Connectivity in Latin America and the Caribbean

The Role of Internet Exchange Points

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1. Introduction

Internet connectivity is increasingly recognized as a fundamental lever for development. While basic connectivity to the global Internet is available throughout Latin America and the Caribbean region, the state of the Internet infrastructure varies widely between countries as well as among geographical areas within countries themselves. This results in large variations in the price, the quality, and the coverage of Internet access services across the region.[1] Improving the state of Internet infrastructure is a major challenge for the region over the next decade.

Both theoretical models and practical experiences indicate that further development of Internet exchange points (IXPs) in the region can make a significant contribution to this goal. IXPs refer to interconnection facilities in which different players in the Internet ecosystem (ISPs, content providers, hosting companies, etc.) exchange IP traffic. They range from small exchanges interconnecting local ISPs at the city or municipal level to large distributed facilities connecting hundreds of networks at the regional level. This report takes stock of the development of IXPs in Latin America and the Caribbean, documenting best practices in four selected cases: Argentina, Brazil, Colombia and Ecuador. It argues for accelerating the development of IXPs as a necessary step towards improving the quality and coverage of access services in the region.

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[1] This is well documented by Jordán et al. (2013) and Galperin (2012), among many others.

2. The Case for IXPs: Key Facts

As a network of networks, the Internet critically depends on adequate interconnection between the different participants in the Internet ecosystem. For simplicity, these may be divided into:

- Internet Service Providers (ISPs), which sell access services to end-users in local markets (residential and corporate);
- Internet backbone providers, which sell wholesale connectivity to ISPs (and other very large network customers);
- Content providers and aggregators, who either buy distribution from specialized vendors (e.g., Akamai) or connect with their own infrastructure to backbone providers and ISPs.[2]

The interconnection arrangements between these actors have varied over time, and depend on factors such as the parties' location in the Internet topology, the amount of traffic generated and the network infrastructure they operate. There are two basic types of IP interconnection agreements:

1. **Peering.** In a peering agreement two or more network operators agree to provide each other access to their customer base for the exchange of IP traffic. The decision to peer is a matter of commercial negotiation between the parties, and generally requires that networks share similar characteristics in terms of network capacity, geographical coverage and quality of service provided. Balanced traffic loads are also important for peering, in order to share costs and benefits equally between contracting parties. Peering was originally the privilege of very large backbone providers located in the US and Europe (the so-called Tier 1 operators).[3] Today, peering is also common between local ISPs, large content providers and other network operators (this is often called secondary peering). Peering is typically a settlement-free agreement, although paid peering is increasingly common.
2. **Transit.** In a transit arrangement, a network operator (e.g., a local ISP) pays a higher-level operator (e.g., a backbone provider) for access to the global Internet. Unlike peering, under a transit agreement the sending party must pay the full cost of interconnection. Transit prices are negotiated between the two parties, and depend on market conditions and traffic volume. It is important to note that, while in a peering arrangement the parties will only have access to each other's downstream customers (in other words it is not transitive to other agreements the parties may have), in a transit agreement the paying party buys access to all Internet destinations from the selling party. Peering therefore requires agreements with multiple other parties in order to reach all possible Internet destinations, while a single transit connection allows an ISP to access the entire Internet.

The architecture of the early Internet presented a clear hierarchy between a few large Tier-1 networks peering at the core (located in the U.S. and Europe), and a vast number of regional (Tier-2) and local (Tier-3) networks at the edges, where transit agreements prevailed. Today's Internet is less of a hierarchy than a complex mesh of peering and transit between ISPs of various sizes and coverage, regional and international backbone providers, and content providers and distributors that many times own and operate infrastructure comparable to large ISPs.[4]

Peering may be further divided into bilateral and multilateral

[2] For further discussion see Clark et al., 2011.
[3] Although there is no formal definition of a Tier 1 operator, it commonly refers to network operators who are able to reach all Internet destinations through peering agreements.
[4] For further discussion see Yoo (2010).

peering. Bilateral peering refers to agreements between two network operators, which decide to exchange traffic at one or more locations. Multilateral peering refers to IP traffic agreements in which network operators exchange traffic at third-party locations to which several other operators are also connected. Because peering is costly (requiring physical connections, routers and other equipment at each peering point), the availability of neutral points of IP traffic exchange for multiple parties reduces overall capital expenditures and other costs associated with bilateral peering. These locations are generally referred to as Internet Exchange Points (IXPs).

The general benefits of IXPs have been well-documented in several studies. They include:

- **Lower interconnection costs.**[5] A single connection to an IXP allows peering with multiple other operators. In turn, the more parties are connected to an IXP, the more valuable it becomes, further attracting new members. This classic example of positive network effects provides a strong rationale for the development of IXPs.
- **Enhanced quality of service.** IXPs allow adjacent networks (such as two local ISPs) to exchange traffic directly, reducing the number of hops for data packets traveling between operators, thereby reducing latency as well as transit costs. When content distribution networks (CDNs) and other large content providers peer directly at IXPs, the quality of access to popular content is dramatically increased. The presence of IXPs also increases the number of routes available, further enhancing network performance and resiliency.
- **Incentives for infrastructure investments.** Local ISPs tend to be at the bottom of the Internet hierarchy, and in many cases are little more than resellers of Internet connectivity supplied by larger ISPs. IXPs provide

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[5] Among them Cavalcanti (2011) and Kende and Hurpy (2012).

incentives for local ISPs to invest in their own physical infrastructure in order to transport traffic to a neutral point where it can be negotiated or aggregated with other networks. By controlling their own infrastructure local ISPs are able to climb the so-called "ladder of investment" and compete at higher levels in the Internet value chain.[6]

For a number of reasons, the case for IXPs is particularly strong in emerging regions such as Latin America and the Caribbean. First, IXPs allow local traffic generated by neighboring ISPs to remain local, thus minimizing tromboning, a common process whereby local ISPs exchange traffic over transit routes provisioned by international backbone operators. Minimizing international tromboning is an important factor since, in contrast to the regime that regulated international interconnection tariffs in voice telephony (the so-called "accounting rate" system), there are no provisions for cost-sharing between IP network operators exchanging traffic across borders.[7] International connectivity thus represents an important cost factor for ISPs in emerging regions.[8]

Second, IXPs have a positive impact on quality of service through several mechanisms. As mentioned, keeping traffic local reduces latency, which as discussed below remains high over many routes within Latin America and the Caribbean. In addition, the increase in traffic at the IXP creates incentives for content providers to place their content closer to end-users by installing content caches or creating more direct routes to server hosts. When content providers peer directly at IXPs, the transit requirements of its members are significantly reduced. Lastly, IXPs create cooperative mechanisms to share best practices on issues such as network security and spam control, which also facilitate the adoption of innovations (such as IPv6) among the local Internet community. Given that interconnection agreements between network operators remain highly informal (Weller and Woodcock, 2013) and often do not involve service-level agreements (SLAs), building cooperation and trust among network peers is essential for the growth of the local Internet ecosystem.

Third, IXPs play an important role in promoting Internet development in areas serviced by small and medium-size ISPs, which tend to be poorer and more isolated than those serviced by larger ISPs.[9] By peering at an IXP, these operators can not only exchange local traffic but, even more critically, aggregate outbound traffic. This allows small and medium-size ISPs to collectively negotiate better transit prices, and to attract peering from content providers. When sufficient traffic is aggregated, international backbone providers have incentives to establish PoPs closer to the IXP, thus balancing international transit costs more evenly between parties. As mentioned, IXPs also create incentives for small network operators to invest in their own infrastructure in order to reach a neutral point where traffic can be negotiated with other participants.

Figure 1 summarizes IXPs' contribution to the Internet ecosystem's growth in emerging regions at different stages of development. These are stylized facts that can vary significantly from country to country. The key points are:

- At the early stages of Internet development (transition from stage 0 to stage 1), the establishment of an IXP (generally in the main city or country capital) contributes to control costs and enhance quality by minimizing international tromboning between adjacent ISPs. The primary value proposition of the IXP in stage 1 is therefore to localize traffic among operators of comparable size and reach. Multilateral peering is often made mandatory in IXPs at stage 1.
- As the IXP matures and traffic grows (transition from

6 For further discussion about the ladder of investment model see Cave (2006).
7 For further discussion about these differences see Lie (2007).
8 Though estimates of this cost vary widely, more reliable figures put it at 15–35 percent of total costs for ISPs (Lie, 2007). These costs tend to be significantly higher for ISPs in countries where international bandwidth is under-provisioned due to poor access to submarine cable capacity and/or monopoly control of international gateways by incumbents (Garcia Zaballos et al., 2011).
9 Specific examples from Latin America and the Caribbean can be found in Galperin and Bar (2007) and Aranha et al. (2011).

stage 1 to stage 2), domestic and international content providers as well as other noncommercial networks (universities, government agencies, etc.) establish a presence at the IXP. This further reduces transit costs and significantly increases service quality (in particular when popular content is cached locally or peered directly), resulting in a more affordable and better experience to end users. At this stage some ISPs may decide to peer bilaterally for competitive reasons. The key value proposition for IXPs in stage 2 is to provide a neutral interconnection platform for agreements (paid or unpaid) between a more heterogeneous group of network operators.

- As more networks join and traffic continues to grow (stage 2 to stage 3), the IXP becomes a knowledge-sharing hub, contributing to build a community of practice among network peers. The IXP becomes a virtual network of data centers with PoPs in several locations across the country, thus promoting infrastructure growth in less populated markets. The IXP also expands into additional services to its members such as DNS root servers and network security training.

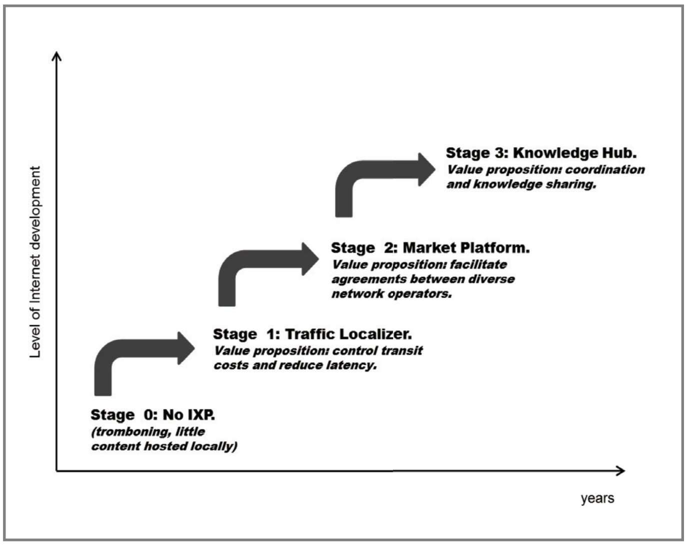

Figure 1. Value Proposition of IXPs by Level of Internet Development

3. The State of IXPs in Latin America and the Caribbean

The current state of IXPs in Latin America and the Caribbean can be summarized as follows:

- **There are 46 IXPs operating in the region in 16 different countries.**[10] This means that only about a third of countries in the region (including dependent territories) have an operational IXP. For comparison, there are 25 IXPs in Africa located in 19 countries (also about a third of the countries in the continent), 88 in North America (US and Canada) and over 130 in Europe.
- **The situation of IXPs differs significantly across the region.** While there are IXPs operating in most countries in South America (though with varying levels of development), Central America accounts for a single IXP (in Panama). The entire Caribbean region is served by only six IXPs (in Cuba, Dominica, Grenada, Haiti, Curaçao and Sint Maarten).
- **IXPs in Latin America tend to be relatively small, peering on average 12 operators (slightly more in South America and less in the Caribbean).** The exception is PTT Metro São Paulo, by far the largest in the region, where over 300 networks exchange traffic (making it the seventh-largest worldwide in terms of participants). For comparison, large IXPs in Europe are peering over 500 networks.
- **IXPs in the region tend to operate as noncommercial organizations administered by its members or under the umbrella of trade associations.** Brazil is the exception, where Terremark (owned by Verizon) operates NAP Brasil under agreement with Fapesp, a public research foundation. However there are many other datacenters where networks peer bilaterally. In Chile, there are several private IXPs (PITs) operated by large ISPs themselves (this is further discussed below).
- **Operational costs are typically shared proportionally to the number of ports and capacity (such as rack space) utilized by each member.** When additional services (such as transport and access to content caches) are offered, costs are allocated according to actual traffic generated by each participant.
- **Many IXPs in the region require multilateral peering, whereby each member agrees to exchange traffic with all other members.** This rule creates negative incentives for large operators, and implies that traffic imbalances must be compensated with other advantages associated with IXP membership. Some IXPs also allow private or bilateral peering at their premises.
- **The volume of traffic exchanged varies widely.** PTT Metro in São Paulo exchanges 135Gbps during peak times. On the other hand, other IXPs located in smaller countries or at the local (e.g., municipal) level exchange 100Mbps or less. Whether the incumbent ISPs are members is a key factor determining traffic volumes. For international comparison, DataIX in Russia exchanges 460Gbps, while the largest European IXPs exchange over 2Tbps during peak times.
- **IXP membership is increasingly diverse.** Most IXPs in the region started as associations composed almost exclusively of local ISPs (stage 1). As they evolved (stage 2) participants became more diversified, and today include content providers, government agencies, international backbone operators and academic research networks. Unlike other regions such as Europe and Asia, it is uncommon for network operators based in one country to establish a presence in an IXP located in another country (the sole exception is the presence of

[10] Source: Packet Clearing House and author analysis. This excludes exchange points ran by operators themselves such as in the case of Chile.

Uruguayan operator Antel as a member of NAP Buenos Aires in Argentina).

- **Government regulation of IXPs in the region is minimal.** The exceptions are Bolivia and Chile, where by law ISPs must exchange national traffic locally and interconnection quality is regulated.[11] However, policymakers' concerns about the cost and quality of Internet services (either at the national or local level) have often played an important catalyst role for the establishment of IXPs.

The first IXPs in Latin America were established in the late 1990s. Until then, the lack of local interconnection points was largely a result of two factors. First, the early development of the core Internet infrastructure in the US, where most content was located and where most traffic was exchanged. As a result, local ISPs competed on the basis of price/quality of their routes to the U.S. Since local traffic was very limited, tromboning this traffic through international transit routes represented a cost-effective solution. Second, the relative slow pace of liberalization of telecommunications markets in the region kept domestic transport prices high, thus discouraging local peering.

The ground became significantly more fertile for IXPs in the late 90s. On the one hand, the benefits of market reforms in the telecommunications sector implemented during the early 1990s began to materialize, as competition from new entrants began to exert downward pressure on domestic transport prices. Further, as the base of subscribers grew and infrastructure investment intensified, more content began to be hosted locally. Overall, legacy barriers for the development of IXPs in the region were progressively lifted, while changes in traffic patterns created incentives for network operators to localize traffic exchange.

While there are IXPs operating in most countries in South America (though with varying levels of development), Central America accounts for a single IXP. The entire Caribbean region is served by only six IXPs.

[11] In the case of Chile, the regulation dates back to SUBTEL Resolution 1483 of October 1999. In Bolivia, a new interconnection regime passed in October 2012 required that ISPs set up an interconnection point within the country, which is yet to be established at the time of writing (July 2013).

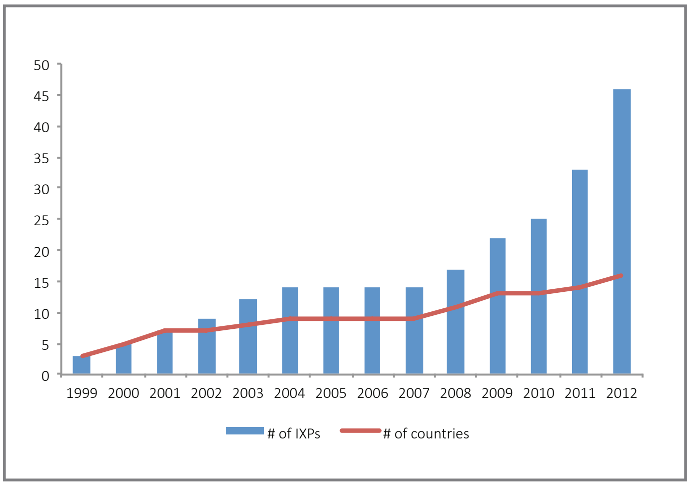

Figure 2. IXPs in Latin America, 1999–2012 *(Source: Author analysis based on data from Packet Clearing House)*

Figure 2 corroborates the steady growth of IXPs in the region since 1999. Yet it also reveals that the number of countries with operating IXPs has not grown at the same rate (the CAGR over the period is 22% for total IXPs but 13% for the number of countries). The reason is that most of the growth has been concentrated in two countries, Argentina and Brazil, where IXPs were first established in the region. On the one hand, this confirms the positive feedback effect brought about by IXPs: local traffic growth creates incentives for the establishment of an IXP, which further promotes growth of the entire national Internet ecosystem. On the other, it suggests the need for IXP development initiatives to correct for these imbalances and catalyze infrastructure growth in markets which currently lack adequate interconnection facilities for local network operators.

4. IXPs in Action

As previously explained, IXPs can positively affect Internet development in Latin America and the Caribbean by reducing access costs, increasing quality, and promoting infrastructure investments in more isolated communities serviced by small and medium-size operators. In addition, IXPs promote knowledge transfer and coordination among the local Internet community, which further helps growth of the ecosystem as a whole. The examples selected below illustrate and provide preliminary quantitative estimates of this contribution.

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4.1. How IXPs help reduce transit costs

Until recently, underprovisioning of international capacity severely restricted the development of Internet services in Ecuador. As the country was bypassed by the main undersea cable in the western coast of the continent (the SAm-1 cable), direct international connectivity was restricted to the older Pan-American cable, in which capacity was often saturated. Much international traffic was routed through Colombia, adding significant transport costs. Not surprisingly, retail Internet services in Ecuador were among the most expensive in the region, as ISPs faced steep transit costs in their international routes (Albornoz and Agüero, 2011).

The establishment of the first IXP in the country in 2001 was a direct response to this problem. NAP.EC was initially formed by six ISPs with the primary goal of reducing transit costs by exchanging local IP traffic (stage 1 of IXP development). Two exchange points were established in the cities of Quito and Guayaquil, which were later interconnected in 2007. While the original members were small to medium-size ISPs, larger operators (such as the state-controlled incumbent CNT) and content providers were progressively interconnected (stage 2). Currently NAP.EC interconnects a variety of networks, from international backbone operators such as Level 3 to large content distributors such as Google and Akamai, in addition to many local ISPs (see current network topology in Annex 1). As NAP.EC matured, it began to promote the introduction of new Internet protocols (such as IPv6) as well as agreements about anti-spam filtering among its members, thus expanding into a critical knowledge hub for the local Internet community (stage 3).

The costs savings made possible by NAP.EC can be estimated as follows: NAP.EC currently exchanges about 6Gbps during peak traffic. International transit costs in Ecuador hover around USD $100 per Mbps per month.[12] By contrast, local traffic can be exchanged at NAP.EC for as little as USD $1 per Mbps per month. Assuming that in the absence of NAP.EC operators would exchange local traffic through international transit routes (i.e., assuming no bilateral peering agreements), the additional wholesale costs for local ISPs would be USD $7.2 million per year. Even discounting the costs associated with peering at the IXP (transport to the IXP facilities, membership fees and related equipment) and bilateral peering for part of this local traffic, the cost savings associated with NAP.EC are very significant.

The case of NAP CABASE in Argentina illustrates a related mechanism through which IXPs contribute to reduce access costs, specifically in less populated areas. Argentina ranks high in Internet adoption in the region, and in contrast to Ecuador has abundant international bandwidth capacity, which has helped keep international transit prices low in regional comparison. **Yet due to high domestic backhaul prices, ISPs outside the primary fiber routes connecting Buenos Aires with other large cities faced significant domestic transit costs. Moreover, transit services were often available exclusively from the former telecom incumbent, which also competed with its own Internet retail services. As a result, access prices remained significantly higher in less populated cities, thus slowing market growth.**[13]

CABASE is a trade group of small and medium-size ISPs and other network operators. Drawing on its experience operating NAP Buenos Aires, the first IXP in Argentina (and in the entire region), CABASE embarked on an initiative to establish IXPs in small and medium-size markets across Argentina. The new IXPs would not only allow local network operators to exchange traffic but also to interconnect through NAP Buenos Aires, thus forming a virtual IXP with national reach. With support from the local government, the first IXP was established in the city of Neuquén in May 2011. To date, nine IXPs are operational, connecting over 80 network operators through a central routing hub in NAP Buenos Aires.

The cost benefits associated with the initiative can be divided into a) savings resulting from the aggregation of outbound traffic by local ISPs and b) savings from peering for local traffic exchange. First, by aggregating outbound traffic at the IXP, small network operators were able to negotiate better contract terms with upstream transit providers. For example, in the city of San Martin de los Andes (population 25,000), Internet transit costs were as high as USD $500 per Mbps per month for COTESMA, a local telecoms cooperative. Once the Neuquén IXP became operational (May 2011), COTESMA was able to buy Internet transit at the premises at prices comparable to those in Buenos Aires (USD $100 or less per Mbps per month). As more IXPs were established the national transit market was further disrupted, with prices declining to current levels of about USD $40 per Mbps per month.[14]

Second, the wholesale cost savings associated with local traffic exchange at the new IXPs can be estimated as follows. Before the establishment of IXPs in other cities, NAP Buenos Aires was exchanging around 2Gbps during peak traffic. Today traffic peaks are as high as 12Gbps (figure 3). Again, assuming this additional 10Gbps of traffic was previously exchanged between local operators over transit agreements,

[12] Estimate based on personal interviews. See also Mejia, Fabian, "NAP.EC e IPv6," presented at IPv6 in Ecuador, June 6, 2012. Available at 02 presentacion nap_ec ipv6_2012-06-06.pdf.

[13] As an example, in the second quarter of 2011 the monthly cost of an ADSL connection at 1Mbps in Buenos Aires was AR $109, while the equivalent service sold for AR $200 in Cutral Có-Plaza Huincul, a city of 50,000 in the southern province of Neuquén. Source: author's price database (available on request).

[14] Source: personal interviews.

and assuming a very conservative transit cost estimate of USD $100 per Mbps per month (as the example of COTESMA shows prices were much higher for some ISPs), the new IXPs are generating wholesale savings of USD $12.3 million per year. Even discounting transport costs to the IXP (which as explained below aggregate traffic from large geographical areas), IXP fees and related equipment costs, the savings are very significant, and tend to be higher for operators in less developed markets.

4.2. How IXPs help improve service quality

Service quality is an important factor for the development of the Internet ecosystem. Several studies reveal that high latency discourages adoption and reduces use.[15] Poor quality also stymies the growth of the over-the-top (OTT) industry (particularly in VoIP and video streaming services), while it encourages content providers to host outside the country, limiting the scale of the local market and thus further aggravating quality. In the absence of higher-quality services, local Internet markets tend to be trapped in a cycle of low adoption, low traffic volumes, little local content and applications, and ultimately slow Internet growth.

As noted, **IXPs help unlock growth by reducing latency, by increasing route redundancy, and by facilitating content location closer to end-users.** The Colombian case illustrates the quality benefits associated with IXPs. The Colombian exchange point (called NAP Colombia) was started in 2000 in response to the frequent disruptions in the domestic backhaul lines and international links of the incumbent telecommunications operator Colombia Telecom. By exchanging traffic locally (stage 1), and later by installing caches of large content providers (stage 2), local ISPs were able to reduce their dependence on international routes, thus reducing costs but, most importantly, increasing service

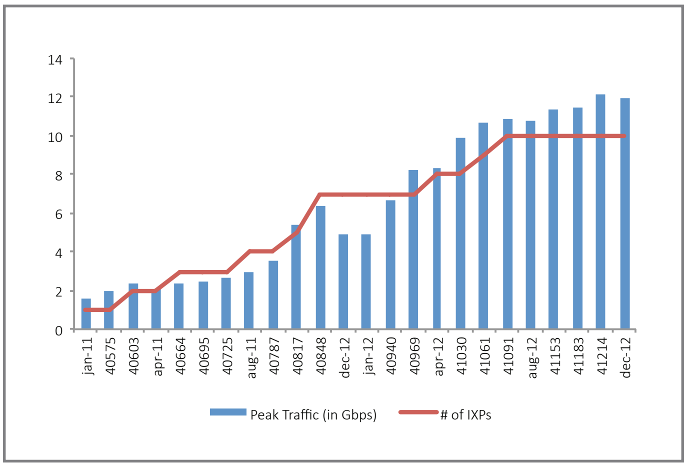

Figure 3. Peak Traffic at NAP Buenos Aires and Number of IXPs in Argentina, 2011–12 *(Source: CABASE)*

[15] See Nokia (2009).

An AEPROVI, Cisco, LACNIC, and Internet Society-Supported Resource Public Key Infrastructure (RPKI) Training Workshop Offered in Quito, Ecuador.

One of the biggest challenges for Internet growth in Latin America and the Caribbean in the next decade is the mitigation of regional imbalances in basic infrastructure and access.

reliability.[16] Today, while the physical infrastructure is more robust and outages are infrequent, NAP Colombia remains strong not only in terms of traffic exchanged (currently at 18Gbps during peak times and growing at 5% annually) but also in terms of additional services provided to members (stage 3), which account for 95% of Colombian Internet subscribers.[17]

Because of its privileged geographical location and adequate supply of international bandwidth capacity, latency in the routes to the US is a relatively limited concern for Colombian operators, with estimates of about 45ms from the capital city Bogota to the NAP of the Americas in Miami. Yet this compares to a latency of 3ms for local traffic, which provides a strong rationale for hosting content locally. Interestingly, latency is significantly higher in routes from Colombia to other Latin American countries such as Brazil (150ms) and Argentina (190ms), which illustrates the deficiencies in regional connectivity between countries in the continent (see Garcia-Zaballos et al., 2011).[18]

Reduced latency is not the only mechanism by which IXPs contribute to service quality. As noted, IXPs provide incentives for large content distributors to place content closer to end-users, thus significantly improving the quality of access to popular sites. In Ecuador, after installing the first CDN cache in its Quito facilities in 2009, NAP.EC saw traffic increase over 700%. Today both Google and Akamai have local caches at NAP.EC, which in turn has significantly increased the value of peering at the IXP for other networks. Latency for local content is reported at about 20ms, compared to 150ms for content located abroad.[19]

In Argentina, according to estimates by several ISPs, Google properties accounted for about 70% of the traffic over transit routes.[20] Since October 2011, a combination of caches and

16 Source: personal interviews.
17 Source: NAP Colombia.
18 Source: CCIT (2012). Similar results are reported by de Leon (2012).
19 See Mejia, Fabian, “NAP.EC e IPv6”, presented at IPv6 en Ecuador, June 6, 2012. Available at 02 presentacion nap_ec ipv6_2012-06-06.pdf.
20 Source: personal interviews.

peering with Google at NAP Buenos Aires has localized this traffic for ISPs participating in the national IXP initiative, thus reducing costs but most importantly increasing quality of access to popular content. For example, ISPs in Neuquén estimate that latency to Youtube and other Google properties has since dropped by a factor ten (from over 300ms for routes to the NAP of the Americas in Miami to about 34ms over the Neuquén-Buenos Aires link).

Further, as IXPs evolve into knowledge hubs (stage 3) they contribute to a more robust infrastructure by promoting cooperation in the adoption of new protocols and network security standards, as well as by facilitating availability of critical ISP services. Many IXPs in the region provide optional services to its members such as DNS root servers and antispam filtering. In addition, IXPs in the region have been instrumental in disseminating technical expertise on critical issues such as the transition to IPv6. IXPs also help comply with local content regulations, such as the filtering of child pornography sites in Colombia. At the regional level, informal cooperation between IXPs has always existed, with organizations such as LACNIC and the Internet Society providing critical support for knowledge sharing and technical dissemination activities. In April 2012 such cooperation was formalized with the launch of LAC-IX, a regional association of IXPs. LAC-IX members include seven of the largest IXPs in the region, as well as other supporting organizations. Among its key

City	State	Pop. (in 000s)	# peers	Peak traffic (Mbps)
Americana	SP	213	12	39
Belem	PR	1.392	11	879
Belo Horizonte	MG	2.375	25	2,000
Brasilia	DF	2.562	17	2,510
Campina Grande	PB	383	13	42
Campinas	SP	1.080	25	2,660
Caxias do Sul	RS	410	4	7
Curitiba	PA	1.746	38	5,400
Florianopolis	SC	408	25	1,100
Fortaleza	CE	2.447	13	1,100
Goiania	GO	1.301	20	256
Londrina	PA	766	22	1,800
Manaus	AM	1.802	2	1
Natal	RN	806	9	128
Porto Alegre	RS	1.409	55	7,640
Recife	PE	1.536	10	117
Rio de Janeiro	RJ	6.323	29	6,300
Salvador	BA	2.676	37	3,050
São Jose Campos	SP	615	12	316
São Jose Rio Preto	SP	425	2	4
São Paulo	SP	11.244	306	135,000
Vitoria	ES	320	9	359

Table 1. Snapshot of the PTT Metro Initiative (Location, Members and Peak traffic), April 2013 *(Source: CGI and IBGE)*

Name/City	State	Pop. (in 000s)	# peers	Peak traffic (Mbps)
NAP Cordoba	Cordoba	1,390	9	100
NAP Bahia Blanca	Buenos Aires	301	12	180
NAP de la Costa	Buenos Aires	70	5	90
NAP La Plata	Buenos Aires	731	8	120
NAP Mar del Plata	Buenos Aires	765	4	270
NAP Mendoza	Mendoza	916	9	130
NAP Neuquén	Neuquén	233	13	750
NAP Rosario	Santa Fe	1,251	16	180
NAP Santa Fe	Santa Fe	500	8	55

Table 2. Snapshot of the CABASE Initiative (Location, Members and Peak traffic), April 2013 *(Source: CABASE and INDEC)*

objectives are "to share best practices" and "to simplify the cooperation among the IXPs to address operational issues, deploy new services, address security related events".[21]

4.3. How IXPs promote infrastructure investment in smaller markets

One of the biggest challenges for Internet growth in Latin America and the Caribbean in the next decade is the mitigation of regional imbalances in basic infrastructure and access. As many studies have shown, such imbalances both reflect and reproduce long-term economic and social disparities that characterize the region, while the impact of universal service programs designed to alleviate them has been modest at best.[22] As Galperin and Bar (2007) argue, small and medium-size telecommunications operators can make an important contribution to mitigate such regional disparities across the continent, as they typically provide services in less populated and more isolated areas of little interest to larger firms.

IXPs are vital to the development of small and medium-size ISPs for the several of the reasons already noted. They are critical for aggregating traffic in smaller markets, allowing network operators to negotiate better transit prices, while also making local caching or peering more attractive for content providers and other larger networks. They also provide incentives for ISPs to build their own physical infrastructure and invest in switching equipment

[21] LAC-IX statute. Available at www.lac-ix.org.
[22] See among many others Stern (2009) and Barrantes (2011).

and logical resources, for example by requiring that members run their own ASN (Autonomous System Number). Further, they play a critical role as a knowledge hub for operators with very limited ability to invest in human capital and R&D. **A cooperative approach to technological evolution is a necessity for small network operators.**

The case of Brazil illustrates these points. Until 2003, only three cities in Brazil (the fifth largest country in the world by area) had an operational IXP. This resulted in significant tromboning of local traffic, negatively affecting both costs and quality of service outside the larger urban areas. In 2004 the Comitê Gestor da Internet (CGI), a multistakeholder body responsible for coordinating and promoting the development of the Internet in Brazil (including administration of the .br domain name), launched an initiative called PTT Metro to create IXPs in cities across the country.

The first IXP of the initiative was established in the city of São Paulo in late 2004. As noted, PTT Metro São Paulo is now the largest in the region both in terms of peers and traffic exchanged. By 2008 the initiative had expanded into eight cities. As of April 2013 there were 22 IXPs in operation, covering 16 of Brazil's 26 states (see Table 1). On aggregate, the IXPs associated with the PTT Metro initiative are exchanging over 170Gbps at peak time. While PTT Metro São Paulo explains much of this growth, traffic in most PTTs has at least doubled during 2012.[23]

It is also worth noting that the largest PTTs cover wide metropolitan areas (such as PTT São Paulo, PTT Rio de Janeiro, PTT Porto Alegre and PTT Brasilia) and operate as virtual IXPs with many distributed interconnection locations. These points-of-presence, called PIX, have been established by a variety of network operators (from universities to large ISPs themselves), with CGI responsible for network administration. Such a distributed architecture reduces transport costs for smaller players while still providing a neutral platform for traffic exchange with other network operators.

Further, as Cavalcanti (2011) notes, the newly established IXPs have improved network performance and created critical redundancy in routes for operators located in smaller markets. The example of SERCOMTEL, a medium-size operator based in the city of Londrina (population 766,000), illustrates this point. Before the initiative, much of SERCOMTEL's traffic was transported over a single transit agreement with a large backbone provider (see "before" topology in Annex 2). By establishing a presence at three PTT Metro exchange points (São Paulo, Curitiba and Londrina), SERCOMTEL has not only significantly increased the number of its peers but also balanced traffic more evenly over different routes (see "after" topology in Annex 2). **Critically, by peering at PTT Metro São Paulo, it has established a more direct route to key content providers such as Google. Average latency on its routes has since dropped from 50 ms to 10ms.**[24]

Argentina is another case where exchange points have enhanced Internet infrastructure in smaller markets. As noted, the initiative to establish IXPs across the country was launched by CABASE in 2011. At the time, the only operational IXP in Argentina was located in the capital city of Buenos Aires, and its traffic was limited after the decision of the four largest ISPs to de-peer from the exchange point in 2004. Since 2011, nine IXPs have been established in five provinces (see Table 2). CABASE's initiative differs from the PTT Metro project in that the new IXPs are interconnected through a hub in Buenos Aires. Given that NAP CABASE requires multilateral peering from its members, the result has been a virtual IXP with national reach, currently representing over half of the ASNs allocated to Argentina.

[23] Source: CGI.
[24] Source: Barros Tonon (2011). Presented at NAPLA 2011, May 15–20, 2011.

It is interesting to note that the data from Table 2 suggests an inverse relationship between local market size (in population) and traffic exchanged. While this finding could be partly explained by differences in the number of months under operations between IXPs (see Figure 3), it suggests that the positive impact of IXPs may be larger in smaller markets. This is consistent with the arguments outlined above: the bigger the market, the more likely that several large ISPs are present, and the more likely the area is serviced by several transport and transit providers competing for their business. Aggregating outbound traffic and avoiding tromboning is more critical in smaller markets, where local IXPs typically face higher transit costs and longer routes to the more desirable content. The exponential rise in traffic (from 2Gbps to 12Gbps in peak traffic) resulting from the establishment of new IXPs has allowed the Buenos Aires hub to attract peering from new operators. The most important has been Google, which as noted has joined NAP Buenos Aires as a special member in late 2011.

As a result of the availability of a neutral point for traffic exchange at the local level, several small ISPs in Argentina have made significant investment in their own infrastructure. The case of COTESMA provides a good example. As noted, this small local cooperative in the southern city of San Martin de los Andes faced transit prices as high as USD $500 from the telecom incumbent, which competed with its own retail services. The establishment of NAP Neuquén in May 2011 prompted COTESMA to invest USD $1.5 million to build its own 400-kilometer radio link between its central premises and the city of Neuquén. With control of its own transport infrastructure to the IXP, COTESMA's transit costs have been reduced by a factor of ten.

Limitations in the availability of disaggregated data make it difficult to accurately estimate the impact that CABASE's IXP initiative has had in the relevant markets. However, **the available data suggests that Internet adoption is growing faster in local markets where IXPs have been established. According to official estimates residential Internet subscriptions in Argentina grew by 34.8% between December 2011 and December 2012.**[25] Over the same period, residential access in the province of Neuquén (where the first local IXP was established in May 2011) grew by 69.8%, almost doubling the country average. For comparison in Tucumán, a larger province in northern Argentina which still lacks an IXP, residential access grew by only 19.4%. While several other factors are at play, these findings suggest that IXPs are making a significant contribution to the alleviation of regional imbalances in Internet access in Argentina.

[25] Source: INDEC.

5. Conclusion

Both theoretical arguments and empirical evidence support the case for IXPs. In Latin America and the Caribbean, IXPs have promoted Internet infrastructure growth through several mechanisms. The relevance of each of these mechanisms depends on the level of development of the local Internet ecosystem. In the early stages, IXPs have helped local ISPs reduce international transit cost and increase service quality (stage 1). As traffic grew and the market matured, attracting content distributors and international backbone operators, IXPs provided a cost-effective, neutral platform for interconnection agreements between a more diverse set of network operators (stage 2). The availability of such platform also created incentives for local ISPs to invest in network resources and build their own transport infrastructure. Further, IXPs have promoted cooperation and knowledge-sharing mechanisms, helping build trust and promote the adoption of innovations among the local Internet community (stage 3).

The evidence suggests that there are several enabling factors for IXPs. First and foremost is a competitive telecommunications market that facilitates entry and promotes competition in the domestic transport market. Unless domestic transport prices are competitive, local IXPs will have few incentives to exchange traffic at local facilities. In several countries in the region this basic condition for the development of IXPs, and hence of the local Internet ecosystem as a whole, is yet to be met.

Second, governments can play a catalyzing role by providing political support for the establishment of local traffic exchange facilities. This is particularly true in countries where the government controls the legacy telecoms operator, as is the case in several of the least developed Internet markets in the region. It is clear that without active cooperation by incumbent operators IXPs are unlikely to succeed. Yet detailed government regulation of IXPs is ill-advised. As the examples discussed show, IXPs require flexibility to adapt to local market conditions. A cooperative approach to administration and rule-making has proved successful in several of the cases examined in this report. Such bottom-up approach is not only more likely to engage relevant network operators but also to provide the flexibility for IXPs to adapt to an ever changing interconnection environment.

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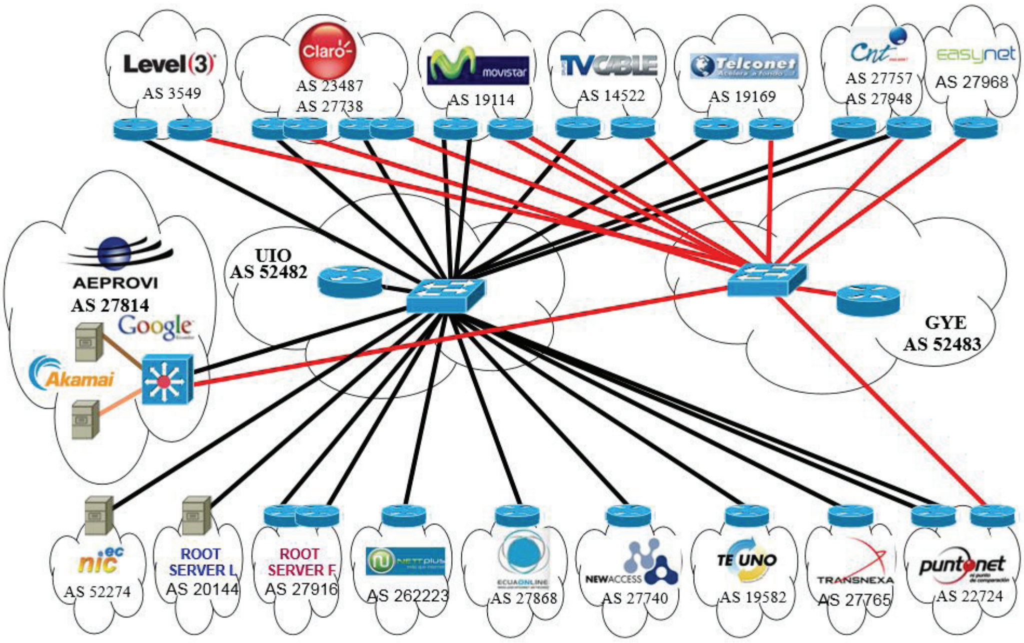
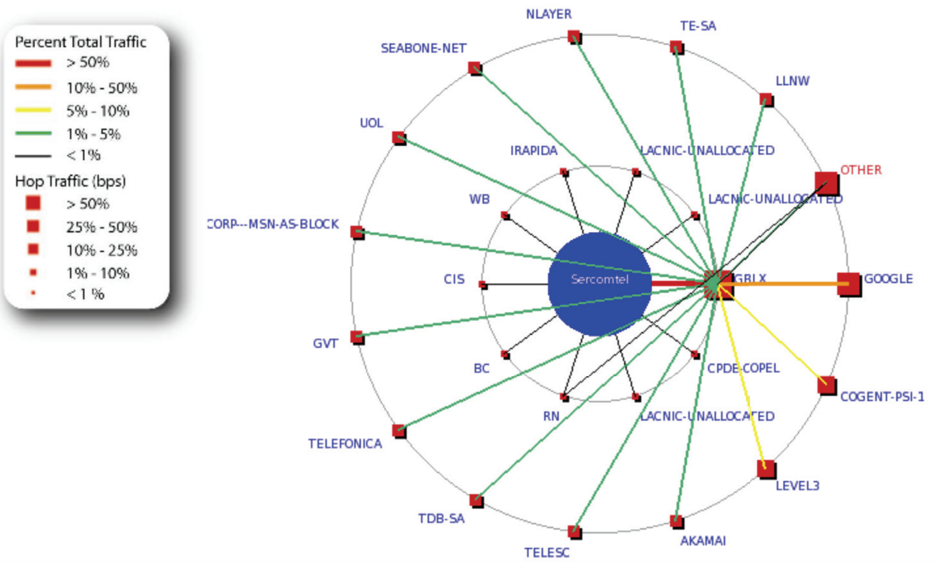
7. Annex 1: NAP.EC Topology

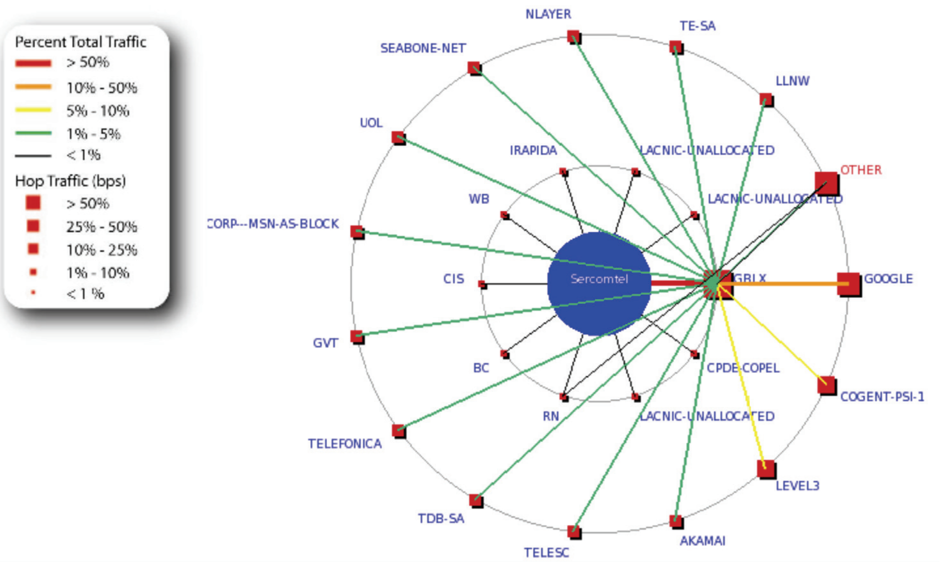


7. Annex 2: SERCOMTEL Peering

A. Peering agreements before PTT Metro initiative



B. Peering agreements after PTT Metro initiative



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