Internet Node as a Network of Relationships:

Sociotechnical Aspects of an Internet Exchange Point

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Abstract

This research paper examines the formation of an Internet Exchange Point (IXP) in a country with a low level of telecommunications competition in the Global South. The research applies the Actor-Network Theory (ANT) framework to the policy dynamics around the first IXP formed in Mexico, contributing to unveil the materiality of internet infrastructure and the imaginary that surrounds it. Following Michel Callon (1984)'s three principles: *agnosticism* – to be impartial with the parts of a controversy; *symmetry* – to analyze different perspectives with the same lens; and *free association* – to break the divide between society and technological artifacts, the analysis shows how technical and political aspects are completely interlaced in the design and implementation of an IXP, here defined as a network of relationships. Organizations—characterized by their design and governance—along with individuals, documents, laws, and technology artifacts, are significant actors in the scenario where social, political and economic goals are delegated to the IXP's technical functions. The lack of convergence among these actors, however, prevents the project from succeeding in the first years of deployment as its implementers expected, while regulatory documents work as the supporters of a dynamic equilibrium to keep the project ongoing.

Key words: Internet Exchange Point (IXP), Internet Governance, Internet Interconnection, Actor-Network Theory, Science and Technology Studies (STS).

Introduction

In May of 2014, a cadre of companies, policymakers, and journalists convened at an event for launching a new part of the internet architecture in Mexico—an Internet Exchange Point (IXP). An IXP can be initially understood as an internet node, a physical facility where different networks can interconnect and

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make private agreements for the purpose of optimizing their respective resources to exchange traffic on the internet. Networks, in this context, can be Internet Service Providers (ISPs) (e.g. Comcast, AT&T, Telmex); content providers (e.g. Google, Facebook, Amazon); also banks, universities and other organizations which have an autonomous system number (ASN) to uniquely identify their networks on the internet, known as the "network of networks." In terms of internet infrastructure, autonomous systems run networks, but here both terms will be used interchangeably.

Although IXPs are considered a critical part of the internet architecture, they are not essential for the internet to operate; autonomous systems can do bilateral agreements to interconnect with each other and share their data traffic directly—a constant occurrence among big players. In fact, many countries do not have an IXP (e.g. Uruguay and Venezuela in Latin America; Algeria and Libya in Africa; Afghanistan and Iraq in Asia; Tonga and the Solomon Islands in Oceania, to name a few).[1] In Mexico, the IXP under study is responsible for a low amount of internet traffic at the moment, with a speed of 10 to 20 Gigabits per second (Gbps) according to interviewees. For a rough comparison, as information about the internet traffic per country is privatized and not available, the main IXP in Latin America, located in Sao Paulo, Brazil, has an average of more than 2 Terabits per second (Tbps).[2] Another metric to contextualize the volume of data passing through the first Mexican IXP is the number of autonomous systems in the country connected to that facility: of the 366 ASNs assigned within Mexico, fewer than 10 are connected to the IXP. Together, these sources can be considered an indication that the internet traffic in the country continues to go through bilateral agreements in private facilities that precede the relatively new available IXP in Mexico City.

Nonetheless, the benefits of IXPs are generally recognized, particularly in that they allow the joining of many networks at the same place, facilitating private agreements and interconnection arrangements, also known as *peering*, which reduces international traffic and traffic costs, and improve, as a consequence, the internet quality by keeping local content locally, diminishing latency and leveraging speed (Fanou, Valera, Francois, & Dhamdhere, 2017). And although there are divergences on the number

[1] www.pch.net/ixp/summary

[2] Mexico is responsible for 1,5% of the global web traffic while Brazil, located in the same region, responds to 3,5%. www.akamai.com/us/en/solutions/intelligent-platform/visualizing-akamai/real-time-web-monitor.jsp

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of IXPs in the world depending on the source considered, there are likely more than five hundred IXPs, which are unequally distributed and more numerous in affluent areas of the globe (Klöti, Ager, Kotronis, Nomikos, & Dimitropoulos, 2016).

With regard to the launching of an IXP in Mexico, Carlos Casasús, who is the president of the committee formed to coordinate the new facility, mentioned to a journalist some benefits that would justify the implementation of the first IXP in the country (Rivera, 2014). His considerations encompass four key issues:

a) Leveraging the quality of the internet, through the "decrease of latency between connections" and the "improvement of the internet traffic";

b) Strengthening sovereignty, through avoiding unnecessary international routes, "enriching the country's technological infrastructure," enabling the country to join others "that are at the forefront of technology";

c) Leveraging market competition, helping to establish "a healthier competition among telecommunications operators," and "attract more foreign investment"; and

d) Generating social benefits, "narrowing the digital divide by making the internet more accessible to more people," and "encouraging further development of national content online."

While these reasons reflect local motivations, they incorporate components of a prevailing dialogue among international organizations. Many different agencies, including the Organisation for Economic Co-operation and Development (OECD), the Inter-American Development Bank (IDB) and the World Bank, have produced reports on broadband development, emphasizing the role of IXPs in improving connectivity rates in "developing" countries (Agudelo et al., 2014; Blackman & Srivastava, 2011; Intven & Tétrault, 2013; OECD & IDB, 2016; Weller & Woodcock, 2013).

By unveiling a very opaque technology underlying the internet architecture, what this paper elucidates is that the expectations about the first IXP in Mexico are based on assumptions that depend on different sociotechnical processes and actors intertwined, and are not—as can be understood by a technology deterministic approach—sustained by the IXP "affordances" themselves. Affordances are *"the possible actions a person can perform upon an object"* (Norman, 2010, p. 228), or yet, the "promise and permission" of artifacts, which, in action, merge their characteristics with who handles them, supporting new

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actions that emerge in a process named “translation” (Latour, 2002)—only conceivable if object and subject are considered altogether. In this paper, I analyze the incomplete realization of such a translation process in the case of the Mexican IXP, or the reasons for the expectations of some groups involved in broadband discussions and in the deployment of the IXP to be frustrated.

This research is guided by Actor-Network Theory (ANT), “a method for mapping how every object or actor is shaped in its relations” (Law, 2016, p. 10, emphasis in the original). In this framework, there is a call to look at micro structures where social relations are built between humans and non-humans, society and technological artifacts. Despite the scale difference, ANT theorists understand that the macro structure of society is not distinct from its micro structure. In fact, from an ethnographic approach, ANT seeks to avoid not only technology determinism, but also social determinism, dismissing the existence of a social structure ruling life, without disregarding the existence of patterns that may be identified. This is why, in this framework, power relations are expected to be unveiled only after a certain web of relations is understood (Callon, 1984; Latour, 1991).

Authors from this stream of thought assume not only a symmetric relation between society and artifacts, but also understand that there is a continuous interchange between humans’ goals and artifacts’ functions. This happens in such a way that a speed bump, for instance, can be understood as a “delegation” of engineers’ goals in pavement and concrete, and a “translation” of an action—the speed law enforcement—into a technique (Latour, 1999). In other words, the desired action of making drivers slow down is, in this case, is not only *expressed* by a “negotiable” speed limit sign, in which the driver has the opportunity to ignore it. Instead, the action is *provoked* by “unnegotiable speed bumps” (Latour, 1999). Thus, mediating human goals, the technique influences human behavior with its own functions and characteristics.

I apply this approach to the study of IXPs using three principles presented by Michel Callon (1984): *agnosticism* – to be impartial with the parts of a controversy; *symmetry* – to analyze different perspectives with the same lens; and *free association* – to break the divide between society and technological artifacts. In the next section I examine the dynamics of IXP formation and the actors that emerge from it. I then analyze the translation process throughout four moments that are shown to be

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embedded by social, political and economic factors. Finally, I conclude defending an IXP sociotechnical definition as a way to illuminate the complex dynamics that characterize an Internet Exchange Point.

The Formation of an IXP

In 2012, the Organisation for Economic Co-operation and Development (OECD) released an influential report on Mexico, one of its few member-countries from the Global South, stating that "The welfare loss attributed to the dysfunctional Mexican telecommunication sector is estimated at USD 129.2 billion (2005-2009) or 1.8% GDP per annum" (OECD, 2012, p. 9). Among its recommendations, the report stated that the telecommunications regulator, the Federal Telecommunications Institute (IFT), should have the power to impose regulations and sanctions to leverage competition. With regard to infrastructure specifically, the report says that "The inability to mandate, or at least set out, reasonable conditions for infrastructure sharing is arguably one of the main bottlenecks that prevent competition" (OECD, 2012, p. 12). Since then, the report has been a respected voice in policymakers' circles discussing infrastructure-sharing projects and the intensification of asymmetric regulation applied to the preponderant economic agent, Telmex. Carlos Casasús' story of conversations about creating an Internet Exchange Point in the country at the regulatory agency is an example:

> We were already talking about having an IXP. I was the chairman of COFETEL's Advisory Board [currently IFT]. I had a meeting with the COFETEL's president [Mony Sacha de Swaan] and I said 'Why do not we do that? It is an OECD recommendation.' He said: 'Do you think we can do that? We have been working for many years…' So, we managed to get [some] partners to start.[3]

Casasús is known for his efforts within the not-for-profit organization Corporación Universitaria para el Desarrollo de Internet (CUDI), whose goal is to congregate and escalate resources among higher education institutions in Mexico.[4] It is in this context that he and colleagues thought about building an IXP first in the beginning of the 2000s to improve universities' internet connectivity, keep the country's content local and decrease dependence on the United States' infrastructure. Hans Ludwing Reyes Chávez, one of

[3] This and other verbatim quotes are from interviews with the author.
[4] Previously to this role, he was the Financial Director of Telmex, when it was a state company, and worked in the front of the Federal Law of Telecommunications discussions, approved in 1995 (www.diputados.gob.mx/LeyesBiblio/abro/lftel/LFTel_abro.doc). He was then the first COFETEL president in 1996, the regulatory agency replaced by IFT in 2014.

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the engineers who work for CUDI and who is currently responsible for the IXP in México, remembers that: "[The idea] did not prosper because there were not enough fiber networks to do it."

According to Casasús, an inspiration for CUDI and the IXP project has been the Brazilian National Research and Educational Network (RNP), a network of universities in Brazil whose goal is to integrate academic institutions with the support of a backbone fiber network running since 1992. Currently, RNP has access points in all 27 Brazilian states, facilitating the interconnection of networks in different regions, and serving as points of interconnection of some IXPs within the country. Unlike RNP, though, CUDI does not have a fiber network in Mexico. The organization depends on an agreement between the Ministry of Communications and Transportation (SCT) and the Federal Electricity Commission (CFE), which interconnects approximately 40 universities, but constantly presents technical problems, according to the interviewees.

This is an important context to understand, that the first IXP initiative in Mexico was led by an educational organization with clear purposes, but devoid of internet infrastructure resources. In 2014, CUDI, and more specifically its president, put together five companies to start the exchange point in Mexico City: Kio Networks, Megacable, Nextel, redIT, and Transtelco. These organizations constituted the IXP's founding partners, which envisioned some benefits for themselves, including sharing infrastructure and exchanging traffic among the parties and the opportunity to become the host of new networks. Interestingly, the group of the IXP founders does not comprise other academic institutions, which would be required to have autonomous system numbers to interconnect, and is reported to have difficulties in receiving ASNs from NIC Mexico—and Telmex, the telco incumbent.

While the participation of a player like Telmex cannot guarantee the success of an IXP, Telmex competitors and the IXP founders defend that it is a crucial contributor to it, given that Telmex not only has the biggest number of clients, concentrating 57.7% of the internet market,[5] but it also has the largest infrastructure to reach different parts of the country, with more than 190,000 km of optic fiber (Telmex, n.d.). For instance, an Internet Service Provider (ISP), which needs to deliver data packets in places where its own optic fiber mesh does not reach, has two possibilities: buy transit or do peering with another company

[5] The other big players are Grupo Televisa, with 21,5% of the market, and Megacable-MCM, with 13.5% (IFT, 2017, p. 27).

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to deliver it. However, an incumbent agent has very few incentives to share its own infrastructure and peer with potential competitors. Economically, it can conclude that it is more advantageous to sell transit to some ISPs than to peer with them. In Mexico, due to its reach, Telmex would be one of the most likely companies from which this supposed ISP would buy transit. Thus, for Telmex, it is reasonable to think that an Internet Exchange Point would likely to reduce its clients and would not benefit its business. Moreover, all the costs for the incumbent to be connected to the IXP are supposed to be covered by the company.

To address this controversy, and guided by the purpose of leveraging competition in the country, two months after the beginning of the IXP operation, the law that marks the reform in the telecommunications sector in 2014 determined that the preponderant agent, Telmex, should: "Have a physical presence in the Internet exchange points in the national territory, as well as to enter into agreements that allow Internet service providers the internal exchange of traffic in a more efficient and less expensive way according to the terms that the Institute define" (Mexico, 2014, Art. 138, VIII). As of the time of writing, though, Telmex was not yet an IXP member, but the expectations were that it would happen in 2018, if the company does not appeal to the guidelines issued to enforce the law in 2017 (Mexico, 2017).

This type of regulation to require interconnection, while it has reflected significant lobbying from CUDI, has not been received unanimously among players in the market and specialists. In the illustrative opinion of a content provider representative, who is responsible for interconnection issues at a company that already maintains private peering agreements with Telmex, he points out that an IXP is useless in a market where there is a low level of competition, and not an ISP ecosystem to benefit from interconnecting publicly at an exchange point. He defines the Mexican IXP as a "party where all the guests already have relationships with each other," so being asked to pay for a "ticket" to participate in such party would be unnecessary. In other words, for this interconnection specialist, in a market like Mexico, the equipment necessary to build an IXP and the structure necessary to maintain it becomes costly, and will not solve the competition problem by itself: "A switch helps the small players, but if they do not exist (…) an IXP will not generate small players." In this vein, he sees the regulation to require a player to participate as an unwelcome interference: "When there are no commercial reasons [to interconnect], one makes the law," he says.

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On the other side, IXP defenders shift the focus to the challenges faced by small players that do not have the resources for interconnecting directly, or other Telmex competitors, which depend exclusively on transit services. It is not uncommon that a Telmex competitor needs to send its traffic to an IXP in the United States, where global internet networks—also known as Tier 1 networks—with agreements with Telmex will redirect such traffic to return to Mexico. IXP defenders will say that this boomerang route, also known as a trombone, raises cost issues for the companies, internet quality issues for the users and sovereignty issues for the country.

Julio César Bravo, an incumbent competitor representative whose company is one of the IXP founders, believes that there are viable business opportunities to raise in an IXP in México, but Telmex needs to be part of it to make it attractive to Content Delivery Networks (CDNs). CDNs are companies that cache highly accessed web content to make it easier and quicker for users to reach. They have an interest in becoming a member of an IXP if a great amount of traffic is expected to circulate through its facilities. Although Bravo would agree that the IXP is currently a party with guests that are already linked among them, his company accepted to be an IXP founder based on future business perspectives, such as providing connection to the IXP to the United States. “In the end it's business (…) There is no altruistic issue. Everything is totally and completely business,” he admits.

Thus, for the IXP team and participants, the state regulation to require the incumbent to be part of the exchange point is positive, and generates expectations that other important players will interconnect to the IXP in the near future. On the other side, consequential players, including the incumbent and the ones that already have interconnection agreements with it, such as big content providers, do not see benefits from connecting to an IXP in the present conditions. In fact, although the IXP has already been working for some years, its outcomes have not been measured or made public, which generates critics: “I have no elements to know if I can trust the IXP operator or not. In theory, yes, because I'm in a university and I have to rely on CUDI, right? But I do not even know where IXPs’ performance measures are, if I do not have numbers I cannot have confidence,” says Luis Miguel Martínez Cervantes, a professor and also the Internet Society Chair in Mexico.

Luis Martínez argues further that building an IXP in Mexico at that moment was “a political and not a technical decision,” meaning that the IXP was a government response to the OECD report agenda,

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while his academic colleague, Judith Mariscal, a professor and specialist in telecom and digital divide issues (Flores-Roux, Mariscal, & Aldama, 2009; Galperin & Mariscal, 2016), argues that the IXP was Carlos Casasús' and CUDI's agenda, indicating lack of involvement in the discussion. Clearly, CUDI's IXP lobby was directed to government and some companies and did not incorporate other academics and civil society organizations in its process.

To finalize this examination session, it is important to explain the governance and design of the IXP, here understood as two sides of the same phenomenon (DeNardis, 2014; Musiani, 2013). The IXP governance is under the auspices of the not-for-profit organization Consortium of Internet Exchange Traffic (CITI, A.C.), which is led by the CUDI president, Carlos Casasús, and complies with the partner organizations of the IXP that meet every three months. As of the time of writing, these organizations are Akamai, Cloudfare, CUDI, Enlace TPE (TotalPlay Empresarial), Google, KIO Networks, NIC Mexico, Megacable, y Transtelco. Interestingly, some companies that were connected to the IXP in its beginning are not considered connected anymore. This happens because, on the one hand, the IXP has not attracted new participants, and on the other, there is a merging trend among businesses (e.g. AT&T bought Nextel Mexico and KIO Networks bought redIT), an expression of technology convergence that may reduce the number of IXP participants.

KIO Networks is the company that owns the data center which hosts the IXP's equipment, being responsible for the colocation and the building infrastructure—electricity, cooling and security. It has an important role in IXP governance, once its policies are crucial in the design of the IXP and its location.

To be part of the IXP consortium, the organizations need to pay $810 or $2,430 monthly to have a port of 1Gbps or 10Gbps, respectively, but companies such as Content Delivery Networks may negotiate these terms due to the importance of having their cached content for the quality and economy generated to IXP participants. To be connected to the IXP, a network—owned by a company, a community or the government—needs to be an autonomous system, which means having an autonomous system number assigned by NIC Mexico, and to be physically connected to the IXP in Santa Fé, Mexico City, where the KIO Networks data center is located. If an interested network is already based in this data center, it will purchase a "cross-connection" service from KIO to have its cables connected to the IXP. If this is not the case, a point-to-point link is necessary. In this scenario, one of the challenges is that the usage cost for

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local fiber lines is expensive and wireless lines are not abundant in the country, contributing to preventing significant IXP attractiveness. As Luis Martínez exemplifies:

> What happens is that for [my network] to arrive from a town 10 km from the IXP, I have to use the Telmex network. And in this case, I find it cheaper to use the Telmex internet service than what the IXP is going to give me. Because what Telmex will charge [for a fiber line] to take me to IXP is going to be more than what Telmex will charge to provide me the internet service without having to go to IXP.

Part of this scenario is due to the access that the incumbent has to passive infrastructure throughout the country, including antennas, posts, and right-of-way—the legal possibility of passing cables through public spaces. Interviewees mentioned the difficulty of small players having access to right-of-way. In the past, Telmex used to be a public company and kept better negotiations with supporting infrastructure historically.

The Incomplete Translation Process

The analysis that follows is based on the actors that stood out in the dynamics of the IXP formation: the OECD report, CUDI's president, the telecommunication regulator, the telco incumbent, the telecommunications law, NIC Mexico, the fiber networks, the passive infrastructure (posts, optical fiber, right-of-way), big content providers/CDNs, incumbent competitors, global networks (Tier 1 network), civil society (including academics) and the core actor, the IXP, that from the narrative goes beyond its equipment—cabinet, switch, router, cables—, and includes the data center, the networks connected to it, and the governance consortium team. Independently of being human or non-human, actors are considered symmetrically, including individuals, networks, supporting infrastructure and documents, who have had an active role in the dynamics. In ANT, action is conceived not as an exclusive "property of humans," but as a result of a combination of agents or "actants," including technical artifacts (Latour, 1999). Regarding documents, the very argument to consider them more than sources of information is that text transcends authors and their intentions. They can instigate actions and can "be considered as actors in their own right" (Prior, 2008, p. 822).

The IXP formation is a result of numerous social, political and economic goals that are delegated to this artifact, in a translation process in which actors' identities and characteristics are negotiated in relation to the others. Michel Callon (1984) suggests four moments of observation to understand this

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translation development: problematization, interessement, enrolment and mobilization. These moments are not independent of each other, though. They need to be understood as dynamics that can overlap.

Problematization

The problematization moment is when certain actors "establish themselves an obligatory passage point in the network of relationships they [are] building (…) [or] indispensable in the network." (Callon, 1984, p. 204). In the present case, this actor is the IXP, voiced by CUDI's president and can be considered IXP's "spokesman" (Callon, 1984).

The goal of building the first IXP of the country required CUDI's president to negotiate with several actors. In this context, the OECD report worked as a catalyst for the interconnection facility formation once it recommended reducing market concentration; the IXP promises, echoed by CUDI's president, conveyed this possibility, which was in accordance with the telecommunications regulator interest. The document worked as both a symbolic and material supporter for CUDI's president to resort to it in his dialogues to enable a group of supporters.

Notably, even when the IXP was just a project, it was already an actor in terms of the outcomes expected. The question was if there would be enough support to physically build it. CUDI's president starred the problematization moment, defending that it was the best moment for joining efforts to build an IXP, and that such a technological artifact was the best answer to address not only economic disparities in the market, but also social and political issues.

Interessement

The interessement moment arises when the IXP project needs to attract enablers and distance them from other alternative responses to the existent problems. CUDI's president defended that, once formed, an IXP would improve internet traffic and quality; avoid international routes and strength sovereignty; leverage market competition; narrow digital divide and encourage development of national content online. Interestingly, the CUDI organization has for a long time been interested in improving

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Mexican universities' connectivity, but devoid of an academic backbone network, sharing infrastructure in the IXP was seen as an alternative to their difficulty in negotiating effective fiber networks connections.

The regulator, IFT, heard CUDI's president voice parallel to the OECD report repercussions and moved to delegate its policy goals to law and guidelines requiring the telco incumbent to participate in the incoming IXP. The law issued in 2014 worked as a guarantee for companies to invest and engage in the project. The IXP would, in this case, start with a small number of participants. However, the promise of making agreements and sharing infrastructure with the incumbent in the near future also supported private investments. The players interested were in unison, understanding that without the law, the telco incumbent would not integrate the project.

Advertised outcomes of the IXP showed technical, political and economic purposes completely intertwined. Beyond the government collaboration, they attracted companies interested in optimizing their costs and leveraging their profits based on the belief that in a certain period of time the IXP would deliver what had been promised, especially business with the incumbent. The specificity of the networks attracted to the IXP project is that they were at a disadvantage in the market in comparison with the incumbent infrastructure and the dependence on Tier 1 networks in the United States to connect to the Telmex network. The regulator's law and guidelines requiring Telmex to be part of the IXP give the reasons necessary for them to join the project, and more importantly, keep the project ongoing even after three years (as of the time of writing) of no expected results. The law and the guidelines, which the telecommunications regulator issued to enforce the law, are key actors for keeping the IXP live in a fragile equilibrium.

Notably, companies read the expected outcomes with an economic lens. Reducing the international traffic does not necessarily mean strengthening sovereignty, but saves money in traffic costs and decreases latency. Thus, the association of social benefits to the IXP does not have the same significance or attractiveness for different actors involved.

Enrolment

Callon points out that "To describe enrolment is (…) to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessements and enable them to succeed"

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(Callon, 1984, p. 211). The IXP formation depended on actors not always visible and ready to support the project: a data center designed to securely host its equipment—servers, switches, routers, cables, fiber internet links—and autonomous system numbers. For the networks to interconnect using an IXP they need to "negotiate" (Callon, 1984) with these actors; otherwise, they become barriers for networks to effectively be part of the IXP. For instance, the difficulty faced by some universities to be assigned an autonomous system number by the NIC Mexico has kept them apart from the IXP. Legal and economic constraints that restrict the offer of affordable fiber links to Santa Fé can reduce interest of regional networks based far from Mexico City in connecting to that internet node, as well as induce them to continue buying internet from the incumbent as exemplified earlier by an interviewee. Additionally, to keep the IXP equipment functional and sustain its colocation at the data center—IXP members are asked to pay a monthly contribution in dollars, which also becomes a barrier for small internet service providers. In the end, the design and governance of the data center are altogether crucial for IXP performance, not only for what they allow, but also for what they constrain. While the IXP itself is considered to be physically formed by a cabinet with switches, routers, servers and cables, it is in fact intertwined with the attributes of the data center where it is colocated, the networks that are successfully connected to it, and the ones that are not connected due to failed negotiations with other infrastructure actors marked by legal and economic constraints.

There are certain actors that were not involved in the formation of IXP, although the social outcomes that the IXP spokesman advertised to attract supporters are of great interest to them. These include civil society groups who advocate for affordable internet, who are responsible for building community networks in places where internet service providers are not willing to serve, and academics who are important voices in the area of telecommunications and the digital divide. Considering that, despite CUDI's president and the telecommunication regulator, the other active actors engaged in the formation of the IXP who voiced their interests do not mention concerns with the digital divide or with sovereignty. Such promised outcomes seem to be primarily a rhetoric tool for the IXP spokesman, and not a mobilizer used to aggregate actors interested in these issues around the IXP. In this scenario, modeling the IXP in this direction is thus unlikely to happen, once such outcomes are restricted to the desire of some actors.

Interestingly, in this case, IXPs become similar to other infrastructures in which beyond their technical functions, their form, "or the poetics of infrastructure" (Larkin, 2013, p. 329) shows political facets

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through the “imaginary” and the “fantasy” created around them. Furthermore, as Cynthia Cockburn argues, if based on the way and by whom they were built, technologies are masculine and cannot be seen in a sexless mode (Cockburn, 1983), the Mexican IXP is also a commercial entity, used to facilitate commercial agreements, and based further on its governance and design, cannot be seen differently even if led by a not-for-profit organization.

Mobilization

Convergence and a certain level of consensus around a proposition mark the success of the mobilization moment. In the case of the IXP formation project and the actors that emerged in the dynamics, the mobilization results can be considered only partial. The project was formulated based not only on the affordances of an IXP—or what it can do—but on the successful translation of organizations’ goals into technology functions. Yet the fact is that after some years since the IXP formation, that didn’t happen. IXP development has maintained the interest of new networks in connecting to the first Mexican IXP low, keeping the number of its members less than ten. Lack of abundant and affordable links to connect networks in other regions to the data center shows the role of fiber networks and passive infrastructure as actors that constrain such interest. Companies that founded the IXP were acquired by other businesses (e.g. AT&T acquired Nextel; KIO Networks acquired redIT) and the IXP stage was not enough to initially attract new big players as AT&T to the project.

Public information about IXP performance is not available, but the reported IXP traffic in interviews is modest. Thus, there is no evidence that key promised outcomes, such as reducing international traffic and latency, leveraging competition and access to the internet for more people, have been addressed. Some academics are skeptical and still not engaged in the project.

On the other hand, it is not a trivial outcome that, despite all the frustrated expectations, the IXP in Mexico is still running while there are numerous defunct IXPs in the world.[6] The mobilization moment that started with the formation of the group that would support the IXP formation, including the telecommunication regulator and some companies, has been continuously sustained. For this to happen,

[6] A filter at the Packet Clearing House database (www.pch.net/ixp/dir) shows 112 defunct IXPs in the world.

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the most important actors in this scenario seem to still be the law and the guidelines that require the telco incumbent to adhere to the IXP. They generate the expectancy that after the Telmex connection, IXP traffic will exponentially increase, networks will not need to use Tier 1 networks in the United States to connect to the incumbent, and new networks will be attracted to the IXP, contributing to the likelihood that the IXP will prosper. Such results, however, are not a given. They are part of the infrastructure imaginary around the IXP and will depend on negotiations among the actors when Telmex changes its position in the scenario. The regulatory documents thus support a dynamic equilibrium based on this imaginary that allows the project to continue.

Conclusions

In internet network scholarship, authors have defined Internet Exchange Points as "a network infrastructure with the purpose to facilitate the exchange of Internet traffic between Autonomous Systems and operate below layer three" (Chatzis et al., 2013, p. 20), or "a shared layer-2 switch fabric environment, with three or more participants, where new participation is not rigorously constrained, and over which the members peer with each other, exchanging customer routes" (Fanou et al., 2017, p.4).[7] Such definitions have been built on a network framework focused on highlighting the IXP affordance of conducting node-to-node communication and are guided by the industry definition that is compiled in an European association of IXPs report where: "An Internet Exchange Point (IXP) is a network facility that enables the interconnection and exchange of Internet traffic between more than two independent Autonomous Systems" (Euro-IX, 2015, p. 3).

From a sociotechnical vantage point, the evidences obtained with the present analysis enable understanding IXPs as relationships of players with goals and functions that mesh to become an interconnection facility in the internet. Such networks of relationships are dynamic and are defined relative to each player in the scenario, which includes individuals, organizations—characterized by their design and governance—, documents, laws, and technology artifacts, such as IXP equipment and the passive

[7] Where "layers" refer to the OSI model extensively used by the community to define a network ecosystem in terms of seven conceptual layers. The layer-2 switch that is below layer-3 is the data link layer that provides point-to-point data transfer (Shaw, 2017).

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infrastructure. Negotiations are continuous, and as players' strategies and characteristics change, the relationships also change, strengthening or weakening IXP equilibrium.

IXPs may have different deployments and pathways depending on where they are built. In fact, it is unlikely that one can just transfer an IXP from one country to another, given that actors will likely to be different in each territory, and will require, in consequence, adaptations of other players, including in terms of design and governance when appropriate. Because of that, definitions in which there is a locked understanding of an IXP such as in Fanou et al. (2017), who state that an IXP is "where new participation is not rigorously constrained," are clearly normative and not a generalizable conceptualization as the Mexican IXP demonstrates.

"The Internet is only virtually stable" (Star & Bowker, 2010, p. 237). The study of IXPs reiterates that. It is not that IXPs are formed and then expected to be perennial. Incomplete translation processes can generate discontinuation provoked by a chain of actors. As affordances are learned and not static or given (Lievrouw, 2014; Star & Bowker, 2010), a continuous interpretation of an IXP, based on local meanings, needs to be in action to understand the dynamic ties established among players involved with the IXP deployment, design and governance. With that, the IXP may be de-blackboxed and its materiality is unveiled.

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References

Agudelo, M., Katz, R., Flores-Roux, E., Botero, D., Cristina, M., Callorda, F., & Berry, T. (2014). *Expansión de infraestructura regional para la interconexión de tráfico de internet en América Latina*. CAF. Retrieved from http://scioteca.caf.com/handle/123456789/522

Electronic copy available at: https://ssrn.com/abstract=3171107

Blackman, C., & Srivastava, L. (Eds.). (2011). *Telecommunications Regulation Handbook* (Tenth Aniversary Edition). Washington, DC.: The International Bank for Reconstruction and Development / The World Bank, InfoDev, and The International Telecom munication Union.

Callon, M. (1984). Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay. *The Sociological Review*, *32*(1_suppl), 196–233. https://doi.org/10.1111/j.1467-954X.1984.tb00113.x

Chatzis, N., Smaragdakis, G., Feldmann, A., & Willinger, W. (2013). There is More to IXPs Than Meets the Eye. *SIGCOMM Comput. Commun. Rev.*, *43*(5), 19–28. https://doi.org/10.1145/2541468.2541473

Cockburn, C. (1983). Caught in the Wheels. *Marxism Today*, 16–21.

DeNardis, L. (2014). *The global war for Internet governance*. New Haven: Yale University Press.

Euro-IX. (2015). *euro-ix Internet Exchange Points: 2015 Report* (p. 21). European Internet Exchange Association (Euro-IX). Retrieved from https://www.euro-ix.net/media/filer_public/11/2c/112c450a-7f3c-4947-9c0b-6104b3a38659/euro-ix-ixp-report-2015-final.pdf

Fanou, R., Valera, F., Francois, P., & Dhamdhere, A. (2017). Reshaping the African Internet: From scattered islands to a connected continent. *Computer Communications*, *113*, 25–42. https://doi.org/10.1016/j.comcom.2017.09.006

Flores-Roux, E. M., Mariscal, J., & Aldama, F. A. (2009). Propuesta de licitación de la fibra oscura propiedad de la CFE: solución que genera escasez artificial, tanto presente como futura. *DIRSI, TELECOM-CIDE, IDRC-CRDI*, 1–45.

Galperin, H., & Mariscal, J. (2016). *Internet y pobreza: Evidencia y nuevas líneas de investigación para América Latina*. CIDE.

IFT. (2017). *Tercer Informe Trimestral Estadístico 2016* (p. 91). Mexico City: Instituto Federal de Telecomunicaciones.

Intven, H., & Tétrault, M. (Eds.). (2013). *Telecommunications Regulation Handbook*. Washington, DC: World Bank. Retrieved from http://hdl.handle.net/10986/15249

Klöti, R., Ager, B., Kotronis, V., Nomikos, G., & Dimitropoulos, X. (2016). A Comparative Look into Public IXP Datasets. *ArXiv:1611.02624 [Cs]*. Retrieved from http://arxiv.org/abs/1611.02624

Electronic copy available at: https://ssrn.com/abstract=3171107

Larkin, B. (2013). The Politics and Poetics of Infrastructure. *Annual Review of Anthropology*, *42*(1), 327–343. https://doi.org/10.1146/annurev-anthro-092412-155522

Latour, B. (1991). Technology Is Society Made Durable. *The Sociological Review Monograph*, (38), 103–131.

Latour, B. (1999). *Pandora's Hope: Essays on the Reality of Science Studies* (1 edition). Cambridge, Mass: Harvard University Press.

Latour, B. (2002). Morality and Technology. *Theory, Culture & Society*, *19*(5–6), 247–260. https://doi.org/10.1177/026327602761899246

Law, J. (2016). STS as Method. In *The Handbook of Science and Technology Studies* (4th ed., pp. 1–24). MIT Press. Retrieved from http://heterogeneities.net/publications/Law2015STSAsMethod.pdf

Lievrouw, L. A. (2014). Materiality and media in communication and technology studies: An unfinished project. In T. Gillespie (Ed.), *Media technologies: Essays on communication, materiality, and society* (pp. 21–51).

Mexico. (2014, July 14). Ley Federal de Telecomunicaciones y Radiodifusión.

Mexico. (2017, July 24). DOF - Diario Oficial de la Federación. Retrieved from http://www.dof.gob.mx/nota_detalle.php?codigo=5491665&fecha=24/07/2017

Musiani, F. (2013). Network architecture as internet governance. *Internet Policy Review*, *2*(4), 1–9.

Norman, D. A. (2010). *Living with Complexity*. Cambridge, Mass: The MIT Press.

OECD. (2012). *OECD Review of Telecommunication Policy and Regulation in Mexico*. OECD Publishing. https://doi.org/10.1787/9789264060111-en

OECD, & IDB. (2016). *Broadband policies for Latin America and the Caribbean: a digital economy toolkit*. Paris: OECD Publishing.

Prior, L. (2008). Repositioning Documents in Social Research. *Sociology*, *42*(5), 821–836.

Rivera, A. (2014, May 2). Forman en KIO el primer IXP de México. Retrieved August 1, 2017, from http://boletin.com.mx/datacenter-almacenamiento-y-respaldo-boletin/item/755-forman-en-kio-el-primer-ixp-de-mexico/755-forman-en-kio-el-primer-ixp-de-mexico

Electronic copy available at: https://ssrn.com/abstract=3171107

Shaw, K. (2017, December 4). The OSI model explained: How to understand (and remember) the 7 layer network model. Retrieved April 15, 2018, from https://www.networkworld.com/article/3239677/lan-wan/the-osi-model-explained-how-to-understand-and-remember-the-7-layer-network-model.html

Star, S. L., & Bowker, G. C. (2010). How to Infrastructure. In *Handbook of New Media: Social Shaping and Social Consequences of ICTs, Updated Student Edition* (pp. 230–245). London: SAGE Publications Ltd. https://doi.org/10.4135/9781446211304

Telmex. (n.d.). Retrieved from http://blog.telmex.com/?s=fibra+optica

Weller, D., & Woodcock, B. (2013). *Internet Traffic Exchange: Market Developments and Policy Challenges* (OECD Digital Economy Paper No. 207). OECD Publishing. Retrieved from https://econpapers.repec.org/paper/oecstiaab/207-en.htm

Electronic copy available at: https://ssrn.com/abstract=3171107