Quo vadis Open-IX?

Trying to boost public peering in the US

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ABSTRACT

The recently launched initiative by the Open-IX Association (OIX) to establish the European-style Internet eXchange Point (IXP) model in the US suggests an intriguing strategy to tackle a problem that some Internet stakeholders in the US consider to be detrimental to their business; i.e., a lack of diversity in available peering opportunities. We examine in this paper the cast of Internet stakeholders that are bound to play a critical role in determining the fate of this Open-IX effort. These include the large content and cloud providers, CDNs, Tier-1 ISPs, the well-established and some of the newer commercial datacenter and colocation companies, and the largest IXPs in Europe. In particular, we comment on these different parties' current attitudes with respect to public and private peering and discuss some of the economic arguments that will ultimately determine whether or not the currently pursued strategy by OIX will succeed in achieving the main OIX-articulated goal – a more level playing field for private and public peering in the US such that the actual demand and supply for the different peering opportunities will be reflected in the cost structure.

Categories and Subject Descriptors

A.1 [**Introductory and Survey**]; C.2.1 [**Network Architecture and Design**]; C.2.3 [**Network Operations**]: Network Management; C.2.6 [**Internetworking**]: General

Keywords

Internet Exchange Point; Peering; Content Delivery.

1. INTRODUCTION

As discussed in more detail in [45], compared to the European peering ecosystem, the US counterpart is well-known for providing very limited interconnection options for its constituents.[1] Simplifying the picture slightly, we follow here [50], define the *Internet's peering ecosystem* to mean the set of all publicly routed Autonomous Systems (ASes) interconnected with *peering* and *transit* links or relationships, and are mainly interested in *Internet peering*; that is, a bi-lateral business relationship between two networks whereby they reciprocally provide access to each other's customers.

Specifically, we distinguish between *public peering* which is Internet peering across a shared switching fabric or platform and *private peering* which is Internet peering across transport (i.e., "cross-connect") with exactly two parties connected (e.g., via a fiber connection or point to point circuit). Public peering is typically only offered at IXPs, but private peering happens at most IXPs as well as in a major way also at many of the commercial colocation facilities or datacenters across the globe. In most cases, an IXP's public-facing switching fabric supports all of its public peering links and handles all the traffic resulting from those particular business relationships among an IXP's members. Private peerings and the corresponding traffic are invisible to this public-facing switching fabric.

To illustrate the most striking difference between the European and US peering ecosystems, we note that as the largest European IXPs are seeing the number of connected members exceeding the 500 or 600 mark and as their public-facing switching infrastructures are handling aggregate traffic that is peaking at multiples of Tbps, they individually support peering fabrics that consist of some 50K-100K actively used public peering links [42, 45]. In fact, most IXPs in Europe maintain and publish up-to-date lists of their members, partly to advertise their success, and partly to create a possible "network effect" – attracting new networks as IXP members because many of these networks' business partners are already members at the IXP. At the same time, while the number of private peerings or cross-connects established in those IXPs in particular and in Europe in general is not known,[2] it is widely believed to be at least an order of magnitude smaller than the number of public peerings. Even less is known about the amount of traffic that traverses these private peering links.[3]

In stark contrast, the largest IXPs in North America are typically owned and operated by leading commercial datacenter and coloca-

[1] Although this applies more generally to the North American peering ecosystem, we focus on the US and not on Canada, where an effort on building neutral IXPs is under way [8]. With respect to other regions of the world (e.g., Africa, Asia/Pacific), efforts such as the recently-formed Internet eXchange Federation (IX-F) [25] are intended to create, maintain, and publish up-to-date databases about IXPs and IXP operations worldwide and build a global IXP community.

[2] An exception is DE-CIX in Frankfurt, Germany, that states that it has some 900 private cross-connects in service [16].

[3] As a rare exception, LINX in London provides estimates that suggest that in terms of volume, the private peerings carry similar amounts of traffic than the much larger number of public peerings [28].

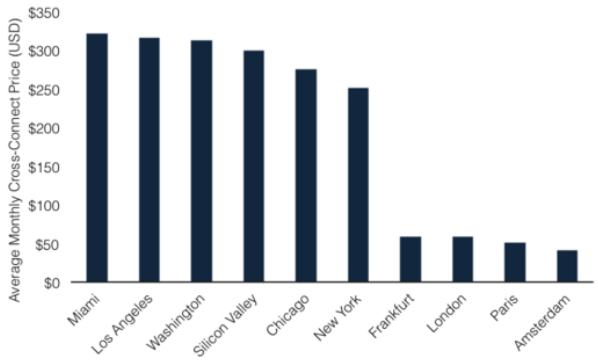

Figure 1: Average Fiber Cross-Connect Price by Metro Area, H1 2013 (source: TeleGeography).

tion facility providers, and those companies provide in general little or no information about their customers or operations. However, scanning their annual or quarterly reports shows that, for example Equinix, a critical player in the US interconnection marketplace, managed at the end of September 2014 some 75K cross-connects in the US alone [20]. Telx followed with some 50K [38] and CoreSite with some 15K cross-connects [9].

With respect to public peerings, while some of the US IXPs make the list of their members publicly available on their websites (for similar reasons as the European IXPs[4]), US-wide or colocation provider-specific numbers about their public peerings are unavailable but are generally believed to be at least an order of magnitude smaller than the number of private peerings. In short, even a cursory glance at the two interconnection marketplaces reveals that thanks to a wealth of public peerings, European networks can in general select from a rich and diverse portfolio of available peering options. In contrast, networks in the US have typically very limited options – their primary vehicle for interconnection are cross-connects.

One of the most telling ramifications of this discrepancy between the European and US peering ecosystems is illustrated in Figure 1. It depicts the average monthly cross-connect prices in major cities in the US and Europe as obtained from an operator survey conducted in mid-2013 by TeleGeography [37]. The data shows that cross-connects in the US cost up to six times as much as in Europe. A main reason for this discrepancy is that in the US marketplace, IXPs have historically been owned and hosted by commercial providers and interconnections have mainly focused on a single facility or campus operated by that provider. These aspects have fostered an environment that has limited competitive interconnection options for networks and has inflated the cost associated with the dominant form of interconnection (i.e., cross-connects). Thus, from a strict cost perspective, for many of todays Internet players, having the opportunity to choose among a rich and diverse set of peering options can potentially be a game-changer.

However, cost is often not the only reason for a network to connect to an IXP [53]. For example, for large content providers or CDNs, the capacity and bandwidth provided by an IXP are public in the sense that they can be used without restrictions to serve end users anywhere (e.g., AS or country). In contrast, the capacity and bandwidth over cross-connects often come with restrictions that are imposed by the peering partner (e.g., ISPs). Moreover, for the large content providers or CDNs that want to reach many different eyeball ASes, managing connectivity to them through separate cross-connects requires purchasing, monitoring, and managing one (or more) port(s) or router(s) per peering. In contrast, given the option to use public peering, those same networks can reach the same number of eyeball ASes using and having to manage only one (or a couple of) port(s) of an IXP. In fact, depending on the size of those networks, the amount of traffic they carry, or other criteria, they often have the option to establish either multi-lateral peerings (i.e., use the IXP's route server) or bi-lateral peerings (see for example [51]).

Thus, when combined with the latest 100 Gbps port speeds offered by many IXPs in Europe [5, 12, 17], almost every network across the entire spectrum of today's Internet players in Europe is in a position to choose among different peering options depending on its own assessment of the associated cost, performance or operational benefits, and other more intangible features (e.g., privacy, security). In comparison, for networks in the USA, it has been "slim picking" when it comes to available peering options, and the situation has hardly changed over the years. In this context, it is telling that thanks to content providers such as Netflix, Google, or Facebook, there is more (estimated) traffic in the USA than anywhere else (except for the Asia Pacific region), but the largest IXPs (in terms of membership or traffic) are all located in Europe.

It is a combination of these observations that was responsible for the launch of the *Open-IX Association (OIX)* in September 2013 [30]. Formed as a neutral, non-profit industry association to promote better standards for data center interconnection and Internet Exchanges in North America, OIX is an Internet community derived effort to improve the landscape of Internet peering and interconnect in the United States. *"OIX is seeking to help unify a highly fragmented industry and change the way networks connect with one another in North America by creating a new network of member-governed IXPs housed in multiple neutral data center facilities that allow participants to interact and exchange content without the usual fiscal burden of commercial providers"* [34]. It aims to promote common and uniform specifications for data transfer and physical connectivity and improve Internet exchange performance by developing criteria and methods of measurement to reduce the complexity that restricts interconnection in fragmented markets like the USA. In a nutshell, the basic idea behind the Open-IX effort is to try and establish the "European IXP model" in the US to increase the number of peering options available to US networks and in the process reduce the cost of cross-connects.

The purpose of this article is to raise awareness about OIX among the network research community as a whole and discuss some of the main implications that this recent effort, if successfully executed, could have for much of the Internet peering ecosystem. To this end, we provide a bare-bones comparison between the European and US IXP business models and discuss the Open-IX effort, the key players behind it, and the latest OIX-related developments. We discuss a number of economic and non-economic reasons for why the time may indeed be right to challenge the traditional data center interconnection and IXP business model and operations in the USA and why the US peering ecosystem may be ready for an overhaul that would result in an amount of peering opportunities in the US comparable to what has been available in Europe for some years and has been taken for granted by the full range of Internet stakeholders that do business there.

[4]Note that some of the Equinix Internet Exchanges in Europe (e.g., Zurich, Paris) behave like European IXPs with respect to available IXP-specific information but follow the US IXP model in the sense of being for-profit, owned and operated by a commercial, publicly-traded company.

2. OPEN-IX IN A NUTSHELL

Simply put, *"the Open-IX Association (OIX) is an Internet community-derived effort to improve the landscape of Internet peering and interconnect in the United States"* and it *"encourages the development of neutral and distributed Internet Exchanges in North America while promoting uniform, cost-efficient standards of performance for interconnections backed by the Internet community."* [30].[5]

It is important to note that at this point, OIX is a group of individuals and does not have the formal endorsement of individual companies. For example, while many board members of OIX are individuals associated with companies such as Netflix, Google, or Akamai, none of these (or other) companies has publicly supported OIX.

More OIX-specific details can be found in the reference document [41] that was put together by the early members of OIX. In this document, OIX is described as *"serving as a self-regulatory body of owners, operators, users and those concerned with Internet exchanges in North America. Open-IX intends to (1) encourage the creation and development of, and the investment in Internet exchanges by developing minimum standards of performance; (2) promote common and uniform specifications for data transfer and physical connectivity; (3) improve IX performance by developing criteria and methods of measurement to reduce the complexity that restricts interconnection in fragmented markets; and (4) certify Internet Exchanges that meet these standards."* Moreover, the proposed OIX framework and standards are intended to create *"an organized and deliberate method to foster this change efficiently, rapidly and in partnership with the datacenter and IX community, fully supported by the Internet community at-large."*

In addition to describing the original motivation for the Open-IX initiative and stating the problem that OIX is trying to address, [41] also discusses the early ideas for standards and certification processes for Internet exchanges and data centers alike. For example, the criteria for an IXP include meeting preferred market definitions (e.g., New York, Silicon Valley), meeting or exceeding minimum service offerings, satisfying basic operational requirements, meeting infrastructure-related requirements, and agreeing to maintain a publicly available website with a detailed list of information about the IXP, its members, specific traffic-related measurements and statistics, and the cost for the different offered services. For a datacenter, the criteria are mainly about physical requirements (e.g., secure access, space, power), operational requirements, external and internal network access, and pricing transparency. The two standardization efforts are explicitly linked by requiring that "an Open-IX approved data center must also provide non-discriminatory access to any Open-IX approved IXP for a minimum of 12 months after approval subject to available space, power, and cooling" [31].

These early ideas have by and large shaped the current certification requirements that are spelled out in great detail in the latest versions of the application forms for IXP (IXP Certification Requirements – OIX-1) and data center (Data Center Certification Requirements – OIX-2) certification, respectively [31]. Becoming certified signifies that *"the IXP/data center is not only adopting the standards but that the global and authoritative Internet user and operator community of Open-IX has jointly certified its operations and provides it with the right to utilize its certification marks so that the public can easily identify an Open-IX IXP or Open-IX Data Center and enjoy the benefits that it brings."* While such standardization and certification efforts that focus on IXPs and data center operators are unique to OIX, it will be interesting to see if and how this focus will help OIX to achieve its ultimate goals that are inherently tied to basic economics – reducing the cost of cross-connects in the US by enabling alternative peering options.

[5]The International Internet eXchange Network, Inc. [24] started a related effort in 2011 but is a commercial rather than community-driven entity and has received comparably little attention.

3. PARTIES WITH VESTED INTERESTS IN OPEN-IX

3.1 Large content and cloud providers

The reasons why the large content providers and leading CDNs and also increasingly the emerging cast of cloud providers have a keen interest in gaining access to rich public peering opportunities around the globe, but particularly in the US, are in general fairly obvious. Besides basic economics (i.e., an increase in competitive peering options creates downward price pressure for cross-connects), another important business objective of those players is to locate content or resources as close to the end users as possible to reduce latency and achieve best-in-class performance. IXPs with a rich public peering fabric are a perfect vehicle for those players to achieve parts of their goals, because members of such IXPs often experience improved network performance and QoS due to reduced delay (e.g., decreased round-trip times) and routing efficiencies (e.g., reduced number of hops for typical end-to-end paths) [48, 52, 46]. This is especially true for eyeball ISPs that are not interested in hosting servers of CDNs or content/cloud providers in their own datacenters as well as for CDNs or content/cloud providers (e.g., Limelight) whose business strategy precludes the hosting of their servers in networks owned and operated by eyeball ISPs.

At the same time, to support their business objective and gain a competitive advantage, a number of large content/cloud providers and CDNs have been busy pursuing strategic alliances with eyeball ISPs [21, 43, 54, 29, 1, 35, 36, 26, 39, 18] with the goal to deploy their own servers in those ISPs' networks. As owners of potentially massively distributed network infrastructures that result from these alliances, these players quickly recognize the potential that an abundance of peering opportunities has for efficiently and flexibly routing content to end users or, in the case of cloud providers, identifying available resources closest to where they are required. The earlier-mentioned feature of unrestricted use of an IXP's bandwidth and capacity for serving end users irrespective of where they are is viewed as an additional benefit by these players. Last but not least, important players in today's Internet ecosystem such as Google often "incentivize" other networks to connect at IXPs by making a network's presence at certain IXPs or at a certain number of IXPs an explicitly stated requirement for engaging in public peering with them [22, 23].

3.2 National datacenter/colocation companies

A second group of Internet companies that plays an important role in the context of the Open-IX initiative consists of national providers of datacenter solutions and interconnection services. These private (typically publicly-traded) companies build, run and operate network-neutral datacenters across the US where they offer different interconnection services to their customers at a price that the local market supports. Interestingly, even though some of these companies are global players (e.g., Equinix, Telehouse) and offer similar services outside the US, their business approach often differs significantly from region to region. For example, in Europe, datacenter companies like Equinix often house colocations of some of the distributed infrastructures of other IXPs in their very own facilities (e.g., DE-CIX in Frankfurt or AMS-IX in Amsterdam) which

also serve as locations of Equinix's own IX offering (i.e., Equinix Internet Exchange). No such sharing of Equinix's (or similar companies') facilities with colocations of a competitor's IXP has been done in the US, despite the economic argument that states that the value of a datacenter increases with the number of IXPs it houses (see also Section 4).

However, this model of excluding competitors from offering an Internet exchange service out of one's own datacenter(s) has recently experienced dramatic changes in the US. First, in mid-2012, CoreSite that operates 14 datacenters located in 9 major communications markets across the US and serves more than 750 customers [11] made a move that was considered "unusual" for the US IXP marketplace. As owner and operator of Any2, the nation's second largest IXP, with some 200 participants in California alone [10], it agreed to house a colocation of a competitor's IXP (e.g., NYIIX owned by Telehouse) in its New York City datacenter (at 32 Avenue of the Americas) where it operates its own Any2 Internet exchange. This was the first reported instance in the US where a for-profit IXP's colocation was placed in a competitor's datacenter, and it did away with the preconceived notion that a for-profit IXP is owned and operated by the same datacenter company that houses the IXP's colocations.

To blur the traditional boundaries between the European IXP business model and its US counterpart even further, CoreSite announced in late 2012 newly established relationships with both AMS-IX and DE-CIX. A main reason for these new business relationships was to provide direct access to the two largest IXPs in the world from multiple CoreSite locations throughout the US in an effort to build an *Open Internet Exchange* [10]. As a pre-OIX effort, the main idea of the Open Internet Exchange was to enable networks to access these IXPs within CoreSite's own facilities for more interconnection and peering opportunities, as opposed to the historic model that would limit these networks to just the participants within the data center provider's on-site Internet exchange

CoreSite's effort stopped however short of OIX's focus on setting standards for business-neutral and member-governed Internet exchanges and datacenters and defining a set of agreed-upon certification requirements. OIX argues that such standards and requirements will encourage the establishment of European-style interconnection facilities in the US outright which, in turn will enable the aggregation of the interconnection capabilities of the world's leading IXPs and provide all networks (not just CoreSite's customers) in the US with viable peering alternatives. However, only time will tell if the standardization/certification-based effort advocated by OIX will bear fruits. In the meantime, the application process for OIX certification opened up in late 2013, first for the Northern Virginia market and shortly thereafter for the entire North America market. In January 2014, OIX issued its first multi-site data center certification to the global colocation solutions provider CyrusOne for six of its data centers located in the Dallas, Houston, Austin, Cincinnati and Phoenix markets. In April 2014, additional OIX certifications were issued to commercial data center and colocation companies such as Digital Reality Trust (for four of its data centers in NYC, San Francisco, LA, and Dallas), DuPontFabros (Ashburn, VA), Continuum (West Chicago, IL), and Evo Switch (Manassas, VA), and other applications have been issued or are pending (see Section 4).

3.3 The large European IXPs

Much of the observed abundance of public peering opportunities in Europe can be attributed to the success of the European IXP model and its popularity with the full spectrum of networks and Internet stakeholders that do business there [42, 45, 44]. In particular, when studying the largest managed non-profit IXPs in Europe, a pronounced common feature is that the uninterrupted growth in port and data volume demand from their constantly expanding customer bases has forced those IXPs to constantly innovate and grow, both with respect to their switching infrastructures and service offerings (e.g., free use of their route servers to their members [51]). At the same time, it is important to keep in mind that while there are indeed a number of highly successful IXPs in Europe (i.e., AMS-IX, DE-CIX, LINX, Netnod, MSK-IX), there also exist a significant number of not-so-successful European IXPs, indicating that by itself, the European IXP model provides no guarantee for success.

For example, over the years, AMS-IX has not only constantly upgraded its switching infrastructure, but has at the same time also expanded into new locations within Amsterdam. Moreover, in 2012 AMS-IX teamed with Hutchison Global Communication (HGC) to establish a stand-alone IXP in Hong Kong (AMS-IX HK) [3]. Since early 2013, AMS-IX has also a presence in the Caribbean region after taking full responsibility for the management and operations of the Caribbean Internet Exchange (CAR-IX, renamed AMS-IX Caribbean) [2]. Later that same year, AMS-IX started the AMS-IX East Africa Exchange Point, a new regional Internet exchange hub in Mombasa, Kenya, in collaboration with the Kenya Internet Exchange Point (KIXP). Finally, in late 2013, in direct response to the Open-IX initiative and in support of the OIX's stated effort to set up neutral and distributed Internet exchanges in the US and establish a community-based certification process, AMS-IX announced that its newly-formed subsidiary AMS-IX USA Inc. had reached agreements with Digital Realty, DuPont Fabros Technology, Sabey Data Centers and 325 Hudson in the New York/New Jersey area to build and operate a new distributed Internet Exchange, named AMS-IX New York. AMS-IX New York received OIX certification in February of 2014, and the exchange was officially launched two months later, with Netflix and the IX reseller IX Reach being the first two connected customers, followed by Twitter and Datagram. In the meantime, AMS-IX USA established AMS-IX Bay Area in San Francisco in September of 2014 [6] and opened a month later the first Point-of-Presence of AMS-IX Chicago in the Cermak Hosting Facility in Chicago [7].

Likewise, DE-CIX has also experienced enormous growth in the past years. It is currently spread over a number of datacenters in different locations within the Frankfurt city limit and has recently completed the migration of its customers to the new DE-CIX Apollon platform with a core capacity of some six Terabits per second. At the same time, DE-CIX has also expanded beyond Frankfurt, but has first focused on Germany where it now owns and operates two stand-alone regional IXPs in Hamburg and Munich [13, 14]. However, in late 2012 DE-CIX expanded beyond Germany and took full responsibility for managing UAE-IX, the first carrier-neutral IXP for the Middle East in Dubai (United Arab Emirates) [40], and a year later, DE-CIX announced the opening of DE-CIX New York, its New York City Internet exchange operated by DE-CIX North America Inc. While partly aligned with some of OIX's efforts but not formally OIX-certified, DE-CIX New York is owned and operated by DE-CIX North America, Inc. which is fully owned by DE-CIX International AG, and its initial sites include key locations such as 60 Hudson Street, 111 8th Avenue, 32 Avenue of the Americas, 325 Hudson Street and 165 Halsey Street in Newark, New Jersey. The initial list of customers includes Akamai, Zayo, Apple, and IXP resellers such as IX Reach and IIX and is expected to see the addition of a "major" search engine operator in the not-too-distant future. As disclosed in late 2013, DE-CIX also plans to expand its secure, distributed exchange model to other critical mar-

kets across the US, including Los Angeles and the San Francisco Bay area.

Finally, the London Internet Exchange (LINX) that was formed in 1994 when five UK-based ISPs linked their networks to keep local traffic local (or else incur astronomical transatlantic bandwidth costs) was the last of the three large European IXPs to expand beyond London but the first to build a new IXP in the US. In particular, after finishing a major upgrade in early 2012, today's LINX network consists of two separate high-performance Ethernet switching platforms installed across ten locations within London. Soon thereafter, a new LINX exchange was established in Manchester (IXMancester), and in late 2013, the new LINX IXP in Edinburgh (IXScotland) went live. At the same time, LINX also announced the opening of LINX-NoVA, its first Internet exchange in the U.S. The new exchange is located across three different facilities in Northern Virginia (i.e., Ashburn, Reston and Manassas) that are operated by data center providers DuPont Fabros, CoreSite and EvoSwitch respectively. LINX NoVA went live in early January of 2014, with Leaseweb and the IXP reseller IX Reach as the first networks to connect over the new exchange. Later that same month, LINX-NoVA became the first IXP in the world to be awarded the OIX-1 certificate by the Open-IX Association.

3.4 Equinix

As the dominant player in the US cross-connect marketplace and as owner and operator of a for-profit IXP (i.e., Equinix Internet Exchange), Equinix plays a special role in the US Internet peering ecosystem. While other companies like Telx and CoreSite compete in the same space, it is worthwhile recalling how Equinix developed over the years into a major data center and interconnection provider.

The story of how Equinix, within a few years after it was founded in 1998, beat MAE-East, an IXP that was run by WorldCom and dominated the eastern US IXP marketplace, is discussed and well-documented in [49]. A key aspect of its strategy to become a worldwide leader in providing network-neutral datacenters and interconnection services has been its ability to leverage "network effects"; that is, its early success in lining up critical Internet players (i.e., Tier-1 ISPs) as customers compelled other networks to buy interconnection services from Equinix which, in turn attracted yet more networks to become customers of Equinix. For example, many of Equinix's dealings in Europe that involve offering low/no cost space/power in its own datacenters to selectively-chosen IXPs in exchange for housing one or more of their colocations are a critical part of this strategy and has contributed to Equinix's massive customer base that covers multiple different business ecosystems (e.g., financial, cloud, content, mobile).

Today, Equinix owns and operates the Equinix Internet Exchange, a for-profit global IXP that aggregates thousands of peering sessions onto a shared fabric and connects peers at 19 IXP locations in 17 metro areas around the world [19]. However, for historical reasons, Equinix's focus over the years has been on selling cross-connects, and today, Equinix is widely recognized as a key player in the North American datacenter and interconnection marketplace [47]. To illustrate, Equinix's cross-connect business in this region generates about 250M dollars of revenues annually. A main reason for favoring selling cross-connects over offering public peering has been that pretty much from day 1, Equinix's main customers in the US included the Tier-1s whose attitude towards public peerings is succinctly captured by a comment quoted in [50]: *"If you think that public peering is a good idea, you're just not large enough yet."*

As a result of this business perspective of the US Tier-1s and because of the dominant role that they have played in the past within the US Internet peering ecosystem, none of them engaged in public peering at any of the US IXPs. In turn, they effectively decided which other networks that wished to establish private peerings with them could do so. The business model of these Tier-1 ISPs was built around Internet transit, and their pursuit of revenue-generating customer-provider relationships has in large parts shaped the US Internet peering ecosystem with its vast dominance of Internet transit over Internet peering, especially public peering.

However, times have changed, and the original cast of Tier-1 ISPs has not been immune to past changes in the Internet ecosystem. Indeed, they have reacted to economic upheavals such as the burst of the dot-com bubble in 2000 by either tweaking their business model, re-inventing themselves, or becoming targets for or actively pursuing mergers and acquisitions. As a result, today's cast of Tier-1 ISPs is less homogeneous than the original one and includes a more diverse set of players. For example, Level 3 not only expanded as an ISP by acquiring in 2011 Global Crossing to become the dominant provider of IP transit worldwide, but has at the same time morphed into a global CDN.

At the same time, original Tier-1 ISPs such as AT&T, Verizon (i.e., Worldcom, formerly MCI), and Sprint have over time focused less on IP transit, have instead turned their business focus more towards wireless communication, and have in the meantime become the leading mobile providers in the US. In addition, we have seen the transformation of cable operators into large eyeball ASes and a blurring of the boundaries between Tier-1 and non-Tier-1 ISPs by networks such as XO Communication, the Zayo Group, CenturyLink and others. All this has led to an environment in which many of today's players are less pragmatic about how to connect with whom and are more interested in what kind of interconnection model is best suited for their increasingly diverse business objectives and practices.

4. ONE YEAR OF OPEN-IX

Figure 2 shows a timeline of the major milestones of the Open-IX effort to date. Although OIX is still in its infancy, as of November 2014 and about one year since its official launch, some 190 individuals have already signed up as members [33]. However, due to its nature of being a "grass roots" organization, OIX does not have the formal support of any commercial companies. In terms of OIX's focus on standardization/certification, by November 2014, it had issued OIX-1 Certificates to two IXPs (i.e., LINX-NoVA and AMS-IX NY). Moreover, numerous colocation/datacenter service providers (e.g., CyrusOne, Digital Realty Trust) applied and already received OIX-2 Certificates for a number of their US-based datacenters, with other companies awaiting approval. As of November 2014, 21 datacenters located in nine different states and in 15 major cities and owned by nine different data center and interconnection service providers have been OIX-2 certified. Note that many of these cities have been identified as markets with high-priority for establishing OIX-approved IXPs [41]. For an up-to-date list of members, OIX-1 certified IXPs, and OIX-2 certified datacenters, see the OIX-maintained online directories [32].

When compared to related efforts (e.g., CoreSite's Open Internet Exchange Hub, or the International Internet Exchange IIX) that also try, among other things, to boost the interconnectivity options in the US, OIX seems to take a different approach. It's strategic decision to target both the Internet exchange operators and data center providers and let them drive the development of the critical technical and operational standards necessary to promote uniform specifications for data transfer and interconnectivity in the form of a formal certification process is partly based on practical experience. For example, an important lesson from the successful Euro-

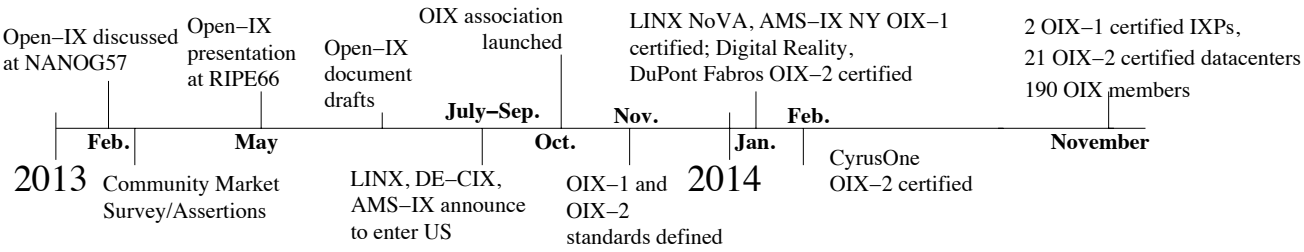

Figure 2: Major milestones of Open-IX effort to date.

pean IXPs is that such opposing business interests as pursued by the for-profit data center providers on the one hand and the large non-profit IXPs on the other hand can not only co-exist but can actually be mutually beneficial. In particular, the ability to house some of the switching infrastructure of the non-profit IXPs essentially for free in facilities that are owned and operated by commercial data center or colocation companies results in clear benefits for those IXPs in the form of reduced costs. The benefit for the for-profit data center providers is that they gain access to a new pool of potential customers in the form of the IXPs' members.

In this sense, a main reason for the mutually beneficial co-existence of non-profit IXPs and for-profit data center providers in Europe has been the simple economic arguments that *data center or collocation space is more valuable with an IXP than without an IXP*. Interestingly, some of the global commercial data center providers, including those which themselves operate for-profit IXPs (e.g., Equinix with its Internet Exchange solution, Telehouse America and its Global Interlink service) have applied this economic argument successfully in Europe, but have shown little interest to date in applying it in the USA as well.[6] Clearly, OIX banks on the fact that there are no logical reasons why this basic economic argument wouldn't apply in the US marketplace with its for-profit IXPs and for-profit data center providers. In fact, it is exactly this argument that data center companies like Digital Realty, DuPont Fabros Technology, or Sabey Data Centers bet on and that motivates them to become OIX certified in an attempt to compete for the business of housing colocations of yet more OIX-certified IXPs.

However, boosting the interconnectivity options for networks in the US is unlikely to be achieved by simply betting on the fact that such basic economic arguments will prevail. In fact, given the nature and culture within the US marketplace where cross-connects have traditionally been critical money makers for some of the major commercial colocation/datacenter and interconnection service providers, the potential challenges associated with trying to elevate public peering to a first-class citizen within the viable Internet peering options in the United States remain formidable. Steep discounts to entice a first set of customers to join the newly-established IXPs AMS-IX New York, DE-CIX New York, or LINX-NoVA [4, 15, 27] certainly help initially. However, in the longer term, much will depend on how the incumbent cast of interconnection providers will respond to the activities of these "newcomers." Ultimately, it will all depend on whether OIX can muster enough momentum and create a sufficiently strong "network effect" that is similar in nature to the one that propelled Equinix into the dominant market position it occupies today. If the required network effect materializes and causes a significant number of the current customers of the incumbent cross-connect providers to seriously consider public peering at IXPs as a viable alternative to private peering, then the market can be expected to respond to the increasing demand for public peering which, in turn, is also likely to put pressure on the high cross-connect costs in the US – all this is exactly what OIX is all about. However, this sketched road to success for the currently pursued Open-IX efforts includes a number of "if's" and "when's" that add a certain amount of uncertainty concerning the OIX-identified end goals. In particular, whether or not OIX's unique focus on standardization and certification will create the necessary network effect remains to be seen.

[6]The first instance was CoreSite's decision in 2012 to house Telehouse's NYIIX in its NYC data center (see Section 3.3).

5. CONCLUSION

Open-IX is a current, largely community-based effort to tackle the often lamented scarcity of peering opportunities in the US, especially when compared to Europe. This paper describes the Open-IX objectives in more details, portrays the various Internet stakeholders that have a vested interest in the fate of this initiative, and discusses the latest developments on the OIX front. Given the nature of today's US interconnection marketplace, OIX is purposefully advocating the introduction of a "disruptive" technology to change the basic economics of interconnection.

We discuss economic and technological reasons for why the time may indeed be right to challenge the traditional interconnection business model in the USA and why the US peering ecosystem may be ready for an overhaul. At the same time, we also argue that the fate of OIX will largely depend on its ability to generate enough of a "bandwagon effect", with large content/cloud providers and CDNs being the initial targets and betting on their ability to attract other networks in sufficiently large numbers to join their efforts. In particular, we question whether by itself, the current approach chosen by OIX to generate the necessary bandwagon effect (i.e., a formal certification process for IXPs and data centers) is sufficient to create the envisioned abundance of peering opportunities in the US, on top of the already existing richness of private peering options. However, whether or not OIX will achieve its main objectives, the networking community ought to be aware of the latest developments affecting the Internet peering ecosystem. In particular, the current OIX-related activities make it blatantly clear that Internet peering is all about economics and that repeated attempts at studying the Internet peering ecosystem as an abstract graph-theoretic construct are necessarily futile and hence no longer worth pursuing.

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