Research Journal of Information Technology 5(2): 35-44, 2013
DOI:10.19026/rjit.5.5785
ISSN: 2041-3106; e-ISSN: 2041-3114

Submitted: October 30, 2012 Accepted: December 21, 2012 Published: June 01, 2013

Research Article

Development of an Infrastructure for a Research and Education Network in Ghana

[1]G.O. Ofori-Dwumfuo and [2]Grace A. Anim
[1]Methodist University College, Ghana
[2]Ghana Telecom University College, Ghana

Abstract: In order to address the global challenges of today, researchers can no longer work in isolation. They must collaborate in cost-effective ways to enable them achieve more together. This project aims at designing an infrastructure in Ghana to support a Research and Educational Network (REN) linking two local universities. Research and Educational Networks are physical high speed telecommunications networks designed to promote educational and research purposes. REN is considered an essential infrastructure for the advancement of research and education and exist in most developed countries. This paper outlines the steps undertaken to plan and implement a scalable REN for research institutions in Ghana.

Keywords: Education networks, Ghana REN design, REN, REN infrastructure, research and education networks, research networks

INTRODUCTION

Research and Educational Networks (RENs) (also called National Research and Education Networks (NREN)) are products of academic research to facilitate efficient and cost effective sharing of scarce and expensive computer resources for communication and collaboration between researchers for academic purposes (Tusubira, 2011). They are physical high-speed telecommunications networks designed to be essential infrastructures for the advancement of education and research. RENs have evolved over the last two decades, and they exist in most developed countries.

Evolution of RENs: In 1976, Norway established UNINET followed by Computer Science Network (CSNET) in 1981 and then NSFNET in 1985 in the USA. The Joint Academic Network (JANET) in the UK was established in 1984, the Swiss Education and Research Network (SWITCH) in 1987 and NORDU Net for the Nordic countries in 1988 (Corbin, 1991). In Africa, the establishment of RENs started in South Africa in 1991. This was followed by Zambia in 1994 (ZAMNET), and Mozambique in 1995 (Barry, 2011). The first regional REN in Africa was the East and Southern Africa Network (ESANET), established in 1991 (McClure, 1991).

In Ghana, the first attempt at REN was in 1995 when the University of Ghana's Balme Library connected five public university libraries and the Ghana Centre for Scientific and Industrial Research (CSIR) through the Fidonet email systems. These nodes provided access to the institutions where they stored and forwarded mail for onward transmission to London (Info Dev, 2011). Three years later, the Technical University of Denmark and the University of Ghana implemented a network infrastructure which connected to the internet backbone using satellite, and consisted of the five above-mentioned universities ring and the Balme Library network as associated networks. Other institutions in the Accra area were later connected via Wi-Fi. Due to lack of collaboration and supporting policies, however, this network has not been operational. With the increase in telecommunication companies in the country now, the national fiber optic backbone infrastructure is almost complete. The view of this paper is that the re-establishment of a REN at this point will therefore be worthwhile.

Project objectives: The main objectives of this project ((Anim *et al.*, 2010), at the Ghana Telecom University College) are to identify the infrastructural needs of a REN and their connectivity issues in some countries, review and analyze the infrastructures used in two universities in Ghana (the Ghana Telecom University College (GTUC) and the University of Ghana (UG)), identify their limitations, and finally develop an infrastructure that would be cost-effective, stable and sustainable to connect them into a national REN (Tusubira, 2009).

We believe that the study would be of importance to various stakeholders:

- The Government of Ghana (in economic development REN would serve as a platform for collaboration between researchers)

Corresponding Author: G.O. Ofori-Dwumfuo, Methodist University College, Ghana

- Educational institutions (REN would offer a platform to enhance teaching through the involvement of other lecturers worldwide via distance learning, video conferencing etc.)
- Students (REN would enable students to interact with colleagues, lecturers and researchers worldwide to broaden their scopes in their fields of study)

RESEARCH AND EDUCATIONAL NETWORKS

What RENs are for: RENs are designed to integrate many research works and teaching methodologies and drive academic co-operation (Dyer, 2009). A REN supports online collaboration by enabling simultaneous sharing and interaction of data, voice, video and other media across multiple locations, through high speed data transfer. A good REN also provides essential services such as video conferencing support, network security, advanced communication and research tools, online resources, teaching and learning to enhance national development (Ndiwalana, 2011; Fox, 2011). A major objective of a REN, therefore, is the ability to offer a forum to collaborate, innovate and share knowledge to enhance the development of research (Martin, 2006).

Services provided by RENs: RENs provide a number of services to their users, among which are the following:

- Access to a dedicated, reliable, high-speed physical telecommunications network
- Provision of affordable Internet access to participating institutions
- Provide network services and applications (such as web hosting, Domain Name Services, etc.)
- Support new and innovative ways of teaching and learning, such as distance learning, e-learning and m-learning (Balsanti, 2006; Adam, 2003; Bingimlas, 2009)
- Undertake and support advanced research
- RENs support linkages with other sectors, i.e., between the academic community, industry, government, etc
- Provision of centralized advisory services and expertise that would be too expensive for each institution to procure on its own
- Provision of services to the general public, e.g., Domain registration services

The need for RENs: The academic community usually has special needs that cannot be met by commercial internet and network providers. In particular, huge investments are required to provide the infrastructure, service and applications needed for advanced research. The academic community, being small in size compared to the private business sector and the general public, does not ordinarily have the financial means to pay for its needs. Though the community has demand for very large amounts of information and corresponding bandwidth, commercial ISPs are not strongly motivated to handle the community's needs, as mentioned above. Accordingly, many tertiary institutions worldwide have had to, independently, invest heavily in network infrastructure, and often governments have to support in order to establish such networks; a burden that most African institutions and governments are unable to afford (Haouba, 2005).

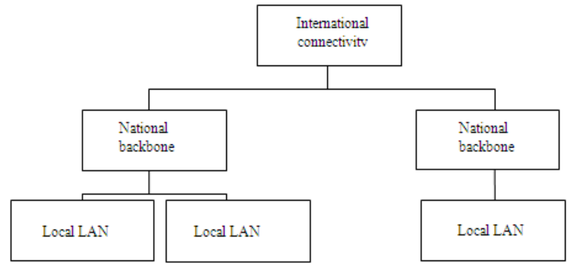

Fig. 1: Network module

Another reason that necessitated the formation of RENs is that rural learning centers were cut off and did not have the same facilities as urban centers in order to provide rural users similar opportunities in education and knowledge. The establishment of a REN is therefore, an attempt to unite institutions to put their resources together to build a better network infrastructure that can support their research and educational needs, whether they are in urban or rural areas (Twinomugisha, 2007; Dyer, 2009).

REN network components: In setting up a REN, the dimensions that are important are as shown in Fig. 1. The four main levels or geographical domains of interest are local, access (metropolitan or regional), national and international levels. Networks at various levels are usually interconnected:

- The local network called, the *campus network*, is the internal institutional network and the one closest to the end user.
- The access network is the portion between the institution and a high-speed, usually nation-wide network, i.e., the national backbone. It is also known as the *last mile*.
- The national network or national backbone is the high-speed network linking major towns and cities in a country, usually owned and operated by the nations or major telecommunications companies.
- The international network connects the national network to other national networks or to continental or international networks.
- The access and national backbone segments of the network are usually collectively referred to as the *national infrastructure*. In Africa, these segments

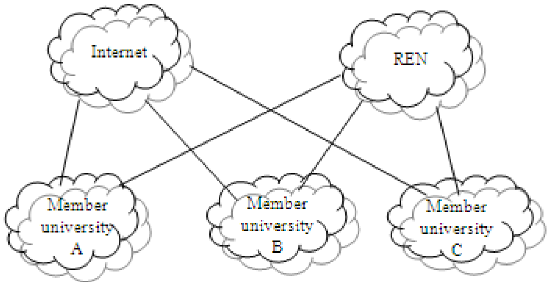

Fig. 2: REN as a peering network

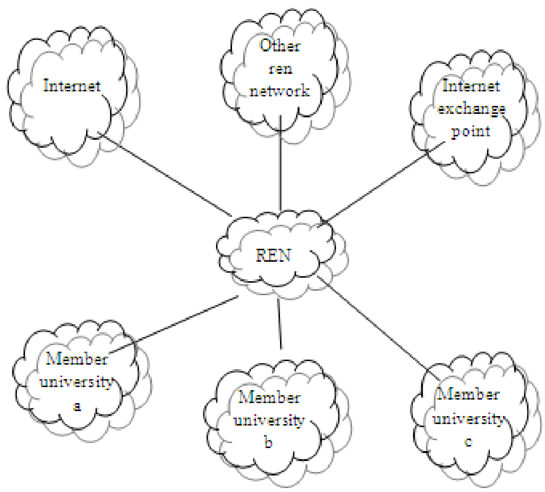

Fig. 3: REN as an ISP

are usually of low capacity, unreliable and only available in major metropolitan areas.

These layers comprise of the physical infrastructure, the logical transport and transmission system, and the services (applications). Service Level Agreements and business contracts often determine the interfaces between layers.

How RENs operate: RENs can be modeled in two ways; one as a peering network (Fig. 2) or as an Internet Service Provider (Fig. 3). *Peering* refers to the voluntary interconnection of administratively separate networks for the purpose of exchanging traffic freely between the users of each network for mutual benefit. Peering provides members with the advanced networking capabilities to reach and effectively collaborate with their colleagues around the world.

A REN may also provide internet services to its member institutions, at modest costs, without peering with a commercial service provider (Patel, 2010).

Technologies deployed in RENs: The underlying technologies that operate a REN may be considered at core and access network levels. The core network is mostly a high-speed network that supports the transport of data and operates within the physical to the network layer of the OSI model. It best employs fiber optics as the most appropriate transmission medium (Iniewski *et al*., 2009).

Access network is a packet-switching network that provides high-speed internet connectivity to homes and organizations. For REN, this is seen as the parts that connect educational institutions to the high-speed core network. The major technological platforms here include Digital Subscriber Line (DSL), Fiber to the X, Cable and Broadband Power Line and Wireless Technologies (Oaiya, 2010).

Examples of RENs: Some existing African national RENs include:

- The Moroccan Academic and Research Wide Area Network, MARWAN, is a national computer network that evolved from connecting schools in two cities in 1998, through sixteen cities to more than two hundred institutions in 2003 (MARWAN, 2011).
- CEDIA, the Research and Education Network in Ecuador, was officially created in September 2002 with a membership of 7 Universities, 2 Research Institutions and 2 Government Agencies. By August 2005 it had 24 members throughout the country (AAU, 2005).
- KENET, of Kenya, is one of the more established NRENs in sub-Saharan Africa, established in 2001, now has over 50 member institutions. All universities in Kenya have been connected since 2003. International partners of KENET include the Partnership for Higher Education in Africa, Tufts University, USAID and NSRC at the University of Oregon (AAU, 2005).
- SANREN, the South African National Research Network, started in 2006. As of September 2008, SANREN has connected three higher educational institutes and the South African Council for Scientific and Industrial Research. With further phases of the project coming on line, most of the public universities in the country are expected to be included (San, 2011).

METHODOLOGY

As stated earlier, this project is aimed at designing a network infrastructure to support REN in Ghana, starting with Ghana Telecom University College (GTUC) and the University of Ghana (UG). In this regard, we need to understand the user requirements for both universities suitable for the network. To achieve this:

Table 1: Returned questionnaires according to discipline

Student respondents	UG	GTUC
No of questionnaires sent	340	260
No of questionnaires returned	218 (64%)	208 (80%)
Humanities	52 (15%)	67 (26%)
Science	85 (25%)	91 (35%)
Business	81 (24%)	50 (19%)
Faculty respondents		
No of questionnaires sent	90	30
No of questionnaires returned	83 (92%)	30 (100%)
Humanities	28 (31%)	5 (17%)
Science	35 (39%)	20 (67%)
Business	20 (22%)	5 (17%)

- Questionnaires were sent to various stakeholders; students and faculty members.
- Interviews were conducted on heads and staff of the various IT departments on technical knowledge of the networks of both institutions.
- The authorities of both institutions were also involved (in order to determine the policies driving the needs of their respective institutions).
- Selected service providers were also interviewed on their core network infrastructure (The selection was based on the service provider's nationwide presence and use of modern technologies in service delivery.).

Questionnaires:

Student Questionnaires: Questionnaires were distributed to six hundred (600) students from both universities, structured to cover three broad areas, namely:

- **Respondent identification information:** This was to highlight the network resource needs of different student groups, ranging from the Sciences to the Humanities, Business and Arts.
- **Network applications and services:** This area entailed the network applications and services that students are currently using on their respective campuses.
- **Capacity and network infrastructure:** The third area of concern was to determine how the students perceive their current network infrastructure in their various institutions.

Faculty questionnaires: The structure of the faculty questionnaires was similar to that of the students', with slight modifications to determine their needs in relation to teaching and research work. The faculty questionnaires spanned their online behavior, collaborative behavior and network application services requirements. The distribution of questionnaires by general discipline for the two universities is given in Table 1.

Interviews:

Interviews with university authorities: Interviews with some university authorities were aimed at gathering information on the following areas; current student population, projected student population growth within 5 years, student to computer ratio per faculty, rate of introduction of new courses within the next five years and direction of teaching and learning modes. The questions were to help make projections for a REN that will serve both researchers and students even after five years. Concerns were raised by the authorities that with the current high student admissions, the present-day lecture rooms and facilities will not be able to support the numbers of students within the near future.

According to these institutions, they are planning to run some of their courses online, and as such the provision of a REN will be helpful. Since online programmers' can be shared between universities, a particular institution will not need to have all the resources required to run a particular programme; she can rely on a sister university through the use of video conference facilities for lectures and remote laboratories.

Interviews with heads and staff of I.T department: Interviews were arranged with the Heads and staff of IT departments of both universities to know the current infrastructures of their various institutions. The interviews were to gather information on existing network infrastructures, network topologies, connections to service providers and the network services offered. Questions asked ranged from knowing the current bandwidths, how they are connected to the internet and the kind of network services that are provided on their networks. The questions also included who their current internet service providers are.

Interviews with service providers: Selected service providers were also *interviewed* on their core network infrastructure. Questions were based on the service provider's nationwide presence and use of modern technologies in service delivery, the types of service they provide-whether voice and data networks, and their coverage area. Vodafone, MTN and Airtel companies were selected.

ANALYSIS OF RESULTS

Student questionnaire results: Figure 4 shows results of user response to various networking applications and services used by students in both institutions. Questions grouped under these categories were aimed at finding out how much time students spent actively using data network applications and services for their studies. Sixty percent of the students indicated that they spent about 2 h daily using the internet, with over half of them using network resources for less than half of that time. Ten percent of the students responded using internet actively for more than 4 h a day. Most of this category of students falls within the science fields of study. Expectation for services like video conferencing,

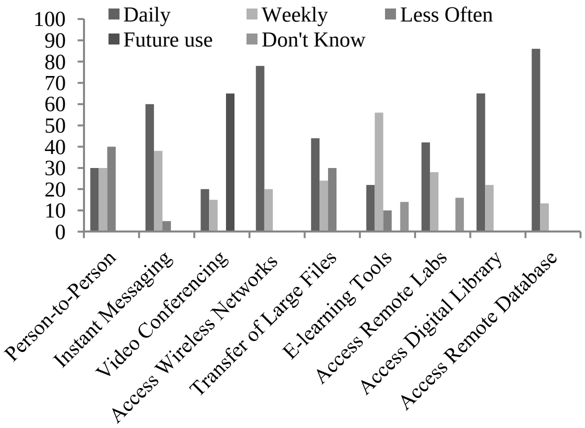

Fig. 4: Student response to networking applications and services (both institutions)

e-learning tools and access to digital content or library seems to be within the range of (70%) and above. This reflects the need for higher bandwidth capacity to support such applications and services for the institutions.

From the information gathered, students in the science fields of study (which include computer science, telecommunication engineering and medicine) tend to use the internet for their research more frequently than those in the other fields of study. In effect, institutions with science oriented programmers' will require more bandwidth as compared to non-science oriented universities, based on our analysis.

Questions grouped under network infrastructures were answered *strongly disagreed* by 68% of students from both institutions. These questions centered on areas of whether their current network infrastructures offered continuous and reliable services and if their network guaranteed any security and protection of data. From the responses gathered it is indicative that the concepts of Quality of Service (QoS), data protection and network security need to be critically considered in the design of the Ghana REN.

Faculty questionnaire results: The response of the faculty was similar to that of the students, with some additional observations. Most faculty members currently have face-to-face interaction with fellow researchers and students. Based on this, it is required that future enhancement of their network should support much video interaction. Based on this observation, the appropriate REN will need to make room for higher bandwidth that can support video conferencing and other bandwidth intensive applications.

University authorities interview results: From the university authorities, the current population of students of the Ghana Telecom University College is approximately 1600. Based on the figures within the past two years the expected projected growth within the next five years is expected to be 20%. The University of Ghana has a larger student population-about 30,000. According to approximations done within the past ten years, the student population is expected to grow at a rate of 5% within the next 5 years. From these figures, the design of a REN must take into consideration the growth rate of students and faculty of the various universities. This requirement will help design a network that is scalable and able to adapt to growth in population, and as such bandwidth demand.

IT departments interview results: The questions asked were to provide information about whether these institutions can be connected together by their current infrastructures in the design of a REN for Ghana. Information gathered revealed that GTUC has a bandwidth of 14 Mbps and UG has a bandwidth of 45 Mbps. Both universities use a fiber last mile connection to the internet, with Vodafone communications Company as their service provider.

Service provider interview results: Incidentally, both universities under study are connected by fiber interface to Vodafone. Vodafone Ghana is one of the largest service providers in the country serving voice and data networks. They currently have a core network which serves as a backbone to their operations. This consists of an optical network in a three-ringed topology, comprising a layer one network of an unlimited fiber optic cable, and a layer two of a Dense Wave Division Multiplexing (DWDM) system. The DWDM system has a capacity of sixteen wavelengths of which two are currently being used to provide a 10 Gbps core bandwidth. This connects all the regional capitals in the country to an IP/MPLS cloud sitting between layers two and three (Fiakpornu, 2011). In our study, we focus on the city of Accra since both institutions are within that coverage area.

CAMPUS NETWORK

University of Ghana: The University of Ghana currently has fiber laid to all parts of the university. The university hosts all its network services, ranging from DNS, Web server, Email services, and online library services in-house. The university operates a three-tier network, with core network router connected by fiber interface to Vodafone. Within the three-tier network is a distributed network which is made up of managed switches connected to the access network with redundancy support. The access network, which is a star topology, connects the various departments, library and other important units of the university to the core network. Wireless access points can also be found in specific locations within the university.

It was gathered that the average upload speed over a monthly period for UG is 12.79 Mbps while the download average over the same period is 37.29 Mbps. The upload can be attributed to the university community sharing some of their contents with the rest of the world via emails, YouTube, etc., while the download is representative of research and study materials, social events and entertainment.

Ghana telecom university college: The architecture of the Ghana Telecom University College network has some resemblance to that of the University of Ghana, with slight differences in the kinds of network services currently being hosted by the university. Currently, the web server of the university is hosted in the cloud, not on campus. GTUC also operates a three-tier network with the core network router interface connected by fiber to Vodafone. The access network is made up of an Ethernet twisted pair star topology network. In terms of wireless access, the university currently has a campus-wide wireless coverage made up of IEEE 802.11 b/g/n.

We also gathered that the average download traffic on a monthly basis for GTUC is 7.96 Mbps while that of the upload is 551.85 Kbps. The upload is representative of the university community sharing some of its contents with the rest of the world while the download can be attributed to research and study materials, entertainment and social events. Although GTUC downloads a lot of study materials from other universities, it utilizes a caching technology to reduce the amount of download traffic, hence utilizing its bandwidth quite efficiently.

DESIGN OF GHANA REN (GREN)

From the questionnaires, literature reviews and interviews, the core network of the national fiber optic backbone and the various last mile options it offers were considered to enable us design a stable, affordable and easily scalable research and educational network for use in GTUC and UG, and hopefully, Ghana and the sub-region. Four core areas were looked into; namely the campus network, the access network connecting the campus to the national grid, the core network of the national grid and international connectivity options.

GREN campus network: The campus network (which would be the network for each member university in the REN) is mostly made up of a TCP/IP network. This network has a layer three device (router) which connects both the ISP on the wide area network and the campus local area network. Within the local area network, an extended star topology is employed with layer two devices (switches) distributing and segmenting the network into various forms. On the wide area network, there exists a point to point connection between the ISP and the campus. A campus may decide to add additional connectivity based on its needs. From the design point of view, campus networks will be managed by the individual institutions with available help from the REN to ensure efficient use of the network.

Access network: The access network of GREN is basically controlled by the ISP and acts as a path for the campus network to communicate externally. Depending on the location and demand of the campus, fiber, microwave, or copper links could be extended from the ISPs to the campus. In Ghana, most of the ISPs currently provide data services using microwave technology, with a few using fiber. Due to reliability, speed and amount of data passing through a REN, we would consider an access network using fiber. Currently Vodafone’s network, inherited from the national fiber optic backbone, is the most scalable network using fiber and it has nodes all around the country.

Core network: The GREN core network describes how the ISP routes packets (data, voice and video) from one point of the country to the other. This setup can be done in several modes using Ethernet, microwave or fiber as the transmission medium with technologies as SDH/SONET and IP. Various multiplexing techniques (such as Time Division Multiplexing (TDM), Wave Division Multiplexing (WDM)) may be employed to achieve the bandwidth required for the core network. The national backbone currently comprises of a Dense Wave Division Multiplexing (DWDM) technology which connects all the regional capitals together with a bandwidth of ten gigabits per second (10 Gbps), and further connects the metro network for each region via a gigabit passive optical network. We would adopt this technology to design our GREN.

International connectivity: The international connectivity of GREN option deals with how the nation is able to connect to the rest of the world. Currently there are two main ways of achieving this in Ghana. One is by satellite and the other via an undersea fiber cable. Three companies currently have landed their cables on the Ghanaian shores, and two are operational (Van Percy, 2011). SAT3/WASC (Southern Africa-Western Africa Submarine Cable) is a 15,000 km high-performance fiber optic cable linking Europe with South Africa and a number of countries on the West African coastline. It provides a capacity of 130 Gb/sec (130 Gbps). Main One Cable System is a 7,000 km submarine cable which links Europe to Africa with landing points in Nigeria, Ghana and Portugal. The cable delivers high speed bandwidth of 1.92 Tb/sec. Glo1 and WACS are other sources for international connectivity yet to be activated. Although Main One currently has a bigger bandwidth, it has fewer

Table 2: Summary of data (GTUC/UG)

	UG	GTUC
Current population	29,754	1,600
Available bandwidth for institutions	45 Mbps	14 Mbps
Average utilization	39.79 Mbps	12.5 Mbps
Percentage of usage of bandwidth Intensive applications	50%	70%
Access infrastructure to institutions	Fiber	Fiber
Bandwidth intensive applications	50%	30%
Average upload bandwidth	12.79 Mbps	551.85 Kbps
Average download bandwidth	37.29 Mbps	7.96 Mbps
Internet service provider	Vodafone	Vodafone

landing sites than SAT3; hence we would adopt the SAT3 backbone for our international connectivity with Main One as backup. Undersea Cables (2011) shows the landing sites of the international connectivity of fiber companies along the shores of Africa.

GREN technical design: The technical design goals were based on scalability, resilience, affordability, reliability, manageability and performance. Based on the questionnaires and analyses, we came out with a table of requirements which would serve as a basis for the design (Table 2). UG would serve as a national node which would house the equipments for the REN due to its extensive infrastructure.

From Table 2, we deduce that we lease fiber on the core backbone of Vodafone, since currently Vodafone is using only two out of the sixteen wavelengths on their DWDM core network. This would provide a dedicated channel on which GREN would run in order to connect the two institutions and subsequent subscriptions from other universities. From the table,

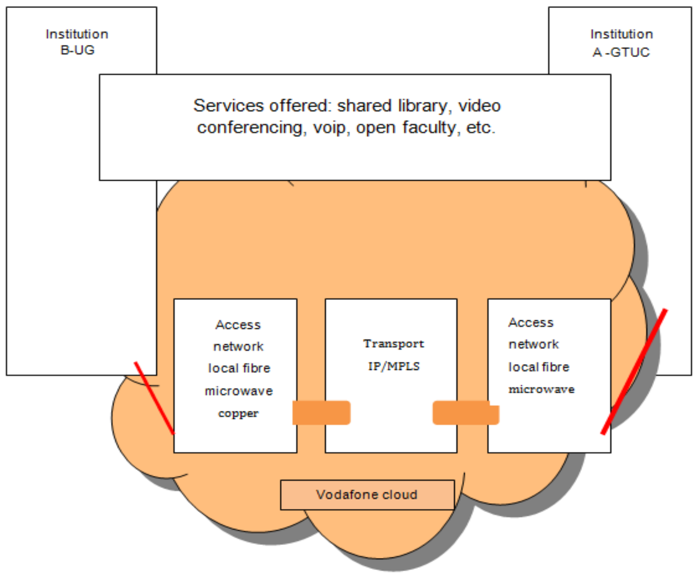

Fig. 5: Conceptual design of a REN for Ghana

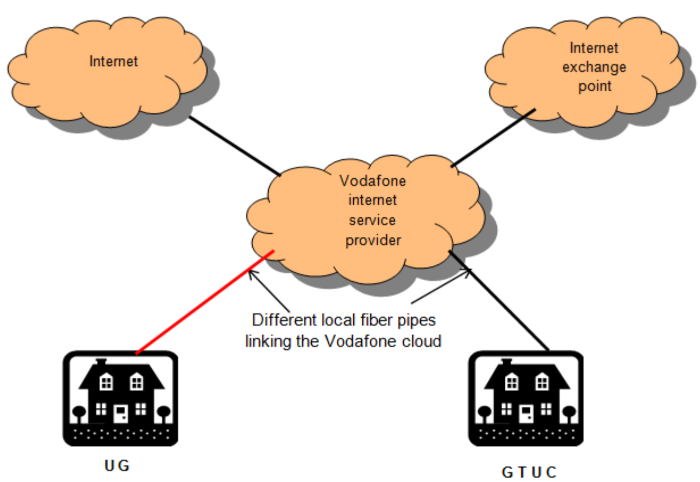

Fig. 6: Current state of connectivity from individual institutions to Vodafone

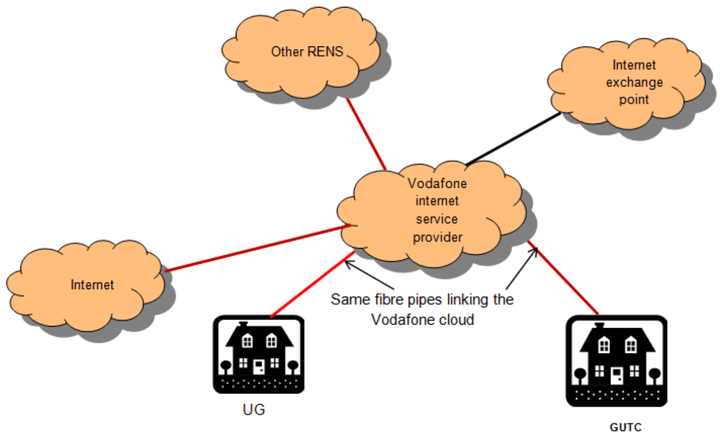

Fig. 7: Proposed design of REN for individual institutions

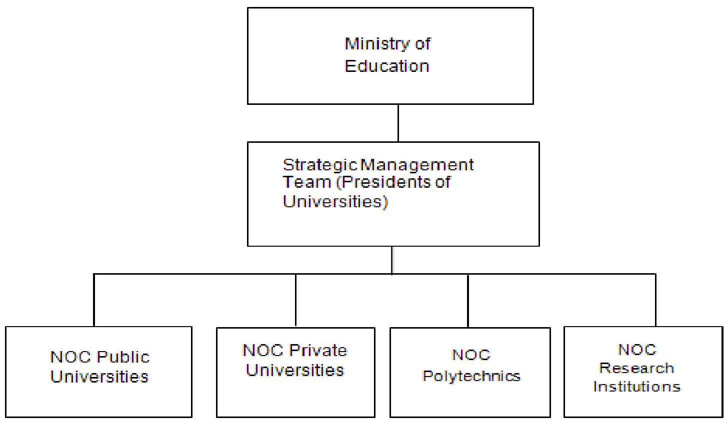

Fig. 8: REN administrative structure

we can compute the total bandwidth requirements for both institutions and conveniently lease an eight gigabit (8 Gb) pipe from Vodafone's core network to provide the infrastructure on which the two institutions would run. In our analysis, we also found that technically-focused universities have high usage needs for internet bandwidth as compared with less technically-focused universities. In this regard, for technically focused universities, we would make provision for a bandwidth to user ratio of 2 Mbps: 1.

Figure 5 is a conceptual diagram for GREN, our research and educational network for Ghana. The nodes would connect to the access network via a layer one fiber cable, although other connectivity options are available. This would in turn connect to the leased backbone on the national backbone.

The current state of each institution is as shown in Fig. 6. Each university connects to the internet via an internet service provider (Vodafone). This model limits all the traffic from the institution to be directed through the internet.

Our design makes it possible for individual institutions to route research specific queries through GREN, while general queries use the internet gateway. In using this model, individual institutions can collaborate and share resources from other universities and other research institutions ensuring a better network model (Fig. 7).

GREN organizational structure: A governing body, e.g., the existing Ghana Academic Research Network (GARNET) may be proposed for the Ghana REN. This governing body may comprise of Government organizations (such as the Ministries of Education and Communication) and heads of GREN member institutions. GARNET may be considered to have two types of membership: the ordinary membership (research and education institutions) and the sponsoring membership (any Ghanaian or foreign entity or organization). GARNET may then form its appropriate organizational sub-divisions, (which would include a management and administrative sub-structure) while guaranteeing total ownership at the campus level for all member institutions. A proposed management structure for GREN is shown in Fig. 8 (Galagan and Looijen, 2011).

A Networking Operation Center (NOC) would be headed by a network operations manager and supported by a team of IT staff from GTUC and UG. This center could be sited in GTUC since it has comparatively adequate networking infrastructure, resources and access to the national fiber-optic backbone. Total responsibility of the center would also include network monitoring, handling of network acquisitions and contracts with service providers, organizing training and workshop for member institutions as well as liaising with the respective network administrators at the local level. Both GTUC and UG would be responsible for their local area networks as well as campus-wide networks.

GREN funding: Sustenance of a national research and educational network is as important as its development. To run a network, the following two aspects play important roles; costs (expenditure) and income. Two groups of network costs can be distinguished; development costs (such as establishment and upgrades of backbone and external channels' bandwidth, equipment upgrades, innovative networking improvements, etc.) and operating costs (such as costs of connections, service, personnel, the depreciation of equipment, administrative expenses, etc.).

To cover network costs, sources of income may come from categories such as user fees, Government subsidies and donor grants. User fees usually cover operating costs. It is a periodic source of income, which usually comes monthly or annually. Government subsidies can cover both operating and development costs. Donor grants, most often, cover development costs. In this case, they will be concerned with the establishment of the network.

In our case of Ghana REN, we would advocate for a Government subsidized model where member institutions share the costs with the Government. The Ghana Government can invest in the long term aspects like infrastructure and setup while member institutions invest in the short term services involving the usage of the GREN. This hybrid solution would be beneficial to both the state and member academic institutions. To ensure sustainability, there should be collaboration between the Government bodies and member institutions, with member institutions being mainly involved in campus level management.

CONCLUSION

Research and Education Networks (REN) are important to institutions of higher learning in this era of technological advancement. The development of REN requires a well resourced networking infrastructure and the financial backing from both Government and the institutions involved. In Ghana, there have been initiatives to develop such a network to interconnect the universities and other research institutions. A major setback has been the critical analysis of the networking infrastructure that would be required to support such a network.

The project for this paper was focused on designing a network infrastructure, that will be easily accessible, stable, scalable and affordable to support research and education networks in Ghana using Ghana Telecom University College (GTUC) and the University of Ghana (UG) as initial member institutions. An overview of the network infrastructure of Ghana, as well as, an assessment of the infrastructure of GTUC and UG were analyzed. It was realized that there already exist adequate resources that could be tapped to create a REN for Ghana. The national fiber optic backbone, telecommunication networks, the SAT-3 and Globacom undersea cables, and the Main One cable, as well as campus-wide networks at various educational institutions are good candidates for this project to produce a good and sustainable REN for Ghana.

Since GREN is scalable, other tertiary institutions should be encouraged to join. There could also be collaboration with other universities in the sub-region who are already connected to SAT-3 to join and pave the way for connection to other national networks in Europe and elsewhere.

REFERENCES

AAU, 2005. African research and education network infrastructure. Proceeding of Conference on African REN Infrastructure. Tunis. Retrieved from: http://www2.aau.org/tunis/presentation/proceedings.pdf (Accessed on: October 6, 2012).

Adam, L., 2003. Information and communication technologies in higher education in Africa: Initiatives and challenges. JHEA/RESA, 1(1): 195-221.

Anim, G.A., F.A. Okai, C. Pinkrah-Sam and K.A. Aboagye, 2010. Designing an appropriate network infrastructure in Ghana to support research and educational networks using Ghana telecom university college and university of Ghana. Unpublished M.Sc. Thesis, Trimester Project Report, Ghana Telecom University College.

Balsanti, U., 2006. Challenges in preparing tomorrow's teachers to use technology: Lessons to be learned from research. Turkish Online J. Educ. Technol., 5(1): 33-36.

Barry, B., 2011. The State of Research and Education Networking in Africa. National Research and Education Networks, Retrieved from: https:// edutechdebate. org/ research- and- education- networks/ the -state-of-research-and-education- networking-in-africa/.

Bingimlas, K.A., 2009. Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. Eurasia J. Math. Sci. Technol., 5(3): 235-245.

Corbin, R.A., 1991. The development of the national research and education network. Inform. Technol. Librar., 10(3): 212-220.

Dyer, J., 2009. The Case for REN. Retrieved from: http://www.terena.org/publications/files/20090127-case-for-nrens.pdf, (Accessed on: October 4, 2012).

Fiakpornu, F., 2011. Private Communication. Active Access Network Engineer, Vodafone Ghana.

Fox, L., 2011. African NRENs can Expand Educational Opportunities across Education Sectors. National Research and Education Networks. Retrieved from: https://edutechdebate.org/ ...education.../ african-nrens-can-expand-...

Galagan, D. and M. Looijen, 2011. National research and education networks: Analysis of management issues. Ph.D. Project Working Paper, Delft University of Technology, Netherlands, Retrieved from: http://www.isoc.org/inet99/ proceedings/ 3h/3h_1.htm, (Accessed on: October 6, 2012).

Haouba, A.O., 2005. Prospects of development of the network sought and education in Mauritania (French). Proceeding of Conference on African Research and Education Networking Infrastructure. Tunis.

Info Dev, 2011. Ghana: Research and Education Network. ICT Regulation Toolkit, Retrieved from: http://www.ictregulationtoolkit.org/en/practicenote.aspx?id=1942, (Accessed on: October 4, 2012).

Iniewski, K., C. McCrosky and D. Minioli, 2008. Network Infrastructure and Architecture: Designing Highly Available Networks. John Willey and Sons Inc, Hoboken, N.J., pp: 526, ISBN: 0470253517.

Martin, D.H., 2006. Research and Education Networking in Africa. Paper Presented to iWeek 2006, Kyalami, South Africa.

MARWAN, 2011. The Moroccan Academic and Research Wide Area Network. Retrieved from: http:// www.terena.org/ activities/compendium/ 2003/MARWAN/ basicinfo.php; (http://www.marwan.ma/) (Accessed on: October 4, 2012).

McClure, C.R., 1991. The National Research and Education Network (NREN): Research and Policy Perspectives. Ablex Publishing Corporation, Norwood, NJ, ISBN: 0-89391-813-X.

Ndiwalana, A., 2011. The Role of NRENs in National Development. National Research and Education Networks. Retrieved from: https://edutechdebate.org/research-and-education-networks/ the-role-of-nrens-in-national-development/.

Oaiya, O., 2010. Connectivity and bandwidth in West and Central Africa. Paper Presented at the 2010 Euro-Africa Week on ICT Research and e-Infrastructures, Helsinki, Finland.

Patel, A., 2010. New models for NREN's and Universities in era of broadband and web 2.0 applications and innovations. Proceedings of the 3rd Ubuntu Net Alliance Annual Conference. Johannesburg, SA.

San, R., 2011. South African Research Network. Retrieved from: http://www.sanren.ac.za/, (Accessed on: October 6, 2012).

Tusubira, F.F., 2009. Creating the human and infrastructure networks research and education networks in Africa. Proceeding of the TERENA Networking Conference. Malaga.

Tusubira, F.F., 2011. How can Research and Education Networks increase African Educational Development? National Research and Education Networks. Retrieved from: https:// edutechdebate.org/research-and- education-networks/ how-can-research-and-education-net works-increase-african-educational-developm ent/.

Twinomugisha, A., 2007. Understanding NRENs and Key Considerations in establishing them. Global e-Schools and Communities Initiative, GeSCI. Retrieved from: http://www.gesci.org/old/files/National%20Research%20and%20Education%20Networks%20 in%20Africa%20-%20 Report.pdf, (Accessed on: October 4, 2012).

Undersea Cables, 2011. Landing Points of Fiber Companies. Retrieved from: http://manypossibilities.net/african-undersea-cables, (Accessed on: October 4, 2012).

Van Percy, P.A., 2011. Private Communication. Director General: National Communications Authority, Ghana.