – Networked PCs per 100 users</td>
<td>The sub-indicators measure the extent of availability of Internet in an institution</td>
</tr>
<tr>
<td>NA3 - Internet affordability</td>
<td>♦ NA3.1 - Internet bandwidth costs as a percentage to the total expenditure of the institution or campus ♦ NA3.2 - Cost of Internet per 1,000 students</td>
<td>The sub-indicators measure the extent to which Internet is affordable</td>
</tr>
<tr>
<td>NA4 - Network speed and quality</td>
<td>♦ NA4.1 - % of students who think on-campus e-mail always works ♦ NA4.2 - % of faculty who think on-campus e-mail always works ♦ NA4.3 - % of students who think Internet speeds are better than those for Cyber Cafés ♦ NA4.4 - % of faculty who think Internet speeds are better than those of Cyber Cafés</td>
<td>The sub-indicators measure the quality of e-mail and Internet services in an institution</td>
</tr>
</tbody>
</table>

In order to stage the indicators and sub-indicators on a scale of 1 to 4, it was necessary map actual range of values to a stage for each of the variables shown in Table 1. For example, the Internet availability indicator NA2 had three sub-indicators, NA2.1 (the uplink bandwidth per 1000), NA2.2 (downlink bandwidth per 1000 students) and NA2.3 (PCs per 100 students). Table 2 shows how the values were assigned in the E-readiness survey of 25 Kenyan HE institutions in 2007 [2]. Targets used for each of the 17 ICT indicators for are available at http://eready.kenet.or.ke.

Table 2: Example mapping range of values for sub-indicators of Internet availability

<table>
<thead>
<tr>
<th>Stage</th>
<th>NA2.1 range of values (uplink bandwidth per 1000 students)</th>
<th>NA2.2 range of values (downlink bandwidth per 1000 students)</th>
<th>NA2.3 range of values (PCs per 100 students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>&lt; 128 kb/s</td>
<td>&lt;512 kb/s</td>
<td>NA2.3 &lt; 5</td>
</tr>
<tr>
<td>Stage 2</td>
<td>128 &lt;= NA2.1 &lt;= 512 kb/s</td>
<td>512 &lt;= NA2.2 &lt;= 2048 kb/s</td>
<td>5 &lt;= NA2.3 &lt;= 20</td>
</tr>
<tr>
<td>Stage 3</td>
<td>512 &lt;= NA2.1 &lt;= 1024 kb/s</td>
<td>2048 &lt;= NA2.2 &lt;= 4096 kb/s</td>
<td>20 &lt;= NA2.3 &lt;= 50</td>
</tr>
<tr>
<td>Stage 4</td>
<td>&lt;= NA2.1 &gt;= 1024 kb/s</td>
<td>NA2.2 &gt;= 4096 kb/s</td>
<td>NA2.3 &gt;= 50</td>
</tr>
</tbody>
</table>

The range of values shown in Table 2 were selected based on actual data collected from the 25 higher education institutions assessed in Kenya. That is, they represented the range of
values achieved by the HE institutions in Kenya. For example, the highest Internet bandwidth offered by one of the HE institutions surveyed was considered the minimum in the stage 4 range. Similarly, the worst Internet bandwidth offered was the highest range in stage 1. We note that most of the institutions were mapped into stage 2 or 3 of the framework. This tool therefore allows institutions in a given region or country to select appropriate values for staging.

Another factor that was considered in assigning the values for the NA2 sub-indicator range of values was the fact that only satellite Internet bandwidth was available to the Kenyan (and East African) institutions. In general, an asymmetrical ratio of uplink to downlink bandwidth ratio of 1:4 has been used at most of the institutions. Thus, NA2.2 values were four times NA2.1 values.

Table 2 shows that the minimum total satellite bandwidth for stage 4 institutions would be 5 Mb/s per 1000 students while stage 4 PC ratio would be a minimum of one PC for every two students. This was only achieved in some of the ICT departments in some of the institutions.

### 3.2 Networked Campus

The networked campus category contains only two indicators, namely, network environment and the e-campus indicators. This category of indicators is closely related to the network access indicators. For example, the network environment indicator measures both the ICT power supply environment and the security for ICT equipment and software. ICT power supply and security are big challenges for most of the campus networks and systems and determine availability of ICT on campus. Table 2 shows the indicators and the sub-indicators in this category of indicators and the main purpose for the indicators.
Table 2: Networked campus indicators and sub-indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key Sub-indicators</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC1 – Network environment</td>
<td>◆ NC1.1 - Existence of UPS in computer laboratories</td>
<td>The sub-indicators measure the ICT power supply availability and security of ICT equipment and software, which includes disaster recovery, plans</td>
</tr>
<tr>
<td></td>
<td>◆ NC1.2 - Existence of UPS in offices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.3 - Existence of licensed anti-virus software</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.4 - Existence of institutional firewall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.5 - Existence of physical security in laboratories</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.6 - Existence of off-site back-up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.7 - Number of years of administrative experience of the Head of ICT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.8 - % of ICT staff who have worked with users for more than 3 years</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC1.9 - Frequency with which ICT staff upgrade their skills</td>
<td></td>
</tr>
<tr>
<td>NC2 – E-campus</td>
<td>◆ NC2.1 - % of units with websites</td>
<td>The sub-indicators measure the degree of automation of internal processes and electronic interactions of the campus with students, staff, suppliers and other key stakeholders</td>
</tr>
<tr>
<td></td>
<td>◆ NC2.2 - Frequency of updating website information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC2.3 - Level of integration of computerized systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NC2.4 - Extent of online interaction</td>
<td></td>
</tr>
</tbody>
</table>

To be in stage 4 in network environment indicator means that an institution is in stage 4 in the ICT power supply sub-indicators and the ICT security sub-indicators. It also means that majority of ICT staff have many years of experience working with users (more than three quarters of the ICT staff have worked with users for over three years) and that ICT staff upgrade their skills at least every year.

The electronic campus or E-campus indicator measures ICT usage for internal as well as external operations. A stage 4, a campus would have fully automated internal operations and would also be using ICT to interact with suppliers, students, staff and other key stakeholders. This means that the campus and associated departments would have interactive and transactional websites that are regularly updated.

3.3 Networked Learning

The networked learning category contains four indicators as outlined earlier. We borrowed aspects of application of ICT to teaching and learning, application of ICT in research, and application of ICT in libraries from the AAU self-assessment guide. We added an additional indicator on developing the ICT workforce. The four indicators are:

(a) Enhancing education with ICT
(b) Developing the ICT workforce
(c) ICTs in the libraries
(d) ICT research and innovation
Although “enhancing research with ICTs” was considered as a separate indicator, data collected was incomplete to inform the staging framework. This indicator was therefore not analyzed. We intend to pick it up in our next iteration of the model. Table 3 shows the indicators and the sub-indicators in this category and the main purpose for the indicators.

### Table 3 – Networked learning indicators and sub-indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key Sub-indicators</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **NL1 - Enhancing Education with ICT** | ✷ NL1.1 - Educational software usage  
✷ NL1.2 - Usage of course management system (Moodle, WebCT)  
✷ NL1.3 - % of integration of ICT in curricula  
✷ NL1.4 - Use of ICT in the classroom  
✷ NL1.5 - Use of ICT in student projects | This indicator measures the integration of ICT in curricula and the readiness of institution to offer e-learning courses and use ICT in the classrooms. Stage 4 institutions have integrated the ICT in curricula and ICT used in all stages of learning and projects (even non-ICT projects) |
| **NL2 - Developing ICT Workforce** | ✷ NL2.1 - % of ICT staff with professional certification  
✷ NL2.2 - % of employees trained on productivity tools  
✷ NL2.3 - % of ICT staff who have received network administration training | Sub-indicators measure the extent to which an institution is preparing and training its ICT workforce. In stage 4, institution has proficient users of ICT who are regularly trained. |
| **NL3 – ICT Research and Innovation** | ✷ NL3.1 - ICT undergraduate degree program  
✷ NL3.2 - ICT Master’s degree program  
✷ NL3.3 - ICT PhD degree program  
✷ NL3.4 - Participation by students in international design projects and exhibitions (e.g., IEEE exhibitions) | This indicator measures ICT research and innovations. The sub-indicators selected as indirect measures of ICT research and innovations. For example, Master’s and doctoral ICT programs offered increase the research output of institutions. Stage 4 institutions have ICT doctoral degree programs and students participate in ICT exhibitions and competitions. |
| **NL4 – ICT in Libraries** | ✷ NL4.1 - On-campus OPAC  
✷ NL4.2 - Off-campus OPAC  
✷ NL4.3 - Availability of Internet databases  
✷ NL4.4 - Information literacy training  
✷ NL4.5 - Local digital content (digital library)  
✷ NL4.6 - Use of E-mail updates to library holdings | Sub-indicators measure the degree of automation of library and usage of ICT for back-end library operations. In stage 4, library is fully automated (front-end and bank-end operations) with support and training of users |

### 3.4 Networked Society

The networked society category of indicators measures the readiness of the community to use ICT for teaching, learning, research, and management (or administration). It consists of the following group of indicators:

a. People and organizations online  
b. Locally relevant content  
c. ICTs in everyday life  
d. ICTs in workplace
Table 4 summarizes the indicators and the associated sub-indicators used for staging.

### Table 4: Networked society category of indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key Sub-indicator</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS1 - People and Organizations Online</td>
<td>◆ NS1.1 - % of respondents who have never used the Internet</td>
<td>Indicator measures the intensity of use of on-line resources and what they need the Internet for. Stage 4 means less than 1% have never used the Internet, over 75% of students and faculty use the Internet daily and all students and faculty have e-mail addresses.</td>
</tr>
<tr>
<td></td>
<td>◆ NS1.2 - % of respondents who consider Internet most important for e-mail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.3 - % of students who consider Internet most important for academic work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.4 - % of faculty using Internet daily</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.5 - % of students using Internet daily</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.6 - % of students who think that the institution’s website is interactive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.7 - % of students who do not know about their institutional website</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS1.8 - % of students with e-mail accounts</td>
<td></td>
</tr>
<tr>
<td>NS2 - Locally Relevant Content</td>
<td>◆ NS2.1 - % of faculty visiting 1-2 local websites</td>
<td>Indicator measures availability of websites with local content. It could be academic, news or entertainment. It also measures the degree to which users are attracted to the locally relevant websites. In Stage 4, students, faculty and staff have access to relevant local content</td>
</tr>
<tr>
<td></td>
<td>◆ NS2.2 - % of students and faculty looking for academic information from the Internet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS2.3 - % students looking for news/entertainment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS2.4 % of students and faculty visiting Web portals with local (national) information</td>
<td></td>
</tr>
<tr>
<td>NS3 - ICTs in Everyday Life</td>
<td>◆ NS3.1 - % of students with campus access to computers</td>
<td>This indicator measures access and usage of ICT on- and off-campus.</td>
</tr>
<tr>
<td></td>
<td>◆ NS3.2 - % of faculty with campus access to computers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS3.3 - % of students whose main access to computers/Internet is cyber café</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS3.4 - % of students with home access to computers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS3.5 - % of faculty with home access to computers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS3.6 - % of students and faculty using computers for e-mail/Internet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS3.7 - % of students and faculty using PCs for word processing</td>
<td></td>
</tr>
<tr>
<td>NS4 - ICTs in the Workplace</td>
<td>◆ NS4.1 - % of faculty using Internet for academic work</td>
<td>Data obtained from staff (academic and non-academic staff). Measures readiness and usage of ICTs at work (e-mail, ERPs, e-learning platform, Productivity tools)</td>
</tr>
<tr>
<td></td>
<td>◆ NS4.2 - % of faculty using e-mail for internal communications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS4.3 - % of faculty who access Internet from office</td>
<td></td>
</tr>
<tr>
<td></td>
<td>◆ NS4.4 - % of faculty staying on-line for more than 1 hour</td>
<td></td>
</tr>
</tbody>
</table>

Each of these indicators was sub-divided into sub-indicators that were then staged. The **people and organizations online** indicator measures the use of Internet resources for learning, research, news and entertainment. It assumes that users have access to e-mail as
well as informational, interactive and transactional websites. E-mail accounts could be provided either by the institutions or other ISPs.

The *locally relevant content* indicator measures the degree to which local on-line resources are available in Kenyan higher education institutions websites or other websites hosted in Kenya. Such local websites could contain local news and entertainment or locally developed learning resources like databases or e-learning courses. The indicator measures the extent to which Kenyan Internet content has been locally developed and its relevance to the higher education academic community.

*ICT in everyday life* indicator measures the readiness and use of a variety of ICT services and equipment by the higher education community. For the purpose of this indicator, ICTs are defined broadly to mean computers, PDAs, mobile phones or fixed line phones, televisions, and radios. Such ICTs equipment or services need not be provided by the institutions but could be available at cyber cafés or even at home. Data for this indicator was collected using the field-based perceptions survey.

*ICT in the workplace* indicator was specific for academic and non-academic staff of HE institutions. It measures the readiness and usage of ICT at work. For an academic staff member, this means using ICT for classroom presentations, preparation of notes and e-learning content, and for Web-based research. It is also used to measure the use of ICTs for internal and external communication. Non-academic (administrative) staff, for example those in an accounts department could use institutional information systems for their daily work. Administrative staff could also use ICTs to interact with suppliers, government, off-campus students and staff.

3.5 Institutional ICT Strategy

The Institutional ICT Policy category of indicators is composed of three indicators, namely:

(a) ICT strategy
(b) ICT financing
(c) ICT human capacity

ICT strategy is measured using several sub-indicators, including the alignment of ICT strategy to the corporate strategy, the extent of ICT strategy implementation, and the reporting levels of the Head of ICT. ICT financing was borrowed from the AAU self-assessment guide and is measured using the sub-indicator of percent of annual institutional expenditure used to purchase Internet bandwidth. Although a sub-indicator that measures the percent of budget allocated to ICT was specified, most of the institutions could not provide the required data to calculate the percentage. The ICT human capacity indicator is measured using several sub-indicators that included the business and technical experience of the Head of ICT, the frequency of upgrading the skills of the ICT staff, and the retention of ICT staff.
Table 5 summarizes the indicators and the associated sub-indicators used for staging.

**Table 5: Institutional ICT strategy category of indicators**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Key Sub-indicator</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIS1 – ICT Strategy</td>
<td>◆ IIS1.1 - Status of ICT in the institution ◆ IIS1.2 - Reporting level of the head of ICT ◆ IIS1.3 - ICT leadership ◆ IIS1.4 - Extent to which ICT strategy is known or understood by students and staff ◆ IIS1.5 - Extent ICT strategic plan is aligned to the corporate strategic plan</td>
<td>The indicator assesses the extent to which strategic ICT planning takes place and is linked to corporate strategic planning, who provides leadership for ICT and the organizational structure of ICT</td>
</tr>
<tr>
<td>IIS2-ICT financing</td>
<td>◆ IIS2.1 - Percent of Internet or ICT costs to the total institutional expenditure ◆ IIS2.2 - Proportion of ICT capital budget from internal sources ◆ IIS2.3 - Total ICT hardware and software costs per 1,000 students</td>
<td>The indicator measures the degree to which an institution has sufficient budgetary allocation for ICT</td>
</tr>
<tr>
<td>IIS3 - ICT human capacity</td>
<td>◆ IIS3.1 - Highest qualification of the head of ICT ◆ IIS3.2 – No. of years of administrative experience of the head of ICT ◆ IIS3.3 - % staff who have worked with users for more than 3 years ◆ IIS3.4 – Frequency of upgrading skills for ICT staff</td>
<td>The indicator measures the degree to which an institution has competent and well trained ICT professional and support staff. The ICT staff must be especially well trained in networking technologies.</td>
</tr>
</tbody>
</table>

As an illustration, ICT strategy addresses strategic planning for ICT, the championship of ICT, and the organizational structure of ICT. To be in stage 4 in this indicator, an institution needs to have an ICT policy and strategic plan that is tightly linked to corporate strategic plan and known by most students and staff, have the head of ICT report to the CEO and a member of the top decision-making body of the institution and have the CEO provide the leadership for ICT.

Data for staging this category of indicators was obtained from hard facts questionnaires. We note that stage 3 or better readiness in this category of indicators is a pre-requisite for readiness in all the other indicators especially network access and networked learning.

**4. Conclusions and recommendations**

This paper has reviewed the existing e-readiness assessment models. It has proposed a new e-readiness assessment diagnostic model based on 17 ICT indicators. It was derived from the CID tool and AAU assessment guidelines. The main contribution of the model is the definition of ICT indicators and sub-indicators with quantifiable targets. These targets were
considered meaningful to higher education institutions in countries classified in the Low Average in the ITU ICT Opportunity Index [18]. The model was used successfully in the assessment of 25 higher education institutions in Kenya in the year 2006 [2] and 50 universities in East Africa in 2008 [3]. It was also used in the year 2010 to assess 10 EA universities that developed roadmaps for accession to higher stages roadmaps (results to be published in 2012). Figure 1 shows the radar diagram for the 17 Kenyan universities that were assessed both in 2006 and 2008 for the 17 indicators. This is an example of how the framework has been used.

Figure 1 – 2006 and 2008 Comparison of assessment data for 17 Kenya Universities

The researchers found that the following six sub-indicators could be considered the most critical for accession to the networked learning category of indicators:

- Internet bandwidth cost per 1000 students
- Internet bandwidth per 1000 students
- Internet bandwidth or ICT budget as a percent of the total expenditure
- PCs per 100 students
- Extent of ICT strategy implementation
- Integration of ICT in curricula

The researchers have discovered that three of the above sub-indicators indicators are particularly effective in communication with the senior leadership of universities in EA about their e-readiness status:
a) Networked PCs or laptops per 100 students (Stage 2 target is 10 shared and networked PCs per 100 students).
b) Internet bandwidth per 1000 students (stage 2 target is 2 Mb/s per 1000 students)
c) Internet bandwidth or ICT budget as a percent of the total expenditure (stage 2 target is 1.5%)

The proposed higher education e-readiness assessment model will help higher education institutions in economically developing countries to adopt a set of indicators that will help them integrate ICT into teaching, learning, research and management. The proposed model constitutes a relatively sound framework to act as a good starting point for empirical studies on the assessment of the integration of ICT in higher education institutions. Although the model is still being tested and will require further development and refinement, we invite researchers to use and test it in order to build the required knowledge in this area. At the same time, we invite practitioners in institutions of higher learning to adopt the indicators, modifying where necessary, to guide integration of ICT into higher education and increase e-readiness of HEIs.

We recommend further research to establish relationships between the indicators and sub-indicators and to derive a University in developing country e-readiness index.

References

Expanding E-Learning Initiatives in Malawi

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Abstract

As the demand for nurses and midwives increases in Malawi, Kamuzu College of Nursing (KCN) (The University of Malawi School of Nursing) is committed to respond to this need by increasing student in-take. It has also diversified into several research MSc Programmes. KCN has two campuses 400 km apart and also provides leadership at curriculum level to a variety of nursing colleges across the country. However, to achieve this broad mandate, there was a need for multi-dimensional approach. As such, while the college is expanding classroom space, it was imperative that other modes of delivery of the curriculum be explored as well. This paper describes these modes of delivery that depend on a reliable campus and national network for effective delivery.

Given the critical shortage of nurses, KCN has doubled the student intake for registered nurses over the past five years. However, the increase has come with some challenges including the need for additional classrooms, increased work-load for faculty; and increase in operational costs, increased demand for teaching and learning materials. These challenges required consideration of other modes of delivering the curriculum. KCN is now putting in place e-learning infrastructure to solve these problems, where two systems are being implemented.

The Student Management system which handles the administration part of students i.e admission, examination records, assessment process, finance, room allocation, transcripts, students union electronic voting, mobile text messaging exam results feedback etc

The other system is the curriculum management system which handles the academic and learning resources where lecturers upload their modules, electronic resources, quizzes, discuss forums, video simulations by The development of these modules is an interactive process between lecturers, the ICT department and College Administration conduct The response of staff and students to the system is The fuller implementation of MAREN to facilitate wider delivery of these valuable training materials over the academic network will enhance the system.

1.0 Introduction

As institutions little by little are making efforts to get connected there is little focus on what happens when there will be a network connection between academic institutions. With the connectivity initiatives KCN took an advantage in developing resources that solve its critical problems and deploy it across the shared network. Miller, [1] stated that over 30
studies have found that interactive technologies reduce learning time requirements by an average of 50 percent.

KCN developed a Student Management System and Curriculum Management System shared among two geographically separated campuses using the academic network.

2.0 Background

Kamuzu College of Nursing (KCN) is a constituent college of the University Of Malawi (UNIMA) which has two campuses in Lilongwe and Blantyre, separated by a distance of about 300 kilometres, and major clinical sites in Blantyre, Lilongwe, Zomba and Mzuzu. Traced back from 1965 when it was called a National School of Nursing, and then upgraded to a full constituent college in 1979, the college has been offering a variety of courses in the fields of Nursing and Midwifery.

The National Human Resources for Health (HRH) Census [2] puts the number of Nurses at 4000 representing 13% of the total health workforce. This translates to about 1 nurse per 3000 people in Malawi representing a nurse to patient ration of 1:3000. The student nursing output with support from the Emergency Human Resources plan increased to about 600 nurses annually with 100 being registered nurses. However, the challenges for Malawi remain to train double the number of registered nurses (university trained nurses) currently less than 25% of all nurses in the health system.

To date, KCN is the largest national producer of high quality professionals in nursing and midwifery. Offering a wide choice of programmes at Diploma, Degree and Masters levels, the college is the major trainer of nurses for Government, private and mission hospitals, as well as a training institution for almost all nursing and midwifery instructors in CHAM private colleges, the only alternatives to KCN in as far as training of nurses and midwives is concerned. This leaves KCN with a major responsibility and role to play in ensuring quality nursing and midwifery services in Malawi.

3.0 Why KCN adopted an E-learning platform

- Pressure to increase intake currently at 100 for generic B Sc program, 30 for Post Basic BSc programme, 30 University Certificate in Midwifery, 20 Diploma in Nursing and 16 MSc in Midwifery and Reproductive Health, which are all very to meet the demand of the Malawi health system.
- Inadequate numbers of faculty teaching staff.
- High mobility of faculty members and students between campuses and teaching sites including district hospitals in Malawi

3.1 Strategies put forward to address the challenges

- Training of faculty in ICT and development of e-learning tools and content
- Development of KCN curriculum and course content to be delivered using ICT tools and equipment
• Development of an internet and intranet systems to enable KCN curriculum and course content delivery using ICT tools and equipment
• Introducing systems for students to access teaching and learning materials, assignments and examinations using ICT tools and equipment
• Introducing post basic training programs decentralized through the two teaching campuses and two major clinical teaching areas while students continue working in their places of work

3.2 Available Resources
• MTL has already established a backbone Fiber connection that is currently running across Malawi and connects to Mozambique and Tanzania.
• KCN Blantyre campus benefited on an initiative made by research and education institutions in which MAREN took a lead by installing Fiber connection between College of Medicine, KCN Blantyre campus, Malaria Alert Centre, MLW, QECH and other institutions around that area which enables them to have fast internet connectivity. Since this is a shared contribution, it also enabled them to share resources such as; networking, antivirus, research, journals and many more within their huge network.
  This initiative came as a result of the common problems that these institutions were facing on Internet connectivity. Each of these organizations has previously subscribed to different Internet service providers which has been very slow, expensive, and not very reliable
• The college currently has a campus network installed in 2005, which it hopes to integrate with the proposed network. Equally, the college has technical staff in ICT and administration that will be assigned to the project.
• Faculty members are very committed to delivering their courses online as there is duplication of effort under the current setup. They pledged all their full support to the project.

4.0 Curriculum Management System
In December 2009 after analyzing the problems faced and assets available, lecturers sat down and came up with ideas of the proposed curriculum management system (CMS).

4.1 Requirements and Ideas for the CMS at KCN
• Deliver content to students in a context that is relevant to their curriculum
• Editable by staff who are responsible for their teaching materials
• Provide additional information that is relevant to staff / students
  – News / Noticeboard
  – Discussions
• Course Based layout with time table embedded per unit/topic
• An approach that directly represents the curriculum structure
• Each level of the curriculum can be represented in the CMS with its own page
• Each page can contain written content, links to web-resources, and downloadable files
• Permissions can be set to only give access to pages to students who are enrolled on the particular course

The ICT team came together and customized a Moodle framework to arrive at the ideal curriculum management system that covers all aspects the lecturers highlighted, where lectures can upload their modules, electronic resources, quizzes, discuss forums, video simulations etc. the resources are linked systematically according to the module structure.

4.1.1 Curriculum Management system setup
The system is web based, divided into 3 pages to navigate
Home page
• Introduction Text
• Personalized list of Modules
• Generic Links
• News Feed
Module Page
• Editable Text area for providing Overview Information
• Links to Supporting Material (Learning Outcomes, etc)
• Links to Units
• Links to Downloadable Module Packs
Unit Page
• Course Overview Information
• Display an overview of the unit Show a list of the activities to be covered
• Show the learning objectives of the unit
• Show any related resources for the unit
• List of upcoming teaching events in the unit

As the CMS platform was completed, there was the need for the lecturers to create resources and also discover way of how easily can the students access the e-resources. We therefore partnered with University of Edinburgh who had successfully implemented their CMS. They helped our faculty in redesigning their content in an electronic resource, also provided tools for creating e-resources, quizzes, flash and videos to be uploaded in CMS. University of Edinburgh brought 80 brand new computers and Servers to provide adequate access for the students to the CMS.

We started conducting continuous professional development workshops after every 3 months in teaching the lecturers in the following
• how to use tool for creating e-resources such as engage processes, quizzes, surveys and flash animations
• how to create videos, create storyboards, edit videos, voice over
• how to link the resources to CMS in the appropriate module topic

4.2 Project work Plan

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<tr>
<th>ACTIVITY</th>
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<th>YEAR 2</th>
<th>YEAR 3</th>
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<td>Getting requirements from Lecturers</td>
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<td>Customization of Moodle and deployment across 2 campuses</td>
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<td>Resource creation User training and Creating of e-resources</td>
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<td>Evaluation of Impact</td>
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4.3 How KCN CMS has improved collaboration

Since we deployed the CMS on MAREN network linking the two campuses, lecturers at KCN also share content with College of Medicine, which is on the same network. KCN lecturers have been able to link resources in College of Medicine repositories, which is relevant to nursing and vice versa. Some of the electronic resources have been core authored by lecturers between the two colleges through collaboration.

Apart from local collaboration, there is also external collaboration:

University of Edinburgh has played a big role in bringing together lecturers from Edinburgh and KCN to collaborate in creating electronic content for the nursing programmes. With the coming of the UbuntuNet network and the AfricaConnect project, the opportunities for linkages such as these, both with European Universities and other Universities in our region open up.

In addition, OER (Open Education Resources), coordinated by Neil Butcher and Associates (South Africa) has assisted in working with Faculty in transforming learning materials into dynamic visual e-learning resources.

Other international partners are also excited at the possibilities offered by the KCN CMS.

5.0 Student Management System

Apart from lecturers delivering content to students administration also had a requirement to manage the students from the administration part.

Student management system was created in house to assist in registration of students, financial recording, examination grades records, transcript generation, student accommodation management, and keeping student records.

5.1 Student management system setup
5.1.1 Admission
- Captures student demographic data (names, RegNo, Gender, address).
- Captures student photos
- Captures student’s programme registration
- Print nominal roll report with registered students highlighted
- Search engine to retrieve by full name, single name, name key, full registration number, and registration number key
- Read and reply student messages

5.1.2 Academic
- Capture exam results (assignments, tests, examination, projects and practical marks)
- Prints class size, class roster (list of students registered to a course)
- Print Course based examination results
- Print student progressive reports (statements of examination results)
- Print student transcripts
- Excel files Imports
- Lecturer course allocation
- Publishing and un-publishing examination results
- Records student exam remarks

5.1.3 Billing
Integrates with ACCPAC accounting software and retrieves the following
- Captures student payments
- Captures student refund records
- Prints individual student payments reports
- Prints cohort payments reports
6.0 Conclusion
As MAREN is making an initiative in interconnecting the research and education institutions it is hoped that Institutions will start developing more and more e-resource initiatives so that when the network is completed, it shall be fully used and help increase access of local content within institutions. The curriculum management system at KCN shall benefit many research and education institutions in the sense that there is already massive electronic content online developed by lecturers at KCN just waiting to be accessed.

7.0 References
CHAIN: Model for cooperation between European and non-European e-Infrastructures

Ludek MATYSKA

Abstract

The EU CHAIN project (Coordination and Harmonization of Advanced e-INfrastructures) aims to elaborate a strategy and define the instruments to ensure coordination and interoperation of the European Grid Infrastructures with other external e-Infrastructures. In its first stage, the project aims to develop a coherent operational and organisational model. To guarantee an up to date and relevant information, a questionnaire has been prepared and distributed in April 2011 in all the regions relevant for the CHAIN project. Two versions of the questionnaire have been released, one targeting a regional and the second the national (and smaller) levels.

The questionnaire answers were collected in June 2011 and are currently being analysed to contribute to several important deliverables: D2.2 "Interoperability and interoperation guidelines", due in September 2011, and D4.1 "Specificities of the various regional e-Infrastructures", due in July 2011.

While some principles of building e-Infrastructures should be common to all world regions, differences arising from different expectations, previous experience, current scientific potential, and governance models will be identified and described in the Deliverable D4.1. This analysis will allow to propose a first operations and organisational model that will be used to prepare the guidelines for interoperability and interoperation (the D2.2 Deliverable).

In the conference presentation and paper we will summarize the findings. A first version of a coherent organizational and operational model for interoperable e-Infrastructure will be also presented, to demonstrate project progress after the first year of work.

Abstract only, full paper not available
SUVL, SUIN and SudRen; the history of the Sudanese Education Network

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Abstract

Sudan used to be the largest country in Africa now separated into two countries, the Republic of the Sudan and the Republic of Southern Sudan. The Sudan (the new one) has a very large backbone of fibre owned by the telecoms, the national Electricity Grid and the petrol pipe lines.

SUVL (Sudanese Universities Virtual Library) started in 2004 on a frame relay (120kbps) connecting all thirty public universities, the connectivity was then described as frustratingly slow or dead slow. Interaction with African and international partners through UNet alliance encouraged a small group of stakeholders to fight for fibre and that was achieved by a fund from the national regulatory body. Now 27 public, 3 private universities and the National Research Centre are connected. SUVL first developed into SUIN (Sudanese Universities Information Network) and finally changed to SudREN owned by the Association of Sudanese Universities. A business model has been developed and the universities are gradually taking over the running cost of the new body. Internet connectivity through STM-1 is made available and a minimum of 2 mbps is allocated for each university. The users are still complaining; where are we failing?

Key words: Sudan. SUVL, SUIN, SudREN, NREN

1. Introduction

Sudan used to be the largest country in Africa until the 9th of July 2011 when it is separated voluntarily after a public referendum to the people of southern Sudan to generate two countries the Sudan and the Republic of Southern Sudan (1). Higher education started during the colonial time with small numbers in separate programs like the Khartoum Memorial College 1902, School of Medicine in 1924 and other such schools. At the dawn of independence those schools were brought together with the memorial college to make the University of Khartoum in 1956. Since then the institutions of higher education increased gradually until 1991 when a revolutionary increase was imposed so that every State will have its University so that the number became 30 public universities, 5 private or nonprofit universities and more that 40 other private colleges. The number of students crept from 30,000 in 1991 to more than 500,000 today (2). The republic of Southern Sudan has gone with its share of universities now 5 running. Internet service was established in 1997 and since then universities strived to utilize this new tool of communication. However, networking was not realized until 2004 when the Ministry of Higher Education started a project of virtual library for Sudanese universities and SUVL was born to serve this purpose. Thirty public universities were connected by frame relay with a server accessing the internet hosted by the University of Khartoum. Librarians of the universities were asked...
to upload theses generated by their respective universities, 250,000 records including theses, books and periodical were provided from 6 universities. SUVL also provided links to free access literature, such as WHO Hinari, Agora, as well as access to some publishing houses like Oxford University Press. During that period the telecom company Sudatel had laid massive fibre backbone in the northern part of the country now the Sudan and it was clear there is a great unused resource under the ground. There is another fibre backbone with the petrol pipe lines starting from 1997 and the national electric grid covering vast areas of the country. Canar Telecom Company added more fibre in the country. SUVL was transformed into SUIN (Sudanese Universities Information Network) to serve as the national NREN to facilitate research and learning networking among the Sudanese tertiary education institutions and with regional and international institutions to breach the gap of the needs created by the expansion within scarcity of resources. SUIN was also administered by the Ministry of Higher Education. Pressure from enthusiastic users explored the possibility of connecting fibre to the respective members of SUIN to maximize the benefits of networking. That was possible by a fund from the national regulatory body the National Telecommunication Corporation (NTC) and 12 universities were connected in the first phase in 2008-2009, NTC was also paying for the internet of 15 Mbps for all universities with the NOC in the University of Khartoum. Another leap came when a meeting with the Minister of Communication and Information Technology (August 2010) resulted in sponsoring STM-1 with 155 Mbps for SUIN from Sudatel which started February 2011. The ownership of SUIN continued with the Ministry of Higher Education until a need for reform arose due to joining UbuntuNet Alliance, the ministry transferred its rights to the universities which took over at the end of 2009 through their representative body the Association of the Sudanese Universities (ASU). SUIN was granted a license from NTC to operate as an internet service provider (ISP) for its members in 2010. The CEO continued her post but moved to the University of Khartoum and a board was elected from Vice Chancellors and other persons beside the CEO. The board agreed to change the name SUIN to SudREN in conformity with the other NRENS in UbuntuNet Alliance.

2. Situation analysis

a. Governance
SudREN is a nongovernmental body governed by a board elected from the owners the general assembly of the Association of Sudanese Universities. The governing board is responsible for policies, setting of prices of the bandwidth and employment. Executive administration (CEO) is responsible day to day running of the network and is accountable to the board.

b. Connectivity
The network is connected by fibre to each university. The connectivity is provided by STM-1 (155mbps) distributed to the members with the minimum being 2 Mbps. The larger universities subscribed to 30 Mbps, 10 Mbps and 5 Mbps.

c. Business plan and sustainability
SUIN/SudREN started as a government body which changed since end of 2009 to operate autonomously. However, still is largely dependent on government funds for the infrastructure. A financial expert is commissioned to establish a financial department and set a business plan for the organization. The business model depends on costing of the bandwidth shared by the members to cover the STM-1 costs, salaries and the
running costs. CEO, financial staff and the technical staff are contributed by the University of Khartoum and Sudan University of Science and Technology. SudREN pays top up salaries to be competitive.

d. Bandwidth Management
   The administration and the technical team have imposed continuous online bandwidth management. The users’ compliance to good use policy can be monitored by the administration and the other users. For example inappropriate use at odd times is clearly monitored. Weekly and monthly reports of bandwidth usage are generated and sent to members. The technical support staff is working on the development of knowledge management protocols.

e. Regional and International Relations
   SudREN became the sixth member of UbuntuNet Alliance as the consequence became part of the U-NET projects in collaboration with European Union and the international community (AfricaConnect). SudREN is a member of AfriNIC organization and has got its own AS name and a good range of IP addresses. SudREN is a founding member of ASREN the Arab research and education network.

f. Services Provided
   Apart from the internet connection the REN provides the following services
   i. Virtual library containing links to a great number of journals and scientific publications including BioOne, Cambridge University press e-journals, IOP, Oxford University press e-journals, Jstor, Aluka, Agora and Hinari (WHO) freely accessed within the network. SUVL also contains links to international libraries.
   ii. Video Conference System funded by NTC in 32 locations in the Sudanese universities and is administered from Sudan University of Science and Technology. The system is used for distance learning and meetings.
   iii. E-Science depending on tools like Grid computing which created an opportunity for interaction of researchers in the Sudan with others in Europe through CHAIN project.
   iv. Integrated Library and Digital Library System through a fund from UNESCO in collaboration with Sudan University of Science and Technology to be implemented in three Sudanese university libraries using open source protocols.

3. Lessons learned

The process of establishing the SudREN offered an opportunity to extract lessons which can benefit other organizations and the e-government project in the Sudan

   a. The collective purchase of bandwidth gave evident benefit of prize reduction
   b. Compliance to good use policy must strictly be observed
   c. Continuous monitoring of the bandwidth usage helps users and administration and gives a continuous feedback on the use.

4. Opportunities
   a. The improvement of ICT infrastructure and connectivity
   b. The enhancement of access to learning and research materials
c. The automation of academic and managerial procedures at the higher education institutions.
d. Introduction of modern learning techniques such as video conference, e-learning, e-medicine
e. Collaborative research opportunities between Sudanese institutions and more developed ones in Europe using tools such as grid computing.

5. Challenges

a. Sustainability of the network
b. Conflicting interests of telecom companies and the developing user ambitions
c. Breaching the digital gap between the senior administrative group in the institutions of higher education and the young generations

Where are we failing?

If we succeed to answer this question then we will be successful in managing and curing the different problems we are facing in our practice concerning the SudREN. Yes we can claim knowing some of those obstacles like

a. Most of the universities have no campus network.
b. In those campus connected universities they use mostly wireless for connecting the different campuses and a lot of complains from interruption of the system and hence mistrust
c. The culture of the networking is not well established among the leading groups in the higher education in the Sudan and therefore they give less attention to the network
d. We started with free internet for five years and the universities have still to learn to spend for their internet as it turned to be in the recent business model
e. Funds allocated for networking are small and come low in priority in almost all universities
f. SudREN needs to develop its communication strategies.

These issues collectively or separately have contributed to low accessibility of internet and other services to staff and students which is the main objective of the networking. There are efforts made by the board and SudREN administration to increase the awareness by targeting the ICT community in the universities by videoconferences to motivate them and provide them with the right information to train and motivate others in their campuses, and targeting specifically the vice chancellors and chief executives to make them aware of the benefits and to ask for their support for the project. The outcomes of such intervention cannot be assessed immediately. However, there is a positive feeling that we are following the right track from simple indicators such as the timely payment of the monthly fees and increased utilization of the bandwidth by several universities as shown on the weekly reports.
6. Methods of the study
This report depends on a triangulation of document analysis, questionnaire and observations. The questionnaire is conducted by telephone interview with the heads or operators of the net in the different universities. SudREN administration has distributed telephones to each center for their follow up and communication purpose. The questions included the time of connection, whether the university campuses are connected, if so with which system, whether staff and students have accessibility to the internet, if so free or paid, whether the staff and students are satisfied with the service, if so what rate of 1-10, the operators were also asked of their satisfaction with the rate of 1-10. The operators were asked of the problems they face if any and finally if they have any recommendations for improvements. The data were presented as quotations of the different interviewees, compared to the reports of the network administration and the observations made by the investigator.

7. Results
The results were taken from documents and 14 respondents from 14 universities. Twenty seven universities and one research center are connected to the Sudanese research and education network hosted in the University of Khartoum. The University of Sudan for Science and Technology hosts the center for videoconferences. Two universities are connected by wireless as the fibre has not reached its area, another university though connected by fibre insisted to use its ADSL subscribed directly to the telecom company. Twelve universities had been connected in the first phase during 2008-2009 and the rest of the universities were consequently connected until early 2011. Since 2008 the network had 15 Mbps internet connection for all universities until February 2011 when STM-1 of 155 Mbps was connected. The minimum subscription was 2 Mbps for each university with the larger universities subscribing 5, 10, 20 or 30 Mbps respectively. The usage of this bandwidth is monitored continuously and displayed on the website of the network. All universities had single point connections to the network and each university connects its campus(es). Only two universities, Khartoum and Sudan University for Science and technology connected all their campuses, few others are partially connected. Most of the universities are waiting for the coming project of campus connection funded by NTC. Surprisingly big universities in Khartoum State have not yet connected their campuses. Most of the interviewed persons stated their major problems include lack of funds for the networking, lack of internal connection of the campuses and problems with the wireless connections. Their recommendations included mostly the importance of connecting university campuses with fibre, allocating more funds for ICT. Some recommendations coming from single individuals but seem important include, regular meetings of the network leadership and technical staff in different universities to exchange experience, establishment of technical support unit for internal and external connections, group purchase of equipment with appropriate technical support. Fig (1) shows the weekly report of the administration of the bandwidth usage. This figure shows clearly the variation between universities in utilization of the subscribed bandwidth. The rating of the services varies from 4 to 10 of 10 with average of 7.8 of 10 likewise the satisfaction rate of the staff varies between 6 and 10, with average of 7.9. Some universities have no accessible internet for staff and students so not possible to talk about satisfaction.

8. Discussion and Recommendations
SudREN is the 6th member of UbuntuNet alliance and is counted among the well established NRENS in Africa. This is true looking at the history of its development under
the Ministry of Higher Education until today when its an independent entity owned by the beneficiaries. The initial steps were important when the ministry was able to provide the funds for starting the network. The role of NTC which is the regulatory body was very crucial both for facilitation, licensing the NREN and funding the fibre infrastructure as well as paying the internet access until the organization was able to take over. They are still there to give hand whenever needed. SudREN gained from the establishment of a new Ministry of Communication. The Minister of Communication used to be an energetic member of SUIN Technical Support Committee. The network has advantage of being considered a priority project for the government in its strive to reduce the digital divide in the country. SudREN is operating autonomously which gave it the flexibility recommended by Terena (2010) (3) of the European Union and excellent relation with government bodies securing protection and funding known to be important in African setup (4). Given all these positive remarks still the REN is facing challenges mainly the marked difference between the member institutions in their readiness to develop their in campus connectivity and payment of the massively subsidized bandwidth cost. It is clear that some of the universities leadership lag behind in understanding the importance of the REN as a tool for development, giving no priority to any issues relating to ICT world. This is clear at least a few universities (One Vice Chancellor followed the advice of ill-motivated technical staff to continue subscribing directly to the telecom company of much less bandwidth for much higher cost, another vice chancellor said they don’t need all this bandwidth and asked to have one quarter in spite of all explanations to him, a third one without giving a reason is not paying). Many institutions are not giving priority to development of ICT. However, the administration and technical staff of SudREN are gaining more grounds every day with dedication and patience as the core of the trained and motivating technical staff is forming a growing pressure group supported by a nationwide political will to empower this sector. The varying rating of satisfaction in this study shows clearly the varying institutional support for the REN. The difficulties mentioned by the technical staff mostly talking of in-campus connection and funding are issues for the board to work with though the connection of campuses is approved to be supported by the ministry of telecommunication. There are many important recommendations apart from the connection which will certainly increase the awareness and give solidarity to the less privileged ones.

In conclusion SudREN is a well established entity (4) with members of varying awareness, capacity and dedication but all are working towards the same goal. As there are great challenges there are opportunities to be realized. We are not failing but slowing down now and then to manoeuvre some obstacles to have yet another leap. The door will continue to be open to those who could not join now especially the private universities without discrimination.

Acknowledgements

I would like to thank Dr. Iman Abuel Maaly CEO SudREN for assistance with the NREN documents and for reading the manuscript. I also thank the technical staff at SudREN and all respondents from member universities.

References


Biography

Abdelrahim O. Mohamed a medical doctor, professor of biochemistry at the Faculty of Medicine, University of Khartoum. Former Vice Chancellor of the University of El Imam El Mahdi, former State Minister of Health in North Darfur, Western Sudan. Worked with colleagues to secure fibre connection for the Sudanese universities, now heading a committee for campus connection and working as a board member of SudREN. MBBS, MSc, PhD, Professor, SudREN Board Member
Innovative photonic devices for emerging NRENs

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Abstract

We present a conceptual paper about photonic networks and devices for emerging NRENs. The fundamental difference between NRENs and ISPs is highlighted and non-standard applications for optical networks are discussed. We introduce open approach for network devices, where their advantage in NRENs optimization is explained. We identified three optical network development approaches that bring considerable savings for NRENs. At last, all-optical networks are found as a way into future and should be supported by NRENs.

Keywords

Photonic devices, Open networks, Customer Empower Fiber networks, Nothing-in-line, Single fiber bidirectional system, Czech Republic

1. Introduction

1.1 NRENs

The incredible rate of today’s innovation can’t be followed without global communication and that is place where National Research and Education Networks (NRENs) come into play. Supported by local government and global projects NRENs deliver internet connection to nonprofit partner organization like universities, research institutions and also hospitals and schools. It is important to highlight that NRENs are not competitors to Internet Service Providers (ISPs), because beside the internet connection their main aim is to provide collaborative and educational environment that allows adoption of the latest learning methods and extensive training local students [1]. Such environment must provide also network applications that are not cost-effective, and therefore not supported by ISPs, but are requested by Research and Educational Community (REC). Moreover NRENs usually help minimize distance and digital divide by offering services to all partners at the same price.

1.2 New applications

Access to the Internet obviously opens new ways to find and acquire information, but NRENs can utilize their networks to provide applications beyond means of the Internet.
Connected NRENs can enhance end-to-end collaboration by forming a photonic channel that allows special applications. Some of them can be delivering large data flows during real time High Definition (HD) video broadcast. Such real time broadcast was set up across 150km to connect the unique Da-Vinci Robot [3] in a Hospital with lecture room of medical university [2]. Students were able to communicate with a surgeon during the operation in real time and discuss details of operation, see Figure 1. Such extensive training translates into improved level of graduate students. Similar robotic applications can be conducted also over thousands of kilometers and between continents [5]. Clearly such new applications that are not yet supported by ISPs, drive innovations further [6]. We may expect more novel applications in specific environment of Africa continent.

2. Open photonic network devices

A communication network that is required by REC should flexibly react to community needs to fulfill its role. Flexibility of networks strongly depends on expertise of NREN staff and nature of the network. Expertise can be gained from proper training in networking, but hands-on experience is best obtained by practice with suitable hardware. Most optical network vendors deliver turn-key systems suitable for telecommunication operators that look for maximum network capacity at account of its customization and flexibility. Also a network that allows nothing more than network of ISPs and telecommunication operators can be easily considered a competition to private sector. Therefore the added value of NREN should be evident. It translates into nature of network that is best shaped if network devices are open to modifications and allows adding the value through new services for REC. The openness of our photonic network devices could be referred to similar approach as in open sources, open standards and open information [7]. This approach ensures access to all information about device and creates opportunity for end-users like NREN experts to customize it to suit whatever application is requested by REC. Open photonic network devices have modular design so any part can be replaced by latest model or desired manufacturer. All technical documentation is freely available and supported by community. We designed CzechLight, a full family of network devices that can form optical network following latest trends [8][9].

2.1 System optimization & Cost-effectiveness

It is essential to stress that as NRENs has different mission than networks of telecommunication operators also their networks could be built differently to achieve NRENs goals. Obviously ISPs aim for maximum network capacity to increase their profit, but NRENs usually experience lower traffic and need to react quickly at REC requests. Since network vendors design their systems for ISPs, we found that optical networks optimized for NRENs are slightly different from their commercial counterparts. Such optimization brings saving in both Capital Expenditures (CAPEX) and Operational Expenditures (OPEX). We identified three main approaches for NREN optimization.

2.2 Customer Empowered Fiber network (CEF)

CEF represent approach in building of optical networks entirely according to wishes and possibilities of customer. The fundamental resource in optical network planning and development is fiber infrastructure. It is essential for NRENs that their network is based on...
dark fibers. A dark fiber means that an NREN has full access and control over optical fiber and can deploy any technology at it, particularly the technology that suits NREN the best. This approach allows NREN to build on top of dark fiber infrastructure a future-proof network that is flexible to REC requests. Although fiber plant of African countries may not be yet fully developed, it is worth of noting that in Europe the majority of fiber cable deployment cost is for labor work. CEF networks workshops are periodically held every two years in Czech Republic discussing advances and challenges of optical networking [10].

### 2.3 Nothing-in-line (NIL)

Most vendors have their optical systems optimized for maximum capacity and customer has to provide housing for network equipment every 80 km [ref]. Such request can be complicated or even impossible in some places. It might be challenging to provide secure housing with electricity in the middle of barren land [11]. It is essential to point out that 80 km can be easily overcome and transmission over single span of 200 km has been successfully demonstrated [12]. Moreover majority of optical network of CESNET, NREN of Czech Republic, has fiber spans in range of 100-200 km. CESNET developed photonic network devices, called CzechLight, to support as long spans 200 km and offer technology transfer to other NRENs.

We see great potential in this approach for emerging African NRENs that usually needs to connect distant places with minimal CAPEX and OPEX.

### 2.4 Single fiber transmission (SFT)

Although technology for bidirectional SFT is commercially available for quite long time, it is seldom deployed in field. It is mainly because market is oriented for ISPs needs and there is usually large fiber plant available. Still annual rental of fiber pair in central Europe is about 0.5 EUR/meter/year [13] and rental of a single fiber comes at 60% of price of fiber pair. An annualized cost of commercial transmission system is about 0.12 EUR/meter/year for 4 years amortization and 10 Gb/s transmission rate and from 0.035 to 0.047 EUR/meter/year for open transmission systems [13]. Bidirectional SFT has just half the capacity of fiber pair, but if you consider more than 70 optical channels, at 100 GHz grid, just within C-band then one can easily have 350 Gb/s data flows in both directions with well matured 10Gb NRZ transceivers. Since that capacity is hardly to be required by any NREN, we believe that bidirectional SFT is a promising approach for emerging NRENs with limited resources.

### 3. The way to all-optical networks

Once NREN acquire dark fiber infrastructure it is up to them to select whatever they will use open, commercial or multivendor systems. Clearly commercial systems allow just features that are vendors aware of and are prone to fast modifications for REC requests. In contrast open systems permit any modification and give full hands-on experience to NREN experts that can shape the network according to current needs. Therefore it is possible to form truly all-optical networks that can establish light-path between any locations in network. Such network satisfy even the most demanding REC requests as atomic clock comparison [14] and is suitable for any other application with strict requirements on
latency jitter. All-optical networks are limited in their reach by lack of all-optical regeneration that still remains a challenge for research community.

4. Conclusion - Optical networks that suits Africa

We emphasize the role of NRENs as the leading institutions in supporting of REC and breaking the digital divide. These activities translate into better education of local experts and hands-on experience with emerging technologies that in long run increase overall standard of living. We introduced open photonic devices that are suitable for building of cutting-edge photonic networks with enhanced flexibility. Following the three above mentioned approaches, we can claim that CAPEX and OPEX of optical networks can be effectively cut down with careful planning and proper network equipment. These approaches may be considered by emerging NRENs to ease their start or early development. A few novel applications were described to show the big potential of optical networking.

References

A new method of accurate time signal transfer demonstrates the capabilities of all-optical networks (online) at http://www.ces.net/doc/press/2010/pr100401.html

Biographies

**Pavel Škoda** joined in 2005 the project “Components for high transmission rate all-optical networks” at the Institute of Photonics and Electronics at the Academy of Sciences of Czech Republic. He graduated in 2008 at the faculty of electrical engineering of the Czech Technical University in Prague. After graduation Pavel went to the Tyndall National Institute in Ireland to study the dynamics of mutually coupled laser system. Since 2009 he has been working at Optical networks activity in CESNET z.s.p.o. in Prague. In 2010 Pavel started the Ph.D. study at the Czech Technical University in Prague.

**Jan Radil** received the M.Sc. and Ph.D. degrees in electrical engineering from the Czech Technical University, Praha, in 1996 and 2004, respectively. Jan joined the Research and Development Department, CESNET, Praha, in 1999, where he is responsible for optical networking and the development of the next generation of the Czech research and educational network. Jan participated in the EU projects SEEFIRE, Porta Optica Study, Phosphorus, GN2 and GN3.

**Stanislav Šíma** holds Dipl. Ing. (1967) and PhD. (1983) degrees from Czech Technical University (CTU) in Prague, Faculty of Electrical Engineering for the study of formal semantics of computer systems. He joined CESNET in 1996. Since 2000, Stanislav has been leading the CESNET research activity in optical networking. He is promoter of Customer Empowered Network concept for R&D networking and he has great experience with building of lit fiber infrastructure not only national but also international level. Recently, he has been involved in SEEFIRE, Phosphorus, Porta Optica Study and GN3 projects.

**Josef Vojtěch** joined Research and Development Department of CESNET, a.l.e., in 2002, where he is active in applied research in the area of photonic networking. He received the M.Sc. degree in Electrical Engineering and B.Sc. degree in Pedagogy from the Czech Technical University, Prague, in 2001 and 2003, respectively. In 2009 he defended his Doctoral thesis “All-optical networking” at the Czech Technical University in Prague. In Scopus, 24 records have been found with 29 citations, h-factor was 3.

**Lada Altmannová** holds Dipl. Ing since 1983 from Czech Agriculture University in Prague, Faculty of economy. She joined the Computing centre of this University. She joined CESNET since 1996. She was Head of Financial department and since 1999 she is deputy of Head of Research and development department. She is interested in dark fibres lines for CESNET2 and CzechLight networks and has extensive experience of wavelength and fibre procurements on national level. Since year 2000 she was responsible for transformation of CESNET2 from wavelength service to dark fibre lease.

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Modelling the Internet Price Behavior in Kenya-A System Dynamics Approach

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Abstract
This research aims to establish and model the dynamic relationships between the factors that define the behavior of Internet Pricing in Kenya.

The methodology used is based on the System Dynamics framework which is a discipline that is used to understand and solve complex problems by breaking them into three components - Events, Patterns and Structures (Kirkwood, 2010). System Dynamics holds that addressing complex problems (events) requires one to identify their behavior (pattern) and establish the underlying Structures behind these problems. Long-term solutions that address the root causes of the problem can then be proposed given that behavior is a consequence of the underlying Structures.

Using the ITU (2011) series of Internet Price data, this preliminary research builds and proposes an Internet Price Model that is driven by a goal-seeking Structure - whereby Telecommunication Operators seek to meet specific financial and operational targets within the constraints of competitive and regulatory pressures. The model presented offers Policy makers extra insights and provides policy touch-points - from where they can simulate and view the impact of various policy proposals that address the Internet Price problem.

Keywords: Decision Support, Internet Policy, Internet Price, System Dynamics
Annexe 1: List of Participants to the UbuntuNet-Connect 2011

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