Internet Governance Forum (IGF) 2015

Best Practices Forum on Internet exchange points (IXPs)

Enabling Environments to Establish Successful IXPs

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Outcome document of the IGF 2015 Best Practice Forum on IXPs
Editor: Wim Degezelle

Table of Contents

Summary

Enabling environments to establish successful IXPs is one of the Best Practice Forums (BPFs) of the 2015 IGF. The BPF brought together experts and stakeholders in an open and collaborative process to develop a useful and tangible best practices outcome document. Stakeholder input was collected via discussions on an open mailing list, regular virtual meetings, public input via the IGF review platform and during the in-person session at the 2015 IGF meeting in João Pessoa.

This best practice document explains why IXPs matter and focuses on ways to create enabling environments that allow IXPs to develop and flourish. The information and examples provided are meant to serve as the foundation of a flexible framework, useful regardless of the country or continent, for creating an environment that fosters IXP success and development.

The Internet is a large network of networks and each network needs to be able to send and receive traffic to any other network. *Internet exchange points (IXPs) are physical locations where Internet networks are connected at a common point to exchange data*. The practice of exchanging data between networks at an IXP is called peering. Peering is in a majority of the IXPs a cost-neutral transaction.

When local networks are exchanging traffic, an IXP can reduce the network's operational costs, keep traffic local and decrease latency, allow better control and more autonomy of a network's own resources, create a more stable and robust local Internet and enable competition by facilitating the entrance of new service providers on the local market. IXPs are an opportunity to strengthen, amplify, and accelerate Connecting the Next Billion and final billions.

Setting up an IXP requires finding peers that agree to set-up and run the IXP, and investing in equipment, training and capacity building. However, more than 80% of the success of the IXP depends on its capability to create an environment of trust and cooperation amongst its stakeholders.
Governments and regulators can play a facilitating role by resolving potential legal and regulatory issues that prevent IXPs to develop, by providing support at start up, by bringing stakeholders together and by stimulating the development of the country's infrastructure, including a healthy competitive market for national and international connection.

No local situation is alike and there is no golden solution or one formula for the success of an IXP. This best practices document provides case studies, references and links to background material that will inspire and help stakeholders to create an environment that enables the establishment of successful IXPs.

Further work can be done on IXPs moving forward by looking into questions that have been raised by contributors to the BPF, for example, what to do in a land-locked country relying mostly on satellite connectivity or how to revive a dormant IXP and other problems articulated.

1. Introduction

1.1. IGF Best Practices Forums

The Internet Governance Forum (IGF) is a global forum where governments, the technical community, civil society, academia, the private sector, and independent experts discuss Internet governance and policy issues.[1] The annual IGF meeting is organized by a Multistakeholder Advisory Group (MAG) under the auspices of the United Nations Department of Economic and Social Affairs (DESA). The 10th annual IGF meeting will take place in João Pessoa, Brazil, on 10-13 November 2015.[2]

The IGF Best Practice Forums (BPFs) bring experts and stakeholders together to develop a tangible and useful best practice output through a collaborative, bottom-up process. The BPF "Enabling Environments to Establish Successful IXPs" is one of the six BPF topic areas that led up to the 2015 IGF meeting.[3] The BPFs are an answer to the call for intersessional work and more tangible outputs of the IGF.

The IXP BPF finds inspiration in paragraph 50 of the Tunis Agenda[4] on international Internet connectivity for the development of strategies to increase affordable global connectivity, and from chapters 4 and 6 of the World Summit on the Information Society (WSIS) Action lines[5] that address capacity building and an enabling environment.

1.2. IXPs at the IGF

Given their essential function in the Internet, IXPs are not a new topic for the IGF. IXPs have been a recurring theme of panel discussions and workshops at the IGF since the first IGF meeting in 2005 in Athens, Greece.[6] In addition to the activities of this BPF, there are also two IXP workshops scheduled to take place at IGF 2015.[7]

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[1] IGF website: http://www.intgovforum.org.
[2] IGF 2015 Host Country website: http://www.igf2015.br.
[3] IGF Best Practices Forums: http://www.intgovforum.org/cms/best-practice-forums.
[4] Tunis Agenda for the Information Society: https://www.itu.int/wsis/docs2/tunis/off/6rev1.pdf.
[5] WSIS Plan of Action: http://www.itu.int/wsis/docs/geneva/official/poa.html.
[6] For example:
IGF 2007, Rio de Janeiro, Brazil: "Internet Traffic Exchange in Less-Developed Internet Markets and the Role of Internet Exchange Points."
IGF 2012, Baku, Azerbaijan: "Strategies for expanding IXPs and other Internet/Cloud infrastructure." Additionally, Patrick Ryan and Jason Gerson prepared a white paper that provides an overview of IXPs, which was done in preparation for workshops at IGF 2012, titled "A Primer on Internet Exchange Points for Policymakers and Non-Engineers."
IGF 2013, Bali, Indonesia: "Internet Exchange Points and the Domestic Internet Economy."
[7] WS 201: Ensuring sustainability for IXPs in the developing world and WS 171 IXPs: Driving connectivity and local economies.

1.3. Purpose of this document

Internet exchange points (IXPs) are a well-established concept. There is a substantial body of knowledge within the IXP operator and member community regarding best practices and the characteristics of local environments that are conducive to the formation and success of IXPs. However, such knowledge is not evenly distributed, and some stakeholders have expressed a need for greater awareness. Therefore, the aim of this BPF is to make existing community knowledge more widely available.

This document will explain why IXPs matter and focus on ways to create enabling environments that allow IXPs to develop and flourish.

The information and examples are useful regardless of the country or continent, but this BPF will also address the request from some developing countries for more information about IXPs.

A wide range of experts and stakeholders through an iterative and open process has provided the best practices outlined in this document. They are meant to serve as the foundation of a flexible framework for creating an enabling environment that fosters IXP development and success. They are not meant to be static, they are rather meant to serve as starting points that can be improved upon as more IXPs are deployed around the world.

1.4. What this document is not

The IGF is not an appropriate forum to discuss or teach the technical knowhow that is needed to create and/or run an IXP, nor is this outcome document a technical manual for routers and switches. There are specialist meetings and forums that dive into the technical details of how to establish, operate, and sustain an IXP. In addition, technical guidelines and reference documents are available from IXP operators and managers. For those seeking technical guidance and technical best practices, a non-exhaustive overview of reference documents from IXP-related fora has been included in this document (see Appendix 1).

1.5. Methodological note

This document is the outcome of an open and iterative process that occurred over the months preceding the IGF meeting as part of the IGF 2015 Intersessional work program. The structure and content of the document was developed through online discussions on an open mailing list and through regular virtual meetings in which all community members could participate and contribute. In addition, a survey was used to collect input from IXP operators. These real life experiences and testimonials helped to shape this best practices document.

Drafts of this document were made available on the IGF website for public comment prior to (and during) the IGF 2015 meeting in João Pessoa, Brazil. The best practices were presented at the BPF IXP session during the IGF meeting.
For additional information regarding the IXP BPF process, please refer to the IGF website.

2. What is the role and benefit of an Internet exchange point?

An IXP enables Internet Protocol (IP) networks to efficiently exchange data traffic at a common point. When two local networks are exchanging traffic, an IXP can reduce the portion of a network's traffic that must be delivered via upstream transit providers, thereby reducing the average per-bit delivery cost of service and latency as well as improving routing efficiency and fault-tolerance.

2.1. What is an IXP?

The Internet is a large network of networks, a global communication network composed of thousands of individual networks interconnected in a densely populated mesh. Each of the networks is in some form a portion of the Internet.[8] Different kinds of networks exist; for instance, consider networks with various users, services or resources. To effectively be part of the Internet, each network needs to be able to send and receive traffic to any other network. Different networks can interoperate because they all speak the same language: IP.

Internet exchange points are physical locations where networks interconnect and exchange traffic with each other. The practice of exchanging traffic between and among networks at an IXP is called peering. Internet service providers (ISPs) generally peer at IXPs, where they exchange traffic that originated from each other's network or from each other's customers' networks usually – but sometimes with exceptions[9] – on a settlement-free basis. Peering is largely based on voluntary agreements by both networks as a result of acknowledging the value of being directly connected: IP packets are routed directly using the shortest and cheapest path between both networks. By exchanging traffic at an IXP, ISPs do not have to build out their networks to all their "peers," which cuts costs, frees up money, labor, and resources, and allows for a more competitive market environment.

The Internet is large in scale and geographically spread over countries and continents and as a consequence a majority of networks cannot interconnect directly. Thus, most networks must use a third-party network to route packets to and from the rest of the Internet. This commercial service is known as "transit" and typically involves a payment based on a contractual obligation as opposed to settlement-free peering. This point is especially significant for networks in countries without an IXP that are more likely to route inter-network traffic via expensive transit facilities.

2.2. IXPs in the world: A global snapshot

The IXP model of network interconnection and traffic exchange is a widely-adopted industry practice with nearly 500 known IXPs in 120 countries.[10,11]

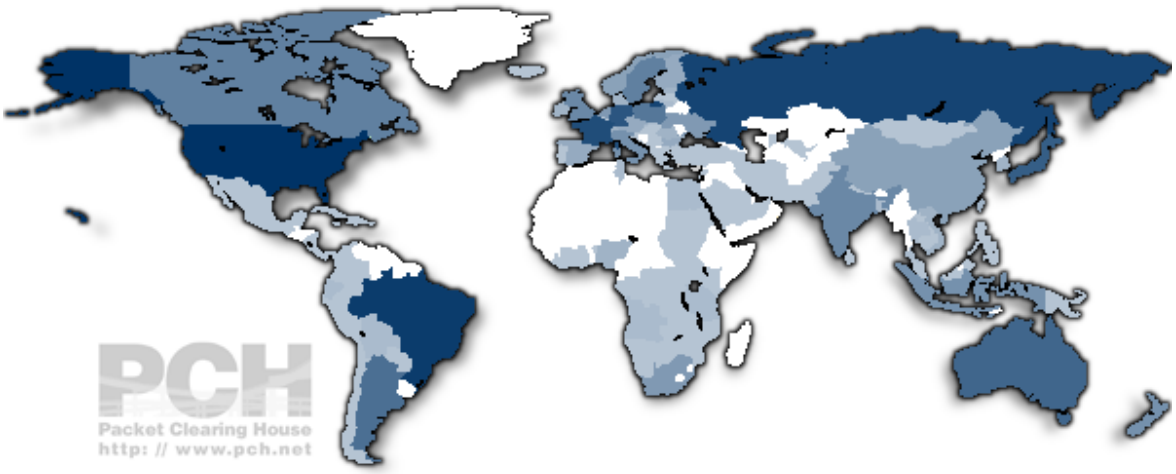
[8] "Internet happens," a video by the European Internet Exchange (Euro-IX) explains the role and benefit of an IXP: https://youtu.be/QuBde4Sn3f0.
[9] In some cases, ISPs interconnect using paid peering where one ISP pays the other for traffic exchange.
[10] https://prefix.pch.net/applications/ixpdir/.

The location and distribution of IXPs in the world can be explained by looking at several factors such as country demographics, market conditions, and global economics.

First, population density in most cases establishes the location(s) of the first IXP(s) in a country. Countries with one IXP will usually have it located in the capital city because it aggregates the highest population density of the country. Normally, additional IXPs will be placed in other largely populated areas such as secondary cities.

Second, market dynamics and the policy and regulatory environment also influences the number and locations of IXPs in a given region or territory. In some countries, the volume of the Internet industry (service providers, carriers, data centers, content providers, etc.) has resulted in the development of multiple IXPs to accommodate the growth of traffic exchanged among networks. Regulation can also force the establishment of IXPs, which as opposed to a market-led initiative, does not constitute a good practice.

Finally, global economics also influence the location and density of exchange points. For example, in regions with higher dependence on the digital economy, there is a larger concentration of service providers, carriers, and data centers that can foster the demand for IXPs.



Region	Number of IXPs	Number of countries	Number of cities
Africa	37	28	31
Asia	99	25	49
EME region[12]	214	49	142
LAC region[13]	60	16	49
North America	102	2	57

Table 1. *– The number of IXPs, by region (source)*

[11] https://www.euro-ix.net/ixps/ixp-map/.
[12] Europe and the Middle East.
[13] Latin America and the Caribbean.

2.3. What are the benefits of an IXP?

- **Reduction of a network's operational costs**

Using cost-neutral transactions for the exchange of traffic between networks at an IXP reduces the average-per-bit-delivery cost of a network. What this means is that it becomes cheaper for the network to be part of the Internet and provide service to its clients (residential users, businesses, and others).

- **Keeping traffic local and decreasing latency**

Since IXPs facilitate the direct interconnection of networks, the newly created routes among them allow for the traffic destined for each other to remain local and be delivered with the lowest possible latency. Latency is the time elapsed between the transmission of IP packets from the originator and reception of those IP packets at the receiver. It is one of the four parameters that define the QoS (quality of service) of an Internet connection.[14]

- **Better control and more autonomy of networks' own resources**

Using IXPs gives networks more autonomy and control over their own resources, including routing and traffic management, because it decreases a network's dependency on third-party networks.

ISPs that exclusively use a single transit provider and do not connect to an IXP (either by choice or because there is no local IXP) are totally dependent on the service of that one upstream provider. This means that there is no additional option for cheaper service provision other than that one upstream provider, giving the network less resiliency and fewer competitive options for basic and auxiliary services.

In addition to the first level of benefits that networks enjoy, other benefits can be extended to the local ecosystem and community where an IXP is located, they are described below.

- **More stability and robustness for the local Internet**

Increasing the number of direct paths and routes between networks increases the stability and robustness of the Internet in the case of network outages, denial of service (DoS) attacks, and other related circumstances. Some of the largest IXPs serve as hubs to more than 500 networks. It is easy to understand the impact that IXPs have on both the local and regional level when the growth and connectivity of networks are factored in over time.

- **Enable competition by supporting new market entrants**

Evidence suggests that IXPs can enable competition by facilitating the entry of new service providers in a cost-effective way. For instance, new entrants do not have to build out their networks to all the other networks they are exchanging traffic with at an IXP. Additionally, an

[14] The other three being packet loss, jitter, and out-of-order delivery.

IXP generally provides a neutral traffic exchange point whereas bilateral interconnection with incumbents and/or larger networks can be both expensive and include other barriers to entry. Improving competition is often a key policy objective of liberalized telecommunication markets and policymakers are often attracted by the self-regulatory secondary effect of IXPs.[15]

An IXP can attract content and other service providers. For example, some of the large content delivery networks were not interested in the small Caribbean Islands but started offering packages for these local markets after the launch of several IXPs in the region. The IXP had made it easier to bring content closer to the market.[16]

3. Identification of the main stakeholders and their roles

This section aims to describe the main stakeholders and their respective roles in contributing to an environment conducive to the successful development and operation of IXPs. It provides an overview of some of the functions and responsibilities of each role, but is not meant to be comprehensive.

The different stakeholders that participate in the IXP ecosystem can be grouped according to their role, interest, and involvement in the establishment and operation of an IXP. The role stakeholders play does not necessarily depend on their belonging to one of the traditional Internet governance stakeholder groups (governments, civil society, the private sector, and academia), but rather on the function they fulfil at the IXP or in its environment. A particular stakeholder can play multiple roles (e.g., a government can be a network operator as well as a regulator), and the roles played by the different stakeholders can also depend on the business model of the IXP (e.g., clients or shareholders at a for-profit IXP vs. members of a nonprofit IXP).

The main roles involved in the creation and operation of an IXP can be classified as:

- IXP members/participants
    - Network operators
    - Providers of other services
- IXP operator
- Regulator/ministry/other government body
- Community/facilitators
- Building/facilities operator

Ed. note: In this section, "connect to the IXP" means to provide connectivity from a network's point of presence (POP) to the IXP location, and "interconnect at the IXP" means to connect from a network's router located at the IXP through the IXP switching infrastructure to another provider's network router at the IXP including routing connectivity. Also, a "participant" or "member" is used to refer to an entity that interconnects at the IXP with other participants.

[15] see for example: "Broadband Networks and Open Access" (OECD 2013), pp. 32-34,
[16] Bevil Wooding, Packet Clearing House, at the BPF IXP Session, IGF 2015, 10 November 2015, João Pessoa.

3.1. IXP members/participants

A network operator can operate any type of network such as an ISP network, government network (e.g., for e-government services), university or National Research and Education Network (NREN), private enterprise network (e.g., that of a bank), or a content distribution network (CDN). IXPs exist to interconnect networks, thus, the first role that can be defined at an IXP is that of operator of one of the networks that are interconnected (peering) at the IXP. Many IXPs obtain their funding from network operators peering at the IXP. The IXPs' funding model and the role the members play in the IXP will depend to a great extent on its governance and business models.

During the creation of a community-based, nonprofit IXP, network operators must first build a community of interest together to agree to create the IXP. Together they must agree on the rules of operation (e.g., bylaws), the method of operation (e.g., OAM&P[17]), the location of the IXP, and the funding of the IXP.

To connect to the IXP, a network operator must build out its network to the IXP from its nearest POP, and includes acquiring connectivity to the IXP (e.g., leased line or microwave link), installing equipment (e.g., routers) at the IXP.[18] The network operator must also negotiate peering agreements with other network operators and configure its router(s) accordingly.[19] It then must provide ongoing management and maintenance. These various tasks and components require both non-recurring and recurring investment. The network operator should also conduct ongoing traffic monitoring and financial analyses to determine if new peering agreements are needed or if it needs to connect to another IXP.

Another responsibility of the network operator is to participate in the ongoing governance of the IXP, including participation in membership meetings, management meetings, and sustainability discussions. There are different ways to organize and operate an IXP. The role of the network operator in the IXPs governance will depend on the model that is chosen, the networks participating at the IXP, and other community-based factors (the different models are discussed in section D). Moreover, an additional but related role is to participate in Internet governance discussions like the IGF and other fora for the development of policies conducive to the creation, operation, and sustainability of IXPs.

3.2. IXP operator

The IXP operator is responsible for the budgeting, management, maintenance, and operation of the infrastructure of the IXP. The operator is not responsible for the maintenance and operation of third-party equipment placed at the IXP (e.g., participant routers, servers, and related equipment). This includes the cabling and switching gear that constitutes the heart of the IXP, but can also include other services such as route servers, route collectors, servers, time-servers,

[17] The acronym OAM&P refers to an operations, administration, maintenance, and provisioning model.
[18] In some cases, the ISP can leave their router at their POP and connect to the IXP via a remote layer 2 connection.
[19] Some IXPs have multilateral peering policies that can eliminate the process of one-by-one negotiation of peering agreements.

the IXPs' website, AS112 service, and reverse domain name system (DNS). Responsibilities can also include working with the building operator to provide racks, power, cooling, security, and other infrastructure requirements of the IXP.

The IXP operator commonly has primary responsibility for promoting the IXP and encouraging participation, supported by the other stakeholders in the IXP community. Furthermore, the IXP operator also works closely with participating network operators (members) at the IXP to make sure that operations run smoothly, equipment is connected and configured correctly, and to manage technical support requests. The operator provides the necessary technical documentation, provides information when requested, and runs mailing lists. The operator will engage and consult with the IXPs' members to collaborate and agree on policy and governance for the IXP, among other topics and concerns, via member meetings and budget meetings. While consultation and engagement are key for any successful IXP, the way in which members are involved in the policy depends largely on the chosen governance and business models as well as how the IXP is established from the beginning.

3.3. Providers of other services

Providers of other services, which are not network operators, can also participate in and interconnect at an IXP, including providers of content caches (CDNs), DNS root server instances, country code top-level domain (ccTLD) name server instances, time servers, and Looking Glass or Routeview servers[20]. Providers of other services can be private companies, non-governmental organizations (NGOs), government networks, or the IXP operator itself.

Like network operators, these providers must install and maintain their equipment at the IXP and must support their services, which usually involves acquiring connectivity to their equipment. The provider will also need to negotiate agreements to interconnect to the network operators and other participants at the IXP.

Depending on the IXPs governance model, providers of other services might also be included in the management of the IXP, including participating in management and business meetings. Depending on the type of service offered and agreements negotiated with the other members, the provider might also provide resources (e.g., funding) for the IXP.

3.4. Regulator/ministry/other government body

The role of the regulator will depend on the country and the legal and regulatory regime for that country. In general, the regulator defines the regulatory environment in which the IXP and its members will operate. This environment will affect, for example, who can (or must) interconnect at the IXP, how (and if) networks connect to the IXP, where the IXP is located, and how it operates. In cases of uncertainty during the establishment of an IXP, the founders might need to

[20] Publicly accessible Looking Glass or Routeview servers can be accessed to obtain routing information.

engage with the regulator to uncover and resolve any potential problems related to regulation and legality.

In addition to the regulatory environment, the government is also responsible for the legal environment in which the IXP operates, including financial law, competition law, environmental law, tax law, and other relevant regulatory and legal parameters.

There are examples where the government has played a facilitating role in the development and operation of an IXP, including:

- Acting as the convener for initial development discussions
- Providing seed funding to establish an IXP
- Providing a carrier-neutral data center for IXP start-up purposes
- Providing tax incentives for the IXP
- Acting as an intermediary with national or non-national organizations (e.g., NGOs, civil society organizations (CSOs), and/or intergovernmental organizations (IGOs)) for capacity building or other assistance
- Discussions with other countries to allow for cross-border connections (e.g., to allow an ISP in another country to interconnect at the IXP)

3.5. Building/facilities operator

An IXP has to be located in a building with sufficient facilities to support it, which includes fulfilling its space, power, cooling, and security needs. In most cases, the neutrality of the IXP location is one of the most critical factors (in addition to neutral management of the IXP). In some cases, the IXP can rely on the facility's operator for other infrastructure such as racks and cabling. The facility's operator needs to work with the IXP operator to plan for growth as well as negotiate ongoing fees for use.

Note that as long as the facilities meet the requirements for the IXP, the operator is not restricted to any one of the traditional stakeholder groups.

3.6. Community/facilitators

Although not directly participating in an IXP, other stakeholders can have important roles to play, both as beneficiaries of a successful IXP and as contributors toward its success. For instance, the community can include the local/national technical community, network operator groups, university project teams, civil society, and private sector companies who are engaged in the local or regional Internet sector, and who interested in the development of an IXP. For example, a local organization (e.g., Internet association, business association, university, etc.) can act as convener or mediator in the development of an IXP or in some cases can assume the role of IXP operator.

In addition to the local community, non-local organizations such as NGOs, IGOs, or private-sector groups can also play a role as facilitators for the development of the IXP by providing the following:

- Local government training
- Equipment and services
- Capacity building such as technical, regulatory, and commercial training

As illustrated above, members of the traditional Internet governance stakeholder groupings (governments, civil society, the private sector, and academia) are able to function in most of the roles described above. Moreover, some are able to function in more than one role. They all need to work together to create the environment for the successful development and operation of an IXP. Partnerships are critical to Internet infrastructure development and sustainability.

4. IXPs: Environmental constraints, challenges and opportunities

4.1 Introduction: Dimensions of the environment

As described above, IXPs serve a very specific function within a specific technical environment. Understanding the nature and characteristics of the environment in which IXPs operate is critical for any initiative seeking to establish or further develop them, as it helps to define constraints, challenges, and opportunities. Environments that nurture successful IXPs typically limit constraints and turns challenges into opportunities.

An IXPs' environment has multiple dimensions including policy and regulation, technology and infrastructure, capacity development and community. Stakeholders can play different roles in each dimension with more or less influence. A government, for example, has an important and decisive role in the policy and regulatory dimension, but can also play a stimulating role in the development of an IXP's technology and infrastructure as well as support the development of the community.

- **Policy and regulation**

This dimension encompasses the different laws, rules, and regulations that directly or indirectly have an influence on an IXP. This includes local, regional, national, or international policies that are in place along with other rules, whether economic or trade-related, that can constrain or nurture IXP development. In countries where the national telecom or incumbent network operator is fully or partially state-owned, the rules and policies regulating its position also impact the IXPs environment.

- **Technology and infrastructure**

The accessibility of the host facility to participant networks, the reliability of key utilities (e.g. power), and availability of modern equipment can all have an impact on an IXP's development and growth potential. A limitation in any of these areas can considerably increase the overall cost of establishing and maintaining an IXP and can reduce its reliability and effectiveness over time.

- **People and community**

The people running and supporting an IXP comprise the third important dimension. IXPs are often established by a multi-stakeholder community or by volunteer initiatives, and many rely on volunteers long after their launch. There are almost always one or two champions that pull the IXP community together and keep momentum going.

IXPs typically function best if there is a sense of community and trust among its members. By organizing meetings and networking events, an IXP can foster the relations necessary to build and maintain trust among its community members. The importance of building this "community of trust" cannot be under-estimated. Many organizations help support and foster IXPs and support community and trust building, but there really must be a local network of people working together.

Also essential to the success of the IXP are technically able experts to manage, run or operate the IXP, and experts in the operator community peering at the IXP. Training and capacity building become indispensable as the IXP grows and changes. IXP experts have remarked on the importance of a strong technical community not only for more efficient and effective operations, but for a stronger overall local Internet ecosystem. Supporting local technical training for the IXP community is critical. Many organizations exist to assist in this dimension and are listed in Annex 3 to this document

4.2. Challenges

This section looks at the different challenges IXPs face when they are created and after their launch. The challenges can be situated in one of the different dimensions of the environment that were discussed: policy and regulation, technology and infrastructure, or people and community. Enabling environments to establish successful IXPs means recognizing and acknowledging the challenges and turning them into chances and opportunities. This is a task for the different stakeholders, each within their own scope.

As every IXP works in its unique, local environment, each has to address a different set of challenges and issues. "It is not possible to define a specific set of instructions for starting an IXP. Every new IXP will face different challenges and operate under different economic, technical, and legal circumstances."[21]

[21] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.

4.2.1. Bringing together the peers, setting up the IXP, and forming a community

- **Finding peers**

The first step in establishing an IXP is to bring potential peers around a table to take the decision to start. There needs to be a minimum number of network operators interested and willing to interconnect their networks before it makes sense to invest in equipment and facilities for the purpose of setting up an IXP. If there is a lack of interest, the traffic[22] at the IXP will remain low thereby leading to network operators still having to negotiate multiple private bilateral connections in order to effectively serve their clients. Moreover, an IXP in these cases will find it extremely difficult to attract new members and grow.

Unfortunately, there is no golden rule or minimum number of local networks that is needed before it makes sense to establish an IXP. The amount of local traffic that can be expected depends on different factors, including the size of the individual networks, the overall size of the market, and the local infrastructure that is in place and available. However, it is generally assumed that the presence of five networks can usually justify the establishment of an IXP. This number may even be lower in the case of small island economies, where the presence of "just two access provider networks may be sufficient in order to reduce long-haul traffic costs and to promote traffic exchange with local content networks."[23]

Most new IXPs that are established will experience low traffic volumes, which is a cause for concern for most members that are interested in helping to establish an IXP[24] – in particular, in countries where less content is stored locally (e.g., developing countries or emerging markets). As a consequence, initial local traffic will remain low and operators might not be encouraged to connect to an IXP. However, the presence of an IXP can stimulate local content as one African survey respondent pointed out: "Slowly, due to the presence of the IXP, certain operators started new projects to host local content and developed a new business."[25] The end result is that traffic levels do grow and the IXP develops over time.

In most countries and in particular in the developing world, it is an extra challenge to convince incumbent networks to connect to the IXP. Incumbent operators tend to resist connecting to the IXP because they do not see the need and fear losing traffic, clients, and income. The latter are generally excuses. An IXP brings in a more competitive interconnection environment.

Mexico, for example, was until mid- 2014 the only OECD[26] country without an IXP, and Internet traffic had to travel to an exchange in the United States and return to Mexico – the classic trombone effect.[27] One of the main reasons it took so long to establish an IXP was that "the

[22] Traffic volume is one but not the only indicator of the success of an IXP.
[23] The Internet Exchange Point Toolkit & Best Practices Guide, February 2015. Available at: https://www.internetsociety.org/sites/default/files/Global%20IXPToolkit_Collaborative%20Draft_Feb%2024.pdf.
[24] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.
[25] BPF Survey, African IXP.
[26] Organisation for Economic Co-operation and Development.
[27] Tromboning is the term to describe the process where ISPs use their international Internet connections for domestic traffic exchange, usually because it is more cost-effective than connecting directly.

major telecom operators had already signed individual peering agreements, leaving out smaller companies."[28]

In Brazil, the key telecom companies, responsible for 70 to 80% of the country's broadband traffic, are not strongly participating in IXPs. Nevertheless, Brazil has a strong IXP project that succeeded in distributing the competition. IXPs are operating in 25 different cities and there is a strong participation of CDNs and content providers.[29]

Elsewhere, a 2013 report described how, in several African countries, the incumbent's behavior was a barrier to the growth of local and regional connectivity. "In several countries […] the incumbents explicitly avoid participating in local IXPs for what they perceive to be their strategic interests, and as a result are unlikely to have the vision to support growth of regional connectivity."[30]

- **Chose a governance and business model**

There are several ways IXPs can operate, and IXP models vary across regional markets. Most European IXPs grew from non-commercial ventures while most African IXPs were established by ISP associations and universities. Commercial IXPs are more typically found in the United States and parts of Asia. Based on an IXP's institutional background and the parties that are involved in establishing and running the IXP, they fall into four categories:

- Nonprofit industry associations of ISPs
- Operator-neutral commercial and for-profit companies
- University and government agencies
- Informal associations of networks

In many examples of the creation of an IXP, there is no formal body - the IXP is run and managed by general consensus between the parties involved. The informal cooperation – for example between the ISPs that will benefit from the presence of the IXP – is often the most efficient and easiest mechanism to establish an IXP. However, when an IXP starts to grow, a consensual model as such is put under pressure and the members need to consider more formal management structures to assure the IXP to be self-determining, remain within legal and regulatory constraints, agree on technical upgrades and security, maintain neutrality, and be financially secure.[31]

On the other hand, a recent screening of the IXPs in Latin America concluded that "even an IXP with the necessary technical capabilities can still suffer from a lack of adequate administrative or decision-making capacity. [This] shows that […] regardless of which organizational model is

[28] 'Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge,' A. Prince and L. Jolias, 2015.
[29] Henrique Faulhaber, CGI.BR, at the BPF IXP Session, IGF 2015, 10 November 2015, João Pessoa.
[30] "Lifting barriers to internet development in Africa: Suggestions for improving connectivity", R. Schuman and M. Kende, May 2013, Analysys Mason for ISOC.
[31] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.

adopted, the importance of the 'champion' or entrepreneur driving the initiative plays a key role in an IXP's development and maturation."[32]

Each IXP model carries with it certain advantages, and some IXP approaches are better than others depending on the economic and policy conditions in the region. Often, the challenges that stem from adopting a given IXP model will have widespread impact. For this reason, the way in which IXPs govern themselves matters, as do their public relations and outreach efforts to their Internet communities.[33]

"Many ISPs have expressed strong feelings about the importance of the neutrality of IXPs, and most of the larger European IXPs attribute their success to their neutrality."[34] A non-commercial entity is possibly better placed to maintain neutrality.

- **Build a community**

Finding peers and agreeing on how to run the IXP are the first steps in launching the IXP. Meanwhile, the process to build a community around the IXP occurs in parallel. IXP community support is almost indispensable to establishing an IXP, and is essential if one wants the IXP to become a success. "Setting up an IXP is '80% human and 20% technical' – without an environment of cooperation between ISPs, an Internet exchange will not be successful."[35]

A European IXP made this clear in its submission to the survey:

The main reason [to establish the IXP] was the high cost of transit. To lower the costs, we started to interconnect multiple entities (i.e., bandwidth users) and by transit [in] bulk (price per [megabit] Mb goes down when the number of Mb goes up). It became obvious that we had a local IXP. The next step was to gather more people to build a community and help grow the local [information technology] IT economy.[36]

Developing this supportive community in which the IXP's members and other stakeholders should be involved is one of the most important tasks of the IXP operator – apart from the purely technical aspects of running the IXP. Building an IXP community is work and time intensive. The community and in particular the trust among its members grows slowly as noted above. *"Building IXPs is all about community building [and] this takes years, not weeks. No amount of investor capital or public sector support will help you if you don't get that right."*[37]

Moreover, a European survey respondent said: "The community was developed by constant outreach and hard work to involve community members in interesting and fun activities."[38]

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[32] "Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge," Internet Society with A. Prince and L. Jolias, 2015.
[33] Ibid.
[34] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.
[35] The Internet Exchange Point Toolkit, ISOC.
[36] BPF survey, European IXP.
[37] Keith Mitchell, at UKNOF 2015, video available at: https://www.youtube.com/watch?v=Cr827f4cDj4.
[38] BPF survey, European IXP.

Most IXPs have mailing lists and organize meetings for their members. Networking events and member meetings are important for many IXPs to develop their community. Most IXPs also have closed mailing lists through which their members can discuss and share information. IXP events and mailing list discussions easily tend to cover a variety of topics and are not strictly limited to technical or organizational issues directly related to the IXP. Where this happens, the IXP becomes "a natural forum for discussions of subjects of interest to the industry in general."[39]

As one European survey respondent stressed:

The community was developed through people, networking, and presentations. It is time-consuming and people who are not already into a 'peering for all' state-of-mind need a lot of time to understand the benefits. Many people know about the [IXP], but only a few are member[s] and only a few of them are active.[40]

- **Capacity building: How to run an IXP**

One survey respondent answered that the main challenge after setting up the IXP was to get "a varied understanding of how an IXP works and how it should operate among the peers and potential peers."[41]

Technical expertise is one thing, but the IXP needs to be run, managed, and further developed. Much depends on the organizational form that is chosen, especially since some IXPs do not have their own staff and are run by volunteers. As one European survey respondent noted, "Low levels of membership [was a challenge] for years until the point that the IXP took on a management team to develop the company."[42]

When IXPs further develop, they can decide to take on other activities and services to better serve their members and it becomes more attractive for new operators to join.
Many IXPs will:

- Work with local network operator groups or local and/or global organizations to hold network training events
- Local, regional, and global IXP associations will hold meetings and provide training
- Regional peering meetings will be held where IXPs and local, regional, and international operators will attend, and where technical, policy, and sustainability issues will be discussed
- Regional Internet Registries (RIRs)[43] will hold workshops and/or local and regional meetings that provide training as well as technical/human networking events
- IXPs will ask organizations such as the Internet Society (ISOC), Network Startup Resource Center (NSRC), Packet Clearing House (PCH), and the International

[39] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.
[40] BPF survey, European IXP.
[41] BPF survey, African IXP.
[42] BPF survey, European IXP.
[43] See Appendix 2 at the end of this document for the list of RIRs.

Telecommunication Union (ITU) as well as IXP associations (IXPAs) and/or individual experts to provide training.

- **The role of Internet exchange point associations (IXPAs)**

Internet exchange point associations (IXPAs) play an important role as platforms for knowledge and best practice exchange within the IXP community. They support their members in addressing the challenges they face. The IXPAs are knowledge centers and can be a first point of contact for governments that look for advice on IXP development.

IXP operators and the Internet's technical community came together with the intention to further develop, strengthen, and improve the IXP community with the formation of IXPAs. The IXPAs recognized a need to combine their resources in order to coordinate technical standards, develop common procedures, and share and publish statistics and other information that could help sustain and grow the IXP community globally.

The IXPAs[44] are:

- AFIX - www.af-ix.net
- APIX - www.apix.asia
- Euro-IX - www.euro-ix.net
- LAC-IX - www.lac-ix.net

The four IXPAs listed above formed the Internet Exchange Point Federation (IX-F) to build a global IXP community and help the development of IXPs throughout the world. IXPs should be encouraged to join their local IXPA for knowledge sharing, best practices, and ongoing support. Excellent data and resources can also be found on the IX-F website with respect to best practices and technical issues.

IXPAs provide support to IXPs by holding regular meetings; they maintain the IX-F database (which is the only database maintained on IXPs); they have mailing lists where IXPs provide support to each other on a variety of topics – technical, commercial, and regulatory; and they provide documentation for best practices and tools that can be used by the networking community as well as IXPs.

4.2.2. A supportive government and an enabling (regulatory) environment

- **Turn resistance into support**

Governments and regulators might be resistant to the idea of an IXP; thus, their decisions can have an important direct or indirect impact on the IXP. They are one of the important stakeholders that shape the IXP's environment. Governments can also play a motivating role as supporters, co-initiators, or sponsors of IXP projects. They have responsibilities for the development of the country's infrastructure, and can intervene to avoid market distortion (for example, on the wholesale market for international connection). Governments can also support

[44] It should be noted that efforts are underway to form a North-American IXPA.

IXP development to create a more competitive local market that encourages much needed investment in the long-term.

Often, unfamiliarity with the concept of an IXP and a lack of understanding of its purpose and the potential benefits for the development of the Internet, explains why governments are sometimes disinterested or unsupportive. Instead of seeing the envisaged positive impact, they might fear a negative social and economic influence. In some countries, the government may also still be supporting the incumbent operator and be reticent to change the local status quo.

For example, in some countries, existing or historic bonds between the government and the incumbent operator may restrain the enthusiasm for the IXP project. As one African IXP operator said in the BPF survey, "There was initial resistance from the government [because] they support the main telco but this has been counteracted by the support from the regulatory authority."[45]

An IXP operator based in one of Europe's larger cities (with more than 500,000 inhabitants) explained in the BPF survey how they struggled to get support and convince local and regional authorities of the benefits of a local IXP. The different authorities did not understand what the IXP could bring to the region when there was already an IXP in the country's capital. An African IXP operator underscored that the country's regulator feared that "the presence of an IXP is an opportunity to earn money at the expense of [a] universal service [fund]".[46] It would be worthwhile to note that many countries could use their universal service funds to help establish IXPs.

Raising awareness among governments and providing clear information on the role and benefits of an IXP is an important step to address these challenges and misconceptions. Some regional communications groups like the Caribbean Telecommunication Union (CTU) and the Organization for American States' Inter-American Telecommunication Commission (CITEL) embraced IXP development and started organizing discussions with governments, local and regional experts, and Internet community organizations.

In some countries, the existing regulatory regime and policies may hinder the growth of the IXP. For instance, policies that inhibit competition on broadband terrestrial infrastructure may limit the options available for local interconnection.[47] A Nigerian case study explained how the high cost of rights of way offered market power to network owners, which allowed them to charge high wholesale prices. This undermined their motivation to connect and make use of the local IXP.[48]

[45] BPF survey, African IXP.
[46] Translated from French: "A titre illustratif, pour la régulation, la présence d'un IXP est occasion de se faire de l'argent au détriment des services universels."
[47] Michuki Mwangi, Senior Development Manager for Africa, ISOC, November 2012. Available at: https://meeting.afrinic.net/afrinic-17/slides/27nov/3_2_Michuki.ppt.
[48] "Lifting barriers to internet development in Africa: Suggestions for improving connectivity", R. Schuman and M. Kende, May 2013, Analysys Mason for ISOC.

A Government that wants to adopt a supportive role in the creation of an IXP can "use its convening power to bring stakeholders together, provide the initial funding to establish the IXP, [or by] participating on the board of the IXP."[49]

In Argentina, the government played a facilitating role in the development of regional IXPs through the "Argentina-Conectada" project that deployed a more than 12,000-kilometer-long fiber optical fiber network, 'which brought down the cost of [establishing] provincial IXPs thanks to the lower cost of connecting to the federal capital."[50]

The Bolivian IXP, which began operating in 2013, is the direct result of the government working with the Internet's technical community. Government measures were passed that obliged ISPs to exchange traffic at an IXP within the country. The government was involved in the creation of the IXP, and specified the rules for composition and operation (e.g., sharing of costs among the members, non-discriminatory mandatory multilateral peering, etc.). Moreover, the IXP is hosted in government-owned properties.[51] In addition, the local ISP community and local experts are discussing moving the IXP to a more neutral location, an Internet Service Providers Association (ISPA) is likely to develop as a result of the work being done in the community to build and develop the IXP, and two additional IXPs are being discussed for other major cities.

The recent success story of UAE-IX (Dubai) in the Middle East is stimulating other countries in the Middle East and North African (MENA) region to establish their own IXP(s) and expand existing exchanges, driven by initiatives from the government or regulator.[52]

However, not all government involvement will accelerate the development of IXPs and some decisions – taken in good faith – may have a counterproductive effect. Decision-makers should be very cautious if they plan to operate the IXP, regulate the IXP, or enact laws about IXPs or the interconnection at IXPs.[53] Governments and regulators are advised to duly consider if they actually need to regulate an IXP or simply need to allow it to develop. Should the legal regime still require a "measure" to be taken to allow for the IXP, this measure should be kept as flexible as possible.[54]

In Lesotho, for example, the government through the communications regulator has been essential to the development of the IXP. A "constitution" was written and ratified for the IXP that allowed it to be established and developed.[55]

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[49] Dawit Bekele, African Regional Bureau Director, ISOC, November 2014. "The role of Governments in Creating an enabling environment for establishing and developing IXPs. Available at: http://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2014/IXP/Presentations/Panel%201_ISOC_Role%20of%20governments.pdf.

[50] "Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge," A. Prince and L. Jolias, 2015 for the Internet Society.

[51] Ibid.

[52] "How Internet exchange points (IXPs) drive growth of the Internet ecosystem in the Middle East: The case of UAE-IX," Johan Adjovi, June 2015, available at: http://www.analysysmason.com/About-Us/News/Insight/UAE-IX-case-study-Jun2015/.

[53] Dawit Bekele, Internet Society African Regional Bureau Director, November 2014, "The Role of Governments in Creating an Enabling Environment for Establishing and Developing IXPs."

[54] Sofie Maddens, November 2014, "National Legal Frameworks for the Establishment of IXPs', available at: http://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2014/IXP/Presentations/Panel%202_ISOC_Tunisia%20presentation%20Sofie%20Maddens%20November%202014.pdf.

[55] The Internet Exchange Point Toolkit & Best Practices Guide, ISOC , February 2014, pp. 17-18.

4.2.3. High cost of domestic and international connectivity

‘“Joining an IXP will be attractive if the cost of exchanging traffic locally is cheaper than purchasing international bandwidth (IP transit) from an upstream provider for routing traffic overseas.”[56] Otherwise there is no incentive for network provider to connect to the IXP.

For example, prior to the IXP being established in Quito, Ecuador, the cost of international transit was $100 per megabits per second (Mbps) per month. After the IXP was established, the cost of exchanging traffic at the IXP was $1.00 per Mbps per month.[57] Furthermore, “high prices for [domestic connectivity] and poor availability of flexible cost-effective services like Ethernet, tend to limit the development – and therefore the benefits – of the IXP.”[58]

The high investment required to build the infrastructure (networks, cross-border connections, etc.) and exchange traffic (transit through other countries, access to and capacity rights on submarine cables, etc.) are “entry barriers that may confer market power on incumbent operators [or] monopoly rights granted to operators of international infrastructure. Such market power can lead to above-cost prices for international connectivity.”[59] After Kenya agreed to liberalize its undersea cable market, the cost of international connectivity started to drop, and more investors became interested in Kenya. Kenyan Internet Exchange Point (KIXP) and the team at Technology Service Providers of Kenya (TESPOK)[60], have been instrumental to encouraging competition in the Kenyan Internet landscape.[61]

Landlocked countries, sealocked countries and small islands are faced with specific challenges.

Afghanistan, for example, is a landlocked country surrounded by mountains and known for its rough surface. ISPs largely depend on satellite technology to bring bandwidth to the country. ISPs are connected with their satellite provider but not with each other. Since 2010, NIXA, the National Internet Exchange of Afghanistan, deployed a network to connect all ISPs in Kabul city, but the fact that ISPs don’t have fixed premises and relocate makes it difficult to connect them via fiber. Plans to use microwave technologies are delayed due to a lack of funds.
Also in Afghanistan the lack of local content is a challenge.[62]

[56] The Internet Exchange Point Toolkit & Best Practices Guide, ISOC, February 2014.
[57] Connectivity In Latin America and the Caribbean: The Role of Internet Exchange Points, Hernan Galperin for the Internet Society, page 10, available at: http://www.internetsociety.org/doc/connectivity-lac-ixp-study
[58] “Lifting barriers to internet development in Africa: Suggestions for improving connectivity”, R. Schuman and M. Kende, May 2013, Analysys Mason for ISOC.
[59] “Lifting barriers to internet development in Africa: Suggestions for improving connectivity”, R. Schuman and M. Kende, May 2013, Analysys Mason for ISOC.
[60] TESPOK is a professional, non-profit organization representing the interests of Technology service providers in Kenya.
[61] “Assessment of the impact of internet exchange points (ISPs): An empirical study of Kenya and Nigeria,” May 2012, Analysys Mason for the ISOC.
[62] Zmarialai Wafa, PKI Afghanistan, at the BPF IXP Session, IGF 2015, 10 November 2015, João Pessoa.

4.2.4. Location, equipment, and technical capacity

- **Select the location, procure the equipment, and receive initial funding**

Modern IXPs can cost very little to set up and run. Establishment and operational budget estimates range from 5,000 - 8,000 USD or less[63] (low-end) to a maximum of 50,000 USD.[64] Finding the adequate location that is neutral and low-cost to host the equipment is very important. When considering possible locations, the following elements need to be taken into account: space, environmental control, security, reliable and redundant power, access to terrestrial infrastructure, cabling, and support. In addition to these practical and technical considerations, the location must be perceived as neutral by all members of the IXP. The ownership of the facility can be a reason for mistrust in the IXP. For example, if one member of the IXP hosts the equipment, some may believe that that member will benefit more.[65] If an incumbent offers to host the IXP, this also can lead to mistrust given past behavior of the local operator community in a country.

In many cases, in particular for the non-commercial IXPs, the founders compiled the initial resources and equipment, and developed mechanisms for the funding of the IXP. Other IXPs received funds or equipment from the local ISPA, could count on the support of a university network, received donations in the form of money, equipment, or technical expertise from organizations such as ISOC, PCH, NSRC, or were sponsored by private companies. Development agencies and institutional donors such as the World Bank, the African Union, or the Latin American Development Bank have track records of supporting initiatives to create IXPs.

As one North American IXP explained in the survey:

We have received the odd line card here or there. At first we started off as a donation-based IXP; however, we moved to a proper funding model with port fees about 6-7 years ago. Since then our growth has been absolutely exceptional.[66]

A case study of seven large IXPs[67] that were established through initiatives involving academic and research networks to interconnect with local ISPs and other service providers found that their initial setup generally consisted of "informal agreements, donated equipment, donated space, and volunteers to run the operations."[68] The London Internet Exchange (LINX), now one of the

[63] Some argue that starting up an IXP should not exceed 3000 USD, even less with donated equipment. These calculations, however, do not include for example the travel cost of experts brought in to give the needed training which, in developing countries, easily mounts up to 3000 USD.
[64] BPF mailing list exchange.
[65] Jane Coffin, November 2014, available at: http://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2014/IXP/Presentations/Panel%202_ISOC_Arab%20IXP%20Group%20Workshop_11%20Nov_Jane.pdf.
[66] BPF survey, IXP North America.
[67] LINX, AMS-XI, DEC-XI, Netnod, HKIX, SGIX, and KINX.
[68] "Assessment of the impact of Internet Exchange Points (IXPs): An empirical study of Kenya and Nigeria," May 2012, Analysys Mason for ISOC. Available at: http://pages.au.int/sites/default/files/02-Case-Study-of-Large-IXPs.pdf.

largest in the world, started with five members and a donated switch.[69] In case of donations, it is advisable that the sponsors put in writing the nature of the agreement for the IXP to use the equipment. This will improve transparency, avoid discussions and assure the neutrality and trust of all members in the IXP. This also can encourage an IXP to think longer term about equipment upgrades and longer-term planning.

To encourage members to join the country's first and only IXP in Costa Rica, one of the initial promoters NIC Costa Rica[70] agreed to cover all operating costs for the first year after it was launched in July 2014.[71]

As stressed above, governments can support and encourage the establishment of IXPs. A European IXP operator explained in the survey how it had received a government agency loan to help make the IXP viable until it reached a critical mass of members. The loan was paid back before its due date, and had been enormously useful as it allowed the IXP to hire staff.

Adequate funding is not only important to start the IXP, it also helps the IXP to professionalize and develop its organization. As a European IXP, which had received a government agency loan, explained in the survey: "Looking back at it, we would have survived with much less money. But from a cash account point of view, it enabled us to hire the staff we needed."[72]

Those seeking a detailed list of recommended equipment should consult Annex 3 of the "Internet Exchange Point Toolkit & Best Practices Guide."

- **Technical capacity building**

When the decision to establish the IXP is taken, a neutral location is found, and the equipment is setup, the IXP needs the technical know-how to establish and run the IXP. This technical knowledge is needed both on the side of the IXP member/network operator and at the IXP's operational level. Finding and training the technical staff is a challenge for new IXPs. This was also a common survey response: "We had no real technical clue how to run an IXP – this took time to develop."[73] "There are no permanent engineers to operate the IXP."[74]

The Internet community has a tradition of sharing first-hand experiences, teaching, and helping each other by sharing practices and solutions. There are a wide-range of organizations and places where developing and existing IXPs can find training and expertise. Organizations such as ISOC, PCH, and NSRC, along with most of the RIRs, provide crucial support and training to IXPs, especially those in the planning and developing stages or newly established ones. Meetings of network operators groups (NOGs) and of the RIRs often have special IXP workshops where experts from the IXP community give presentations. The IXPAs are another resource that

[69] Sofie Maddens, November 2014, available at: http://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2014/IXP/Presentations/Panel%202_ISOC_Tunisia%20presentation%20Sofie%20Maddens%20November%202014.pdf.
[70] NIC Costa Rica is an organization within the Academy of Sciences and the .cr domain registry.
[71] "Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge,", A. Prince and L. Jolias, 2015.
[72] BPF survey, European IXP.
[73] BPF survey, European IXP.
[74] BPF survey, African IXP.

provides information, training, networking, and business opportunities. Appendix 3 contains an overview of related organizations and venues.

4.3. Indicators of a successful IXP

There is not one indicator to measure the success on an IXP and too easily one is triggered to only take into account the volume of traffic that passes through the IXP.

Members' decisions to privately peer directly might reduce the IXP's growth but is not necessarily a sign of failure of the IXP. IXPs encourage interconnection and the growth of local traffic. However, over time, the amount of traffic between any two providers may reach levels where they may prefer to off-load that traffic to a private network interconnection (PNI). This occurrence would reduce the traffic volume on the exchange switch but only as a result of the IXP's success.

If a content delivery network (CDN) is shared across an exchange from one provider to many and one or more recipient networks start using enough of the CDN's services that they qualify to receive their own instance of that CDN, the traffic flowing across the exchange will reduce. Yet, the level of CDN utilization (and thus its benefits) within the IXP's region will have remained the same or grown. This is another potential example of traffic reduction at an IXP being the result of the IXP's successful impact on the market.

It is about critical mass. Do you have traffic, do you have participants? Is there peering? […] It is also about longevity. If you still have your IXP after five years then you're probably successful. If you're not going to make it, then you're probably going to fail within five years. I think it's also about: do you have a functioning organization, is there transparency, is there neutrality, is there effective governance? Is there physical sustainability, is there sustainability in terms of personnel and facilities? I think it is one of those things that is self-evident but also measurable.[75]

AMS-IX[76] has a strategy that aims at growth based on the belief that a larger number of actors strengthen the network. "Continuous growth is what defines the value of an exchange, first and foremost in the number of connected parties, with associated growth in ports, traffic rate, volume, and routes."[77]

The assessment of an IXP needs to take into account a whole list of divers indicators, of which traffic volume is only one metric. To get the whole picture, factors such as local transport costs, building space, power, port speeds and peering policies need to be included and it's important to consider to which extend the IXP is successful in generating sufficient funding to operate and grow. The assessment will be incomplete if it ignores the IXP's community building role.

[75] Keith Mitchell, at UKNOF 2015, video available at: https://www.youtube.com/watch?v=Cr827f4cDj4.
[76] AMS-IX runs the Amsterdam Exchange point and three Internet exchanges abroad: AMS-IX Hong Kong, AMS-IX Caribbean on Curacao, and AMS-IX East Africa in Mombasa.
[77] "Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge," A. Prince and L. Jolias, 2015 for ISOC.

5. Case studies

Case study 1:
The importance of local content for the development of the Kinshasa Internet Exchange Point (KINIX)[78]

Since November 2012, the Democratic Republic of the Congo (DRC) has run a project to establish KINIX.

KINIX is the first realization of the RDC-IX project (République Démocratique du Congo Internet Exchange Point), which was initiated by the ISPA-DRC (Internet Service Provider Association – Democratic Republic of the Congo) to develop the necessary infrastructure the DRC needed to keep national traffic local. ISPA-DRC realized the country's first IXP in the capital Kinshasa (KINIX) and has plans to establish IXPs in two other major cities in the short and medium turn, LUBIX (Lubumbashi Internet exchange point) and GOMIX (Goma Internet Exchange Point). ISPA-DRC signs for KINIX's management and maintenance.

After its launch, KINIX grew slowly and had difficulties due to the low volumes of traffic exchanged between the local operators as well as struggled to attract new operators to connect to the IXP and make its operations sustainable.

The lack of locally stored content is the most important factor that helps to explain this situation. It also seems to influence other factors, such as the enthusiasm of Internet operators to engage in the development of KINIX and the involvement of the official instances (the government and regulator) in the environment.

The lack of content stored in the DRC is only one of the logical consequences of the lack of a dynamic Internet community and local ownership. This can be explained by the fact that:

- Almost all Congolese content is hosted outside the African continent (mainly in Europe and the U.S.) due to a lack of local hosting infrastructure, a situation that results in a large consumption of international bandwidth
- The primary and secondary servers of the national top-level domain (ccTLD) .cd are hosted outside the country, which has an impact on accessibility and latency. In addition, a .cd domain name costs around 150 USD, and has limited popularity as a result.

To remedy this situation, ISPA-DRC has undertaken certain actions to promote the creation of local content:

- The deployment of added services (and values) to KINIX
- A partnership with certain content providers to host a local cache
- Raising awareness about the hosting of content by local hosting providers and the creation of local data centers

[78] Case study contributed by Nico Tshinu-Bakajika, ISPA-DRC.

- The promotion of the use of the Internet by government institutions as a measure of good governance (e.g., the ability to pay taxes online)
- Involvement in the re-delegation process of the .cd domain name servers via the .cd Domain name charter and the establishment the NIC-DRC to manage the domain name registry.

The first results are already noticeable; some initiatives have had a direct impact on the development of KINIX while others have had an indirect impact. The direct impact can be observed in the growth of traffic volume, the interest of operators to connect at KINIX, and the motivation to financially contribute to the functioning and exchange of services at KINIX. The direct impact includes:

- The hosting of a Google Global Cache (GGC) at KINIX and its launch in October 2015
- The acquisition of servers, via a donation by ISOC, for the hosting of added services at KINIX

The indirect impact includes:

- The promulgation of the .cd domain name charter by the Congolese government
- The granting of the legal personality to the NIC-DRC by the Congolese government

Case study 2:
NAP.EC - Ecuador[79]

NAP.EC[80] Ecuador was another early IXP in the LAC region. This IXP was created in July 2001 for the main purpose of reducing the high costs ISPs had to pay for international transit. Until the establishment of the exchange point, direct international connectivity was restricted to the Pan-American cable. This is why much of the traffic had to go through Colombia, thus increasing transportation costs.

NAP.EC was founded by six companies (Satnet, Impsatel Ecuador, Ramtelecom Telecomunicaciones, Megadatos, Infornetsa, and Prodata), which came together with the primary aim of reducing international traffic costs by establishing two exchange points.

AEPROVI[81] is a nonprofit association that impartially manages NAP.EC, providing technical support and enforcing the commitment assumed by each member. AEPROVI currently has 29 members, although only 13 are part of the IXP. Conversely, joining NAP.EC does not require being a member of AEPROVI. In other words, while the Association manages the IXP, the two operate as separate institutions.

[79] Case study based on: "Internet Exchange Points in Latin America and the Caribbean: From Reducing Costs to Sharing Knowledge," A. Prince and L. Jolias, 2015 for ISOC.
[80] NAP stands for network access point, a synonym for the now more-popular term IXP.
[81] AEPROVI - Asociación de empresas proveedoras de servicios de internet, valor agregado, portadores y tecnologías de la información.

There are no specific regulations in Ecuador regarding IXP operations; the state, however, requests the association to publish some information such as traffic statistics and link utilization rates. The multilateral peering policy is mandatory, i.e., each provider connected to NAP.EC must exchange traffic with all other participants, similar to what happens in other cases in the LAC region.

In time, the IXP's growth led different actors – among them CNT (Ecuador's state-owned incumbent operator) – to realize the benefits of interconnection and notice the existence of infrastructure. This action facilitated added value, including root DNS servers, .EC domain name servers, and cache servers for major CDNs such as Google or Akamai. In addition, the IXP also serves as a place for knowledge sharing and professional development through various activities, workshops, and training on topics such as spam filtering or Internet protocols. The advantageous consequences of the installation of local caches by content providers are two-fold: on the one hand, a significant increase in traffic (more than 700%); on the other hand, latency experienced while accessing local content is approximately 20 milliseconds (ms) – 130 ms quicker compared to latency experienced for content hosted abroad, which is 150 ms.

Case study 3:
The importance of the cooperation between ISPs and Government institutions for the development of Costa Rica´s IXP (CRIX)[82]

Costa Rica´s first neutral Internet Exchange Point (CRIX) was created on April 29th 2014 and it involved cooperation from all sectors of the telecommunications local industry during a period several months.

Costa Rica´s telecommunications market was a state monopoly for 60 years and opened up for competition in 2011. At this point, there was a clear need for an IXP to improve the efficiency of the local Internet connectivity.

There were several failed attempts to create an IXP due to the high costs associated with membership, the lack of a physical neutral location other than the headquarters of an ISP or a governmental institution, and lack of support from all ISPs. In 2013, the Telecommunications Regulator of Costa Rica (SUTEL) initiated a joint effort with the Ministry of Science, Technology and Telecommunications (MICITT) to create a national IXP located in a neutral location that could provide the appropriate maintenance and technical support for its optimal performance.

The Network Information Center of Costa Rica (NIC Costa Rica) was an ideal candidate due to its good relationship with all parties involved in the telecommunications market, its existing vast technical expertise and because it offered a neutral space that could host the IXP. NIC Costa Rica is in charge of managing the .cr top-level domain and leading several Internet infrastructure

[82] Case study contributed by Rosalía Morales, CEO of NIC Costa Rica.

initiatives to improve the resilience and development of Costa Rica´s Internet. Furthermore, SUTEL had contacted Packet Clearing House (PCH), an international not for profit organisation with global experience in the implementation and management of IXPs globally, to provide guidance throughout the process.

MICITT, SUTEL and NIC Costa Rica, reached out to several ISPs to discuss their willingness to establish an IXP. The local incumbent and telecom operator, the Instituto Costarricense de Electricidad (ICE), was the first provider contacted and after about a year of negotiations ICE agreed to be part of a neutral IXP. The execution of the IXP project was eventually delegated to NIC Costa Rica and the project started supported by PCH, the Internet Society (ISOC), NIC .br and NIC .cz and other regional IXPs. All parties involved at the early stages were global leaders in the implementation of IXPs and had experience and practical know-how on technical and administrative good practices to manage an exchange point. NIC Costa Rica made all the initial investments to run the IXP, it adjusted its datacenter to the needs of the IXP, acquired the necessary technical equipment and provided technical maintenance and administration. PCH and ISOC donated additional key equipment for the growth of IXP.

By October 2015 and after 15 months of operation, CRIX (www.crix.cr) counts 19 members and is currently discussing the inclusion of content providers' servers based on the needs of the IXP's members. The openness of the CRIX has been essential to its success and still applies today: any interested party could join if they met the basic technical requirements, there were no initial costs associated with the membership of the IXP and any member could choose to end its membership at any point in time. The incumbent could not reach internal agreement in time to join CRIX at the official inauguration of the project but the internal decision making process to join CRIX is still ongoing.

This project is based purely on cooperation, with no regulation involved at any stage. The project has grown and keeps growing stronger thanks to the active participation of new members and collaboration of all involved parties.

Case study 4:
Expansion of IXPs in Canada - the Role of the ccTLD manager[83]

The Canadian Internet Registration Authority (CIRA) is the manager of the .ca ccTLD for Canada. In 2012 CIRA realized that with just 2 IXP's, Canada was lagging behind in the world in terms of IXP development. CIRA started by commissioning a paper by Bill Woodcock and Benjamin Edelman[84] which explained the problem and summarized the benefits of establishing more IXPs.
CIRA then held a series of 'townhall' style meetings in cities lacking IXPs to explain the benefits and encourage the local communities to form local groups to proceed with development. CIRA

[83] Contribution by Allan MacGillivray, Senior Policy Advisor, CIRA
[84] Toward Efficiencies in Canadian Internet Traffic Exchange, Bill Woodcock and Benjamin Edelman for the Canadian Internet Registration Authority, September 2012
https://cira.ca/sites/default/files/attachments/publications/toward-efficiencies-in-canadian-internet-traffic-exchange.pdf

did not establish new IXPs nor did it take a leadership role, but rather assisted these local communities. CIRA is very pleased that in just over two years, 5 new IXPs have been established: In Vancouver British Columbia, (VANIX), Calgary Alberta (YYCIX), Winnipeg Manitoba (MBIX), Montreal, Quebec (Échange Internet de Montréal QIX) and Halifax, Nova Scotia (HFXIX)

Groups and countries wishing to establish a new IXP may wish to consider engaging their ccTLD manager as they can be a valuable resource in this process. Among the strengths that ccTLD managers may be able to bring are the following:

1. Neutral Player.
   One of the main challenges of starting IXPs is that it requires industry competitors to cooperate for mutual benefit. There can often be suspicions about the motives when an ISP takes the initiative to start an IXP. In many countries a ccTLD operator can be seen to be a neutral player to avoid these challenges, as ccTLDs are not competitors to ISPs.
2. Technical Knowledge.
   ccTLDs often run their own networks for nameservers etc. so they often and have considerable technical knowledge.
3. Contacts in the Industry.
   ccTLDs generally know many people in the equipment vendor community as well as many ISPs and can introduce representatives of IXP groups to them, potentially enhancing the credibility of these newly formed groups.
4. Organizational Skills.
   The majority of ccTLDs are not for profit organisations and are therefore well positioned to advise starting IXPs to deal with for example the processes of incorporation, creating a board of directors.
5. Resources.
   Within their capabilities, ccTLDs may provide support, sponsoring or limited financial assistance to starting IXPs.

6. Draft conclusion and key policy messages

- **IXPs do not provide international transit connectivity directly**
  Internet exchange points provide the infrastructure and support for networks to interconnect at a common place. While IXPs can be a good location to distribute international transit connectivity, IXPs do not typically offer this service themselves. Doing so could put an IXP in competition with its members, and might also have licensing implications.

- **The need for an IXP is driven by market conditions**
  Internet exchange points typically emerge in response to unsatisfied demand for network interconnection, often due to the high cost of alternatives (e.g., transit). A top-down approach to multiply the number of IXPs in a geographic region will not necessarily

multiply the benefits, and may even be counter-productive. Having too many exchanges can fragment the market and increase the overhead cost for networks to peer.

- **IXPs need time to mature**
  Establishing an IXP is only the first step. It can take significant additional time to promote the IXP, attract additional network operators, and build a community. It is important to manage expectations about the time it takes for IXPs to be successful.

- **Neutrality**
  IXPs typically function best when their ownership and governance system is neutral and does not directly or indirectly favor one or more exchange participants. Neutral access policies are also important for facilities that host IXPs.

- **IXPs are only one piece of the puzzle**
  Effective approaches to cross-border infrastructure, data centers, content, and licensing are also important components of any national broadband strategy.

- **Traffic is not an accurate measurement of success**
  Successful IXP - measurement by pure traffic numbers is a horrible metric, this is very much regional focused and isn't representative of many other indicators (i.e.: local transport costs, building space/power, port speeds, peering policies, etc). Other interesting indicators are sufficient funding to operate the IXP (and grow in the future), frequent social events between participants.

- **Need to solve licensing-related issues**
  IXPs should work with local government to understand local licensing requirements. Many countries do not require a license, but some do require authorization.
  For example, if a Kenyan network wishes to directly connect to an IXP in Uganda but does not wish to sell access services in Uganda, they should not be required to adhere to all of the burdens of an access service provider license

7. Next steps

What is the nexus between the good practices and experiences collected in this document and a sustainable development for, and connecting the next billion? How to accelerate and speed up connecting the next and last billion and provide solutions for the development that the Internet enables?

Building connectivity (infrastructure); building communities (people and stakeholders); capacity development (training, face2face and online); and the policies that enable them (bottom up governance and local and international governmental and environmental factors) are the ingredients of a formula that has proven to work. This formula works through partnerships, people that work together and build human trust networks for targeted sustainable development.

We have an opportunity to strengthen, amplify and accelerate this formula to connect the next billion and final billions.

The 2015 BPF on IXPs collected and described a range of good practices of which starting and developing IXPs can select depending on their local situation and needs. The practices in this document are not static but can be improved and completed based on new experiences as more IXPs deploy around the world.

More can be done one IXPs moving forward by focusing on some of the key issues that have been raised, for example the special situation of landlocked countries relying mostly on satellite connectivity; problems established IXPs encounter or a community can reboot or revive a dormant IXP.

8. List of contributors

With the risk of not being fully comprehensive the list below represents a record of active contributors to the BPF *Enabling Environments for Establishing Successful IXPs* by their contributions on the mailing list, their participation to the virtual meetings or direct involvement in the drafting this document.

Emmanuel Akin-Awokoya
Jane Coffin
Henrique Faulhaber
Bastiaan Goslings
Gaël Hernández
Gary Hunt
Malcolm Hutty
Milton Kaoru Kashiwakura
Allan MacGillivary
Coppens Pasteur Ndayiragije
Michael Nelson
Jon Nistor
Michael Oghia
Mauricio Oviedo
Matt Peterson
Rosalía Morales
Bijal Sanghani
Chip (Hascall) Sharp
Julio Sirota
Kyle Spencer
Nico Tshintu Bakajika
Zmarialai Wafa
The BPF IXP survey respondents
Wim Degezelle (editor)

9. Appendices:

Appendix 1: Non-exhaustive list of technical forums and reference documents
Appendix 2: Non-exhaustive list of Community-organized IXP training
Appendix 3: The global IXP landscape: Background data (references)

Appendix 1: Non-exhaustive list of technical forums and reference documents

IXP Construction Checklists

https://wiki.pch.net/pch:public:ixp-construction-checklist

https://wiki.pch.net/pch:public:basic-ixp-guide

https://www.euro-ix.net/ixps/set-up-ixp/ixp-models/

https://www.euro-ix.net/ixps/set-up-ixp/ixp-infrastructure/

IXP Toolkit (ISOC)

http://www.ixptoolkit.org

http://www.internetsociety.org/internet-exchange-points-ixps-0

IXP Best Current Operational Practices (Euro-IX)

https://www.euro-ix.net/ixps/set-up-ixp/ixp-bcops/

Open-IX: OIX1 IXP Standards & Certification

http://www.open-ix.org/standards/ixp-technical-requirements/

Other IXP Best Practices Efforts:

ITU Council Working Group on Internet-related Policy Issues: Open Physical Consultation
http://www.itu.int/en/council/cwg-internet/Pages/consultation-june2015.aspx

Appendix 2: Non-exhaustive list of Community-organized IXP training

Source: Internet exchange point (IXP) training, "For the community, with the community, by the community," IXP Toolkit.

Network operator groups (NOGs):

NOG meetings are key places to obtain technical training, connect with experts, and build a community and human networks of trust.

- African Network Operator Group: AFNOG
- Asia-Pacific Regional Internet Conference on Operational Technologies: APRICOT
- Caribbean Network Operator Group: CaribNOG
- Eurasia Network Operator Group: ENOG
- Latin-American Network Operator Group: LACNOG
- Middle East Network Operator Group: MENOG
- North American Network Operator Group: NANOG
- South Asian Network Operator Group: SANOG

Regional Internet registries (RIRs)

RIRs offer key training sessions at their meetings, and work with ISOC and others to conduct trainings around the world.

- AfriNIC and AfriNIC Mailing Lists
- ARIN and ARIN Mailing Lists
- APNIC and APNIC Mailing Lists
- LACNIC and LACNIC Mailing Lists
- RIPE and RIPE Mailing Lists

IXP Associations (IXPAs):

IXPAs provide training, networking, and business opportunities. For newly established IXPs, they also provide an excellent venue to obtain mentoring or "twinning" assistance. Basically, an established IXP can help a newly established one by working closely together. You also can meet people from organizations like ISOC, PCH, NSRC, and RIPE NCC who can offer equipment, hands-on training, and more.

- Asia-Pacific Internet Exchange Association: APIX
- African Internet Exchange Association: AFIX
- European Internet Exchange Association: Euro-IX
- Latin American and Caribbean Internet Exchange Association: LAC-IX

IXP Resources:

IXPs have created resources like INEX's IXP Manager to better manage, troubleshoot, collect data, and improve operations and processes: https://www.inex.ie/index.php.

The Internet Engineering Task Force (IETF)

IETF meetings are where technical experts converge to build and develop Internet standards (known as protocols), examine Internet architecture issues, exchange information, and build technical capacity. You can find more out about the IETF here.

The Network Startup Resource Center (NSRC)

NSRC experts conduct training all over the world at NOG meetings. They also conduct hands-on training. Contact them here.

African Union Internet Exchange System: Best practices and technical assistance workshops (AXIS)

Appendix 3: The global IXP landscape: Background data (references)

Public and reusable data can be taken from:
https://prefix.pch.net/applications/ixpdir/summary/

https://www.euro-ix.net/ixps/list-ixps/