

Evaluation of Research Education Networks in Zambia a case study: Zambia Research Education Networks (ZAMREN)

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ABSTRACT: Zambia Research Education Networks (ZAMREN) is a National Research Network (NREN) in Zambia, established on 19th September, 2007, which has its network along the line of rail, that is, from Livingstone town to Chililabombwe town, and it connects to rest of the world through 2 fibre channels at 1Gbps. The use of high performance computing (HPC) services or data intensive applications such as video conferencing is desirable and a quicker means of fostering e-learning over the internet. Sustaining such a service is, however, expensive as it requires a substantial bandwidth allocation as well as computers with adequate capacity. Therefore, knowing the capacity of the network, strategies on how to manage HPC service applications in Research Education Networks (REN)s is essential. This research was an evaluation of Research Education Network in Zambia. The research had three objectives; (i) to highlight challenges faced by ZAMREN's affiliates, (ii) identify and document current network parameters for ZAMREN, (iii) conduct a simulation in OPNET using the current parameters in (ii) to determine the point of failure while subjected to a HPC application that is video conferencing. The research instruments used were questionnaires and Opnet network simulation software. The results were that, for objective (i); Power outage was the major challenge faced by the majority of the affiliates which had 19%, followed by financial constraint and other challenges such as, fibre cuts, which had a 12% respectively, while the rest of the challenges were between 0% and 10%, Objective (ii) the channel capacity of ZAMREN was 1Gbps, and objective (iii), the network failed at 6752 users or nodes with total traffic sent 1036800 bytes/sec.

KEYWORDS: Research Education Networks (RENs), ZAMREN, High Performance Computing (HPC).

I. INTRODUCTION

In this global village, the use of Information, Communication and Technology (ICT)s, particularly, access to computers and the Internet, are innovative resources that have become recognized as vital tools for research, education and lifelong learning [19][24].

The existence of National Research and Education Networks (NREN) can be traced in the late 1960s. These early NRENs were represented by adhoc facilities, and subsequently evolved into a common set of standards of data networking operating over telephone circuitry and managed by dedicated organizations. However, the first successful network NREN was known as Advanced Research Projects Agency Network (ARPANET) and was developed in 1969. ARPANET connected government-sponsored research organisations [24]. The trend of NREN refinement continued till early 1980s when major developments were achieved in NREN and this period was probably the dawn of modern NREN [20][23][24].

Therefore, the origin of modern Research and Education Networks (RENs) is traced in the mid-1980s in Europe [6][9]. In 1984, National Science Foundation Network (NSFNET) was successfully developed as a general purpose research network and served as the backbone for the Internet followed by the adoption of X.25 protocol as a common

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connectivity platform between research and education communities, then evolved into high speed dedicated networks that integrate networking interfaces, switches, and routers and facilities running computationally intensive research and education (R&E) applications and services that are often not found on the Internet [24]. Fig.1 shows the general building blocks of connectivity of RENs.

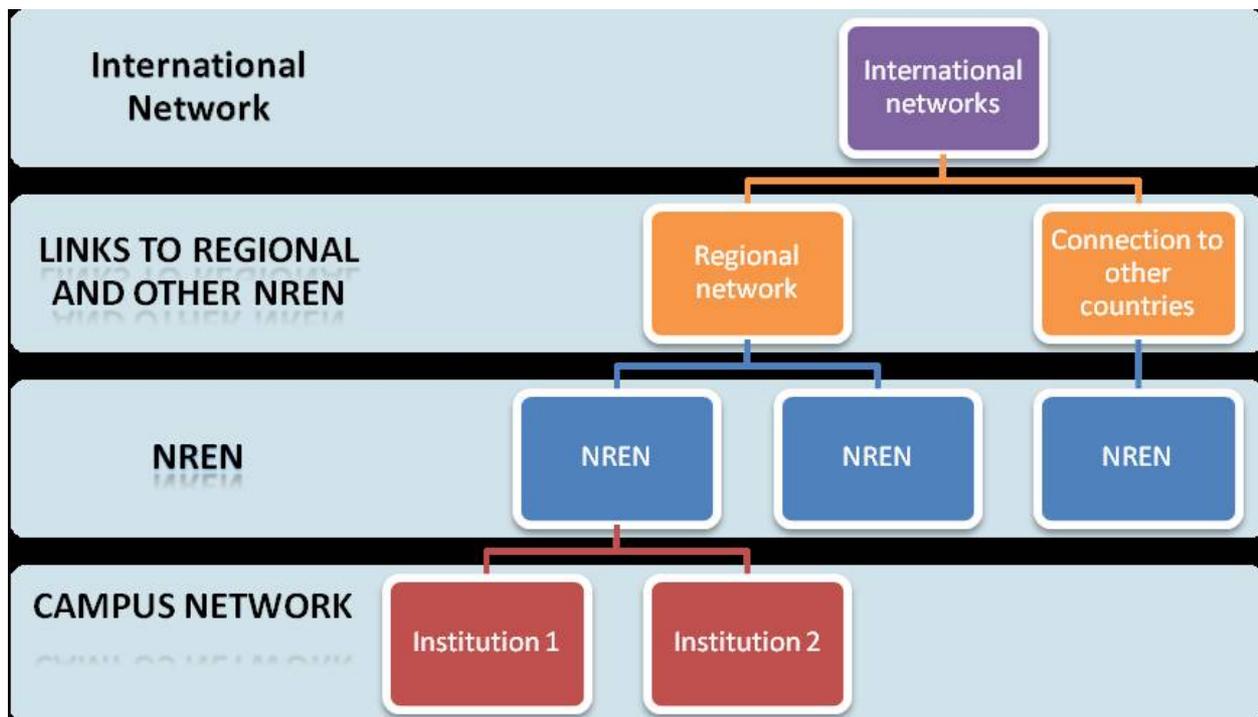


Fig. 1 Building block of REN [24]

RENs are high speed Internet Service Provider (ISPs) education networks. They provide internet services, mainly, to research and academic institutions at a very low rate than other ISPs [10]. However, their operations and services are regulated to ensure that they do not gain competitive advantage over commercial ISPs and other players in the market. Instead, RENs are set up purely for the provision of a service to education and research institutions, and to some extent to hospitals.

RENs are latest forms of enhancing and conducting education over the Internet. This type of education offered through RENs is known as electronic learning (e-learning). E-learning uses ICT facilities, that is, the REN's infrastructure or network tools [6][7]. In other words, RENs provide a platform for institutions, students and researchers to access and share information through the means of Internet.

II. BACKGROUND

As the world stands today in terms of technology advancement, education, research, science and technology are the key ingredients of sustainable social and economic development[11][23][35]. The establishment of a robust education and research society in a country cannot be overemphasized. It is key for prosperity, development, stability, and national, regional and international integration in this age where ICTs are vital in supporting research and education, and in the creation of an innovative and lifelong learning society, which has a community of abundant scholars, researchers, engineers, technicians and firms engaged in production of knowledge, goods and services. RENs are not exceptional because they are part and parcel of research community. In actual sense, RENs are regarded or viewed as

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an essential national infrastructure, 'public goods', in comparison to, for instance, roads, water, ports and energy services due to its positive implications on the society, that is, impact on the knowledge economy, general economic development and social cohesion [11][40][44].

The role of RENs is to lease, operate, maintain, support and manage a physical telecommunications network for the benefit of the education and research society. In other words, they provide national scale networks that interconnect universities and other knowledge generating institutions. Their service is based on high performance as well as national network coverage connecting academic and research institutions. RENs are regarded as vital component of modern teaching, research and learning throughout the world. For instance, about a 100 countries in the world, especially, in Europe have adopted RENs as the cornerstones of their ICT plan for tertiary education institutions and for connecting research institutes inclusive of hospitals[11][20][23].

RENs can also be described as non-commercial Internet Service Providers (ISPs) whose services are usually uncongested, high speed coupled with advanced communications capabilities [11]. RENs at national level are sometimes known as National Research Education Network (NREN). The NREN or REN provides linkage through higher networks known as Regional Research and Education Network (RREN) backbones ultimately connect internationally via high speed networks[11][40][44].

III. LITURACTURE REVIEW

EUROPE

In Europe, RENs have proved to be one of the most successful institutions which have evolved and are forging collaboration among researchers and educators both at national and regional levels, and enabling the creation of a family of inter-connected research and academic communities across Europe as well as the globe [11]. The history of RENs in European country can be traced back in the 1980s, however major improvements mostly started in 1993 with the creation of Delivery of Advanced Networking Through Europe (DANTE). In fact, Europe is the pioneer of RENs [30][35].

DANTE

DANTE was formed by consortium of European countries and provided connection to NRENs and established a research community [13]. In conjunction with the European Union (EU), DANTE provides financial support to RENs, among others, includes; Trans-European Research and Education Networking Association (TERENA), GEANT, Trans-Eurasia Information Network (TEIN) networks as well as to Latin America, Middle East and African countries. However, in the last five years its focus has been on the African RENs. This has been driven by availability of undersea cable in the eastern and western coast Africa [30][35].

GÉANT

GÉANT is the pan-European research and education network which provides interconnecting to Europe's National Research and Education Networks (NRENs). GÉANT connects over 50 million users at 10,000 institutions across Europe. Its operational speeds are up to 500Gbps. It is the most advanced research network in the world [6]. It facilitates collaborative research in various ranges of disciplines, including high-energy physics, radio astronomy, biomedicine, climate change, earth observation and arts and culture the network connectivity and service provision in most GÉANT partner countries, is now 10Gbps, although some NRENs have reached 20Gbps and even 40Gbps. This is has been as the result of backbone dark optical fibre connection. The optical fibre is able to handle high capacities with increased capacity and economically viable mode of transmission [14][6].

GÉANT began as a project Nov. 2000 and became a full production in December 2001 and subsequently replaced a network called TEN-155, in Apr. 2005. This project was completed in 2005. In 2004, another second project was initiated known as GEANT2.

GÉANT2 is the high-bandwidth, academic Internet serving Europe's research and education community connecting over 30 million researchers with a multi-domain topology spanning 34 European countries and links to a number of

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other world regions and is at the heart of global research networking. GÉANT2 is co-funded by the European Commission and Europe's national research and education networks, and is managed by DANTE. GEANT2 was set up as a project and has since to a completion [62]. GEANT2 was completed in 2009.

The next GÉANT project (GN3) began on 1 April 2009 and continued until April 2013. GÉANT3 is the pan-European data network dedicated to the research and education community. Together with Europe's national research networks, GÉANT connects 40 million users in over 8,000 institutions across 40 countries.

In general, the GÉANT as evolved through projects and has grown during its iterations (GN1, GN2, GN3, GN3plus and now GN4-1) to incorporate not just the award-winning 500Gbps pan-European network, but also a catalogue of advanced, user-focused services, and a successful programme of innovation that is pushing the boundaries of networking technology to deliver real impact to over 50 million users [62][64].

Trans-European Research and Education Networking Association

TERENA compendium was established 10 years ago and has grown, become an authentic reference point for researchers and organisations that are interested in the development of research and education network. The Trans-European Research and Education Networking Association (TERENA) was formed as a non-profit association of European national research and education networks (NRENS) incorporated in Amsterdam, The Netherlands. The association was originally formed on 13th June 1986 as Réseaux Associés pour la Recherche Européenne (RARE) and changed its name to TERENA in October 1994. In October 2015, it again changed its name to GÉANT and at the same time acquired the shares of GEANT Limited (previously known as DANTE). The objectives of TERENA are to promote and develop high-quality international network infrastructures to support European research and education. The objectives were, among others; investigating, evaluating and deploying new network, middleware and application technologies, supporting new networking services where appropriate, knowledge transfer, advising governments and other authorities on networking issues and liaising with networking organisations in other parts of the world.

In the recent years, several NRENS in Europe have innovatively changed and evolved their business models and service offerings. The emphasis now is on international collaborations. The innovation is the development and deployment of new Authentication and Authorisation Infrastructures (AAI) and use of Dark fibre [14]. Quick spread of dark fibre connection in Europe is probably being stimulated by both technological and price advantages [24].

ASIA

Trans-Eurasia Information Network

Trans-Eurasia Information Network (TEIN) was the initiative between Asian countries and France to enhance Research and educations. In October, 2000 it transformed to TEIN2 to include European countries. TEIN2 it is the first largest scale research and education network for Asian pacific countries at high speed of up to 1Gbps. It is composed of nine countries, namely, Korea, China, Singapore, Philipppians, Vietnam, Indonesia, Japan, Thailand and Malaysia. Tein2 also connects to Australia and Europe via two connection, Copeghan and frunkurt. Currently, the link between TEIN2 and GEANT2 support up to 60,000,000 users across Asian and Europeans countries. The presence of TEIN2 has brought out transformation in education and research, real-time and international research as well as bridging the digital divide [18]. TEIN2 has involved to higher level known as third generation (TEIN3) and its horizon spectrum is broadened and itscoverage is 19 Asian pacific countries. [11][18].

Afghanistan Research Education Network

Afghanistan Research Education Network(AfgREN) is a NREN which is found in Afghanistan. It provide internet connections to universities, researchers, students, lecturers and research institutions in Afghanistan nation, region and to rest of the world [24]. The AfgREN utilises HPC applications, in particular, video conferencing for online distance teaching purposes. For instance,video conferencing was conducted between Kabul based universities, with good facilities and expert professors and provincial universities mainly new,with poor facilities and suffering from the lack of professors. This facility provided an opportunity for expert professors from Kabul to teach in Afghan provincial universities via a AFgREN and the challenge was and still sufficiently addressed through use of video conferences. In

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addition, video conference is still being used in Afghanistan for the official weekly meeting of minister of higher education with the chancellors of public universities which ultimately has reduced on travel expenses as well as on time [24].

AFRICA

The role of NREN in developing countries cannot be emphasized, especially in Africa and particularly Zambia. They are significant because they provide internet connection to educational and research institutions worldwide [20][35]. Conversely, commercial Internet Service Provider (ISP)s are not viable and sustainable for research institutions, researchers and students because their internet services provision in terms of bandwidth is narrower and connection cost is higher than NRENs. Usually, commercial ISPs network provision is in Megabyte per second (Mbps) whilst the NREN's is gigabytes. NREN can offer higher capacity that is "Gbps" and yet at lower cost of connectivity [20].

African Southern Mediterrean Arab Research Education Network

African Southern Mediterrean Arab Research Education Network (ASREN) is the regional network which serves seven countries in the southern mediterranean Arab region, namely; Algeria, Egypt, Jordan, Morocco, Palestine, Syria and Tunisia. The network provides high capacity and high quality Internet connectivity for use by the research and education communities connected to the NRENs in the beneficiary partners, and connected to the European user communities via links to GEANT network in Europe [24].

West and Central African Research and Education Network

West and Central African Research and Education Network (WACREN) is a regional REN for Western and Central Africa countries[22][23]. It was established to provide, among others, includes; world class network infrastructure, develop state of the art services, promote collaboration among national, regional, international research and education communities and build the capacity of the REN community. In terms of legality, WACREN exists as a corporate body with its own legal personality distinct from that of its members and office bearers. It own assets and incur liabilities like any other corporate organization and notwithstanding the ability to sue or be sued when need arises. In order to sufficiently meet its objectives, Some of WACREN functions includes; Maintain communication and collaboration platforms in at least French and English, establish international focus groups to undertake research on matters of significance to the scientific, social and economic development of Africa, and negotiate and secure rights in the name of its members with no authority to undertake obligations or liabilities in their name, unless so instructed by an explicit authorization from the members concerned [22][23].

UbuntuNet Alliance

UbuntuNet Alliance was formed in the year 2005 as a regional body Providing connectivity to research and education community in Eastern and Southern Africa through NRENs good [9][19][58]. The role of UbuntuNet Alliance is to work with NRENs in the region as well as enhancing the network capacity and resilience of the broadband research and education backbone network. It also thrives to provide the interconnection to other networks in the world via its gateways. The Alliance is also mandated to for push for conducive policy and regulatory environments in the region which promotes the growth and development exploitation of research and education networking in the region. It also leads a way in setting up NRENS where they are non-existence in member countries as well as promoting communities of practice and applications that exploit the opportunities of high speed regional and global connectivity [58].

ZAMBIA

Zambia Research Education Network

ZAMREN is non-profit NREN in Zambia which was registered as an association on 19th September, 2007 in Zambia under the registrar of societies Act 119 of laws of the Zambia. In other words, it is an association for tertiary level research and education institutions collectively with intentions of the following:

- i. Secure cost effective broadband connectivity.
- ii. Share their education resources via dedicated infrastructure.

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- iii. Provide Advanced ICT services to its member institutions in a closed user group.
- iv. To network with regional and international partners to promote and enhance best practices in RENs.

IV. SCOPE AND SIGNIFICANCE OF RESEARCH

Scope

The main purpose of the study was to evaluate ZAMREN network so as to determine whether or not its current network setting parameters can support HPC applications which are important in the enhancements of e-learning, particularly in Zambia. In order to achieve this purpose, an appropriate sample population of this study was selected and the sample population was ZAMREN network as well as all its 56 affiliates. A sample was useful in providing meaningful conclusions drawn from the entire population. A combined approach of sampling techniques, that is, cluster and simple random sampling was used in order to produce accurate results in accordance with literature review [1][65][68][69][71]. ZAMREN it does not have yet its own structure or building rather its offices and core installations are at the University of Zambia under the school of Education. Participating affiliates were predominantly found in urban towns and along the line.

Significance

The findings of this study are significant for decisions making purpose to stakeholders, inter alia; ZAMREN, ZAMREN affiliates, Ministry of Higher Education (MOGE) and Ministry of General Education (MOGE). The findings are also a contribution to the body of knowledge.

Limitation

In essence, limitations are matters and occurrences which arise in the study which are beyond the control of the research and each research study has own peculiar limitation. The limitations of this study, included; financial constraints, questionnaire respondents delay and time.

V. METHODOLOGY AND DISCUSSION

The study employed a mixed method approach for collecting and analysing data. This was so because any method used on its own had limitation and biasness would not be minimised. A mixed method approach is cut across of both quantitative and qualitative approach. The qualitative approach catered for both objective (i) and (ii) of the research. It was used to record and analyse questionnaire responses. The questionnaires were distributed to ZAMREN affiliates and their responses were transcribed into a spreadsheet application, Microsoft-excel (MS-excel). Furthermore, qualitative approach was used in objective (ii) and a thoroughly document review of ZAMREN was conducted in order to establish its current network settings parameters. The approach was used in objective (iii) quantitative. The justification for this approach is that quantitative catered for the simulation component of the research which was empirical.

The simulation was conducted using a network simulator known as OPNET 14.5 simulator. ZAMREN bandwidth was simulated to ascertain its point of failure while subjected to video conferencing which is a HPC application. Two simulations or scenarios were performed. In the first simulation, the settings were that: video conferencing was set to normal and the total number of users or nodes was 56. The first was primarily used as a benchmark purposes and the assumption was that video conferencing application was not used at all. However, the amount of data sent over the network was observed and recorded.

The second simulation was configured with the heavy video conferencing application, total number of users was maintained at 56 and the network did not fail. The number of users was gradually incremented until the point of network failure. The amount data sent was also observed and recorded by the researcher. A comparison simulation between the two scenarios was conducted also in order to derive the difference and for analysis and interpretation purposes.

The data or results from the simulations was analysed and charts created using the same software. Additionally, data was exported from OPNET software to Microsoft Excel 2007 (Ms-excel) for ease data analysis, interpretation as well as for better charts creation or publishing. During the quantitative stage, the researcher acted role of an observer and did not interfere in the study in order to conform to scientific research decorum [1].

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In addition, the researcher used the qualitative component for description purposes. The description was based on the results of the quantitative. The description was a detailed explanation which endeavoured to carefully analyse the gathered data, verify possible behavioural patterns and to properly explain the phenomena of the study. The procedures used in this research are explicitly described so as to enhance credibility, rigor and solidity of the research.

VI. RESULTS

Objective I: ZAMREN Affiliates Challenges

Fig. 1 shows the results of for objective (i).The findings were that most ZAMREN affiliates were faced by a challenge of power outage. Power outage had the highest percentage of 19% and it followedby 12%forboth financial and other challenges which included fibre cuts.

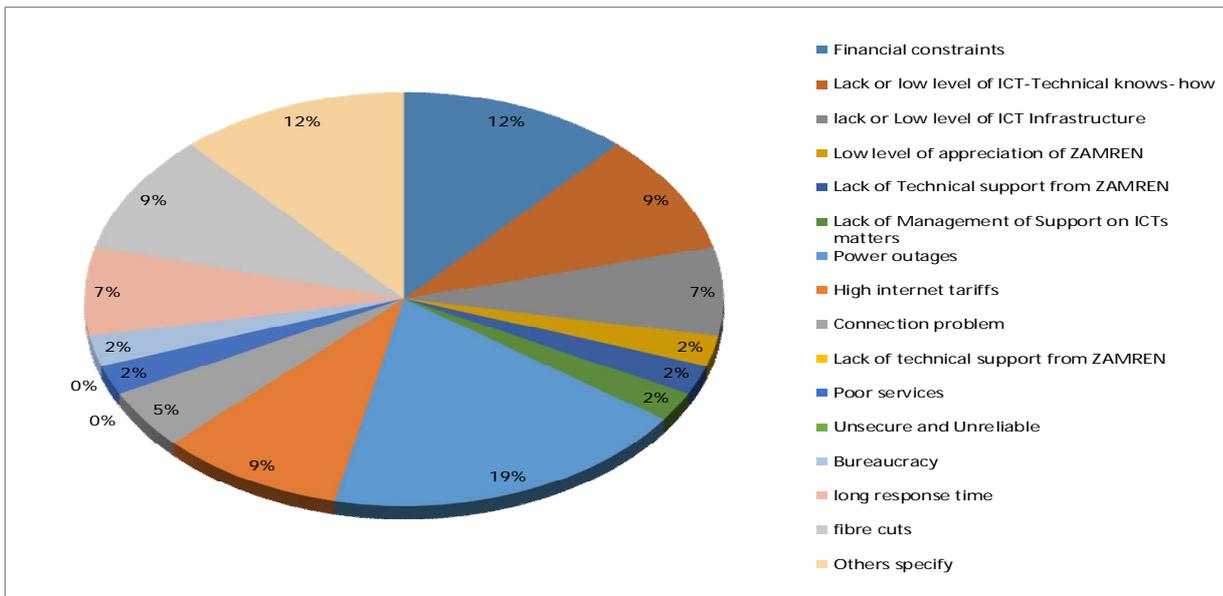


Fig. 2ZAMREN affiliates challenges

However, the remaining challenges which included; lack or low level of ICT technical knows-how, high internet tariffs, bureaucracy, lack of management support on ICTs matters and poor service had low percentage below 12%.

In order to facilitate clear presentation, publishing and interpretation of results, the above challenges in fig. 1 was caterogised into four, namely; technical, administrative support, operations and training and other challenges. Both fig.2and table 1 shows information related to the decomposition or categorised challenges.

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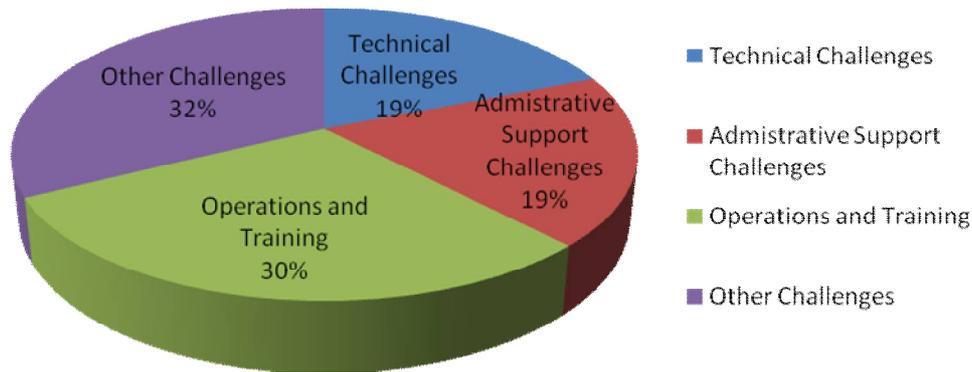


Fig. 3: Categorized affiliates challenges

Table 1.Categorized affiliates challenges

	Category	Score	Perc.(%)
1	Technical Challenges		
	Lack of Technical support from ZAMREN	0	-
	lack or Low level of ICT Infrastructure	3	8
	Lack or low level of ICT-Technical knows- how	4	11
	Technical Challenges	7	19
2	Administrative Support Challenges		-
	Financial constraints	5	14
	Bureaucracy	1	3
	Lack of Management of Support on ICTs matters	1	3
	Administrative Support Challenges	7	19
3	Operations & Training Challenges		
	High internet tariffs	4	11
	Connection problem	2	5
	Poor services	1	3
	Unsecure and Unreliable	0	-
	long response time	3	8
	Low level of appreciation of ZAMREN	1	3
	Operations & Training Challenges	11	30
4	Other Challenges		
	Fiber cuts	4	11
	Power Outages	8	22
	Other Challenges	12	32
	Grand Total	37	100

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Objective II: ZAMREN Network Parameters

A thorough document review conducted revealed insightful information which relates to the network setting parameters of ZAMREN and table 1 shows a summary of this information.

Table 2 Existing network settings parameters of ZAMREN

External Links Capacity	1 Gbps
Internal links	50 Mbps
No. of affiliates	56
Highest link capacity	1Gbps
No. Point of presence(pop)	7
National Operation Centre	1
High Performance Computer	1
No. of International links	2
No. of Redundancy links	1

The maximum link capacity of ZAMREN is 1Gbps of backbone fibre channel. The other parameters are; 7 point of presence (PoP), 1 HPC, 1 redundancy link and 2 international links

Objective III: Simulation - scenario 1(Normal video conferencing)

This simulation had the following configurations: Video Conferencing set to normal, number of users was 56 users or nodes, total data traffic sent was 345600 bytes/sec, duration time was 3564 seconds and bandwidth utilisation was at 0.276 %. Table 2 shows a summary of information about pertaining this simulation. This simulation was used as benchmark and the assumption that the video conferencing was not active.

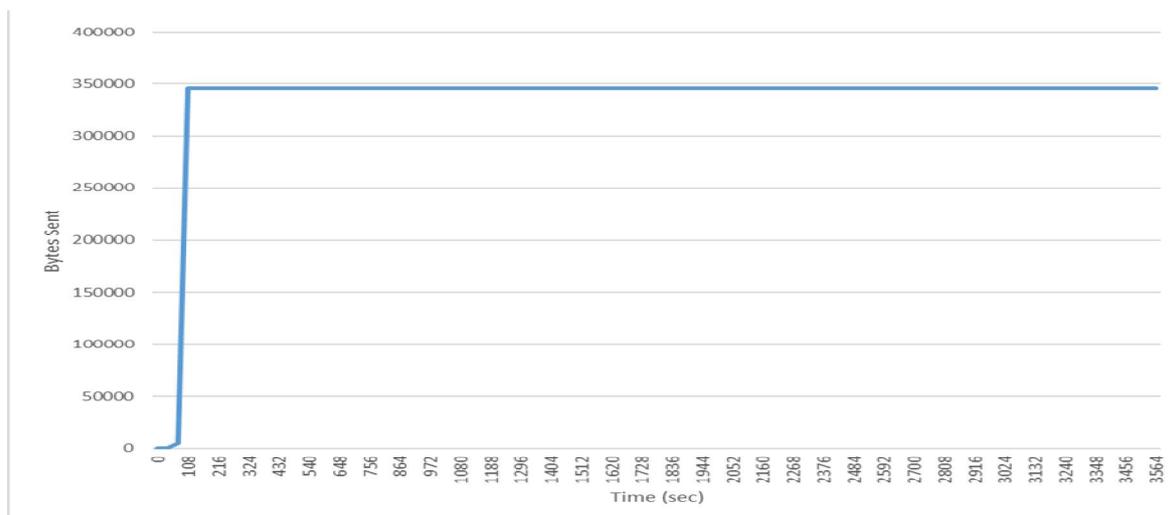


Fig. 4: Simulation - scenario 1(Normal video conferencing)

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Table 3: Summary of Simulation- Scenario 1

Total Traffic Sent (bytes/sec)	345600
Avg Traffic Sent(Bytes/Sec)	6171.43
Total bandwidth Utilisation(%)	0.27648
No. Users	56

Objective III: Simulation scenario 2 –Heavy Video Conference

Under this simulation the following configuration: Video Conferencing set to Heavy I, number of users was maintained at 56 users or nodes, total data traffic sent was 1036800 bytes/sec, duration time was maintained 3564 seconds and bandwidth utilisation was at 0.8294%. Table 3 shows a summary of information about pertaining Heavy video conference simulation.

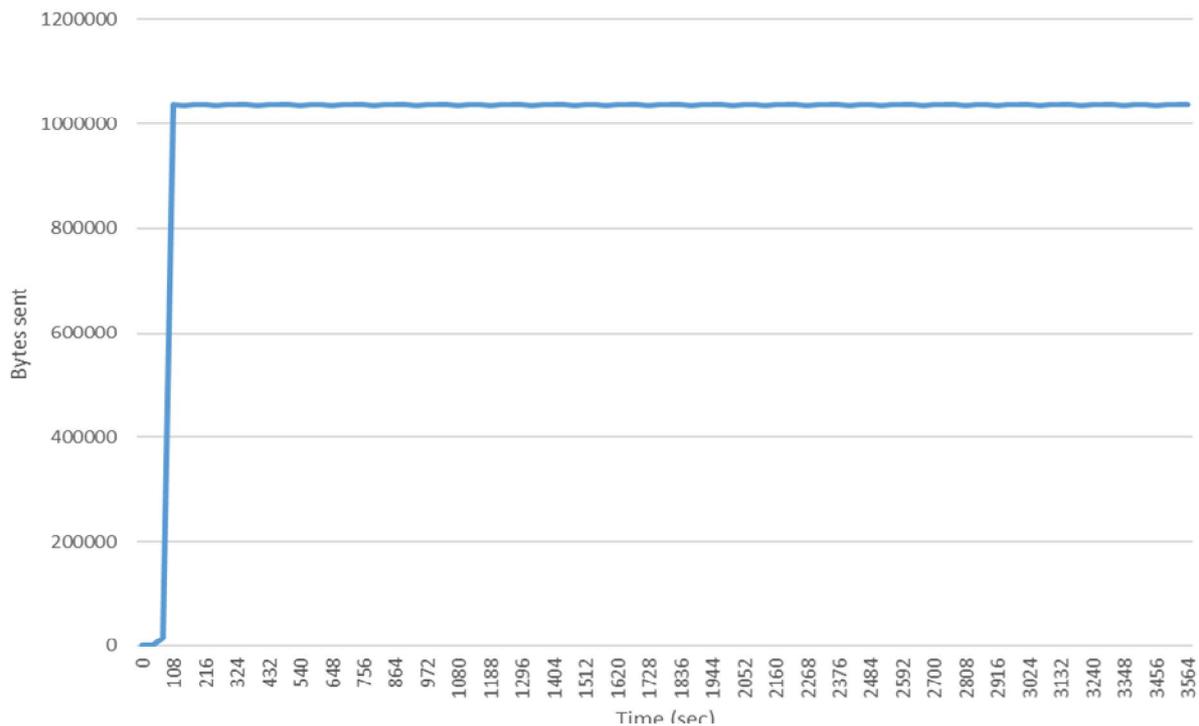


Fig. 5Simulation - scenario 2 (Heavy video conferencing)

Table 4Summary ofSimulation - scenario 2

Total Traffic Sent (bytes/sec)	1036800
Avg Traffic Sent(Bytes/Sec)	18514.29
Total bandwidth Utilisation(%)	0.82944
No. Users	56

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ObjectiveIII: Comparison - Scenario 1 and 2

Fig. 4 is comparison of scenario 1 and 2. Scenario 2 represents Heavy video while scenario 1 normal video conferencing. It can be noted 691200 bytes/sec is the difference between the 2 scenarios. Duration time and number of users are same for both scenarios and are shown summary table. 6

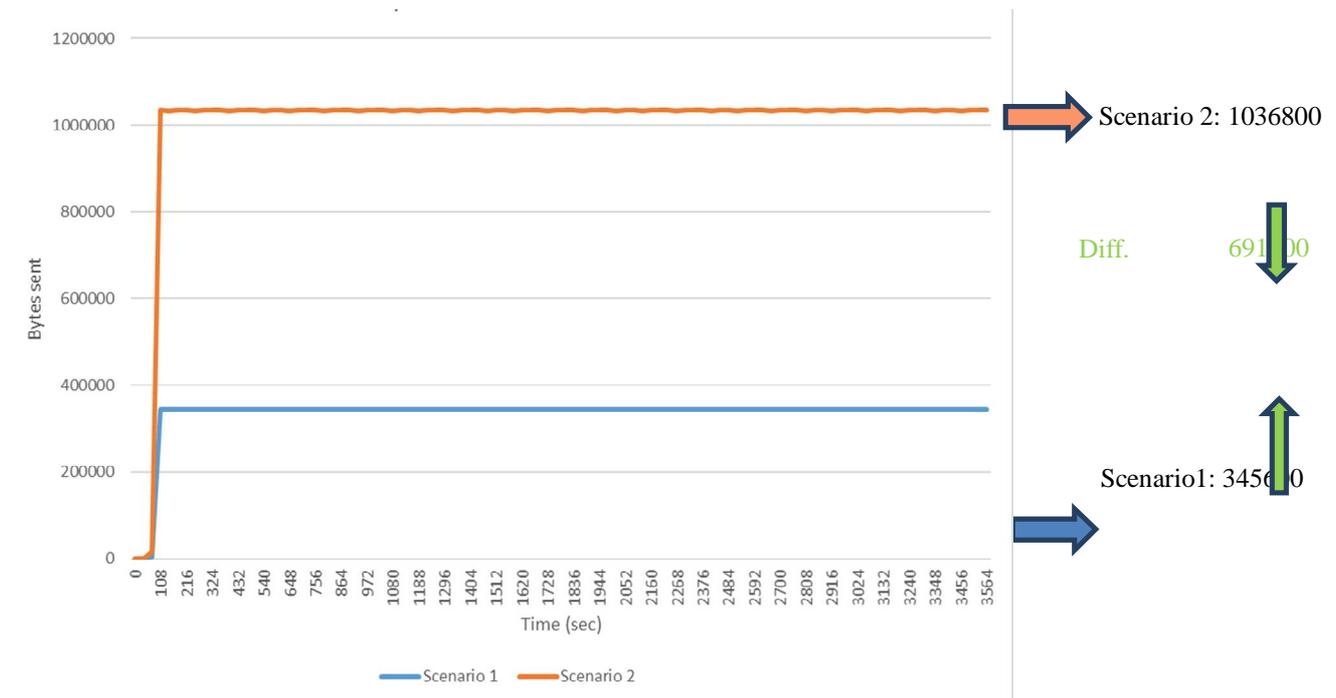


Fig.6Comparison of scenario 1 and 2

Table.5Summary of comparison between scenario 1 and 2

Total Traffic Sent (bytes/sec)	345600	1036800
Avg Traffic Sent(Bytes/Sec)	6171	18514
No. Users	56	56

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Objective III: Point of failure

Fig. 6 depicts the point of failure for ZAMREN while subjected to Video conferencing. It can be noted that the network failed precisely with 6752 users or nodes concurrently using video conferencing. During the entire simulation process, ZAMREN channel capacity remained constant but the number of users was gradually incremented until the point of failure.

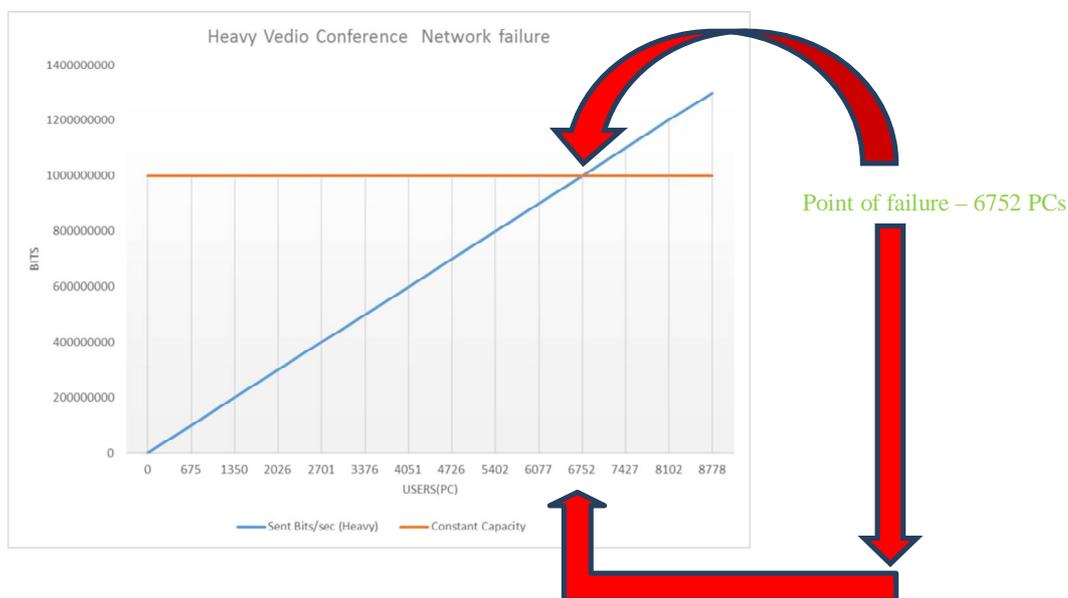


Fig. 9 Point of Failure ZAMREN

VII. CONCLUSION

Generally, it was noted that ZAMREN as NREN in Zambia it is providing affordable rates of internet services to both private and public learning institutions as well as research organisations. For instance, affiliates, researchers and students are using non-HPC applications to download and upload text documents via ZAMREN network quickly and affordably. ZAMREN also provides capacity building to its affiliates in forms such as seminars and workshops. Additionally, it is a key participant in ICTs initiatives, innovations, programmes and projects both locally and regionally. For instance, ZAMREN is a stakeholder in last mile fibre project spearheaded ZICTA. It is a Government of Zambia project undertaking of laying a backbone fibre country wide in a bid to make internet connectivity easily available and affordable to the citizen in turn spur development through ICT. Therefore, it can be described as a vital ICT tool in Zambia which fosters, enhances and promotes education over the internet.

However, in spite of these positive achievements or activities, in line with research objectives, it was also noted that: (a) Most affiliates faced a challenge of power outage followed by both financial and other challenges (fibercuts); (b) Maximum current channel capacity of ZAMREN was 1Gbps and (c) Point of failure for ZAMREN network was at 6752 users. Therefore, it was concluded that ZAMREN network capacity can support HPC applications, in particular, video conferencing and may continue using 1Gbps channel for a while, however, immediate plans should be put in place soon to scale up the channel capacity. The rationale is that affiliates are already using non HPC application which is consuming certain amount of the capacity yet this was not accounted in this research. Therefore, the assumption is that if is taken into account the failing rate point will be reduced. The other justification for network scaling up is that ZAMREN literature review revealed that is gradually spreading or expanding its network catchment to rural urban. This means that there will also be gradual increase on the number of users accessing the ZAMREN network and

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demand for the bandwidth. Following our simulation, an increase in the number of user has correlation on the bandwidth consumption of the network and point of failure. This same principle is also true for the expansion of ZAMREN. Lastly, RENs literature revealed that RENs, particularly, in America, Asia and Europe are operating above 5Gbps as such ZAMREN still has gap and needs to scale up its capacity cope up with other RENs in the world.

Affiliates were re-grouped into four categories, namely, Technical, Administrative Support, Operation and Training and other challenges. Other challenges predominantly composed of power outage and fibre cuts had 32% which correlated to the earlier findings. Operational and Training followed with 30% while the remaining two each had 19 %.

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