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Report for the Internet Society

Assessment of the impact of Internet Exchange Points – empirical study of Kenya and Nigeria

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Contents

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1 Executive summary

As the Internet increasingly globalizes, the interconnection between networks, content providers and users is more and more critical to creating the ‘network of networks’ that is the Internet. At the center of this globalization are Internet exchange points (IXPs), facilities where all Internet players can interconnect directly to each other, thereby improving quality of service and reducing transmission costs. IXPs have already played a key role in the development of an advanced Internet ecosystem across North America, Europe and Asia. This paper details the impact that such IXPs have had in two emerging markets in sub-Saharan Africa: Kenya and Nigeria. The benefits for Internet Service Providers (ISPs) alone includes savings on international capacity costs, along with an improved quality of service resulting in additional revenues, with a total value worth millions of dollars per year.

IXPs typically follow a gradual evolution path, building on the growing number and diversity of their members over time. Early in the Internet development cycle in most countries, Internet Service Providers often find it cost-effective to use their international Internet connections to exchange domestic traffic, a process often known as ‘tromboning.’ Tromboning is the result of unilateral action, with each ISP independently concluding that it is more cost-effective to use its international connections for domestic traffic exchange than to connect to every other ISP separately. However, the use of international capacity for domestic traffic is expensive, and this tromboning can be eliminated, with corresponding cost savings, if ISPs adopt a co-operative approach to create a local IXP where domestic traffic can be exchanged.

The establishment of an IXP in the country enables local ISPs to connect directly together and exchange domestic traffic, typically with settlement-free peering, thereby reducing or eliminating tromboning and saving cost on international transit while reducing latency (by avoiding local traffic to be carried internationally). To the extent that the IXP begins to build critical mass, involving most or all of the ISPs, it will also begin to attract content providers, along with business, academic, and government users, and thereby become the center of a vibrant Internet ecosystem in the country. Further, the IXP can also begin to attract international content and connectivity providers, becoming a regional hub for Internet traffic.

The benefits of localizing Internet interconnection are increasing, due to consumers’ growing demand for services with increasing bandwidth (such as video) and lower tolerance for latency (such as Voice over IP). In developed countries, IXPs have played a key role in advancing the Internet ecosystem over the past 15 years. Today, IXPs are also progressively growing in Africa, despite a more challenging economic and telecommunications environment.

In this report, the benefits that IXPs are generating have been quantified for two African countries: Kenya and Nigeria. In each of these countries, the IXPs are booming and contributing to the growth of the surrounding Internet ecosystem in a number of ways:

- In Kenya, the Kenya Internet Exchange Point (KIXP) currently localizes more than 1Gbit/s of peak traffic, dramatically reducing latency (from 200-600ms to 2-10ms on average), while allowing ISPs to save almost $1.5 million per year on international connectivity. The IXP also increases mobile data revenues by an estimated $6 million for operators having generated at least an additional traffic of 100Mbit/s per year[1]; helps the localization of content in the country including from Google; is critical to raising government tax revenues, and increasingly acts as a regional hub for traffic from neighboring countries.

In Nigeria, the Internet Exchange Point of Nigeria (IXPN) currently localizes 300Mbit/s of peak traffic with corresponding reductions in latency, and allows national operators to save over $1 million per year on international connectivity. The presence of the IXP induced Google to place a cache in Nigeria as the first step in plans to build out Google infrastructure to Lagos, and is at the center of a partnership to improve communications between universities. The IXP also helped repatriate previously externalized financial platforms for online banking services.

These effects are summarized in Figure 1.1 below. Overall, the IXPs have had the direct effect of lowering the operating costs for local ISPs, while increasing the traffic, and where relevant corresponding revenues, of ISPs, with further benefits for those sectors that have incorporated the IXP in their delivery of services, notably the revenue authority in Kenya, and educational and banking sectors in Nigeria. Finally, it can be expected that over time, together with the decrease of international bandwidth costs, the IXPs will help reduce Internet access tariffs and result in increased Internet penetration and usage.

1 This figure represents the total cumulative additional revenues for mobile operators having increased their total traffic by 100Mbit/s thanks to the presence of the IXP, over an estimated total traffic of 1Gbit/s. As described below in Section 3.2.2, this estimate is very conservative.

Figure 1.1: Summary of key benefits [Source: Analysys Mason, 2012]

Benefit	KIXP	IXPN	Summary
Latency	Reduced from 200-600 ms to 2-10 ms	Reduced from 200-400 ms to 2-10 ms	Noticeable increase in performance for end users
Local traffic exchange	1 Gbit/s peak	300 Mbit/s peak	Savings on international transit of over $1 million per year in each country
Content	Google network present locally, along with rehoming of domestic content	Same as in Kenya	Increase in usage and corresponding revenues for mobile data traffic
E-government	Kenya Revenue Authority gathers taxes online	Usage by education and research networks	Social benefits from e-government access to IXPs
Other benefits	An increasing amount of regional traffic exchanged at KIXP	Financial platforms hosted locally	Further economic benefits resulting from IXPs

Within their respective regions, Kenya and Nigeria are in a strong position with respect to Internet access and usage. This is a reflection of a number of interdependent variables; a positive macro-economic environment; a liberalized telecom environment led by a widely respected regulator; a significant and increasing amount of international capacity; and a strong and competitive mobile sector. However, into this mix must be included the IXPs, whose success feeds off these other variables, but also helps to fuel them. In particular, an IXP helps to deliver the benefits of liberalization – lower prices and greater usage – which in turn can provide support and credibility for further efforts to liberalize and develop the sector. IXPs can also help to improve connectivity between neighboring countries, further increasing Internet usage and benefits.

Examples of more advanced IXPs should encourage stakeholders in Africa to increase their usage of IXPs, in order to lower their costs and improve the quality of their services. Furthermore, policy makers should help to promote the establishment and development of IXPs by adopting sector reforms when necessary and offering targeted support when possible, as advanced IXPs ultimately benefit the entire ecosystem.

Note: this study was commissioned by the Internet Society (ISOC), a non-profit organization that provides leadership in Internet-related standards, education and policy, and a key independent source on these issues.

2 Introduction

As the Internet increasingly globalizes, interconnection between networks, content providers, and users is increasingly critical to creating the 'network of networks' that is the Internet. At the center of this globalization are Internet exchange points (IXPs), facilities where all Internet players can interconnect directly to each other, thereby improving quality of service and reducing transmission costs. These IXPs have already played a key role in advancing the development of the Internet ecosystem across North America, Europe and Asia.[2]

Despite a more challenging economic and telecommunications environment at the moment, the Internet is progressively growing in Africa, and a number of leading countries on the continent are currently experiencing trends similar to those experienced in more developed countries:

- increasing usage of Internet with, among others, the development of mobile Internet technologies
- improving national connectivity, based on expanding Internet infrastructure
- growing access to international connectivity across the continent, notably new submarine cables that circle the continent
- development of IXPs to facilitate local and regional connectivity and leverage access to international connectivity.

Existing literature on the impact of IXPs details numerous advantages such as cost, quality, and redundancy; this paper aims to quantify those benefits, with a focus on emerging markets.

We concentrate on Kenya and Nigeria, each with IXPs that appear as best-in-class examples of booming IXPs in the sub-Saharan region. The study also compares the situation in these two countries with other comparable countries in the region, and proposes some projections based on more advanced examples such as the IXP in South Africa, which has succeeded in establishing itself as a regional hub for international Internet traffic.

This study was commissioned by the Internet Society (ISOC), a non-profit organization that provides leadership in Internet-related standards, education and policy, and a key independent source on these issues. The ISOC strongly believes in the value of IXPs in the development of a vibrant Internet ecosystem. However, in the emerging markets of Africa, the development of such IXPs is lagging, on average, for a number of reasons, including that:

2 See for instance "Overview of Recent Changes in the IP interconnection ecosystem," by Michael Kende, Partner, Analysys Mason.

- potential users of such IXPs may not perceive their full business benefits, limiting the creation of new IXPs and the growth of existing ones
- policy makers may not understand the general benefits, limiting necessary sector reforms that would help to promote the establishment and growth of a successful IXP.

As part of ISOC's drive to educate relevant stakeholders, this study aims to highlight the concrete benefits of helping to promote the establishment and the use of a successful IXP to Internet service providers (ISPs), content providers, enterprises, academic and government users, and policy makers.

2.1 Impact of an IXP

IXPs provide a mechanism for their members, including ISPs, backbone providers and content providers, to interconnect their networks and exchange traffic directly. The exchanges encourage the local routing of domestic or regional Internet traffic, by facilitating the interconnection between all of the players in order to reduce costs and maximize performance. While the movement to localize traffic exchange continues as a means of saving money on international connectivity (and will increase given the savings of accessing high-bandwidth content locally), the performance benefits of localizing interconnection are increasing, due to consumers' growing demand for services with increasing bandwidth and lower tolerance for latency.[3]

2.1.1 Background

The Internet is a network of networks interconnected to one another, and operated by different providers. Broadly speaking, there are four types of companies to consider:

- An *ISP* offers its customers access to the Internet via a fixed or mobile access line such as dial-up, DSL, 3G, WiMAX, or fiber. Its customers are Internet end users and content providers.
- A *content provider* creates and/or aggregates content for the Internet, to make it available to its customers. A content provider will get Internet access via an ISP, which provides the data transmission service to the rest of the Internet.
- An *Internet backbone provider* delivers traffic to and from third-party networks through its infrastructure of national and/or international high-speed fiber-optic networks. An Internet backbone interconnects with other backbones to sell Internet access to ISPs and enterprise users.
- An *end user* accesses the Internet via a fixed or mobile device connected to the Internet by an ISP. The end user may be an individual consumer, an enterprise, government, or an educational body.

3 Latency is a measure of time delay experienced in a communication system. Latency refers here to "round-trip" latency, i.e. the delay between the source sending a "packet" of IP traffic to the destination and then receiving a response.

In order to create the Internet, these stakeholders must all interconnect to facilitate access between end users and with content providers. Historically, a number of factors affect the relationships between the stakeholders, and resulting traffic flows, however, there seems to be a historical pattern that has been followed in developed countries towards increased local interconnection at IXPs, and this pattern continues in emerging markets.[4]

2.1.2 Conditions leading to an IXP

While each country has unique conditions, in terms of Internet adoption levels, regulation of telecommunications and access to content, most countries generally follows a similar pattern for Internet interconnection: they tend to first rely on expensive international connections until economic, technical, and other potential benefits encourage them to localize interconnection, in order to take advantage of lower costs and better quality of access.[5]

Early in the Internet adoption cycle, ISPs typically purchase international transit from at least one backbone provider in order to provide access to the entire Internet, including content, services, and other users. However, while access to international users and content is critical, end users also have a strong interest in access to domestic Internet content and services, to send business and personal emails, and for any interactions with local government, educational institutions, and business websites and services.

Early in the adoption cycle the cost of domestic connections between domestic ISPs may be significant, in particular where there are a number of ISPs (each of which would require a separate connection) and/or where domestic connectivity is not very competitive (and therefore expensive). Because all ISPs purchase international transit in any case, some often find it most cost-effective or convenient to include domestic traffic in these links, particularly in countries where access to domestic backhaul infrastructure is limited and related prices are high. As a result, domestic traffic, including even an email between neighbors, may leave the country in order to be exchanged – a process sometimes known as *tromboning*. This is detailed in Figure 2.1 below, in which each of the ISPs in Country A uses international transit to exchange traffic with one another, as well as to exchange traffic with foreign ISPs and content providers.

4 For further background, see http://www.analysysmason.com/About-Us/News/Insight/Insight_Internet_connection_Jun2011/?ReturnUrl=http%3A//www.analysysmason.com/Search/%3Fquerytype%3DAnyWords%26page%3D1%26perpage%3D10%26query%3Dkende%26new_search%3Dtrue%26sortby%3DRelevance%23%21/__Search__Filter__%3Fquery%3Dkende%26featuredItemsCount%3D0%26back%3Dtrue.

5 As the historical base of the Internet, the USA always had an inward focus for traffic exchange and access to content. At the same time, developed countries in Europe and Asia first relied on the USA for traffic exchange until traffic exchange slowly localized, as described in this section. This pattern is now extending to emerging markets in Africa and Latin America, as we describe below with two examples from Africa.

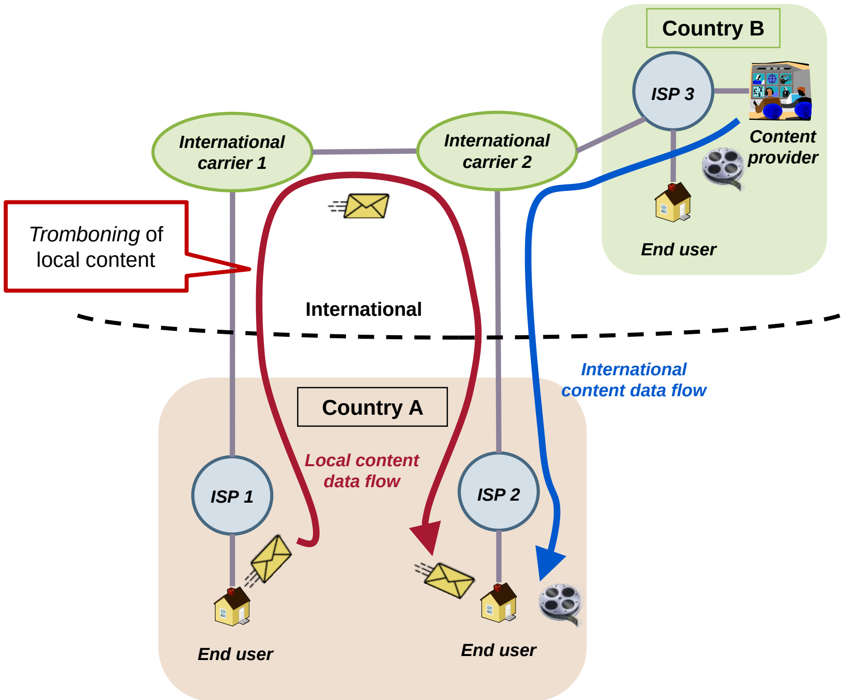

Figure 2.1: Example of using international connectivity for local and international communications and content [Source: Analysys Mason, 2012]

While tromboning may appear to be more straightforward and cost effective compared with a network of potentially more expensive domestic links between ISPs, it imposes three significant constraints on the providers in particular, and on the ecosystem in general.

- *Latency*: tromboning can add a significant amount of time to the delivery of Internet traffic, not just because of the extra distance that the traffic travels, but also because of the number of extra hops[6] that the traffic must traverse to get from one ISP to another. This latency can delay the adoption of those advanced Internet services such as voice over IP (VoIP) and video that suffer the most from high latency.
- *Cost*: introducing an international transmission round-trip for domestic traffic exchange is intrinsically inefficient and adds cost to the services. This cost is ultimately passed on to end users in high access fees and/or high usage fees, and also negatively impacts the firm's ability to make capital investments in their infrastructure, thereby impacting the adoption and usage of Internet services.

6 Note: a hop refers to the link between two distinct network nodes, where Internet traffic is successively routed throughout the network infrastructure. IP traffic is typically routed through multiples nodes, and each hop adds traffic carriage and switching time, which negatively affects the quality and resilience of the transmission.

- *Growth of ecosystem*: in an environment where there is little domestic interconnection between networks, domestic content providers will often choose to host their own content abroad, in order to serve local customers via existing international links. This adds costs to serving local content, and also slows the emergence of a domestic content industry that would serve to fuel further internet adoption.

Tromboning is the result of unilateral action, with each ISP independently concluding that it is most cost-effective to use its international connections for domestic traffic exchange. However, a co-operative approach between ISPs to create an IXP can change the status quo and eliminate tromboning, as described in the next section.

2.1.3 Creation of an IXP

As seen in numerous countries, ISPs acting in concert have both the ability and the incentive to develop an IXP that will reduce or eliminate tromboning, in order to lower their costs and improve the quality of service they provide. As seen in the following figure, the ISPs can connect to the IXP with a single link, and use that link to exchange domestic traffic with the other ISPs, typically using settlement-free peering,[7] while reserving their international links for international traffic.

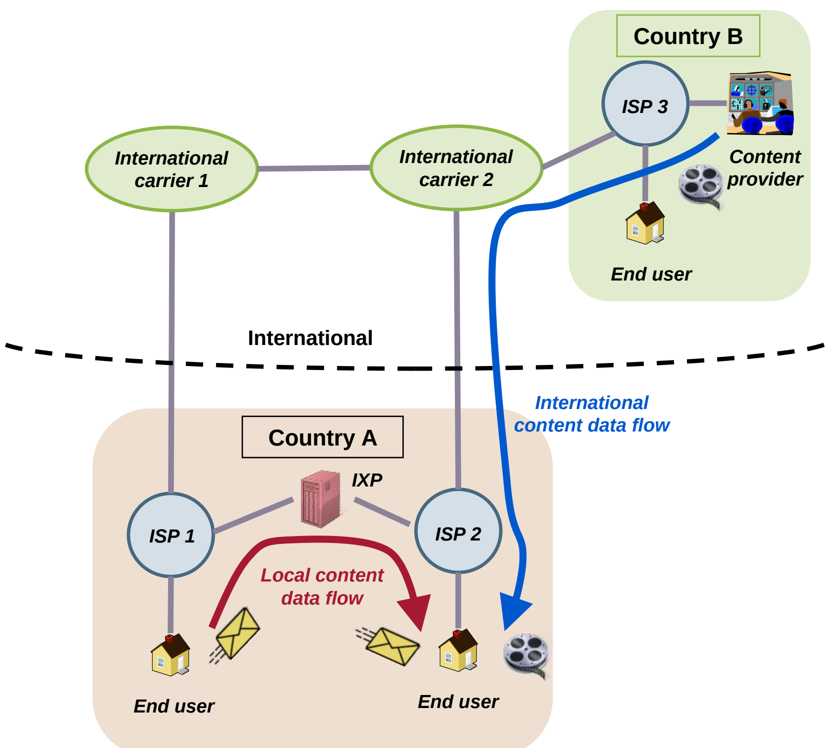

Figure 2.2: Impact of an IXP on domestic traffic flows [Source: Analysys Mason, 2012]

7 Under a peering agreement, providers agree to exchange their customers' traffic with each other. When the providers perceive that the exchange is essentially equal, based on the amount of traffic exchanged or other metrics, then peering is settlement-free. Typically peering is a bilateral arrangement, either privately between providers or through a public IXP switch. However, some IXPs, including the two examined here, have a multi-lateral peering arrangement, whereby each member of the IXP is required to peer with all others, resulting in maximal connectivity between the members.

An IXP can have short-term and longer-term benefits: the short-term benefits of creating an IXP are as follows.

- *Reduced latency*: all domestic traffic will now avoid international hops, thereby significantly reducing the latency of transmission, which becomes particularly important for time-sensitive services such as VoIP calls.
- *Reduced costs*: in addition, exchanging domestic traffic via peering at the IXP, and thereby eliminating tromboning will save on the cost of international transit, as the originating ISP does not have to pay transit to send domestic traffic to an international exchange point, while the receiving ISP does not have to pay transit to bring that traffic back to their domestic network.
- *Increased autonomy*: in many instances, outages on submarine or satellite connectivity impair national and regional connectivity. IXPs eliminate the dependency on International connectivity for local communication which results in a robust and reliable local internet infrastructure.

In the longer term, these benefits increase. While the reduction in latency is largely based on physics – the shorter the distance, and the fewer the hops, the lower the latency – in practice some of it also results from lower costs. Specifically, international transit may be under-provisioned given its significant cost, particularly during peak hours. This under-provisioning further increases the latency of tromboning and the corresponding improvements from an IXP (the domestic links of which are typically cheaper and thus less prone to under-provisioning).

The elimination of tromboning and the corresponding reduction in latency may also increase revenues. It is well understood that increased latency reduces usage, as users are reluctant to wait for an application that loads slowly.[8] Therefore, as latency falls through the introduction of an IXP, consumers will increase their use of services that are positively affected, leading to a dual benefit for providers: by linking services through an IXP they will not only lower their costs, but they will also increase usage, which can directly or indirectly increase revenues. For instance, mobile operators may sell data by the bit, and therefore greater usage directly increases revenues. At the same time greater usage translates into more content access, with a corresponding indirect increase in advertising and/or subscription revenues.

These interacting benefits from lower costs and latency can lead to a virtuous circle that enables the IXP to grow to have critical mass, as discussed in the following section.

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8 For instance, latency experiments conducted on Bing and Google search sites showed that a 2 second slowdown changed the number of queries per user by -1.8% and the revenue per user by -4.3% for Bing, while a 400 millisecond delay resulted in a -0.59% change in the number of queries per user for Google. Source: http://perspectives.mvdirona.com/2009/10/31/TheCostOfLatency.aspx

2.1.4 Development of critical mass

An IXP benefits from network effects – the more members it has, the more valuable it becomes to join the IXP in order to be able to exchange traffic with the existing members. As a result, a well-run IXP providing the benefits described above can develop critical mass, becoming home to many or all of the ISPs and content providers in the country, and bringing significant benefits to its members and the surrounding ecosystem.

In particular, as the ISPs connect and localize communications, there are three further sources of growth for the ecosystem that can center on the IXP.

- First, domestic websites hosted abroad may 'come home' in order to reduce foreign hosting and transit charges, while also benefitting from lower latency. The IXP provides a means for the website to be easily accessible to all local users through one connection, and thus negates the need to be hosted abroad for that purpose.
- Second, services – notably e-government services – become more feasible with when there is a low-cost means to reach all online users, such as that afforded by access via the IXP.
- Finally, international content providers, or content delivery networks, may build network infrastructure (e.g. put a cache[9] or server) in the country to increase their customer base and usage.

In addition to providing consumers with better quality access to more online services, such growth also increases investment – both foreign and domestic – along with providing more jobs to provide these services and innovate new services.

Further, as the IXP grows, it may evolve into a hub for regional traffic, where ISPs from other countries exchange traffic and international content may be hosted, as illustrated in Figure 2.3, where the arrows indicate the traffic flows.

9 Note: a cache is a dedicated network server that stores Internet content (e.g. Web pages or video content) retrieved by users, in order to serve future requests for the same data more quickly. The first time a user asks for a piece of content, such as a YouTube video, it is delivered from the international server to the user, while also stored in the local cache – subsequent users will then be served from the cache, saving on the cost and latency of accessing the international server.

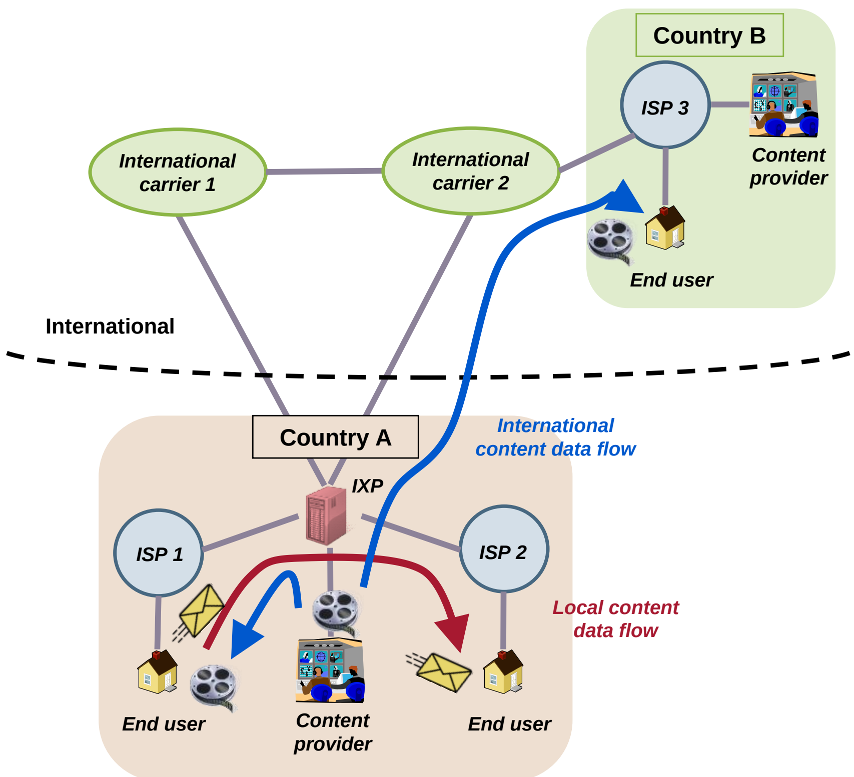

Figure 2.3: Development of a regional hub [Source: Analysys Mason, 2012]

The ability to turn an IXP into a hub for international content and connectivity is likely to be beyond the sole control of its members, as it relies on an enabling environment, including open-access policies at international gateways, and minimal licensing requirements and obligations that will enable foreign carriers and content providers to connect easily into the IXP and sell their services to other members of the IXP.

2.1.5 Conclusion

There are several stages to the evolution of an IXP. First, the establishment of an IXP in the country enables local ISPs to connect together and thereby eliminates the cost and latency of tromboning. To the extent that the IXP begins to build critical mass, involving most or all of the ISPs, it will also begin to attract content providers, along with business, academic, and government users, and thereby become the center of a vibrant Internet ecosystem in the country. Further, the IXP can also begin to attract international content and connectivity providers, becoming a regional hub for Internet traffic.

2.2 Methodological notes

The analysis below relies on market insight, as well as qualitative and quantitative data and evidence from two existing IXPs in Africa: the Kenya Internet Exchange Point (KIXP) and the Internet Exchange Point of Nigeria (IXPN). These two IXPs have been selected as the most relevant for this study, being successful examples of growing IXPs that stand out in Africa.

Data cited in this report have been gathered via a questionnaire sent to many relevant local stakeholders, who were promised confidentiality in return for sharing business-sensitive data. Analysys Mason followed up with an interview of the stakeholders by phone or in person in both countries (see full list in Appendix B). The assessed impacts of these two IXPs have been compared with the situation observed in other comparable benchmark countries, and a future path for these IXPs is projected using data from more advanced IXPs.

3 The Internet ecosystem in Kenya and Nigeria

In this section, we provide a high-level overview of the development of the Internet ecosystem in Kenya and Nigeria, and describe the impact of their respective IXPs on the ecosystem in these two countries. In our review of the Internet ecosystem, we include the mobile and fixed operators offering Internet access, as well as the national and international connectivity used to provide such access.

3.1 The Kenyan ecosystem

3.1.1 Internet access

The total number of Internet subscriptions (fixed and mobile) rose from 3.2 million at the end of Q3 2010 to 5.4 million at the end of Q3 2011.[10] Mobile Internet is by far the primary connection medium, representing 99% of all connections, followed by fixed DSL and terrestrial wireless data subscriptions.

Broadband is in the early stages of development; the number of broadband subscriptions rose to 127,000 in late 2011 (an increase of close to 50% in just one year), representing just 2.33% of total Internet subscriptions. Overall, low household PC penetration limits the demand for broadband in Kenya. In addition, the fixed market in Kenya is extremely small, and most subscribers use fixed wireless or mobile Internet access.

The introduction of WiMAX services, following universal licensing in 2008, helped boost fixed broadband subscribers in 2009. Safaricom's 3G roll out during 2008, together with Orange Kenya's in 2009, helped boost mobile broadband numbers in 2009 and 2010. As at Q3 2011 Safaricom held a 79% market share in terms of (broadband and narrowband) Internet subscriptions with just over 4.3 million subscribers, followed by Celtel Kenya at 8.5% with 460,000 lines, and Telkom Orange at just under 2% market share with 106,000 lines.

An additional source of Internet access is through cyber cafés and other shared access. As a result, the estimated number of Internet users reached 14.3 million at the end of Q3 2011, compared to 8.7 million a year before.[11]

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10 Communications Commission of Kenya (CCK)

11 Source: CCK, *Sector statistics report Q1 2011–2012*

3.1.2 Domestic and international connectivity

International connectivity in Kenya has dramatically improved in the past couple of years, with the landing of several high-capacity submarine cables (see Appendix A.1.2), including the East African Submarine Cable System (EASSy), The East African Marine System (TEAMS), and SEACOM cables which all improved Kenya's bandwidth availability and telecommunications connectivity.

- *SEACOM*: the SEACOM submarine fiber-optic network launched in July 2009 as the first submarine cable to serve east Africa. It was installed, and is managed, by SEACOM, a privately owned company, and comprises a 17,000km fiber-optic network that runs along the southern and eastern African coasts and connects the region to the Internet via Europe and India.

- *TEAMS*: the TEAMS cable was completed in September 2009. It is 4500km long, and connects Kenya and the United Arab Emirates (UAE). It is 85%-owned by TEAMS Limited, a consortium that includes Telkom Kenya, Safaricom, Kenya Data Networks and other local operators, with UAE-based Etisalat owning the remaining 15%.

- *EASSy*: this cable was completed in April 2010 and launched in July 2010. It is 10,000km in length and stretches along the east coast of Africa. It has nine landing stations, including one in Kenya. The project is owned and operated by a large consortium that includes Etisalat, Bharti Airtel, TTCL and Zantel, as well as other African operators, international carriers and development funding institutions.

In addition, an extension of the Lower Indian Ocean Network (LION1) that currently connects Madagascar, Réunion and Mauritius to Kenya is underway, with commercial launch expected in the first half of 2012.

The addition of new fiber-optic capacity has dramatically increased the amount of international Internet bandwidth available in Kenya, as shown in Figure 3.1. By mid-2010, Kenya had 20Gbit/s of international Internet bandwidth, an increase of 20 times since just before the cables landed and an astounding 2000 times more than since the beginning of the decade. Kenya can also draw on an available undersea capacity of 200Gbit/s if needed, while satellite now accounts for just 1% of capacity used.

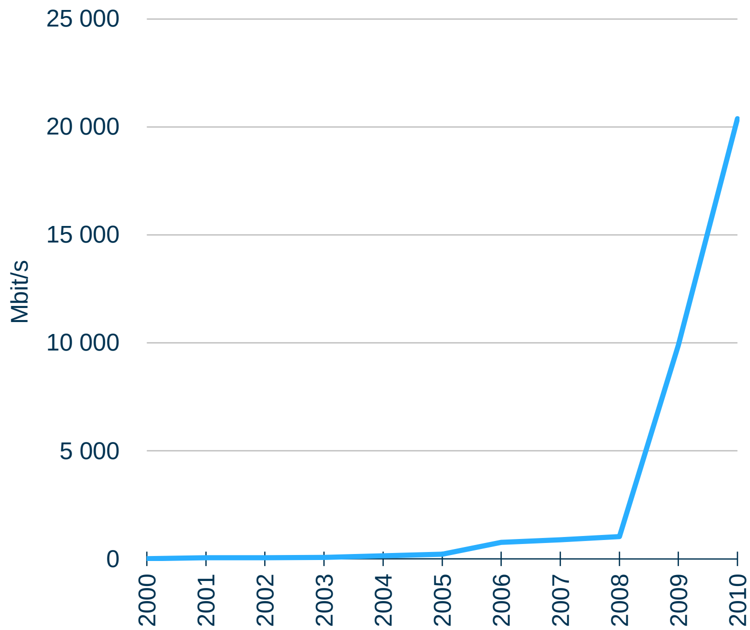

Figure 3.1: Kenya's international Internet bandwidth capacity (Mbit/s) [Source: CCK, 2011]

Kenya has several terrestrial networks that connect to the undersea cables that land in the country. The government set up a 4469km National Optical Fibre Backbone Infrastructure (NOFBI), and has recently announced plans to extend this network to all districts of Kenya. The Kenya Power & Lighting Company (KPLC), the power utility company in Kenya, was granted a Network Facility Provider license by CCK, enabling it to construct, install and operate a fiber-optic network which, in turn, is leased to licensed operators Safaricom, Wananchi Group and Jamii Telecoms. There are also two private national fiber networks in Kenya, operated by Orange and Kenya Data Networks, which covered around 70% of the Kenyan population as of 2010. Finally, in November 2011, Safaricom announced plans to build its own terrestrial fiber-optic network of 4000km.[12] Thanks to these deployments, national connectivity prices have significantly reduced. As a result, domestic capacity between Nairobi and Mombasa is cheaper than international capacity to main international destinations like London (from either Nairobi or Mombasa), which helps to promote the use of the IXP.[13]

12 In addition to this national connectivity, there are a number of city network. Specifically, four providers (Wananchi Group, Jamii Telkom, Frontier Optical Networks (FON) and Access Kenya Group) have substantial fiber in the main urban cities of Nairobi and Mombasa.

13 As we will see in the Nigeria case study below, it is not always the case in emerging markets that domestic connectivity is cheaper than international connectivity, and such a price difference may slow the adoption and usage of a domestic IXP given the costs of access.

In terms of regional connectivity, there are two existing links to Uganda and a planned link to Ethiopia[14], while points of presence (PoPs) have been established in Kenya to link the country to the Tanzanian national fiber-optic network.[15] The government also announced, in October 2011, plans to build new infrastructure connecting the country to Southern Sudan, including a direct fiber-optic link.

3.1.3 The KIXP

There are two IXPs in Kenya: one located in Nairobi and one in Mombasa. Both IXPs are operated by the Telecommunications Service Providers Association of Kenya (TESPOK), a non-profit organization that represents ISPs and the interests of other telecommunications operators. The first IXP, known as the Kenya IXP (KIXP), was launched in Nairobi in 2000, but, following a dispute raised by the incumbent Telkom Kenya, which complained that the IXP was not licensed and violated its exclusive rights to carry international traffic; the IXP was forced to shut down. Following a year of debate, KIXP Limited was allowed to re-open, albeit with an operating license granted by CCK in November 2001, making Kenya the first country in the world to require an IXP to be licensed.

Since then, following the arrival of the undersea cables and in anticipation of an increase in local and regional Internet traffic, a second IXP was launched in 2010 in Mombasa, which is the landing point for the undersea cables described above. This development allows the region's traffic to be exchanged locally, thus improving the end-user experience, and lowering costs for ISPs and operators that no longer have to exchange regional traffic via Nairobi. Unlike the Nairobi IXP, which is hosted at a neutral location, the Mombasa one is hosted by SEACOM and will remain so for a few years. Nonetheless, having access to multiple cables in Mombasa allows balancing of traffic between the cables, better aggregation of regional traffic, and wider population coverage.

At launch, KIXP used 64kbit/s links only, but grew rapidly and now ranks amongst the world top 15 IXPs in terms of growth in traffic exchanged. Local Internet traffic through KIXP reached 1Gbit/s of peak traffic in July 2011, from about 250Mbit/s only a year before.[16] The KIXP now boasts more than 25 members, including MTN, Safaricom, KDN, Airtel, and Jamii Telkom.[17] In addition, KENIC (the .ke country code registry), KENET (an educational network), Government IT Services and the Kenyan Revenue Authority (KRA) all connect to the KIXP. In order to ensure widespread connectivity, KIXP operates a Multi-Lateral Peering Agreement (MLPA), which means it is mandatory for every member to peer with each other via the KIXP route servers. While peering with the other members at the exchange is settlement free, there are usage fees to fund the operation of the IXP.[18]

14 Source : African Fibre and Satellite Markets 2nd edition, Balancing Act, 2010

15 Source : http://www.biztechafrica.com/article/tanzania-fibre-optic-network-rolling-out-steadily/1483/

16 Source: http://allafrica.com/stories/201107190352.html

17 Source: http://www.tespok.co.ke/index.php?option=com_content&view=article&id=77&Itemid=92

18 The monthly connection fees range from KES25,000 ($300) per 10Mbit/s port to KES45,000 ($540) for a 1Gbit/s port.

3.2 Benefits of KIXP

This section analyses the direct benefits of the Nairobi KIXP, observed by the IXP itself and its members. As described above, these benefits include benefits for domestic connectivity (in particular, transmission costs), international connectivity (in particular, reliance on international links), and quality of service (e.g. latency and resilience).

3.2.1 Core benefits

The core immediate benefits of the IXP are in reducing latency of transmissions and reducing the related costs of transmission.

KIXP, and a number of its members, reported a range of latency impacts, reflecting differences in routing and access. Nonetheless, ISPs uniformly reported latency above 200 milliseconds (ms), and as high as 600ms, without the IXP. For reference, latencies higher than 300ms resulting from tromboning expose VoIP to network inefficiencies that often impair two-way conversations. With the IXP, the ISPs uniformly reported latency less than 10ms, and as low as 2ms, paving the way for VoIP as well as other latency-sensitive applications.

In terms of the impact on traffic, the ISPs credited all of their local traffic exchange to the impact of KIXP – stating that without the KIXP all of their traffic would trombone. This means that without the IXP, the entire current 1Gbit/s peak traffic exchanged through the IXP would be exchanged over expensive international transit connections. In terms of the value of those circuits, we heard a wide variety of values ranging from $90–250 per Mbit/s of traffic per month for wholesale service, to one user which was paying $650 per Mbit/s per month for retail services. The differences in values for wholesale services reflect a number of differences between buyers, including traffic volume, use of self-owned capacity, and routing; one learned observer suggested an average value of $120 per Mbit/s for international transit. Using that relatively conservative value, the wholesale savings of exchanging 1Gbit/s at KIXP instead of using international transit to trombone the traffic is $1,440,000 per year.

3.2.2 Towards critical mass

In order to leverage the value of KIXP, in April 2011 Google installed a Google Global Cache (GGC) in Kenya. The cache was initially provided to one operator in Nairobi, under the condition that the contents would be made available to all members of KIXP. The cache retains static content after it has been downloaded in Kenya, such as YouTube videos, and all interviewees noted the significant impact that the GGC had on their traffic levels. Figure 3.2 below illustrates the increase in traffic exchanged at the KIXP, which shows a dramatic surge after April 2011. This increase mostly reflects users' increased usage of Google content, notably an increased willingness to stream YouTube videos based on lower latency of access.

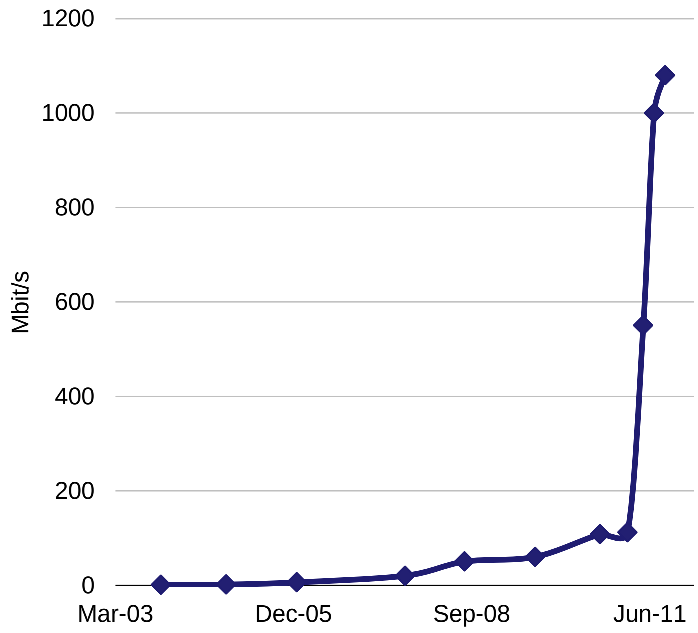

Figure 3.2: Traffic exchanged at the KIXP [Source: KIXP, Analysys Mason, 2012]

For instance, the educational network, KENET,[19] reported a roughly ten-fold increase in Google usage, from 20Mbit/s to 200Mbit/s, after the cache was established in Kenya and made accessible through the KIXP. KENET attributed this increase to students' willingness to download more videos at the faster speed; in this situation, cost was not an issue for the students, as they do not pay for usage. While students were not paying for this increased usage, the universities had been paying KENET $200 per Mbit/s per month for international Internet access, and thus this increased usage would have cost an additional $432,000 per year, were it not for the local Google cache. KENET also reported that the shift of traffic to the local cache had the additional benefit of freeing up valuable international capacity for research needs.

The ability to exchange domestic traffic more efficiently and access content hosted at the local cache has had two other bottom-line impacts for ISPs in Kenya.

- First, several ISPs reported that access to the KIXP is often included as a necessary requirement for winning tenders issued by businesses and government agencies for Internet access services, sometimes going so far as requiring KIXP to certify an ISP's membership during the tender process. This signifies that businesses and government have identified the benefits that access to the KIXP would provide for the delivery of local Internet traffic. Internet Solutions, the host of the

19 KENET's aim is to connect all universities and research institutes in Kenya with a private network, while also providing Internet access. See http://www.kenet.or.ke/.

KIXP back-up site, reported that the back-up site has been an important element in 75% of its new sales in the three years since it won the open tender to host the back-up.

- Second, mobile operators in Kenya charge by the MB for Internet access, and thus increased usage resulting from the KIXP translates into increased revenues. In particular, all mobile operators have witnessed increased usage of Google as a result of the cache, because of increased speed of download. We estimate conservatively that at least one operator sees an increase of at least 100Mbit/s of traffic as a result of the availability of cached content, for which consumers pay an estimated average of KES1.25 per MB. Thus, the increased revenues for an operator that has seen an increase of 100Mbit/s of mobile data traffic will realize an increase in yearly revenues of just under $6,000,000. Across the mobile operators we believe this is quite a conservative estimate, given that the total increase in traffic resulting from the Google cache is at least six times more than 100Mbit/s, as seen in Figure 3.2, and that 99% of Internet connections are mobile, as discussed in Section 3.1.1.

Another key user of the KIXP is the KRA, which relies on the IXP to allow online income tax reporting for citizens, as well as clearing customs for importers. The KRA reported 160,524 citizens filed their income taxes online in the first half of fiscal year 2011,[20] and 5,000 users are registered for the customs system, representing 95% of the industry. Firms are also able to take advantage of online applications and filing, saving the private sector $4.5 million according to the World Bank.[21] The KRA reports that the KIXP has facilitated this online system by significantly lowering latency, and that it is now reliant on the KIXP to help to deliver services to taxpayers while also ensuring that valuable revenues are captured through KRA’s online system.

Another significant user is KeNIC, the Kenyan domain name registry for the .ke country code domain.[22] By directly connecting to the KIXP, KeNIC has firmly established .ke as the preferred domain name in Kenya, and has seen .ke overtake .com as the most popular domain. Users experience more personal service in registering in Kenya for their domain name, which in turn resolves more quickly than generic top level domain names that are not based in Kenya. The figure below details the steady increase of growth experienced by .ke over a select period.

20 Revenue Performance Report, Kenya Revenue Authority, 24 January 2012. http://www.kra.go.ke/notices/pdf2011/Revenue-Performance-Report-jan2012.pdf

21 “Comprehensive Reform in Kenya Yields Broad Business Impact,” *Investment Climate*, January 2012, World Bank Group. http://www.kra.go.ke/notices/pdf2011/Revenue-Performance-Report-jan2012.pdf

22 See http://www.kenic.or.ke/.

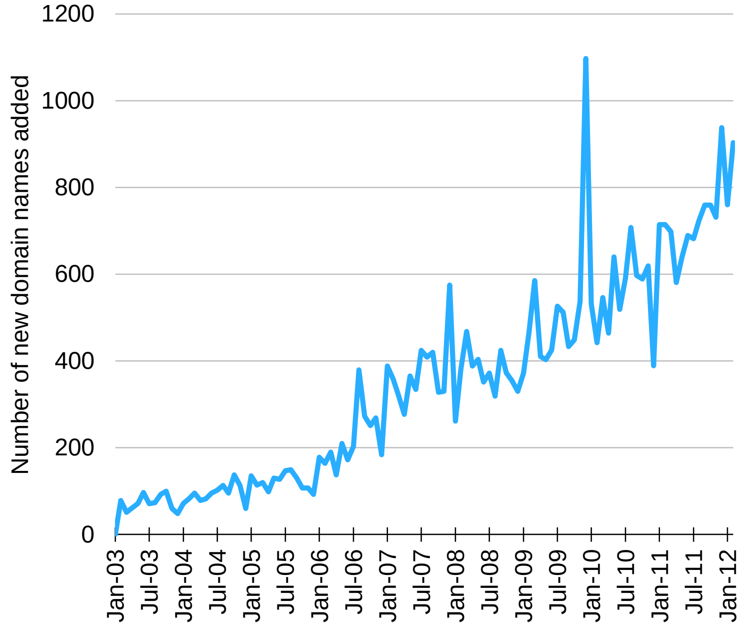

Figure 3.3: Growth of .ke domain names [Source: KeNIC, 2012]

At the time of the interviews for this study, several immediate future benefits of the KIXP were identified, which would further build the critical mass of the IXP.

- First, a local cache from a large international content delivery network (CDN) was going to be made available to all members of the KIXP, in a similar fashion to the access to the GGC. This cache would enable access to all of the content of the CDN's customers, including several large global providers, and is expected to further increase local traffic, lower latency, and provide savings on international transit costs.

- Second, one ISP noted that the KIXP would play a key role in providing cloud services in Kenya. While this provider was already offering cloud storage services in Kenya, via the KIXP, it was set to begin to offer applications over the cloud. As such applications are quite latency sensitive, it is important that they are hosted locally and available to all end users over local connections through the KIXP. While Kenyans already famously benefit from cloud services in the form of mobile banking (e.g. M-PESA), those services are proprietary to each mobile operator's customers, and therefore are not dependent on the KIXP (as the traffic is not exchanged between ISPs). The new cloud services, however, will be available to all Internet users, and thus will rely on the KIXP for delivery from the service provider to all ISPs.

Other likely benefits will arise from foreign investment, which is just starting. For instance, Google had corporate offices in five African countries as of December 2011: Ghana, South Africa, Kenya, Uganda and Senegal. The Kenya/Uganda offices are covering the east African region (Kenya, Tanzania, Uganda, Rwanda, South Sudan and Ethiopia), while Nigeria and Senegal cover the west coast.

Since setting up in Kenya in 2007, the company has focused on designing training programs, developing local content, and forming partnerships with local developers and telecommunications providers. As a result, Kenya benefits not just from the additional traffic from the Google cache, but also from the broader impacts on the ecosystem.

3.2.3 KIXP regional impact

The benefits of the KIXP are beginning to extend beyond Kenya's borders, as the KIXP members are beginning to win customers in neighboring countries and are exchanging the resulting traffic at the KIXP. Indeed, as of January 2012, 56% of the Autonomous System numbers[23] routed through the KIXP in the previous six months were from 16 foreign countries, ranging from Botswana to Zimbabwe, and as far away as the United States, a significant increase over previous years.

Furthermore, in an effort to regionalize traffic within the country, and take advantage of immediate access to the newly landed submarine capacity, the second IXP location in Mombasa was recently opened. This location is also likely to attract traffic from neighboring countries, as well as content caches and servers from abroad.

3.3 The Nigerian ecosystem

3.3.1 Internet access

In Nigeria, most Internet users connect using dial-up modems installed in cyber cafés and other public places. While large corporations in Lagos are served by fiber access, overall the broadband sector remains underdeveloped, with only an estimated 150,000 (fixed and mobile) broadband subscribers at the end of March 2011, although it had enjoyed a significant 54% growth in only a year.[24] Subscriber growth is hampered by the poor state of the fixed infrastructure of the incumbent Nigerian Telecommunications (NITEL), the unreliable power supply, and the low PC penetration. Several operators offer DSL service (such as NITEL or 21st Century Technologies), but mobile broadband technologies from both GSM and CDMA operators have been gaining a strong momentum in the past few years.

23 An autonomous system (AS) number is assigned to an entity such as an ISP or large enterprise, which enables it to present a single routing policy to Internet traffic.

24 Source: Telegeography

The market is highly fragmented, with several large ISPs such as Starcomms or Multilinks, and a large number of small ISPs with limited geographical coverage. Service prices are still very high and are not affordable for the vast majority of the population. There is significant geographical variation in retail prices, which are particularly high in regions distant from submarine cables landing stations, reflecting expensive national backhaul costs, as described below.

In spite of these access challenges, usage is growing based on public Internet access. Among other trends, there has been a significant rise in the number of Nigerians using social networking websites recently, with an estimated 4.8 million Facebook users in Nigeria at the beginning of 2012.[25]

3.3.2 Domestic and international connectivity

Given the poor state of the incumbent's fixed core network infrastructure, most ISPs prefer not to rely on it, but instead invest in proprietary fiber-optic infrastructure for Internet access. However, such deployment is hampered by administrative burden (in particular the "right of way", a government tax paid by ISPs to lay down fibers) and other challenges including the vandalism of installations, especially in poor suburbs. The result is that national connectivity costs in the range of several thousand dollars per Mbit/s per month for a link between Lagos and Abuja for instance, around ten times the price of international connectivity from Lagos to London.

Several ISPs have developed relatively large fiber-optic backbones – for instance Phase 3 with its 1500km network and Multi-Links Telecommunications (MLTC) with its 8200km network (as of January 2012)[26] – along with microwave backhaul. However, reach is limited given the vast areas to be covered nationally. There is also a fair amount of duplication in rollouts, as operators are generally unwilling to share networks, often for competitive reasons. At the same time, the government has initiated a nationwide network infrastructure initiative, Nigeria's National Broadband Carrier Network Project, which will ultimately consist of a 14,000 km open-access fiber-optic backbone network, linking regional network owners and large ISPs' existing networks. But this project has so far faced difficulties in its realization, and national links remains extremely expensive.

In the past, the lack of international bandwidth has been one of the main constraints to growing domestic Internet access, and the development of the Nigerian broadband market, because of its large impact on the speed of services and on prices. Historically, Nigeria's main source of international bandwidth has been the SAT-3 cable for which the incumbent NITEL holds a monopoly. But the arrival of competing cables, namely Main One and Glo 1 in 2010, has been a real catalyst for Internet access.[27] With the arrival of these cables (described below in Appendix A.1.2), prices for international

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[25] Source: http://www.socialbakers.com/facebook-statistics/

[26] Source: http://www.businessdayonline.com/NG/index.php/tech/78-computing/31483-multi-links-introduces-lowest-tariff-with-free-calls

[27] In addition, the WACS cable goes live in 2012, further increasing competition.

bandwidth have decreased around ten-fold in just three years, and there was an estimated 30Gbit/s of international Internet bandwidth for Nigeria at the end of 2011[28], while a large amount of unused capacity remains available for future needs.

3.3.3 The IXPN

The IXPN was established in 2006 in Lagos as a neutral exchange, with the stated objective of reducing reliance on international transit for exchanging local traffic between members, and to improve efficiency of operations and communications. As such, a decision was taken that only local traffic is allowed to be exchanged at the IXP. In addition, the IXPN operates an MLPA similar to KIXP in order to promote connectivity.

As of December 2011, the IXPN served over 30 members, including Google, Gateway, Linkserve, Main One Cable, Internet Solution Nigeria, Swift Networks, KKON, Simbanet, Netcom, NIRA, Skannet, and Tara Systems.[29] Fixed-line incumbent NITEL is not a member of the IXP, nor are some major ISPs (like Multilinks and Rosecom) and mobile operators (like MTN and Globacom). It appears that large ISPs that own private fiber backbone and mobile operators that own capacity on submarine cables may see the IXP as a competitor in the transit market, which limits their interest in joining the IXP. Large ISPs also already exchange local traffic together directly, thus making a connection to the IXP less relevant for some of their local traffic. However, given the growing amount of traffic exchanged at the IXP, these operators may soon see the financial benefit of connecting to the IXP, to lower their costs and improve access to content accessible via the IXP.

The IXPN aims to become a leading IXP in Africa by the year 2015, building on the satisfactory growth in the past few years culminating in 300Mbit/s of peak traffic exchanged through the IXP today. In particular, the IXP aims at becoming a regional hub for West African countries, and a one-stop-shop company for content and service providers, which will necessitate removing the current restriction on allowing regional traffic to be exchanged at the IXP. This is also predicated on national and cross-border connectivity in the region becoming more affordable.

[28] Source : Telegeography

[29] Source: http://www.nixp.net/index.php?option=com_content&view=article&id=13&Itemid=13

3.5 Benefits of IXPN

3.5.1 Core benefits

The IXPN has largely been successful in reducing, if not eliminating, tromboning among its members. The small ISPs we interviewed state that all of their local traffic is now exchanged at the IXPN, while larger ISPs who belong to IXPN estimate that most of their local traffic is exchanged at the IXP, while the rest is exchanged privately. Prior to the IXP, most, if not all, of their local traffic was tromboning. Thus, the core benefits of IXPN are in reducing latency of transmissions and reducing the related costs of transmission for local content:

- All the IXP members have observed a significant reduction in latency for access to local content, typically from 200–400ms without the IXP to between 10ms and as low as a few milliseconds with the IXP.
- In terms of the value of those international routes, ISPs are today typically paying in the range of $250–400 per Mbit/s of traffic per month for international transit (the differences in values for wholesale services reflect a number of differences between buyers such as traffic volume, route, and use of self-owned capacity). Using an average cost of $300 per Mbit/s for international connectivity, the wholesale savings of exchanging 300Mbit/s at IXPN instead of using international transit to trombone the traffic is $1,080,000 per year.[30]

Given these trends, we believe that benefits will continue to increase as existing members increase their use of IXPN for all their local traffic and as additional members such as the mobile operators join and begin routing traffic through IXPN.

3.5.2 Toward critical mass

In March 2011, Google extended their European network to Lagos. As in Kenya, the cache holds static content, notably YouTube videos, enabling Nigerian ISPs to receive Google content locally rather than over international capacity. Figure 3.4 below illustrates the increase in traffic exchanged at the IXPN, which shows a dramatic surge after the arrival of Google. In addition, we understand that the full potential of Google's presence has yet to be realized, given some capacity constraints on the link between Google servers and the main data room of the IXP that are soon to be alleviated. Also, the presence of more ISPs at the IXP will increase the corresponding traffic.

30 The costs of using the IXPN should also be considered; including the set-up costs to reach the IXP and the connection to the IXP – a FastEthernet connection costs $300.

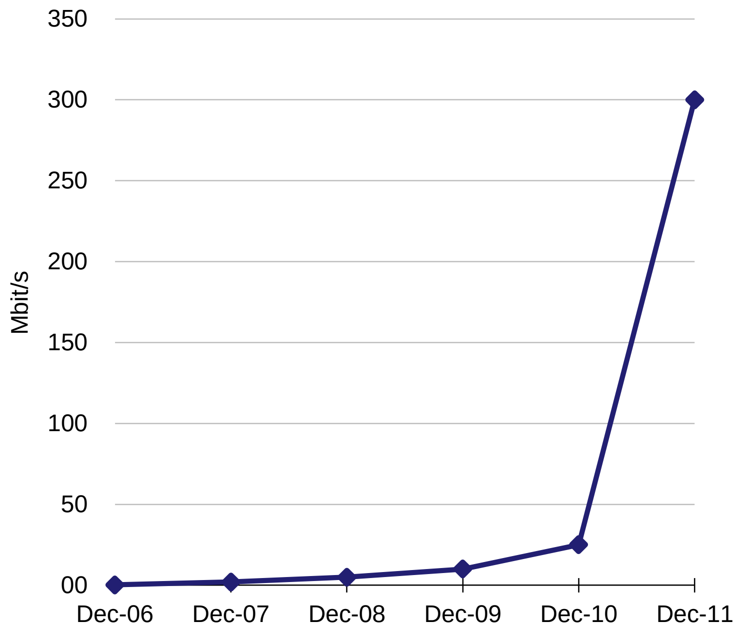

Figure 3.4: Traffic exchanged at the IXPN [Source: IXPN, Analysys Mason, 2012]

All interviewees noted the significant impact that Google's presence had on their traffic levels, with Google traffic representing more than 50% of the total traffic exchanged at the IXPN. While the amount of traffic may be relatively low, in the range of a few hundreds of Mbit/s total, all interviewees acknowledge the dramatic increase in quality of service for their customers. The presence of Google has been made possible by the presence of the IXPN, which offered a simple and direct access to a multitude of ISPs for Google, through one installation.

Second, as in Kenya, mobile operators do charge by the MB for Internet access, and thus increased usage resulting from the IXPN would translate into increased revenues. While the impact may be relatively low so far, it can be safely assumed that mobile operators present at the IXP should reap significant benefits from their monetization of local content, as traffic exchanged at the IXP grows.

A few examples illustrate tangible benefits that the IXP has been able to provide thus far in Nigeria. For instance, the dominant platform for e-transactions and e-payment in Nigeria, Interswitch, is connected to the IXP via an ISP. Interswitch was established by seven Nigerian banks to facilitate transactions using infrastructure that links debit, credit and prepaid cards to a wide range of payment channels including point of sale terminals, automated teller machines and web merchants. Interswitch today runs a network of 10,000 ATMs and 11,000 point-of-sale terminals. With the take-up of Interswitch, financial platforms that were formerly hosted abroad have begun to migrate back to Nigeria, and all transactions on these platforms are now exchanged locally by ISPs connected together via the IXP. This platform is expected to grow in the coming years, to support the large and still unsatisfied demand for such services.[31]

Another example of improvement of access to local content can be found in the membership of the West African Examination Council (WAEC) at the IXP. The WAEC is a body that conducts two major exams in Nigeria: the General Certificate of Education Examination – GCE – and the Senior Secondary Certificate Examination (SSCE) for secondary school leavers. Nigerian students are required to register online in order to get access to their exam results via the WAEC online portal. Before the IXP, congestion to access the WAEC servers created considerable delays. With the participation of the WAEC in the IXP, congestion issues have been solved overnight.

The IXPN also has an active impact in other areas of education. For instance, the Eko-Konnect project (Lagos Higher Education Connectivity Project) launched at the end of 2009 saw, as a first development phase, the linking of the University of Lagos, the Federal College of Education (Technical), the Yaba College of Technology and the Lagos University Teaching hospital. This ring is connected to the IXPN by a 100Mbit/s fiber link. Eko-Konnect also peers via the IXPN with the Google University Access Program and its partner institutions (Lagos State University, University of Nigeria Nsukka, University of Benin, Benson Idahosa University and Convenant University). The IXPN also hosts a dedicated hub link for the establishment of ngREN, the national research and education network, which will allow in the future the connection of additional specialized networks across Nigeria.

3.5.3 Future developments

The IXPN aims at implementing Points of Presence (PoPs) in the main six geopolitical zones of Nigeria. Once this development is achieved, the IXPN will be in position to play a useful role as regards national connectivity, allowing members across the country to connect at different points within the country and exchange traffic at lower costs than the one currently applied for national backhaul.

For instance, the new IXPN PoP in Abuja might effectively provide a decrease in the tariff of national backhaul between Lagos and Abuja overall, which is still today almost ten times more expensive than between Lagos and London for some ISPs. Currently, the connectivity provided by the IXPN between its PoPs in Lagos and Abuja provides ISPs with savings on their exchange of local traffic between those cities. While IXPN currently does not allow the exchange of international traffic, an increased level of collaboration between ISPs in aggregating their demand for national capacity may enable them to aggregate their demand for international capacity as well.

31 The success of Interswitch is also based on positive regulations. For instance, a daily cash-withdrawal limit of 150,000 naira for individuals and 1 million naira for companies will take effect in June 2012 in Lagos, encouraging more online financial transactions. This initiative from the Central Bank aims at reducing the amount of cash circulating in the country and encouraging online banking.

Further, according to IXPN all arrangements have been finalized to connect the main government data center to the IXP. Once the connections have been implemented (which will be facilitated by the presence of a PoP of the IXPN in Abuja, the administrative capital), the IXP will contribute greatly to the localization of most of the government services currently hosted abroad. This could in turn potentially lead the way to the development of more affordable and advanced data-centers in Nigeria.

The IXPN could also replicate its role in localizing online financial services for other types of applications and services. For instance, the IXPN can play a key role in providing cloud services in Nigeria. As such cloud-based applications are typically quite latency sensitive, it will improve their chances for commercial success if they are hosted close-by and available to all end users over local connections through the IXPN.

Another growth opportunity for the IXP is related to the extremely dynamic local movie industry. This industry – so-called Nollywood – is the second largest film industry in the world (in terms of number of annual film production), behind the Indian film industry and ahead of the United States.[32] This constitutes a tremendous potential for local movies to be digitized and then served via online platforms (e.g. streaming websites) to local or foreign users. Also, with the proper incentives, the industry could turn to directly creating online content, be they videos or games, and offer them to the local audience.

Finally, as mentioned above, the IXPN currently only allows local traffic to be exchanged at the IXP, and therefore the IXPN does not have any impact on regional connectivity at the moment. However, it can be safely assumed that this situation will evolve in the short to medium term, as the IXPN aims at becoming a regional hub for West African countries by 2015.

3.6 Conclusion

In Kenya, the KIXP has proven to be a critical infrastructure to localize domestic traffic and help to leverage the growing international connectivity. As shown in the above sections, KIXP, in addition to helping to localize domestic traffic exchange, is increasingly being used for regional traffic exchange – and could grow into a regional hub for traffic. We can summarize the benefits of KIXP in the following chart.

32 Source: http://www.economist.com/node/17723124?story_id=17723124&CFID=153287426&CFTOKEN=59754693

Figure 3.5: Summary of the key benefits of KIXP [Source: Analysys Mason, 2012]

Benefit	Without KIXP	With KIXP	Summary
Latency	200-600 ms	2-10 ms	Significant increase in performance
Local traffic exchange	Negligible	1Gbit/s peak	Estimated total saving of $1,440,000 per year on international transit
Content	All content was accessed through international links, almost all content hosted abroad	Google network present locally. Expansion and rehoming of content hosted abroad	Increased revenues up to $6 million per 100 Mbit/s of new mobile data traffic
E-government	KRA collected taxes manually	Revenues collected online	Significant reliance on KIXP to clear customs and raise revenues
Domain names	.com was the predominant domain, registered overseas	.ke is the predominant domain, registered and based locally	KENIC uses KIXP to help increase service delivery for .ke
Regional routes	All regional traffic tromboned internationally	An increasing amount of regional traffic exchanged at KIXP	KIXP more attractive to content providers and backbones able to access regional users

The key benefits of the IXPN are relatively similar to the one of the KIXP, as summarized in the table below, and the Nigerian IXP seems on the way to reproduce the success of the Kenyan IXP in the coming couple of years. The main difference appears to stem from the higher costs for national connectivity, and the decision of some of the larger operators to not yet engage with IXPN.

Figure 3.6: Summary of the key benefits of IXPN [Source: Analysys Mason, 2012]

Benefit	Without IXPN	With IXPN	Summary
Latency	200-400 ms	2-10 ms	Significant increase in performance
Local traffic exchange	Negligible	300Mbit/s peak	Estimated total saving of $1,080,000 per year on international transit
Content	All content was accessed through international links, almost all content hosted abroad	Google network present locally. Expansion and rehoming of content hosted abroad	Increased revenues of new mobile data traffic
E-government	Congestion of education & research networks	Eko-Konnect, WAEC connected to IXPN for local traffic exchange	Improved access for students and researchers
E-commerce	No service platforms hosted locally	Financial platforms hosted locally and traffic routed locally	IXPN allowed financial transactions to remains local

In particular, the high cost of national connectivity in Nigeria would appear to invert to some degree the typical development cycle and benefits of an IXP, as illustrated in Kenya. The KIXP delivered benefits both in saving the cost of international connectivity as well as reducing latency from having used expensive, and therefore congested, international links. In Nigeria, however, some traffic still trombones because it may be cheaper for some ISPs to continue to use their international links for exchanging local traffic due to the high cost of national links. Further, those ISPs that do begin to use the IXPN may still not receive the full benefits, because they may not be able to afford to provision enough national connectivity to fully reduce latency and thereby deliver the benefits of local connectivity. Regulatory intervention, based on a broader policy of increasing Internet usage, may be needed to address the higher costs of national connectivity.

4 Benchmarking and projections

4.1 Regional benchmarks

This section aims to assess the achievements of Kenya and Nigeria detailed in the previous section, by comparing them at a high level with benchmark countries, while accounting for the evolution of the demographic and ICT environments in these countries. Given their relatively similar market situation and their geographical proximity, the following countries have been selected as benchmarks:

- Kenya benchmarks – Tanzania, Uganda and Sudan
- Nigeria benchmarks – Ivory Coast, Ghana and Senegal.

A critical aspect of the comparison lies in the impact of each country's demographic, policy and telecommunications infrastructure levels. These main external factors are detailed in Appendix A, an understanding of which helps to isolate the benefits of the IXP presence in Kenya and Nigeria in terms of the impact on the Internet ecosystem.

While a number of the benchmark countries have IXPs, they have varying levels of success, which can be a function of timing, regulatory conditions, and access to international and regional bandwidth. KIXP is clearly the largest IXP within its benchmark group based on the amount of traffic carried, and is about to capitalize on the cables landing in Mombasa to further grow. Tanzania lags in the usage of their IXPs, reflecting in part a lower Internet usage (see Appendix A), while Sudan just launched an IXP at the end of 2011. Finally, although Uganda has greater Internet usage than Kenya, and otherwise a similar environment, its IXP lags significantly behind Kenya's in terms of traffic, reflecting the lower number of members (as well as the incumbent's 40% share of the fixed Internet market,[33] which may negatively impact the development of competition).

Compared to its benchmark countries, Nigeria appears to be the only country with a significant IXP, as the IXPs in Ivory Coast and Ghana are still very small in terms of number of members and traffic exchanged, while Senegal does not have an IXP, likely reflecting the significant role played by the incumbent in delivering Internet traffic.

33 Source: TeleGeography

Figure 4.1: IXP presence in benchmarked countries (end of 2011) [Source: PCH.net]

Country	IXP	Date of launch	Number of participants	Average traffic (in/out) in Mbit/s
Kenya	KIXP	Nov 2000 (Nairobi) Aug 2010 (Mombasa)	25	871
Nigeria	IXPN	2006	32	300
Tanzania	TIX & AIXP	TIX (Jan 2004) AIXP (2007)	25	6
Uganda	UiXP	May 2003	10–15	26
Sudan	SIXP	December 2011	6	n/a
Ivory Coast	CI-IXP	June 2007	n/a	4
Ghana	GIXP	May 2005	10–15	n/a
Senegal	No	-	-	-

Figure 4.2 below indicates international Internet bandwidth per capita. Within the two benchmark groups, Senegal was the leading country as of the end of 2010, a reflection of its overall strong and growing level of broadband penetration. However, Kenya's bandwidth per user as of end of 2011 has already surpassed that of Senegal the year before, a growth at least in part due to a successful IXP that is becoming a regional hub for traffic. Nigeria remained at lower the end of its group at the end of 2010, but experienced a significant increase in 2011, also matching the figure of the most advanced country of its benchmark group a year earlier.[34] We note that South Africa far surpasses both benchmark groups, and we detail in the next section the role that the South African IXPs play in this performance.

34 In addition, as noted above the IXPN is not open for the exchange of regional traffic, and thus any impact of the IXPN would not be felt on the international bandwidth, as might be the case in Kenya.

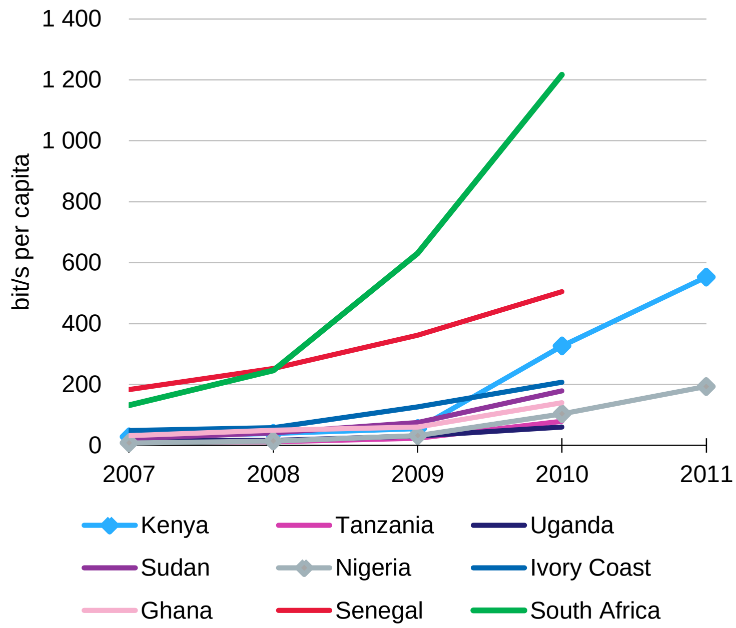

Figure 4.2: International Internet bandwidth per capita, 2007–2011 [Source: TeleGeography, 2012]

Note: 2011 figures for countries other than Kenya and Nigeria were not available at the time of writing

In conclusion, within its region Kenya is in a strong position with respect to Internet access and usage. This is a reflection of a number of interdependent variables; a liberalized telecom environment led by a widely respected regulator; a significant and increasing amount of international capacity; and a strong and competitive mobile sector. However, into this mix must be included a successful IXP, which both feeds off these other variables, but also helps to fuel them. In particular, as we have seen above, an IXP benefits from a strong user base, but in turn helps to increase usage by attracting content and thereby lowering the latency, and cost, of access. Likewise, a strong IXP can establish itself as a regional hub, further increasing its usage and benefits.

Nigeria lags behind Kenya in terms of growth, but thanks to increased international bandwidth from new submarine cables and a fast growing IXP facilitating the exchange of local traffic, the country has the potential to quickly catch up with successful countries like Kenya and in the longer term South Africa. At this point, the two factors hindering Nigeria in comparison to Kenya are the fact that not all ISPs (including mobile operators) have joined the IXPN yet on the one hand, and the high national connectivity charges that reduce the benefit of domestic traffic exchange via the IXPN on the other.

4.3 Projections

Based on the dynamic early developments of the Kenyan and Nigerian IXPs, it is fair to assume that these IXPs might follow in the footsteps of other dynamic IXPs beyond their regions. As shown above in Figure 4.2, Kenya and Nigeria still lag behind South Africa in terms of international Internet bandwidth per capita, while Figure 4.3 below shows the trend of Internet bandwidth per capita in developed countries, highlighting particularly the growth for 'hub' countries such as the Netherlands, and that Kenya and Nigeria have tremendous room for growth.

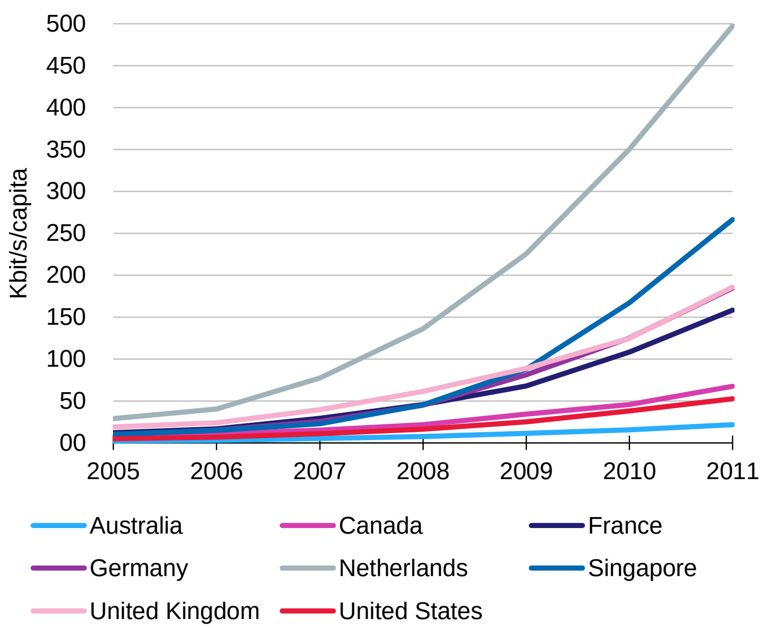

Figure 4.3: International Internet bandwidth per capita [Source: TeleGeography, 2011]

This section provides more details on some very successful IXPs, and then assesses potential development trajectories for Nigeria and Kenya.

4.3.1 Evidence from other countries

IXPs in three countries are examined at a high level in this section, in order to gather a better understanding of what the Kenyan and the Nigerian IXPs could potentially achieve, were they to succeed in fully establishing themselves as regional IXPs for traffic exchange and access to content. In this section, we look in turn at:

- JINX and CINX in South Africa
- AMS-IX in Amsterdam
- LINX in the UK.

JINX and CINX: South Africa

South Africa is the predominant hub for Internet traffic in the sub-Saharan African region, thanks to the general size and condition of the market, and the specific success of the two national IXPs in the country: the Johannesburg Internet Exchange (JINX) and the Cape Town Internet Exchange (CINX), which were established in 1996 and 2009 respectively. These IXPs are operated by the Internet Service Providers' Association (ISPA), a non-profit Internet industry body comprising more than 145 ISP members, which also allows non-ISPA members to connect to its IXPs. The IXPs functions in an open mode, and the ISPA does not require its users to interconnect with all other users; each user is expected to establish its own policy for interconnection and to negotiate interconnection agreements with the other members.

ISPA is also currently in the process of selecting a host for another IXP – the Durban Internet Exchange (DINX). The launch date was expected before the end of 2011, and while this has not yet been finalized, an operational launch can be expected for 2012. According to the ISPA, the "CINX and JINX both process massive volumes of traffic with more than 30 ISPs peering with JINX and 16 peering with CINX. With Internet traffic volumes surging in Durban in recent years, there is a clear need for the city to have an Internet Exchange of its own."[35]

Most major South African operators have chosen to exchange traffic via the JINX, including MTN, Cell C, Internet Solutions, Neotel, TENET, iBurst, Vox Telecom and MWEB. As of September 2011, the more than 30 ISPs connected at the JINX exchanged close to 3Gbit/s of traffic during peak periods, up from 2Gbit/s less than a year before.[36] The only high-profile telecommunications operators absent from JINX are the incumbents Telkom and Vodacom. At the same time, CINX was exchanging more than 1Gbit/s during peak times (up from 500Mbit/s in 2010) with 21 service providers, including Google.[37]

South Africa benefits from multiple cross-border connections into other neighboring countries including Mozambique, Zimbabwe, Botswana and Namibia. Also, the falling (but still expensive) price of national and cross-border connectivity is helping to make South Africa a crossroads for Southern Africa internet traffic. As in most African nations, international bandwidth has greatly increased over the past few years, mostly due to the landing of the SEACOM submarine cable, and the upgrade of the SAT-3 submarine cable. This international bandwidth capacity should further increase dramatically in the short term, thanks to the new EASSy and WACS cables. .

South Africa appears as an ideal example of what Kenya or Nigeria could achieve in the medium to long term in their own regional area. Confronted with more difficult macro-economic conditions, these

35 Source: http://www.teraco.co.za/data-centre-news/article/2011/09/19/durban-internet-exchange-here-soon/206.html

36 Source: http://mybroadband.co.za/news/telecoms/27439-ispa-expands-jinx.html

37 Source: http://mybroadband.co.za/news/internet/33742-jinx-and-cinx-boasting-gbps-traffic.html

two countries can, nevertheless, rely on an improving supply of international capacity, leading position in their regions, and sustained demand for Internet connectivity and services to bring them closer to this goal. While both IXPs lag the size of JINX in number of members and traffic, KIXP is roughly comparable to CINX. One advantage that KIXP already has is the participation of the incumbent and largest mobile operator, which will ensure that KIXP grows in proportion to the growth of all ISPs in Kenya, including the strongest. This differs from the situation in South Africa, where Telkom and Vodacom do not participate in the IXPs, impacting otherwise strong growth.

AMS-IX: the Netherlands:

The Amsterdam Internet Exchange (AMS-IX) is not comparable to what the Kenyan and Nigerian IXPs could aim for in the short to medium term, given the relative levels of economic development, in general, and in particular the penetration of broadband in the region. Nonetheless, AMS-IX can be used as a best-in-class example to follow for the long-term.

AMS-IX started operations in 1994 and is today one of the largest IXPs in the world. It operates as a non-profit, neutral and independent IXP. According to its own policy statement, the AMS-IX functions as "a catalyst, boosting dynamics and growth in the local economy and ICT infrastructure," and only asks the regulator to "ensure that there is a level playing field, avoiding barriers that prevent free and fair competition." The member base is increasingly international and the majority of members, since a number of years, are from abroad (a 30/70 distribution of national versus international).[38] There are 472 networks connected to the AMS-IX,[39] with a current average traffic exchange of 250PB per month as of end of December 2011 (see Figure 4.4 below).

One of the key drivers of success is that AMS-IX is a virtual IXP. A virtual IXP places nodes in a number of independent data centers, connecting them together with fiber and thereby enabling a member in any of the data centers to connect with a member in any other data center. The data centers compete with each other for hosting services, allowing their customers to access a variety of services in addition to the nodes of the IXP. As noted by AMS-IX's Managing Director, for instance, a successful IXP such as the AMS-IX is useful for telecommunications operators as it increases their buying power in negotiating transit prices (transit can be purchased at $1–1.5/Mbit/s today at AMS-IX),[40] optimizes their networks (higher efficiency, lower latency, etc.), creates redundancy, and increases their marketing value (as being a member of the exchange makes operators more connected and thus more attractive to potential interconnection partners).

Figure 4.4 illustrates the historical growth of monthly traffic exchanged at the AMS-IX.

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38 Source: AMS-IX website at http://www.ams-ix.net/

39 Source: http://www.ams-ix.net/connected

40 Source: Job Witteman, "Building critical mass at an Internet Exchange", African Peering and Interconnection Forum, August 2010

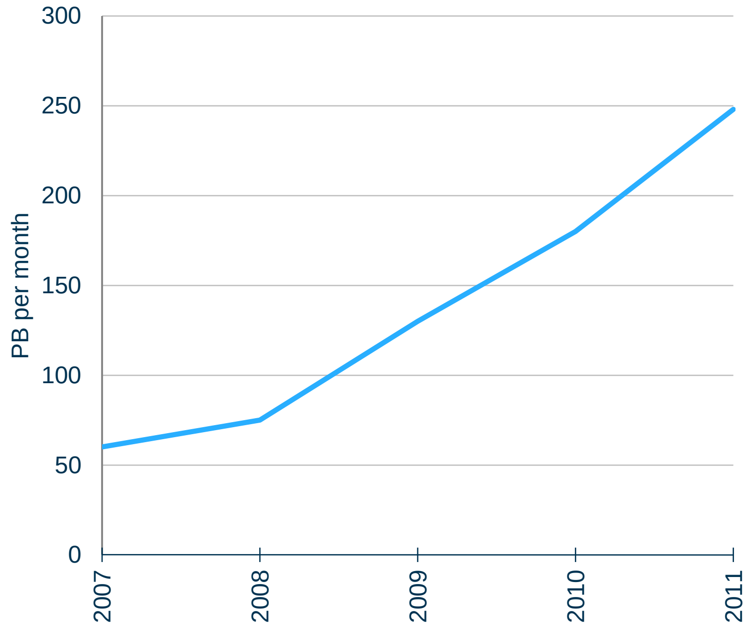


Figure 4.4: Mid-year monthly traffic exchanged at the AMS-IX [Source: AMS-IX, 2011]

It is noteworthy that AMS-IX has been able to grow significantly beyond what the Netherlands needs, creating a hub for regional traffic, resulting in the Netherlands having the highest international Internet bandwidth per capita of the countries included in Figure 4.3. While the relative position of AMS-IX has a lot of causes, including early deployment in Europe and a well-run neutral operating structure, the lesson to note in particular is the benefit of the virtual IXP framework, allowing members a choice of competing data centers, while using the IXP to connect to each other.

LINX: United Kingdom

Similarly to the AMS-IX, the London Internet Exchange (LINX) is one of the most successful IXPs in the world and was one of the first major IXPs in Europe. LINX was launched in 1994, at first switching only domestic traffic via a simple 10Mbit/s Ethernet hub. Today, the exchanged traffic at LINX amounts to an average of 600Gbit/s (as of mid-2011), and over 1.1Tbit/s of peak traffic (as of November 2011).[41] As with AMS-IX, LINX is a virtual IXP, connecting nodes in multiple independent data centers.

Similar to AMS-IX, LINX operates as a non-profit organization, governed by its own members collectively. Initially LINX membership was restricted to operators of traditional ISPs, but this restriction was relaxed in 2000 and today a wide variety of networks peer at LINX exchanges. While the IXP today counts more than 390 members connecting more than 50 countries, the diversity of

41 Source: LINX website at https://www.linx.net/

service providers peering at LINX is increasing and comprises over-the-top services providers, gaming specialists, DDoS mitigation specialists[42], advertising networks, etc.

Figure 4.5 illustrates the historical growth of mid-year traffic exchanged at the LINX – as for the AMS-IX, the traffic is still following an upward exponential trend, more than 15 years after launch.

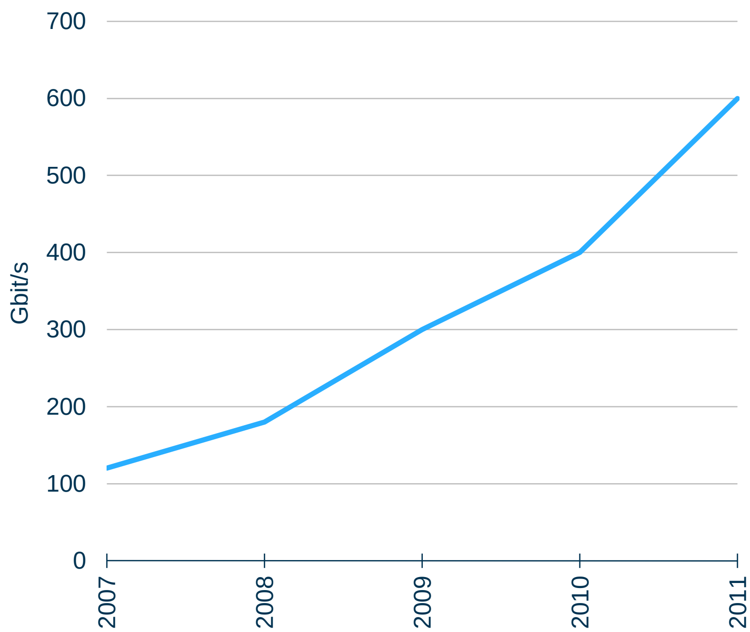


Figure 4.5: Mid-year average exchanged traffic at the LINX[43] [Source: LINX, 2011]

LINX has been a particularly worthy example of a leading IXP, as it has been at the forefront with regard to technology implementation in several instances. For example, LINX was the first Internet exchange in the world to deploy a 100-megabit switch, in 1996. In January 1999, LINX also led with the implementation of a MAN over gigabit Ethernet and further developed this to be the first to use 10GB Ethernet. In addition, LINX's 'LINX from Anywhere' service enables ISPs to have a secure, virtual presence on the exchange by piggybacking on existing networks, thereby eliminating the high capital expenditure for the smaller players.

42 DDoS: Distributed denial-of-service attacks correspond to attempts to make a network server unavailable to its users, typically by saturating the target server with external communications requests, such that it cannot respond or responds so slowly that it becomes effectively unavailable. Mitigation specialists work to prevent such attacks.

43 Note: This graph shows the aggregated traffic that flows across all LINX switches and sites, together with an estimate of the additional traffic that flows bilaterally between members across the LINX private interconnect service

4.3.3 Projections for Kenya and Nigeria

The Internet ecosystems of African countries have historically faced very specific challenges at the macro-economic level, with struggling economies and limited disposable income on the demand side, and at the industry level, with poor telecommunications infrastructure and feeble international connectivity on the supply side. However, Africa also has key strengths which provide development potential for the Internet sector, including its youthful population and the evident demand for Internet access.

The recent growth in the Internet in sub-Saharan Africa can partially be explained by the launch of the SEACOM, TEAMS, and EASSy cables on the east African coast, and Main One and Glo-1 on the west coast, which contributed to increased competition and lower prices. Nigeria and Kenya saw particularly robust growth: international Internet bandwidth connected to Nigeria and Kenya has essentially doubled every year since 2007. In 2011, these two countries had 30Gbit/s and 23Gbit/s of international bandwidth, respectively, while South Africa continued to lead the region with over 35Gbit/s of international capacity[44].

Finally, cross-border terrestrial networks are expanding in sub-Saharan Africa to facilitate access to cables for land-locked countries and regional traffic exchange. Historically, operators mainly used international links to interconnect, given the relative weaknesses of intra-African cross-border links. But it appears that South Africa, Senegal, and, most recently, Kenya, now serve as important regional Internet hubs, sustained by the take-up of locally hosted content. The extent to which African countries can grow and improve their cross-border infrastructure, including by clarifying related cross-border regulations and licensing regimes, will impact the ability of ISPs, content providers, and other services to take advantage of continental-wide market opportunities and achieve greater economies of scale.[45]

Kenya is well positioned in comparison with South Africa, based on its current position and ever increasing bandwidth landing in the country. Comparisons with AMS-IX and LINX are clearly more long-term, based on the significant economic differences between the countries. However, while KIXP has a similar governance structure to those exchanges a significant difference is that the latter IXPs are virtual, connecting multiple data centers together, a structure that is missing from KIXP. In particular, enclosing KIXP within one or more data centers might further increase the attractiveness of the IXP by further attracting the content providers, end users, and backbone operators that will further fuel the

44 Source: Telegeography, 2011

45 We note that initiatives such as the World Bank West Africa Regional Communication Infrastructure Program (WARCIP), and the NEPAD UMOJANET project in much of the rest of Africa aim to deploy terrestrial links, among other goals, that could significantly increase regional connectivity in Africa. WARCIP is focusing on increasing connectivity in the ECOWAS region by connecting underserved countries (ongoing work: Burkina Faso, Sierra Leone and Liberia) and leveraging electricity transmission lines in other selected countries (work to follow: Nigeria, Benin, Ivory Coast, Mali, Senegal, the Gambia). Umojanet is devising strategies and business plans to encourage investors and operators to link existing networks to a single infrastructure, ultimately connecting 29 countries in north, west and central Africa.

growth of the IXP into a regional hub for traffic. While there is a second IXP in Mombasa, the two IXPs have not been connected to create a virtual IXP, which may not be necessary anyway given the existing competition for links connecting the two cities.

The Nigerian IXP also shares the same governance structure as the best-in-class IXPs, and seems clearly on the same growth trajectory as the Kenyan one, with a lag of one or two years. With its tremendous potential and the significant efforts put in its development, there are strong reasons to believe that the IXPN will achieve similar results as KIXP. As a virtual IXP with PoPs installed in a growing number of cities, the IXPN may also provide a solution for the national backhaul issue, by stimulating the aggregation of demand by small and medium ISPs (and thus bringing down costs of inter-city links through volume-based discounts). However, this should not prevent policy makers in Nigeria from addressing the issue of high national connectivity charges in order to further stimulate Internet access and usage by enabling ISPs to fully provision these links to promote domestic traffic exchange at the IXPN.

5 Conclusion

The success of the IXPs in Kenya and Nigeria confirms that these facilities constitute an essential component of healthy Internet ecosystems, and have a key role to play to foster the development of the Internet in emerging markets. By facilitating the interconnection between telecommunications operators, content providers, and users, these IXPs have improved the quality of service and have helped reducing the transmission costs for Internet traffic in their respective country.

- In Kenya, KIXP has improved the quality of service by reducing the latency of local traffic from 200–600ms to 2–10ms on average. The IXP now exchanges 1Gbit/s peak of traffic that would otherwise represent tromboning traffic, which translates into estimated savings of close to $1.5 million per year. The IXP has also favored the localization of content in the country, with initiatives such as the Google Global Cache project which, besides quality improvements and costs savings, also helps local operators to increase revenues from additional demand for mobile data traffic (for an estimated total value of $6 million per year per 100Mbit/s of increased mobile traffic, a conservative estimate). The KIXP also sustained the development of e-government initiatives, particularly in simplifying the collection of taxes. Finally, the KIXP is increasingly becoming a regional hub for traffic exchange between neighboring countries.
- In Nigeria, the IXPN has improved the quality of service by reducing latency of local traffic in similar ranges as KIXP. The IXPN is at an earlier stage of development than the KIXP and the traffic currently localized – i.e. prevented from tromboning – amounts to 300Mbit/s peak. However, this translates into estimated savings on international bandwidth of more than $1 million per year given the higher costs of international bandwidth. The IXP has also favored the localization of content in the country, with initiatives such as Google's network build to Nigeria, but also initiatives in the Education and Research area, with for instance the partnership of universities and research centers toward a cost-efficient and improved common network (e.g. Eko-Konnect). The IXP also helped bringing back in the country previously externalized services, such as the financial platforms for online banking.

These benefits have contributed to the development of the Internet, by increasing the quality experienced by Internet users, and lowering operating costs for ISPs. However, the volume of traffic localized compared to the total traffic exchanged remains small in both countries, while the costs of international bandwidth remains significant. Additionally, local ISPs are facing other constraints, such as power supply (for which they have to invest in very expensive autonomous and/or redundancy power solutions), security, and poor (but improving) supporting infrastructure (such as national fiber backbone).

In Nigeria, particular constraints are that all ISPs (including mobile operators) have not yet engaged with the IXPN, while national connectivity remains in some cases more expensive than international capacity. In Kenya, additional growth is expected as the second PoP in Mombasa begins to grow, while a large content delivery network is preparing to make its content available through a cache connected to KIXP (in a manner similar to the Google cache). Consequently, both IXPs are poised for additional growth and benefits in the near future.

Overall, the KIXP and the IXPN have the potential to become regional Internet hubs in their respective countries, as the JINX/CINX exchanges are in South Africa. It can be expected that in only a few years, these IXPs will have greatly contributed to the development of regional interconnection, and helped change an unsustainable situation where tromboning local traffic was more economical than exchanging traffic locally or regionally. Examples of more advanced IXPs should further encourage market players to participate in the success of the IXPs we studied, which ultimately benefits the entire ICT market.

Finally, we note that the very factors that have led to having a leading IXP in Kenya and Nigeria are more generally beneficial to the Internet ecosystem, namely supportive policies and regulations and fully engaged stakeholders. This suggests that consideration of IXPs should be included in any extensive effort to develop Internet access at a national level in any emerging market. For instance, any efforts to lower the cost of international and national backhaul in a country should be taken to lower the cost of Internet access for all users, in general, while such actions are also important as they will specifically increase access and usage of the IXP.

Appendix A: Benchmarking data

This section aims to assess the achievements of Kenya and Nigeria detailed in the previous section, by comparing them at a high level with the chosen benchmark countries, while accounting for the evolution of the demographic and ICT environments in these countries. Given their relatively similar market situation and their geographical proximity, the following countries were selected as benchmarks:

- Kenya benchmarks – Tanzania, Uganda and Sudan
- Nigeria benchmarks – Ivory Coast, Ghana and Senegal.

A critical aspect of the comparison lies in the impact of each country's demographic, policy and telecommunications infrastructure levels, as detailed below.

A.1 Demographic overview

The table below provides a high-level comparison of the main demographic indicators for Kenya and the selected benchmark countries.

Figure A.1: Main indicators for Kenya and comparable countries [Source: EUI, World Bank, Euromonitor, TeleGeography]

Indicator (in 2010)	*Unit*	*Kenya*	*Tanzania*	*Uganda*	*Sudan*
Population (mid-year)	million	41	45	34	43
GDP per capita	$ thousands/year	763	531	504	1550
Area	km^2	582,650	945,087	236,040	2,505,810
Population density	persons/km^2	70	50	144	1.7
Urban population	%	22.2	26.4	13.8	40.1

Kenya's population is slightly above 40 million, putting it in the middle of the benchmarked countries, which ranged from 34 million to 45 million in 2010. GDP per head is also relatively comparable at around $760 per year for Kenya in 2010. In Sudan, GDP reached around $1550 in 2010, but given the large disparity of income in Sudan, it can be argued that the mass market can afford a comparable share of disposable income to telecommunications services. Kenya is one of the smaller benchmark countries, with a population density in the middle range. For all these countries, there is a roughly comparable distribution of population between urban and rural areas

Similarly, Figure A.2 below provides a high-level comparison of the main indicators of Nigeria and the selected benchmark countries.

Figure A.2: Main indicators for Nigeria and comparable countries [Source: EUI, World Bank, Euromonitor, TeleGeography]

Indicator (in 2010)	*Unit*	*Nigeria*	*Ivory Coast*	*Ghana*	*Senegal*
Population (mid-year)	million	152	22	24	13
GDP per capita	$ thousands/year	1290	1030	1330	947
Area	km2	923,768	322,460	239,460	196,190
Population density	persons/km^2	160	70	100	67
Urban population	%	49.8	50.6	51.5	42.4

Nigeria is the most populous country of sub-Saharan Africa, with more than 150 million inhabitants, putting it far above the benchmarked countries, which ranged from 13 million to 24 million in 2010. For all these countries, there is a comparable distribution of population between urban and rural areas. GDP per head is also relatively comparable at around $1290 per year for Nigeria in 2010, while benchmarked countries ranged from $950 to $1330 per year.

In conclusion, the benchmarked sets of countries are relatively similar at the demographic level, except that Nigeria possesses by far the largest population.

A.1.1 Policy and regulatory environment

Figure A.3 below provides an overview of the policy environment in Kenya and Nigeria, together with those of the selected benchmark countries.

Figure A.3: Main policy variables [Source: Analysys Mason, ITU, 2012]

Country	*Privatization status of incumbent*	*Mobile competition*	*International gateway*	*ISP competition*
Kenya	**Partially privatized**	**Competitive**	**Competitive**	**Competitive**
Nigeria	**State-owned**	**Competitive**	**Competitive**	**Competitive**
Tanzania	Partially privatized	Competitive	Competitive	Competitive
Uganda	Privatized	Competitive	Competitive	Competitive
Sudan	Partially privatized	Competitive	Partial competition	Partial competition
Ivory Coast	Privatized	Competitive	Partial competition	Partial competition
Ghana	Partially privatized	Competitive	Partial competition	Partial competition
Senegal	Partially privatized	Partial competition	Partial competition	Partial competition

Note: Partial competition means a situation in which one market player seems to have a “dominant” position

Kenya is among the most liberalized countries, with only Uganda having a fully privatized incumbent. Otherwise, all the countries have a competitive mobile sector, while Sudan is less competitive in the international gateway and ISP competition. In Nigeria, the fixed incumbent is still state-owned, but faces competition from many wireless fixed players, and has no monopoly on the international gateway (while other benchmark countries are less liberalized as regards international access). The ISP market tends to be more competitive but also more fragmented in Nigeria compared to other benchmarked countries, while most of the considered mobile markets are similarly competitive.

A.1.2 Infrastructure and interconnection environment

The figure below highlights the status of fixed and mobile competition in Kenya, Nigeria and the selected comparable countries.

Figure A.4: Penetration of fixed and mobile infrastructure, 2010 [Source: TeleGeography, ITU, 2012] (= 2011 statistics)*

Country	Fixed penetration (% HH)	Mobile penetration (% population)
Kenya	4.3	60.1
Nigeria	3.5	57.4
Tanzania	2.2	46.7
Uganda	5.7	37.7
Sudan	9.7	55.4*
Ivory Coast	6.7	68.3
Ghana	6.0	79.3
Senegal	22.4	64.2

As in most sub-Saharan countries, the lack of reliable and extensive fixed access infrastructure has, historically, been the main weakness of the ICT environment, and has been an obstacle to broadband development. Local loop unbundling is rarely developed, and deployment costs are massive. In all benchmarked countries, fixed penetration was still below 10% as a percentage of households, except in Senegal where this ratio was 22% as of 2010.[46] Moreover, these penetration levels tend to diminish over time, due to the fixed-to-mobile substitution effect, and the fixed broadband markets are usually not growing sufficiently to compensate for declining fixed voice revenue.

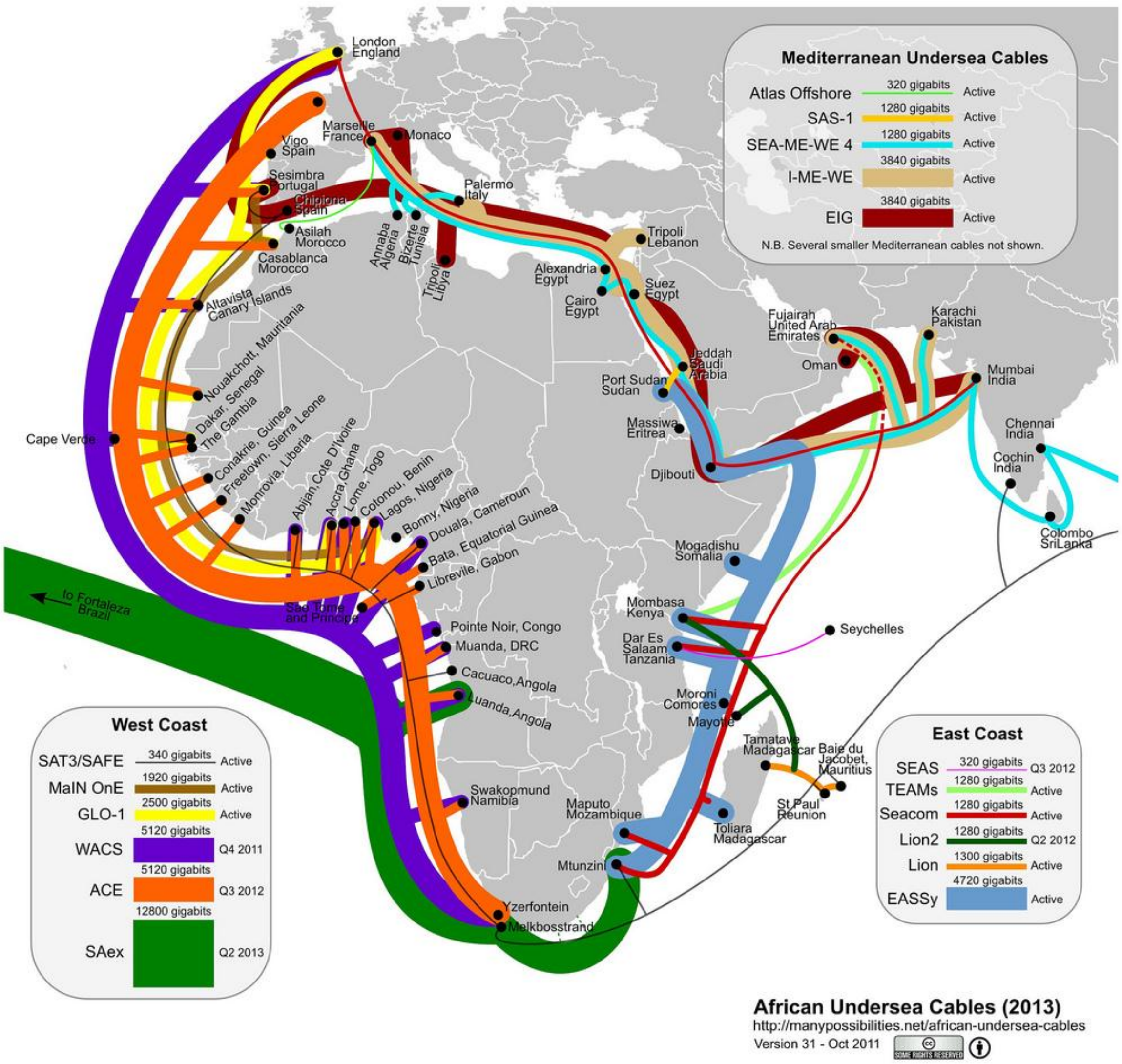
However, access levels have changed dramatically with the advent of mobile broadband technologies for network access. In 2010, mobile penetration was around 58% on average for the benchmarked countries. Kenya has the highest mobile penetration in its group of benchmarks, while Nigeria has the lowest in its grouping. Mobile adoption paves the way to the development of mobile broadband, with the uptake of mature 3G technologies in these countries in particular.

46 Source: TeleGeography

In terms of international connectivity, according to the ITU, between 2005 and 2010, international Internet bandwidth in Africa increased from 3500 to 82,000Mbit/s, with the greatest growth rate registered between 2009 and 2010. This is mainly the result of a number of new and competing submarine cables that went live in 2010, as described above. These include the 10,500 km EASSy cable, which connects Africa to the rest of the world and runs from South Africa to Sudan, with landing points in nine countries and further connections to at least ten landlocked African countries which therefore no longer depend solely on satellite access to the Internet.

The figure below illustrates the cables landing and those expected to land as of the end of 2011.

Figure A.5: African fiber optic submarine cables [Source: http://manypossibilities.net/african-undersea-cables/, October 2011]



As explained above and illustrated above, all coastal countries in the benchmarks now have access to decent international connectivity via different submarine cables. A total of 20Tbit/s of submarine cable capacity linking African countries to each other and the rest of the world will be in place in 2012, and there is around 350,000km of terrestrial backbone fiber infrastructure on the continent.[47] For instance, Uganda can connect to three submarine cables: SEACOM, EASSy and TEAMS. TEAMS is the longest established among the three, reaching Uganda in June 2009. It runs from Kenya to UAE with a current capacity of 120Gbit/s. Sudan is well also connected to the rest of the world through three undersea submarine cables, namely SAS-1, Flag Falcon and EASSy.

There is also an increasing amount of infrastructure being developed that will help to increase regional connectivity between countries and to the submarine cables. For instance, the East African Backhaul System (EABs) is a joint venture project among operators from Tanzania, Burundi, Rwanda, Uganda and Kenya. The backhaul system links the five East African Community (EAC) countries, and is particularly important for the three landlocked EAC countries Burundi, Rwanda and Uganda. The EABs involves about 30 operators in eastern and southern Africa and feeds from the cable systems that have landed in Mombasa and Dar es Salaam. When finished, the fiber system will run nearly 16,000km across the five countries, making it the largest interconnected region in the continent. The aim is to create a connection between the terrestrial fiber system and the submarine fiber-optic cables on the east African coast.

At present, Burundi is working on the completion of its 1300km cable while Tanzania has completed links to the main borders and is working on its 10,000km cable. Uganda lags behind the other countries and is trying to keep up with its three-phase project, having completed the first phase and with the second one due by the end of the year. In contrast, Kenya is working very efficiently and has already completed some 5,000km of fiber optics.[48] This regional infrastructure will help traffic to remain within the region, and may enable an advanced IXP such as KIXP to grow into a regional hub for traffic exchange.

In West Africa, Phase3 started the implementation of the Wire Nigeria project in partnership with ECOWAS in February 2012, with plans to connect its aerial fiber optic network in Nigeria to other West African countries including Benin, Togo and Niger, and on-going plans to extend the network to Ghana, Ivory Coast and Senegal. The World Bank is also financing the West Africa Regional Communications Infrastructure Project (WARCIP), which started at the end of 2011 and will contribute greatly to the improvement of connectivity in the Gambia, Guinea and Burkina Faso.

[47] Source: African Peering and Interconnection forum, Unlocking Africa's regional interconnection, August 2010, AfPIF

[48] Source: http://www.intelligencecentre.net/2010/05/28/fixed-broadband-in-africa-is-finally-turning-the-corner/

A.2 Internet usage indicators

With the notable exception of Senegal, with close to 6% broadband household penetration resulting from significantly higher fixed penetration, all benchmarked countries had household penetration below 2% as of June 2011, as illustrated below. This is largely a function of low fixed penetration in general, along with low PC ownership to take advantage of fixed access.

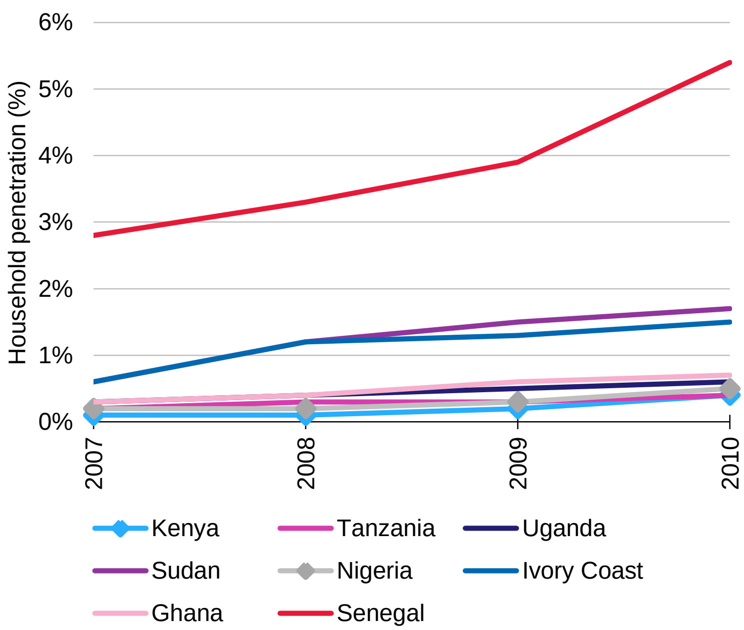


Figure A.6: Broadband household penetration [Source: Globalcomms, 2012]

Looking more broadly at Internet usage, the percentage of Internet users in Kenya and Nigeria is higher, as illustrated below. In this regard, Nigeria exhibits the greatest Internet use with its population penetration standing at 28% at December 2010 according to the ITU. Within its benchmark group, Kenya is close to Nigeria and overtakes Senegal and Uganda in usage. These data demonstrate that Nigeria and Kenya both have a leading role in Internet access in their respective regions.

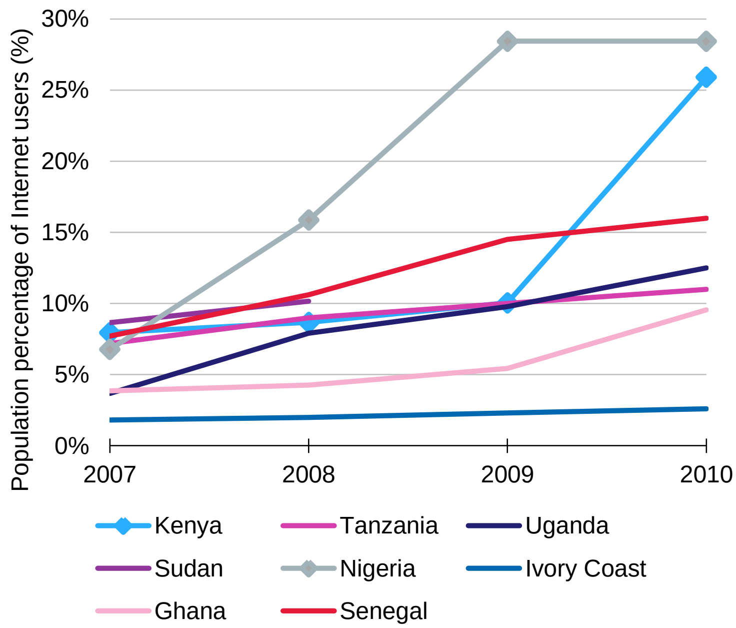


Figure A.7: Internet population penetration, 2007–2010 [Source: ITU, 2011]

A.3 Conclusion

Compared to similar countries, the benefits of the IXPs we studied are important, but the presence of IXPs does not fully explain the main differences in terms of Internet access between countries. Macro-economic factors, infrastructure developments, national regulation and policies are all key factors that can significantly alter the telecommunications outlook and the Internet development in particular. As a result, it would be misleading to assign any impact on Internet access to the IXP alone. On the other hand, it is likely that the very factors that have led to having a leading IXP are also the same factors that lead to high Internet access, namely supportive policies and regulations; engaged stakeholders seeking to grow the ecosystem; and a resulting population eager to access and use the Internet.

Appendix B: Interviews conducted for this study

This report is partially based on qualitative and quantitative data and evidence provided by the Kenya Internet Exchange Point (KIXP) and the Internet Exchange Point of Nigeria (IXPN).

Data cited in this report have also been gathered from different local stakeholders via questionnaires and follow-up calls and meetings, with a promise of confidentiality on sensitive information in return for sharing business-sensitive data. These stakeholders include the following:

- In Kenya: CCK, Google, Internet Solutions, JTL, KDN, Kenet, Kenic, KRA, Orange Kenya, Safaricom, Telkom Kenya, Wananchi.
- In Nigeria: 21stCentury, Cyberspace, Gateway, Google, Internet Solutions, KKON, Linkserve Limited, Netcom, Phase3telecom, Simbanet, Swift, Tara systems, Unilag.

Appendix C: Glossary

- **Autonomous System Number (ASN)**: collection of connected IP routing prefixes controlled by one or more network operators that presents a common routing policy to the Internet
- **Caching (of web files)**: technique used to reduce bandwidth usage, and perceived latency by Internet users. The technique consists in storing copies of content files received by Internet users from hosting servers, as they transit through the Internet network. These copies are stored in dedicated caching servers that will satisfy subsequent requests of similar content (instead of the original hosting servers)
- **Content Delivery Network (CDN)**: a CDN typically consists of a network of caching servers geographically distributed, connected by fiber, which feeds copies of content (provided by their clients) directly to ISPs to which they are connected. A CDN's role is to ensure that the content of its clients is distributed to end users with good performance, independently of the location of the end user
- **Content provider**: a content provider (and aggregator) creates content for the Internet and/or aggregates this content, to make it available to its Internet users or customers
- **Internet backbone provider**: operator delivering traffic to and from third party networks through its infrastructure of national or international high-speed fiber optic networks
- **Internet Exchange Point (IXP)**: physical infrastructure through which typically Internet Backbone providers, ISPs and Content providers exchange traffic between their networks using peering or transit
- **Internet Service Provider (ISP)**: operator offering its customers access to the Internet via a data transmission technology such as dial-up, DSL, cable modem, wireless or dedicated high-speed connection
- **Latency**: latency is a measure of time delay experienced in a communication system. In this report, latency refers to "round-trip" latency, i.e. the time from the source sending a "packet" of IP traffic to the destination and back to the source
- **Peering**: relationship typically between two Internet backbone providers, where each backbone exchanges traffic between its own customers and those customers of the other backbone. Often, but not always, these relationships are 'settlement-free' in which no money is exchanged as compensation for delivering the exchanged traffic in either direction.

- **Point of Presence (PoP)**: Network facility at which customers of an Internet Backbone Provider can interconnect their networks with the Internet backbone

- **Transit**: relationship typically between an ISP and an Internet backbone provider, where the Internet Backbone provides the ISP with access to the rest of its transit customers as well the customers of other backbones with which it peers, in exchange for payments based on the volume of traffic.

- **Tromboning (international tromboning)**: tromboning occurs when traffic from within one country flows through another country to be exchanged and delivered back to the original country. See Section 2.1.2 for more details.

Appendix D: About us

D.1 About ISOC

The Internet Society is a leading advocate for a free and open Internet, promoting the open development, evolution and use of the Internet for the benefit of all people throughout the world. We are the trusted independent source for Internet information and thought leadership from around the world. The Internet Society has worked for more than 20 years to ensure the Internet continues to grow and evolve as a platform for innovation, economic development, and social progress.

The Internet Society educates, informs, and communicates with technology, business and government stakeholders, as well as the general public, to promote an open Internet for everyone. We advocate for the ongoing development of the Internet as an open platform that empowers people to share ideas and connect in new and innovative ways, and which serves the economic, social, and educational needs of individuals throughout the world. To achieve this mission, the Internet Society:

- facilitates open development of standards, protocols, administration, and the technical infrastructure of the Internet
- supports education in developing countries specifically, and wherever the need exists
- promotes professional development and builds community to foster participation and leadership in areas important to the evolution of the Internet
- provides reliable information about the Internet
- provides forums for discussion of issues that affect Internet evolution, development and use in technical, commercial, societal, and other contexts
- fosters an environment for international cooperation, community, and a culture that enables self-governance to work
- serves as a focal point for cooperative efforts to promote the Internet as a positive tool to benefit all people throughout the world
- provides management and coordination for on-strategy initiatives and outreach efforts in humanitarian, educational, societal, and other contexts.

The Internet Society is at the center of the largest global network of people and organizations focused on ensuring the Internet continues to evolve as a platform for innovation, collaboration and economic development. By tackling issues at the intersection of technology, policy and education, we work collaboratively to preserve and protect the multi-stakeholder model of development and management that has been key to the Internet's success. With more than 120 organizational members and over 55,000 individual members in over 90 Chapters, the Internet Society represents a worldwide network of corporations, non-profit organizations, entrepreneurs, and individuals who are interested in working to identify and address the challenges and opportunities that exist online.

Among its many initiatives, the Internet Society has embarked on a multi-year programme to assist emerging economies in developing robust, cost-effective, and efficient Internet interconnection and traffic exchange environments. Our work includes a range of activities, such as:

- Assisting universities, government network operators, and ISPs to gain the world-class knowledge and skills needed to build reliable, cost-effective, and interconnected networks,
- Facilitating the development of new Internet Exchange Points (IXPs), and helping stakeholders to maximize the use of IXPs already in place,
- Assisting policy-makers and regulators in developing approaches to expanding the Internet achieving a beneficial interconnection and traffic exchange landscape, and
- Facilitating multi-stakeholder collaborations on these issues, including the African Peering and Interconnection Forum (AfPIF), and supporting the Latin American and Caribbean IXP association (Lac-IX).

For more information about the Internet Society, including our work to improve the Internet interconnection and traffic exchange environment in emerging economies, please visit our website at http://www.internetsociety.org

D.2 About Analysys Mason

The only constant is change. What worked yesterday won't necessarily work today. That's why we look beyond the obvious, seeing things from a client's perspective so that a truly effective solution is delivered every time. A key part of this is our international perspective. Business never sleeps, and with offices spanning six time zones, neither does Analysys Mason.

Telecoms, media and technology are our world; we live and breathe TMT. This total immersion in our subject underpins and informs everything we do, from the strength and reliability of our market analysis, to improving business performance for clients in over 100 countries around the globe.

We're experts in telecoms, media and technology (TMT). This knowhow underpins everything we do and helps our clients change their businesses for the better.

At the heart of our approach is a simple, but enormously powerful idea: applied intelligence. By harnessing our collective brainpower we can solve real-world problems and deliver tangible benefits for our customers. As a Japanese proverb says, ‘all of us are smarter than any of us’.

We’re passionate about what we do, with the focus and determination to take on and solve the toughest problems to help our clients. We’ll rise to the challenge and enjoy it. In fact when it comes to problem solving, there’s a real sense of ‘the tougher the better’. It’s this unique combination of our applied intelligence, effective problem solving and the ability to look closer and see further that makes Analysys Mason special.

D.2.1 Consulting from Analysys Mason

For more than 25 years, our consultants have been bringing the benefits of applied intelligence to enable clients around the world to make the most of their opportunities

Unlike some consultancies, our focus is exclusively on TMT. We advise clients on regulatory matters, support multi-billion dollar investments, advise on network performance and recommend commercial partnering options and new business strategies. Such projects result in a depth of knowledge and a range of expertise that sets us apart.

We look beyond the obvious to understand a situation from a client’s perspective. Most importantly, we never forget that the point of consultancy is to provide appropriate and practical solutions. We help clients solve their most pressing problems, enabling them to go further, faster and achieve their commercial objectives.

We blend our range of skills each day, every day, to solve our clients’ most complex challenges

For more information about our consulting services, please visit www.analysysmason.com/consulting.

D.2.2 Research from Analysys Mason

Our subscription research programmes address key industry dynamics in order to help clients interpret the changing market

The programmes focus on five areas:

- consumer services
- enterprise services
- network technologies
- telecom software
- market data.

We analyse, track and forecast the different services accessed by consumers and enterprises, as well as the software, infrastructure and technology that underpins the delivery of those services. Subscribing to our research programmes gives you regular and timely intelligence. It also provides direct access to our team of analysts – that is, the opportunity to engage one-to-one with our subject experts for insight, opinion and practical advice relating to your most-critical business decisions.

Take advantage of this service and you'll be in good company. Many of the world's leading network operators, vendors, regulators and investors subscribe to our programmes and rely on our insight on a daily basis to inform their decision making.

Our custom research service offers in-depth, tailored analysis that addresses specific issues to meet your exact requirements

Our experienced custom research team can undertake market sizing and analysis, and competitor and partner profiling, supported by all the analysis and insight you require. In addition, we can carry out expert interviews and quantitative surveys to obtain fresh and genuine insights, and we can deliver reliable benchmark data together with first-class interpretation and advice on getting the best from such information.

Clients call on us for our authoritative market forecasts, which are based on our comprehensive knowledge of the TMT industries, and draw on a large base of data that we have collected over many years and refresh through continuous research. Our subject experts also produce tailored white papers, which prove highly valuable for sales and marketing campaigns, and deliver presentations and facilitate workshops that keep your teams up to date with the latest emerging trends and technologies.

For more information about our subscription research programmes and custom research services, please visit www.analysysmason.com/research.

D.3 About the Authors

Michael Kende is a Partner and the co-head of the global Regulation and Policy group at Analysys Mason. Prior to joining Analysys Mason, Michael was the Director of Internet Policy Analysis at the Federal Communications Commission, where he was responsible for managing a wide range of policy analyses and regulatory decisions on Internet policy. Michael led the review of several mergers involving Internet backbones and wrote a FCC working paper entitled *The Digital Handshake: Connecting Internet Backbones*. At Analysys Mason, Michael has worked with operators and regulators in six continents, providing advice on a variety of Internet issues. In particular, he has consulted on IP interconnection issues for companies or governments in Australia, Brazil, Ireland, Singapore, Saudi Arabia, Sri Lanka, the United States, and for the European Union. He is the lead author of the report *Overview of recent changes in the IP interconnection ecosystem* (January 2011). He also led the team that worked with the Infocomm Development Authority (IDA) in Singapore to establish the Singapore Internet Exchange (SGIX) and is doing the same for another government in the Middle East.

Charles Hurpy is a Lead Consultant in Analysys Mason's USA office and has strong expertise in the IP interconnection issues: Charles participated extensively in the production of our report *Overview of recent changes in the IP interconnection ecosystem* (January 2011) and is currently managing a project aimed at establishing an International Internet Exchange Point for a government in the Middle East. Charles has been involved in numerous regulatory projects with Analysys Mason, ranging from competition and market analysis for telecom regulators, support to regulatory department of alternative operators on termination rates and legal disputes, telecom market review, and retail and wholesale services benchmarking.

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