White Paper (DRAFT) on

Internet Exchange Points

Importance of IXPs to Development of the Internet in the Caribbean

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Executive Summary

Accelerating the spread of the Internet, encouraging development of Internet-based economic activity and reaping consequent social benefit in the Caribbean is dependent on reducing Internet connectivity and bandwidth costs and improving quality of service. The Internet Exchange Point (IXP) is an internationally recognised mechanism for achieving cost and service gains and ICT sector growth.

An IXP is a location at which Internet Service Providers (ISPs), in country or locality, exchange domestic Internet traffic domestically between their customers on a cost-neutral basis. By so doing ISPs avoid having to send domestic-bound traffic across expensive international transit providers.

At present there are only three relatively small IXPs in the Caribbean region, all activated within the last 6 months. As a result, nearly every Caribbean ISP must rely on expensive international transit providers for connectivity. Among the central inhibitors to IXP deployments in the Caribbean are:

1) **Dominant Telecom Operators & ISPs** - misguidedly seeking to obstruct effective competition
2) **Legal Provisions** - ranging from burdensome tax treatments to prohibitions on non-regulated telecommunications facilities and restrictive licensing regimes.
3) **Regulatory Agencies** - often reflexively seeking to extend statutory authority over telephony to Internet infrastructure

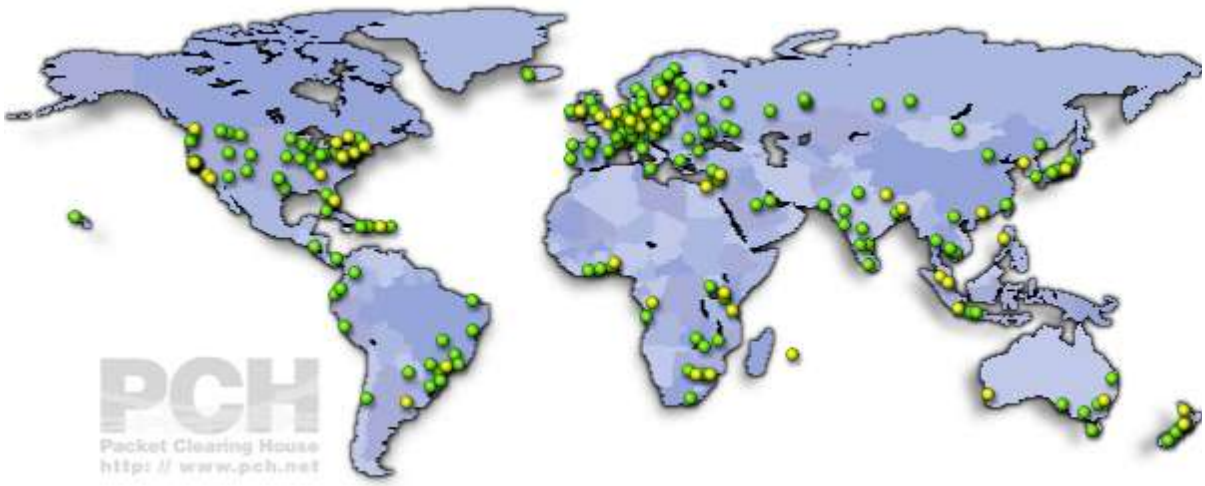
The strategy to support the deployment of IXPs in the region should consist of three core elements:

1) Education & Training
    - organizing educational workshops that bring together government officials, regulators, academics, ISP executives, technical experts, content providers and other stakeholders, to examine the economic, regulatory, technical, political and legal issues surrounding IXP deployment
2) Policy and Regulatory Guidance
    - advising governments and stakeholders on how to remove legal/regulatory/policy obstacles to the deployment of IXPs
3) Stakeholder Support
    - assisting neutral, nonprofit ISP associations and stakeholder groupings in their efforts to establish IXPs

This paper focuses on opportunities for IXP deployment in the Caribbean. However, the principles and strategies presented are equally relevant across the developing world.

What Is an IXP?

Internet eXchange Points (IXPs) are the locations at which Internet Service Providers (ISPs) exchange traffic between their customers on a cost-neutral basis. Essentially all Internet traffic is ultimately derived from an IXP somewhere, though that location may be distant from the customers. Having a local IXP allows ISPs to interconnect directly, locally, at no cost, rather than by purchasing transit services from other ISPs who carry the traffic from more distant IXPs on their behalf.



Global Distribution of Internet Exchange Points, July 2009

The IXP is a Layer 2 physical network facility, typically operated by a single entity to facilitate the exchange of Internet traffic between three or more ISPs. Often, an IXP will be administered by a no-for-profit association of its participants. The IXP usually owns and operates the switching platforms used to interconnect its participants. The IXP consists of a shared switch fabric, where participants typically arrange peering via bi-lateral agreements and then establish sessions between their routers to exchange routes and traffic[i].

ISPs who take advantage of interconnection, or "peering" at a local IXP to deliver their local traffic reduce the portion of their traffic which must be delivered via their upstream transit providers, thereby reducing the Average Per-Bit Delivery Cost of their service, and increasing their profitability, reinvestment, and competitiveness. More than 300 IXPs exist, and in the regions in which they are most ubiquitous and nearest-at-hand, ISPs enjoy the highest levels of growth and profitability.

Why Are IXPs Important?

IXPs are among the most critical elements in the infrastructure of the Internet. The Internet is a network of interconnected networks; IXPs are the points at which these multiple networks interconnect. Without IXPs, there would be no Internet as we know it.

There are numerous technical and non-technical advantages to the direct interconnection IXPs facilitate, but the primary reasons are cost, latency, and network capacity.

Cost Advantages

The primary purpose of an IXP is to allow networks to interconnect directly, via the exchange, rather than through one or more 3rd party networks. IXPs reduce the portion of an ISP's traffic which must be delivered via their upstream transit providers, thereby reducing the Average Per-Bit Delivery Cost of their service. ISPs' Average Per-Bit Delivery Costs, or APBDC, are the measure of their efficiency in delivering traffic.

Currently, the majority of developing countries lack IXPs. This means that all inter-ISP traffic (both domestic- and foreign-bound) must be exchanged through Internet Exchanges outside the country via international links, most commonly submarine fiber and occasionally satellite.

International links entail both upstream and downstream packet traffic. The costs associated with transmitting these packets must be borne by either the sending or the receiving ISP.

This is where exists a most troubling imbalance: In the telephony world, International Telecommunications Union (ITU) mandated rules require that the costs of international calls be shared 50/50 between telecom operators. However, international Internet connectivity operates according to the peering/transit model. In this model ISPs are not subject to the ITU's cost-sharing rules. Instead, connectivity costs are allocated according to bilateral contracts, which can generalized as being either peering or transit agreements[ii]. The distinction is most significant.

Peering Agreements

A peering agreement is a bilateral business and technical arrangement in which two connectivity providers agree to accept traffic from one another and from one another's customers, and their customers' customers.

In a peering agreement, there is no obligation for the peer to carry traffic to third parties. There are no cash payments involved – rather, it is more like barter, with each ISP trading direct connectivity to its customers in exchange for connectivity to its peer-ISP's customers.

Transit Agreements

A transit agreement is also a bilateral business and technical arrangement, but one in which the transit provider agrees to carry traffic from the customer to third parties, and from third parties to the customer. The customer ISP is thus regarded as an end point for the traffic.

The transit provider serves as a conduit to the global Internet. Generally, the transit provider will undertake to carry traffic not only to/from its other customers but to/from every destination on the Internet. Transit agreements typically involve a defined price for access to the entire Internet.

For virtually all developing country ISPs, the only option for connectivity to the global Internet is a transit agreement. That is, a given developing country ISP has such a small customer base that the international Tier-1[iii] and Tier-2[iv] providers have no business incentive to enter a shared-cost peering agreement with it. Instead, the developing country ISP must sign a transit agreement with an upstream provider. Consequently, developing country ISPs must pay the cost of both outbound and inbound traffic.

By contrast, the ISP on the other end of the international link does not have to share the cost of exchanged traffic. This means that the developing country ISP must pay 100% of the international transit costs for all packet traffic (email, web pages, file transfers, etc.) that originates with its customers and that terminates with its customers.

Reducing the APBDC, or "cost of goods" allows ISPs to maintain higher levels of profitability, reduce costs, or increase reinvestment. All else remaining the same, decreasing the cost of delivering any segment of one's traffic results in a corresponding reduction in one's overall APBDC, and realized benefit.

IXPs provide a no-cost outlet for the local portion of one's traffic, thereby reducing the APBDC of all participants in the IXP, and giving them a significant advantage, and one which grows even greater over time, over any competitors who fail to participate in the IXP.

Reduced Latency and Improved Quality of Service

Network latency is the time it takes for a packet to cross a network connection (as seen at Layer 3, the network layer), from sender to receiver[v]. Direct interconnection at IXPs allows ISPs to reduce the latency that their customers experience by alleviating the need to send domestic traffic across national borders (typically to the US, potentially across continents) to get from one local network to another.

Significant network latency translates into relatively slow data transfer speeds for users, putting a tremendous range of Internet services out of practical reach. Local Internet enterprises also find themselves at an inherent disadvantage if they attempt to serve international customers.

In addition, having local ISPs to interconnect in another country places a major obstacle to the development of domestic Internet-based business. Indeed, many Caribbean Internet services are hosted on servers in the United States or Europe.

Further compounding the problem, nearly every country in the region is experiencing rapidly growing demand for Internet connectivity. This has resulted in ISPs having to provide faster local connections as users consume greater volumes and more bandwidth-intensive types of Internet services.

The growth in demand places ever-increasing burdens on the transmission capabilities of ISPs, whose provisioning of bandwidth must keep pace. In many cases, ISPs use their transmission lines at near peak capacity, resulting in packet drops, re-transmissions of dropped packets, and a resulting compounded latency for completing Internet transactions.

Establishing an IXP can significantly reduce network latency by eliminating the need for any expensive international hops in the routing of domestic-bound traffic. The result is that more customers use domestic Internet services, increasing local demand for bandwidth and prompting a cycle in which ever more bandwidth is dedicated to local interconnection.

Since domestic bandwidth is always cheaper than international bandwidth, the business cases for domestic Internet enterprises improve dramatically – not just for ISPs, but for online banking, e-government, content hosting, domestic e-commerce, enterprise VPNs, media streaming, et cetera.

In the Caribbean it is reasonable to expect that latency would be reduced from ~140ms to 3ms-5ms through the use of a local IXP. This will vastly and tangibly improve the customer experience for local content, gaming, file-sharing, and latency-sensitive applications like voice and video.

There is an additional benefit to the reduction in latency IXPs bring. The increased number of paths learned through an IXP improves routing efficiency and fault-tolerance for participants and renders participants far more resilient to international cable failures.

Network Capacity

In telecommunications speed times distance equals cost. Thus, for the same price, a decrease in distance yields an increase in speed, or network capacity. Or, for the same speed, a decrease in distance yields a decrease in cost. Therefore, keeping the physical path traversed by packets as short as possible produces measurable improvements in service cost, performance, and efficiency.

For example, in the case of moving the exchange point from New York, USA to Basseterre, St Kitts (a reduction of 3,500 miles round trip to perhaps one mile) the decrease in distance is so dramatic that cost can be minimized to near zero, while speeds can be increased from some multiple of STM-1 to 1gb or 10gb. Because each of the potential peers at a local IXP have their own fiber network and are capable of lighting strands on that network with 1gb or 10gb Ethernet at essentially no increase in recurring costs, there is no question but that a local IXP would result in a vast increase in the network capacity available for sale to domestic customers, without demanding any significant corresponding capital or operational investment, as would be the case for additional STM-1s of international capacity.

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National Benefits

Industry Growth

An IXP is a prerequisite to the development of any significant domestic content production, hosting, or co-location industry. An IPX must first be established in a jurisdiction before major content providers like

Google, Amazon, Akamai, or UltraDNS will even consider providing local services within Caribbean national markets.

The improved price/performance ratio (reduced APBDC) of local traffic in the wake of the formation of a local IXP, enables high-bandwidth, low latency applications like multimedia, gaming, and file-sharing. The increased demand for these services, and ISPs' ability to supply them at a new, lower price-point, serves to increase both market penetration and the total revenue-value of the market, relative to the pre-IXP status-quo.

Human Resource Development

The maturation of the local network infrastructure provides a nucleus for education and retention of the Internet-skilled labor force that ISPs need in order to continue their growth and economic progress.

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Privacy Control

Sending sensitive data across national borders presents a privacy risk to governments and corporations.

By keeping local traffic local, sensitive data is not subject to inspection by other governments and it enables co-ordination of security, infrastructure protection, abuse response activities

Can act as a "center of expertise" for Internet technology

Facilities growth and development of stakeholder community which can engage in other activities promoting local interests.

Additional Benefits

Enables co-ordination of security, infrastructure protection, abuse response activities

- Can act as a "center of expertise" for Internet technology
- Facilities growth and development of stakeholder community which can engage in other activities promoting local interests

Makes available a logical place to locate, and hence attract, other Internet infrastructure resources

- e.g. top-level name servers, time servers, performance measurement tools, research projects

Opens the opportunity for increased diversity and resilience for participants

- e.g. mutual backup arrangements

Can create market for out-of-region transit providers to sell services to entire community of national ISPs at single cost-effective location

- lower costs for competitors can lead to greater revenues for all, stronger investment from abroad, and lower-cost, higher-quality services for all users

Obstacles to IXP Deployment

The objective of IXPs is to enable the domestic exchange of domestic Internet traffic. This requires the organization, deployment and management of neutral, local Internet exchange points.

There are some common themes found in a examination of the obstacles to the establishment of exchange points globally.

Dominant Telecom Operators & Large ISPs

Incumbent providers of international leased-line, submarine cable, or regulated VSAT connectivity often initially resist the establishment of IXPs in their market.

Dominant operators often misguidedly seek to prevent effective competition. Monopoly telecom operators often seek monopoly rents or leverage legal exclusivity over international links. In addition to the fear of effective competition, the incumbent will generally fail to appreciate that reducing the cost of Internet connectivity for domestic consumers will generate vastly greater investment, more users, and greater international leased line revenues. Indeed, it is also reasonable to conclude that an increase in domestic Internet use is likely to result in even greater use of international direct-dial telephony as consumers seek to cultivate both personal and commercial international relationships.

In addition, because Governments in developing countries are often heavily dependent on revenues from the dominant telecom operators, they are reluctant to sanction activities which might negatively affect those revenues. For a variety of reasons the dominant provider's views often carry significant weight with regulatory authorities.

Regulatory Agencies

Often regulators reflexively seek to extend their statutory authority over telephony to Internet infrastructure.

Often, statutory or other licensing requirements exist which may arguably be applied to IXPs. In most cases the regulatory authority is, at least initially, unfamiliar with the technical and economic aspects of Internet facilities and ISP traffic exchange.

Competitive ISPs

ISPs who have a deficient understanding of IXP economics often fear the effects of cheaper connectivity.

ISPs that feel secure in their market position and who have a deficient understanding of the economics of an internet exchange, often fear the effects of making connectivity cheaper for their competitors.

Moreover, an IXP essentially allows any interested domestic ISP in a developing country to peer with its domestic competitors. This requires a degree of trust among competing ISPs that is quite common in the developed world, but not necessarily as common in the Caribbean region.

International Providers

International transit and content providers currently have little inclination to peer locally or otherwise support regional development.

Proceeding with Regional IXP Deployments

The case for establishing Internet Exchange Points in the Caribbean is most compelling, and the obstacles relatively clear, well-understood and entirely surmountable.

With more than three hundred prior examples of successful IXPs, and several dozen examples of failed IXPs to learn from, one need not engage in any expensive or time-consuming experimentation to arrive at a plan for a successful IXP. One need only consider the common characteristics of the most successful IXPs in similar markets, and emulate their strengths.

Neutrality is Key

The vast majority of IXPs hew relatively closely to a common model: they are consortia of their participants, with one vote allotted to each participating organization in matters of governance. They are operated at little or no expense, imposing no cost-burden upon their participants, and leaving the profits to be realized directly by each of their participants. Neutrality is key, in that if an IXP falls disproportionately under the control of any one or subset of its participants, it will not be trusted by the remainder, and will fail.

An IXP may be a formally-incorporated entity, or an informal project, but its participants generally share a common written understanding of the business and technical terms under which they come together, in an "IXP policy document," and that document is generally as light-handed and non-prescriptive as possible. In keeping with both their neutrality and the business interests of their participants, IXPs welcome all potential participants without discrimination, while letting each individual participating network determine which other networks it will exchange traffic with, and which of its routes it will advertise as reachable at the exchange.

Lastly, and perhaps most importantly, IXPs never compete with their constituent participants in any way; they do not operate business ventures or carry traffic beyond the scope of the point at which their participants meet.

In order to realize the proliferation of IXPs in the region what is required is

1) regulatory support not constraint
2) overcoming of dominant telecom provider resistance and competitive ISP mistrust

3) organization of competitive ISPs into not-for-profit associations capable of neutrally administering shared facilities on behalf of their members.

Governments, regulators and competitors alike all need to be educated and convinced of the impressive and incontestable benefits of domestic Internet traffic exchange, and of the broader proposition it holds for economic and social development.

About Packet Clearing House

Packet Clearing House is a not-for-profit educational charity with offices in San Francisco, London, and Kathmandu. In keeping with its charitable charter, PCH provides services to the public without cost or restriction wherever possible. PCH staff are drawn from the ranks of senior engineers and executives of Internet and telecommunications networking companies in many countries. Their decades of real-world experience in diverse regions of the world inform the organization's work, perspective, and ability to bridge disparate communities of interest.

Much of PCH's work consists of training and organizational workshops. We teach sixty to seventy workshops each year, most of them to ISPs wishing to form IXPs, to regulators and communications ministers wishing to better understand Internet regulatory policymaking, and to ccTLD administrators wishing to operate more reliable DNS service at a lower cost. We also teach more specific seminars on such topics as IPv6 peering configuration, DNSsec implementation, inter-CERT coordination and communication, datacenter design, and transition from regulation of voice minutes settlement to VoIP peering, among many others. Slides used in some of these workshops can be found on our website: http://pch.net/papers.

Another large component of our work is the direct support of Internet exchange points and their operators, through organizational assistance and equipment grants. Over the past sixteen years, our staff and volunteers have built or supported more than a third of the world's three hundred IXPs. We provide Ethernet switches, components, and vendor service contracts to IXPs in their initial formative stages and assist with later-stage growth when it is within our budget. We conduct educational and organizational workshops that help ISPs achieve the level of cooperation necessary to form an IXP and begin peering, and follow-up workshops to convey routing and peering technical skills. Our outreach to governments helps policymakers understand the economic improvements and the changes to the regulatory and business environment that an IXP will bring. Our engineers work with ISPs and entrepreneurs to find business opportunities and develop market niches in content provision, data-center operation, access technologies, and technological innovation. We also engage in longer-term and larger-scale economic development and national infrastructure planning projects that allow countries to take full advantage of the opportunities of the Internet economy.

PCH also aids the operators of root and top-level domain nameservers with training, logistical support, and more direct support in the form of domain name services operated from our global anycast service

platform. Since 1997, PCH has been an innovator in anycast technology, which brings faster, more stable, and lower-cost Internet services to a global audience, directly addressing the inequities of the "digital divide." Our anycast platform maintains server clusters directly within IXPs in more than fifty locations on six continents and provides domain name service for more than sixty national (ccTLD) and commercial (gTLD and sTLD) top-level domains. The vast majority of the TLDs on our platform are national or not-for-profit, which we host on a noncommercial basis. Support provided by the few commercial TLDs covers operational costs and ensures the long-term sustainability and availability of the system to the public.

PCH Tools & Services

PCH develops and supports a variety of tools and services for the ISP, policymaking, and research communities. Examples include:

- The canonical directory of IXPs around the world: http://pch.net/ixpdir
- The INOC-DBA hotline phone system, which facilitates communication between the network operations centers of more than eleven hundred ISP, telecommunications, and critical infrastructure operators: http://pch.net/inoc-dba
- A global network of looking glasses that provide insight into Internet routing dynamics: http://pch.net/lg
- A routing-security expert system for backbone network operators: http://pch.net/prefix
- Archived Internet routing tables, with daily snapshots covering more than a decade: http://pch.net/routing-tables
- Monthly statistics on the annualized growth of Internet traffic by country and region: http://pch.net/annual-growth
- A daily routing-security report detailing origin inconsistencies: http://pch.net/routing-origininconsistency
- A daily report on the distribution of root nameservers: http://pch.net/root-servers
- A daily report on the distribution of IXPs: http://pch.net/ixp-summary

[i] see RFC 1771, http://www.ietf.org/rfc/rfc1771.txt, which describes the Border Gateway Protocol

[ii] ISPs have developed a wide range of interconnection agreements, often involving highly sophisticated settlement regimes; however, for purposes of analyzing developing country connectivity costs and options, the basic models apply to most scenarios.

[iii] a Tier 1 network is a transit-free network that does not pay settlements to any other network to reach any other portion of the Internet.

[iv] A Tier 2 Network is an Internet service provider who engages in the practice of peering with other networks, but who still purchases IP transit to reach some portion of the Internet.

[v] http://fengnet.com/book/Optimizing-Applications/ch03lev1sec1.html