Promoting the use of Internet Exchange Points (IXPs)

A Guide to Policy, Management and Technical Issues March 2012

1. Introduction

The Internet is not a single entity, but is made up of independent networks which agree to share traffic with each other's customers using a common protocol (TCP/IP). Without this it would be impossible for users of two different networks to even send each other email. In this respect the key task of an Internet provider is to ensure that its users are able to most cost-effectively, rapidly, and securely connect to any point in the world that is connected to the Internet, be it a web site on the provider's network or a user connected to another network, in the same city or in a distant part of the world.

Internet Exchange Points are a vital part of this system. Without them, the Internet would not function efficiently because the different networks that make up the Internet would need to directly interconnect with every other network in order to be able to exchange traffic with each other. The simplest form of an exchange point is in fact a direct connection between two Internet Service Providers (ISPs), which may be the best option if there are no other ISPs in the same location, or where they have special needs to interconnect their users. When more than two providers operate in the same area, an independent hub usually operates more efficiently as a common interconnection point at which to exchange traffic between the local networks. This is similar to the development of regional airport hubs where many different airlines are served. At these locations airlines exchange passengers between their flights in much the same way that networks exchange traffic across the IXP.

For Internet providers and users, there are many advantages to local routing of Internet traffic via a common exchange point:

- Substantial cost-savings are made by eliminating the need to put all traffic through the more expensive and often slower or more congested long-distance links to the rest of the world.
- More bandwidth becomes available for local users because of the lower overall costs of capacity.
- Local links are much faster (often up to 10 times) because of the reduced latency in the traffic which has to make fewer hops to get to its destination.
- New local content providers and services that rely on high-speed low-cost connections become available, further benefiting from the broader user-base available via the IXP.
- More choices for Internet providers become available via the exchange point to send their upstream traffic to the rest of the Internet, making the wholesale transit market smoother and more competitive.

As shown in the chart below, more than 350 IXPs are now operational worldwide¹ with the US leading, at about 86 IXPs around the country. The other countries with more than 10 IXPs are: Australia (11), Brazil (19), France (15), Germany (14), Japan (16), Russia (14), Sweden (12), and United Kingdom (12). As can be seen from this list, these are generally the larger or more densely populated countries with mature Internet infrastructure, although there are some notable absences in the list, such as Canada, China, India and Spain. In general at least one well functioning IXP is likely to be needed in each country, however only 91 countries have so far established operational IXPs. As would be expected the developing countries have generally lagged behind the rest of the world in establishing IXPs and Africa is the region with the fewest IXPs (only 21 of the 53 nations have them today).



Regional distribution of IXPs

The table below lists the 23 IXPs with over 100 participant networks. They are largely located in Western Europe and North America, although a few of these largest IXPs also exist in some cities of other regions, namely: Cape Town, Hong Kong, Moscow, Sao Paulo, Sydney, Tokyo, and Warsaw.

Region	Country	City	Exchange Name	Participants
Europe	Netherlands	Amsterdam	Amsterdam Internet Exchange	472
	United			
Europe	Kingdom	London	London Internet Exchange	407
Europe	Russia	Moscow	Moscow Internet Exchange	344
Europe	Germanay	Frankfurt	Deutscher Commercial Internet Exchange	325

IXPs with over 100 members

 $^{1 \} https://prefix.pch.net/applications/ixpdir/index.php?show_active_only=1 \& sort=country \& order=ascillations/ixpdir/index.php?show_active_only=1 \& sort=country & sort=country & sort=country & sort=country$

Europe	Netherlands	Amsterdam	Netherlands Internet Exchange	294
North				
America	United States	Los Angeles	One Wilshire Any2 Exchange	216
Europe	Poland	Warsaw	Polish Internet Exchange	204
Latin				
America	Brazil	São Paulo	Ponto de Troca de Tráfego Metro	167
	United			
Europe	Kingdom	London	XchangePoint London IPP	166
North				
America	United States	Seattle	Seattle Internet Exchange	151
Africa	South Africa	Cape Town	Cape Town Internet Exchange	150
Europe	Germany	Frankfurt	KleyReX Internet Exchange	138
North				
America	United States	New York	New York International Internet Exchange	137
Europe	France	Paris	Paris NAP	133
Europe	Switzerland	Zurich	SwissIX	132
Asia-				
Pacific	Japan	Tokyo	Japan Internet Exchange	125
North				
America	Canada	Toronto	Toronto Internet Exchange	116
	United			
Europe	Kingdom	London	London Network Access Point	114
Europe	France	Paris	Free-IX	106
Asia-				
Pacific	Australia	Sydney	PIPE Networks Sydney	105
Europe	Austria	Vienna	Vienna Internet Exchange	105
Asia-				
Pacific	China	Hong Kong	Hong Kong Internet Exchange	104
Europe	Italy	Milan	Milan Internet Exchange	102

Because of the limited amount of local online content and services in many developing countries, most of the Internet traffic generated by users is international, resulting in large capital outflows paid to foreign Internet providers. Furthermore, local content providers in these countries tend to operate their services offshore, where it is cheaper to host them due to the lack of low-cost local infrastructure (of which an IXP is an integral part). Thus the presence of an IXP helps to encourage more local content development and creates an incentive for local hosting of services. This is not only because of the lower cost, but also because of the larger pool of local users who are able to access online services faster and more cost effectively.

In this respect, from a public policy perspective, ensuring the presence of local IXPs has become an increasingly important priority in order to make sure that online services are equally accessible to all local users, as well as to enhance competitive opportunities and generally improve the quality and affordability of Internet services.

As a result of the lack of IXPs in many countries, ISPs located there must exchange traffic via expensive international links (or in some cases they pay high prices for local traffic exchange through what is often a monopoly international telecommunication provider). This occurs despite the fact that one of the largest costs for network operators in

developing countries is the cost of international capacity, and the fact that IXPs are relatively inexpensive to set up. By one estimate, an expenditure of about USD 40 000 is all that is required to establish a national IXP. Yet many countries without IXPs probably pay much more than this every few weeks to foreign operators for carrying local traffic, which further (and unnecessarily) increases foreign capital outflows.

The barriers to establishing IXPs in countries where they do not yet exist are usually not technical – instead there is often a lack of appreciation among ISPs of the mutual benefits, and resistance from the ISPs with market dominance. In addition, limited skills, and the lack of open competitive markets in telecommunication and Internet services in some countries make it more difficult to establish an IXP.

This guide aims to provide an introduction to IXPs, outlining their role as a key component of Internet infrastructure, and covering the policy, management, financial and technical issues that need to be considered in their establishment. In addition, an account of some selected IXPs is provided, along with a glossary which explains in more detail many of the terms used.

2. The Role of Internet Exchange Points

Commercially, the Internet consists of a hierarchy of global, regional, national and local providers. These either sell "transit services" to other operators for the traffic they pass on through their networks to the rest of the Internet. Or, when two networks of similar size or market position exchange similar amounts of traffic, then instead of charging each other for transit, they may enter into a settlement-free arrangement called peering. Peering or transit can take place between two networks if they are physically interconnected, or via an independent exchange point where many such carriers meet.

The term "Internet Exchange Point" (IXP or IX) is often used interchangeably with 'Exchange Point' (EP), "Internet Peering Point" (IPP), and "Network Access Point" (NAP). While there are no formally agreed definitions for these different terms, the most commonly used are IXP, IX or 'peering point'. NAP is an older term, originally used for the original four exchange points in the US which provided access to the Internet backbone operated by the National Science Foundation (NSFNET), prior to the global development of the Internet.

As the Internet developed, the original NAPs were joined by other commercial and nonprofit exchange points, first within the US, and then in other nations, wherever significant amounts of local traffic was generated by more than one network operating in the same area. As shown in the diagram below, any network can be part of the Internet by having only one connection to the Internet 'cloud'. This allows it to pass traffic between its users and others on different networks.



But if two networks that are independently connected to the Internet are close to each other, perhaps in the same city or country, it is usually faster and cheaper to use a separate connection to send local traffic directly between the two networks, as shown in the diagram below.



When there are more than two local networks that need to exchange traffic with each other, it becomes more efficient to set up a hub (the IXP) to which each network can connect. The diagram below shows how three ISPs would share a local IXP to route all of their local traffic. An IXP can thus be viewed as the centre of a star network that makes it possible for all local traffic from any local network to any other to traverse through a single connection to the hub. This cuts the telecommunication and management costs of having to set up multiple direct links between each network and speeds up local traffic by minimising the number of network hops needed to reach any other local network.



While the above diagram shows the most simple example of an exchange point used to route traffic, various local factors affect the viability of an IXP and create a wide range of permutations in the implementation of this basic model. As mentioned above, the two key factors in connecting to, or setting up an IXP are 1) the amount of traffic that is likely to flow between the local networks, and 2) the cost of the physical connection between the network and the IXP, versus the cost of the connection to the upstream Internet cloud.

To take a simple example, assuming that each of the three networks above have 10Mbps international connections to the upstream Internet cloud, which, in a developing country, could cost them each about USD 30 000 per month, i.e. a total annual cost for all three networks of 3 X 30 000 USD per month X 12 months = USD 1 080 000. Assuming only 20% of the traffic is local would mean that roughly USD 216 000 per year is being spent on routing local traffic via the upstream Internet link. If the three networks can self-provide their links to the IXP at no cost (such as by using a wireless circuit or when they have facilities located in the same building), then aside from providing faster service to local users, an IXP would pay for itself in a few months.

In practice networks may need to lease connections from a licensed telecom provider to reach the IXP, in which case the cost for local bandwidth might be as much as USD 1000 / Mbps/ month in a developing country. This gives an annual cost for local links of 20% X 30 Mbps X 1000USD/month X 12 months = USD 72 000. Even taking this additional cost into account, the hypothetical IXP still provides an annual saving of almost USD 150 000 per year, although a portion of this would need to be applied to maintaining the IXP. Naturally if there are more local networks, greater capacities involved or higher costs for upstream links, or in the proportion of local traffic, much greater savings can be provided by an IXP. And even if the direct cost savings on capacity purchases are taken out of the equation, an IXP still offers tangible benefits in improving the performance of local internetwork traffic, promoting the development of local content and providing a location for shared services, such as domain name servers (DNS), caching and time-servers.

Once a national exchange point has been established to keep traffic within the country, additional exchange points might then be established to serve smaller geographic areas where it is cost effective to keep traffic within the local area. This can be particularly important in developing countries where national telecom backbone infrastructure is often poorly developed, congested or especially costly - a common situation when cities are still connected via satellite links or when monopoly pricing is in force. As a result IXPs are often necessary in the secondary cities as well.

By contrast, IXPs can attract international membership when they are situated where competitively priced international optic fibre links are available. Networks from other countries may be generating sufficient traffic with members of the foreign IXP to warrant the cost of a direct international link versus paying another network for transit. For example, LINX, an IXP in the UK has members from about 50 countries.

Reducing operating costs by establishing a local IXP not only decreases Internet access prices to the end user but also provides much faster response times from local web sites or other services. This is because the latency (delays) caused by routing local traffic internationally can be cut from seconds to a few milliseconds when two local networks are connected directly. As a result, response times for local web sites are dramatically improved and more advanced local services which require low-latency connections, such as VPNs, multimedia streaming and VoIP become more viable. When links between networks rely on satellite connections, many of these services cannot be provided with acceptable quality, and some do not run at all. As a result a local interconnection point is critical to ensuring their availability to users.

A further advantage of an IXP is that it reduces transactional costs and improves choice for its members. If a network decides to switch transit providers at an IXP, they can do so in a matter of minutes and without physical intervention (simply by changing a configuration setting on the router). Without the IXP this would have involved having a new physical circuit installed, incurring significant waiting time and additional financial charges. This fluidity available through the IXP thus encourages greater price competition, further driving down costs for access providers and ultimately end-users.

Once an IXP is established, it also becomes a natural location to host a variety of other services which reduce bandwidth requirements and improve the speed and reliability of Internet access for local users. The most important of these include DNS (to provide local resolution of country code and generic top level domains (ccTLDs and gTLDs) such as .eg, .com and .net), root server mirrors, time servers and content servers. In addition a variety of administrative facilities for network operators are often hosted at an IXP, such as routing and traffic measurement facilities. While some IXPs may only allow access providers to be members, content providers are also usually permitted to connect to IXPs.

The presence of an IXP can also attract telecommunication operators which may establish a point of presence at an IXP because it then becomes easier to sell services to potential customers located at the exchange, since all parties are reachable at low cost. In this respect IXPs help to encourage the development of local telecom infrastructure such as national and international fibre cables. Also, to improve reliability, prior agreements may also be made so that in the event of a disruption to a network's upstream Internet link, the IXP could be used as a temporary route to the Internet via one of the other IXP participants.

The opportunity to use an IXP to provide members with a shared connection to the Internet, or to interconnect national IXPs, have been suggested as ways of further cutting costs and keeping traffic within the region. So far, these strategies have not usually been successful because they negatively affect the business of some of the IXP members that sell these services to clients. Once an IXP is in place, market related forces based on competitive pricing for the underlying infrastructure tends to drive the direction of traffic toward the most cost-effective traffic exchange mechanisms without the need for special intervention by government or groups of operators.

However an IXP can also have isome ndirect benefits on the pricing of bandwidth, for example, in some countries the IXP has assisted in negotiating lower rates for international connectivity for its members. Such negotiations could occur independently of the IXP, but the creation of the IXP can have a catalytic effect, and by having a group of networks at the same location, the IXP can negotiate a better deal with the upstream providers on behalf of customers located at the IXP.

3. Institutional and operational models for IXPs

There are a variety of institutional models that have been adopted to operate IXPs, which roughly fall into four categories:

- 1. A non-profit industry association of ISPs
- 2. An operator neutral commercial/for-profit company
- 3. A university or government agency
- 4. An informal association of networks

Of these models, probably the most common are IXPs operated by a non-profit industry association of ISPs. This is particularly the case in Europe where many IXPs are typically mutual, not-for-profit organisations where members collectively "own" the facility. Operating costs are shared among members who usually pay a once-off joining fee, and a monthly, quarterly or annual operating fee. The fee may be determined by the capacity of their connections to the IXP, or less commonly, by the volume of traffic which is passed across the exchange. In the US, commercial IXPs are more prevalent, operated by specialised companies such as CIX, Any² and Equinix. These types of specialist companies are almost always provider neutral and do not compete with ISPs in providing services to end-users.

Note should also be made here of the presence of so-called 'phony IXPs' where the dominant Internet operator provides local exchange points in one or two major cities. In these cases the IXP is used more as a marketing term by the commercial transit provider, but is really no more than a router offering peering for the sale of local and/or international transit.

IXPs are usually formed by a initial group of network operators who decide on the best model that fits the local environment. The key questions that usually need to be addressed when deciding the most appropriate institutional and business model are:

- 1. Will the IXP have permanent staff or be operated by volunteers?
- 2. Will the IXP be a non-profit or for-profit organisation?
- 3. Will the IXP be entirely cooperatively owned by its members or will it have external ownership?
- 4. Where will the IXP be located/hosted?
- 5. What cost-recovery method will be used?

In developing the appropriate institutional arrangements for the IXP, a variety of choices need to be made. In order to connect to an IXP, it is often required that the network must be a recognised legal entity and must be licensed to operate (if a license is required). In some cases it is also a policy that member networks transmit third party content or services. Increasingly it is found that any entity which needs to exchange traffic with other IXP members is allowed to join. This option allows the operators of large private networks which provide services to the public, such as hosting providers, government departments or banks, to take advantage of only having to establish a single link in order to reach the users of other local networks.

Technically, there have been two models for IXP operation. In the simplest form, the IXP exchanges all traffic between member networks inside a single router. This is usually called a 'Layer 3 IXP'. Today, the most common model is the 'Layer 2 IXP' in which each network provides its own router and traffic is exchanged via a simple Ethernet switch. Overall, the Layer 3 model may be less costly and simpler to establish initially, but it limits the autonomy of its members who have less control with whom they can peer with and are dependent on a third party to configure all routes correctly and keep them up-to-date. This requires greater technical skills from the IXP staff. In contrast, the Layer 2 model does not require the staff to have any routing knowledge. As a result the Layer 3 model has generally been superseded by the Layer 2 model.

The requirements for traffic routing agreements between IXP members varies depending on the IXP's institutional model and other local policies. Some IXPs require a Mandatory Multilateral Peering Agreement (MMLPA) in which anyone who connects with the IXP must peer with everyone else who is connected. This may create a disincentive to large ISPs to interconnect and may reduce incentives to keep technical operation in top condition. Other IXPs may require each network to enter into Bilateral Peering (BLP) arrangements with the other network members, and some IXPs may limit the use of the facility for such transit traffic.

Flexible peering policies that permit the coexistence of multilateral and bilateral peering arrangements allows peers at an IXP to enter into separate bilateral peering or transit agreements. It is also usually acceptable for IXP members to restrict (filter) traffic originating from or destined for any member's network in accordance with the member's policies, which are normally specified in the Internet Routing Registry (IRR).

Other important policies and strategies that IXPs and their member networks normally adopt include:

- Payment for the cost of and management of the link between the network and the IXP (including a redundant link if required) is usually the responsibility of the member. However some IXPs have adopted policies to smooth these costs so that each member pays the same amount to access the IXP. This helps to ensure that commercial operators who happen to be located in the same building as the IXP do not have an unfair advantage.
- 2. It is not usually acceptable to pass traffic to the IXP that is destined for networks that are not members of the IXP unless transit is allowed and specific agreements with the IXP and the members providing transit are made.
- 3. Monitoring or capturing the content of any other member's data traffic which passes through the IXP, is limited to data required for traffic analysis and control, and members usually agree to keep this data confidential.
- 4. Mandatory provision of routing information and looking-glass sites.
- 5. Routing and switch-port information can either be made public or restricted to members-only.
- 6. Provisions for responses in the event of security problems, infrastructure failures, routing equipment failures, and software configuration mistakes.

4. Practical Considerations in Establishing IXPs

At the outset, as described above, the first step in considering the establishment of an IXP is determining the need. This would be based on a provisional assessment of the number of providers (at least three) that are willing to support and use the IXP, the amount of traffic that would be exchanged, and the likely cost of connecting to the IXP. A meeting of local network operators and technical advisers should be sufficient to establish this.

If the outcome of this assessment proves positive, the next step would be to build support for the project among all stakeholders and identify any potential policy problems or market barriers to the establishment of an IXP. These usually arise from either the potential members themselves, or as a result of inappropriate government policies.

The establishment of a local IXP is often seen as a threat by competing commercial providers who may not be aware of the full advantages of collaboration and local traffic exchange. There can be lack of trust and a fear of making business cheaper for (or even subsidising) competitors, and concerns that "interconnection" means stealing of customers. These issues will need some time to be discussed, supported by awareness-raising on the role of IXPs, before all the relevant parties may be in full support of the IXP.

There may also be outstanding issues regarding participation in the IXP when there is a dominant commercial Internet service provider in the market. These may be resistant to participation, or they may participate but severely under-provision the link to the IXP. This is known as the 'Thin Pipe Stratagem'. Here, the customers of competitors encounter slow connections to dominant provider's customers and understandably, they fault the competitor for the poor connection. This creates a strong incentive for users to switch to

the dominant service provider. If unsolvable by other means, this problem may be cause for regulatory intervention.

Some network providers may also be concerned that IXPs could be overly complicated for their needs. This is especially the case for small ISPs with only one connection to the rest of the Internet who may not have the technical expertise to implement multi-path routing. This may be amplified by contact with large developed country IXPs which have more sophisticated switches and powerful routers. Equipment marketing agents can also contribute to this view, selling equipment which may not be appropriate for the needs of a small IXP. To address these issues, further awareness raising and training activities may be necessary. At a minimum, potential members will need a staff member familiar with the Border Gateway Protocol (BGP), used for routing between the networks, and each network will need to have a publicly registered Autonomous System Number (ASN) for their traffic exchange, obtained from the relevant Regional Internet Registry (RIR).

In most markets, exchange points are not regulated by any form of government policy, and most activity within an exchange is considered entirely private between the parties, free from government regulatory oversight. In many developing countries government policies can restrain the establishment of an IXP in a variety of direct and indirect ways. Because IXPs only exist where there are many providers needing to exchange traffic, in many countries the presence of a monopoly service provider is probably the major reason for the lack of an IXP. Alternatively, the lack of an IXP may indicate the existence of a single player with monopoly power over certain infrastructure or rights of way, such as international gateways. If low levels of competition exist, networks may have little choice but to exchange domestic traffic via the dominant player rather than directly between themselves. In the immediate term, there may be little that can be done by potential IXP members to address this problem, however continued lobbying of government policy makers and regulators should ultimately help to open markets and relax restrictions on new market entrants.

Even where the market is more open, incumbent telecom operators may still resist the establishment of an IXP. Unfortunately the incumbent operator's views often carry great weight with regulatory authorities, for a variety of reasons (ranging from close personal relationships to corruption). They also reflect the concerns of developing-country policy makers whose governments are often heavily dependent on revenues from the state-owned telecom operator, and are reluctant to sanction activities which are thought to limit profits. Some policy makers may even see IXPs as a form of anti competitiveness on the part of industry. Often, statutory or other licensing requirements exist which can arguably applied to IXPs and in most cases, the regulatory authority is, at least initially, unfamiliar with the technical and economic aspects of Internet facilities and ISP traffic exchange.

In these cases IXP founders need to ensure that policy makers, regulators and incumbent operators are aware that reducing the cost of Internet connectivity for domestic consumers will generate much greater investment, more users, and thus greater international leased line revenues. Increased use of the Internet, also leads to greater use of international telephony to foster the commercial and personal international relationships that are

supported through the Internet.

In view of these factors, some governments, such as in Chile, have made it mandatory for networks to establish a peering point. Superficially this may seem like a good policy, but it could actually hinder growth by removing the incentives for an ISP to competitively expand its connections beyond a single exchange.

Other government policies that may need to be examined for their dampening affect on strategies for the establishment of an IXP include any limitations on self provisioning of links between network members and the IXP. This could also include limitations on use of radio frequencies and on use of space on telephone poles, or rights to dig up streets and lay cables (rights-of-way).

Once the IXP's founding members have addressed these issues, it will be necessary to decide on the appropriate management structure and policies, as outlined in section 3 above. Following this, the required technical expertise will need to be identified and a technical committee established to design the IXP, cost it, and find the most appropriate location to host it. This would be likely to include an assessment of existing facilities which could be used and then comparing this to the cost and effort involved in setting up a new independent facility. In many countries, costs associated with leasing space, purchasing power, and hiring staff can be high, and hosting the IXP in an existing data facility can substantially reduce startup and operating expenses. Existing facilities that might be considered include the premises of telecom operators, university networks, datacentres or city emergency services.

The most important features of potential sites that would need to be examined are:

- Proximity to the networks of the potential members. This may also depend on whether the IXP is to be centralised in one room, located in a campus of adjacent buildings or more widely dispersed across a broader area, such as by using fibre channel switched fabric.
- Availability of electric power, including backup supply or generator.
- Availability of air-conditioning.
- Availability, capacity and reliability of telecommunication links to the site
- Access to fibre facilities or rights-of-way.
- Ability to build antenna towers or dig trenches for fibre.
- Ease of access. Independent 24X7X365 access for IXP member staff is highly desirable.
- Quality of security. CCTV, 24 hour monitoring, fire and break-in detection is desirable.
- Availability of ancillary equipment and services equipment cabinets, telephones, etc.

Finally, once the design of the IXP, the institutional structure and the site(s) have been identified, a more detailed business plan can be developed which covers set-up and maintenance costs, and proposed revenues/cost recovery projections.

To help establish IXPs in developing countries where they do not exist, financial support may be available from appropriate development agencies or donors. Since the financial assistance needed for the start-up costs of an IXP are relatively modest compared with the potential long term economic benefits, a strong case can usually be made for development assistance. In addition, as the majority of IXPs are non-profit facilities, financial aid can be seen to be assisting the growth of the market and not distorting its natural development. Thirdly as the majority of the expenditure is on the initial training of staff, to establish and maintain the facility, it meets the objective many donors have for local capacity building.

5. General Summary and Conclusions

The primary role of an IXP is to keep local traffic local and reduce the costs associated with traffic exchange between Internet providers. The case for IXPs is compelling, and the obstacles relatively clear and well-understood. In order to achieve wider IXP deployment in developing countries the key needs that have to be addressed are:

- Regulatory reform and liberalisation. Open markets and low cost domestic capacity are vital, and regulators and operators alike, need to be convinced of the overwhelming benefits of competitive domestic Internet traffic exchange, and of the broader proposition that lower costs lead to greater revenues for existing operators.
- Overcoming resistance and lack of understanding from potential members, especially those with market dominance and monopoly telecom operators.
- The organisation of competitive ISPs into associations capable of neutrally administering shared facilities on behalf of their members.

Governments should not require IXPs to be licensed nor mandate peering and other policies concerning IXP operations. However government can play a positive role to encourage networks to keep domestic traffic local, in particular, policies aimed at encouraging competitive access to leased lines and wireless connections will help lower the costs associated with connecting to an IXP. Governments can also play a positive role by restraining anti-competitive behaviour of incumbents, including attempts by large carriers to block the development of IXPs.

6. Some IXP Examples

Aspects of some selected IXPs are presented below to illustrate the variety and different approaches to their establishment and operations. These examples draw on information from the IXP web sites and a variety of case-studies that have been carried out on some developing country IXPs (see end of section for further details). The first example, KIXP in Kenya, is presented in more detail than others due to the greater availability of case-study information.

5.1 The Kenya IXP (KIXP)

KIXP in Nairobi is operated by the Telecommunication Service Providers Association of Kenya (TESPOK), which is a professional, non-profit organisation representing the interests of ISPs and other telecommunication service providers in Kenya. After attending the Networking Workshop for Developing Countries hosted by the Internet Society (ISOC) in California in 1999, one of Kenya's Internet engineers obtained knowledge about how to design, set up, and maintain an IXP. Upon returning to Kenya, he shared this information with other network operators who were keen to begin work on establishing a local IXP. After about a year of preparatory work, including the design and implementation of the technical operation, funding model, and legal framework, the KIXP was launched in November 2000. KIXP does not have a separate governance structure and policies are established through committees of the Kenyan ISP association (TESPOK).

Almost immediately following its launch, the incumbent telecom operator, Telkom Kenya, filed a complaint with the national regulator, the Communications Commission of Kenya (CCK), arguing that the KIXP violated Telkom Kenya's exclusive monopoly on the carriage of international traffic. Within two weeks, the CCK concluded that the KIXP required a license and ordered that it be shut down as an illegal telecommunications facility.

In response to the CCK's closure order, a case was then presented to the Communications Appeals Tribunal with a strong technical argument showing that KIXP was merely a standard, off-the-shelf Ethernet hub. If the KIXP were to be shut down, then the CCK would need to shut down every computer network in the country since the technical architecture and components were equivalent. Telkom Kenya's opposition to KIXP was fierce, fed by the fear of losing a significant portion of its international leased line revenues, but the Kenyan Internet providers also argued that the KIXP was a closed-user group, and therefore would be legal under the Kenyan Telecommunications Act. In addition it was also pointed out that the local exchange of domestic Internet traffic does not contravene Telkom Kenya's international monopoly, as all international traffic would continue to flow over its international links.

After nearly a year of intensive efforts, including public pressure, threats of litigation, and private diplomacy, TESPOK finally received the approval of CCK in the form of a license, granted in November 2001. It was clear that Telkom Kenya had misrepresented the situation and, because the matter was made public and had received a significant amount of attention and coverage in the local and international media, it was necessary to find a face saving solution. The approach eventually adopted was the establishment of a company called KIXP Limited, which then applied for an IXP licence, which CCK duly granted. This made Kenya the first country in the world to have an IXP licence.

KIXP finally went live again in mid-February 2002 having interconnected five Kenyan ISPs. In the course of 2004, it was decided by TESPOK members that the policies governing membership and use of KIXP were restrictive since they allowed only licensed ISPs to be members and to connect to the IXP. This prompted a policy review which lifted all restrictions on membership and lowered joining fees by 600%. Currently membership costs KSH20,000 (about USD 330) per month and there are now 25 members peering at the KIXP – 16 ISPs, one Government network (Kenya Revenue Authority), one education network operator, one ccTLD Operator, three Internet Backbone Gateway Operators, one Value Added Telecommunication Services Provider and two GSM operators.

One of the biggest issues in establishing KIXP related to deciding where it would be hosted. A number of options were evaluated which included the following:

• Telkom Kenya was ostensibly the most suitable option since it was the incumbent public national telecoms operator. Some of the reasons cited in favour of Telkom

Kenya included the fact that as national operator, all Internet providers already had existing links to its data network. Additionally, due to its central location, it would be much easier for the members to gain physical access to the IXP, regardless of their location. However this option proved to be unworkable because as described above, Telkom Kenya saw the IXP as a threat to its business and declined the ISPs' request to host KIXP.

- The University of Nairobi was considered as an alternative host for KIXP mainly due to its dynamic computer studies faculty and its central location. The biggest concern about using the university was the frequency of student riots. Since the KIXP was expected to serve a mission critical purpose, this concern eliminated the university as a viable option.
- A couple of Internet providers that had their offices conveniently based in the Nairobi CBD offered to host the IXP. The challenges here were a) which ISP to choose out of the two, and b) the fact that most of the other ISPs expressed a high level of dissatisfaction and would not trust them as competitors to handle the IXP without seeking to give themselves undue advantage.

In order to ensure the acceptability of the IXP concept in Kenya, it was essential to emphasize the neutrality of the facility and obtain consent from prospective members on its location. After an evaluation all of the various existing options without finding one that satisfied all the potential members, the idea of leasing space in a provider neutral, conveniently located building was posed. This option allayed most of the fears and concerns expressed and a lease was taken up for 1500 square feet on the top floor of a strategically located office building in the Nairobi city centre.

The main operational consideration was cost. As with any other type of data networking or communications infrastructure, costs fell into two broad categories: set-up and operating costs. set-up costs included the cost of purchasing equipment for the core of the IXP as well as furnishing the room where the IXP was to be located with backup power, air-conditioning, equipment cabinets, and the relevant security fixtures. The initial equipment was funded both by a donation from Cisco Systems as well as a small grant from the United Kingdom's Department for International Development (DfID). Other set-up expenses were covered by funds from TESPOK. Since the space where KIXP was located was not free, it was necessary to find a way of covering the operating costs, such as rent, electricity and insurance costs. A monthly subscription fee for all members connecting to KIXP was introduced to cater for these.

A number of different technical models were evaluated for the Kenya IXP and it was agreed that the KIXP would be based on the same model as the Hong Kong Internet Exchange - a Layer 2 Route Reflector IXP. As a result the KIXP facility consists of two high speed Ethernet switches and each KIXP member has the option of connecting their routing equipment to both switches. That way if one switch should fail, the other would take over automatically. The core is supplemented by two 'route reflectors' – specially configured routers that bounce routing logic to all members at the KIXP until all the routers have the same view of the network. This design aspect allows for quick and easy policy implementation at the exchange point, which is capable of supporting up to 48 networks. Capacity can be extended further to support up to 200 networks.

Until KIXP, all Internet traffic in Kenya was exchanged internationally. Roughly 30% of upstream traffic was to a domestic destination. International bandwidth currently costs about USD 5,000 per megabyte, while the local price is about USD 500–1,000. During the first two weeks of KIXP's operation, measurements indicated that latency was reduced from an average of 1200–2000 milliseconds (via satellite) to 60–80 milliseconds (via KIXP).

Local traffic has also improved compared to 2007 due to the rise in local content from digitisation of some government services and the arrival of international companies such as Google who now host their services locally. All Google traffic (searches, mail, maps, applications and documents), goes through KIXP. ISPs only pay for the local traffic and Google pays for the capacity from Kenya to their network in the US.

Due to the limited capacity on the incumbent telecom operator's leased lines, most Internet service providers have moved to terrestrial fibre to connect to the KIXP which means that they have links of multiple megabits per second into the exchanges.

KIXP has implemented local instances of the Internet's F and J root servers, in addition to local .com and .net resolution services. As a result, locally originated lookup requests for these services no longer need to transit international links for a response.

In 2005, the Kenya Network Information Centre (KENIC), in line with its mandate to promote access to the Internet in Kenya, set up a GPS enabled NTP Server at the KIXP to provide date and time integrity for computers. Most service providers had implemented time synchronisation on their systems utilising network time servers located in foreign countries. However, these services were not extended to their clients due to the unreliable connectivity and prohibitive costs associated with international links. Some of the organisations using the local NTP services include Government bodies, ISP's, banks, companies and some educational institutions who are able to save on organisational expenses resulting from operational failures and data losses due to time inconsistencies.

The KIXP operates a Mandatory Multilateral Peering Agreement (MLPA) in which each member must have a peering session with every other member.

Overall, traffic now hits 1Gbps during peak time. KIXP publishes detailed information on Internet usage patterns. The data reveals that traffic flows are highest during week day business hours, highlighting the opportunity for ISPs in Kenya to maximize off-peak use by developing products and encouraging content attractive to home Internet users.

http://www.kixp.or.ke

5.2 The Nigeria Internet Exchange (IXPN)

In Nigeria, IXP activity first began outside the capital, in the city of Ibadan in 2003, when the first IXP in Nigeria went live with two members connected to a 10/100Mbit/s Ethernet switch and a route server. The maximum recorded traffic between the two ISPs was about 100Kbit/s. In early 2005, the ISP Association of Nigeria (ISPAN) began discussions on setting up an exchange in Lagos which was expected to be managed by an independent entity to be set up by ISPAN. In November that year, the President of Nigeria, Olusegun Obasanjo, directed the national regulator, the Nigerian Communications Commission (NCC), to ensure that a national IXP is established as soon as possible. The Interim Board of the Nigerian IXP was finally inaugurated in March 2007 and the NIXP was established with 15 initial members.

Since then the membership has grown to 35 and IXP which has established two operating sites in Lagos in partnership with two co-location operators connected by fibre switch fabric across the locations. Each location has two Foundry switches connecting separate peering LANs to ensure reliability. The primary peering LAN is interconnected on a 1Gbps circuit (fibre), while the secondary peering LAN is interconnected on a 450 megabit wireless backhaul. Two of the three operating locations have route servers in place. All the NIX switches provide 10/100BaseTX switched Ethernet and 1000BaseSX Gigabit Ethernet over mult-mode fibre connections. NIXP plans to expand to other cities in the near future.

NIX is overseen by the a board comprising the CEO and six directors. A technical committee assists the NIX staff and advises the Board on technical matters relating to NIX operations.

http://www.nixp.net

5.3 The London Internet Exchange (LINX)

LINX is one of the world's largest and longest established Internet exchanges. It is a mutually owned membership association for Internet operators, which also represents the interests of its members on public policy matters.

LINX currently has 399 members in 51 countries. While most of the members are from Europe, many are based outside, particularly from North America but also from Africa, the Middle East, Asia and Oceania.

Initially LINX membership was restricted just to operators of Internet access networks (traditional ISPs). In 2000 this restriction was relaxed and now a wide variety of networks peer at LINX exchanges, including the large content providers such as the Google, Yahoo and the BBC. The diversity of service providers peering at LINX is increasing, and also comprises gaming and gambling specialists, media streaming providers, DDoS mitigation specialists, software-as-a-service providers and advertising networks.

The LINX network consists of two separate Ethernet switching platforms installed across ten locations in the UK. LINX facilities have over 890 connected member ports with about 450 member-facing 10GigE ports and over 1.2Tb/sec of peak traffic. To provide fault-tolerance at least two switches from different vendors (Extreme Networks and Juniper) are installed in every LINX location, and the locations are interconnected by multiple 10 Gigabit Ethernet circuits linked via optic fibre to form two physically separate backbone rings. Physical protection of the dark fibre network is achieved by using diverse paths where available. LINX does not own any of the sites itself. At each of them LINX is a tenant in some form of co-location facility or carrier hotel.

Management of the logical redundancy of the network is carried out using rapid-failover protection mechanisms (EAPS or MRP). In the event of the loss of a network segment, these activate the redundant links within tenths of a second to restore connectivity.

http://www.linx.net

5.4 The Johannesburg Internet Exchange (JINX)

South Africa's largest city hosts the Johannesburg Internet Exchange, operated by the Internet Service Providers' Association (ISPA), a non-profit Internet industry body. ISPA currently has more than 150 members, of which about 50 are members of JINX, comprised of large, medium and small Internet service and access providers. An exchange is also operated by ISPA in Cape Town. Aside from operating these IXPs, ISPA facilitates dialogue between the different independent Internet service providers, the South African Government Department of Communications, the national regulator (ICASA), telecommunication operators and other service providers.

All members of ISPA may connect to JINX but ISPA membership is not a requirement for participating in JINX. Monthly port charges depend on the speed of each port used by an ISP. For ISPA members, there is a minimum membership requirement for access to some ports. For access to 10 Gbps and 1 Gbps ports, ISPs must be Large ISPA members. For access to 100 Mbps ports, ISPs must be either Medium or Large ISPA members. Small, Medium and Large ISPA members can all use 10 Mbps ports. Peak traffic on JINX is about 3Gbps.

All interconnection at JINX must take place via the JINX switch fabric. This means that within the JINX cage there may be no peer-to-peer interconnection, and all traffic exchanged must be via the switch. The policy does not apply to an ISP paying the 10 Gbps port charge; this gives that ISP the right to interconnect privately. A JINX user can pay the 10 Gbps port charge to gain this benefit, but make use of a lower speed port on the switch.

ISPA does not require jINX users to interconnect with all other JINX users. Each organisation is free to establish its own policy for interconnection. It is up to each user of JINX to negotiate interconnection agreements with the other JINX users. Each JINX user must provide ISPA with a clear policy for interconnection with other JINX users and must notify ISPA of any changes to this policy. Members not publishing a specific interconnection policy of their own agree to exchange traffic with all other participants on a no-charge basis. JINX members may also offer transit services to other members.

Content-server hosting is not available at the exchange. ISPA's policy is not to compete with its own members, which provide hosting services, and while it may seem appealing to host a server at a central location, ISPA points out there is a negligible difference in performance if the server is hosted on the network of an ISPA member with a high-speed connection to JINX.

An example statement of an ISP's interconnection policy is provided by the Internet access provider Storm, which states that it will exchange traffic with all other participants on a no-charge basis, provided that they:

- are in the business of providing Internet access to more than one organisation or group of companies with common shareholding;
- act in good faith and in a co-operative manner on issues relating to the interconnection;
- respect Storm's acceptable-use policy and the generally accepted Internet etiquette;
- utilise the interconnection in such a manner as to reduce the costs of exchanging traffic between the parties and improve connectivity between the parties;

- take all reasonable measures to ensure that they do not compromise the integrity or stability of Storm's network; and,
- comply with the technical requirements required to facilitate the interconnection, including ensuring that sufficient bandwidth is always available on interconnection links.

http://www.ispa.org.za/jinx

5.5 The Rwanda Internet Exchange (RINEX)

RINEX has been operational since mid 2004. In October 2003, SIDA (the Swedish International Development and cooperation Agency) began an initiative to assist Rwanda in establishing a national IXP, in collaboration with the Swedish Royal Technical Institute (KTH). Prior to this Internet providers in Rwanda had been discussing the need for an IXP but the question of funding remained an issue. For SIDA, Rwanda fulfilled the prerequisites needed for assistance including the presence of a neutral body to host the peering point, the existence of at least two independent ISPs in the country and a team of technicians from the various Internet providers trained in the techniques of setting up and maintaining a peering point. The Government's Rwanda Information Technology Authority (RITA) took responsibility for the project, with assistance from four people drawn from the two main educational institutions (which were also commercial ISPs) – the National University of Rwanda (NUR) and the Kigali Institute of Science and Technology (KIST).

A major problem in establishing RINEX was that the country did not have an industry association that could take over its management. As a result RITA is continuing to manage the exchange until its members are able to establish an appropriate management structure and non-profit institution to host it. In the interim a simple administrative model has been adopted where all members are equal independent of size. The management structure consists of 2 entities: the RINEX Council and the Executive Committee. The RINEX Council is a formal managerial unit which is responsible for making decisions regarding RINEX, having one representative from each connected organisation or member, and a president. The president for the initial 6 months is RITA. After this initial trial period, RITA will transfer the presidency to the RINEX Council. This will be continued on a rotational basis among all the members.

Finding the appropriate host for the IXP was also an issue in setting up RINEX. Obtaining an independent premises with electricity, a backup power generator, security, telephones, office space, and an air conditioner proved impossible. The academic entities in Rwanda lack physical facilities, and the private ISPs had limited capacity. So it was decided to host the IXP at the premises of the incumbent telecom operator, Rwandatel, which already had existing connections to most of the Internet providers.

A Layer-2 based IXP model was agreed by the stakeholders because of its simplicity to set up and to administer, its reliability and independence. Each network operator provides a circuit from its backbone and a router which connects to the IXP switch. As shown in the diagram below, the inner box represents the equipment that is located in the IXP premises. This consists of the IXP core and member routers and communications equipment. Currently there are 5 members of the exchange and they are all required by government to exchange routes to their customers directly with each other over the exchange.



cooperation and tacit support from governmental authorities can lead to the rapid and successful establishment of an IXP in a developing country. In January 2001, a group of leading Mongolian network operators met in Ulaanbaatar to explore the creation of a national IXP. At the time, all Mongolian ISPs were interconnected via providers in the United States or Hong Kong. As a consequence, satellite latencies amounted to a minimum of 650 milliseconds (over half a second) for each packet of data in each direction. Costs were needlessly high and not surprisingly, very few Mongolian Internet business services were hosted within Mongolia.

Without intervention from the Mongolian government, Mongolia's three leading Internet providers were able to complete planning for an independent exchange within 3 months. MIX was launched in April 2001 with three ISP members. By March 2002, the MIX had six ISP members, with steadily increasing traffic between them. Local latency was reduced to less than 10 milliseconds per transaction (compared with a minimum of 1300 milliseconds in the pre-MIX days). Moreover, each domestically-exchanged transaction effectively freed up an equal amount of international bandwidth, improving connection speeds and reducing latency over Mongolia's international links.

For further information see:

IP Traffic Exchange - Market Developments and Policy Challenges. OECD Report Dennis Weller 2011.

http://www.internetac.org/wp-content/uploads/2011/10/DSTI_ICCP_CISP20112_REV1.pdf

Internet Exchange Points. Their Importance to Development of the Internet and Strategies for their Deployment – The African Example. Global Internet Policy Initiative. Andrew McLaughlin, May 2004. www.gigiproject.org/practices/ixp.pdf

McLaughlin, Andrew and Ethan Zuckerman: <u>Introduction to Internet Architecture and</u> <u>Institutions</u>. Berkman Center for Internet and Society, cyber.law.harvard.edu/digitaldemocracy/internetarchitecture.html#Notes Huston, Geoff: Interconnection, Peering and Settlements. Internet Society, www.isoc.org/inet99/proceedings/1e/1e_1.htm

AFIX Decision-makers' Workshop: Session 1 http://afix.afrispa.org/decisionmakers/D1/D1_handout.doc

Internet eXchange Points (IXPs) and Continental Backbone for Africa: Means to an End? Internet Governance Research Project. John Walubengo, Kenneth Msiska, Timothy Kasonde Kasolo. http://www.diplomacy.edu/poolbin.asp?IDPool=127

Glossary

ASN	Autonomous System Number. Unique ASNs are allocated to Internet operators by the regional internet registries (RIRs) for use in multi-path routing. An ASN is only issued when an institution demonstrates the means to maintain an independent routing policy. This generally entails having direct interconnections with at least two other, similarly independent external network entities. In the widest sense, an Autonomous System is a connected group of one or more IP prefixes run by one or more network operators which has a single and clearly defined routing policy.
Backbone	The trunk routes of a network used as the path for transporting traffic between different networks. Backbones can be the physical telecommunication infrastructure, or the Internet circuits established over them by a particular Internet operator.
Bandwidth	The size or capacity of a communications channel to transfer data, usually measured in the speed of data transfer, in bits per second (bps), although also often stated in the frequency range assigned to the channel, measured in Hertz (Hz).
BGP	Border Gateway Protocol. The protocol standard used to ensure that there is more than one route to the Internet provider's network. BGP supports both route aggregation and classless inter domain routing (CIDR).
BLPA	Bilateral Peering Arrangement – an agreement between two networks to exchange traffic.
Bps	Bits per Second. The number of bits passing a point every second. The transmission rate for digital information, i.e. a measure of how fast data can be sent or received. Often expressed as Mbps, for Megabits per second for broadband links.
Broadband	A high speed (multi-megabit) data connection.
ccTLD	Country Code Top Level Domain. The two-letter codes which signify the origin of Internet traffic in a human readable form, e.g. 'es' for Spain, 'br' for Brazil.
Connection Redundancy	Two or more physically separate connections via different network providers. Redundancy ensures continued links to the Internet in the event of one connection going down.
Domain Name System (DNS)	The Domain Name System (DNS) matches human readable/more memorable names with the IP addresses needed to route traffic. The DNS uses a tree structure which divides the internet into a hierarchical structure of domains and subdomains. Top-level domains (TLDs) include generic domains such as .com, .edu and .org, and country code domains – ccTLDs – such as .uk, .za, .gh or .ke. Administrators of each TLD can create as many subdomains as they wish. An international network of DNS servers, maintains up-to-date information about which domain name goes with each IP address; changes can be made on any one server and are rapidly propagated through the network.
Fibre optic cable	A technology using glass fibre for the transmission of data. The signal is imposed on the fibre via pulses (modulation) of light from a laser or a light-emitting diode (LED). Because of its high bandwidth and lack of susceptibility to interference, fibre optic cable is used in long-haul or noisy applications. With advances in modulation technology,

	international fibre cables are now usually deployed with terrabit capacities.	
Gbps	Gigabits per second	
Gigabit	One billion bits.	
Interconnection	Interconnection refers to any direct connection between two networks which could be private or commercially operated Internet-based networks, or the telecom networks of fixed or mobile operators. The cost of interconnection is usually paid for by the two parties on each end of the connection.	
International gateway	Technically, this is a facility to consolidate and share the cost of international links and termination points. In practice it is a licensing term used by many developing country governments who may only allow the state owned monopoly operator and perhaps a small number of other licensed telecom operators to carry international traffic. Most often these are the licensed mobile operators.	
Internet	A global mesh of computer networks using the same communications protocol called TCP/IP. The Internet's national and international backbones are high-speed fibre trunk lines owned by telecommunication companies. National Tier-1 service providers aggregate data traffic and pass it over the backbones. They work with local service providers who connect to customers via digital links or modems.	
IRR	Internet Routing Registry – a globally distributed routing information database used to ensure stability and consistency of the Internet-wide routing by sharing information between network operators. The IRR consists of several databases in which network operators publish their routing policies and their routing announcements such that other network operators can make use of the data. In addition to making Internet topology visible, the IRR is used by network operators to look up peering agreements, determine optimal policies, and more recently, to configure their routers.	
ISP	Internet Service Provider – a generic term for organisations providing Internet services such as web site hosting and Internet access. Internet Service/Access Providers purchase bandwidth from other companies that have direct links to the Internet. The Internet Service/Access Providers in turn sell that bandwidth to consumers and businesses in smaller chunks. For example, an ISP may take the bandwidth of a 45Mbps connection to the Internet and sell it to thousands of 56Kbps dial-up modem users.	
IXP	Internet Exchange Point, also called IX, EP, NAP, or Peering Point. An IXP is both a physical networking location and a logical networking strategy which facilitates interconnection between Internet-based networks.	
Leased Line	A telecommunications circuit, usually rented from a telecom operator to connect two or more locations. Where regulations allow, and the physical location of the two points to be connected makes it feasible, Internet providers may be able to establish their own wireless, cable or fibre link, thereby eliminating the need to lease a circuit from a third party.	
Looking glass	A web-based connection to a router that allows administrators of other networks to look at a network's routing information. Looking glass information may or may not be made available to the broader public.	

MAN	Metropolitan Area Network - usually a fibre optic ring spanning a large city.	
Mbps	Megabits per second. A unit of traffic measurement.	
Megabit	One million bits.	
MLPA	Multilateral Peering Agreement – An agreement by networks connecting to an IXP to exchange data with all other networks connected to the peering point. This agreement is often mandatory when joining an IXP.	
Network	A network running transmission control protocol/internet protocol (TCP/IP). Networks may be commercially run by ISPs, or by any other organisations for their internal purposes, such as companies, and academic networks. 'Network' can also refer to the underlying telecommunication infrastructure, but this is less common in the Internet world.	
Peering	Peering is a zero compensation arrangement where network operators agree to exchange traffic at no charge. This arrangement is common where the networks have roughly the same characteristics and traffic volumes, such that net financial burden from traffic flows between them is likely to be small. In a peering agreement, there is no obligation for the peer to carry traffic to third parties. The process by which a network qualifies for peering is usually privately negotiated based on market position, network coverage, volume of traffic, range of services provided and network reliability. In general, peering only takes place when one of the two networks would not be significantly disadvantaged by termination of the link between them.	
Petabit	One thousand terabits	
PSTN	Public Switched Telephone Network – the traditional voice telephone system, based on switched (rather than packet) networking protocols, usually based on TDMA.	
РТО	Public Telecom Operator, usually refers to the incumbent state-owned monopoly operator, although technically, the distinction between fixed line, cellular operators and ISPs is becoming increasingly blurred.	
RIR	Regional Internet Registry. The five organisations responsible for allocating IP addresses to network operators in their respective regions – Africa, USA, Asia Pacific, Latin America and Europe – AfriNIC, ARIN, APNIC, LACNIC and RIPE NCC.	
Route Server	One or more IXP BGP route server peers which collect and redistribute IXP member routes.	
ROW	Rest of the World.	
TCP/IP	Transmission Control Protocol and Internet Protocol are the two protocols that form the basis for the Internet. Currently most of the Internet is based on version 4 of the IP protocol, but this is changing steadily to version IPv6.	
Terrabit	One thousand Gigabits	
Transit	Transit is an arrangement in which a network sells access to another network to allow it to connect to a third party network. Transit charges are set by negotiation, and are often not disclosed publically. Transit arrangements typically provide access to an array of networks, not	

	limited to one country. In many cases one Internet transit arrangement with a large network can provide a small, remote network with access to the Rest of the World (ROW).
TDMA	Time Division Multiple Access. A commonly used communications protocol used on traditional switched telecommunication networks.
VoIP	Voice over the Internet Protocol – a method to use TCP/IP protocols to carry voice calls. This is not voice-over-the-Internet Protocol, but is based on standard packet switching protocols, supported by additional higher-level protocols such as SIP and H.323.
VPN	Virtual Private Network. An encrypted channel between two end-points on the Internet to provide secure communications.
WiFi	Wireless Fidelity
WiMax	World interoperability for Microwave access

Further Resources

A session at the forthcoming Internet Governance Forum (IGF) 2008 in India is being planned to focus on strategies for encouraging the emergence of more IXPs. http://www.intgovforum.org

A variety of organisations around the world are making efforts to support the establishment of new IXPs and to help ISPs and existing IXPs improve access, functionality and lowered costs. These include:

The Asia Pacific Operators Forum (APOPS). http://www.apops.net

APRICOT (Asia Pacific Regional Internet Conference on Operational Technology). http://www.apricot.net

The African Internet Exchange Point Task Force (AFIX-TF). http://afix.afrispa.org/

The African ISP Association (AfriISPA). http://www.afrispa.org

The Association for Progressive Communications (APC). <u>http://www.apc.org</u>

EP.NET, LLC. http://www.ep.net

The European Internet Exchange Association (Euro-IX). http://www.euro-ix.net

The European Internet Services Providers Association (EuroISPA). <u>http://www.euroispa.org</u>

The European Operators Forum WG (EOF). http://www.ripe.net/ripe/wg/eof

The International Telecommunication Union (ITU). http://www.itu.int

The Internet Society (ISOC). http://www.isoc.org

The Latin American and Caribbean Region Network Operators Group (LACNOG) mailing list. <u>https://mail.lacnic.net/mailman/listinfo/lacnog</u>

The London Internet Exchange (LINX). http://www.linx.net

The Middle East Network Operators Group (MENOG). http://www.menog.net

The Network Startup Resource Centre (NSRC). http://www.nsrc.org

The North American Network Operators' Group (NANOG). <u>http://www.nanog.net/</u>

The Organisation for Economic Co-operation and Development (OECD). <u>http://www.oecd.org</u>

The Packet Clearing House (PCH). http://www.pch.net

The PCH Directory of IXPs. http://www.pch.net/ixpdir

The South Asian Network Operators Group (SANOG). http://www.sanog.org/

The World Bank's InfoDev unit's ICT Toolkit. http://icttoolkit.infodev.org

The World Information Technology and Services Alliance (WITSA). <u>http://www.witsa.org</u>