UNITED REPUBLIC OF TANZANIA

TANZANIA COMMUNICATIONS REGULATORY AUTHORITY
(ISO 9001:2008 CERTIFIED)

REPORT ON

STUDY ON THE IMPACT OF INTERNET EXCHANGE POINTS DEPLOYMENT IN TANZANIA

APRIL 2014 ***Issued by: TCRA***

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ACKNOWLEDGEMENTS

Despite the fact that TCRA has been providing facilities on the ground to make internet communication in the country more affordable through deployment of distributed Internet Exchange Points (IXPs) in Tanzania, there was no clearly established data pertaining to the impact of the internet exchange points since their deployment in Tanzania.

It's from this point of view the Authority through the department of ICT decided to carry out a study in order to evaluate the importance of IXPs on the socio-economic development and establish the impact of Internet exchange points (IXPs) in the country since their establishment. The study was carried out by a team composed of officers from both TCRA and TISPA.

An assignment like this could not have been accomplished without help of others, whom the study team would like to publicly acknowledge here.

***Firstly,** the study team Members is indebted to the Director General of TCRA Professor John S. Nkoma for his initiative to form, finance and trust in this team to carry out such an important study. Similarly, the TCRA Management on her side owes appreciation and is grateful to all individuals who were able to travel within the country and beyond for the purpose of facts finding and situational observations.*

***Secondly,** the team without reservations wishes to express her recognition and gratitude to the Managements of Tanzania Internet Exchange Point (TIX), Arusha Internet Exchange Point (AIXP), Rwanda Internet Exchange Point (RINEX), Uganda Internet Exchange Point (UIXP) and Kenya Internet Exchange Point (KIXP) for their support and acceptance to meet them and also to release their officers to join the team at any point of time during this study.*

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***Finally,** the Study team wishes to express love and gratitude to their beloved families; for their understanding and endless love, throughout the duration of the study. Similarly, the team appreciates the time accorded by various Working Sub-committees including the Report Writing Sub-committee Members for their invaluable commitment, time and constructive ideas in the course of preparing this report.*

As a result of the above, the report offers conclusions which the team believes will be of particular relevance to Government, Regulators across the East African region and beyond. The team also recognizes that the study such as this may provoke many questions and proposals for areas of future study which the team or others may wish to further explore or address.

LIST OF ACRONYMS AND ABBREVIATIONS

AfriNIC	-	African Network Information Center
AIXP	-	Arusha Internet Exchange Point
AUC	-	African Union Commission
AXIS	-	African Internet Exchange System
BOT	-	Bank of Tanzania
CDNs	-	Content Delivery Networks
COSTECH	-	Tanzania Commission for Science and Technology
DCIA	-	Directorate of Consumers and Industry Affairs
DDID	-	Deputy Director ICT Development
DICT	-	Directorate of Information and Communication Technology
DIXP	-	Dodoma Internet Exchange Point
EACO	-	East Africa Communications Organization
EAIXP	-	East Africa Internet Exchange Point
EARPTO	-	East African Regulatory, Posts and Telecommunications Organizations
EGA	-	E-Government Agency
EU	-	European Union
ICT	-	Information and Communication Technology
IP	-	Internet Protocol
ISP	-	Internet Service Provider
ITU	-	International Telecommunications Union
IXPs	-	Internet Exchange Points
KIXP	-	Kenya Internet Exchange Point
MOU	-	Memorandum of Understanding
NPCA	-	NEPAD Planning and Coordination Agency
PoPs	-	Point of Presence
QoS	-	Quality of Service
RINEX	-	Rwanda Internet Exchange
RTT	-	Round Time Trip
SADC	-	Southern Africa Development Community
SPSS	-	Statistical Package for the Social Sciences
TCRA	-	Tanzania Communications Regulatory Authority
TISPA	-	Tanzania Service Providers Association
TIX	-	Tanzania Internet Exchange
TPA	-	Tanzania Ports Authority
TRA	-	Tanzania Revenue Authority
TTCL	-	Tanzania Telecommunications Company Limited
TzNIC	-	Tanzania Network Information Center
UCC	-	University Computing Centre
UDSM	-	University of Dar Es Salaam
UIXP	-	Uganda Internet Exchange Point
USD	-	United States of America Dollar
VoIP	-	Voice over Internet Protocol
ZCU	-	Zonal Coordination Unit
ZM-N	-	Zonal Manager-Northern Zone
ZM-S	-	Zonal Manager-Southern Highlands Zone

EXECUTIVE SUMMARY

The Internet is the "network of networks." It is not a centralized, organized system, but instead a mass of independently operated businesses which carry data from one point to another by exchanging it at their borders. These borders can be simple and bilateral, or they can be rich meeting-points where many networks come to exchange data.

Most bilateral exchanges are private, between a smaller party and a larger one, and require a payment from the smaller party to the larger one in association with the exchange. Most exchanges, which occur at public multilateral meeting-points, on the other hand, are between equals or "peers," and are "settlement-free," that is, they require no payment.

Public Internet exchange facilities, generally called "peering points" or "Internet exchanges," have allowed the growth of the commercial Internet as a business enterprise. Prior to the existence of Internet exchanges, there was a single "backbone" operated by the United States government, which interconnected all of the other networks, which formed the Internet.

The favourable IXPs set-up is through Internet traffic routing using a transiting IXP if the aim is to further reduce down the cost of using international circuits and bandwidth. However this is confronted by various challenges including multiple contracts/Agreements signed between individual local ISPs and foreign bandwidth providers with varying terms, periods, charges and capacities.

TCRA has been providing facilities on the ground to make internet communication in the country more affordable. This has been done through deployment of distributed Internet Exchange Points (IXPs). It's through the objective of deploying IXPs' TCRA needed to establish the impact on the economic development of this country. However, there was no clearly established impact assessment data pertaining to internet exchange points in Tanzania since their deployment.

It's from this point of view the Authority through the department of ICT decided to carry out a study in order to evaluate the importance of IXPs on the socio-economic development and establish the impact of Internet exchange points (IXPs) in Tanzania since their establishment. The study was carried out between mid-February 2014 and March 2014 by a team composed of officers from both TCRA and TISPA.

The charts and tables in this report use data collected through three questionnaires distributed to two Internet Exchange Point managers and 29 peers at respective IXPs in Tanzania as well as a further East African region three respondents from Uganda, Rwanda and Kenya.

This report is organized into four chapters. Chapter one contains the introduction which gives genesis of the IXPs, the problem statement,

the purpose of the study and specific objectives, scope and the expected outcome of the study. Chapter two presents the regional IXPs implementation initiatives at East Africa and Africa levels. Chapter three discusses the study methodology, design, data collection methods, data population and analysis. Chapter four elaborates on the study findings. Chapter five presents the conclusions and recommendations.

The key findings of the study were the following:

i. On whether the speed of internet in accessing a local content after the introduction of IXPs have improved or not; the response were such that 60% said the speed was excellent and 20% said the speed was Very good.

   Further statistical tests revealed that the Quality Index before introduction of IXPs was 1.50 and after introduction of IXPs was 4.75 indicating significant improvement in quality level. This implies that the speed in accessing local content has improved after the introduction of IXPs as compared to when there was no IXPs.

ii. On rating of latency of reaching a local website after the introduction of IXP was that: 60% said the latency was very low and 20% said the latency was low.

   Further statistical tests reveals that Quality Index before introduction of IXPs was 1.25 indicating the latency was high and after introduction of IXPs is 4.75 indicating minimum latency and hence improvement in quality level.

   The result therefore shows that the latency in accessing local website has reduced after the introduction of IXPs as compared to when there were no IXPs.

iii. On rating the status of data packet losses after the introduction of IXP were as follows; 60% said the losses were very low and 20% said the losses were low.

   Further statistical tests revealed that Quality Index before introduction of IXPs was 2.25 and after introduction of IXPs is 4.75 improvement in quality level.

   The results in general indicate that the packets losses in reaching a local website have reduced after the introduction of IXPs as compared to when there were no IXPs.

iv. On rating the reliability of data and internet services after the introduction of IXP were as follows; 20% said data reliability was very high, 60% said high and 20% said moderate.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.00 and after introduction of IXPs was 3.50 indicating some improvement in quality level.

The result indicates that the reliability of data and internet services in accessing a local content has improved after the introduction of IXPs as compared to when there were no IXPs.

v. On rating the cost of internet/data access charges incurred after the introduction of IXP were as follows; 60% said were moderate while 40% said charges were high.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.50 and after introduction of IXPs is 3.50 indicating improvement in quality level. This result is significant hence concluding that the cost incurred by peers on internet and data access charges have been reduced after the introduction of IXPs as compared to when there was no IXPs.

vi. On rating the cost incurred on international internet bandwidth whether have decreased after the introduction of IXP were as follows; 20% strongly agreed, 25% agreed while 35% disagree and 20% could were not aware.

Further statistical test revealed Quality Index of 3.4 indicating good quality. This result is significant concluding that the cost incurred by peers on international internet bandwidth has reduced after the introduction IXPs as compared to when there was no IXPs; and probably will improve further with an increase of local content within the country as more traffic will be destined locally.

vii. On whether the introduction of IXP has helped to reduce the cost incurred on internet monthly access charges were as follows; 40% agreed, 20% strongly agreed while 40% disagree.

Further statistical tests reveal that Quality Index after introduction of IXPs was 4.25 indicating good quality levels. This result is significant concluding that there is reduction of cost incurred by peers on the internet monthly access charges after the introduction of IXPs as compared to when there was no IXPs.

viii. On rating the link utilization to IXP was as follows; 25% said that utilization was high, 45% said utilization was moderate,

25% said utilization was low while 5% said the utilization was very low.

Further statistical tests revealed Quality Index of 3.00 indicating some improvement in link utilization. This improvement is significant hrnce concluding that the introduction of IXPs has helped localize the local traffic and this will keep on increasing depending on the availability of local content.

ix. The traffic exchanged at the IXPs kept on increasing since the establishment of the IXPs. For the case of peers the results shows that the utilization of their links to the IXPs kept on increasing as well since they joined the IXPs. These results conclude that the introduction of IXPs has helped to localize the local traffic and this will keep on increasing depending on the availability of local content.

x. The result from tables 4.42, 4.43 and the figure 4.24 On rating whether local content hosting in the country has increased after the introduction of IXP the results were that; 80% strongly agreed that local content hosting has increased.

Further statistical tests reveal that Quality Index before introduction of IXPs was 1.25 and after introduction of IXPs was 3.00 indicating improvement in quality level. This improvement is significant hence concluding that the introduction of IXPs has positive impact in content hosting as more content is being hosted locally after the introduction of IXPs as compared to when there was no IXPs.

xi. On rating whether e-services activities increased after the introduction of IXP the results were that; 80% strongly agreed that e-services have increased.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.00 and after introduction of IXPs was 3.50 indicating improvement in quality level. This improvement is significant hrnce concluding that the introduction of IXPs has positive impact on e-services.

xii. Reduction of Latency to K-root when it was introduced has reduced with a local instance at TIX.

xiii. For increased traffic growth at IXP's, both consumer (“eyeball”) networks and content providers have to be connected, so that traffic – which is mainly between these two kinds of operators – can flow over the IXP. The presence of content networks has still to be increased.

xiv. TIX is connected with Arusha IXP (AIXP) and Dodoma IXP (DIXP) within Tanzania. But other participants in the other Tanzanian regions are connected through national providers who are connected to TIX, and thus packets flows stay local within Tanzania. Latencies are dependent on the transmission media and distance between source and destinations, and since "tromboning" (inefficient routing through other locations) is avoided, latencies are as good as physically possible. Currently TIX is not connected to any Internet Exchange Point outside the country.

xv. At the time of this writing bandwidth pricing from carriers to ISP's can be valued at around USD 100 per Mbps per month; TIX traffic is reaching 100Mbps. Thus a monthly saving of USD 10,000 is achieved.

While one year ago the traffic at TIX was less than now, international bandwidth pricing was higher, approximately resulting in the same value of USD 10,000 of monthly savings to the industry.

xvi. Online transactions have been attracted by the introduction of TIX in Tanzania, for example:-

- for any inter-bank settlement exceeding 5 million needs to pass through the Bank of Tanzania using the Tanzania Inter-banking Settlement System (TISS).

- TISCAN operated an Imports clearing system, tied to Databases in Dar Es Salaam and Switzerland, which was available at TIX and saw very good traffic. This was handed over to TRA.

- Tanzania Revenue Authority (TRA) have automated all revenue systems paving a way for fully online transactions for almost all the payments related to government revenue collections through TRA.

- Tanzania Ports Authority (TPA) has established a TIX connection; we expect this to be used for new online facilities used to clear customs goods in collaboration with TRA.

xvii. The effect of deployment of IXP was also realized in AIXP where the latency in reaching a local website after the introduction of IXP has dropped from around 600ms to 5ms and packet losses have also significantly dropped.

xviii. For the case of AIXP on its own the annual savings is around 4,000 USD but when connected to TIX the saving is around

2,000 USD per month as compared to when the same traffic was being routed using the international circuits.

xix. The amount of traffic passing the Uganda IXP (UIXP) does steadily increase and this is due to increase of locally hosted services, increased Internet penetration and additional peers connect over time.

xx. UIXP is connected to other IXPs in Eat Africa, for example to Kenyan Internet Exchange Point (KIXP) via ISP transit links. This in turn has significant reduction of latency and packet loss for example to Kenyan services.

xxi. At UIXP the average traffic exchanged per year is around 240 Mbps taking into account the price of 1 Mbps being 225 USD, the total annual saving realized is (240Mbps*$225/Mbps)*12 = 648,000 USD in comparison if the same traffic was to be routed over the international circuits.

xxii. For the case of Rwanda (RINEX), before the latency was between 1200–1600ms and up to 2000ms during congestion. But after the introduction of RINEX the latency dropped to an average of 2.2ms in reaching a local website with no losses.

xxiii. The amount of traffic passing at the RINEX does steadily increase with time and now they have Google cache.

xxiv. At the average the annual saving Rwanda was said to be around 98,843 USD in comparison if the same traffic was to be routed over the international circuits. The calculation is based on the cheapest provider and it might be a little bit higher taking into account other providers.

xxv. For the case of Kenya, before the latency was very high but it has reduced significantly after the introduction of the Kenya IXP (KIXP). Packets losses have dropped as well.

On the basis of the above Study findings the following recommendations for the development of IXPs were made and need to be addressed as appropriate:-

i. More investments in redundant power infrastructures at IXP will ensure the stability of operations;

ii. As a local traffic increases the need for peers to maintain connectivity with IXPs will be essential hence encourage more Content Delivery Network (CDNs) to be connected to IXPs;

iii. Issues of content, we need more content hosted locally inside Tanzania. Some current content providers connected to TIX

(EGA) and additional (international) content networks to start a presence with connection to TIX;

iv. The IXPs should employ permanent staff for efficient operations;

v. Potential peers should be encouraged and educated the importance of IXPs;

vi. IXPs have taken an initiative to bring Google cache to Tanzania and in the similar way more CDNs should be hosted in Tanzania;

vii. More members should be encouraged so that the backhaul cost can be shared;

viii. Interconnecting capacities between IXPs should be efficiently used for local traffic only necessary technical controls should be deployed;

ix. Awareness on the Electronic and Postal Communications (Access, Co-location and Infrastructure sharing) regulations, 2011 requirements should be emphasized and need enforcement; and

x. For cost effective and faster Internet traffic exchanges, some of the available capacities within the public Broadband networks need to be offered by owners to facilitate direct/dedicated connectivity between the deployed IXPs

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CHAPTER ONE

1.0 INTRODUCTION

1.1 The Internet and Internet exchange points (IXPs)

Internet has become an essential tool for communication, commerce, and development in an increasingly globalized world. As the Internet usage increases globally and being part of the day to day activities in different organizations and individual users, the interconnection between Internet Service Providers (ISPs), content providers and users become more and more critical to creating the 'network of networks' that is the Internet. Governments around the world have given high priority to the development of their national Internet infrastructures to achieve higher levels of Internet penetration among their populations. IXPs activities have been supported and catalyzed by national and international stakeholders, including local Internet service provider's information technology businesses and non-profit organizations that believe that the Internet can contribute substantially to the socio-economic development around the world.

Due to this development of internet usage a need to establish facilities like Internet exchange points (IXPs) arose, where all Internet players can interconnect directly to each other and exchange local traffic, reducing international transit costs while improving network performance and quality of service (QoS). An Internet exchange point (IXP) is a facility of Internet infrastructure that can increase the affordability and quality of the Internet for local communities. IXPs enable local networks to efficiently exchange information at a common point within a country rather than needing to exchange local Internet traffic overseas. In many of the developing countries, for example, Internet messages need to be exchanged beyond their borders, which add significant costs because of lack of connectivity between domestic networks.

IXPs have already played a key role in the development of an advanced Internet ecosystem across North America, Europe and Asia. Today, the number of IXPs is increasing in Africa, despite the region's more-challenging economic and telecoms environment. Early in the Internet development cycle in most countries, ISPs considered as cost-effective to use their international Internet connections to exchange domestic traffic.

Tanzania and East Africa as a whole, as far as the internet is concerned are not islands; the Internet industry in Tanzania has experienced an exponential growth in the last five years. Internet services have been available since 1995 but there was no fiber connectivity available to the Internet backbone till 2009. Till then, the connectivity was over Satellite networks to the rest of the world, even to the neighboring countries. The SEACOM and EASSY fiber projects implemented in 2009 and 2010 respectively brought internet connectivity to Tanzania at lower latency and lower cost.

Inadequate interconnection between ISPs and IXPs in Tanzania and the East Africa region has often resulted in the routing of local traffic over expensive international links to reach destinations within Tanzania and the East African region. This leads to capital increase as communication providers have to incur costs for international circuits outside Tanzania and East Africa. The industry has expanded and changed rapidly given advances in technology and growth of Internet usage resulting in a need to establish IXPs in Tanzania and East Africa in order to localize the internet traffic.

Tanzania Internet Exchange (TIX) point started operations under management of Tanzania Internet Service Providers Association (TISPA) in October 2003 with three peers with an objective to keep local traffic local. The establishment of TIX was followed by the deployment of Arusha Internet Exchange (AIXP) point in 2007. This will be followed by establishment of Dodoma, Mbeya and Zanzibar internet exchange points which are currently in different stages.

TCRA on exercising her mandate of being responsible to regulate the communication sector needs to have a good knowledge and understanding of the developments, performance and impact of the IXPs in Tanzania and East Africa region. On that regard therefore, the Department of Information and Communication Technology (DICT) decided to embark on the study of the impacts of internet exchange points in Tanzania since its establishment in 2003 and 2007 for TIX and AIXP respectively. For benchmarking purposes the study also involved Kenya Internet Exchange Point (KIXP), Uganda Internet Exchange Point (UIXP) and Rwanda Internet Exchange Point (RINEX).

The information from the study will be used by the Authority to better understand the industry by analyzing the market and assessing the industry performance, operating characteristics and trends. Furthermore, the information will be used by other users involved in research and policy making and by government to develop national and regional economic policies.

1.2 Problem Statement

There was no clearly established impact assessment data pertaining to internet exchange points in Tanzania since their deployment. It's from this point of view the Authority through the department of ICT decided to carry out a study in order to evaluate the importance of IXPs on the socio-economic development.

1.3 Purpose of the Study

The main purpose of the study was to establish the impact of Internet exchange points (IXPs) in Tanzania since their establishment. As one of its functions and obligation, the TCRA is required to carry out systematic studies on communication sector and get informed on the state of the development taking place in the communication sector in the country. TCRA has been providing facilities on the ground to make internet communication in the country more affordable. This has been done through deployment of distributed Internet Exchange Points (IXPs). It's through the objective of deploying IXPs' TCRA needed to establish the impact on the economic development of this country.

1.4 Specific Objectives

More specifically the study aimed at fulfilling the following specific objectives;

- Establishing if there is improvement on the quality of internet/data services within Tanzania including network reliability, latency and packet losses.
- Determining if there is reduction in internet and data access charges
- Determining if there is increase in local traffic exchange
- Determining if there is increased content hosting within the region due to improved regional access speeds
- Establishing if there is increased e-service activities.

1.5 Scope of the study

The study covered areas with internet exchange points especially Dar es Salaam Internet Exchange (TIX) and Arusha Internet Exchange Point (AIXP) for the case of Tanzania and Kenya Internet Exchange Point (KIXP), Uganda Internet Exchange Point (UIXP) and Rwanda Internet Exchange Point (RINEX) for the case of East Africa taking into account these are the locations with IXPs and active peers as per Annex I and II.

1.6 Expected output of the study

The findings from the study are expected to provide key data to understand the impact of IXPs in Tanzania. The study will come up with the information on the following:

- If there is improvement on the quality of internet/data services in Tanzania, including network reliability, latency and packet losses.
- Whether there is a reduction of access charges on data and internet services; status in local traffic exchange
- If there is increase in content hosting within Tanzania due to improved access speeds
- Trends on e-services activities

The findings from the study will help TCRA to know the benefits of IXP and their impacts in the social economic development. It was a right time for the Authority to fulfill this obligation by collecting such crucial information which will be relevant to investors, government, researchers and policy makers and the public.

1.7 Conceptual Framework Model

As per specific objective above there are benefits associated with the implementation of internet exchange points in Tanzania and East Africa. There was a need of variable identification which guided this study, this include Independent and Dependent variables. The main factor is the effect of internet exchange points on internet and data services in terms of quality of service, reliability, latency, packet losses, access charges, content hosting, e-services and traffic localization.

The implementation of IXP when done properly in one way or another can lead to better internet and data services in terms of quality of service, reliability, latency, packet losses, , access

charges, , content hosting, e-services and traffic localization which are the main goals and are called dependent variables. Internet exchange point is the independent variable which can affect the dependent variables.

The suggested conceptual framework model for the study of the impact of IXPs in Tanzania and East Africa for better internet and data services is as indicated below. This model formed the basis of collecting and analyzing the data. It shows the casual relationship between independent variable (internet exchange point) and dependent variables (quality of service, reliability, latency, packet losses, access charges, content hosting, e-services and traffic localization).

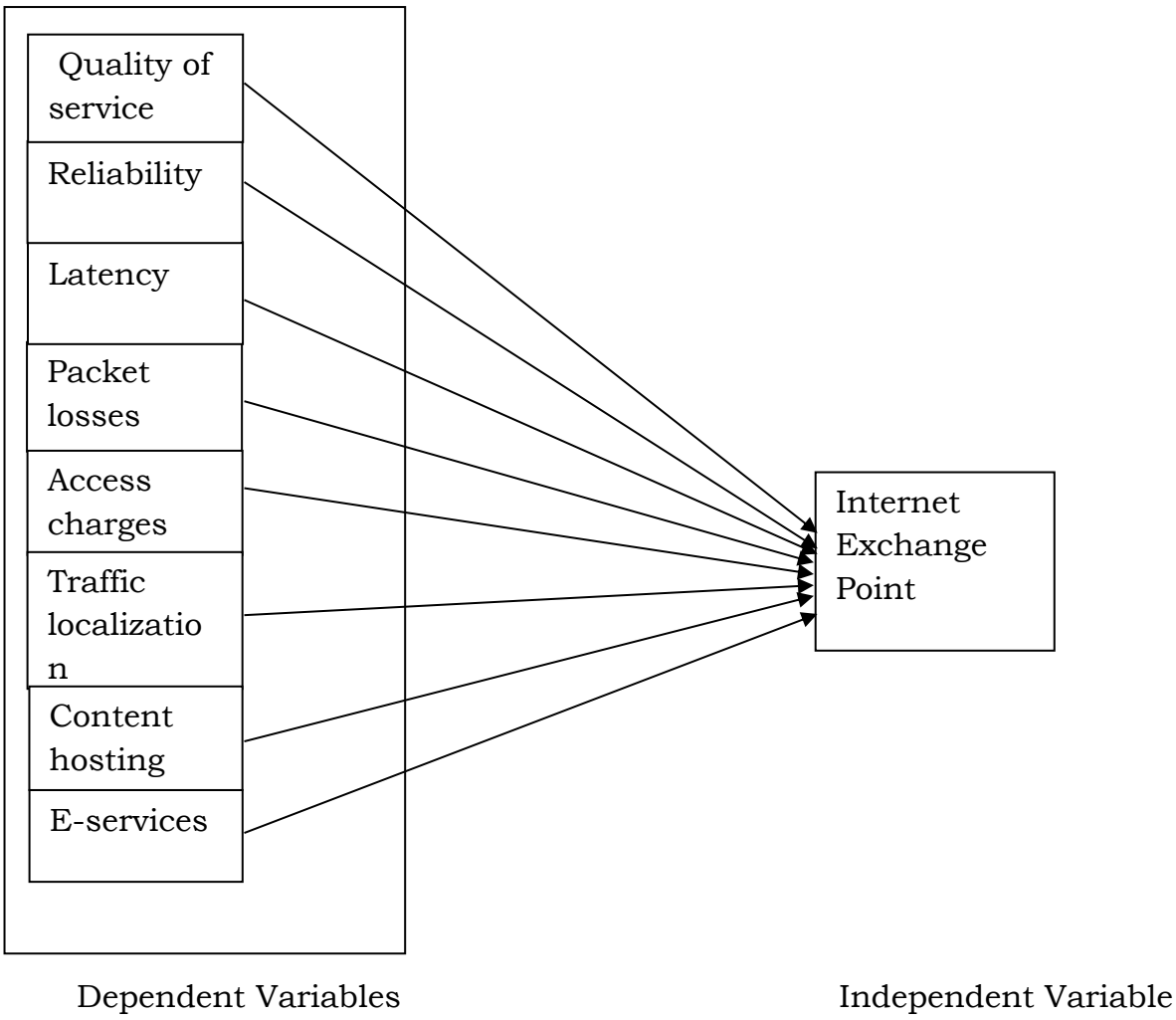


Figure 1 Conceptual framework model

CHAPTER TWO

2.0 REGIONAL IXPs INITIATIVES

2.1 East Africa Internet Exchange Point (EAIXP) Initiatives on Implementation of IXPs

The meeting of the Assembly of Regulators of the East African Communications Organisation (EACO) formerly The East African Regulatory, Posts and Telecommunications Organization's (EARPTO) in 2005 formed a task force to be coordinated Kenya to work on possible ways of interconnecting all Internet Exchange Points (IXPs) installed in their countries. The objective was to keep regional traffic local within East Africa.

In April 2007 the Congress awarded the EAIXP tender to the Simbanet (T) Limited of Tanzania to implement the EAIXP project. However, Simbanet was unable to implement the project due to several challenges including unwillingness by ISPs to participate at the trial phase. To that effect the EACO Congress in May 2010 required the EACO Taskforce on the EAIXP to consider alternative ways of implementing the EAIXP project. The members of the task force from the five East African countries met from 1st to 3rd November 2011 and from 25th to 26th May 2012 to deliberate on the various options as well as requirements of interconnecting IXPs of the respective EACO countries. The task force also considered the developments in the Africa region in respect of implementation of the region's Internet Exchange Point (AXIS).

Also from 15th to 17th April 2013, EACO organized an ICT Conference titled 'Broadband Access to all in East Africa' which was held in Kampala, Uganda. Among other issues the conference discussed issues related IXPs in which it was noted that Internet Exchange Points (IXPs) are critical in supporting Broadband Access within EACO member states. Apart from that it was also learnt that Internet Exchange Points (IXPs) if appropriately deployed can save huge amount of outflows on foreign finances within EACO member states. Lastly the ICT conference recommended that:-

i. The Regulatory Authorities within EACO Membership should facilitate the establishment of IXPs in their respective countries, so as to keep local traffic local to the countries;

ii. For cost effective and faster Internet traffic exchanges, some of the available capacities within the public Broadband networks need to be offered by owners to facilitate direct/dedicated connectivity between the deployed IXPs;

iii. The Regulatory Authorities within EACO Membership should facilitate establishment of an East African Internet Exchange Point (EAIXP) to keep the region's Internet traffic local to the Region.

2.1.1 EAIXP implementation

In their meeting the Task Force agreed that the Regulators should facilitate the implementation of IXPs in their respective countries and that in the case of more than one operating IXP in a country, the situation would be to have regulatory requirement that would require all IXPs to connect to each other. The respective countries IXPs shall interconnect to form the EAIXP. The national regulators should consider various ways of ensuring national Internet traffic stays local as well as to have in place policies to enforce connectivity for the respective service providers to their national IXPs.

2.1.2 EAIXP Topology

The Task Force agreed that to start with a Ring Network Topology as shown in figure 2 will be used in linking all participating IXPs of the respective EACO countries which in later stages will evolve into a mesh topology. This was considered as the best compromise given the technical, operational, commercial and political considerations. The choice of the IXPs to interconnect to form the EAIXP should be based on the distance and efficiency. In achieving the connectivity the national IXPs should lease bandwidth/links from the Network Provider(s) to interconnect with the neighbouring national IXPs. It was further noted that, the scope of the EAIXP may probably change over time as technology and regulations evolve.

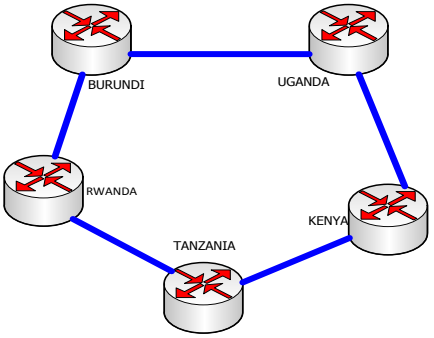


Figure 2

As the connectivity will involve cross border the national regulators were required to facilitate cross border interconnection of telecommunication infrastructures that will allow interconnectivity for the EAIXP. The neighbouring national IXPs which are to be interconnected shall coordinate with each other the technical modalities of interconnectivity.

2.1.3 EAIXP Connectivity Cost

The Task Force agreed that the cost of interconnecting the IXPs between two countries be facilitated by the respective Regulatory Authorities while the cost of operating the links between the IXPs should be catered for by the members of the interconnecting IXPs. In order to attract membership it was agreed that the location of the IXPs' should be neutral and management structures should be transparent as much as possible. The local traffic within the East Africa region should be looked at as legal traffic originating and terminating in East Africa, and that capacity will depend on aggregate traffic requirements (demand-driven).

2.2 International Telecommunication Union (ITU) initiatives on EAIXP

The importance of implementing IXPs does not end at the regional level but also is seen at the international level. In recognizing the effort of EACO in implementing the EAIXP, in 2013 International Telecommunications Union (ITU) gave assistance to EACO by hiring a consultant who jointly with EACO Secretariat visited four countries namely Uganda (21/22 Oct 2013), Kenya (5/6 Nov 2013), Rwanda (7/8 Nov 2013) and Tanzania (18/19 Nov 2013) just to carry out a study on how EAIXP can be realized in a phased approach. From 10th to 11th December, 2013 EACO organized a stakeholder's workshop which

discussed the consultant report on the EAIXP implementation and came up with the action plan which is currently under the implementation.

2.3 African Union initiatives on IXPs

The importance of implementing IXPs is also recognized by the African Union (AU) in which AU established African Internet Exchange System (AXIS) Project with the aim of keeping Africa's internet traffic local by providing capacity building & technical assistance to facilitate the establishment of Internet Exchange Points and Regional Internet Exchange Points in Africa. The African Union Heads of State and Government met in Addis Ababa from the 29th to 30th January 2012 and adopted the AUC 2012 Budget, and for the first time included the AXIS budget. Furthermore the African Union Commission (AUC) signed an agreement with the Lead Financier (Luxembourg Development Agency) for the implementation of the African Internet Exchange System (AXIS) project funded by the European Union (EU)-Africa Infrastructure Trust Fund and the Government of Luxembourg. The AXIS project by the AUC includes:

i. Deployment of Internet Exchange Points (IXPs) in countries without IXPs;

ii. Deployment of Regional IXPs (Hubs).

To facilitate this initiative the Steering Committee for the implementation of the AXIS Project was formed under the coordination of the AUC, and constitutes the following representatives:

i. African Union Commission (AUC)

ii. NEPAD Planning and Coordination Agency (NPCA)

iii. European Union (EU)

iv. Luxembourg Agency for Development Cooperation

v. Southern Africa Development Community (SADC)

vi. East Africa Communications Organization (EACO) and

vii. African Network Information Center (AfriNIC)

The AUC under AXIS project is working with EACO in order to realize the EACO action plan on the implementation of the EAIXP.

CHAPTER THREE

3.0 STUDY METHODOLOGY

This chapter presents the study design and methods employed in conducting the study.

3.1 Study design

The research focused in Tanzania and East Africa especially in those areas with operational IXPs. For the case of Tanzania the study focused Dar es Salaam and Arusha regions; the IXPs involved were Tanzania Internet Exchange Point (TIX) and Arusha Internet Exchange Point (AIXP). For benchmarking purposes the study extended to the following countries Kenya, Uganda and Rwanda, Burundi was excluded as during the study period there was no operational IXP. The IXPs involved were Kenya Internet Exchange Point (KIXP), Uganda Internet Exchange Point (UIXP) and Rwanda Internet Exchange Point (RINEX).

3.2 Data collection methods

The study took into account the available data from the IXPs and other stakeholders which included Internet Service Providers (ISPs) and other organizations which are connected to any of the IXPs in Tanzania and East Africa. However, in order to get more details and evidence from the stakeholders, individual interviews by using a structured questionnaire were conducted to all stakeholders especially peers of the targeted IXPs.

The respondent were visited in their respective areas of work and given questionnaires, the same was done for the collection of those questionnaires. The questionnaires used were close ended.

3.3 Study population

A combination of TIX and AIXP peers are part of this study and for benchmarking KIXP, UIXP and RINEX were also included.

3.4 Data analysis

Quantitative methods have been employed in analysing the collected data. This includes the data from the questionnaires and those from databases of respective peers and IXPs. Most of the questions were answered through questionnaires in order to get information from customers on how they find IXPs in improving the quality of internet and data services. The technique for capturing data was through the structured questionnaire and short interview for the visited IXPs, Internet Service Providers (ISPs) peers and Non Internet Service Providers (ISPs) peers. The questionnaires that were used for the study are appended (Appendix I, II and III). The Statistical Package for Social Sciences 11.5 version (SPSS) was used for data analysis.

CHAPTER FOUR

4.0 STUDY FINDINGS

This chapter presents findings of the study done on the Impact of Internet Exchange Points in Tanzania and East Africa. It addresses the impact of IXPs in delivering services to the citizen in order to bring about the socioeconomic development in respective countries and East Africa as a whole. The analysis dwelled more on the impact of IXPs on issues related to data and internet quality of service, tariffs, traffic localization, content hosting, e-services and internet penetration.

General overview of the data is presented, focused analysis of the data is done and finally interpretation of results is presented based on analytical results. These findings and discussion are the basis on which conclusions and recommendations of the study are going to be made.

4.1 IXPs, ISPs and Non ISPs Peers Response

4.1.1 Response Summary

The data was collected from 23 peers of TIX, 3 peers from AIXP and 4 IXPs. The response results of the questionnaires are presented in the Table 4.1.

Table 4.1 Response Summary

Number of Questionnaires	TIX peers	AIXP peers	IXPs
Number of Questionnaires Sent Out	23	5	5
Number of Returned Questionnaires	23	3	5
Number of Unreturned Questionnaires	0	2	0
Response Rate	100%	60%	100%

4.1.2 IXPs, ISPs and Non ISPs peers perception on the impact of IXPs

IXPs, ISPs and Non ISPs peers perception on the impact of internet exchange points are presented in this section. The IXPS composed of TIX, AIXP, UIXP, KIXP and RINEX while peers composed of customers who are connected to the IXPs especially for TIX and AIXP.

The perceptions of IXPs, ISPs and Non ISPs peers on impact of internet exchange points comes from a number of study questions aimed at to determining the impact of IXPs in Tanzania and East Africa.

The research model presented as figure 1 above provides independent and dependent variables investigated in the course of determining the impact of IXPs. The following are the independent and dependent variables: Quality of service, reliability, latency, packet losses,, access charges, content hosting, e-services and traffic localization.

i. Independent variables.

a) Quality of service
b) Reliability
c) Latency
d) Packet losses
e) Access charges
f) Content hosting
g) E-service
h) Traffic localization

ii. Dependent variable

a) Internet exchange point

4.2 Data analysis as per research questions

In order to establish the impact of IXPs on the independent variables in relation to the internet and data services the following questions were asked to IXPs, ISP and non ISP peers.

4.2.1 Quality of Service

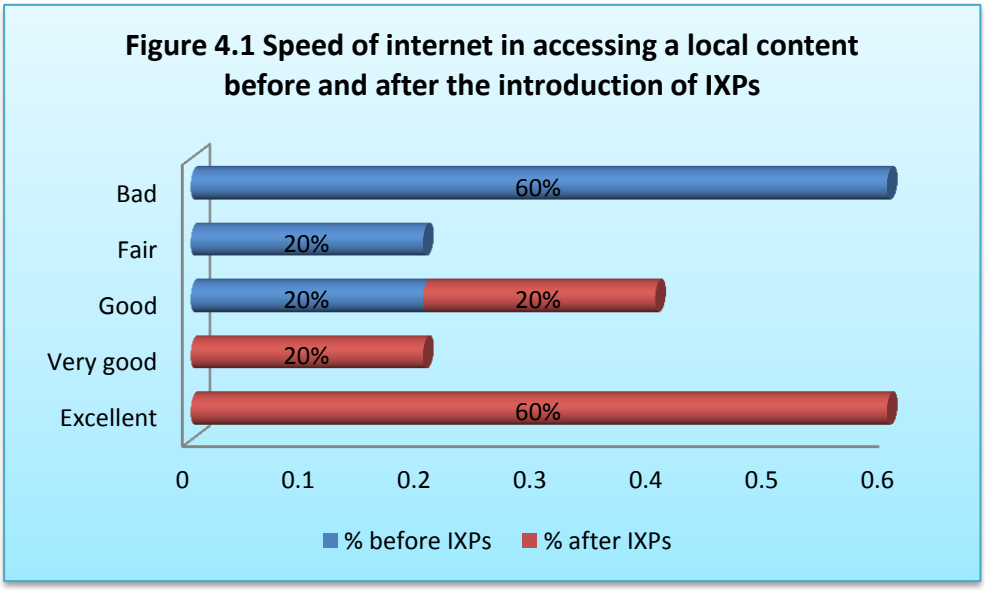
(a) Speed of internet in accessing local content before and after the introduction IXPs

Respondents were asked how they rate the speed of internet in accessing local content before and after the introduction of Internet exchange points. The purpose of this question was to determine if there is a noticeable change on the speed of internet in accessing a local content after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

(b) Response from IXPs

Table 4.2 Speed of internet in accessing a local content before the introduction of IXPs			
S/N	Rating Scale	Number of IXPs	Percentage of IXPs
1	Excellent	-	
2	Very Good	-	
3	Good	1	20%
4	Fair	1	20%
5	Bad	3	60%
	Total	**5**	**100%**

Table 4.3 Speed of internet in accessing a local content after the introduction of IXPs			
S/N	Rating Scale	Number of IXPs	Percentage of IXPs
1	Excellent	3	60%
2	Very Good	1	20%
3	Good	1	20%
4	Fair		
5	Bad		
	Total	5	100%



The result from ***Tables 4.2, 4.3*** and the ***Figure 4.1*** on whether the speed of internet in accessing a local content after the introduction of IXPs have improved response were as follows; 60% said the speed was excellent and 20% said the speed was Very good.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.50 and after introduction of IXPs was 4.75 indicating improvement in quality level.

This improvement is significant t(3), p=0.0065 implying that the speed in accessing local content has improved after the introduction of IXPs as compared to when there was no IXPs.

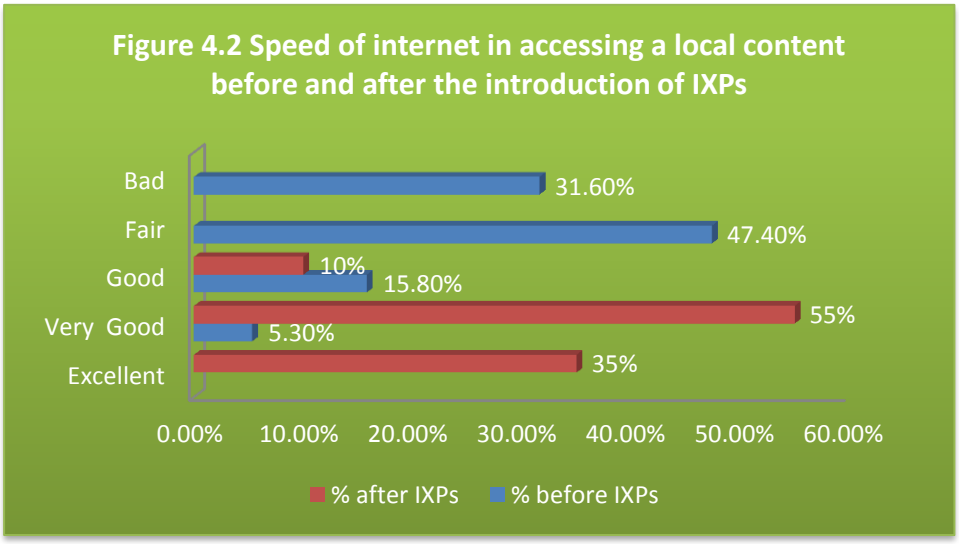
(c) Response from ISPs peers

Table 4.4 Speed of internet in accessing a local content before the introduction of IXPs

S/N	Rating Scale	Number of ISPs	Percentage of ISPs
1	Excellent		
2	Very Good	1	**5.3%**
3	Good	3	**15.8%**
4	Fair	9	**47.4%**
5	Bad	6	**31.6%**
	Total	**19**	**100%**

Table 4.5 Speed of internet in accessing a local content after the introduction of IXPs

S/N	Rating Scale	Number of ISPs	**Percentage of ISPs**
1	Excellent	7	**35%**
2	Very Good	11	**55%**
3	Good	2	**10%**
4	Fair		
5	Bad		
	Total	**20**	**100%**



The result from ***Tables 4.4, 4.5*** and the ***Figure 4.2*** on whether the speed of internet in accessing a local content after the introduction of IXPs have improved, response were as follows; 35% said the speed was excellent, 55%

said the speed was very good while 10% said the speed was good.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.95 and after introduction of IXPs is 4.25 indicating improvement in quality level. The results therefore indicate that the speed in accessing local content has increased after the introduction of IXPs as compared to when there were no IXPs. This improvement is significant t(18), p=0.000 implying that the speed in accessing local content has improved after the introduction of IXPs as compared to when there was no IXPs.

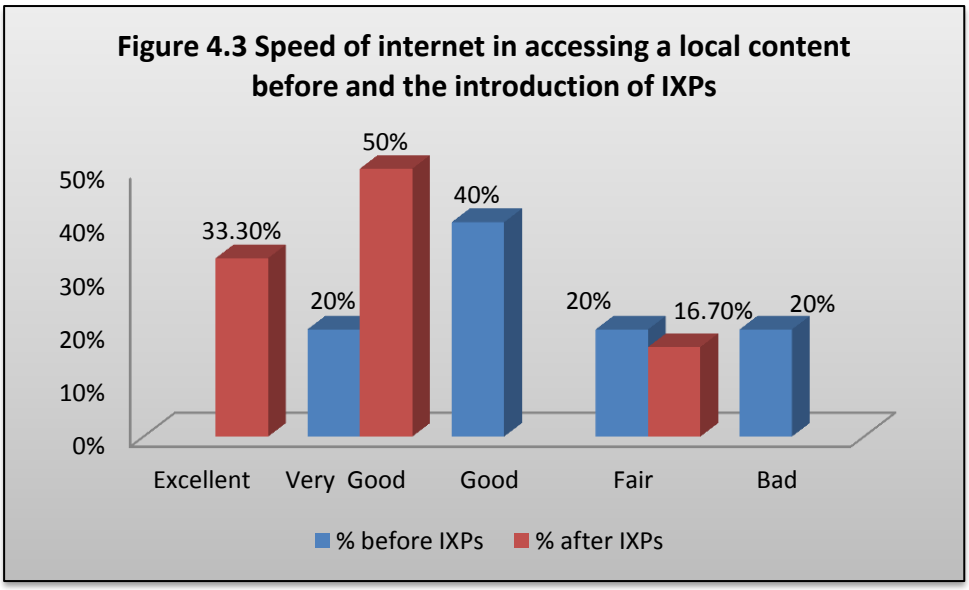
(d) Response from Non ISPs peers

Table 4.6 Speed of internet in accessing a local content before the introduction of IXPs

S/N	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Excellent		
2	Very Good	1	**20%**
3	Good	2	**40%**
4	Fair	1	**20%**
5	Bad	1	**20%**
	Total	**5**	**100%**

Table 4.7 Speed of internet in accessing a local content after the introduction of IXPs

S/N	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Excellent	2	**33.3%**
2	Very Good	3	**50%**
3	Good		
4	Fair	1	**16.7%**
5	Bad		
	Total	**6**	**100%**



The result from ***Tables 4.6, 4.7*** and the ***Figure 4.3*** on whether the speed of internet in accessing a local content after the introduction of IXPs have improved, response were as follows; 33.30% said the speed was excellent, 50% said the speed was very good while 16.70% said the speed was fair.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.20 and after introduction of IXPs was 3.40 indicating improvement in quality level. This improvement is significant t(4), p=0.0017 concluding that the introduction of IXPs has positive impact on the speed in accessing local content as compared to when there was no IXPs.

(e) The latency in reaching a local website before and after the introduction of IXPs

Respondents were asked how they rate the latency in accessing a local website before and after the introduction of internet exchange points. The purpose of this question was to determine if there is a noticeable change on the latency in accessing a local website before and after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

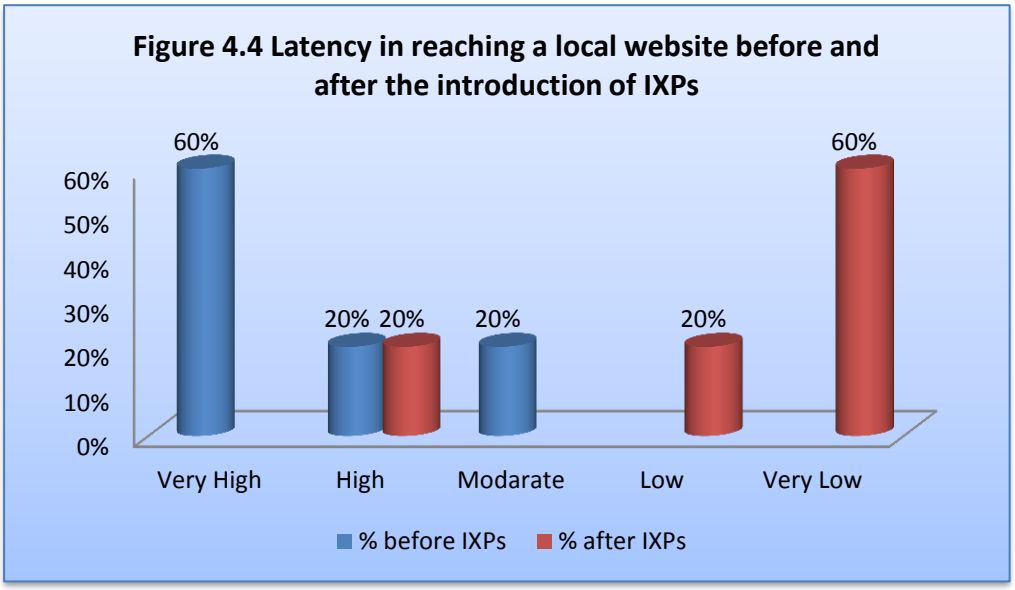
(f) Response from IXPs

Table 4.8 Latency in reaching a local website before the introduction of IXPs

S/N	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High	3	**60%**
2	High	1	**20%**
3	Moderate	1	**20%**
4	Low	-	**-**
5	Very Low	-	**-**
	Total	**5**	**100%**

Table 4.9 Latency in reaching a local website after the introduction of IXPs

S/N	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High	-	**-**
2	High	1	**20%**
3	Moderate	-	**-**
4	Low	1	**20%**
5	Very Low	3	**60%**
	Total	**4**	**100%**



The result from ***Tables 4.8, 4.9*** and the ***Figure 4.4*** on rating of latency of reaching a local website after the introduction of IXP were as follows; 60% said the latency was very low and 20% said the latency was low.

Further statistical tests reveals that Quality Index before introduction of IXPs was 1.25 indicating the latency was high and after introduction of IXPs is 4.75 indicating minimum latency and hence improvement in quality level. This improvement is significant t(3), p=0.0012.

The result therefore shows that the latency in accessing local website has reduced after the introduction of IXPs as compared to when there were no IXPs.

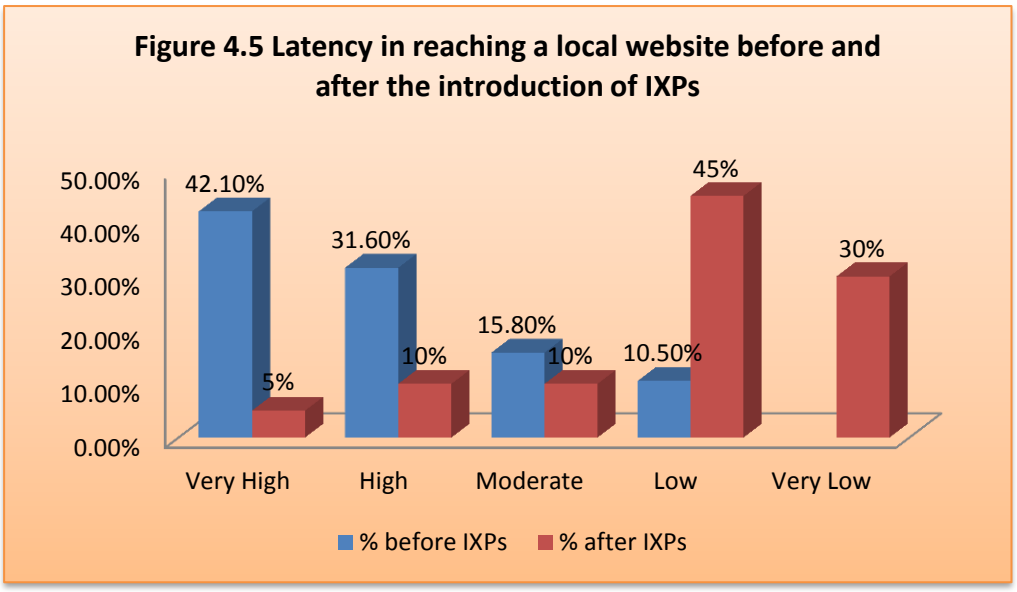
(g) Response from ISPs peers

Table 4.10 Latency in reaching a local website before the introduction of IXPs

S/N	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High	8	**42.1%**
2	High	6	**31.6%**
3	Moderate	3	**15.8%**
4	Low	2	**10.5%**
5	Very Low		
	Total	**19**	**100%**

Table 4.11 Latency in reaching a local website after the introduction of IXPs

S/N	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High	1	**5%**
2	High	2	**10%**
3	Moderate	2	**10%**
4	Low	9	**45%**
5	Very Low	6	**30%**
	Total	**20**	**100%**



The result from ***Tables 4.10, 4.11*** and the ***Figure 4.5*** on rating of latency of reaching a local website after the introduction of IXP were as follows; 30% said the latency was very low, 45% said the latency was low, 10% said the latency was moderate while 10% said the latency was high and 5% said the latency was very high.

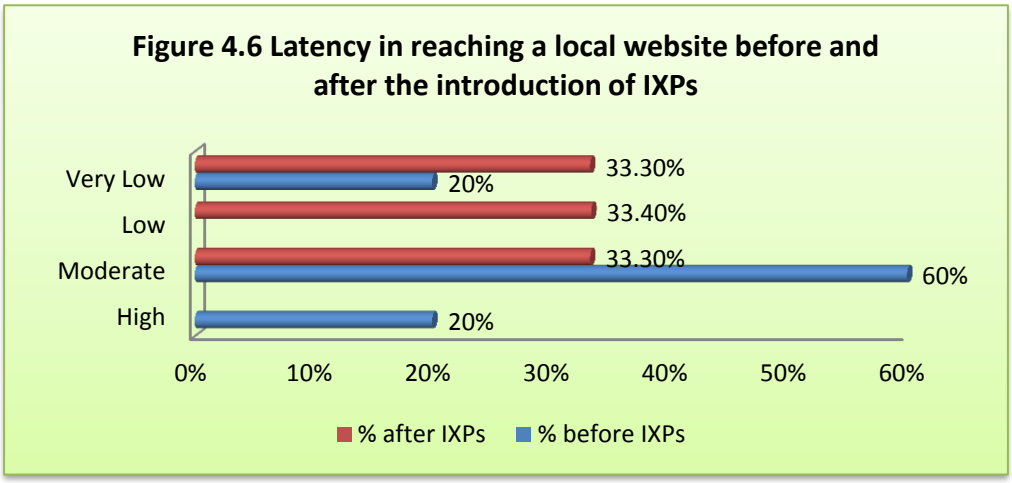
Further statistical tests reveals that Quality Index before introduction of IXPs was 2.15 and after introduction of IXPs 4.05 indicating improvement in quality level. This improvement is significant t(18), p=0.001, indicating that the latency in reaching local website has reduced after the introduction of IXPs as compared to when there were no IXPs.

4.3.1.8 Response from Non ISPs peers

Table 4.12 Latency in reaching a local website before the introduction of IXPs

SN	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Very High		
2	High	1	**20%**
3	Moderate	3	**60%**
4	Low		
5	Very Low	1	**20%**
	Total	**5**	**100%**

Table 4.13 Latency in reaching a local website after the introduction of IXPs			
SN	**Rating Scale**	**Number of Non ISPs**	**Percentage of Non ISPs**
1	Very High		
2	High		
3	Moderate	2	**33.3%**
4	Low	2	**33.4%**
5	Very Low	2	**33.3%**
	Total	**6**	**100%**



The result from tables 4.12, 4.13 and the figure 4.6 on rating of latency of reaching a local website after the introduction of IXP were as follows; 33.30% said the latency was very low, 33.40% said the latency was low while 33.30% said the latency was moderate.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.80 and after introduction of IXPs was 3.20 indicating minimum latency and hence improvement in quality level. This improvement is significant t(4), p=0.001 concluding that the latency in reaching local website has reduced after the introduction of IXPs in compared to when there was no IXPs.

4.3.1.9 Packet losses before and after the introduction of Internet Exchange Point (IXP)

Respondents were asked how they rate the packet losses in reaching a local website before and after the introduction of internet exchange points. The purpose of this question was to determine if there is a noticeable change on the packet losses in

reaching a local website before and after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

4.3.1.10 Response from IXPs

Table 4.14 Packets losses in reaching a local website before the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High		
2	High	3	60%
3	Moderate	2	40%
4	Low		
5	Very Low		
	Total	5	100%

Table 4.15 Packets losses in reaching a local website after the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High		
2	High	1	20%
3	Moderate		
4	Low	1	20%
5	Very Low	3	60%
	Total	5	100%

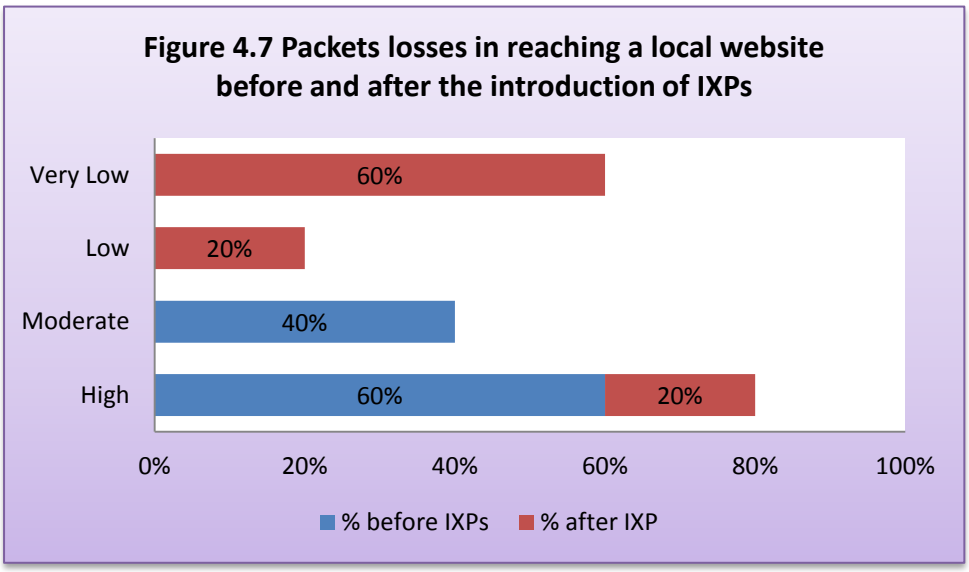


Figure 4.7 Packets losses in reaching a local website before and after the introduction of IXPs

The result from tables 4.14, 4.15 and the figure 4.7 on rating of the status of data packet losses after the introduction of IXP were as follows; 60% said the losses were very low and 20% said the losses were low.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.25 and after introduction of IXPs is 4.75 improvement in quality level. This improvement is significant t(3), p=0.0032.
The results in general indicate that the packets losses in reaching a local website have reduced after the introduction of IXPs as compared to when there were no IXPs.

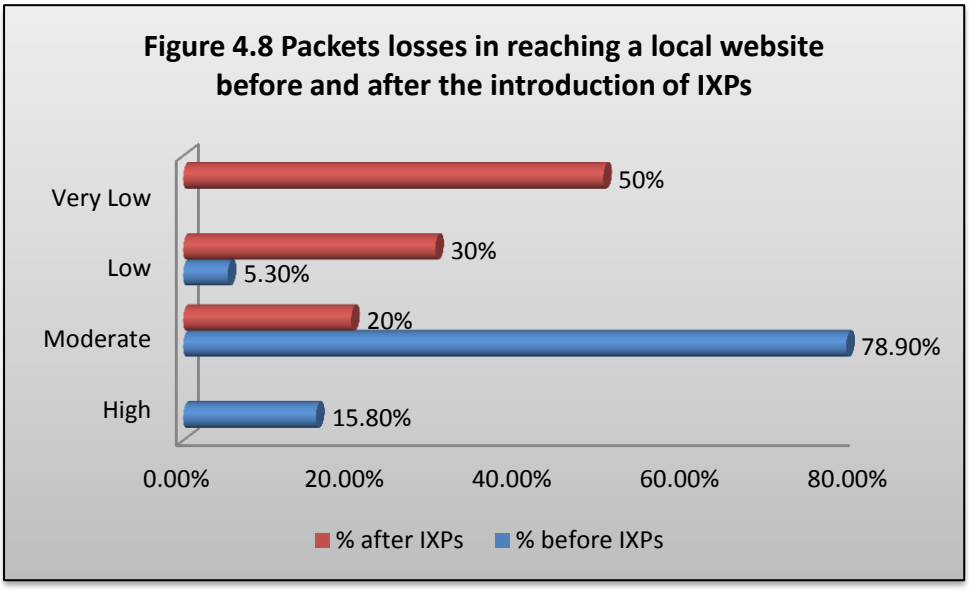
4.3.1.11 Response from ISPs peers

Table 4.16 Packets losses in reaching a local website before the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High		
2	High	3	15.8%
3	Moderate	15	78.9%
4	Low	1	5.3%
5	Very Low		
	Total	19	100%

Table 4.17 Packets losses in reaching a local website after the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High		
2	High		
3	Moderate	4	20%
4	Low	6	30%
5	Very Low	10	50%
	Total	20	100%



The result from tables 4.16, 4.17 and the figure 4.8 on rating of the status of data packet losses after the introduction of IXP were as

follows; 55% said the losses were very low, 30% said the losses were low while 20% said the losses were moderate.

Further statistical tests revealed that Quality Index before the introduction of IXPs was 1.70 and after the introduction of IXPs was 3.11 indicating increase in quality level. This improvement is significant t(18), p=0.000.

The result therefore shows that packets losses in reaching a local website have reduced after the introduction of IXPs as compared to when there were no IXPs.

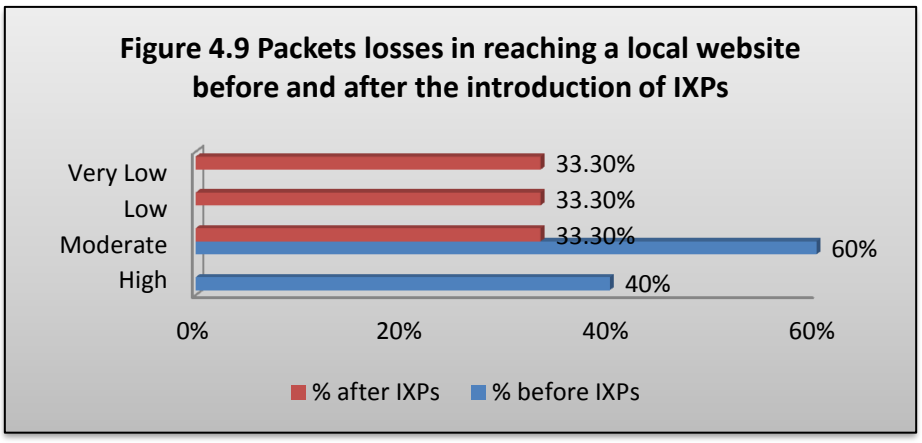
4.3.1.12 Response from Non ISPs peers

Table 4.18 Packets losses in reaching a local website before the introduction of IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Very High		
2	High	2	**40%**
3	Moderate	3	**60%**
4	Low		
5	Very Low		
	Total	**5**	**100%**

Table 4.19 Packets losses in reaching a local website after the introduction of IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Very High		
2	High		
3	Moderate	2	**33.3%**
4	Low	2	**33.3%**
5	Very Low	2	**33.3%**
	Total	**6**	**100%**



The result from tables 4.18, 4.19 and the figure 4.9 on rating of the status of data packet losses after the introduction of IXP were as follows; 33.30% said the losses were very low, 33.30% said the losses were low while 33.30% said the losses were moderate.
Further statistical tests reveals that Quality Index before introduction of IXPs was 2.60 and after introduction of IXPs is 3.80 indicating improvement in quality level. This improvement is significant t(4), p=0.033 concluding that the packets losses in reaching a local website have reduced after the introduction of IXPs as compared to when there was no IXPs.

4.3.1.13 Reliability of data and internet services before and after the introduction Internet Exchange Point (IXP)

Respondents were asked how they rate the reliability of data and internet services in accessing local content before and after the introduction of internet exchange points. The purpose of this question was to determine if there is a noticeable change on the reliability of data and internet services in accessing a local content before and after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

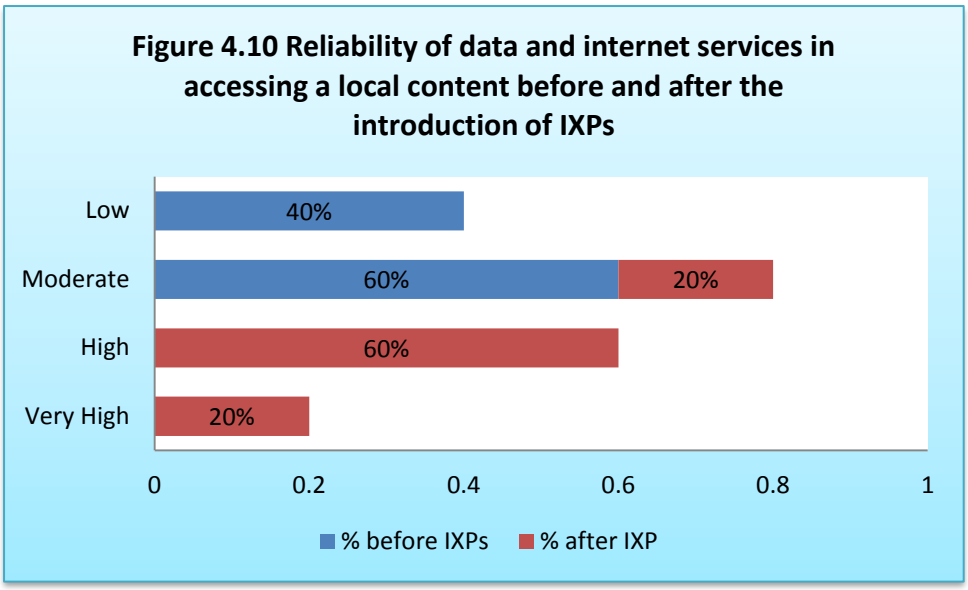
4.3.1.14 Response from IXPs

Table 4.20 Reliability of data and internet services in accessing a local content before the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High		
2	High		
3	Moderate	3	**60%**
4	Low		
5	Very Low	2	**40%**
	Total	**5**	**100%**

Table 4.21 Reliability of data and internet services in accessing a local content after the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High	1	**20%**
2	High	3	**60%**
3	Moderate	1	**20%**
4	Low		
5	Very Low		
	Total	**5**	**100%**



The result from tables 4.20, 4.21 and the figure 4.10 on rating of the reliability of data and internet services after the introduction of IXP were as follows; 20% said data reliability was very high, 60% said high and 20% said moderate.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.00 and after introduction of IXPs was 3.50 indicating some improvement in quality level. This improvement is significant t(3), p=0.05. The result indicates that the reliability of data and internet services in accessing a local content has improved after the introduction of IXPs as compared to when there were no IXPs.

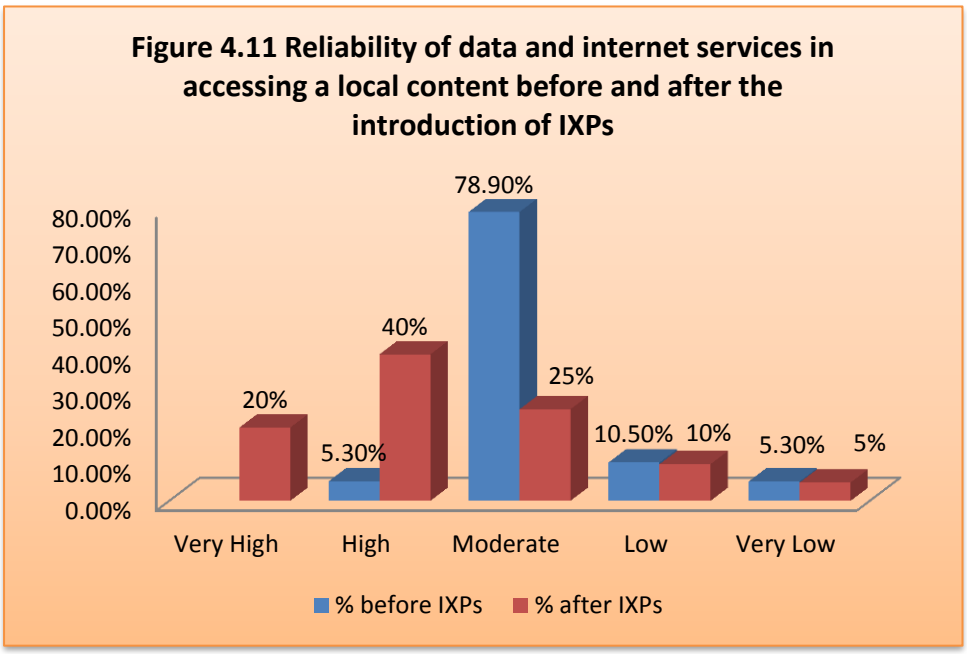
4.3.1.15 Response from ISPs peers

Table 4.22 Reliability of data and internet services in accessing a local content before the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High		
2	High	1	**5.3%**
3	Moderate	15	**78.9%**
4	Low	2	**10.5%**
5	Very Low	1	**5.3%**
	Total	**19**	**100%**

Table 4.23 Reliability of data and internet services in accessing a local content after the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High	4	**20%**
2	High	8	**40%**
3	Moderate	5	**25%**
4	Low	2	**10%**
5	Very Low	1	**5%**
	Total	**20**	**100%**



The result from tables 4.22, 4.23 and the figure 4.11 on rating of the reliability of data and internet services after the introduction of IXP were as follows; 20% said data reliability was very high, 40% said high while 25% said moderate, 10% said low and 5% said very low.

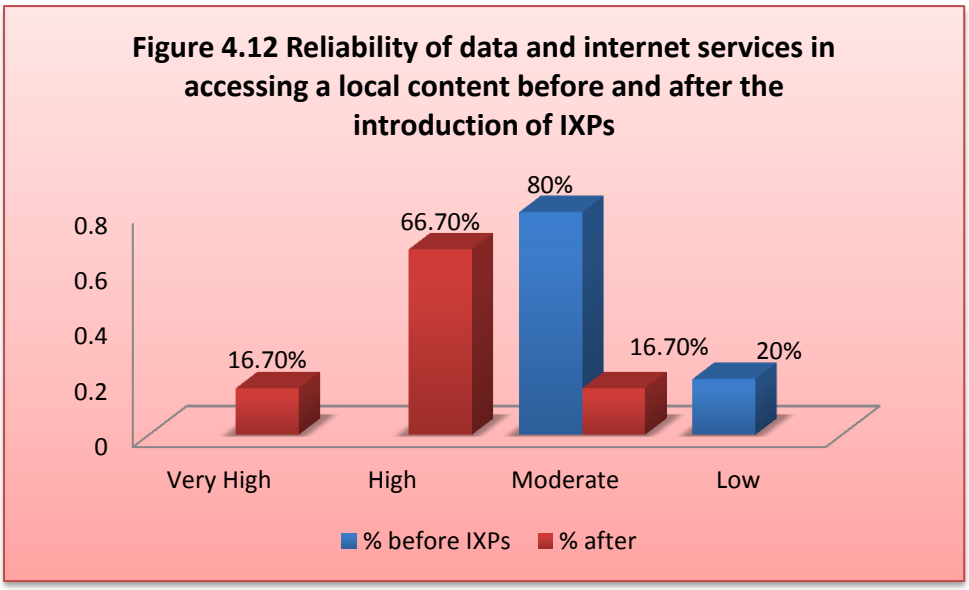
Further statistical tests revealed that Quality Index before introduction of IXPs was 2.84 and after introduction of IXPs was 3.60 indicating improvement in quality level. This improvement is significant t(18), p=0.001 concluding that the reliability of data and internet services in accessing a local content has improved after the introduction of IXPs as compared to when there was no IXPs.

4.3.1.16 Response from Non ISPs peers

Table 4.24 Reliability of data and internet services in accessing a local content before the introduction of IXPs

S/no	Rating Scale	Number of Non ISPs	**Percentage of Non ISPs**
1	Very High		
2	High		
3	Moderate	4	**80%**
4	Low	1	**20%**
5	Very Low		
	Total	**5**	**100%**

Table 4.25 Reliability of data and internet services in accessing a local content after the introduction of IXPs			
S/no	Rating Scale	Number of Non ISPs	**Percentage of Non ISPs**
1	Very High	1	**16.7%**
2	High	4	**66.7%**
3	Moderate	1	**16.7%**
4	Low		
5	Very Low		
	Total	**6**	**100%**



The result from tables 4.24, 4.25 and the figure 4.12 on rating of the reliability of data and internet services after the introduction of IXP were as follows; 16.70% said data reliability was very high, 66.70% said high while 16.70% said moderate.

Further statistical tests revealed that Quality Index before introduction of IXPs was 3.20 and after introduction of IXPs is 4.20 indicating increase in quality level. This is significant t(4), p=0.034 concluding that the reliability of data and internet services in accessing a local content has improved after the introduction of IXPs as compared to when there was no IXPs.

4.3.2 Tariffs

4.3.2.1 Cost of internet/data access charges before and after the introduction of IXPs

Respondents were asked how they rate the cost of internet/data access charges they incurred before and after the introduction of internet exchange points. The purpose of this question was to determine if there was a noticeable change on the cost of internet/data access charges incurred before and after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

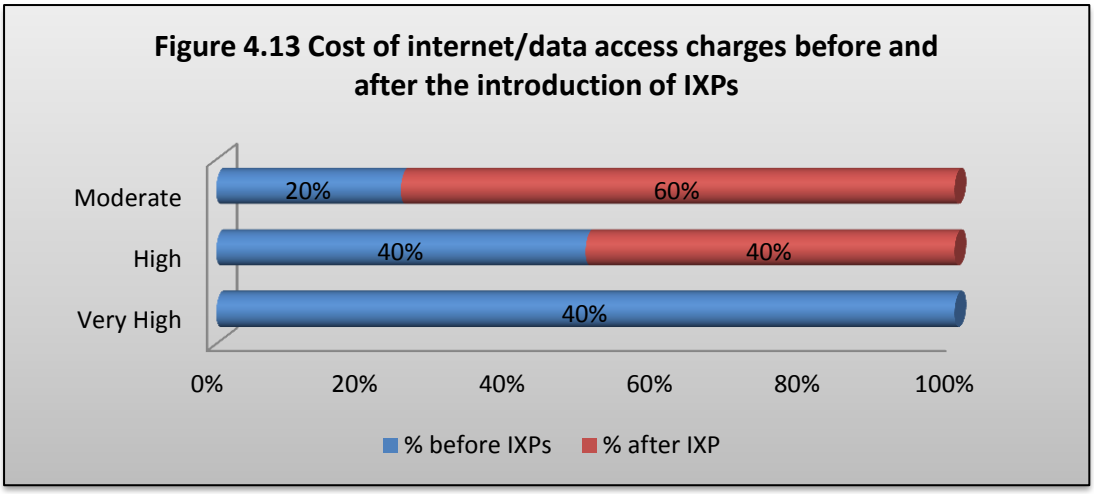
4.3.2.2 Response from IXPs

Table 4.26 Cost of internet/data access charges before the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High	2	**40%**
2	High	2	**40%**
3	Moderate	1	**20%**
4	Low		
5	Very Low		
	Total	**5**	**100%**

Table 4.27 Cost of internet/data access charges after the introduction of IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High		
2	High	2	**40%**
3	Moderate	3	**60%**
4	Low		
5	Very Low		
	Total	**5**	**100%**



The result from tables 4.26, 4.27 and the figure 4.13 on rating of the cost of internet/data access charges incurred after the introduction of IXP were as follows; 60% said were moderate while 40% said charges were high.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.50 and after introduction of IXPs is 3.50 indicating improvement in quality level. This result is significant t(3), p=0.0082 concluding that the cost incurred by peers on internet and data access charges have been reduced after the introduction of IXPs as compared to when there was no IXPs.

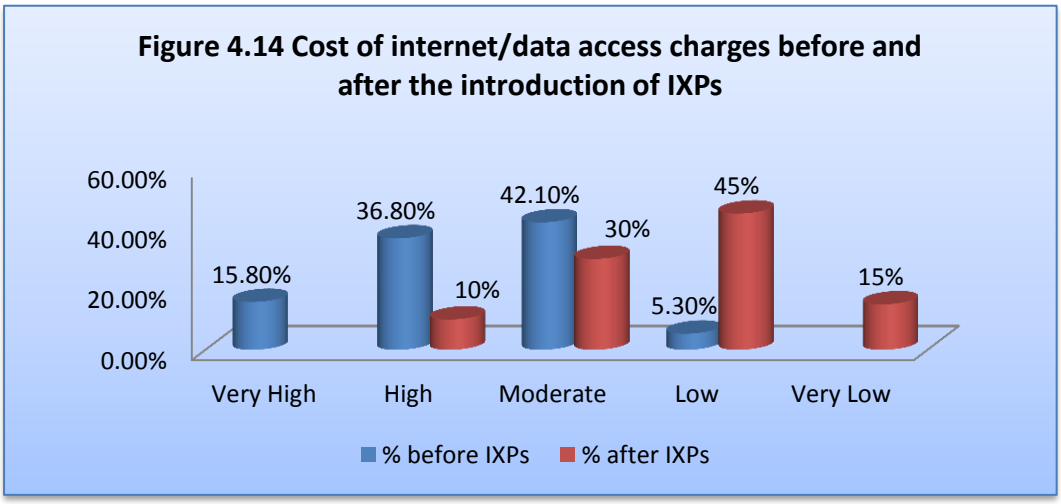
4.3.2.3 Response from ISPs peers

Table 4.28 Cost of internet/data access charges before the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High	3	**15.8%**
2	High	7	**36.8%**
3	Moderate	8	**42.1%**
4	Low	1	**5.3%**
5	Very Low		
	Total	**19**	**100%**

Table 4.29 Cost of internet/data access charges after the introduction of IXPs

S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High		
2	High	2	**10%**
3	Moderate	6	**30%**
4	Low	9	**45%**
5	Very Low	3	**15%**
	Total	**20**	**100%**



The result from tables 4.28, 4.29 and the figure 4.14 on rating of the cost incurred on internet/data access charges after the introduction of IXP were as follows; 15% said were very low, 45% said low while 30% said moderate and 10% said charges were high.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.65 and after introduction of IXPs was 3.63 indicating improvement in quality level.

The result is significant (18), p= 0.000 concluding that the cost incurred by peers on internet and data access charges have been reduced after the introduction of IXPs as compared to when there was no IXPs.

4.3.2.4 Response from Non ISPs peers

Table 4.30 Cost of internet/data access charges before the introduction of IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Very High	1	**25%**
2	High	2	**50%**
3	Moderate	1	**25%**
4	Low		
5	Very Low		
	Total	**4**	**100%**

Table 4.31 Cost of internet/data access charges after the introduction of IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of Non ISPs
1	Very High		
2	High		
3	Moderate	2	**40%**
4	Low	3	**60%**
5	Very Low		
	Total	**5**	**100%**

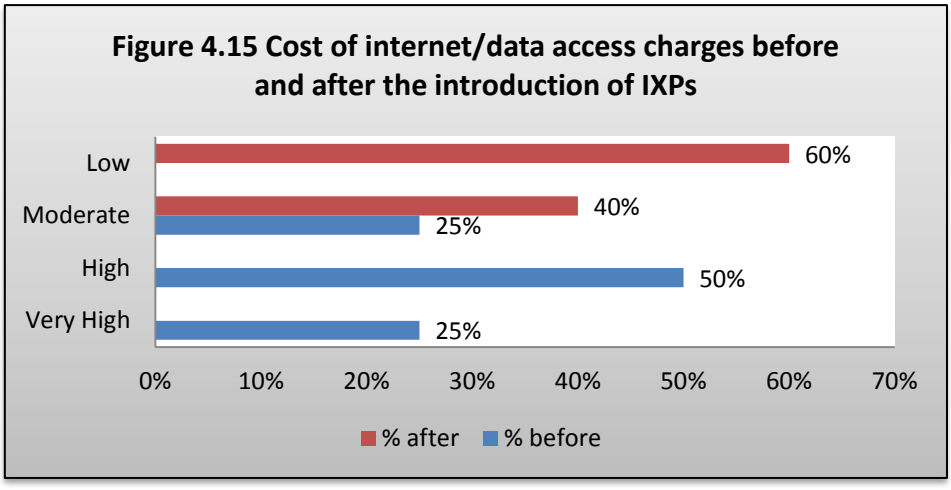


Figure 4.15 Cost of internet/data access charges before and after the introduction of IXPs

The result from tables 4.30, 4.31 and the figure 4.15 on rating of the cost incurred on internet/data access charges after the introduction of IXP were as follows; 60% said were low while 40% said moderate.
Further statistical tests revealed that Quality Index before introduction of IXPs was 2.00 and after introduction of IXPs increased to 3.00 indicating improvement in quality level. This improvement is significant t(3), p=0.092 concluding that the cost incurred by peers on internet and data access charges have reduced after the introduction of IXPs as compared to when there was no IXPs.

4.3.2.5 The cost of international internet bandwidth before and after the introduction of IXPs

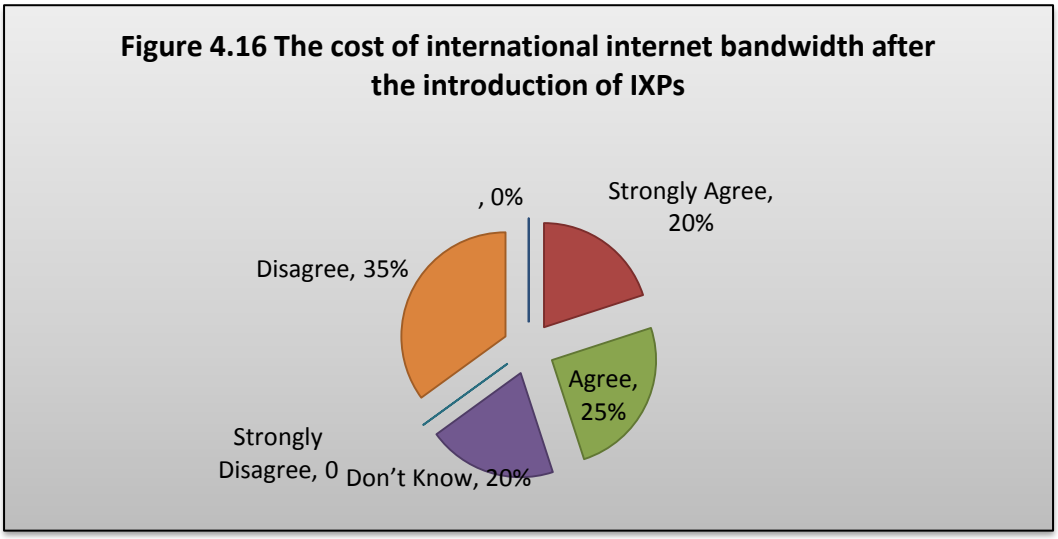
Respondents were asked how they rate the cost they incurred on international internet bandwidth before and after the introduction of internet exchange points. This question was meant for ISPs. The purpose of this question was to determine if there is a noticeable change on the cost they incur on international internet bandwidth before and after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

4.3.2.6 Response from ISPs peers

Table 4.32 The cost of international internet bandwidth after the introduction of IXPs

S/no	Rating Scale	Number of ISPs	**Percentage of ISPs**
1	Strongly Agree	4	**20%**
2	Agree	5	**25%**
3	Don't Know	4	**20%**
4	Strongly Disagree		
5	Disagree	7	**35%**
	Total	**20**	**100%**

Figure 4.16 The cost of international internet bandwidth after the introduction of IXPs



The result from table 4.32 and the figure 4.16 on rating of the cost incurred on international internet bandwidth whether have decreased after the introduction of IXP were as follows; 20% strongly agreed, 25% agreed while 35% disagree and 20% could were not aware.
Further statistical test revealed Quality Index of 3.4 indicating good quality. This result is significant t(18), p=0.002 concluding that the cost incurred by peers on international internet bandwidth has reduced after the introduction IXPs as compared to when there was no IXPs; and probably will improve further with an increase of local content within the country as more traffic will be destined locally.

4.3.2.7 The introduction of Internet Exchange Point (IXP) has created a big role in the reduction of internet monthly access charges

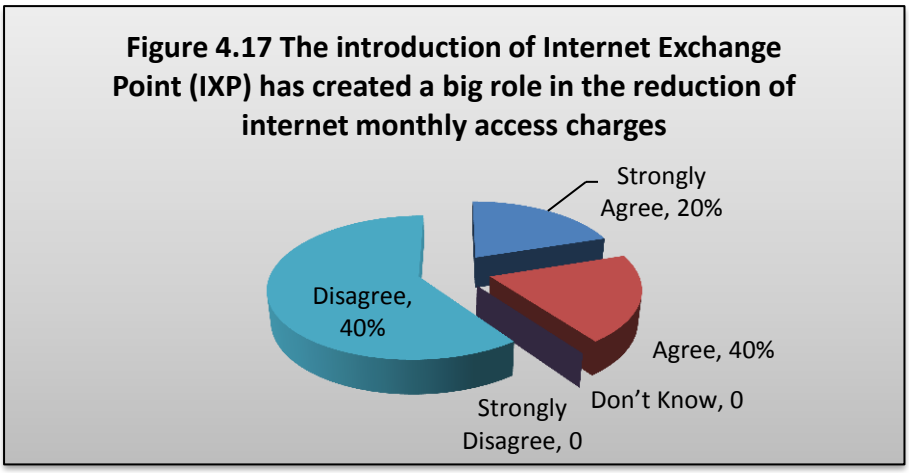
Respondents were asked if the introduction of IXPs has created a big role in the reduction of their internet monthly access charges and this was asked to the IXPs and Non ISPs peers. The purpose of this question was to determine if there is a noticeable change on the cost incurred on internet monthly access charges after the introduction of IXPs. The findings from the respondents revealed the following as per tables below.

4.3.2.8 Response from IXPs

Table 4.33 The introduction of Internet Exchange Point (IXP) has created a big role in the reduction of internet monthly access charges

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Strongly Agree	1	**20%**
2	Agree	2	**40%**
3	Don't Know		
4	Strongly Disagree		
5	Disagree	2	**40%**
	Total	**5**	**100%**

Figure 4.17 The introduction of Internet Exchange Point (IXP) has created a big role in the reduction of internet monthly access charges



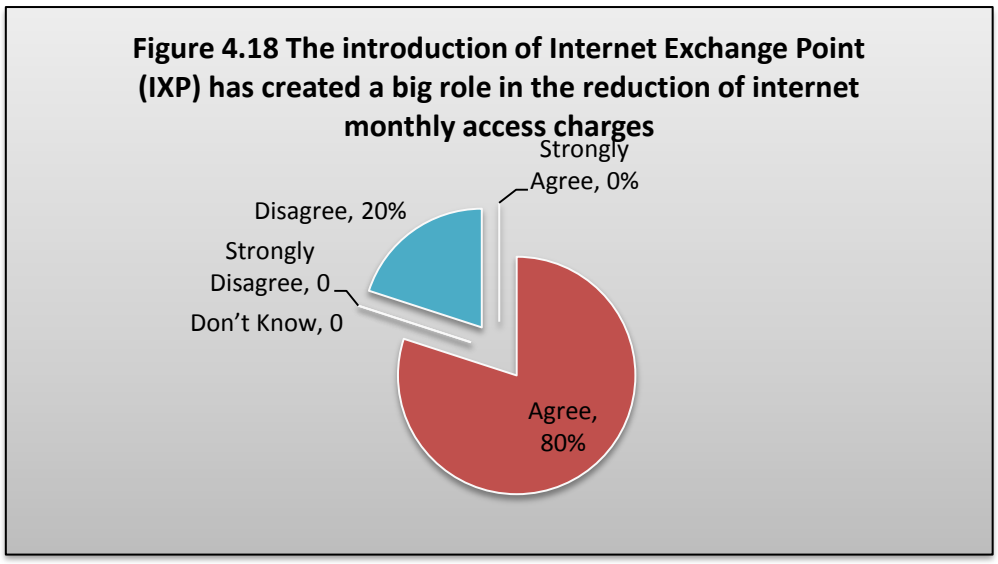
The result from table 4.33 and the figure 4.17 on whether the introduction of IXP has helped to reduce the cost incurred on internet monthly access charges were as follows; 40% agreed, 20% strongly agreed while 40% disagree.

Further statistical tests reveal that Quality Index after introduction of IXPs was 4.25 indicating good quality levels. This result is significant t(18), p=0.0082 concluding that there is reduction of cost incurred by peers on the internet monthly access charges after the introduction of IXPs as compared to when there was no IXPs.

4.3.2.9 Response from Non ISPs

Table 4.34 The introduction of Internet Exchange Point (IXP) has helped your organisation to reduce the cost of internet monthly access charges

S/no	Rating Scale	Number of Non ISPs	Percentage of IXPs
1	Strongly Agree		
2	Agree	4	80%
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	20%
	Total	5	100%



The result from table 4.34 and the figure 4.18 on whether the introduction of IXP has helped to reduce the cost incurred on internet monthly access charges were as follows; 80% strongly agreed while 20% disagree.

Further statistical tests revealed that Quality Index of 4.75 indicating good quality levels and hence low access charges. This result is significant t(4), p=0.000 concluding that there is reduction of cost incurred by peers on the internet monthly access charges after the introduction of IXPs as compared to when there was no IXPs.

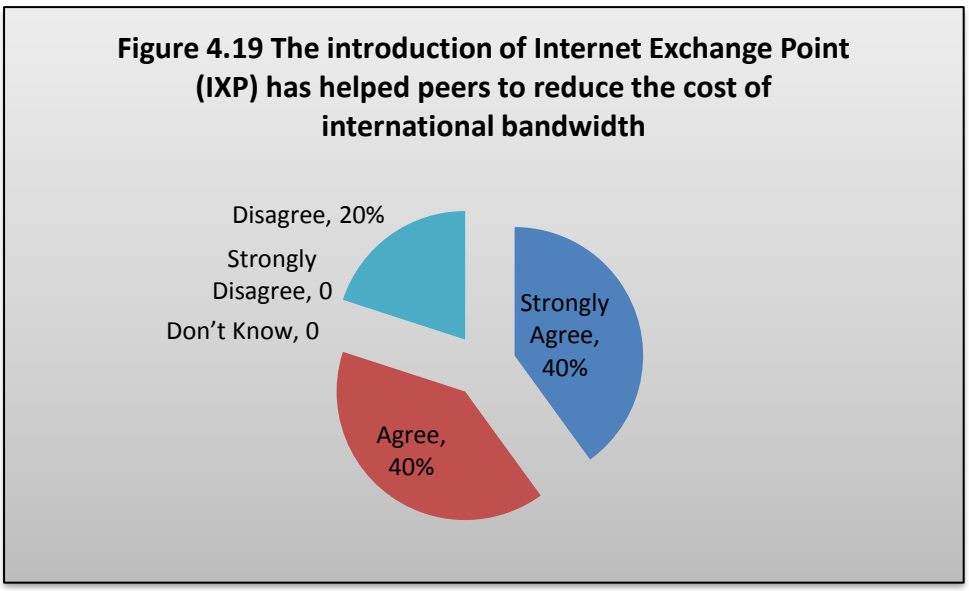
4.3.2.10 The introduction of Internet Exchange Point (IXP) has helped peers to reduce the cost of international bandwidth

Respondents were asked if the introduction of IXPs has helped peers to reduce their cost of international bandwidth and this was asked to IXPs only. The purpose of this question was to determine if there is a noticeable change on the cost incurred by peers on international bandwidth after the introduction of IXPs as compared to when there were no IXPs. The findings from the respondents revealed the following as per tables below.

4.3.2.11 Response from IXPs

Table 4.35 The introduction of Internet Exchange Point (IXP) has helped peers to reduce the cost of international bandwidth

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Strongly Agree	2	40%
2	Agree	2	40%
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	20%
	Total	5	100%



The result from table 4.35 and the figure 4.19 on whether the introduction of IXP has helped peers to reduce their cost of international bandwidth were as follows; 40% agreed while 40% strongly agreed.

Further statistical tests reveal that quality Index before introduction of IXPs was 1.25 and after introduction of IXPs is 3.50 indicating improvement in quality level. This result is significant t(3), p=0.018

implying that there is reduction of cost incurred by peers on the international bandwidth after the introduction of IXPs and may be this will be realized more with introduction of more local content as most of the traffic will be destined locally and hence reduce the use of international circuits in routing the local traffic.

4.3.3 Traffic localization

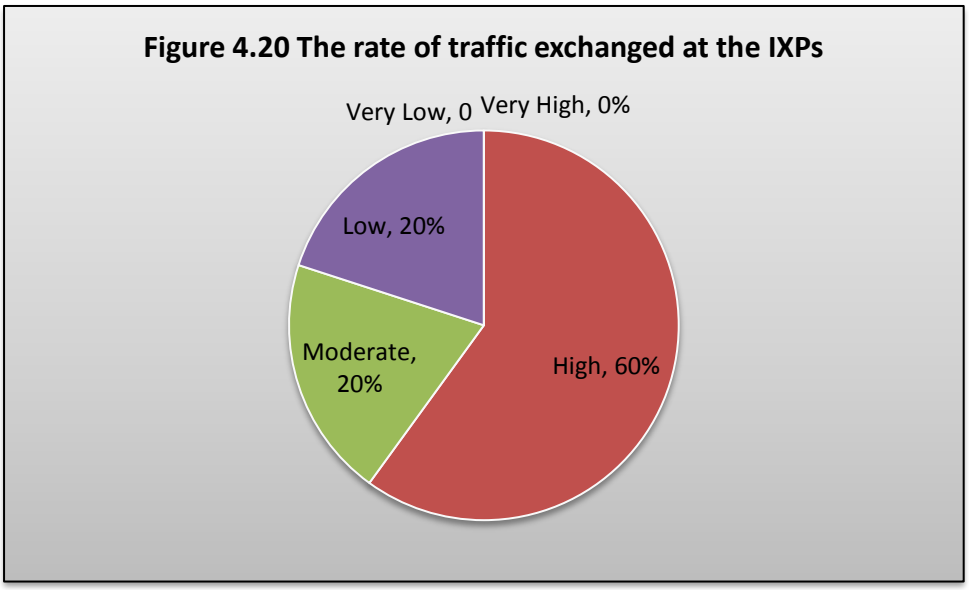
4.3.3.1 The rate of traffic exchanged at the IXPs

Respondents were asked how they rate with time the traffic exchanged at the IXPs for the case of IXPs while ISPs and Non ISPs peers were asked how do they rate the utilization of their links to the IXPs. The purpose of this question was to determine if there is a noticeable increase in traffic exchanged at the IXPs with time. The findings from the respondents revealed the following as per tables below.

4.3.3.2 Response from IXPs

Table 4.36 The rate of traffic exchanged at the IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Very High		
2	High	3	60%
3	Moderate	1	20%
4	Low	1	20%
5	Very Low		
	Total	5	100%



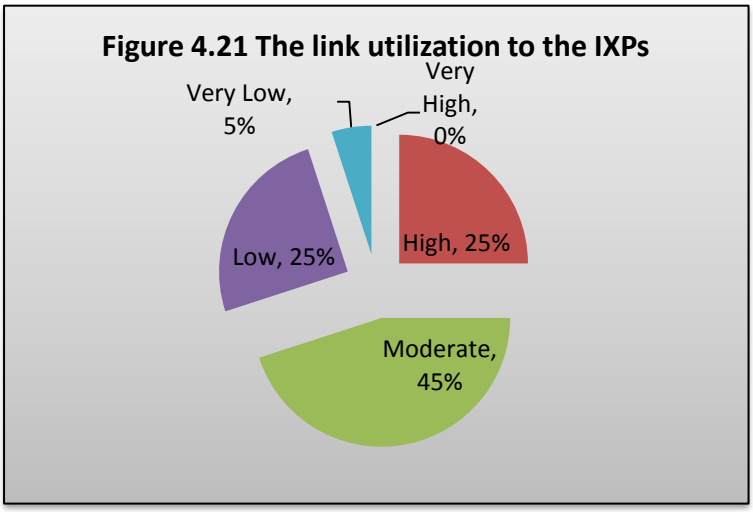
The result from table 4.36 and the figure 4.20 on rate of traffic exchange of local internet/data traffic after the introduction of IXP

were as follows; 60% said that traffic exchanged was high while 20% said that traffic exchanged was moderate.
Further statistical tests reveals that Quality Index after introduction of IXPs was 4.25 indicating improvement in quality level. This improvement is significant t(3), p=0.000.
The general results therefore indicate that the introduction of IXPs has noticeable impact on the volume of traffic exchanged at the IXPs concluding that local traffic is exchanged locally after the introduction of IXPs. This will keep on increasing depending on the availability of local content.

4.3.3.3 Response from ISPs peers

Table 4.37 The rate of the link utilization to the IXPs

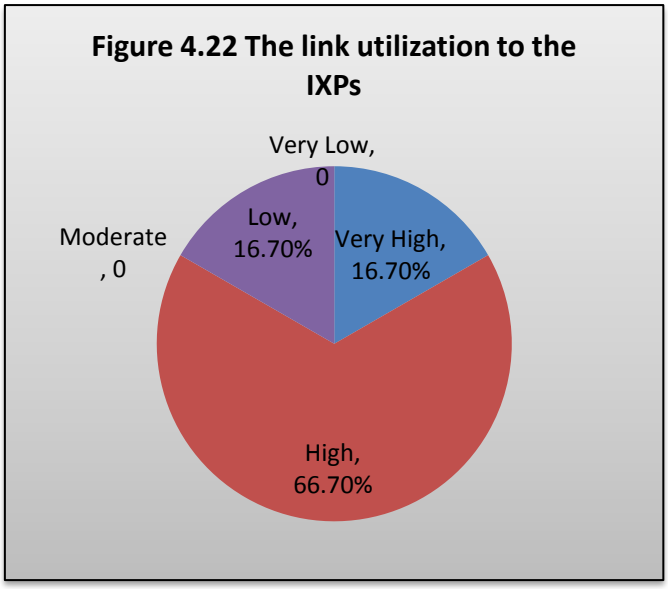
S/no	Rating Scale	Number of ISPs	Percentage of ISPs
1	Very High		
2	High	5	**25%**
3	Moderate	9	**45%**
4	Low	5	**25%**
5	Very Low	1	**5%**
	Total	**20**	**100%**



The result from table 4.37 and the figure 4.21 on rating of link utilization to IXP was as follows; 25% said that utilization was high, 45% said utilization was moderate, 25% said utilization was low while 5% said the utilization was very low.
Further statistical tests revealed Quality Index of 3.00 indicating some improvement in link utilization. This improvement is significant t(18), p=0.000 concluding that the introduction of IXPs has helped localize the local traffic and this will keep on increasing depending on the availability of local content.

4.3.3.4 Response from Non ISPs peers

Table 4.38 The rate of the link utilization to the IXPs			
S/no	Rating Scale	Number of Non ISPs	**Percentage of Non ISPs**
1	Very High	1	**16.7%**
2	High	4	**66.7%**
3	Moderate		
4	Low	1	**16.7%**
5	Very Low		
	Total	**6**	**100%**



The result from table 4.38 and the figure 4.22 result from table 4.43 and the figure 4.24 on rating of link utilization to IXP were as follows; 16.70% said that utilization was very high, 66.70% said utilization was high while 16.70% said utilization was low.

Further statistical tests revealed Quality Index of 3.300 indicating there is an increase in links utilization. This improvement is significant t(3), p=0.000 concluding that the introduction of IXPs has helped to localize the local traffic and this will keep on increasing depending on the availability of local content.

4.3.3.5 Statistics of the traffic exchanged at the IXPs and peers links utilization

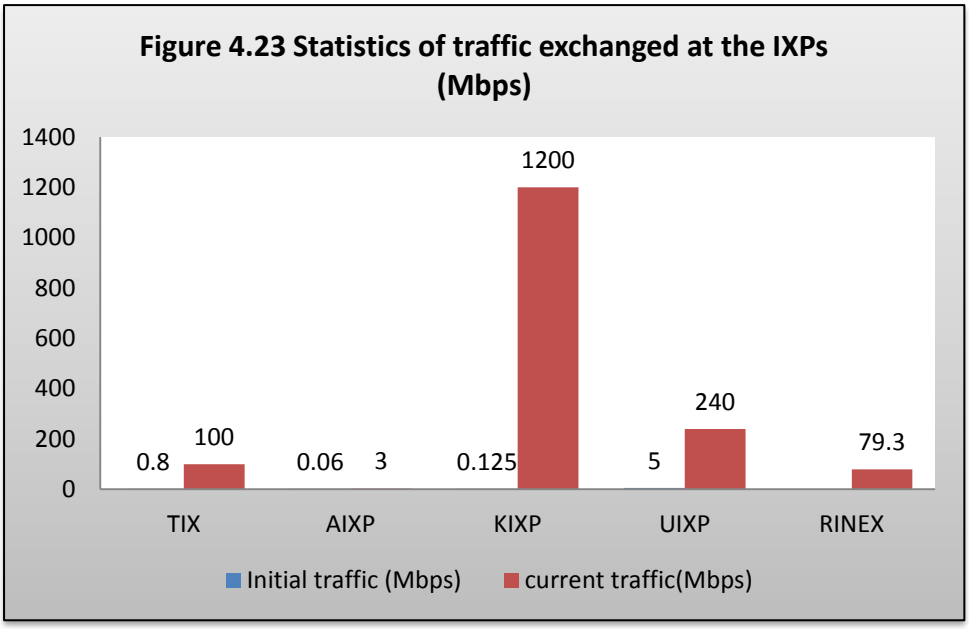
Respondents were asked the date the IXPs/links were established and the utilization of the peer's links to the IXPs since they joined the IXPs. The purpose of this question was to determine if there was a noticeable change on the traffic exchanged at the IXPs and also if there was a noticeable increase in traffic for peer's links terminating at

the IXPs since their establishment. The findings from the respondents revealed the following as per tables below.

4.3.3.6 Response from IXPs

Table 4.39 Statistics of traffic exchanged at the IXPs

S/no	Name of IXP	The year it was established	Initial Traffic	Traffic in 2014
1	TIX	2003	800 Kbps	100 Mbps
2	AIXP	2006	60 Kbps	3 Mbps
3	UIXP	2001	5 Mbps	240 Mbps
4	RINEX	2004	-	79.3 Mbps/
5	KIXP	2002	125 Kbps	1.2 Gbps



4.3.3.7 Response from ISPs peers

Table 4.40 Statistics on the utilization of the link to the IXP

S/no	Name of Non ISP peer	The year it established the link to IXP	Initial Traffic	Traffic in 2014
1.	Raha	2003	256 Kbps	6 Mbps
2.	AfricaOnline	2006	128 Kbps	4 Mbps
3.	Simbanet	2004	256 Kbps	12 Mbps
4.	SatCoNet	2003	512 Kbps	2 Mbps
5.	Spicenet	2010	1000 Kbps	6 Mbps
6.	Afsat	2005	64 Kbps	1.6 Mbps
7.	TTCL	2005	128 Kbps	4Mbps
8.	Vodacom	2007	1 Mbps	6/7.5 Mbps
9.	WIA	2008	5120 Kbps	1.6/1.8 Mbps
10.	Zantel	2009	0.8 Mbps	1.9/5.4 Mbps
11.	Tigo	2009	1.4Mbps	5.6 Mbps
12.	Habari Node Ltd	2008	0.3 Mbps	0.8 Mbps
13.	Selcom Broadband	2007	0.8 Mbps	3.01 Mbps

4.3.3.8 Response from Non ISPs peers

Table 4.41 Statistics on the utilization of the link to the IXP

S/no	Name of ISP peer	The year it established the link to IXP	Initial Traffic	Traffic in 2014
1	Bank of Tanzania (BOT)	2004	0.4 Mbps	4 Mbps
2	TRA	2008	0.5 Mbps	3.4 Mbps
3	TPA	2013	0.3Mbps	0.8 Mbps
4	tzNIC	2008	2.61 Kbps	13.4 Kbps

The result from table 4.39, 4.40, 4.41 and figure 4.23 shows that the traffic exchanged at the IXPs kept on increasing since the establishment of the IXPs. For the case of peers the results shows that the utilization of their links to the IXPs kept on increasing as well since they joined the IXPs. These results conclude that the introduction of IXPs has helped to localize the local traffic and this will keep on increasing depending on the availability of local content.

4.3.4 Content hosting

4.3.4.1 Content hosting before and after the establishment of the IXPs

Respondents were asked their opinion on local content hosting before and after the establishment of IXPs. The purpose of this question was to determine if there is a noticeable increase in local content hosting after the establishment of IXPs. The findings from the respondents revealed the following as per tables below.

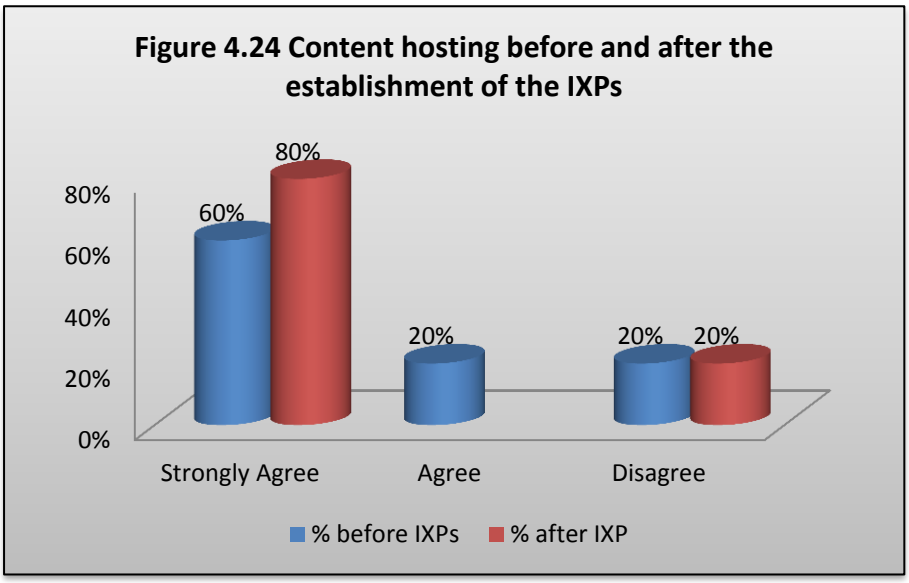
4.3.4.2 Response from IXPs

Table 4.42 Content hosting before the establishment of the IXPs

S/no	Rating Scale	Number of IXPs	**Percentage of IXPs**
1	Strongly Agree	3	**60%**
2	Agree	1	**20%**
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**20%**
	Total	**5**	**100%**

Table 4.43 Content hosting after the establishment of the IXPs

S/no	Rating Scale	Number of IXPs	**Percentage of IXPs**
1	Strongly Agree	4	**80%**
2	Agree		
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**20%**
	Total	**5**	**100%**



The result from tables 4.42, 4.43 and the figure 4.24 on rating whether local content hosting in the country has increased after the introduction of IXP were as follows; 80% strongly agreed that local content hosting has increased.

Further statistical tests reveal that Quality Index before introduction of IXPs was 1.25 and after introduction of IXPs was 3.00 indicating improvement in quality level. This improvement is significant t(3), p=0.0001 concluding that the introduction of IXPs has positive impact in content hosting as more content is being hosted locally after the introduction of IXPs as compared to when there was no IXPs.

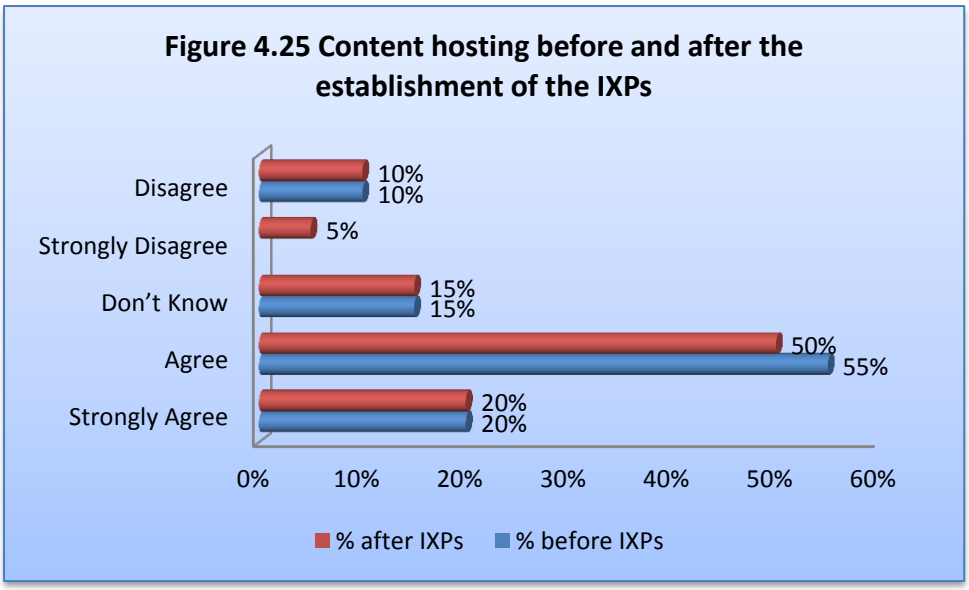
4.3.4.3 Response from ISPs peers

Table 4.44 Content hosting before the establishment of the IXPs

S/no	Rating Scale	Number of ISPs	**Percentage of ISPs**
1	Strongly Agree	4	**20%**
2	Agree	11	**55%**
3	Don't Know	3	**15%**
4	Strongly Disagree		
5	Disagree	2	**10%**
	Total	**20**	**100%**

Table 4.45 Content hosting after the establishment of the IXPs

S/no	Rating Scale	Number of ISPs	**Percentage of ISPs**
1	Strongly Agree	4	**20%**
2	Agree	10	**50%**
3	Don't Know	3	**15%**
4	Strongly Disagree	1	**5%**
5	Disagree	2	**10%**
	Total	**20**	**100%**



The result from tables 4.44, 4.45 and the figure 4.25 on rating whether local content hosting in the country has increased after the introduction of IXP were as follows; 20% strongly agreed, 50% agreed, 10% disagree while 5% strongly disagree and 15% were not aware.

Further statistical tests revealed that Quality Index before introduction of IXPs was 2.85 and after introduction of IXPs was 3.70 indicating improvement in quality level. This improvement is significant t(18), p=0.003 concluding that the introduction of IXPs has positive impact in content hosting as more content is being hosted locally after the introduction of IXPs as compared to when there was no IXPs.

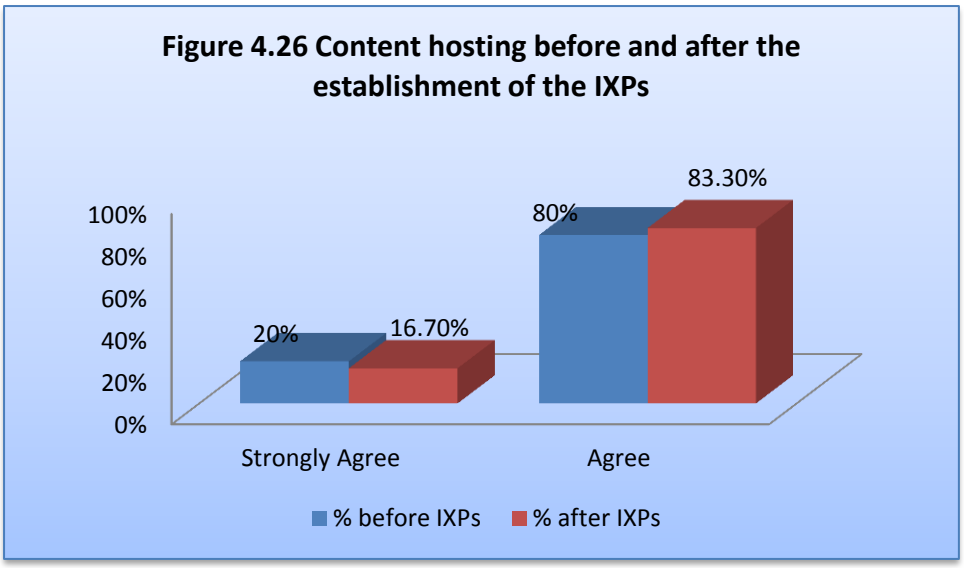
4.3.4.4 Response from Non ISPs peers

Table 4.46 Content hosting before the establishment of the IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of IXPs
1	Strongly Agree	1	20%
2	Agree	4	80%
3	Don't Know		
4	Strongly Disagree		
5	Disagree		
	Total	5	100%

Table 4.47 Content hosting after the establishment of the IXPs

S/no	Rating Scale	Number of Non ISPs	Percentage of IXPs
1	Strongly Agree	1	16.7%
2	Agree	5	83.3%
3	Don't Know		
4	Strongly Disagree		
5	Disagree		
	Total	6	100%



The result from tables 4.46, 4.47 and the figure 4.26 on rating whether local content hosting in the country has increased after the introduction of IXP were as follows; 16.70% strongly agreed while 83.30% agreed.

Further statistical tests revealed that Quality Index before introduction of IXPs was 1.80 and after introduction of IXPs was 3.80 indicating improvement in quality level. The general result indicate that the impact is significant t(4), p =1 concluding that the introduction of IXPs has positive impact in content hosting as more content is being hosted locally after the introduction of IXPs as compared to when there was no IXPs.

4.3.5 Electronic Services

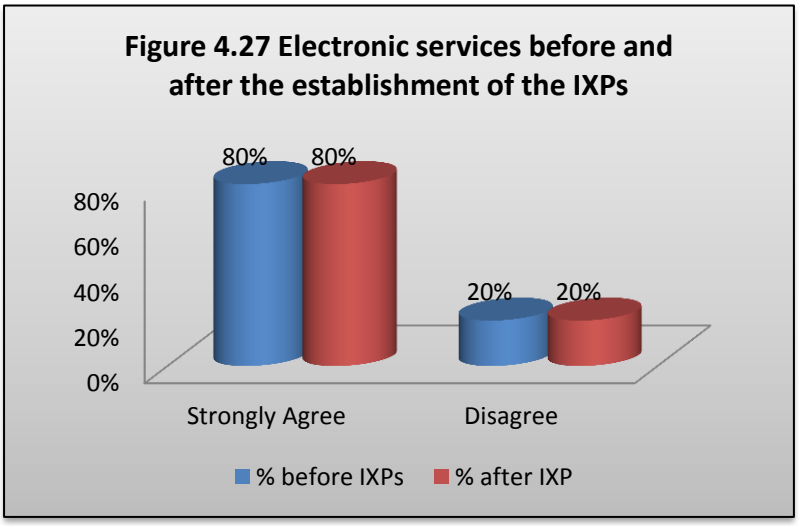
4.3.5.1 Electronic services before and after the establishment of the IXPs

Respondents were asked their opinion on electronic services before and after the establishment of IXPs. The purpose of this question was to determine if there is a noticeable increase in electronic services after the establishment of IXPs. The findings from the respondents revealed the following as per tables below.

4.3.5.2 Response from IXPs

Table 4.48 Electronic services before the establishment of the IXPs			
S/no	Rating Scale	Number of IXPs	**Percentage of IXPs**
1	Strongly Agree	4	**80%**
2	Agree		
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**20%**
	Total	**5**	**100%**

Table 4.49 Electronic services after the establishment of the IXPs			
S/no	Rating Scale	Number of IXPs	**Percentage of IXPs**
1	Strongly Agree	4	**80%**
2	Agree		
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**20%**
	Total	**5**	**100%**



The result from tables 4.48, 4.49 and the figure 4.27 on rating whether e-services activities increased after the introduction of IXP were as follows; 80% strongly agreed that e-services have increased.
Further statistical tests revealed that Quality Index before introduction of IXPs was 1.00 and after introduction of IXPs was 3.50 indicating improvement in quality level. This improvement is significant t(3) p=0.0004 concluding that the introduction of IXPs has positive impact on e-services.

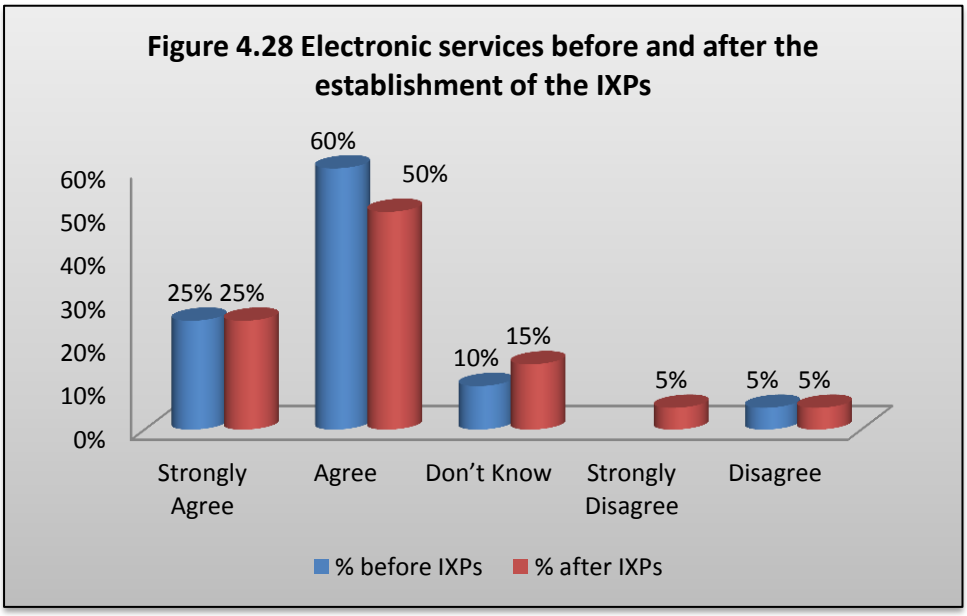
4.3.5.3 Response from ISPs peers

Table 4.50 Electronic services before the establishment of the IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Strongly Agree	5	25%
2	Agree	12	60%
3	Don't Know	2	10%
4	Strongly Disagree		
5	Disagree	1	5%
	Total	20	100%

Table 4.51 Electronic services after the establishment of the IXPs

S/no	Rating Scale	Number of IXPs	Percentage of IXPs
1	Strongly Agree	5	25%
2	Agree	10	50%
3	Don't Know	3	15%
4	Strongly Disagree	1	5%
5	Disagree	1	5%
	Total	20	100%



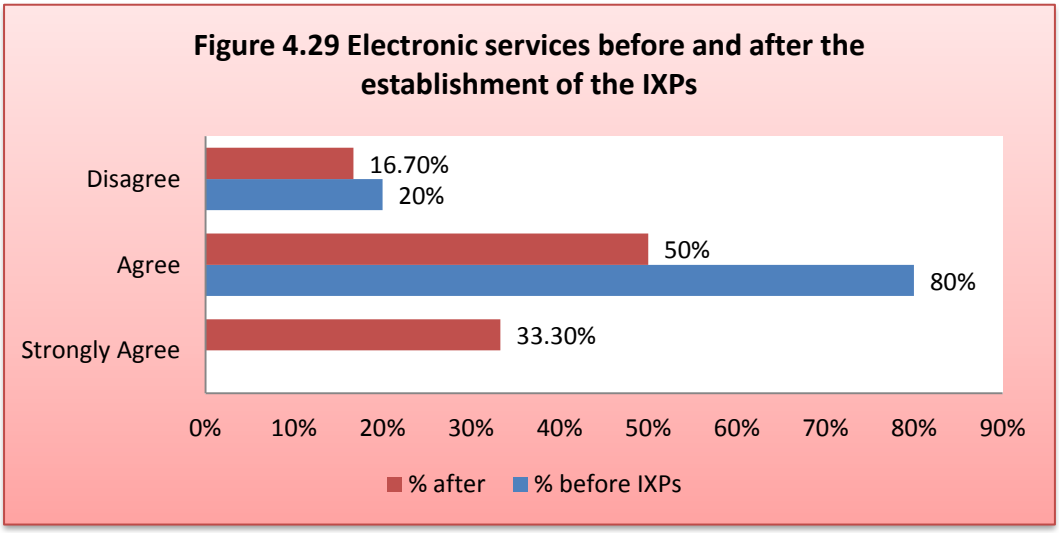
The result from tables 4.50, 4.51 and the figure 4.28 on rating whether e-services activities increased after the introduction of IXP were as follows; 25% strongly agreed, 50% agreed, 15% were not aware while 5% disagreed and 5% strongly disagreed that e-services increased.

Further statistical test revealed that Quality Index before introduction of IXPs was 3.85 and after introduction of IXPs was 4.05 indicating improvement in quality level. This improvement is significant t(18), p=0.001 concluding that the introduction of IXPs has positive impact on e-services.

4.3.5.4 Response from Non ISPs peers

Table 4.52 Electronic services before the establishment of the IXPs			
S/no	Rating Scale	Number of Non ISPs	**Percentage of IXPs**
1	Strongly Agree		
2	Agree	4	**80%**
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**20%**
	Total	**5**	**100%**

Table 4.53 Electronic services after the establishment of the IXPs			
S/no	Rating Scale	Number of Non ISPs	**Percentage of IXPs**
1	Strongly Agree	2	**33.3%**
2	Agree	3	**50%**
3	Don't Know		
4	Strongly Disagree		
5	Disagree	1	**16.7%**
	Total	**6**	**100%**



The result from tables 4.52, 4.53 and the figure 4.29 on rating whether e-services activities increased after the introduction of IXP were as follows; 33.30% strongly agreed, 50% agreed and 15% disagreed.

Further statistical test revealed that Quality Index before introduction of IXPs was 2.40 and after introduction of IXPs was 3.20. This indicates improvement in quality level and hence the result is significant t(4), p=0.00374. The result therefore indicates that introduction of IXP has positive impact on e-services.

4.4 Internet Exchange Points Administration observation on the impact of IXPs deployment

Apart from the questionnaires which were distributed to all peers and IXPs, the study also gathered information on the impact of deployment of IXPs through interviews in which all the IXPs administrators were interviewed and the results for each IXP are as explained herein below.

4.4.1 Tanzania Internet Exchange Point (TIX)

4.4.1.1 The effect of IXPs deployment on latency and packet losses

One of the aims of the study was to understand the effect of effect IXPs deployment on latency and packets losses. For the case of Tanzania, before the establishment of TIX, all providers and also many end-user sites were connected through individual VSAT links to Europe (or North America, or even Asia); a round-trip-time (RTT) of usually 600ms was observed from the site in Tanzania to the providers' satellite hub in Europe. Within Europe or even across the Atlantic to North America the delay was negligible (adding about 80ms in the latter case) for reaching another Satellite provider's hub in order to send the traffic to another site in Tanzania. Thereafter another VSAT hop of 600ms was added to reach the destination in Tanzania. Since these "islands" were not interconnected, the usual latency between any 2 sites in Tanzania was 1200ms, before the inception of IXP's.

Packet loss depended greatly on the level of congestion of the VSAT links, which was partly caused by commercial pressure because VSAT space segments were very costly. As traffic patterns varied during the day and night cycle and weekly, so did congestion on the link and consequently also packet loss caused by the congestion. Another phenomenon of the past was that we observed "scheduled" packet loss and link outage in March and September when ground station, satellite and sun aligned and radiation from the sun interfered and caused "sun outages". These are still happening, but these mostly go undetected nowadays as we no longer entirely depend on satellite links.

When multiple providers were connected to the IXP, mainly microwave wireless links were used and these were immediately of sufficient capacity. Latencies reduced to around 15 – 20m RTT between core networks or servers of two different ISP's in Dar es Salaam. In recent years we have seen a significant uptake of fiber connections into TIX

and RTT between devices (Servers and routers) on the core networks (i.e. not limited end-users) is around 1-2ms via TIX. This is now approaching the physically possible minimum and is as good as it can be. Latencies and loss can still occur and will increase if any peer uses back-haul infrastructure or services that are insufficient for the traffic amounts experienced.

Reduction of Latency to K-root when it was introduced has reduced with a local instance at TIX.

4.4.1.2 Statistics on the Internet/data connectivity and access charges trends before and after the introduction of IXP

Although TISPA was not collecting statistics about pricing in the market but internet access and data connectivity charges depend largely on the costs for the transmission media for the links used. When VSAT connections were used, the price of satellite capacity translated very directly into a price for the end-user. Then and even now the share of Internet traffic transferred over TIX can be estimated at only 1-2% of traffic used by end users. Because of that there was not much saving to be passed on to customers.

The more important aspect is that new applications like, TRA online processing system, local server hosting and mutual internet backup between ISP's were made possible.

The reduction of Internet pricing which did happen has to be mainly credited to Submarine fiber systems landing in East Africa. These cables drastically reduced that cost to obtain connectivity to the rest of the Internet. This also first introduced a system of volume discounts (for a 50 Mbps service less is cheap per Mbps than for a 5 Mbps service) much more significant than what was available over VSAT connections.

This again had two effects: whereas during times of VSAT connectivity every ISP had their own connection to the internet and low economies of scale were realized, now the benefits were much higher and some providers elected to not have their own connections, but rather purchase that as a service from other bigger local players, who in turn could increase their volume (and volume discounts) on international capacity.
Secondly, separate POP's now all needed to be interconnected so that they can all be connected to the submarine fibers. This put “bridges” between the “islands” of VSAT connectivity mentioned before. This again increased the volumes of traffic aggregated in

one place, and it increased terrestrial connectivity within and between providers, increasing the benefits the IXP could offer.

4.4.1.3 Yearly statistics on the Internet/data traffic exchanged since the establishment of the IXP

Statistics on the traffic exchanged at TIX could not be realized because some data were missing, since new servers for the data collection were installed, but generally there was seen a steady increase in traffic exchanged over TIX, with always a little seasonal pause in progress around the December holiday season, as can be expected.

Traffic reached:

- 1Mbps peak in July 2004
- 2Mbps peak in March 2005
- 2-hour average of 1Mbps in September 2005
- Peak 5.5Mbps and 2Mbps of 24-hour average in June 2009 as shown in figure 4.1 below.

Growth September 2004 – September 2005:

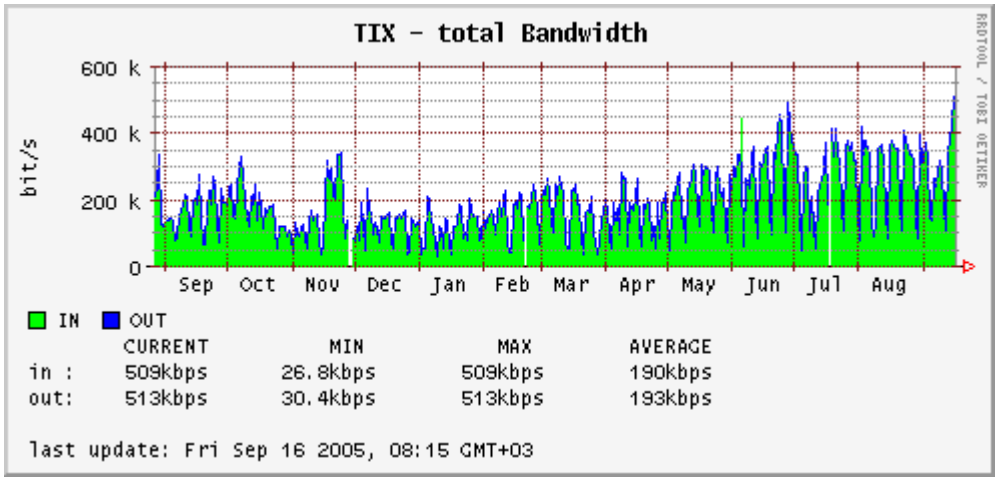


Figure 4.1

4.4.1.4 Traffic trends since the establishment of TIX

The amount of traffic passing the IXP does steadily increase. It has to be mentioned that at the introduction of Submarine Fibers, internet access costs have decreased and QoS and user experience have improved, so that use of external application like free web-based email services hosted abroad is still common place.

The reason for such increase it is probable that until now traffic via the IXP has increased at the same factors as international capacities have increased, thus remaining at a relatively low 1-2%.

There is a need to encourage local hosting of content and connection of all important networks - both content and “eyeballs” (consumer networks). These can be either connected directly to TIX or via any of the established providers who have a connection at TIX, as long as provisions are made that traffic from and to all the other TIX connected networks is exchanged locally. Soon initiatives from UDSM, TERNET and EGA will increase the traffic exchanged locally if can have their networks and services reachable via TIX.

For increased traffic growth at IXP's, both consumer (“eyeball”) networks and content providers have to be connected, so that traffic – which is mainly between these two kinds of operators – can flow over the IXP. The presence of content networks has still to be increased.

4.4.1.5 Membership and charging mechanism at TIX

Before a new peer join TIX need to confirm acceptance of Memorandum of Understanding (MoU) available at TISPA. Charges (also mentioned in the MoU) are a once-off setup charge of USD 500 and an annual port fee of USD 2500 for non TISPA members or USD 2000 for TISPA members.

There is not restriction or charge on the traffic exchanged, maximum use is encouraged. The TIX ports are capable of speeds of 1Gbps.

Peers from other countries are allowed to connect to TIX without any restriction. To date they had one request from a provider in Zimbabwe, but this has not materialized yet. Reachability to Wananchi Group in Kenya is advertised through SimbaNET (member of that group). Networks from neighboring countries (as of now Burundi, Zambia, Malawi and Seychelles) are customers of Tanzania based providers who are at TIX, and thus efficient routing between these networks and others at TIX is achieved.

This trend is contributed by the quality of service, generally when a provider in another country has customers requiring better connectivity (latency, loss, QoS) to networks or users in Tanzania (maybe for VoIP operations), that provider has incentives to build (extend) its network into Tanzania and peer with Tanzania ISP's here, so that there is more control over its traffic and QoS.

It has to be noted here that Tanzania, being at the coast and having Submarine fiber landing stations, has providers who have customers in neighboring countries (Malawi, Zambia and Burundi) and the IP blocks of these are advertised at TIX and traffic between them and most Tanzanian networks is routed within the region. In addition the first network from the Seychelles recently started to be announced at TIX, also because they purchase from an upstream provider (Tanzania based) who is present at TIX.

TIX is connected with AIXP and DIXP within Tanzania. But other participants in the other Tanzanian regions are connected through national providers who are connected to TIX, and thus packets flows stay local within Tanzania. Latencies are dependent on the transmission media and distance between source and destinations, and since “tromboning” (inefficient routing through other locations) is avoided, latencies are as good as physically possible. Currently TIX is not connected to any Internet Exchange Point outside the country.

4.4.1.6 Savings realized for the local traffic exchanged at TIX in comparison with switching the same over the international links

Both bandwidth pricing and TIX traffic were subject to significant variations within the span of one year.
At the time of this writing bandwidth pricing from carriers to ISP's can be valued around USD 100 per Mbps per month; TIX traffic is reaching 100Mbps. Thus a monthly saving of USD 10,000 is achieved.
While one year ago the traffic at TIX was less than now, international bandwidth pricing was higher, approximately resulting in the same value of USD 10,000 of monthly savings to the industry.

4.4.1.7 Services attracted by the introduction of TIX

Online transactions have been attracted by the introduction of TIX in Tanzania, for example for any inter-bank settlement exceeding 5 million needs to pass through the Bank of Tanzania using the Tanzania Inter-banking Settlement System (TISS).

TISCAN operated an Imports clearing system, tied to Databases in Dar Es Salaam and Switzerland, which was available at TIX and saw very good traffic. This was handed over to TRA.

Tanzania Revenue Authority (TRA) have automated all revenue systems paving a way for fully online transactions for almost all the payments related to government revenue collections through TRA.

Tanzania Ports Authority (TPA) has established a TIX connection; we expect this to be used for new online facilities used to clear customs goods in collaboration with TRA. The same trend is seen in the Government under the initiative of E-Government Agency.

4.4.1.8 Charging methodology to sustain the connectivity links

We all realize the benefit of deploying IXPs which in turn need connectivity between IXPs and peers as well as between IXPs. All this is cost and the challenge remains on how this links can be sustained especially between IXPs.

Since the main aims of interconnection are:-

a) Reduction of transit costs
b) Reduction of latency
c) Increase of routing diversity (in order to have alternative links of better quality, performance and/or economics)
d) Additional control over routing.

And;

a) Can be achieved by differentiated offerings by providers (for local transit or long-distance data links) or competitive pricing, which takes locally exchanged traffic into account,
b) Latencies are reduced by use of terrestrial links between cities and advertisement and exchange of all national traffic at TIX,
c) Multiple national carriers are available to provide network services between IXP locations and many other locations and regional operators can interconnect nationally at several locations
d) Can be done over separate back-haul providers.

It can be said that there are alternative means to achieve the same and since the operators of IXP's are membership organization(s) of operators and depending on some cooperation from all network operators and working for the interest of the operators, it is not in the interest for the IXP operator to start offering services which its members also offer, and thus start competing with them.

4.4.1.9 Future development of the of TIX

The future development of TIX is very promising, this being attributed by:-

a) GGC – the Google Global Cache hosts frequently visited content from Google Inc., including YouTube videos. This shall be made available to peers at TIX very soon.
b) Operators from neighboring countries, or based upcountry
c) Websites significant to Tanzania consumers being hosted inside Tanzania including EGA sites and tanzania.go.tz website
d) Carriers providing remote connections into TIX

4.4.1.10 Challenges facing the operations of the TIX

Despite success stories on the deployment of TIX in Tanzania there are some challenges which are being faced in the daily operations which include:-

a) There have been challenges with power stability and dependability throughout the operations of TIX.
b) At times some peers at TIX did not put enough attention into their links at TIX, causing them to be not connected for extended times.
c) Issues of content, as we need more content hosted locally inside Tanzania. Some current content providers connected to TIX (EGA) and additional (international) content networks to start a presence with connection to TIX.

4.4.2 Arusha Internet Exchange Point (AIXP)

4.4.2.1 The effect of IXPs deployment on latency and packet losses

The effect of deployment of IXP is also realized in AIXP where the latency in reaching a local website after the introduction of IXP has dropped from around 600ms to 5ms and packet losses have also significantly dropped.

4.4.2.2 Yearly statistics on the Internet/data traffic exchanged since the establishment of the IXP

For the case of AIXP the traffic exchanged is more meaningful when the AIXP is connected to TIX as depicted in November 2013 when AIXP was connected to TIX on trial basis as shown in figure 4.2 below. The inbound traffic was at 3.7 M as compared to 1.79 M for the outbound traffic.

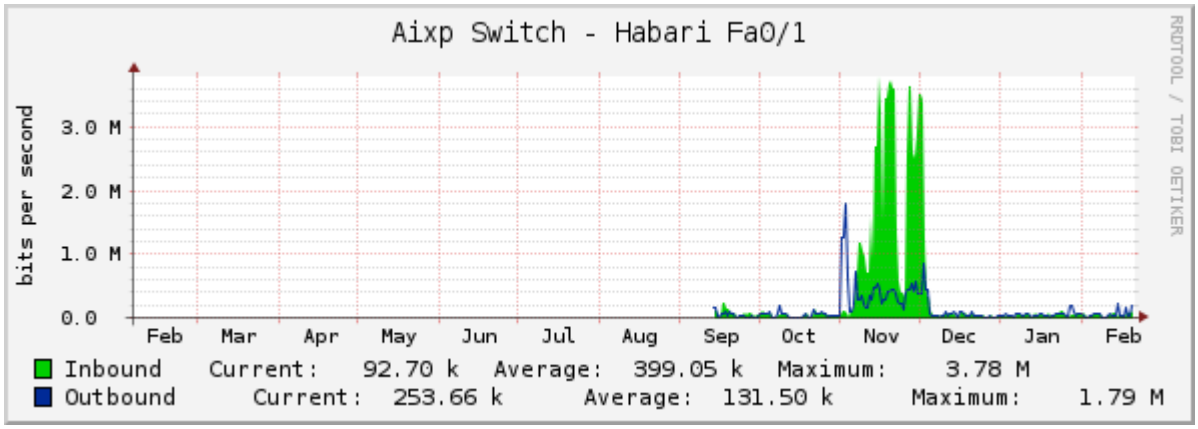


Figure 4.2

4.4.2.3 Traffic trends since the establishment of AIXP

For the case of AIXP there is a slightly increase in traffic as explained part 4.4.2.2 above the main reason being the connectivity between TIX and AIXP. The connectivity of AIXP adds more value as more traffic is guaranteed to be exchanged locally when is connected to other internet exchange points like the case of TIX.

4.4.2.4 Membership and charging mechanism at AIXP

A new peer before join the AIXP need to pay 350 USD as a one-time subscription fee and there after the cost is reduced to 350 USD per month as port fee. There is not restriction or charge on the traffic exchanged, maximum use is encouraged. Peers from other countries are allowed to connect to AIXP without any restriction.

AIXP is connected with TIX within Tanzania. But other participants in the other Tanzanian regions are connected through national providers who are connected to TIX and thereafter to AIXP and vice versa, and thus packets flows stay local within Tanzania.

4.4.2.5 Savings realized for the local traffic exchanged at TIX in comparison with switching the same over the international links

For the case of AIXP on its own the annual savings is around 4,000 USD but when connected to TIX the saving is around 2,000 USD per month as compared to when the same traffic is being routed using the international circuits.

4.4.2.6 Services attracted by the introduction of AIXP

Online transactions have been attracted by the introduction of AIXP in Tanzania, for example TRA online applications in paying Government revenues, IPTV, etc.

4.4.2.7 Future development of the of AIXP

AIXP will be effective if connected with TIX and connectivity costs reduced. Government need to have initiatives to make sure this is realized.

4.4.2.8 Challenges facing the operations of the AIXP

Despite success stories on the deployment of AIXP in Arusha, Tanzania they are faced with some challenges in the daily operations of the IXP which include:-

a) No permanent engineers to operate;
b) lack of reliable standby power;
c) Difficulty of connectivity to TIX, connectivity links especially using fiber are expensive;
d) Difficulty to have small and big ISP together.

4.4.3 Uganda Internet Exchange Point (UIXP)

4.4.3.1 The effect of IXPs deployment on latency and packet losses

One of the aims of the study was to understand the effect of effect IXPs deployment on latency and packets losses. For the case of Uganda, the latency between networks was 1600ms+ due to multiple VSAT hops.

4.4.3.2 Yearly statistics on the Internet/data traffic exchanged since the establishment of the UIXP

They don't have the statistics for the previous years since the establishment of the IXP but the statistics data only exists from January 2013 forward and the aggregate statistics charts can be seen through http://uixp.co.ug as shown in figure 4.3 below.

Growth April 2013 to April 2014:

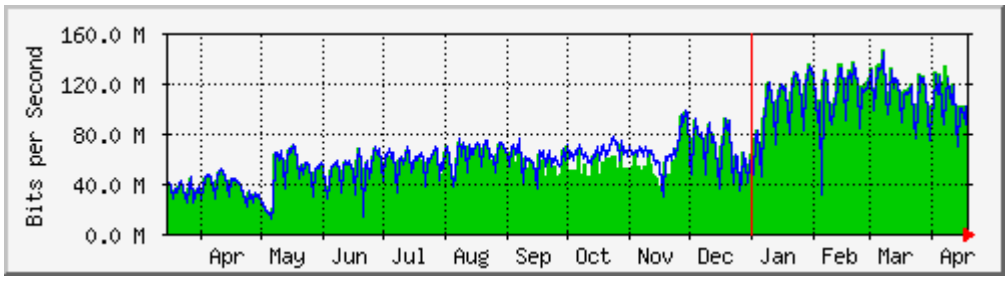


Figure 4.3

4.4.3.3 Traffic trends since the establishment of UIXP

The amount of traffic passing the UIXP does steadily increase and this is due to increase of locally hosted services, increased Internet penetration and additional peers connect over time.

4.4.3.4 Membership and charging mechanism at UIXP

None, though the UIXP is considering the introduction of access charges in the future. UIXP is connected to other IXPs in Eat Africa, for example to Kenyan Internet Exchange Point (KIXP) via ISP transit links. This in turn has significant reduction of latency and packet loss for example to Kenyan services.

4.4.3.5 Savings realized for the local traffic exchanged at UIXP in comparison with switching the same over the international links

The average traffic exchanged per year is around 240 Mbps taking into account the price of 1 Mbps being 225 USD, the total annual saving realized is (240Mbps * $225/Mbps)*12 = 648,000 USD in comparison if the same traffic was to be routed over the international circuits.

4.4.3.6 Services attracted by the introduction of UIXP

A lot of activities have been attracted by the introduction of UIXP in Uganda, for example Data-centers, website hosting, online government services, Google Cache, internet gaming services, electronic health-care services, and more.

4.4.3.7 Charging methodology to sustain the connectivity links

Many Uganda ISPs provide this service to their customers for free because it makes commercial sense to reduce their international transit costs in Mombasa.

4.4.3.8 Future development of the of UIXP

The future development of UIXP is very promising, this being attributed by improved security, additional space, additional value-added services, financial sustainability and additional exchange points in other parts of the country.

4.4.3.9 Challenges facing the operations of UIXP

Despite success stories on the deployment of UIXP in Uganda, currently are faced with space limitation as the UIXP is small and apart from that there security issues. Need permission from building owner Uganda Communications Commission to expand.

4.4.4 Rwanda Internet Exchange Point (RINEX)

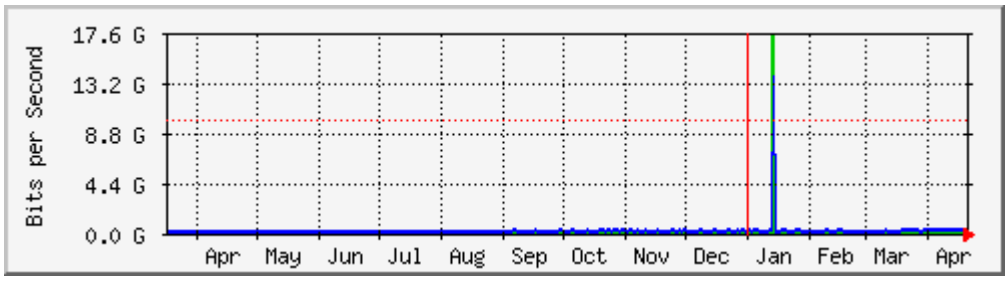
4.4.4.1 The effect of IXPs deployment on latency and packet losses

One of the aims of the study was to understand the effect of IXPs deployment on latency and packets losses. For the case of Rwanda, before the latency was between 1200 – 1600 ms and up to 2000 ms during congestion. They don't have data on the packet losses. But after the introduction of IXP the latency dropped to an average of 2.2 ms in reaching a local website with no losses.

4.4.4.2 Yearly statistics on the Internet/data traffic exchanged since the establishment of the RINEX

RINEX was established in 2004 (www.rinex.org.rw), before it was being operated on voluntary basis, no data were kept. The average traffic per year is as shown in the figure 4.5 below

Yearly graph (1 day average) from April 2013 to April 2014:



	Average	Current	Max
In	17.5 Gb/s (174.6%)	189.9 Mb/s (1.9%)	208.4 Mb/s (2.1%)
Out	13.6 Gb/s (136.1%)	155.8 Mb/s (1.6%)	208.5 Mb/s (2.1%)

Figure 4.5

4.4.4.3 Traffic trends since the establishment of RINEX

The amount of traffic passing the RINEX does steadily increase with time and now they have Google cache. They don't do packet or protocol inspections, can't tell but the aim to have a platform in place first, and then start working deep on monitoring. But the traffic increase may be is attributed by online transactions in the government services.

4.4.4.4 Membership and charging mechanism at RINEX

Currently there are no charges, but they want to put policy in place on charging mechanism, but in future for sure they will start charging.

4.4.4.5 Savings realized for the local traffic exchanged at RINEX in comparison with switching the same over the international links

The average the annual saving is around 98,843 USD in comparison if the same traffic was to be routed over the international circuits. The calculation is based on the cheapest provider and it might be a little bit higher taking into account other providers.

4.4.4.6 Services attracted by the introduction of RINEX

A lot of activities have been attracted by the introduction of RINEX in Rwanda, for example online services, online customs systems, payment of tax online, etc.

4.4.4.7 Future development of the of RINEX

The future development of RINEX is very promising, as they are planning to attract content providers, to be house at RINEX, but they will need to prepare budget and strategy for it.

4.4.4.8 Challenges facing the operations of RINEX

Currently are not faced by any challenges, as they have just taken from RURA/RINEX, and the MOU between RICTA with RURA was signed on 28/02/2014. The aim of RICTA which is currently managing RINEX is to put policy in place to maintain and grow it, before no one was accountable, although they do anticipate challenges.

4.4.5 Kenya Internet Exchange Point (KIXP)

4.4.5.1 The effect of IXPs deployment on latency and packet losses

One of the aims of the study was to understand the effect of IXPs deployment on latency and packets losses. For the case of Kenya, before the latency was very high but it has reduced significantly after the introduction of the KIXP. Packets losses have dropped as well.

4.4.5.2 Traffic trends since the establishment of KIXP

The amount of traffic passing the KIXP increases with time. But the traffic increase may be is attributed by online transactions in the government and private sector services.

4.4.5.3 Membership and charging mechanism at KIXP

The initial joining fee for the peer who wants to connect to KIXP is 30 Kenyan shillings and there is no charge on traffic exchanged between peers. Peers from other countries are also allowed to connect to the KIXP and currently connected are from 6 African countries including South Africa, Zimbabwe and Tanzania. The reason behind is that companies from these countries that connect direct to KIXP have business or their head offices in Kenya.

4.4.5.4 Future development of the of KIXP

The future development of the KIXP is bright but only if we can strive to develop country IXP by increasing traffic.

4.4.5.5 Challenges facing the operations of KIXP

As a non-profit organization, KIXP faces number of challenges including;

i. High operations cost
ii. Lack of funding mechanism to support the sustainability of KIXP

As a way forward, KIXP gets support from International Civil Society bodies with a condition that they meet International standards.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The purpose of this study was to establish the impact of deployment of internet exchange points in Tanzania. For benchmarking it also covered East Africa. This study establishes the benefits of IXPs in order to bring the socio-economic development in Tanzania. . The findings of this study provide useful information in this regard. Based on the findings and information gathered in the process of this study, the study concludes the following:

i. There is a positive impact on the quality of data and internet services due to the existence of IXPs. The results as analyzed by SPSS tool concludes that the introduction of IXPs has helped significantly to improve the quality of data and internet services by reducing the latency from around 600ms to 15ms. The packet losses have reduced significantly, all of them in turn have made the data and internet services more reliable for the content destined in Tanzania. The same has been revealed in Uganda, Kenya and Rwanda where services are more reliable, packets losses and latency has reduced significantly, for example for the case of Rwanda the latency has reduced from 1600 ms to around 3ms with almost zero packet losses.

ii. The study findings have established that the cost incurred by ISPs on international bandwidth has reduced but this not much noticeable due to lack of more local content. But with time as the local content increases this effect will be much realized as most of the traffic will be routed locally contrary to the traditional ways via international circuits.

iii. Study findings have revealed that there is an increased in traffic exchanged at the IXPs which signify that the local content is being exchanged locally. For the peers their links to the IXPs kept on increasing with time. With more development of local content the traffic exchanged at the IXPs will also continue to increase.

iv. Study findings have also revealed that content hosting has increased after the introduction of IXPs. The tendency to host the content within the country is increasing. The availability of data centers with time will also be a catalyst for more content hosting within the country.

v. Study findings have also revealed that the user experience has a positive impact towards electronic services after the introduction of IXPs especially for the Government and its institution as they have started to offer most online services in most of their activities to citizens. The banks and other private institutions are also doing the same. The same is noted in Rwanda and Uganda, for example in Rwanda IXPs has attracted online services, online customs systems, payment of tax online, etc.

5.2 Challenges

Despite of the success stories on the establishment of IXPs and the benefits they bring especially on the socio-economic development there some challenges which if addressed will improve the benefits of deployment of IXPs as highlighted above. Below are study findings on the challenges which are facing the IXPs:-

a) There have been challenges with power stability and dependability throughout the operations of IXPs
b) At times some peers at TIX do not put enough attention into their links at TIX, causing them to have long link outages
c) Most of the local content is hosted outside the country
d) No permanent staff to operate the IXPs as currently the operations of IXPs are run on voluntarily basis by members
e) Some of the potential non-ISP peers have a feeling that connectivity to TIX will be additional expenses
f) Non availability of Google cache and other CDN providers in the country.
g) IXPs interconnection is a challenge due to high backhaul charges
h) Fear of some peers that the IXPs links will be used for transiting
i) Not all ISPs and content service providers are connected to any IXP as required by Electronic and Postal Communications (Access, Co-location and Infrastructure sharing) regulations, 2011.

5.3 Recommendations

On the basis of the study findings the following recommendations for the development of IXPs needs to be addressed as follows:-

a) More investments in redundant power infrastructures at IXP will ensure the stability of operations
b) As a local traffic increases the need for peers to maintain connectivity with IXPs will be essential hence encourage more Content Delivery Network (CDNs) to be connected to IXPs
c) Issues of content, we need more content hosted locally inside Tanzania. Some current content providers connected to TIX (EGA) and additional (international) content networks to start a presence with connection to TIX
d) The IXPs should employ permanent staff for efficient operations
e) Potential peers should be encouraged and educated the importance of IXPs
f) IXPs have taken an initiative to bring Google cache to Tanzania and in the similar way more CDNs should be hosted in Tanzania
g) More members should be encouraged so that the backhaul cost can be shared
h) Interconnecting capacities between IXPs should be efficiently used for local traffic only necessary technical controls should be deployed
i) Awareness on the Electronic and Postal Communications (Access, Co-location and Infrastructure sharing) regulations, 2011 requirements should be emphasized and need enforcement.
j) For cost effective and faster Internet traffic exchanges, some of the available capacities within the public Broadband networks need to be offered by owners to facilitate direct/dedicated connectivity between the deployed IXPs

Annex I. List IXP Peers

S/N	NAME OF ISP/TIX PEER	ADDRESS	TOWN	TELEPHONE NUMBERS
1	Raha	P. O. Box 12933	Dar Es Salaam & Arusha	+255 222125230
2	Africa Online	P. O. Box 2721	Dar Es Salaam & Arusha	255 222 666 728
3	SimbaNet	P. O. Box 14827	Dar Es Salaam	+255 22216 3800
4	Cats-Net	P. O. Box 2599	Dar Es Salaam	+255 22 2121688
5	Bank of Tanzania	P. O. Box 2939	Dar Es Salaam	+255 222233000
6	SatCoNet	P. O. Box 79315	Dar Es Salaam	+255 2180635/8
7	COSTECH / TERNET	P. O. Box 4302	Dar Es Salaam	255-22-2927538
8	Spicenet	P. O. Box 14508	Dar Es Salaam	+255 222123421
9	AfSat	P. O. Box 6154	Dar Es Salaam	+255 22 266 4413
10	UCC	P. O. Box 35062	Dar Es Salaam	+255 222410641
11	DIT	P. O. Box 2958	Dar Es Salaam	+255 222150174
12	TTCL	P. O. Box 9070	Dar Es Salaam	+255 222142000
13	Vodacom	P. O. Box 2369	Dar Es Salaam	
14	Airtel Tanzania	P. O. Box 9623	Dar Es Salaam	+255 784 103 001
15	TRA	P. O. Box 11491	Dar Es Salaam	+255 22 2119640
16	WIA	P. O. Box 5117	Dar Es Salaam	+ 255 22 2129147
17	tzNIC	LAPF Millennium Towers	Dar Es Salaam	+255 22 2772659
18	VIZADA Tanzania	P. O. Box 105905	Dar Es Salaam	+255 (22) 276 1341
19	Zantel	Msasani	Dar Es Salaam	+255775775775
20	Tigo	P. O. Box 2929	Dar Es Salaam	0716123103
21	UhuruOne	P. O. Box 20656	Dar Es Salaam	+255222124713
22	Aptus Solutions	759/10 Azikiwe Street	Dar Es Salaam	+255 22 2128589/90
23	Six Telecoms Company Limited	5th Floor, Barclays House Ohio Street	Dar Es Salaam	+255 786 963 066
24	Tanzania Ports Authority (TPA)	P.O. Box 9184	Dar Es Salaam	(255) 22-22110401/5 22110375
25	Benson Online	P.O. Box 645	Arusha	+255 272 544 321
26	Nexus Digital	P.O. Box 2040	Arusha	+255 (27)
27	Milan Cable Television	P.O. Box 10367	Arusha	255 (27) 2504527
28	CyberNet	P.O. Box 9184	Arusha	255 (27)
29	Datel	P.O. Box 9184	Arusha	+255 (27)

Annex II: List of IXPs

S/N	NAME OF IXP	LOCATION
1	Tanzania Internet Exchange Point (TIX)	Dar es Salaam
2	Arusha Internet Exchange Point (AIXP)	Arusha
3	Uganda Internet Exchange Point (UIXP)	Kampala
4	Rwanda Internet Exchange Point (RINEX)	Kigali
5	Kenya Internet Exchange Point (KIXP)	Nairobi

Appendix I

QUESTIONNAIRE: TCRA-01

UNITED REPUBLIC OF TANZANIA
TANZANIA COMMUNICATIONS REGULATORY AUTHORITY

Dear Sir/Madam:

The Tanzania Communications Regulatory Authority (TCRA) is conducting a Study to establish the impact of Internet Exchange Points (IXPs) on enhancing data and internet services particularly in Tanzania and East Africa in general.

You have been selected to kindly provide your experience on the impact of IXPs just to inform the Authority on the usefulness of IXPs. The Authority hereby requests you to take few minutes to complete this Questionnaire and would like to assure you that the information you are providing is confidential, no name or contact will appear in any of the Report or Document of the Authority.

I look forward to your usual cooperation and support in making this Study a success.

Thank you very much for your time,

Prof. John S. Nkoma
DIRECTOR GENERAL

INSTRUCTION TO RESPONDENTS:

- ***Please Complete this questionnaire and hand it back to the TCRA officer***
- ***ALL information collected from you will be treated confidential and will not be disclosed to any unauthorized person***

CONTACTS DETAILS:

FIRM NAME AND ADDRESS	**CONTACT PERSON NAME**	**DESIGNATION**	**SIGNATURE**	**TELEPHONE NUMBERS & E-MAIL ADDRESS**
				1.
				2.
				E-MAIL ADDRESS:

A. QUALITY OF SERVICE: Please attach statistics on latency and packet losses trends before and after the introduction of IXP

Please write the correct answer in the space provided

Name of the IXP.....				
Quality of internet and data services before the introduction of Internet Exchange Point (IXP)		**Quality of internet and data services after the introduction Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the speed of internet in accessing local content **before** the introduction Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the speed of internet in accessing local content **after** the introduction of Internet Exchange Point (IXP)	**( )**	1 - Excellent 2 - Very Good 3 - Good 4 - Fair 5 - Bad
2.a) How do you rate the latency of reaching a local website **before** the introduction Internet Exchange Point (IXP).	**( )**	2.b) How do you rate the latency of reaching a local website **after** the introduction of Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
3.a) How do you rate data packet losses **before** the introduction Internet Exchange Point (IXP).	**( )**	3.b) How do you rate data packet losses **after** the introduction Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate

				4 - Low 5 - Very Low
4.a) How do you rate the reliability of data and internet services **before** the introduction of Internet Exchange Point (IXP)	**( )**	4.b) How do you rate the reliability of data and internet services **after** the introduction of Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low

B: TARIFFS:

Please write the correct answer in the space provided

Cost of Internet/data connectivity and access charges before the introduction of Internet Exchange Point (IXP)		**Cost of Internet/data connectivity and access charges after the introduction of Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the cost of internet/data access charges incurred by peers **before** the introduction of Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the cost of internet/data access charges incurred by peers **after** the introduction of Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
2) The introduction of Internet Exchange Point (IXP) has created a big role in the reduction of internet monthly access charges to the peers			**( )**	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree
3) The introduction of Internet Exchange Point (IXP) has helped peers to reduce the cost of international bandwidth			**( )**	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

C: TRAFFIC LOCALISATION

Please write the correct answer in the space provided

Exchange of Local Traffic		**Choice**
1) How do you rate with time the traffic exchanged at the IXP	( )	1 - Very High 2 - High 3 - Moderate 4 - Low

		5 - Very Low
2.a) In which year this Internet Exchange Point (IXP) was established		.....
2.b) What was the data traffic exchanged in the first year after the establishment of the Internet Exchange Point (IXP)		.....Kbps .....Mbps .....Gbps
2.c) What is the current volume of data traffic exchanged at the Internet Exchange Point (IXP)		.....Kbps .....Mbps .....Gbps

D: CONTENT HOSTING

Please write the correct answer in the space provided

Local content hosting before the introduction of Internet Exchange Point (IXP)		**Local content hosting after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) Local Content hosting in the country was minimal **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) Local Content hosting in the country has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

E: E-SERVICES

Please write the correct answer in the space provided

E-service activities before the introduction of Internet Exchange Point (IXP)		**E-service activities after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) E-services were very low **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) E-services has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

THANK YOU FOR YOUR TIME

Prof. John S. Nkoma

DIRECTOR GENERAL

Appendix II

QUESTIONNAIRE: TCRA-02

UNITED REPUBLIC OF TANZANIA
TANZANIA COMMUNICATIONS REGULATORY AUTHORITY

Dear Sir/Madam:

The Tanzania Communications Regulatory Authority (TCRA) is conducting a Study to establish the impact of Internet Exchange Points (IXPs) on enhancing data and internet services particularly in Tanzania and East Africa in general.

You have been selected to kindly provide your experience on the impact of IXPs just to inform the Authority on the usefulness of IXPs. The Authority hereby requests you to take few minutes to complete this Questionnaire and would like to assure you that the information you are providing is confidential, no name or contact will appear in any of the Report or Document of the Authority.

I look forward to your usual cooperation and support in making this Study a success.

Thank you very much for your time,

Prof. John S. Nkoma
DIRECTOR GENERAL

INSTRUCTION TO RESPONDENTS:

- ***Please Complete this questionnaire and hand it back to the TCRA officer***

- ***ALL information collected from you will be treated confidential and will not be disclosed to any unauthorized person***

CONTACTS DETAILS:

FIRM NAME AND ADDRESS	**CONTACT PERSON NAME**	**DESIGNATION**	**SIGNATURE**	**TELEPHONE NUMBERS & E-MAIL ADDRESS**
				1.
				2.
				E-MAIL ADDRESS:

A. QUALITY OF SERVICE: Please attach statistics on latency and packet losses trends before and after joining the IXP

Please write the correct answer in the space provided

Which IXP are you peering with?				
Quality of internet and data services before joining the Internet Exchange Point (IXP)		**Quality of internet and data services after joining the Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the speed of internet in accessing local content in Tanzania **before** joining the Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the speed of internet in accessing local content in Tanzania **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Excellent 2 - Very Good 3 - Good 4 - Fair 5 - Bad
2.a) How do you rate the latency of reaching a local website **before** joining the Internet Exchange Point (IXP).	**( )**	2.b) How do you rate the latency of reaching a local website **after** joining the Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
3.a) How do you rate data packet losses **before** joining the Internet Exchange Point (IXP).	**( )**	3.b) How do you rate data packet losses **after** joining the Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low

4.a) How do you rate the reliability of data and internet services **before** joining the Internet Exchange Point (IXP)	**( )**	4.b) How do you rate the reliability of data and internet services **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low

B: TARIFFS: Please attach statistics on bandwidth cost trends before and after joining the IXP (***Please write the correct answer in the space provided)***

Cost of Internet/data connectivity and access charges before joining the Internet Exchange Point (IXP)		**Cost of Internet/data connectivity and access charges after joining the Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the cost of internet/data access charges you incurred **before** joining the Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the cost of internet/data access charges you incur **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
2) The introduction of Internet Exchange Point (IXP) has helped your organization to reduce the cost of international bandwidth			**( )**	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

C: TRAFFIC LOCALISATION

Please write the correct answer in the space provided

Exchange of Local Traffic		**Choice**
1.a) How do you rate the utilization of your link to IXP	( )	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
2.a) In which year your organization established a link to the Internet Exchange Point (IXP)		.....

2.b) What was the initial utilization of your link when you established the connectivity to the Internet Exchange Point (IXP)	.....Kbps .....Mbps
2.c) What is the current utilization of your link to the Internet Exchange Point (IXP)	.....Kbps .....Mbps

D: CONTENT HOSTING: Please attach statistics on local content hosting, before and after the introduction of IXP

Please write the correct answer in the space provided

Local content hosting before the introduction of Internet Exchange Point (IXP)		**Local content hosting after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) Local Content hosting in the country was minimal **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) Local Content hosting in the country has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

E: E-SERVICES (*Please write the correct answer in the space provided)*

E-service activities before the introduction of Internet Exchange Point (IXP)		**E-service activities after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) E-services were very low **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) E-services has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

THANK YOU FOR YOUR TIME

Prof. John S. Nkoma

DIRECTOR GENERAL

Appendix III

QUESTIONNAIRE: TCRA-03

UNITED REPUBLIC OF TANZANIA
TANZANIA COMMUNICATIONS REGULATORY AUTHORITY

Dear Sir/Madam:

The Tanzania Communications Regulatory Authority (TCRA) is conducting a Study to establish the impact of Internet Exchange Points (IXPs) on enhancing data and internet services particularly in Tanzania and East Africa in general.

You have been selected to kindly provide your experience on the impact of IXPs just to inform the Authority on the usefulness of IXPs. The Authority hereby requests you to take few minutes to complete this Questionnaire and would like to assure you that the information you are providing is confidential, no name or contact will appear in any of the Report or Document of the Authority.

I look forward to your usual cooperation and support in making this Study a success.

Thank you very much for your time,

Prof. John S. Nkoma
DIRECTOR GENERAL

INSTRUCTION TO RESPONDENTS:

- ***Please Complete this questionnaire and hand it back to the TCRA officer***
- ***ALL information collected from you will be treated confidential and will not be disclosed to any unauthorized person***

CONTACTS DETAILS:

FIRM NAME AND ADDRESS	CONTACT PERSON NAME	DESIGNATION	SIGNATURE	TELEPHONE NUMBERS & E-MAIL ADDRESS
				1.
				2.
				E-MAIL ADDRESS:

A. QUALITY OF SERVICE: Please attach statistics on latency and packet losses trends before and after joining the IXP

Please write the correct answer in the space provided

Which IXP are you peering with?				
Quality of internet and data services before joining the Internet Exchange Point (IXP)		**Quality of internet and data services after joining the Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the speed of internet in accessing local content in Tanzania **before** joining the Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the speed of internet in accessing local content in Tanzania **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Excellent 2 - Very Good 3 - Good 4 - Fair 5 - Bad
2.a) How do you rate the latency of reaching a local website **before** joining the Internet Exchange Point (IXP).	**( )**	2.b) How do you rate the latency of reaching a local website **after** joining the Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
3.a) How do you rate data packet losses **before** joining the Internet Exchange Point (IXP).	**( )**	3.b) How do you rate data packet losses **after** joining the Internet Exchange Point (IXP).	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
4.a) How do you rate the reliability of data and internet services **before** joining the Internet Exchange Point (IXP)	**( )**	4.b) How do you rate the reliability of data and internet services **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate

				4 - Low 5 - Very Low

B: TARIFFS: Please attach statistics on bandwidth cost trends before and after joining the IXP

Please write the correct answer in the space provided

Cost of Internet/data access charges before joining the Internet Exchange Point (IXP)		**Cost of Internet/data access charges after joining the Internet Exchange Point (IXP)**		**choice**
1.a) How do you rate the cost of internet/data access charges you incurred **before** joining the Internet Exchange Point (IXP)	**( )**	1.b) How do you rate the cost of internet/data access charges you incur **after** joining the Internet Exchange Point (IXP)	**( )**	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
2) The introduction of Internet Exchange Point (IXP) has helped your organization to reduce the cost of internet monthly access charges			**( )**	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

C: TRAFFIC LOCALISATION

Please write the correct answer in the space provided

Exchange of Local Traffic		**Choice**
1) How do you rate the utilization of your link to IXP	( )	1 - Very High 2 - High 3 - Moderate 4 - Low 5 - Very Low
2.a) In which year your organization established a link to the Internet Exchange Point (IXP)		.....
2.b) What was the initial utilization of your link when you established the connectivity to the Internet Exchange Point (IXP)		.....Kbps .....Mbps
2.c) What is the current utilization of your link to the Internet Exchange Point (IXP)		.....Kbps .....Mbps

D: CONTENT HOSTING: Please attach statistics on local content hosting, before and after the introduction of IXP

Please write the correct answer in the space provided

Local content hosting before the introduction of Internet Exchange Point (IXP)		**Local content hosting after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) Local Content hosting in the country was minimal **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) Local Content hosting in the country has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

E: E-SERVICES

Please write the correct answer in the space provided

E-service activities before the introduction of Internet Exchange Point (IXP)		**E-service activities after the introduction of Internet Exchange Point (IXP)**		**Choice**
1.a) E-services were very low **before** the introduction of Internet Exchange Point (IXP)	( )	1.b) E-services has increased **after** the introduction of Internet Exchange Point (IXP)	( )	1 – Strongly Agree 2 - Agree 3 – Don't Know 4 - Disagree 5 – Strongly Disagree

THANK YOU FOR YOUR TIME

Prof. John S. Nkoma
DIRECTOR GENERAL