Internet Society

Moving Toward an Interconnected Africa:

The 80/20 Initiative

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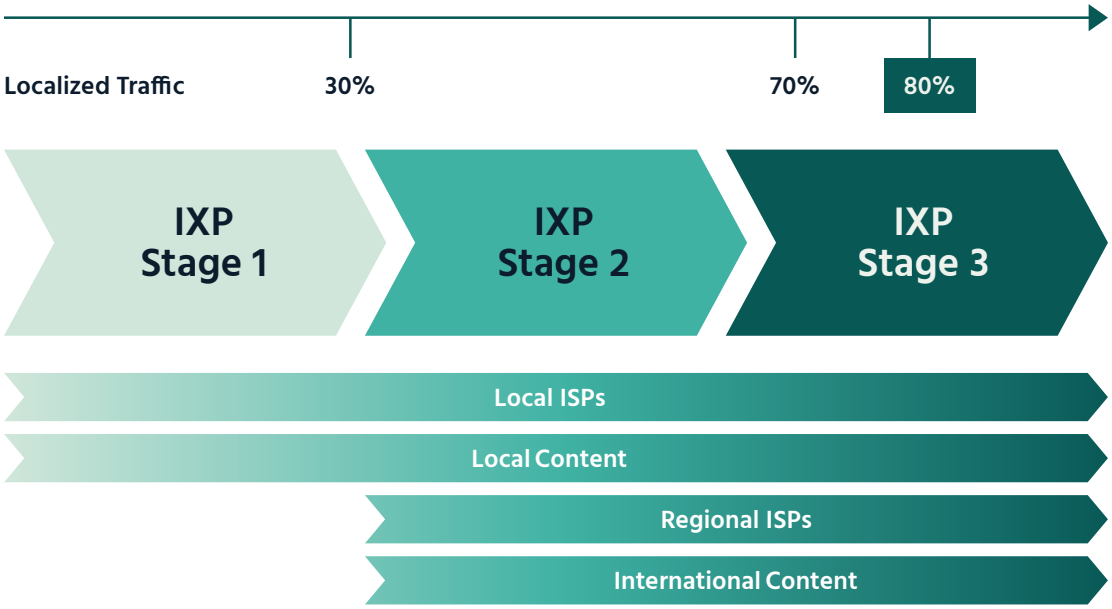
Contents

Executive Summary

The Africa Regional Bureau of the Internet Society has had an Interconnection and Traffic Exchange (ITE) Program for the past 10 years. The Internet Society set a goal, adopted by the Internet community, that 80% of African Internet traffic be accessed in Africa in 2020 ("80/20 by 2020"). Community activities have included longstanding support for Internet exchange points (IXPs) in the region, along with support for local content hosting. The reason for emphasizing the role of IXPs is simple: IXPs are focal points for localizing traffic—their use lowers the cost and latency of traffic exchange and increases the resilience of the Internet ecosystem. This paper assesses the overall status of IXPs in Africa and offers a deep dive into six countries, each representing a subregion of Africa.

In a recent paper,[1] we identified three stages of development, depending on the level of localized traffic, and driven by connections between and among Internet service providers (ISP) and content providers (Figure 1). We showed that both Kenya and Nigeria had moved from the cusp of Stage 2, with 30% local traffic in 2012, to the cusp of Stage 3, with 70% local traffic in 2020. Our review revealed that of all the countries in Africa with IXPs, the most developed Internet ecosystem in Africa is South Africa, which clearly has reached the goal of 80% of localized traffic, followed by Kenya and Nigeria.

Figure 1. Internet Ecosystem Stages of Development (Source: Internet Society, 2020)



1 Michael Kende, "Anchoring the African Internet Ecosystem: Lessons from Kenya and Nigeria's Internet Exchange Point Growth" (Internet Society, June 2020), https://www.internetsociety.org/wp-content/uploads/2020/06/Anchoring-the-African-Internet-Ecosystem-Lessons-from-Kenya-and-Nigeria.pdf

Key Findings

One aspect that Kenya, Nigeria, and South Africa have in common is that each of their largest IXPs has at least 50 members. The number of members at an IXP is a strong indicator of the health of a country's Internet ecosystem—both that there are so many networks and that they are all connected to the IXP. In particular, a high number of members reflects a significant diversity of connected networks. Due to the economics of the business, every country has a limited number of access networks—be they ISPs or mobile network operators (MNOs); the remaining members are generally content providers, government agencies, international carriers, and enterprises.

We also discovered a positive correlation between the number of members in an IXP and the amount of traffic that moves through it, a correlation that highlights the benefits of having more connected networks. Not only does the amount of traffic increase with more members, the amount of traffic per member tends to increase with more members. This trend suggests a generative impact of increased membership as more traffic is exchanged, which, in turn, helps countries attain higher stages of Internet ecosystem development.

Figure 2 details a series of enablers for increasing an IXP's membership and traffic generation. Each enabler maximizes the number of potential members of the IXP, which can be built on with the next enabler.

Figure 2. Membership Enablers (Source: Internet Society, 2021)

On the road to the 80/20 goal, there is much good news to report. Since the launch of the goal in 2010, the number of IXPs founded in Africa has tripled—an inspiring testimony to the power of stakeholder and community efforts. Today, more than half the countries in Africa have an IXP, and six countries have more than one. Similarly, the presence of international content delivery networks (CDNs) has significantly increased, along with locally developed content. While the 80/20 goal was not reached by last year, the community should set a new goal with the confidence that its activities will continue to have a strong, positive influence on the African IXP ecosystem. It is our intention that this paper starts a dialogue toward developing a new goal for the coming decade, and that the new goal be achieved by including the proven membership enablers described herein.

Appreciation

The Internet Society recognizes Facebook for its generous and continued support for IXP development in Africa under the IXP Partnership Project. This paper represents a significant achievement from this collaboration.

Acknowledgments

This paper is the result of assistance by a number of individuals and organizations. First and foremost, the author thanks Jane Coffin and Michuki Mwangi of the Internet Society for their ongoing leadership on these issues and with this project, Israel Nyoh and Ghislain Nkeramugaba for their invaluable input, and Karen Rose for her review. Thanks also to Michelle Speckler for expert editing.

The author gratefully acknowledges the following individuals, who took the time to respond to the IXP survey.

IXP	Country	Respondent
TGIX	Togo	Damnam Bagolibe, Executive Director
MIX	Malawi	Dr. Paulos Nyirenda, Chair of Malawi ISP Association
Angola-IXP	Angola	Silvio Almada, CEO, Angola Internet Association
UIXP	Uganda	Kyle Spencer, Executive Director
AIXP	Tanzania (Arusha)	James Julius, IXP Manager
SIXP	Sudan	Eng. Ahmad Ali Karamallah, Manager
CON-IX	Guinea	Abdoulaye Sivory Sakho, Secrétaire Exécutif IXP-GUINEE
NAPAfrica	South Africa	Andrew Owens, Manager of Interconnection and Peering
LUBIX	Democratic Republic of Congo	Nico Tshintu Bakajika, Operation Manager
SIXP	Gambia	Abdoulie Sowe, SIXP Administrator
DjIX	Djibouti	Hachin-Arafat Mohamed, Data Center Manager
GIX	Ghana	GIX Support Team
RINEX	Rwanda	Richard Buregeya, Network and System Engineer
CIVIX	Ivory Coast	Armand Koffi, Manager
MOZIX	Mozambique	Antonio Godinho, Network Administrator
IXPN	Nigeria	Jacob Dagunduro, Senior Network Manager
Gab-IX	Gabon	Willy Steeve Kaptue Konga, IT Manager
MIXP	Mauritius	Keessun Fokeerah, IXP Operator
BFIX	Burkina Faso	Jean Baptiste Millogo, Executive Director
CAIX	Egypt	Haitham El Nakhal, Senior Expert
KINIX	Democratic Republic of Congo	Daniel Alongi, Technical Manager
TIX	Tanzania	Frank Habicht, Technical Manager-Core Network, SimbaNET
Angonix	Angola	Crisóstomo Mbundu, Business Development Manager

The author interviewed a large number of stakeholders in each of the case study countries, and expresses his appreciation to them, as well. Special thanks to the managers of the IXPs who introduced him to other stakeholders and patiently answered questions about their IXPs.

- Abdourahmane Dia, Managing Director, Virtual Technologies and Solutions, Burkina Faso
- Christian Muhirwa, Chief Executive Officer, Broadband Systems Corporation, Rwanda
- Gabriel Zema, Managing Director, Infoset Group, Democratic Republic of Congo
- Haitham El-Nakhal, Senior Expert, National Telecom Regulatory Authority, Egypt
- Ibrahim Ballo, G-Coud Project Director, Agence Nationale de Promotion des Technologies de l'Information et de la Communication, Burkina Faso
- Ish Sookun, Systems Architect, LSL Digital, Mauritius
- Jean-Baptiste Millogo, Executive Director, Burkina Faso Internet Exchange Point, Burkina Faso
- Jose Assis, Chief Executive Officer, Ipworld Lda–Telecommunications Services, Angola
- Keessun Fokeerah, IXP operator, MIXP, Mauritius
- Martijn Schmidt, Vice President of Network, i3D.net, a Ubisoft company, Netherlands
- Nico Tshintu Bakajika, Operations Director, ISPA-DRC and RDC-IX, Democratic Republic of Congo
- Ranveer K Seetaloo, Head of Telecom Business, Rogers Capital Technology Services Ltd., Mauritius
- Richard Buregeya, Network and System Engineer, Rwanda Internet Community and Technology Alliance (RICTA), Rwanda
- Silvio Almada, Chief Executive Officer, Angola Internet Association, Angola

Thank you to Andrew Owens and Kyle Spencer for providing the data on NAPAfrica and UIXP respectively, and to Bijal Sanghani, Secretary General of EuroIX for her assistance. In addition, the author thanks the members of the three international CDNs, who compiled data and insights on the case study countries and who answered a number of questions about the countries. In addition, other individuals and companies, including Etisalat Misr, provided valuable insight, but did not wish to be thanked personally.

Introduction

The Africa Regional Bureau of the Internet Society has had an Interconnection and Traffic Exchange Program for the past 10 years.[2] The goal of the Internet community has been for 80% of African Internet traffic be accessed in Africa in 2020 ("80/20 by 2020"). Note that the content of the traffic could be international, regional, or local to a country—the issue is to have it hosted in, and accessed from, Africa. Community activities have included longstanding support for IXPs in the region, along with support for local content hosting.

As part of the ITE program, the Internet Society released a paper in 2012 documenting the benefits of having an IXP, with a focus on Kenya and Nigeria.[3] The paper quantified the benefits of eliminating the international tromboning of traffic by lowering both the cost of traffic exchange and latency. As a result of lower latency, the usage of content hosted in the countries increased, which raised the revenues of access networks. A set of follow-up studies focused on the benefits of local content hosting, illustrated and quantified those benefits in Rwanda, and examined factors that enhanced enabling connectivity environments across the region.[4]

In 2020, the Internet Society released an update to the original Kenya/Nigeria study to showcase how those IXPs have evolved and the impact of a number of changes in theirlocal ecosystems.[5] The study documented the significant progress made in those countries since the original 2012 study, and identified the strengths that led to this progress. The study also identified gaps that prevented the countries from reaching the 80/20 by 2020 goal, notably with respect to enticing local content providers and smaller ISPs to connect to their domestic exchanges. Finally, the study offered recommendations for relevant stakeholders, including governments, on how to further develop the IXPs and the broader Internet ecosystems in their countries.

This year's study provides a wider perspective on the evolution of interconnection at IXPs in the African continent via first a birds-eye view of the continent, and then a closer look into one country in each of six subregions: Angola (Southern Africa), Burkina Faso (Western

2 Interconnection and Traffic Exchange Program brochure, https://www.internetsociety.org/resources/doc/2015/interconnection-and-traffic-exchange-ite-program-brochure/

3 Michael Kende and Charles Hurpy, "Assessment of the Impact of Internet Exchange Points – Empirical Study of Kenya and Nigeria," (Internet Society, April 2012), https://www.internetsociety.org/wp-content/uploads/2017/09/Assessment-of-the-impact-of-Internet-Exchange-Points---empirical-study-of-Kenya-and-Nigeria.pdf

4 Michael Kende and Karen Rose, "Promoting Local Content Hosting to Develop the Internet Ecosystem" (Internet Society, January 2015), https://www.afpif.org/wp-content/uploads/2017/10/Promoting-Local-Content-Hosting-to-Develop-the-Internet-Ecosystem.pdf and Michael Kende and Bastiaan Quast, "The Benefits of Local Content Hosting: A Case Study" (Internet Society, May 2017), https://www.internetsociety.org/wp-content/uploads/2017/08/ISOC_LocalContentRwanda_report_20170505.pdf

5 Michael Kende, "Anchoring the African Internet Ecosystem: Lessons from Kenya and Nigeria's Internet Exchange Point Growth" (Internet Society, June 2020), https://www.internetsociety.org/wp-content/uploads/2020/06/Anchoring-the-African-Internet-Ecosystem-Lessons-from-Kenya-and-Nigeria.pdf

Africa), Democratic Republic of Congo (DRC) (Central Africa), Egypt (Northern Africa), Mauritius (Indian Ocean), and Rwanda (Eastern Africa). The study applies the findings of the Kenya/Nigeria update, as well as other learnings and recommendations for creating enabling environments for IXPs and Internet ecosystems, including best practices and policies. In doing so, a running theme emerged: the number and diversity of members in an IXP is a reliable indicator of the strength and development of its ecosystem; increasing the membership should, therefore, be a focus of IXPs seeking to expand.

Finally, this study examines the success of the ITE program—from its inception to the present day, the current status quo, and what remains to be done to achieve its goals, while also raising the question of whether and how to revise those goals. We anticipate this study will provide a foundation for developing future goals and activities for both the ITE Program and the broader Internet community.

The Three Stages of Internet Ecosystem Development

An IXP's role is multifold. It allows local exchange of traffic among access providers, and between content providers and access providers. It can enable the exchange of local traffic and access to content, and it can deliver benefits to local Internet subscribers (aka, end users) and organizations. And as an IXP grows, it can become a hub for exchanging and accessing cross-border traffic within its region, as well as for international traffic and content. While assessing the development of an IXP, it serves us to keep sight of the specific benefits of IXP ecosystem growth. In particular, by enabling local traffic to be exchanged locally, the following three benefits emerge.[6]

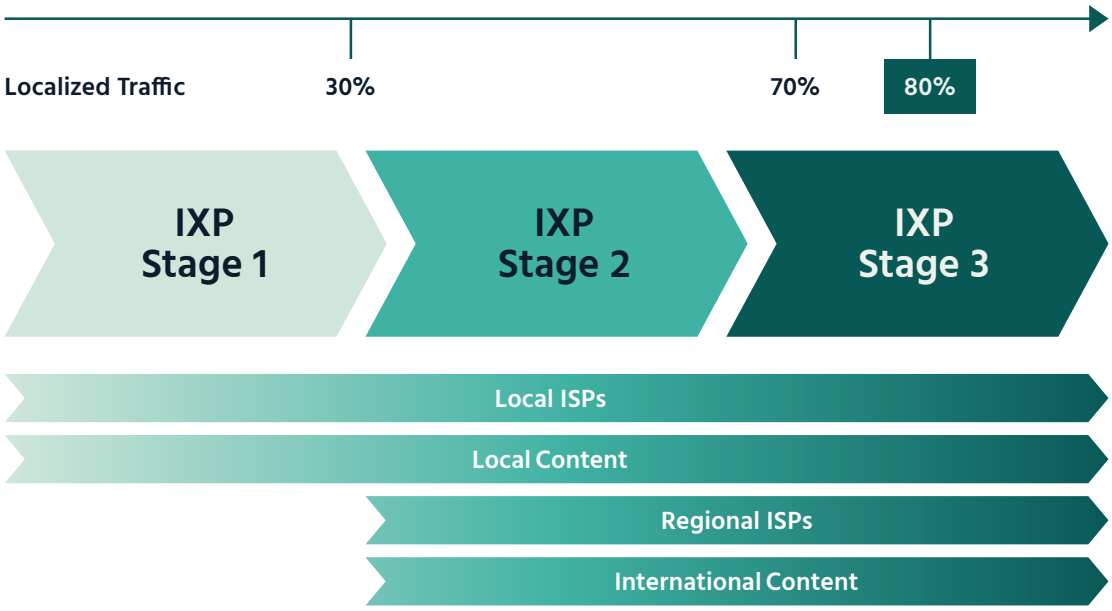
- **Cost savings.** Avoiding expensive IP transit to exchange traffic abroad saves ISPs money, which may be passed on to their customers in the form of lower prices or larger bundles of data.
- **A reduction in traffic exchange latency.** Latency reduction, in turn, increases content usage.
- **More revenues for access networks.** Increased usage increases revenues for access networks that sell data packages to users.

In addition, a much broader impact on the ecosystem appears when local hosting is expanded. As the IXP benefits emerge, so does increased demand for data centers to hold content and services that can be made available over the IXP. This helps to support local hosting providers, increase digitalization of services, and promote the development of skills and businesses to meet the growing demand for local hosting.

Based on the experiences observed in Kenya, Nigeria, and other countries, the Internet Society has identified the three evolutionary stages of development of an Internet ecosystem (Figure 3). As an IXP systematically moves from Stage 1 to Stage 3, the benefits of each stage increase, and a broader ecosystem grows around the IXP.

6 | Kende and Charles Hurpy, "Assessment of the Impact of Internet Exchange Points – Empirical Study of Kenya and Nigeria," (Internet Society, April 2012), https://www.internetsociety.org/wp-content/uploads/2017/09/Assessment-of-the-impact-of-Internet-Exchange-Points---empirical-study-of-Kenya-and-Nigeria.pdf

Figure 3. Internet Ecosystem Stages of Development (Source: Internet Society, 2020)



- **Stage 1. The IXP mainly is used to exchange local traffic between local access providers.** Benefits include lower costs for the access providers, lower latency of traffic exchange from not tromboning traffic, and greater network resilience from not relying on international connections for local traffic exchange. In addition, end users gain lower latency and greater resilience, and they may share in the cost savings reaped by the ISPs.[7] Stage 1 localizes up to approximately 30% of total traffic, as it does not involve significant amounts of content.
- **Stage 2. International content is made available locally, attracted by the IXP and its member networks.** The benefits build on those gained in Stage 1, including increased cost savings, lower latency when accessing content, and greater resilience. The decreased latency results in an increase in usage of that content, which increases the revenues of those ISPs that sell data packages. In addition, the lower cost of accessing content may be passed on to end users; and ISPs from the region may begin to connect to the IXP in order to access cross-border, subregional, and international content. Stage 2 localizes approximately 30% to 70% of total traffic.

7 ISPs save money by not having to use costly international IP transit capacity to exchange traffic; traffic is instead exchanged through the IXP. In a competitive ISP market, the savings afforded by this lower exchange cost can be passed to users in the form of lower data prices or larger data packages for the same price.

- **Stage 3. Local content is hosted locally, rather than in data centers located abroad.** The benefits of this stage build on the gains of locally hosting international content, and help promote a digital economy by providing opportunities for local content developers and the companies that host them.[8] End users benefit from more relevant local content. Stage 3 localizes 70% or more of total traffic.

As noted in our last paper, between 2012 and 2020, both Kenya and Nigeria moved from the cusp of Stage 2, with 30% localized traffic, to the cusp of Stage 3, with 70% localized traffic; South Africa is the only country in Africa currently in Stage 3. Not surprisingly, Kenya, Nigeria, and South Africa also have the only IXPs in the region comprising 50 or more connected networks. With this key fact in mind, on the following pages we provide recommendations to help other African IXPs increase their number and variety of connected networks and successfully move through the three stages of development.

Overview of African IXPs

The Internet Society conducted a broad overview of the members of the African IXP Association (Af-IX), as well as several IXPs that are not members.[9] The information we gained contained good news: more than half of the countries in Africa currently have an IXP, and six countries have more than one IXP (Angola, Democratic Republic of Congo, Kenya, Nigeria, South Africa, and Tanzania). On the other hand, 20 countries still do not have an IXP from which they could benefit.

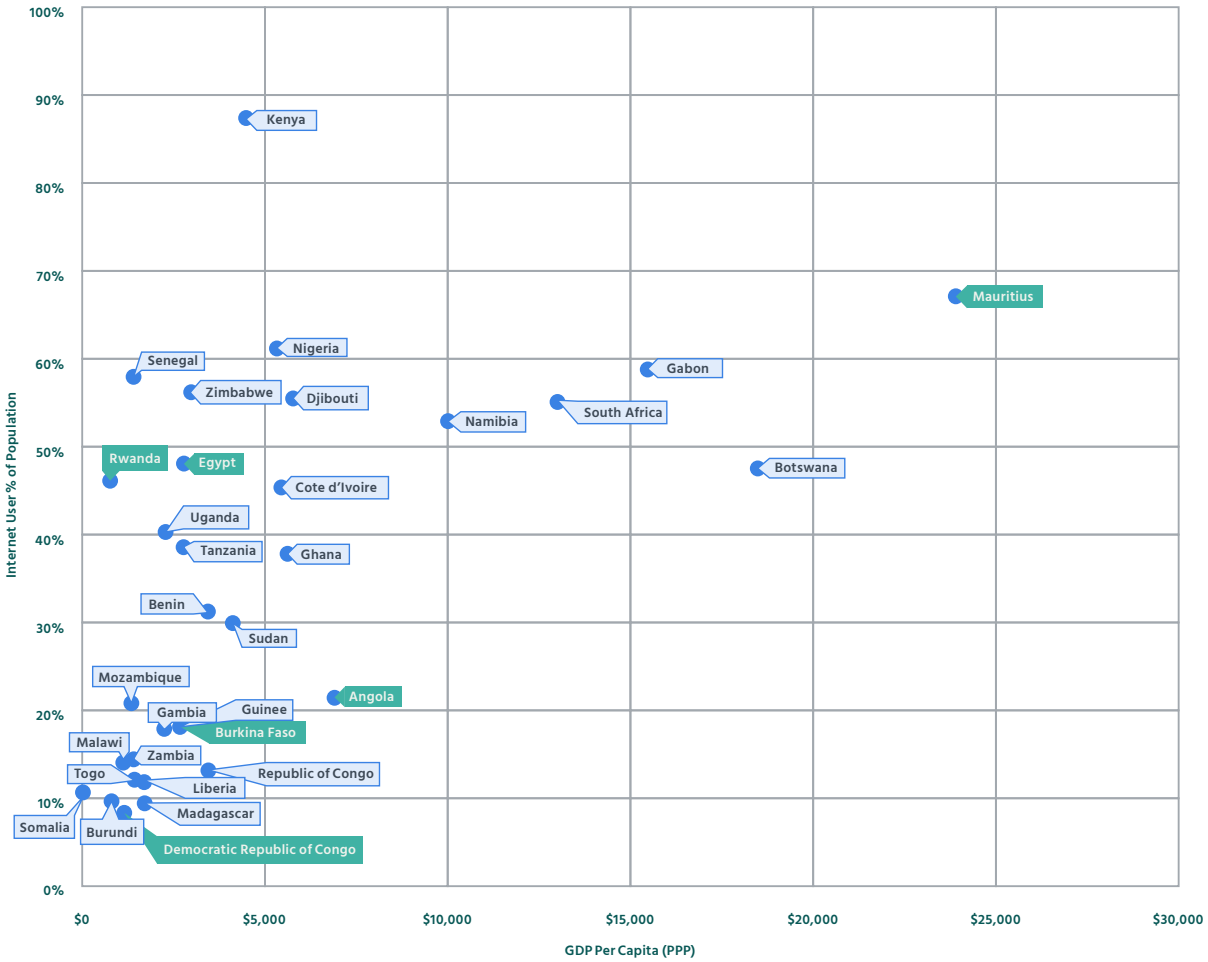
8 For more information on building a local digital economy, see Michael Kende, "Promoting the African Internet Economy" (Internet Society, 22 November 2017), https://www.internetsociety.org/wp-content/uploads/2017/11/AfricaInternetEconomy_111517.pdf

9 See https://www.af-ix.net/ixps-list

Introduction to IXP Host Countries

By examining each IXP in Africa, we were able to identify what is working, what is not working, and where policies might help promote an IXP's establishment and growth. Table 1 details key features of each IXP, including the city, country, region, short name, year of launch, number of connected networks, and peak traffic levels.

Figure 4. Internet Users and GDP per Capita
(Source: InternetWorldStats; World Bank, 2020) Green = Case study countries



Some countries are outperforming others in Internet adoption, despite having similar income levels. See those countries above the trendline, most notably Kenya, with Djibouti, Nigeria, Senegal, and Zimbabwe not far behind. We attribute these successes to the countries' positive enabling environments, including support for the IXP ecosystem, a proven contributor to lowering the cost of Internet access and improving access to content and services connected to an IXP.

Introduction to the IXPs

By examining each IXP in Africa, we were able to identify what is working, what is not working, and where policies might help promote an IXP's establishment and growth. Table 1 details key features of each IXP, including the city, country, region, short name, year of launch, number of connected networks, and peak traffic levels.

Table 1. African IXPs by Region
(Source: Af-IX, member surveys, IXP websites, Packet Clearing House, 2020)
Countries in purple = Case study countries
Numbers in purple = Data provided by the IXP (versus PCH)

Region, Country	Name	City	Launch Date	# of Connected Networks	Peak Traffic (Mbps)
Northern Africa					
Egypt	Cairo IX (CAIX)	Cairo	2002	**5**	**20,000**
Sudan	Sudan Internet Exchange Point (SIXP)	Khartoum	2011	**9**	**650**
Western Africa					
Benin	Benin IX (BENINIX)	Cotonou	2013	6	859
Burkina Faso	Burkina Faso Internet Exchange Point (BFIX)	Ouagadougou	2015	**15**	**10,000**
Cote d'Ivoire	Cote d'Ivoire Internet Exchange Point (CIVIX)	Abidjan	2013	**9**	**1,400**
Gambia	Serekunda Internet Exchange Point (SIXP)	Serekunda	2014	**11**	**4,600**
Ghana	Ghana Internet Exchange (GIX)	Accra	2005	**23**	**60,000**
Guinee	Le Point d'Echange Internet de la Guinee (IXP-GUINEE)	Conakry	2020	**7**	**200**
Liberia	Liberia Internet Exchange Point (LIXP)	Monrovia	2015	**4**	**2**
Nigeria	Abuja IX	Abuja	2011		

Region, Country	Name	City	Launch Date	# of Connected Networks	Peak Traffic (Mbps)
	Internet eXchange Point of Nigeria (IXPN)	Lagos	2007	**74**	**150,000**
	Port Harcourt IX	Port Harcourt	2012		
	West African Internet Exchange (WAF-IX)	Lagos	2018	16	17,842
Senegal	Senegal Internet Exchange (SENIX)	Dakar	2017	6	325
Togo	Togo Internet Exchange Point (TGIX)	Lome	2017	**4**	**730**
Central Africa					
Democratic Republic of Congo	Kinshasa Internet eXchange point (KINIX)	Kinshasa	2012	**14**	**14,000**
	Lubumbashi Internet exchange point (LUBIX)	Lubumbashi	2019	**7**	**3,500**
Gabon	Gabon Internet Exchange Point (GAB-IX)	Libreville	2014	**11**	**500**
Republic of Congo	Congo Internet Exchange (CGIX)	Brazzaville	2013	7	0.020
Eastern Africa					
Burundi	Burundi National Internet Exchange Point (BDIXP)	Bujumbura	2017	8	2.74
Djibouti	Djibouti Internet Exchange (DjIX)	Djibouti	2016	**14**	**11,000**
	Kenya Internet Exchange Point (KIXP)-Mombasa	Mombasa	2014	8	102
	Kenya Internet Exchange Point (KIXP)- Nairobi	Nairobi	2002	52	25,620
Kenya	Asteroid Mombasa (Asteroid)	Mombasa	2018	10	5,030

Region, Country	Name	City	Launch Date	# of Connected Networks	Peak Traffic (Mbps)
Malawi	Malawi Internet Exchange (MIX)	Blantyre	2008	**12**	**6,000**
Rwanda	Rwanda Internet Exchange (RINEX)	Kigali	2004	**15**	**1,400**
Somalia	Somalia Internet Exchange Point (SoIXP)	Mogadishu	2018	6	.006
Tanzania	Arusha Internet Exchange Point (AIXP)	Arusha	2006	15	80
	Tanzania Internet Exchange (TIX)	Dar es Salaam	2004	35	9,900
	Mwanza Internet Exchange Point (MIXP)	Mwanza	2016	12	155
	Zanzibar Internet Exchange Point (ZIXP)	Zanzibar	2018	3	8.79
	Dodoma Internet Exchange Point (DIXP)	Dodoma	2018	4	30
Uganda	Uganda Internet eXchange Point (UIXP)	Kampala	2001	**28**	**13,000**
Indian Ocean					
Madagascar	Madagascar Global Internet eXchange (MGIX)	Antananarivo	2016	9	11.8
Mauritius	Mauritius Internet Exchange Point (MIXP)	Ebene	2008	**14**	**110**
Southern Africa					
Angola	Angola-IXP (ANG-IXP)	Luanda	2006	**18**	**1,000**
	Angonix	Luanda	2015	**24**	**20,000**
Botswana	Botswana Internet Exchange (BIXP)	Gaborone	2005	14	1,000

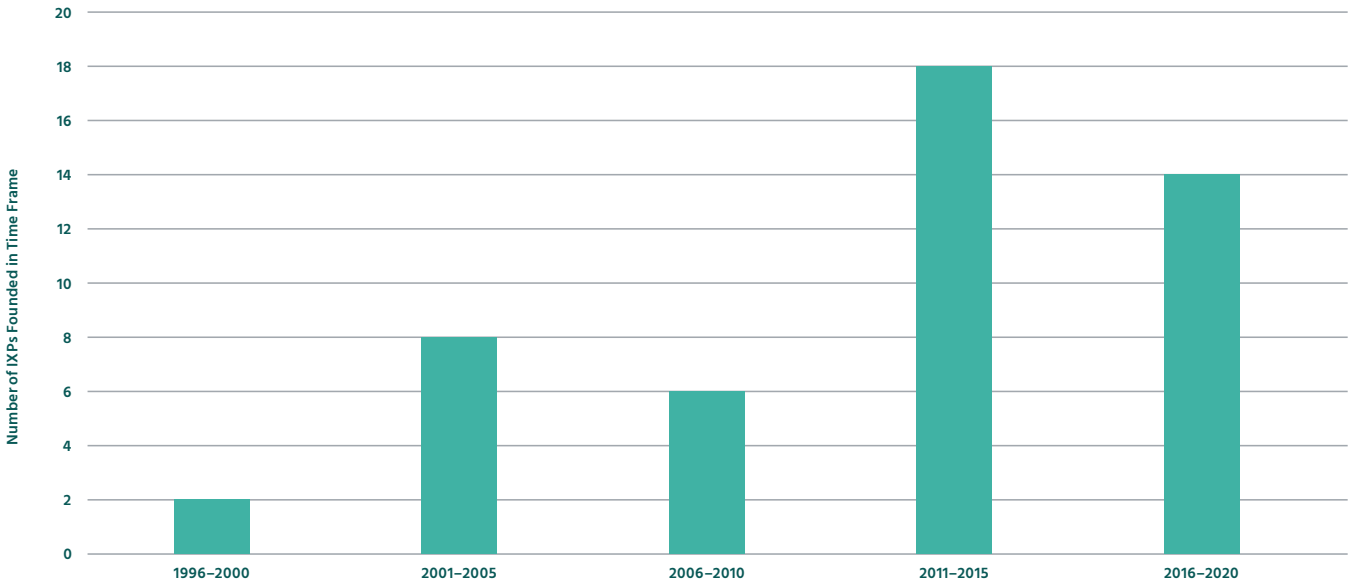
Region, Country	Name	City	Launch Date	# of Connected Networks	Peak Traffic (Mbps)
Mozambique	Mozambique Internet Exchange (MOZIX)	Maputo	2002	**18**	**3,880**
Namibia	Internet eXchange Point Namibia (IXWHK)	Windhoek	2014	11	50
Zambia	Zambia Internet Exchange Point (ZIXP)	Lusaka	2006	13	103
Zimbabwe	Harare Internet Exchange Point (HIXP)	Harare	2017	10	165
South Africa	Cape Town Internet Exchange Point (CINX)	Cape Town	1997	59	21,600
	Durban Internet Exchange Point (DINX)	Durban	2012	69	21,700
	Johannesburg Internet Exchange Point (JINX)	Johannesburg	1996	113	56,300
	NAPAfrica IX Cape Town (Cape)	Cape Town	2012	**202**	**220,000**
	NAPAfrica IX Durban (Durban)	Durban	2011	**93**	**12,000**
	NAPAfrica IX Johannesburg (Joburg)	Johannesburg	2012	**425**	**1,200,000**

The IXPs were founded in the years spanning 1996 to 2020 (Figure 5), with a burst of activity starting in 2011 and tapering a bit to the present day. This timing corresponds with several factors. The Internet Society began the previously described ITE activity between 2008 and 2010, and it held the first African Peering and Interconnection Forum toward the end of 2010 in Nairobi.[10] And in 2012, the African Union initiated its African Internet Exchange System (AXIS) project to help facilitate the establishment of IXPs in Africa.[11] The results of these efforts are described on the pages that follow, including the benefits of increased awareness, capacity training, and the other levels of support that were provided.

10 See https://www.afpif.org

11 See https://au.int/en/blockdatas/axis/axis-page

Figure 5. African IXPs: Years Founded (Source: Af-IX, 2020)



Connected Networks

Two of the key characteristics used to assess IXPs are number of connected networks and total amount of traffic exchanged. While the amount of traffic ultimately indicates the impact of the IXP, in terms of savings from local traffic exchange and the benefits of lower latency, traffic is a measure of the *outcome* of the exchange. It may not indicate the full impact of the IXP. For instance, when members of an IXP are in the same data center and begin to use private network interconnects (PNI) to exchange traffic among select members, that is a benefit flowing from the presence of the IXP—but it would not show up in traffic exchange numbers.

Traffic is generated by members. With that in mind, a more relevant metric for assessing an exchange may be the number of connected networks—a metric of the overall health of the Internet ecosystem in the country and the region, as well as of the IXP itself. The number of connected networks, in turn, determines the amount of traffic exchanged.[12] In addition, even if the members use a PNI to exchange between select networks, they will still connect to the exchange for other traffic exchange.

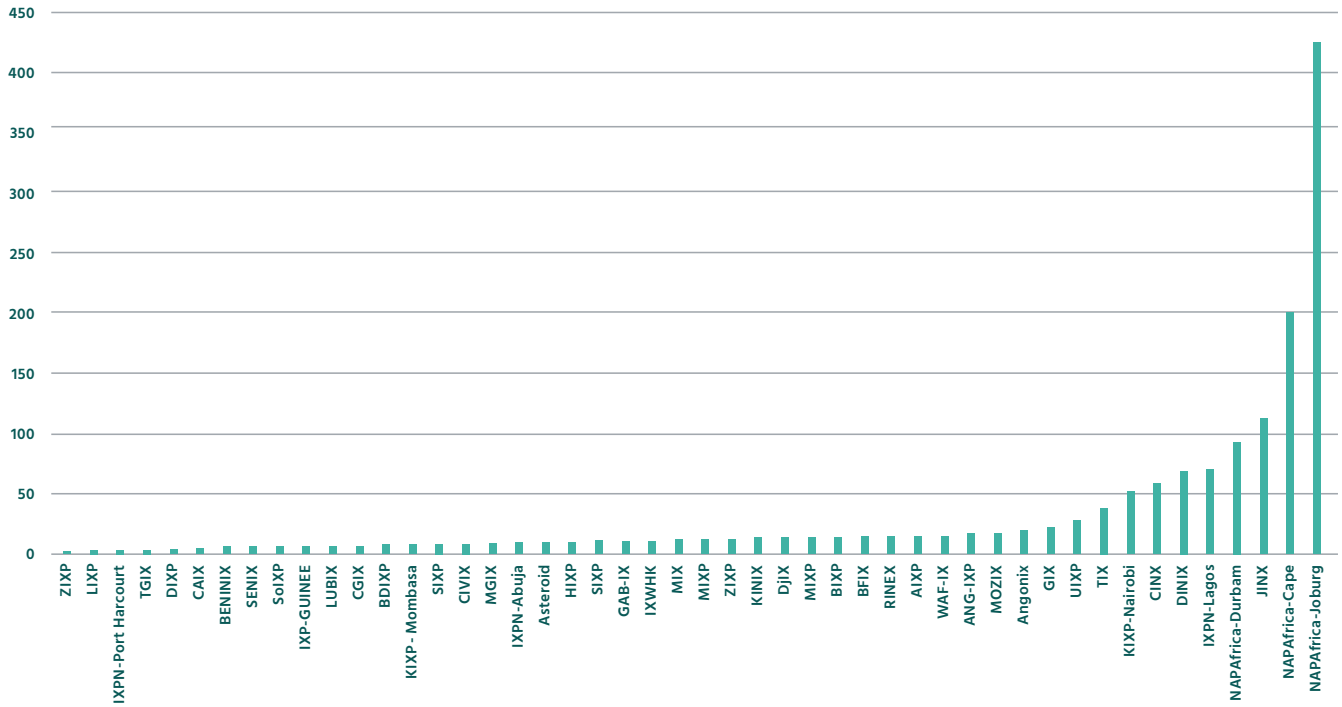
An IXP by definition must have at least three connected networks. This is because one network does not need to exchange traffic, and two can use a simple bilateral agreement.

12 The connected networks can be measured by the number of unique autonomous system numbers (ASNs) at the exchange and by the IP addresses that they announce. Most of the IXPs list their members on their websites.

The number of connected networks in African IXPs spans from the minimum of three to NAPAfrica Johannesburg's more than 400 networks (Figures 6 and 15).

While all the South African IXPs report at least 50 members, only two other African IXPs can say the same: IXPN-Lagos and KIXP-Nairobi. South Africa, Nigeria, and Kenya are generally considered digital hubs in their regions. The aforementioned 2020 Internet Society report showed that both IXPN and KIXP were nearing Stage 3 of IXP development, with 70% of traffic localized, while NAPAfrica reports members that reach 80% or more of their traffic locally.

Figure 6. Number of Connected Networks (Source: IXP surveys, IXP websites, 2020)



The number and diversity of networks connected to an IXP is a clear reflection of the health of the overall Internet ecosystem in a country and the country's position in the region. This ecosystem can be impacted by the following factors: telecom regulations, content environment, and IXP conditions. These factors, described on the following pages, can determine the number of connected networks, including access networks, content providers, and other diverse networks, which in turn impacts the amount of traffic.

Telecom Regulations

Access networks, including fixed ISPs and MNOs that provide data services, typically initiate the development of an IXP as its first members; in some cases, a government develops the IXP for use by access networks. As a result, in practical terms the growth in Stage 1 of the development of an IXP depends on the number of access networks in a country, which in turn depends on the openness of the market. A country that has not fully liberalized its telecom market or that has restrictive licensing for ISPs will have fewer ISPs, and vice versa. Likewise, restrictions that prevent regional ISPs and carriers from entering a country and exchanging traffic will restrict the regional reach of the IXP.

A lack of access network competition has a number of related impacts on an ecosystem. First, it will result in higher Internet access prices and fewer choices in terms of features and broadband speeds, both of which restrict Internet adoption. Second, the amount of traffic exchanged between the access networks will be limited, making the IXP less attractive to content providers.

A related issue is the cost of long-distance connectivity. Within a country, terrestrial connectivity costs impact the number of members that can afford to connect to an exchange. Lowering the costs of deploying backbone networks and enabling competition between backbone providers both lowers the cost of connecting to the exchange and increases the resilience of the network.

Likewise, the cost of international connectivity influences its access by regional ISPs, as well as the cost of accessing content and services abroad. The cost of international IP transit is affected by the level of competition at the international gateway and for domestic backbone transport. As noted, this cost can be high in coastal countries with submarine cables, and even higher in landlocked countries that rely on their neighbors for access.

Access networks are likely to be the early members of the IXP. However, only so many access networks can feasibly operate in a country. On the fixed side, wires to residences or enterprises are required to provide service, and the economics of deploying such networks limits the number of ISPs. On the wireless side, there is a limit on the amount of spectrum in a country, which limits the number of MNOs. An IXP reliant predominantly on access networks will be limited in terms of connected networks.

As IXP membership grows beyond the number of access networks present in a country, it begins to indicate and reflect a greater diversity of players operating in the local Internet ecosystem. For instance, in Kenya, KIXP has more than 50 connected networks, including four MNOs providing data services and nine ISPs with at least 0.1% of the total market

share (and including two of the MNOs).[13] The rest of the IXP's members are a mix of local and international content providers, international carriers, government agencies, and enterprises.[14] Nigeria and South Africa likely have even more diverse IXP memberships, as their IXPs have more members, while their ecosystems face the same constraints on the number of access networks operating in their markets. Thus, to increase membership at the IXP, telecom policies that open the market to access networks are only the first step.

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Content Environment

Providers of content and services represent a large and valued pool of potential IXP members. This includes international CDNs, local content providers, and service providers. A number of factors can influence the number of potential providers in this category.

International content typically includes movies, television shows, and sports competitions developed for both national and global audiences. However, some content is created by users themselves—for example, Facebook posts and YouTube videos—and, as such, its creation is dependent on the level of users in a country. In addition, a number of factors can determine the creation of local content, including relevant education and training and the cost of access. Other determinants of local content availability include the level of digitization by governmental and educational institutions, and the ability to process online payments, which increases financial inclusion and facilitates e-commerce.

Content providers are an important set of potential members, who can contribute a significant amount of content to a local ecosystem. To understand content traffic flows, it is important to distinguish between static and dynamic content. Static content does not change over time, so it can be stored in multiple locations beyond where it was generated. Videos are one of the most common types of static content, including user-generated videos and commercial videos, such as television shows and movies. Dynamic content continuously changes with user requests, and, therefore, it cannot be stored. Direct communications between end users, such as social media messages, online gaming, and video calls are examples of dynamic content.

CDNs represent a new set of providers that deploy caches in order to store popular static content in multiple locations. These caches are often called edge caches, as they reside at the edge of a CDN network—as close to the end user as possible. Another way a CDN may

13 For the latest breakdown of MNOs and ISPs, see https://ca.go.ke/wp-content/uploads/2020/12/Sector-Statistics-Report-Q1-2020-2021.pdf, pp. 18-19.

14 For a full list of KIXP members, see https://portal.kixp.or.ke/customer/details

build out its network in a country is by deploying a point of presence (PoP) that delivers dynamic content and services and that fills edge caches with static content.

Sharing content from CDNs through an IXP can significantly lower the cost of accessing content, while also increasing the amount of traffic sourced locally.

In addition to content providers, other potential connected networks provide online services, including government networks that offer e-government services, research and educational networks (RENs), and enterprises that offer private services, such as banks. Cloud service providers offering cloud storage, communications services, online gaming, and enterprise services also are important, particularly given the increased reliance on Internet services in reaction to the COVID-19 pandemic. As these providers begin to offer services in a country, itself an indicator of the health of the ecosystem, they will face challenges similar to content providers regarding where to host their services.

Not all content and services—be they international or local—are hosted locally. A number of content regulations can impact the local hosting of content, including privacy and data protection laws, intermediary liability, and the nature of takedown requests. In addition, the cost of international IP transit can impact the decision to locate a CDN cache, PoP, or cloud service in a country, as the cost of filling the cache or delivering content to the PoP or service to the cloud must be paid.

Commercial factors also can determine the decision to host content or services locally in a colocation data center. A data center is a facility used to host routers, servers, and other computing resources for applications and data. Colocation means that the data center hosts equipment owned by independent parties, such as ISPs, CDNs, enterprises, and so forth. A data center can be carrier-neutral, meaning it is not majority owned by a carrier that also provides network infrastructure services to the same facility. This enables competition among the carriers, whose services are used to deliver content or services to and from the data center. A carrier-neutral colocation data center is often the preferred type of hosting location.

Even with the availability of carrier-neutral data centers, the costs of hosting in Europe are frequently far lower than in Africa, as a result of the economies of scale in the far larger European markets. It is important to address all of a country's issues that may impact the cost of local hosting, including a low-cost and reliable power supply, the land needed for the data center with connections to carriers, and the cost of building and operating a data center. In addition, while data centers benefit from the economies of scale that come from operating large facilities, competition in data centers also helps to develop the broader Internet ecosystem by offering choice and stimulating the growth of networks.

IXP Conditions

At the most fundamental level, an IXP's requirements may limit its number of connected networks. For instance, in some countries, the government or the IXP effectively only allows ISPs to connect; this can create an upper limit on the number of members. Other IXP conditions, such as mandatory multilateral peering agreements (MMLPA), may dissuade potential members that want to choose with whom they peer, rather than be required to peer with all other members.

The physical deployment of an IXP also can make a difference. If an IXP is hosted in a carrier-neutral data center, it may encourage members who are already there to join the IXP, or even attract new members. An IXP with multiple nodes within a city or in other cities can provide both more diversity and more competition for hosting, which may further encourage networks to join the IXP.

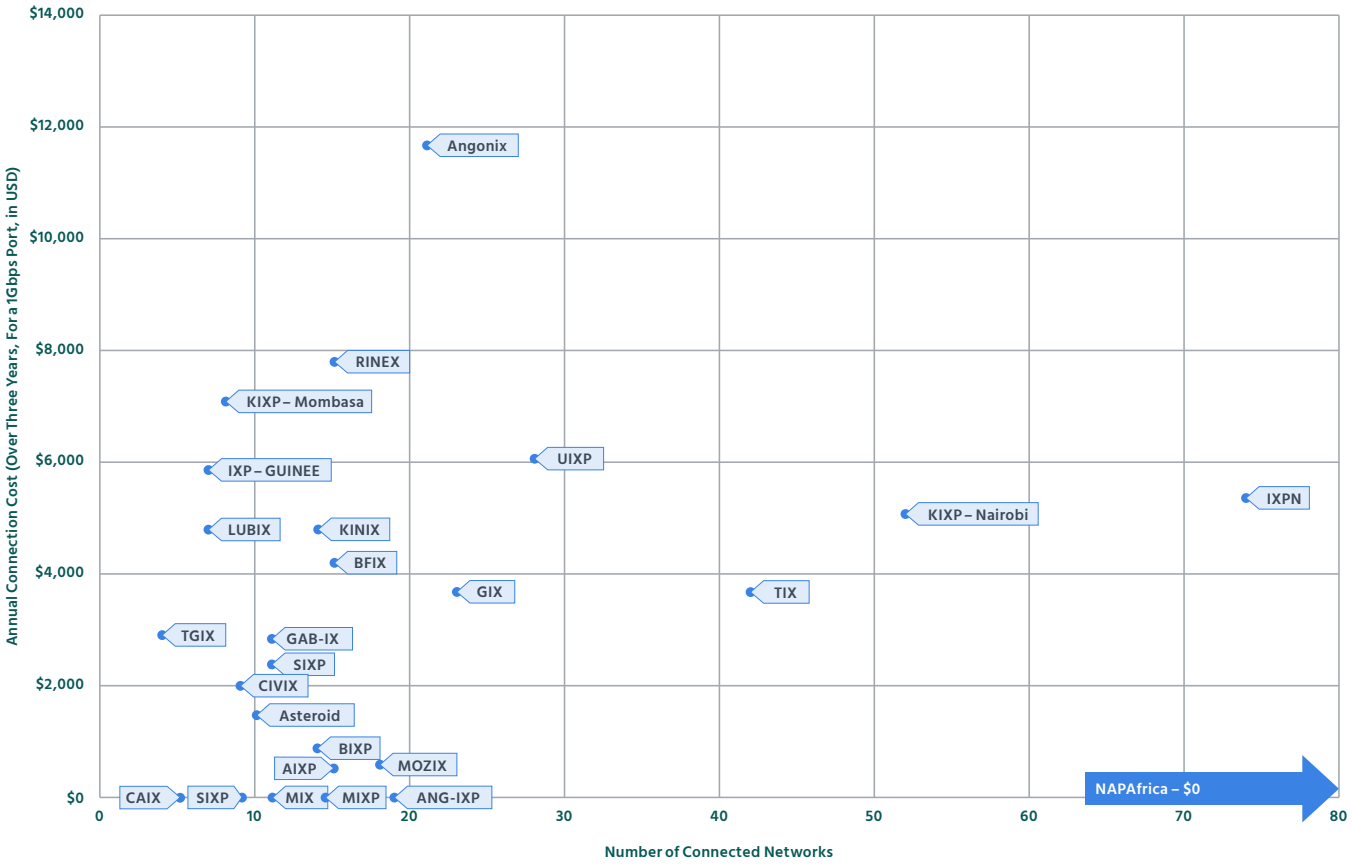
The cost of exchanging traffic through an IXP must be considered, when assessing the number of connected networks. There can be three costs for connection to an IXP: a one-time joining fee, an annual fee, and a monthly port fee that typically depends on the speed of the connection the member wishes to have at the exchange. In order to compare the different costs, we calculated the average annual cost over three years of connection for a 1 Gbps port; costs range from zero to nearly $12,000 (Figure 7).[15]

That said, connection cost does not appear to have an appreciable impact on the number of connected networks. Case in point, NAPAfrica has both zero connection costs and the greatest number of connected members.[16] However, the other free and low-cost IXPs are doing no better than the more expensive ones, including Angonix (Angola) at the high end. The IXPs in the middle range—IXPN (Nigeria), KIXP (Kenya), TIX (Tanzania), and UIXP (Uganda)—have the highest number of connected networks, strongly suggesting that other factors are at play.

15 We excluded those IXPs for which we did not have their costs. We also excluded the South African IXPs, which have up to 425 members. This enabled us to more accurately see the full spread of the included IXPs. See Appendix C for the complete figure.

16 NAPAfrica is located in Teraco colocation centers, but it is not just free for Teraco customers; it also allows 'remote ports' for networks in other local and international data centers.

Figure 7. Three-Year Cost of Connection and Number of Members
(Source: IXP surveys, IXP websites, 2020)



In order to increase the number of connected networks and their associated traffic exchange, two elements are necessary: awareness and capacity building.

- **Awareness.** The importance of providing education about the benefits of peering at an IXP cannot be emphasized enough. Awareness can increase connections in countries by attracting new members, including smaller ISPs, local content providers, government and educational institutions, and even enterprises.
- **Capacity building.** Existing and prospective members of an IXP require training to understand how best to benefit from an IXP and how to ensure efficient routing of their traffic. As the IXP grows in the number of nodes and variety of connected members, ongoing training will help them adapt to the changes.

Awareness and capacity building can be provided by the IXP itself, by the Internet Society, African Network Information Centre (AFRINIC), network operator groups (NOGs), Packet Clearing House (PCH), and others. In addition, an IXP's website is an often-overlooked

asset that comprises information about the benefits of joining the IXP, links to existing background readings and current data, and ways to facilitate the process of joining.

Relationship Between Number of Networks and Traffic

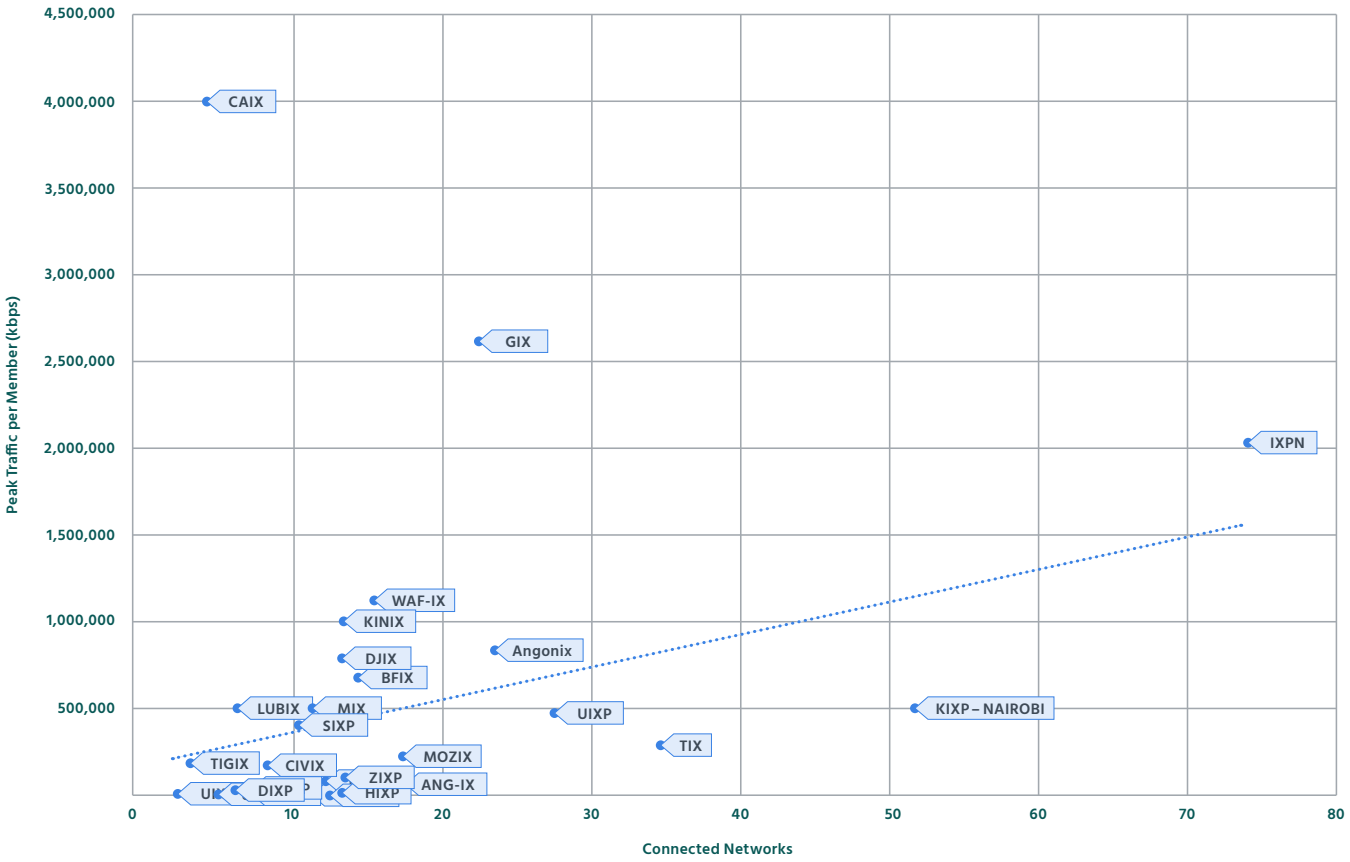
An increase in the number and diversity of connected networks at an IXP indicates a healthy Internet ecosystem in its country and region, and it ensures that the benefit of local peering is widely enjoyed. As each network will generate traffic that might not have otherwise reached the IXP, the more networks that are attached, the greater the total traffic through the IXP. Further, there is an interesting correlation between the number of networks connected to an IXP and the amount of traffic passing through it.

Figure 8 shows that, overall, for the IXPs in this study, the amount of traffic per network tends to increase as the number of connected networks increases.[17] It is no surprise that the total traffic would increase with the number of connected members, but this demonstrates that the average amount of traffic generally increases, as well, as shown by the trendline.[18] This suggests a generative property—as the number of members increases, so does the traffic per member, thereby developing a positive cycle that helps to achieve the goal of increased local traffic.

17 Given the significant number of connected networks and traffic per connected network in the South African IXPs, particularly NAPAfrica Johannesburg, this figure does not include South Africa. See Appendix C for a figure that includes South Africa.

18 Note that there is a significant, albeit unmeasured, use of Private Network Interconnects (PNIs) at KIXP-Nairobi. This makes the traffic-per-connected-member data appear low; it would be significantly higher if the PNI traffic were included.

Figure 8. Number of Networks and Traffic per Network (Source: IXP surveys, IXP websites, 2020)



This trend is not only true across the IXPs in Africa, as indicated by current number of networks and peak traffic; it is also true for individual IXPs as they grow in size. Historical data from two IXPs—NAPAfrica Johannesburg and UIXP—illustrate this phenomenon (Figures 9 and 10, respectively). Note that as the number of connected networks rises, the amount of traffic per connected networks rises; in the case of Uganda, the traffic per network rises even faster than the growth in connected networks.

Figure 9. NAPAfrica Networks and Traffic (Source: NAPAfrica, 2020)

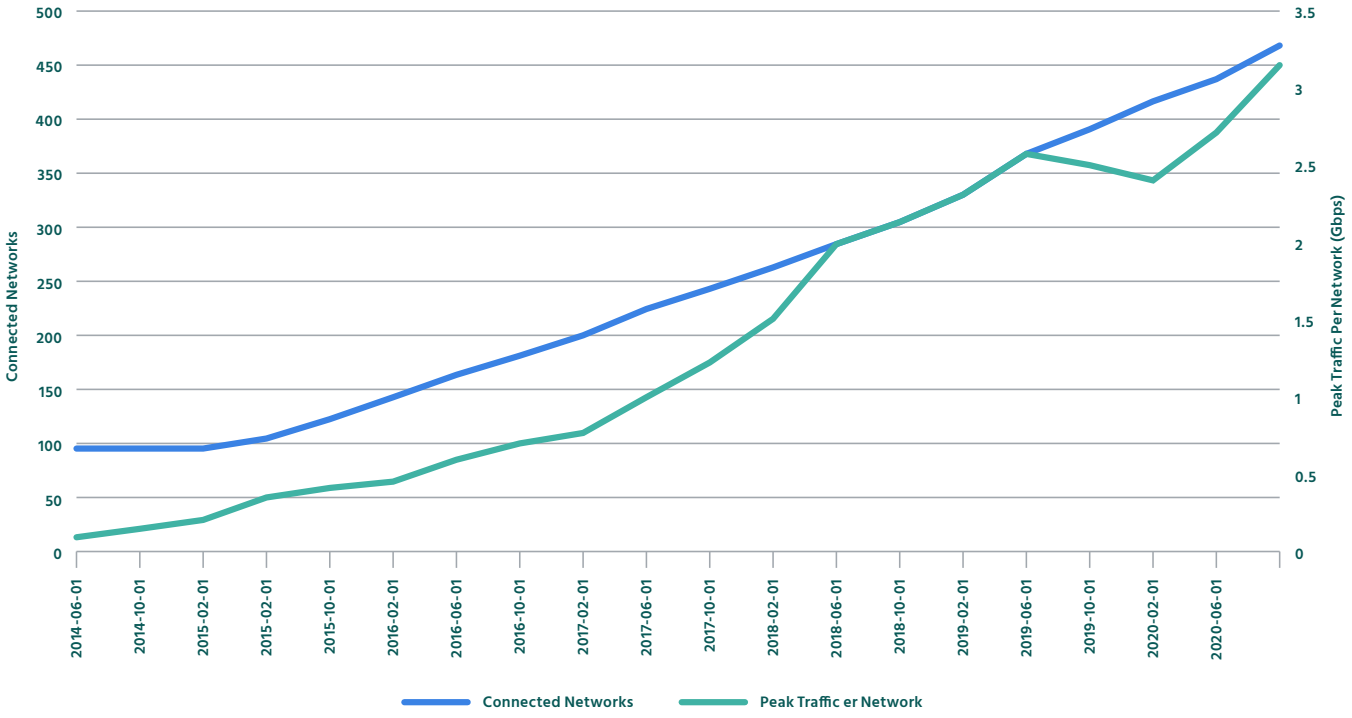
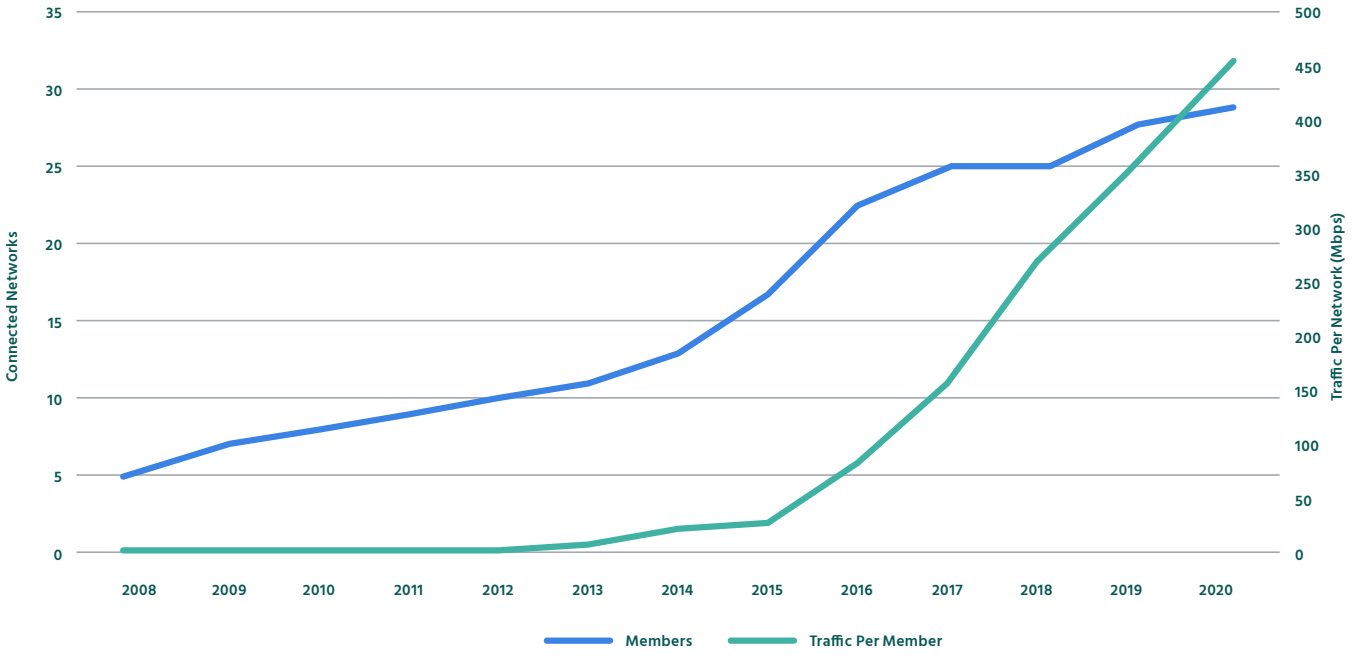


Figure 10. UIXP Networks and Traffic (Source: UIXP, 2020)



The periods covered in Figure 9 (2014–2020) and Figure 10 (2008–2020) involve a significant amount of growth in those countries' Internet ecosystems. However, the traffic per network increased by a factor of 27 in South Africa's NAPAfrica—significantly faster than the growth of 1.28 times the number of Internet users in the same time period. Similarly, in Uganda, UIXP's traffic per network increased by a factor of more than 500, albeit over a longer time period. Since 2014 alone, UIXP's traffic per network increased by a factor of almost 20.

But an increase in the number of Internet users in each country is not the only growth taking place; there is also a measurable increase in capacity throughout the countries' broadband networks. Uganda benefitted from submarine cables landing on the east coast of Africa in 2009, and smartphones and mobile broadband were globally introduced around that same time. Usage also has grown—an increasing amount of video is available, as are other applications that drive up demand. While we would expect the aforementioned to drive up traffic per member in the country, it is the UIXP that has helped to drive the growth in usage.

The low cost and latency benefits of peering at an IXP promote traffic exchange, which, in turn, attracts caches from CDNs to distribute content to their users. Note that when large CDNs began to join UIXP—Akamai in 2016, Google in 2017, and Facebook in 2019—the amount of traffic per connected network quickly rose. The addition of such members validates the role of the IXP and adds a significant amount of traffic both overall and to the traffic per connected network numbers, as seen in Figure 10.

A similar story can be told in South Africa, where plentiful international capacity and traffic volume drive down access costs. In addition to increased mobile capacity and adoption, fiber-broadband rollouts provide increased capacity that is increasingly being met with on-demand video and streaming sports, as well as international CDNs with caches and PoPs. The cost of peering at NAPAfrica is zero,[19] and the IXP's lower latency continues to increase usage, thereby creating a virtuous cycle of growth.

It is clear that the greater the number of networks connected to an IXP, the more attractive that IXP becomes to other networks; those networks then can enjoy low-cost access to an increasing number of networks. This is the cycle that drove the localization of traffic to levels of 80% and beyond in South Africa. Again, low latency promotes usage, and a low cost of connection promotes higher bandwidth services. What's more, the success of the IXP helped drive regional traffic, which further increased the amount of both localized traffic and traffic per connected network.

19 See footnote 16.

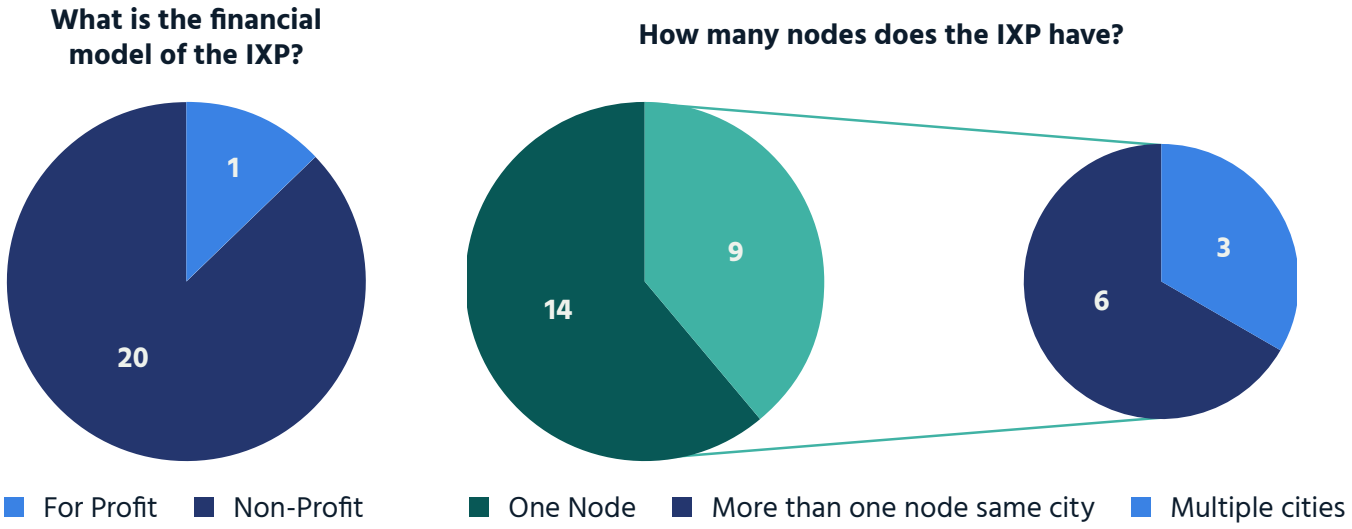
We can conclude that an increased number of networks at the IXP is both a good indicator of a healthy Internet ecosystem and an accelerator of traffic growth. It is worth noting that the only African IXPs with more than 50 connected networks are in Kenya, Nigeria, and South Africa—each of which is in or nearing Stage 3 of development.

IXP Surveys

In order to identify the factors that either contribute to, or inhibit, the growth of an IXP, the Internet Society sent surveys to the directors of every African IXP Association (Af-IX) member—46 active IXPs in 42 cities in 34 countries (see Annex 2).[20] Of those, we received 23 responses, representing 50% of the IXPs, which in our experience is a robust response rate. A summary of survey data and responses follows with some of the more revealing questions and answers highlighted (Figure 11).

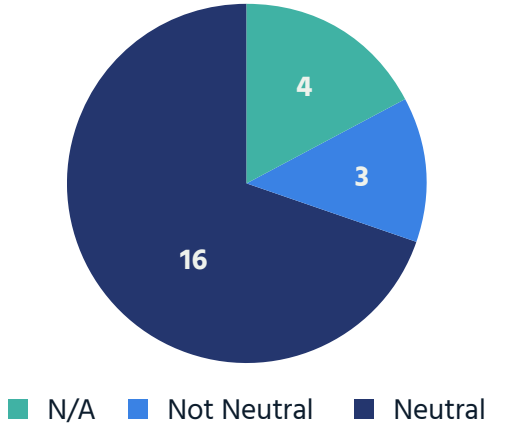
- Twenty IXPs are non-profits.
- Fourteen IXPs have one node.
- Nine IXPs have two or more nodes, of which six have nodes in the same city and three have nodes in multiple cities.
- Sixteen IXPs are located in carrier-neutral data centers, three are not, and four did not indicate a location.
- Eight IXPs employ MMLPAs.

Figure 11. IXP Survey Responses (Source: Internet Society, 2020)

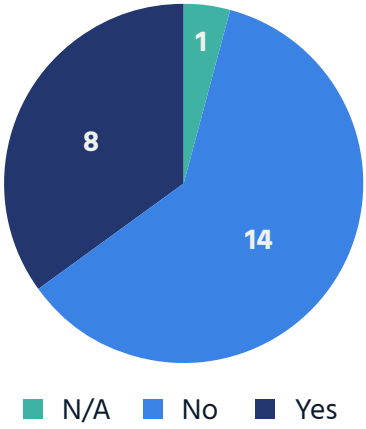


20 See https://www.af-ix.net/ixps-list

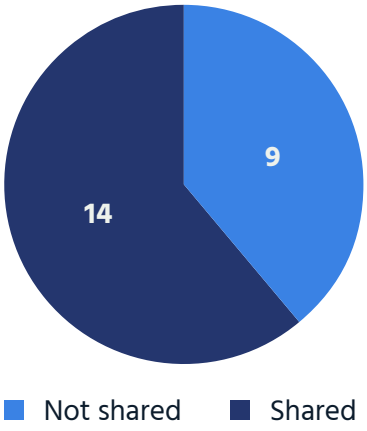
What type of data center is hosting the IXP?



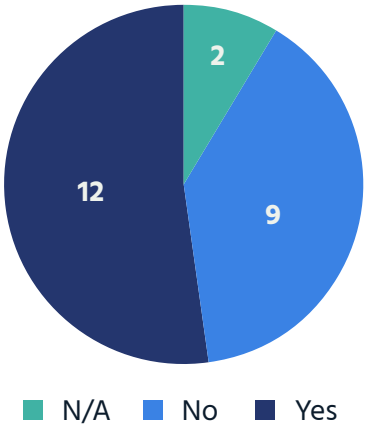
Does the IXP have MMLPA?



Is the content of the CDN caches shared?



Is there a CDN PoP in the country?



All but one of the IXPs reported the presence of at least one international CDN in their country, in 14 cases with a cache connected directly to the IXP, and in the other cases indirectly connected via an IXP. In addition, 12 of the IXPs reported the presence of at least one CDN PoP able to fill the caches and deliver dynamic content to connected ISPs. Facebook and Google were available in almost every country, followed by Akamai in half of them, and Netflix and Cloudflare in a handful of others.

While these international CDNs account for a significant portion of content consumed by users, and therefore the traffic exchanged through the IXP, the ecosystem also benefits by having local content providers hosted in the country and connected to ISPs through the IXP. When surveyed, eight IXP directors said unambiguously that there was significant local content hosted in their country, five said there was some, and nine said there was effectively none. On the other hand, the local content that is locally available is largely available through the IXP, which is positive.

In some countries, the reason given for the lack of locally hosted, local content is that there is little local content available—a result of both the developers' capacity and consumer preferences for international content. However, the local content that is available is often hosted abroad for three significant reasons: lack of infrastructure to host the content, cost of hosting if there are data centers available, and lack of awareness about local options. Each situation warrants further work to increase the amount of local content hosting.

Can you estimate for your country what percentage of total Internet traffic is domestic versus international?

The answers to this question varied widely. Five IXP directors put the number at 5% or less domestic traffic, two directors replied less than 1%, two more said 10%, and four put the number at 20–25%— answers that indicate the majority of the IXPs are still in Stage 1 of development. Two IXPs are in Stage 2, with one director replying 35% and another one around 50%. We know from previous work that Kenya and Nigeria each have approximately 70% domestic Internet traffic, and South Africa reports an even higher percentage. This disparity clearly signifies that substantial work remains to be done in many countries in order to localize and develop content, and to help achieve the community's goal—inspired by the Internet Society—of 80% locally sourced traffic throughout Africa.

Do you feel that there is general awareness of the benefits of an IXP in your local Internet community, particularly with smaller ISPs and local content providers?

Overall, the answers to this question were quite positive, with the majority saying that there is at least a general awareness; only three respondents said that there was effectively no or little awareness.

How has the awareness been built? What could be done to increase the awareness?

Respondents cited a number of means for creating awareness, including meetings, workshops, roadshows, mini seminars, press coverage, online discussions, Internet Society trainings, and publications. Notably, most also said that more could be done, particularly with respect to local content providers and small ISPs.

According to Jacob Dagunduro, senior network manager at Internet Exchange Point of Nigeria, "There is general awareness of the benefits, and that usually forms the basis for interest in the IXP service. Community awareness is built via events, workshops, and media publications on the progress and impact of the IXP. More targeted media campaigns, localization of more government content, more strengthened collaboration between the IXP and data centers, and more awareness campaigns via events and workshops [could help increase awareness]."

Do you feel that there is sufficient capacity building regarding peering and interconnection in your country? What are the sources of capacity building? What could be done to increase the capacity building?

Several respondents replied, yes, that there is sufficient capacity building in their countries; 18 said that more was needed. The main sources of capacity building named include the Internet Society, AFRINIC, local NOGs, PCH, and local Internet service provider associations. Clearly, with more than 40 IXPs in more than 30 countries in Africa, and in particular now with COVID-19, in-person training is largely impossible for the moment. Solutions that create leverage for current resources would be welcome and useful, even after pandemic restrictions are lifted.

Are there any broader policy impediments that impact ISPs in your country? These could be in relation to the level of competition at the international gateway, national backbone, or last mile networks, for instance.

Roughly half of the IXP operators said that there was no regulatory impediment facing ISPs in their countries. Others focused on the cost of international and national backbone, and still others cited a lack of competition as an impediment to growth in their countries.

Are there any policy impediments to develop a data center in your country, or for an international content provider to bring a cache or point of presence into your country?

The IXP operators almost uniformly indicated that there were no policy impediments in their countries. On the other hand, one respondent stated that the government wanted to discourage new data centers in favor of their own, while another pointed to levels of government activity on information and communications technology (ICT) being too low to stimulate demand.

What policy or regulatory changes would most contribute to increasing the usage of your IXP?

Other more-general policy and regulatory changes provided are more indirect. Several respondents noted that the development of more e-government services that could be connected to the IXP would be helpful. Others argued that the IXP could be opened beyond the ISPs, in at least one case, by removing government restrictions on who could join the IXP. And finally, a few operators suggested that ISPs could help the local situation by increasing their willingness to peer, and that those ISPs with CDN caches share the contents through the IXP.

We look deeper into these issues in the case studies that follow.

Survey Question #12: What are you most proud of in the development of your IXP?

1. Our IXP has become attractive and contributes a lot to our Internet ecosystem (improvement of Quality of Service (QoS)).
2. The upgrade to multiple 10G ports for members.
3. We are proud to have moved from 1 Mbps daily to 10 Gbps in 12 months, and from 2 peers to 15.
4. One of our latest is to have a new node in a neutral data centre.
5. *Avoir connecter le plus grand nombre de fournisseurs de services Internet (FAI) du pays et favoriser ne serait-ce qu'à 10% à la circulation de données locale sans transiter par nos câbles sous-marin.* (To have connected the largest number of ISPs in the country and promoted at least 10% of the local data circulation without passing through our submarine cables.)
6. It is exciting to see the improvement in the QoS experience of users as more international content becomes local and more local service providers reduce their cost-of-transit capacity. We are glad that the growth at the exchange is leading to attraction of other content networks and international carriers into the country. The growth will definitely foster more innovations in new Internet services to take advantage of available higher and more-affordable Internet bandwidth.
7. The growth it has reached. Traffic is always increasing, and communications are getting better locally, especially regarding operators' connections to the IXP showing how important they are.
8. I am proud of the motivation of the actors and their total membership of the CIVIX Concertation Committee.
9. Developing consumption of local capacity with our local community.

10. The openness for various networks to peer and to keep local traffic local.
11. Getting all the operators to join and the availability of cache content to users, which makes their browsing experiencing a lot better.
12. Collaboration between members. Keeping local traffic local. Bringing international content closer to the end users of the community.

Country Case Studies

In order to achieve a deeper understanding of the African IXP landscape, we've taken a closer look at one country in each of the continent's subregions. We assessed the stage of development of each of the IXPs in the chosen countries, as well as its surrounding ecosystem, with particular attention on the availability of locally hosted international and local content. This has enabled us to make recommendations on the steps that stakeholders can take to promote successful IXPs and a broader Internet ecosystem in each case study country.

We used the subregion categories as defined by AFRINIC: Central Africa, Eastern Africa, Northern Africa, Southern Africa, Western Africa, and Indian Ocean. In terms of the criteria for choosing the country, the primary criterion was that the country had an active IXP. We looked at countries in varying stages of liberalization and with IXPs at varying levels of development in order to highlight policies that could increase the benefits of an IXP, including attracting more connected networks.

Table 2. Case Study Countries (Source: World Bank, InternetWorldStats, 2021)

The countries we chose are Angola, Burkina Faso, Democratic Republic of Congo, Egypt, Mauritius, and Rwanda (Table 2).

Region	Country	GDP per Capita (PPP)	Internet Users	Other Aspects
Southern Africa	Angola	US$ 6,930	27.3%	Coastal, Portugese
Western Africa	Burkina Faso	US$ 2,280	22.0%	Landlocked, French

Region	Country	GDP per Capita (PPP)	Internet Users	Other Aspects
Central Africa	DRC	US$ 1,144	18.3%	Coastal, French
Northern Africa	Egypt	US$ 2,800	48.1%	Coastal, Arabic
Indian Ocean	Mauritius	US$ 23,942	67.0%	Island state, English
Eastern Africa	Rwanda	$US 780	46.2%	Landlocked, English

The result is a rich tapestry of countries and ecosystems, with two landlocked countries, three coastal, and one island state; two French-speaking, one Arabic-speaking, and one Portuguese-speaking nation; and three countries that are considered low-income, two lower-middle, and one upper-middle income. In terms of Internet coverage, the adoption rates range from just over 18% to 67%. Finally, each country has at least one functioning IXP, and two countries have two functioning IXPs (Table 3).

Table 3. Case Study IXPs (Source: IXP surveys, IXP websites, 2020)

Country	Short Name	City	Year Launched	# of Members	Peak Traffic (Mbps)	Peak Traffic per Member (Mbps)
Angola	ANG-IXP	Luanda	2006	22	1,000	55.55
	Angonix	Luanda	2015	24	20,000	833.33
Burkina Faso	BFIX	Ouagadougou	2015	15	10,000	666.66
DRC	KINIX	Kinshasa	2012	14	14,000	1,000
	LUBIX	Lubumbashi	2019	7	3,500	500
Egypt	CAIX	Cairo	2002	5	20,000	4,000
Mauritius	MIXP	Ebene	2008	14	110	7.85
Rwanda	RINEX	Kigali	2004	15	1,400	93.33

According to survey responses, the IXPs' launch dates range from 2002 to 2019, their sizes range from 5 to 24 members, and their peak traffic ranges from 110 Mbps to 20 Gbps.[21] Based on those responses, only Egypt is in Stage 2 of development, with more than 30% localized traffic; the remaining countries report less than 30% localized traffic, with one estimate as low as 1%.

One of the significant benefits of an IXP is the cost savings by enabling local traffic to be routed locally, rather than using more expensive international IP transit.

Table 4. Costs and Savings per IXP in US$ (Source: Interviews, IXP websites, 2020)

IXP	IP Transit Price/ Mbps/Month	Yearly IP Transit Savings	IXP Port Cost/ Mbps/Month	Yearly Savings per Network
Angola-IXP	$18	$216,000	$0	$12,000
Angonix	$18	$4,320,000	$0.97	$228,350
BFIX	$12	$1,440,000	$0.35	$115,800
KINIX	$23	$3,780,000	$0.40	$163,233
LUBIX	$23	$945,000	$0.40	$37,233
CAIX	$9	$2,040,000	$0	$240,000
MIXP	$100	$132,000	$0	$1,320
RINEX	$15	$254,016	$0.65	$9,000

Table 4 shows the cost of international IP transit per Mbps (in US$ and based on the cost of a GigE connection), and the overall savings and savings-per-network of routing the traffic through an IXP rather than using an international connection. In each case, the average port charge per Mbps (based on the cost of a 1GB port) is either free or significantly lower than the IP transit price, which leads to savings of up to US$240,000 per network. The table also highlights where additional savings could be significant, notably for MIXP, where the IP transit price is high, the port cost is zero, but there is relatively little traffic.

21 Survey responses were collected during summer 2020. Many, if not all of the IXPs, have experienced growth since then, both in general and as a result of increased demand from the COVID-19 pandemic.

Behind the Scenes: International Content Delivery Networks

An important source of traffic in all countries comes from international content delivery networks. Broadly speaking, CDNs can provide content on behalf of customers (e.g., Akamai or Cloudflare), or they can provide their own content (e.g., Facebook, Google, or Netflix). Within the latter category, some provide their own content (e.g., Netflix), and some are platforms for user-provided content, such as videos (e.g., Facebook, Google). That is to say, the content is not all international; users can use these platforms to share their own content with local friends, family, and colleagues.Three international CDNs provided us with data on their provision of content in each of the six countries, as well as conclusions and recommendations about the ecosystem in each country. Each provided slightly different data points that, when combined, underscore the value of a local cache or PoP, in terms of lowering the latency of content provision and increasing the throughput, as well as the resulting impact on the traffic consumed in a country following the provision of a local cache.

Given that the data are commercially sensitive, all three CDNs asked that their names not be cited. As their data and recommendations are valuable, and there is little value in knowing which CDN provided what data, we chose to include the data and respect their commercial requests for anonymity.

The following six case studies highlight the accomplishments and issues facing each country, lessons learned, and recommendations. Each section includes the history of the IXP, its connected networks including international CDNs, efforts to increase awareness and capacity building, regulatory and marketplace challenges, and recommendations. The information was drawn from the IXP surveys, interviews with stakeholders in each country, and publicly available research.

Angola

Angola has two IXPs: Angola IXP and Angonix (Table 5). Angola IXP was established in 2006 by the Angola Internet Association (AAI), formerly the Angolan Association of ISPs (Associação Angolana dos Provedores do Serviço de Internet or AAPSI). Angonix was established in 2015. It is operated by Angola Cables and has backend services provided by the German IXP, De-CIX.

Table 5. Angola IXPs (Source: IXP surveys, IXP websites, 2020)[22]

	Angola IXP	Angonix
Established by	AAI (2006)	Angola Cables (2015)
Model	Non-profit	For profit
Nodes	2	1
Hosted by	Neutral data center	Angonap (owned by Angola Cables)
Three-year total cost (1Gbps)	Free (for paying members of AAI)	US$34,950
Connected Networks	22	24
Access Networks[22]	16	16
International CDNs	None	None
Peak traffic	1 Gbps	20 Gbps
Obligations	MMLPA	Recommend MLPA
Restrictions	No restrictions on members	No restrictions on members

While Angola IXP had a nine-year head start, and is free of charge, Angonix has slightly more members and significantly more traffic. Angola Cables, which operates Angonix, is a majority state-owned enterprise that has capacity in the international cables and arranges IP transit for sale in Angola. Angola Telecoms, the incumbent operator, owns 51% of Angola Cables.

In terms of connected networks, there is considerable overlap, with 10 members of both IXPs. This includes both MNOs; a number of ISPs, including the incumbent Angola Telecom; and PCH, which provides DNS access. Each IXP has other ISPs that are only connected to one of the IXPs. Angonix also has connected a bank, Verisign (DNS), and Angola Cables. Angola IXP has several other ISPs, two banks, and a government agency with e-government services. Both have a relatively high proportion of access networks in the number of connected networks.

The greatest difference between the two IXPs lies in their available content. While Angonix does not have any CDNs connected, Angola Cables has CDN caches connected, and those who purchase IP transit from Angola Cables have access to the CDN traffic. It appears that

22 This includes both fixed IXPs and MNOs that provide data services.

the CDN traffic is made available through Angonix, which is operated by Angola Cables, and thus the IXP is at least partially acting as a transit hub for Angola Cables. Further, on the Angonix website, the connected networks are referred to as *customers*, and not *members* or *peering networks*. This wording reflects the commercial nature of the IXP, which is not typical for African IXPs.

None of the three international CDNs that provided data are directly connected to either of the Angolan IXPs, but all have caches in the country connected to ISPs. One reports that 72% of their traffic is served from within the country, 82% is served within the region, and the remainder comes from outside Africa. A second has caches with at least four ISPs and reports a 250% increase in traffic immediately following the turnup of one of the caches. The third CDN reports that the majority of its traffic is served locally, with the rest coming from Brazil, Portugal, and South Africa. It reports that, on average, its locally served traffic is delivered with lower latency and higher throughput. None of the CDNs report serving traffic from Angola to other countries.

While the CDNs have localized traffic, one of the IXPs indicated that only 10% of traffic is domestic, putting the IXP in Stage 1 of development with most traffic still coming from abroad. For instance, one of the ISPs connected to both IXPs noted that they are seeking a significant amount of traffic from Europe and South Africa.

On the other hand, both IXPs have been successful in attracting nontraditional networks to join them. Both have at least one local bank and a DNS root provider. In addition, Angola IXP has *Instituto Nacional de Fomento da Sociedade de Informação* (INFOSI), a government entity with e-government services, and Angonix has i3D.net, a carrier that hosts multiplayer online games and uses the connection in Angola to connect users to its servers in South Africa in order to avoid the latency of going through Europe. As one can imagine, latency is a considerable disadvantage for gamers.

For the moment, South Africa serves as Angola's regional hub for traffic that is not picked up in Europe. Several stakeholders commented on the desire to leverage their presence in Angola into neighboring DRC, but that has not yet been achieved. One policy challenge is the relatively high price of IP transit in Angola, which is up to 10 times higher than in South Africa. This significantly raises the cost of filling caches in the country, and presents a barrier to neighboring DRC's use of Angola as a traffic hub.

The reason for Angola's high IP-transit costs appears to be that Angola Telecom and Angola Cables own the international capacity coming into the country and the landing stations, and both are state-owned companies—Angola Telecom owns 51% of Angola Cables. As a result of these factors, the cost for accessing IP transit is quite high, making it difficult for Angola to serve other countries, such as DRC.

Finally, efforts have been made to increase awareness of the benefits of the IXPs. Angonix hosted a Peering Workshop on the benefits of peering in 2015, and also hosted a forum on the digital economy and connectivity. The Angola NOG (AONOG) hosts an annual peering forum (AOPF) and develops material to share knowledge. And both IXPs have comprehensive websites that offer information for prospective networks, share peering statistics and information about services provided, and provide links to important international resources.

Recommendations

Liberalization of the sector would help lower the cost of IP transit for both domestic and international capacity and at the international gateway. A wholesale carrier providing competitive rates for IP transit would make the country significantly more attractive for CDN caches, help Angola establish itself as a hub for traffic into DRC and its other neighbors, and lower latency connectivity to Latin America and the United States via the South Atlantic Cable System (SACS) cable.[23]

Awareness building via workshops, forums, and website content appears to have reaped benefits in the presence of banks and other nontraditional members joining the IXPs. Still, more could be done to increase interest and build capacity, including creating specific materials on the benefits and operations of an IXP with guideposts for users to navigate the material.

Burkina Faso

The Burkina Faso Internet eXchange Point (BFIX) was established in 2015 as a non-profit membership association with financing from the World Bank's West Africa Regional Communications Infrastructure Project (Table 6). The IXP is part of a broader project designed to help countries overcome the challenges of being landlocked without direct access to submarine cable landing capacity.

23 See https://www.angolacables.co.ao/wp-content/uploads/2019/11/GUIA-SACS-EN.pdf

Table 6. BFIX Information (Source: IXP survey, IXP website, 2020)

	BFIX
Established by	Association of Members (2015)
Model	Non-profit
Nodes	2
Hosted by	Neutral data center
Three-year total cost (1Gbps)	US$12,600
Connected Networks	15
Access Networks	9
International CDNs	1
Peak traffic	10 Gbps
Obligations	MMLPA
Restrictions	No restrictions on members

The BFIX has nodes in two cities, Ouagadougou and Bobo-Dioulasso, and provides connectivity between them as part of its costs. To date, the bulk of the traffic goes through the initial node in the capitol city of Ouagadougou. The other, newer node was turned up in September 2020 in Bobo-Dioulasso, and is where Facebook is connected. In order to maximize membership, the IXP has no membership restrictions; for the networks that have joined, there is an MMLPA.

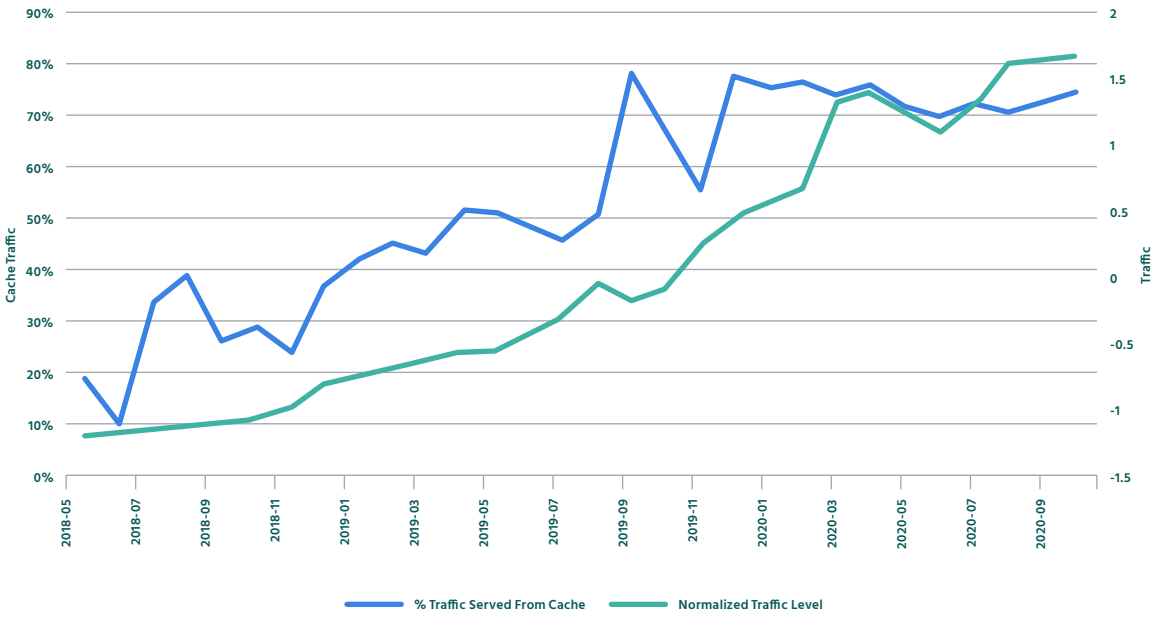
The IXP reports that 20% of its traffic is domestic, which puts the IXP in Stage 1 of development. This is confirmed by the membership numbers. On the positive side, the membership encompasses all of the ISPs and MNOs in Burkina Faso, including the incumbent. It also includes the *Point d'attérissement virtuel* (PAV), or virtual landing point. The PAV provides virtual access from Burkina Faso to submarine cable capacity in Ghana, thereby helping the country to overcome one of the challenges of being a landlocked country by lowering the cost of IP transit.

In terms of content, we understand that one international CDN is connected to BFIX in Ouagadougou with the support of a network providing transit, while a Facebook Network

Appliance (FNA) is connected indirectly to the IXP in that city. The membership includes the *Agence Nationale de Promotion des Technologies de l'Information et de la Communication* (ANPTIC), a government agency that hosts content and services, such as educational resources for the universities. Beyond that, there is relatively little local content, and what does exist is primarily hosted outside Burkina Faso due to cost.

While none of the three international CDNs that provided data are directly connected to the IXPs, two have caches in the country connected to ISPs. One reports that 72% of its traffic is served from within the country, 90% is served within the region, and the rest comes from outside Africa. A second CDN has caches with two ISPs. The impact of local hosting in Burkina Faso has been significant. One CDN, which has a cache connected through the IXP, provided data showing how the level of traffic increased as the percentage served from the cache increased (Figure 12). Another CDN reported an increase in traffic levels of 1,400% when its cache was turned up.

Figure 12. Impact of Localized Content on Traffic (Source: International CDN, 2020)



The third CDN does not have a cache in Burkina Faso, but reports traffic coming from Europe and other countries in Africa. The latency for the majority of traffic served by that CDN is higher than in the other case study countries with a cache, and throughput is slower. This highlights the benefits of local hosting of content.

On a regional basis, traffic can be accessed at the IXP by neighboring Ghana and Nigeria, subject to the content and cost of the transport to get to those two locations. There also

is cross-border capacity to neighboring landlocked Mali and Niger, as well as coastal Togo and Benin. While BFIX can serve content to those countries, the cost of the transport is significant. One of the CDNs reported a small amount of traffic going to Niger, all other content appears to stay within Burkina Faso.

The leadership and policies of BFIX have helped it to rapidly grow over the past months; it has now expanded to a second city. In addition, no stakeholders indicated any regulatory challenges with respect to Internet connectivity or content hosting. Indeed, the government actions with the virtual landing point have significantly lowered the cost of IP transit, and ANPTIC was a founding member of the IXP in order to peer government content with local ISPs.

Recommendations

The challenges in Burkina Faso stem both from being landlocked and the size and development of the country. While BFIX has significantly helped the country to overcome these challenges, the following key shifts would support a movement toward Stage 2 of development by further developing the ecosystem and delivering more localized content to the country and, possibly, the region.

Increased awareness regarding the benefits of the IXP will help to increase membership and usage of the IXP, likewise for increased capacity building. A weeklong training session was delivered in early 2019 by the Internet Society as part of the Facebook IXP Partnership project; it included a one-day roadshow for managers followed by a four-day technical workshop. This training led to a change in the design of the IXP that resulted in a 1,100% increase in traffic through the IXP, as well as a corresponding increase in savings.[24] Still, a number of local stakeholders noted that more capacity building would be welcome for current members, as would roadshows for managers of other organizations to increase membership.

The BFIX website provides a good view of the operations of the IXP, including information about existing members, peering statistics, and information for prospective members. The website could perhaps provide more insights into the benefits of joining, along with links to resources that provide online insights and training, particularly in light of the challenges of travel during the pandemic.

One or more neutral data centers with the ability to host content and services at prices that would make it attractive for additional international and national content would be welcome. Virtual Technologies and Solutions (VTS) is building such a neutral data center, which will be a significant addition to the ecosystem. Until then, it is cheaper to use

24 See https://www.internetsociety.org/blog/2019/05/growing-an-internet-exchange-in-burkina-faso/

international cloud services, which can significantly increase the cost of accessing the content using international capacity.

The cost of international IP transit is still high. The virtual landing point has significantly lowered the cost on the basis of a bulk purchase of transit by the government, which, in turn, lowered the cost of transit tenfold. Nevertheless, the cost per Mbps is still a relatively high US$14 per month. In addition, we understand that international transport (not IP transit), which may be preferred by large users, including international CDNs, is still very expensive. A wholesale operator provider could significantly lower the cost. In the meantime, the Internet Society's partnership with Facebook provided a grant that covers 50% of the cost of filling any CDN cache connected to the IXP, with the members covering the other 50%.[25]

Democratic Republic of Congo

DRC's two IXPs—KINIX in Kinshasa and LUBIX in Lubumbashi—were both established by the Internet Service Provider Association of the DRC (ISPA-DRC) (Table 7). ISPA has plans for a third IXP in Goma, to be called GOMIX.

Table 7. DRC IXP Information (Source: IXP surveys, ISPA DRC website, 2020)

	KINIX (Kinshasa)	LUBIX (Lubumbashi)
Established by	ISPA-DRC (2012)	ISPA-DRC (2019)
Model	Non-profit	Non-profit
Nodes	1	1
Neutral data center	No	No
Three-year total cost (1Gbps)	US$14,300	US$14,300
Connected Networks	14	7
Access networks	9	5
International CDNs	Facebook, One other	Facebook
Peak traffic	14 Gbps	3.5 Gbps
Obligations	MMLPA	MMLPA
Restrictions	No restrictions on members	No restrictions on members

25 For more details on this program, see https://www.internetsociety.org/issues/ixps/facebook-ixp-partnership/

KINIX counts among its members all of the country's major ISPs and MNOs, except the fixed incumbent, the *Societé Congolaise des Postes et Telecommunications* (SCPT), which today provides domestic and international wholesale connectivity. All of the members of LUBIX are a subset of the ISPs and MNOs at KINIX. This overlap can be explained by the approximately 2,300 km distance between the two cities and the cost of national connections—for the larger ISPs it is most efficient to connect in both locations. Goma is at least 1,500 km from both cities, forming a triangle and affording local connectivity at a lower cost when its IXP is ready.

Facebook and another international CDN are connected to KINIX, and Facebook is connected to LUBIX, providing the benefits of peering the content in their caches through the IXP. In addition, Infoset is connected at KINIX, which provides access to its educational and healthcare content. Infoset reports that the quality of its connection to the ISPs improved significantly with the IXP, such that it was able to provide e-learning access to the University of Kinshasa during the recent COVID-19 lockdown. There is, however, relatively little other content available through the IXP, which reports that 1% or less of traffic is locally generated.

Two of the international CDNs providing data have caches in DRC. One reports that 60% of its traffic is served from within the country, 80% is served within the region, and the rest comes from outside Africa. A second CDN has caches with at least three ISPs, and reports up to a 100% increase in traffic immediately following the turnup of each cache. The third CDN has no caches in the country, and reports most traffic comes from Europe and other parts of Africa, with higher latency and lower throughput, on average, than in other case study countries where it has caches. None of the CDNs report serving traffic from DRC to other countries.

Awareness of the benefits of the IXP is high among the ISPs and MNOs—the major ones have all joined, outside of the incumbent carrier. Local content providers could have their awareness increased, to the extent that they are able to host locally. In addition, while the Internet Society and ISPA DRC have offered technical workshops, increased capacity building would be welcome. Information about the IXPs is posted on the ISPA DRC website, but it contains relatively little information other than member and traffic data.

DRC's challenges are based on marketplace conditions and regulations: there is relatively little local content generated, it is hard to raise money to create content, and there are no neutral data centers where the content can be hosted. It appears that content providers and data centers require licenses, which provides an added obstacle to developing local content. In addition, there are relatively few online government services that would benefit from the IXP.

DRC has regulatory challenges: the telecom sector is operating under an outdated 2002 law. While an updated telecommunications law has been passed, it is not yet in effect as of the writing of this paper.

More broadly, the coverage of the mobile operators is relatively low and the cost of service is high, in part due to high taxes on mobile services, including a value-added tax of 16%, an excise tax of 10%, and taxes on handsets. The tax on a 2G phone is US$1 per year, and US$7 per year for a smartphone—not insignificant amounts in a country where 72% of the population lives on less than US$1.90 per day.[26] This helps explain why Internet penetration is under 20% of the population, which, in turn, severely restricts both the size of the market for content, and the amount of traffic available through the IXP.

As a result, one restriction on the usage and benefit of the IXP is the number of users and underlying costs.

Recommendations

The CDNs already connected to the IXPs in DRC have helped to lower the cost of accessing content. Further lowering the cost of IP transit would help lower the cost of accessing content, with the aim of attracting more CDNs. This would not just help users in DRC, but could also help to establish the DRC as a hub for its neighbors by bringing in international content and serving it to other countries in central Africa. As things stand now, it is the other way around—at least one CDN provides content to DRC from Rwanda.

In addition, the IXP website could be upgraded to include more information about the benefits of IXPs, links to capacity-building material, membership requirements, and how to join the IXP. At the same time, more training is needed, specifically to manage Border Gateway Protocol (BGP) traffic flows and other important aspects for current and prospective members.

There are several issues throughout the sector that could be addressed. First, the cost of international IP transit is still significant, at more than US$20 per Mbps. Given the size of the country, the cost of deploying national backbone is high and there is historically relatively little competition.[27] At least one new submarine cable—Facebook's 2Africa—will land in DRC and provide significant added capacity and competition. According to the press, Liquid Telecom has a license for building a second landing station in DRC, and it operates a backbone across DRC to its One Africa network that connects the west coast of Africa to

26 See https://globalvoices.org/2020/12/30/new-tax-on-mobile-devices-threatens-digital-inclusion-in-the-democratic-republic-of-congo/. For a more general discussion of mobile taxation, see https://www.gsma.com/subsaharanafrica/wp-content/uploads/2018/11/GSMA_DRC-report_ENGLISH_72pp_WEB.pdf. Income levels in https://www.worldbank.org/en/country/drc/overview.

27 See https://engineering.fb.com/2020/05/13/connectivity/2africa/

the east coast.[28] Increased access to submarine capacity and wholesale transport would help lower the cost of international access.

Egypt

The Cairo Internet Exchange (CAIX) was established by the Ministry of Communications and Information Technology (MCIT) and is operated by the country's telecom regulator, the National Telecommunications Regulatory Authority (NTRA) (Table 8).

The IXP's connected networks are the licensed ISPs and MNOs in Egypt. There are no content providers attached to the IXP, although their content could be shared through the IXP by their upstream ISP. The traffic through the IXP recently increased more than threefold—the result of an upgrade of the IXP to 10GB ports, plus the increased traffic from COVID-19 restrictions creating more reliance on the Internet, a reliance the Government of Egypt helped to promote.[29]

Table 8. CAIX Information (Source: IXP survey, CAIX website, 2020)

	CAIX
Established by	MCIT (2002)
Model	Government run
Nodes	1
Hosted by	Government
Three-year total cost (1Gbps)	Free
Connected Networks	5
Access Networks	None
International CDNs	None
Peak traffic	20 Gbps
Obligations	ISP License obligation
Restrictions	NTRA approval for CDNs

28 See https://www.developingtelecoms.com/telecom-technology/optical-fixed-networks/9315-liquid-wins-licence-for-drc-s-second-landing-station.html

29 See https://blogs.worldbank.org/arabvoices/digital-transformation-time-covid-19-case-mena

Today's Egyptian ISPs are aware of the benefits of an IXP, as it is a mandatory license condition to exchange local traffic locally, and each has a dedicated team for interconnection and peering. No content providers are connected directly to the IXP at this time.

While none of the three international CDNs that provided data are directly connected to the IXP, all have caches in the country connected to multiple ISPs, and at least one has a PoP in the country. One CDN reports that 90% of its traffic is served from within the country, and the rest comes from outside Africa. The second CDN has a number of caches in the country, each with a different ISP. A third CDN reports that most traffic is served locally through its caches, and the rest comes from European countries. The traffic served locally has much less latency, on average, with higher throughput. None of the CDNs report serving traffic from Egypt to other countries.

Locally available traffic is estimated to be 35% of traffic, which puts the country in Stage 2 of development. However, there are some challenges. International content providers need permission from the NTRA to connect directly to the IXP, presumably to address privacy and security issues. To date, none have asked for permission, as there are no content providers attached to the IXP. While the larger CDNs can afford to place caches with all or most of the ISPs, that is not the case for smaller CDNs; meaning, ISPs must source their traffic from abroad.

Overall, Egypt could take a more prominent role as a hub for domestic and regional Internet traffic. The country itself is the largest in the region in terms of population and potential. Seventeen submarine cables land in the country or are in planning, as the country acts as a passage between Europe, Africa, the Middle East, and Asia. But incumbent Telecom Egypt has an effective monopoly over the landing stations for the international cables, and it is also dominant in fiber backhaul into the country. As a result, there is little domestic benefit from the richness of the submarine cable landings. In addition, domestic data centers have not fully benefited from the location, partly because of the connectivity challenges and partly because a recent data protection law that may increase demand has been passed, but not yet implemented.

Further, Egypt has not been able to fully leverage its geographic location advantages to become a hub for the region. While regional traffic can pass through the country, it must be kept separate from the domestic traffic, leading to some duplication of facilities for CDNs and other companies. And there is relatively little peering within the region between regional ISPs. As a result, much peering that could take place in Egypt is taking place in Marseille, France, where many cables from the region land. Addressing the aforementioned issues could turn Egypt—and, specifically, the CAIX—into a regional hub for traffic exchange.

Recommendations

Awareness about the benefits of the IXP could be increased, thereby providing reasons for content providers to connect directly, while capacity building would also be needed to prepare them. The IXP's website contains good information, which could be supplemented with additional links and information for new members.

While the government provided a significant service in establishing the IXP, and recent actions have led to a significant increase in traffic, membership is still low compared to the other IXPs in Africa. Opening access and providing a multistakeholder management model would help to increase local traffic exchange. Fully liberalizing the international gateway and developing a wholesale network within the country would lower the cost of international access and would help to develop local content hosting. The results would be increased domestic traffic exchange and the ability to better leverage the country's favorable attributes as a regional traffic hub.

Mauritius

The Mauritius Internet Exchange Point (MIXP) was established in 2005 in the Government Online Center (Table 9).

Table 9. MIXP Information (Source: IXP survey, MIXP website, 2020)

	MIXP
Established by	Government
Model	Non-profit
Nodes	2
Hosted by	Government, Neutral data center
Three-year total cost (1Gbps)	Free
Connected Networks	14
Access Networks	7
International CDNs	None
Peak traffic	110 Mbps
Obligations	None
Restrictions	None

The IXP has two nodes in the city of Ebene, one in a government data center and the other hosted by Rogers Capital. Connections between nodes are provided by members. All the major domestic ISPs and MNOs are members of the IXP, as is the National Computer Board and a local media company. A number of international CDNs have caches in the country that are hosted by one or more of the ISPs, but they are not shared through the IXP.

While none of the three international CDNs that provided data are directly connected to the IXP, all have caches in the country connected to the major ISPs. One reports that 90% of their traffic is served from within the country, 99% is served within the region, and the rest comes from outside Africa. A second CDN has caches at multiple ISPs, and reports a 150% increase in traffic immediately following the turnup of the latest cache. The third CDN reports that the majority of traffic is served locally, and the rest comes from South Africa.

Locally served traffic has much less latency, on average, with higher throughput. None of the CDNs report serving traffic from Mauritius to other countries.

MIXP has conducted a number of roadshows to help create awareness for the benefits of the IXP, and has offered capacity-building sessions with peers and potential peers in order to better understand their issues. In addition, the Ministry of ICT hosted a five-day capacity-building workshop with the Africa Union Commission and the Internet Society. Finally, Mauritius has benefited from hosting several large events that helped create awareness and capacity, including AFRINIC-25 in 2016 and the 10th annual AfPIF in 2019.

The Benefits of Capacity Building: La Sentinelle Ltd.

La Sentinelle is a local media company that offers news content and videos. Until 2019, it was hosting with a cloud company in Europe, whereby 80% of the traffic was going back to Mauritius on very expensive international bandwidth. Local ISPs offered to host the company's content, but at a cost even higher than what was being charged in Europe.

Things began to change in 2017, when Ish Sookun, a systems architect at LSL Digital, a division of La Sentinelle, attended an Internet Society meeting on local hosting. While there, AFRINIC staff convinced him to request IP addresses and an AS number, so La Sentinelle could better obtain efficient local hosting. A local ISP, Rogers Capital, cohosted the AfPIF in Mauritius in 2019, and based on the meetings and discussions, agreed to announce the IP addresses for La Sentinelle.

For the rest of its business, La Sentinelle invested in new equipment that enabled it to host its own cloud service locally and meet ISPs at MIXP. The results were significant: latency fell from 250–300 milliseconds (ms) to less than 10 ms, a difference that was noticeable to users. The significantly decreased latency meant that La Sentinelle was able to provide real-time election results, and soon their video news will migrate from YouTube to their own cloud server.

It is worth noting that La Sentinelle had an existing business need to invest in new equipment that enabled cloud service. Local content providers without that business need will still depend on international services, as local cloud hosting is still an order of magnitude more expensive than international.

The IXP reports that 2% of the traffic is domestic, putting Mauritius in Stage 1 of development. However, it is worth noting that the main challenges in Mauritius are fundamental to the market. While Mauritius is an advanced Internet market, it is an island nation with a relatively small population. Internet penetration is 68% of the population, with 100% fiber-to-the-home availability, but that represents just 860,000 users.

The market in Mauritius is fully liberalized, with competition in all segments. However, given the low amounts of traffic, international IP transit costs US$100 per Mbps per month, a significant amount. In addition, given the small size of the market, local hosting also is relatively expensive, and most traffic sits outside the country. As a result, each ISP incurs a significant cost to pick up this international traffic in either South Africa or Asia

Recommendations

While the IXP provides significant savings by localizing traffic between ISPs, sharing cache traffic or connecting caches directly to the IXP would save significant resources, particularly for the smaller ISPs who must access the traffic abroad. Efforts to aggregate demand to lower the cost of hosting would also be helpful to further localize traffic and achieve the full benefits from the IXP.

The IXP's website is fairly basic, with little more than a list of members and statistics. Adding more information to the website could help create awareness and provide resources for capacity building.

Rwanda

The Rwanda Internet Exchange (RINEX) was launched by the Rwanda Information Technology Authority in 2004, and it is now managed by the Rwanda Internet Community and Technology Alliance (RICTA) and hosted at an ISP data center (Table 10). As a landlocked country with the expected challenges accessing international submarine cable capacity, RINEX has played a significant role in helping to localize traffic and avoid relying on coastal access.

Table 10. RINEX Information (Source: IXP survey, RINEX website, 2020)

	Rwanda
Established by	RICTA (2004)
Model	Non-profit
Nodes	1
Hosted by	ISP data center
Three-year total cost (1Gbps)	US$23,400
Connected Networks	18
Access Networks	8
International CDNs	Cloudflare, Facebook, Netflix
Peak traffic	1.4 Gbps
Obligations	None
Restrictions	None

RINEX has a broad base of members. All the major ISPs and MNOs are members, as are several carriers. In addition, four members—AFRINIC, NetNOD, PCH, and Verisign—provide access to DNS servers, which lowers the time for domain-name resolution.

RINEX has a number of both international and local content providers as connected networks. Facebook, Cloudflare, and Netflix are members of the IXP; and Akamai and Google are available through ISP connections. In addition, several of the CDNs are connected directly to multiple ISPs; this provides the benefits of local connectivity, while reducing traffic through the IXP. In terms of local content, Rwanda Education Network

and Rwanda Revenue Authority are connected to the IXP, e-government services are accessible through the ISP BSC, and other local content providers are connected indirectly through ISPs.

All three international CDNs that provided data are directly or indirectly connected to the IXP via ISPs. One reports that 60% of its traffic is served from within the country, 99% is served within the region, and the rest comes from outside Africa. A second CDN has caches with a number of ISPs, and reports that it experienced up to a 100% increase in traffic immediately following the turnup of the caches. A third CDN reports that the majority of its traffic is served locally, with the rest coming from Kenya, South Africa, Uganda, and Europe. On average, the traffic served locally has much less latency and higher throughput. One of the CDNs reports serving traffic through several ISPs to neighboring DRC.

RINEX has an active outreach program that has helped attract its diverse membership. As with many of the IXPs in Africa, capacity building has been provided by the Internet Society, as well as the local RWNOG, but more capacity building could be provided to augment what has been done.

Leading The Way: RINEX.org.rw

Common across nearly all the IXPs in Africa, is the call to raise more awareness about the benefits of joining an IXP and to enable greater access to online capacity-building material. IXP websites are a front-line resource for doing both.

The RINEX website is an excellent example of how an IXP's website can play a strong role in helping to generate awareness and share information about the IXP. Its structure is a model for sharing multiple categories of information.

- Home: Member highlights; access to IXP policies on interconnection, quality of service, data collection, and data access; ASN, port, and switching capacity data; and links to traffic data and the IXP's multi-router looking glass
- About: The IXP's vision, mission, values, and history
- Services: The services available at the IXP
- Contact: Contact information and email inquiry form
- Get Connected: Requirements for connecting to the IXP
- Connected Networks: A list of networks and basic network information
- Pricing: An overview of the IXP's fee structure

Although Rwanda has the intrinsic challenge of being a relatively small, landlocked country, it has done very well, thanks largely to its forward-looking and high-level policies for developing a digital infrastructure and transforming its economy. Challenges remain, however, in its marketplace—the cost of local hosting is relatively high, which leaves local websites to seek hosting outside the country. While the country has one carrier-neutral data center that hosts content and services, it is relatively limited in space and unlikely to deliver the scale economies of the larger data centers abroad. Furthermore, the cost of local transport and international content is relatively high.

Recommendations

Rwanda's market would benefit from increased competition in wholesale capacity, including transport to the coastal countries to access content in Kenya, as well as submarine cable and regional capacities. For instance, Rwanda could become a larger IXP hub for neighboring DRC, with appropriate cross-border transit to that country. These challenges are not regulatory, but rather driven by the market, and may be overcome as Liquid Telecom and other carriers build out their networks.

Conclusions

A long-time community goal for Africa is that 80% of its Internet traffic originates within the continent. For more than 10 years, the Internet Society has been supporting this goal by promoting IXPs as focal points for localizing traffic, lowering the cost and latency of traffic exchange, and increasing the resilience of a country's Internet ecosystem. In this paper, we assessed the current status of IXPs in Africa, and took a detailed look at how this strategy is working in six countries in each subregion of Africa.

We built our analysis on the foundation of the Internet Society's most recent review of Kenya and Nigeria, two of the most advanced IXPs and ecosystems in Africa.[30] In that paper, we identified three stages of development, as defined by the level of localized content, and showed that both countries had moved from the cusp of Stage 2, with 30% local traffic in 2012, to the cusp of Stage 3, with 70% local traffic in 2020. Based on our review of all the countries in Africa with IXPs, the most developed Internet ecosystem in Africa is South Africa, which has achieved the goal of at least 80% localized traffic, followed by Kenya and Nigeria.

30 Michael Kende, "Anchoring the African Internet Ecosystem: Lessons from Kenya and Nigeria's Internet Exchange Point Growth" (Internet Society, June 2020), https://www.internetsociety.org/wp-content/uploads/2020/06/Anchoring-the-African-Internet-Ecosystem-Lessons-from-Kenya-and-Nigeria.pdf

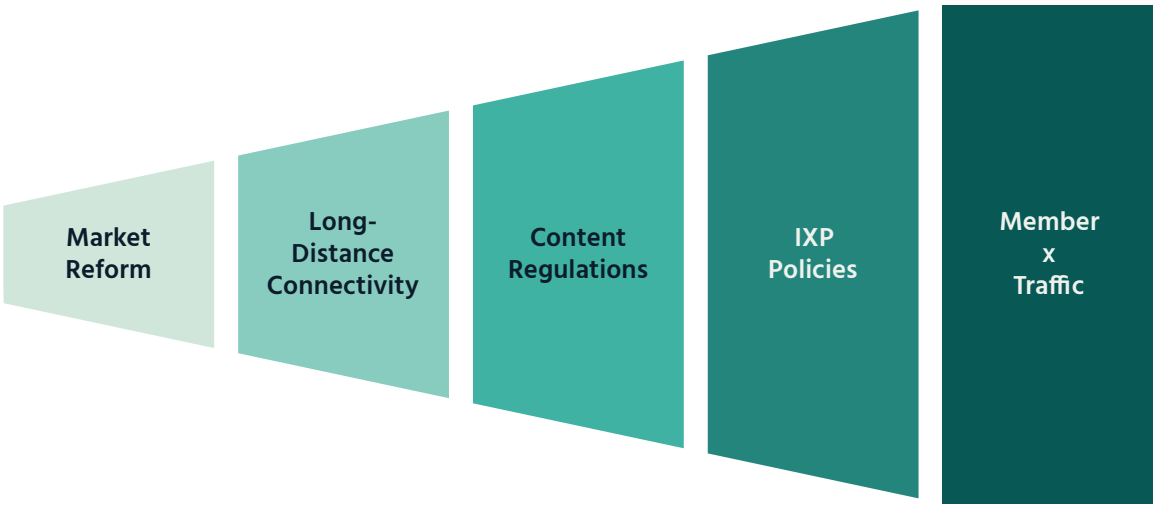
One aspect that Kenya, Nigeria, and South Africa share is large IXPs with at least 50 members. This is a strong indication of the health of the Internet ecosystem in each of these countries—that there are so many networks, and that they are all connected to the IXP. Specifically, it reflects a tremendous diversity of connected networks in each country. Note that every country has a limited number of access networks (ISPs and MNOs) due to the nature of the business and access to necessary inputs, including either wires to households and businesses or spectrum. The number of access networks is the lower limit on the number of connected members; the rest must be content providers, government agencies, international carriers, and enterprises.

Our assessment revealed a positive correlation between the number of members and the amount of traffic through an IXP. This correlation reinforces the benefits of having more connected networks: not only the amount of traffic increases with more members, so does the amount of traffic per member. It suggests a generative impact of increased membership as more traffic is exchanged, which, in turn, helps lead countries toward higher stages of Internet ecosystem development.

A Roadmap for Greater Internet Ecosystem Health

Figure 13 illustrates four membership enablers, proven ways for African IXPs to increase membership and generate more traffic. Each enabler is important and builds upon the previous enablers to maximize the number of potential members.

Figure 13. Membership Enablers (Source: Internet Society, 2021)



Market reform. ISPs typically drive the development of an IXP, and an IXP is only needed if there are at least three ISPs (one ISP does not need to exchange traffic, and two can do it bilaterally). Thus, the first step toward developing demand for an IXP in a country is basic telecom market reform that leads to the emergence of competing access networks, including fixed ISPs and mobile operators that provide Internet access. This means opening the market to competition, and it is improved if there are no limits on the number of licenses and if both the cost- and noncost-based barriers to acquiring a license are low or nonexistent. However, as noted, the number of ISPs represents a lower limit on the number of connected networks at an IXP.

Long-distance connectivity. The topic of long-distance connectivity was raised in a number of the survey responses, and it is critical to developing a healthy Internet ecosystem. Terrestrial connectivity is required to enable ISPs and other organizations to connect to an IXP—competition between connectivity providers ensures that the cost of access is affordable and that the access is resilient. International connectivity is also important. First, liberalizing the gateway promotes that regional and global ISPs join the IXP and turn it into a regional hub; second, low-cost, international IP transit is critical to delivering content to the IXP and attracting international CDNs to deploy caches and PoPs in the country.

Content regulations. Other important factors for attracting content to an IXP are a country's privacy and data protection regulations, and whether platforms are subject to intermediary liability for third-party content. More fundamentally, survey responses pointed to a need for more local content hosting and more local content. With regards to

the former, carrier-neutral data centers are needed to host the IXP, CDNs, and any local organizations wishing to connect to the IXP. With regards to developing local content, governments can promote local content with their own e-government services, with training for content developers, and by promoting digital payments to help facilitate new local services.

IXP policies. An IXP's policies directly impact its number of members, particularly as it grows from early membership of the access networks to a more diverse group of connected networks. IXPs can determine who can join them—a liberal policy, particularly with respect to attracting content and service providers including government agencies, enterprises, and other nontraditional networks, will help to increase its numbers. Having an MMLPA can deter potential members that do not want to peer with all other members.

In addition, African IXPs would be wise to increase awareness of their benefits in order to attract potential new members. Similarly, capacity building would ensure that present members take full advantage of those benefits. Developing a comprehensive website is a key tool for providing awareness and links to member resources, particularly while travel is curtailed during the pandemic and business is increasingly handled online.

Next Steps

Systematically approached, these membership enablers will help African IXPs maximize their number of connected networks and, thereby, expand their country's Internet ecosystem. It is clearly established that IXPs play a particularly central role in creating a healthy Internet ecosystem. While they are the focus of traffic exchange and help to attract content and services to the country; they also are uniquely positioned to leverage their membership to promote the policies and regulations needed to reform the market, lower the cost of connectivity, and develop favorable content-hosting conditions. The Internet Society is confident that by taking the aforementioned steps, African countries will not only develop their local Internet ecosystems, but also promote regional growth and achieve the goal of at least 80% traffic localization within Africa.

The future looks bright for the African Internet ecosystem. More than half the countries in Africa have an IXP, and six countries have more than one. Further, the number of IXPs jumped significantly in response to stakeholder and community efforts. While the 80/20 goal was not reached by 2020, the community should set a new goal, with the confidence that its activities will continue to have a strong influence on the IXP ecosystem. This paper is intended to start the dialogue towards developing, and achieving, the new goal for the new decade, based on a number of membership enablers.

Appendix A: Survey of African IXP Operators

The survey was posted via SurveyMonkey on 29 July 2020, and made available to all Af-IX IXP contacts. Contacts were prompted with several reminders.

1. **Please introduce yourself.**

   Your Name

   Your Title

   Your IXP

   Your Country

   Your City

   Your email address

2. **Please tell us about your IXP.**

   What is your business model (e.g., non-profit, for-profit, etc.)?

   How many nodes do you have?

   If more than one, are all the nodes in the same city or in multiple cities?

   What city/cities are the nodes in?

   Do you provide connectivity between the nodes, or do the members provide it?

   Is at least one of your nodes based in a neutral data center?

   Do you have expansion plans you could share with us?

3. **We would like to learn about your operations.**

   How many peering networks do you have in total?

   What is your peak traffic level?

   What is your average traffic level?

   Can you please estimate what percentage of your traffic is regional?

4. **If you have more than one node, please break down your numbers.**

   Node 1: Location, number of peering networks; peak and average traffic level

Node 2: Location, number of peering networks; peak and average traffic level

Node 3: Location, number of peering networks; peak and average traffic level

Node 4: Location, number of peering networks; peak and average traffic level

5. **What are the prices at your IXP? (Please indicate currencies)**

   Do you have an initial joining fee? If so, how much is it?

   Do you have an annual fee other than the port charges? If so, how much is it?

   Do you have a flat rate monthly port charge? If so, what is it?

   Do you have speed-based port pricing? List the speeds (e.g., 1Gbps) and monthly charges for each?

   Are there other charges for additional services?

6. **Can you estimate for your country what percentage of total Internet traffic is domestic versus international?**

7. **Do you feel that there is general awareness of the benefits of an IXP in your local Internet community, particularly with smaller ISPs and local content providers? How has the awareness been built? What could be done to increase the awareness?**

8. **Do you feel that there is sufficient capacity building regarding peering and interconnection in your country? What are the sources of capacity building? What could be done to increase the capacity building?**

9. **Are there any restrictions at your IXP?**

   Do you have a mandatory multi-lateral peering agreement at your IXP?

   Can any domestic network join the IXP, or only ISPs?

   Can any international network join the IXP, or do they need a domestic license?

   What is the purpose of these requirements, if any?

10. **Please tell us about international content delivery networks (CDNs)**

    Are there international CDNs present in your country?

    Are their caches available at the IXP?

    Do they have PoPs in your country?

Can you name the international CDNs, and what they have in your country?

11. Please tell us about local content providers

Are there a significant number of local content providers hosting in your country?

If there are, are they available at the IXP?

If there is little local content available, why not?

12. What are you most proud of in the development of your IXP?

13. Are there any broader policy impediments that impact ISPs in your country? These could be in relation to the level of competition at the international gateway, national backbone, or last mile networks, for instance. What are the policy impediments?

14. Are there any policy impediments to develop a data center in your country, or for an international content provider to bring a cache or point of presence into your country? What do you think are the policy impediments?

15. What policy or regulatory changes would most contribute to increasing the usage of your IXP?

16. Thank you!

Can we acknowledge your input in the report including your name?

Can we refer to any of your answers in the report (we would check with you first)?

Appendix B: Figures Including South Africa

The South African IXPs significantly overshadow the other African IXPs, both in number of connected members and amount of traffic—this is particularly true for NAPAfrica Johannesburg. Viewed all together, the data can appear skewed. As a result, we excluded the South African IXPs from the body of this paper's figures. We present them here.

Figure 14. Three-Year Cost of Connection and Number of Members with South Africa (Source: IXP surveys, IXP websites, 2020)

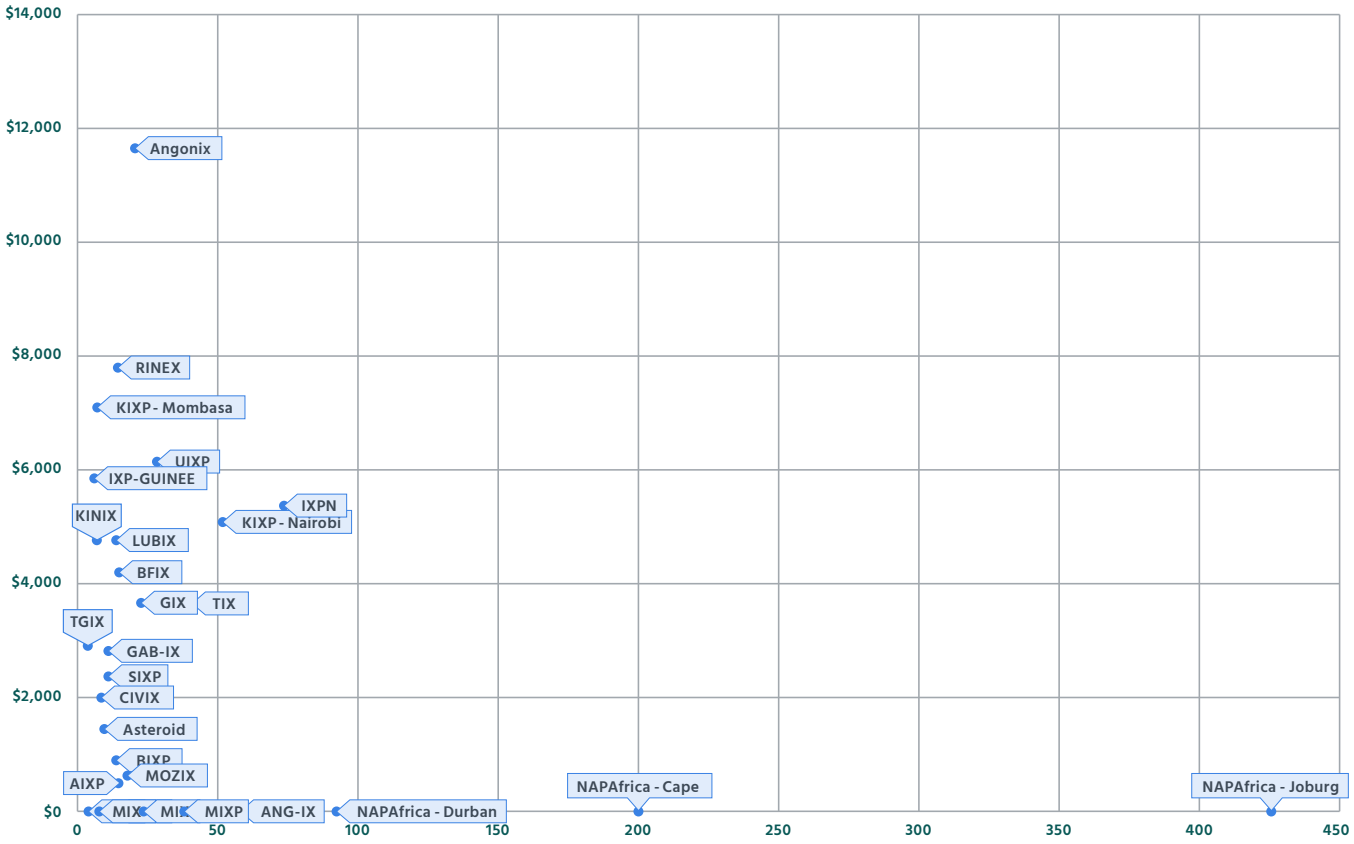


Figure 15. Number of Networks and Traffic per Network with South Africa
(Source: IXP surveys, IXP websites, 2020)

Appendix C: List of Acronyms

ADC	Africa Data Centres (company)
Af-IX	African IXP Association
AfPIF	African Peering and Interconnection Forum
AFRINIC	African Network Information Centre
ANPTIC	*Agence Nationale de Promotion des Technologies de l'Information et de la Communication (Burkino Faso)*
ARDA	African Route-Collectors Data Analyzer
ASN	Autonomous system number
AXIS	African Internet Exchange System
BGP	Border Gateway Protocol
CDN	Content delivery network
CON-IX	Le Point d'Echange Internet de la Guinee (IXP-GUINEE)
De-CIX	Deutscher Commercial Internet Exchange
DRC	Democratic Republic of Congo
DNS	Domain Name System
EuroIX	European Internet Exchange Association
FNA	Facebook Network Appliance
GB	Gigabyte
Gbps	Gigabits per second
GDP	Gross domestic product
GGC	Google Global Cache
ICT	Information and communications technology
IP	Internet Protocol
INFOSI	*Instituto Nacional de Fomento da Sociedade de Informação (Angola)*
ISP	Internet service provider
ISPA-DRC	Internet Service Provider Association of the Democratic Republic of Congo
ITE	Interconnection and Traffic Exchange [Program]
IXP	Internet exchange point
Mbps	Megabits per second
MCIT	Ministry of Communications and Information Technology (Egypt)
MISPA	Malawi Internet Service Providers' Association
MLPA	Multilateral peering agreement
MMLPA	Mandatory multilateral peering agreement
MNO	Mobile network operator
Ms	Milliseconds
NDPR	Nigeria Data Protection Regulation
NIRA	Nigeria Internet Registration Association
NITDA	National Information Technology Development Agency (Nigeria)
NOG	Network operator group
NTRA	National Telecommunications Regulatory Authority (Egypt)

PCH	Packet Clearing House
PAV	*Point d'attérissement virtuel* or virtual landing point
PNI	Private network interconnect
PoP	Point of presence
QoS	Quality of service
RICTA	Rwanda Internet Community and Technology Alliance
SACS	South Atlantic Cable System
SCPT	*Societé Congolaise des Postes et Telecommunications (DRC)*
TESPOK	Technology Service Providers of Kenya
VLAN	Virtual local area network
VTS	Virtual Technologies and Solutions (company)
WAF-IX	West African Internet Exchange

Appendix D: List of Figures and Tables

Figures

Tables