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Internet interconnection infrastructure: lessons from the global South

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Abstract: This article examines the formation of the first internet exchange point (IXP) in Mexico amid the implementation of telecommunication reforms and asymmetric regulations in a market with low level of competition. An IXP is defined as a shared interconnection facility and a key internet governance arena where players with myriad goals and functions mesh in interlaced technical and political dynamics. The study shows how data centres, passive infrastructure and autonomous system numbers play a critical role that stand out in the context of lack of infrastructure in Mexico. The paper argues that the challenges for an IXP to become stable in such a context in the global South is a result of IXP imagined affordances and the way that infrastructure, the telecommunications incumbent, its competitors, the state regulator, and the IXP operator interact, keeping the initiative in a fragile equilibrium.

Introduction

In May of 2014, a cadre of companies, policymakers, and journalists convened at an inaugural event for launching the first internet exchange point (IXP) in Mexico. An IXP can be initially understood as an internet node, a physical facility where networks interconnect through commercial agreements to exchange traffic and routes on the internet. Networks, in this context, encompass internet service providers (ISPs) that offer internet access to both end users and other ISPs, as well as content providers (e.g., Amazon, Facebook, Google), but can be also government agencies, universities and any other organisation which has an autonomous system number (ASN) to be uniquely identified on the internet. In terms of internet infrastructure, these organisations are known as autonomous systems which run internet networks. Here both terms, autonomous systems and networks, will be used interchangeably.

With regard to the launching of the IXP, Carlos Casasús, president of the committee formed to coordinate the new infrastructure facility, outlined publicly the benefits that would justify that investment. His considerations comprised four key issues:

1. Leveraging the quality of the internet, through the "decrease of latency between connections" and the "improvement of the internet traffic";
2. 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"[1];
3. Leveraging market competition, helping to establish "a healthier competition among telecommunications operators," and "attract more foreign investment;" and
4. Generating social benefits, "narrowing the digital divide by making the internet more accessible to more people," and "encouraging further development of national content online." (Rivera, 2014, n.p.)

While these reasons reflect local motivations, they are also indicative of what is being discussed among international organisations. 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, emphasising the role of IXPs in improving connectivity rates in "developing" countries, reducing internet transit prices, and internet market competition (Blackman & Srivastava, 2011; Intven et al., 2000; OECD, 2013; OECD & IDB, 2016; Weller & Woodcock, 2013).

This article offers a "technical controversy-based" (Musiani, 2015) examination of the creation and implementation of the first IXP in Mexico in the context of asym-

metric regulations to balance the economic power of a telecommunication incumbent. It aims to provide an ethnographic understanding of the behind-the-scenes dynamics of internet interconnection to unveil practices of internet governance that inherently lead to certain results over others, impacting the internet that emerges from that. By engaging with ethnographic methods, the paper illustrates the factors that mobilise actors to either support or not the creation of this IXP, and the complex negotiations that keep the initiative ongoing after more than six years of its formation, without delivering the expected results. Negotiations are continuous, strengthening or weakening the emerging facility, in a clear illustration of the competing forces involved in building IXPs in the global South. This case will highlight the need to expand our understanding of an IXP. It is not only "a network facility that enables the interconnection and exchange of Internet traffic between more than two independent Autonomous Systems" (Euro-IX, 2015, p. 3); IXP is a key internet governance arena in which interlaced technical and political dynamics play out.

In the following sections, I present the theoretical framework and methods used in this research. I then examine the dynamics of the IXP formation and implementation for actors who are and are not part of the IXP project, and conclude defining IXP in internet governance terms and pointing to future research.

Theory

Literature on IXPs is extensive, especially in network engineering (Chatzis et al., 2013; Fanou et al., 2017; Klöti et al., 2016), and case studies focusing on single IXPs are noteworthy (Carisimo et al., 2015; D'Ignazio & Giovannetti, 2009; Cardona Restrepo & Stanojevic, 2012). These works build on quantitative methods to elucidate the role of IXPs in internet topology and deployment, with a main focus on internet measurement and performance.

Research and policy reports with a development and economic lens have contributed to understanding the benefits of building IXPs as well as its challenges. They defend that local IXPs promote better internet quality, by keeping local data local and reducing latency, which converts into better user experience and internet price (Galperín, 2016; Katz et al., 2014). Factors that emerge as constraints for IXPs to succeed include the role of government and regulation, the political instability, infrastructure disparities, and lack of a "critical mass", meaning a group of ISPs willing to collaborate and interconnect (Degezelle, 2015; Fanou et al., 2017; ISOC, 2014). On that, especially in the global South, "it is an extra challenge to convince incumbent networks to connect to the IXP (…) because they do not see the need

and fear losing traffic, clients, and income" (Degezelle, 2015, p. 14).

In view of that, some governments have passed legislation aimed at facilitating IXP implementation and functioning (Katz et al., 2014). Until 2014, when the telecommunications sector was passing through reforms in the country, Mexico was the largest state in the world, and the only within OECD, without an IXP (OECD, 2013). Reasons for that include lack of government support, opposition from the incumbent, and the existent alternative for the incumbents' competitors to exchange internet traffic in the United States (Katz et al., 2014).

Internet governance scholarship has increasingly pointed to IXP and internet interconnection as critical topics of everyday practices yet to be investigated (DeNardis, 2014; Epstein et al., 2016; Hofmann et al., 2017; Musiani, 2015; van Eeten & Mueller, 2013). Thus far, works focusing on interconnection that dialogues with internet governance are still scarce (for exception see DeNardis, 2012; Meier-Hahn, 2014; Rosa & Hauge, 2021; Sowell, 2012). This research responds to this gap by exploring the imponderable role of governance in internet infrastructure in Mexico. It is concerned with governance *by* IXP more than *of* IXP (DeNardis & Hackl, 2015), to shed light on how the formation and establishment of an IXP is embedded in social, political, and economic dynamics, and how its supporting infrastructure plays a critical role in the context of a market with low competition.

Due to its unexpected development, the first IXP in Mexico could be used as an example of a "struggling" initiative (Sowell, 2012). Using the global North as a metric, numerous policy reports assess IXPs with such a development focus, especially in Africa, where their deployment has commonly received technical and financial support from international organisations (e.g. ISOC, 2014; Kende & Hurpy, 2012). Rather than examining the dysfunctionalities of the Mexican IXP from an assessment viewpoint, the present work is interested in revealing the specificities of local internet governance, and new facets of the internet architecture's "technopolitics,"—"the hybrid forms of power embedded in technological artifacts, systems, and practices" (Hecht, 2011, p. 3). The dynamics investigated in Mexico shed light on realities in which the power of telecommunications incumbents and the lack of market competition prevent IXPs from becoming stable infrastructures, particularly in the "global South"—a term that supposes common transnational dynamics, or a "shared condition" in the periphery of globalisation (López, 2007, p. 3). Global South breaks with hierarchical understandings of "developed" and "developing" countries to, instead, understand their differences and inequities.

Examining how regulators and incumbent competitors mobilise to create an IXP,

and how the incumbent tries to circumvent such policy, illuminates how the IXP exercises its governance in internet competition. This action is always a shared phenomenon between society and technological artifacts, or infrastructure in this case. Agency, thus, is neither an exclusive characteristic of humans or a property of objects (Latour, 1999); it is a result of their interactions. If action is shared, the object's attributes, or the IXP affordances, should not be taken for granted. Understanding them is as crucial as understanding humans' actions to comprehend any policy outcomes.

Materials and methods

The present work is a result of ethnography of infrastructure (Star, 1999; Star & Bowker, 2010) applied to an IXP for three years. The research was conducted in person between June and September of 2017 in states with different rates of household internet subscriptions (IFT, 2017): Mexico (> 60%), Oaxaca and Chiapas (0-20%), when two unanticipated earthquakes impacted the country. Additional virtual interviews, checks and observations were conducted between 2018 and 2020. More than twenty in-depth interviews—with representatives from indigenous communities, policymakers, not-for-profit organisations, academics, and internet service providers, as well as participatory observation of events, including IXP Mexico activities, the Forum on Indigenous and Communitarian Media, OECD report release—comprise the primary sources analysed. Interviews were conducted in Spanish and were translated by the author. Anonymity is kept in observance to interviewees' options or, in the absence of that, as an author's option when identification does not add to the understanding of the case.

Following an ethnographic approach, facts observed in the field were balanced and compared with interviews and documents related to the formation of the IXP, which include multilateral policy recommendations, regulators' legal documents and norms. Research reaches intended saturation when documents, interviewees' contributions, technologies, and events observations converge in their reports of the facts, independent of their vantage points and perspectives.

Analysis of the data follows the framework of Michel Callon (1984) and the phenomenon of "translation", in which humans' goals and technology functions merge, opening new possibilities of actions and results. In this study, three principles guide the work: *agnosticism*—impartiality to the parts of a controversy; *symmetry*—analysis of different perspectives with the same lens; and *free association*—breaking the divide between society and technological artifacts. By revisiting Callon's approach, internet infrastructure is portrayed as contingent to numerous

negotiations, making salient the policymaking dynamics in underlying layers of the internet.

Results and discussion

IXP as an outcome of telecommunications reform (2012-2014)

In 2012, the OECD released an influential report on Mexico, one of its few members 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 was that the telecommunications regulator should have the power to impose regulations and sanctions to leverage competition, and with regard to infrastructure specifically, it 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).

With the election of a new president that year committed to structural reforms and pro-competition measures (Mariscal Avilés, 2020), this agenda has gained impetus. A brand-new regulator, the Federal Telecommunications Institute (IFT), was created in 2013 to replace the Federal Commission of Telecommunications (COFETEL), recognised for its limited outcomes (Aguerre & Galperín, 2015). Notably, in the same year, IFT started a process to define the preponderant economic agent in telecommunications, toward implementing asymmetric regulations. That culminated, in 2014, in the decision of defining Telmex, Telnor, Grupo Carso and Grupo Financiero Inbursa, whose control is under the holding América Móvil, as the preponderant agents (IFT, 2014). Months later, the telecommunications law reform passed in Congress reaffirmed regulator independence, functions and the primary agenda to leverage telecommunications competition (Mexico, 2014).

Telmex, the main company of the group and the national telecommunications incumbent, was public until its privatisation in 1990. Its concession established "the obligation to both have open architecture and interconnect its networks" (Álvarez, 2018, p. 42, own translation); nevertheless, interconnection and infrastructure sharing have always been a point of controversy between the incumbent and its emerging competitors in telephone and internet services (Corona, 2017; Reuters, 2018), with reasons that will be clear later.

It is in this broader scenario of implementing pro-competition regulations that a project to create the first internet exchange point in Mexico gains relevance, as a

shared facility to support internet interconnection, ideally with the incumbent. IXP became a *prêt-à-porter* solution, for a problem that was there for years. Carlos Casasús explains how the idea took advantage of the broader political scenario:

> 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 and I said 'Why do not we [create an IXP]? 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 (personal communication).

Casasús was the first Mexican telecommunications regulator president in the 1990s, after years of work at Telmex as a public company. He is now known for his efforts within the not-for-profit organisation Corporación Universitaria para el Desarrollo de Internet (CUDI), which is responsible for operating the national research and education network (NREN), with the goal of connecting the higher education institutions throughout Mexico. It was in the context of CUDI work that the idea of building an IXP already existed and was shared with colleagues a decade before, in the 2000s. At that early moment, an IXP was seen as a way to improve universities' internet connectivity, keeping the country's content local and decreasing dependence on the United States' infrastructure. However, as one of CUDI's employees remembers: "[The idea] did not prosper because there were not enough fibre networks to do it" (personal communication).

According to Casasús, an inspiration for CUDI and the early stages of an IXP project came from the Brazilian National Research and Educational Network (RNP), a network of universities in Brazil whose goal is also to integrate academic institutions. RNP has a backbone fibre network running since 1992 with access points in all 27 Brazilian states, facilitating academic network interconnection all over the country, and serving as points of interconnection and data centres of some IXPs. CUDI, though, does not own a fibre network. In fact, the first IXP initiative in Mexico was led by an educational organisation devoid of internet infrastructure resources. This brings about two consequences:

First, to account for a lack of infrastructure, it was essential that the first IXP in Mexico be configured to fit the telecommunications regulator's agenda and other players interested in leveraging market competition, to ensure their support and resources. Such frame composes IXP "imagined affordances", attributes that "emerge between users' perceptions, attitudes, and expectations; between the materiality and functionality of technologies; and between the intentions and perceptions of designers" (Nagy & Neff, 2015, p. 5). These include interests and expectations of outcomes that guide actions toward the IXP, and shape its use.

Second, in relying on others' resources and infrastructure, the IXP becomes an entity coordinated by a not-for-profit organisation that needs to reconcile its public interests, named internet quality, sovereignty, market competition, and digital divide issues, with commercial interests of its partners. This is pivotal because typifying IXPs in terms of their business models, including "for-profit", "non-profit co-operative" and non-profit managed" (Chatzis et al., 2013, p. 22) or in terms of the organisation that they are led by—a not-for-profit, industry association, for-profit company, university/government, or informal associations (ISOC, 2014), tell little about governance, the way that power is performed (Gisselquist, 2012). A non-profit may become less public oriented if it is shaped by private interests and resources.

Implementation and governance of the IXP

In 2014, along with the CUDI president, five companies founded the not-for-profit organisation Consortium of Internet Exchange Traffic (CITI, A.C.): the ISPs Megacable, Nextel, redIT, Transtelco, and the most prominent data centre in the country, Kio Networks. Except for Nextel, all the founders are national companies, motivated to support the project for commercial reasons. For data centres, having an IXP among their co-location clients is beneficial, because the initiative can attract numerous more customers to their facilities. As already noted, "The relation between the data center and the IXP is highly synergic" (Katz et al., 2014, p. 177). For ISPs, that means increased connectivity, lowering their costs of sending and receiving data packets. As noted by one of the IXP founders about their participation in the endeavour, "In the end it is business (…) There is no altruistic issue. Everything is totally and completely business" (personal communication).

The consortium has bi-monthly meetings to discuss administrative issues, including payments, participants, and emergent needs. The networks were required to pay USD 2,400 dollars monthly to be part of the IXP, which gave them access to a port of 10 Gigabits per second (Gbps) to exchange traffic with their peers. While this amount, pushed by the costs of the data centre, follows market practices from the US where data centres run IXPs as for-profit organisations (e.g., Equinix), it is much higher than the price practiced by other not-for-profits in the region. For instance, at the time of writing, in Argentina, a 10 Gbps port in the capital city costs approximately US 870 dollars per month, while in Brazil, with a multistakeholder institution subsidising the project, it costs USD 130 dollars.

This is a key aspect of the Mexican IXP, a not-for-profit with costs of a for-profit data centre. A central decision in building an IXP is choosing its physical sites (ISOC,

2014, p. 20; Katz et al., 2014). Data centres are responsible for housing IXP equipment, providing what is known as co-location services, as well as IXP building infrastructure, including robust connectivity, cooling, electricity, and security. As a matter of fact, data centres in the global South are known for their higher costs, and Mexico, specifically, is classified as having the lowest level of data centre infrastructure development in Latin America (García Zeballos & Iglesias Rodríguez, 2017). These costs are added to the monthly quota that IXP participants need to pay. As IXP personnel note, such amounts may substantially differ based on data centre policies and costs, with differences up to almost three times between locations.

Given that price is always an additional barrier for smaller networks, the IXP has not been able to attract such players. Despite the fact that some new participants joined the Mexican IXP since its beginning, the membership is still under ten as can be seen in their website—a modest portion of the universe of approximately 450 autonomous systems registered in the country at the time of writing.

The most accurate scenario is that IXP Mexico is still not a stable infrastructure more than six years after its creation. Even if completely operational, the facility is not fully used by its participants. Given that they already had commercial relations with each other beforehand, they are not dependent on that new infrastructure to interconnect among themselves, interviewees say. In January 2020, the Mexican IXP was responsible for a low amount of internet traffic, with a speed of 1Gbps according to its administration. For a rough comparison, the main IXP in Latin America, located in Sao Paulo, Brazil, has an average of more than 4 Terabits per second (Tbps) on the same date. Such a difference from giga to tera scales cannot be explained by comparable differences in total traffic within countries, as business estimatives once available showed that Mexico has been responsible for 1% of the global web traffic while Brazil responds to 3% (Akamai, 2020). The controversies around IXP affordances help understand this scenario below commercial expectations.

Imagined affordances for supporting (or not) the IXP

IXPs are at the core of the internet economy, yet not all data that circulates on the internet traverses an IXP. Estimations are that one out of five paths on the internet tends to pass through an internet exchange (Nomikos & Dimitropoulos, 2016). This represents a huge amount of data that go through hundreds of IXPs worldwide.[1] For ISPs—responsible for the traffic of users' data online, an IXP means the possibility of saving money by building "peering" agreements with other net-

works[2]. For instance, every time an end user accesses a website, sends an email, or accepts to update an app, the ISP that serves them needs to find a way to interconnect to that content provider in order to have access to the information requested or to deliver what has been sent. If the ISP is not directly connected to that provider, the alternative is to find who may provide such access. Because of its reach in the country, all Mexican IXP founders were interested in increasing their connectivity with a specific potential peer: the incumbent Telmex, whose routes and clients they could only reach with a third and more costly alternative, which is called "transit". Peering is more advantageous than transit, which is a customer-provider relationship established between two autonomous systems, whereby access to the larger internet (not only to their own routes and customer's routes) is provided through a paid agreement. In a transit relationship, one party with restricted internet reach wants to buy connectivity while the other one has the infrastructural resources and financial settlements to reach any internet address and charge for it. Ideally, transit complements networks' peering agreements, and with a conjunction of these two kinds of arrangements, ISPs are able to deliver internet traffic to the whole internet, making worldwide communication happen (for more, see Faratin et al., 2008; Huston, 2016; Metz, 2001; Rosa & Hauge, 2021).

With regard to Telmex, which did not connect to the IXP project in the beginning, the IXP founders defend that its participation in the initiative is crucial for its success, given that the company not only has the biggest number of clients, concentrating 51.6% of the fixed broadband market, but it also has the largest infrastructure to reach different parts of the country, with more than 190,000 km of optic fibre (Telmex, n.d.). The controversy emerges in that the same reason that makes the incumbent so valuable to a public interconnection facility is also the reason for the company to not express interest in being part of the IXP.

As already noted, "the largest telecommunications companies tend to view IXPs as antagonistic to their business" (Katz et al., 2014, p. 121, own translation). An incumbent, technically known as a Tier-2 ISP for its national reach (as opposed to Tier-1 ISPs with world reach, and Tier-3 with a more regional one), has commercial incentives for not sharing its infrastructure through peering with potential com-

1. Although the number of IXPs in the world is not precise, at the time of writing, there are more than seven hundred active facilities distributed across the globe according to Packet Clearing House (PCH) online database.
2. Peering is a collaborative relationship in which autonomous systems, such as ISPs, allow the networks with whom they peer to have access to both their own routes and clients' routes in order to have the same benefits in return, so they can freely send and receive data packets among each other.

petitors. Economically, it is seen as more advantageous to sell transit to Tier-3 ISPs than to peer with them. In Mexico, Telmex is one of the most likely companies from which any ISP would buy transit, as infrastructure is the incumbents' crucial ally. This is how a former incumbent collaborator, speaking in a personal capacity, synthesises the situation:

> Telmex does not have interest in joining the IXP. Considering the local interconnection in Mexico, the company already has peering with all the relatively big networks. If the small ones want to reach me, [Telmex would say,] they have to pay me transit. I will not give it for free [by peering](personal communication).

The incumbent infrastructure is built on its own network of data centres distributed all over the country, which host the company's own infrastructure only, and a few are used for interconnection with other provider networks for transit relations or peering agreements that Telmex finds convenient to its business. While the incumbent business model is subject to change in view of market conditions, many Telmex competitors are unable to interconnect with the company in Mexico because of its current network design, reporting the need to reach the incumbent network in the US through Tier-1 ISPs.

CUDI and IXP supporters criticise this situation, citing the high international traffic cost for Telmex' competitors and the generation of trombone traffic—when internet traffic with its origin and destination in the same country needs to traverse another country, as when a hypothetical email sent from a Telmex competitor's client to a Telmex client, both in Mexico, needs to go to the US first to reach a Telmex network to be delivered. An IXP in Mexico is consequently a possible solution for that, as it "would provide Mexico with greater sovereignty over data generated by local Internet users," a paraphrase of a Kio Networks representative (ISOC, 2014, p. 60), in a clear reference to a political discourse about digital sovereignty debates (Pohle & Thiel, 2020). Considering that for the regulator IXP's imagined affordances make it a tool to primarily leverage competition and sovereignty, the IXP gained a law as a key ally.

A controversial mandatory peering policy (2014-2017)

Guided by the purpose of leveraging competition in the country, the law that marks the reform in the telecommunications sector had established that the preponderant economic agent should: "Have a physical presence in the Internet ex-

change 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 defines" (Mexico, 2014, own translation). However, Telmex did not act in the direction intended by the regulator.

In 2017, new regulation detailed that the preponderant economic agent or the agent with substantial market power "must establish Connectivity through the deployment of fibre optic links to IXPs that request it, and where there is at least one Internet Service Provider with which [it] does not have a traffic exchange agreement [peering agreement] (…)." (Mexico, 2017, Cap. III, own translation). Moreover, it "(…) must advertise the Routes of [its] clients and accept the Routes of the ISP members of the IXP. The Routes must be kept constantly updated in the Routing Table" (Mexico, 2017, Cap. III, own translation). This regulation aims at enforcing an effective interconnection between the preponderant agent and any player at an IXP interested in peering with the company. In this case, each network, the incumbent included, should cover the costs to physically reach the IXP facilities, and the incumbent is required to expand its infrastructure capacities as the traffic increases.

As already known, regulation making interconnection mandatory for players with substantial market power has significant influence in internet interconnection dynamics, with some internet network experts raising positive opinions related to its effects to small networks, and others pointing to consequent technical restrictions that may distance other players (Meier-Hahn, 2016). Similarly, in Mexico, while the law has reflected significant lobbying from CUDI and the IXP's founders, stakeholders and specialists have not received it unanimously. In the illustrative opinion of a content provider collaborator speaking in a personal capacity, an IXP is useless in a market where there is a low level of competition, and not a robust number of ISPs to benefit from interconnecting publicly at an exchange point. They define the Mexican IXP as a "party where all the guests already have relationships with each other" (personal communication), so paying for a "ticket" to participate in such a party is a waste of money. Their perspective is clearly from the standpoint of who already peers with the incumbent. In this vein, they see the regulation for mandatory peering and participation at an IXP as an unwelcome interference: "When there are no commercial reasons [to interconnect], one makes the law," they say (personal communication).

From this same side of the discussion, an incumbent collaborator, responding in a personal capacity, clearly acknowledges that

> [The law] would give [Telmex competitors] benefits because obviously they do not reach [by themselves] all cities of the country given that they are smaller networks. (…) It is not fair. (…) Telmex (…) is still investing (…). However, other companies, which are not investing in their networks, are waiting to see the moment that they can collect from what [Telmex] has achieved. (personal communication)

Professor Luis Martínez, also the Internet Society (ISOC) Chair in Mexico, speaking in personal capacity, argues further that building an IXP at that moment was "a political and not a technical decision", meaning that the IXP was a government response to OECD's agenda. Also not involved with the initiative, Judith Mariscal, a professor and specialist in telecom and digital divide issues, pointed out in an interview with the author that the IXP was Carlos Casasús' and CUDI's agenda. For this author, the processes of the Mexican reform were notably closed, kept stakeholders apart, and eventual public consultations worked as "clear simulations of a deliberative process" (Mariscal Avilés, 2020, p. 10). Interviews with activists for indigenous connectivity in Southern Mexico support that. Despite not being engaged in the IXP project in Mexico City or the legislation that supports it, Erick Huerta, a lawyer and founder of the NGO Redes A.C. in the capital, explains the challenges to have access to infrastructure at an affordable price to build an IXP with indigenous networks in the state of Oaxaca:

> We could not advance [with the project of an IXP] because it was necessary to build a fibre section. In Oaxaca, there is a problem of the cost of the network. There were only a couple of providers [available]. One is Telmex, which does not sell to you or sells at a very high price. For example, [they charge] 40,000 Mexican pesos for 8 Mbps ($ 248 per 1 Mbps). Which is very expensive (…) as you can get 1 Mbps in Puebla [another state] for 10, 20 dollars. We wanted to get fibre and connect in Puebla, to add all the ISPs in a collective network. Like the one that guif.net has in Spain. (personal communication).[3]

Significantly, access to antennas, posts, and right-of-way—the legal possibility of passing cables through public spaces—is intimately related to this scenario. Because the incumbent used to be a public company, its access to supporting infrastructure is facilitated, making competition lopsided, interviewees report. And

3. These price differences are not particular to Mexico. For instance, in Argentina, small towns used to have 1 Mbps as high as USD 500 dollars, comparing to USD 25 dollars in the capital city (Galperín, 2016).

while this infrastructural imbalance has been an important focus of action in recent asymmetric regulations within the country (IFT, 2018; Lucas, 2018; OECD, 2017), the high costs to access optical fibre links persist. Luis Martínez, who owns a small network, explains why it is not worth it to participate at the IXP to connect to the larger internet, as it is cheaper to get such connectivity as the incumbent's regular customer : "(...) What Telmex will charge [for a fibre 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 the IXP" (personal communication).

It therefore stands out not only that the IXP was not seen unanimously among specialists, but also that CUDI did not incorporate a broader group of actors whose agendas dialogue with the IXP's expected social outcomes, including its promise of "leveraging the quality of the internet" and "narrowing the digital divide". Further, the lack of competition in certain markets, and the incumbent's and other ISPs' price policy create difficulties for new indigenous connectivity projects and small ISPs to flourish with autonomy. Although the formation of the first IXP in Mexico had representatives from academia, the private and public sectors, these actors were restricted to CUDI's president network circle. Broader civil society was and continues to be absent.

From an economic and social perspective, in case the IXP generates the results as expected by regulators—amplifying market competition—this could reduce the connectivity costs that indigenous initiatives and small ISPs face. However, the mandatory peering regulation has not worked as expected.

How the incumbent interconnects circumventing the law (2019-)

In a scenario where actors stand in support of, against, or distant to the IXP, the regulations, which bolstered the IXP initiative the most, have achieved partial results. On the one hand, Telmex physically connected to the IXP in 2019 with the push of the 2017 regulations, as well as the resolution of an official disagreement process with the IXP before the regulator. On the other hand, the company has so far not exchanged traffic as expected.

The disagreement process is revealing. As the regulator defined a group of companies as preponderant, it was necessary now to define the ones who should be physically connected to the IXP and how. Telmex argued, and the regulator accepted the reasoning (IFT, 2019), that some of their companies, although part of the preponderant economic agent, do not have telecommunications licences and should not be required to be physically present at IXPs. As a result, IFT defined

that only one physical connection, meaning one monthly payment, was necessary to function as a tube for Telmex sibling companies to share their traffic with IXP peers.

Regulations at the level of internet infrastructure are intricate. At the time of this writing, Telmex argues to be already complying with the law by being physically present at the IXP. However, IXP representatives counter-argue that the law makes explicit the need to exchange traffic too, which has still not happened. As an IXP representative explains, "There are many traps that one can do" to avoid traffic exchange, and that currently "It is all physically built but [the incumbent] does not activate the logical part that is the BGP [Border Gateway Protocol] session for the exchange of information" (personal communication).

Following arguments from both sides, what this research reveals is that the incumbent has consistently counted on infrastructure as a crucial ally to circumvent regulators and avoid peering at the IXP. As an interviewee clarifies: "When the regulation names Telmex to connect there, [the company] will say, 'I connect, but I will not exchange data because I do not have it, another company does'" (personal communication).

The strategy is based on technical knowledge. A network exchanges traffic through its routers associated with an autonomous system number (ASN), which in the case of Telmex is the AS8151. Public databases disclose that such ASN is owned by Uninet S.A. de C.V., the "Internet connectivity and access provider for TELMEX and corporate customers" (Telmex, 2016, p. 19, own translation). Uninet is a Telmex subsidiary that is not classified a preponderant agent in the law, raising the question about the limits for the regulator to mandate it to exchange traffic. Importantly, in a prior IFT resolution, while a competitor claimed that Uninet *is* part of the economic preponderant agent, Telmex contended that "UNINET is not part of the Preponderant Economic Agent, in the matter of Telecommunications (…)" (IFT, 2017, p. 63). The regulator resolved the issue tangentially, without supporting any of these interpretations—which could have opened a window to reinterpret the role of a data subsidiary of a telecommunications company as a telecommunications company itself.

It becomes clear that the rationale for the incumbent to avoid exchanging traffic at the IXP is that its data subsidiary, which owns its ASN and has the routes to exchange, does not have a telecommunication licence and therefore is not obliged to comply with asymmetric regulations. While the lack of collaboration from incumbents with IXPs in the global South are generally known, and incumbents' prac-

tices to avoid peering have been documented in the global North as well (Meier-Hahn, 2019), what the Mexican IXP case shows are the intricacies of such antagonism via, so far, an effective turn to infrastructure to interpret the law, bringing the telecommunications regulator to the frontier of data regulation. Currently, the law keeps the IXP ongoing in a fragile equilibrium, open to new resolutions. Its limited outcomes allow to highlight the challenges to increase competition in the country, including the infrastructural barriers that deserve some final considerations.

Further barriers and alternatives to IXP stability

Because local interconnection infrastructure plays a protagonistic role on the enrollment (Callon, 1984) of IXP participants, more attention to infrastructure accessibility is warranted to address the policy challenges of creating stable infrastructure in the South. In Latin America, despite the lack of incumbents' interests, the IXP ecosystems in Argentina and Brazil have attracted a significant number of participants (Degezelle, 2015; Galperín, 2016)—more than 170 in Buenos Aires, and more than 1,700 in São Paulo as of 2021. For its lower level of market competition, the Mexico case, however, suggests a closer look at (at least) three infrastructural resources in the deployment of IXPs: data centres, passive infrastructure, and ASNs.

Regarding data centres, when selected to host the IXP, it necessarily adds its policies, costs, technical and geographic characteristics to the internet node. Most importantly, localities where infrastructure is scarce are more impacted by the data centre affordances and its price policy, as fewer alternatives exist. For comparison, in Frankfurt, where DE-CIX, one of the largest IXPs in the world is based, databases (Data Center Map, n.d.) inform approximately sixty data centre sites in the city, and DE-CIX is distributed among nineteen of them, while in Mexico City, there are currently only three sites, and the IXP is based in one. In the region, Brazil's IXP ecosystem has partnerships out of charge with RNP to use its data centres based in public universities. The use of public and low-cost infrastructure may be an alternative for new IXPs.

Access to passive infrastructure clearly stands out as a crucial barrier in the South. To be part of the IXP, an organisation needs to be physically connected to its infrastructure in the data centre(s) where the IXP is collocated.[4] Thus, a network needs to pay for transport to physically arrive at the data centre, e.g., hiring a fibre link

4. Recently, *remote* peering has created different dynamics for physical interconnection, especially in the global North, but this is not covered here (See Giotsas et al., 2021).

from their headquarters to the IXP, if the interested network is not already based in this data centre. Counterintuitively, this kind of link can be more expensive than paying for a regular transit provider, like the incumbent, to give access to the larger internet, because these incumbents commonly have advantages in right of way and access to posts and towers in the country. In Argentina, where this has also been an issue, the government financed twelve thousand kilometres of optical fibre to help reduce internet transit costs, consequently creating an environment to build a network of IXPs in small towns, all connected to the main node in the capital Buenos Aires (Galperín, 2013). More effective mediation of incumbents' practices may also be necessary.

Finally, a blind spot in the IXP literature is the discussion at the level of ASN assignment. A recent study in Latin America suggests a significant relationship between concentration in internet address space and the lack of deployment of IXPs. For instance, in Mexico, Telmex AS8151 owns 55% of the internet protocol addresses delegated in the country, and that ranks it closer to countries with no IXPs or with small ones (Carisimo et al., 2020). Importantly, CUDI reports universities' difficulty to get access to ASNs, preventing their ability to connect to IXP. In fact, data about NIC Mexico, responsible for selling ASNs in the country, indicates a limited number of assignations, as Mexico represents only 4.1% of ASNs (N=457) assigned in Latin America, less than half of Argentina (N=1093) (RIRS, 2020), a much less populous country, but with a mature IXP ecosystem.

In practice, to have an ASN means more control over connectivity to the larger internet, the ability to manage its own routing policies, peer at IXPs and buy transit when necessary, instead of being served by an ISP only. In Mexico, 80% of CUDI's university network have Telmex as their ISP (CUDI, n.d.). While being part of an IXP would not necessarily lead these universities to leave this commercial relationship with the incumbent, it would make them less dependent on an ISP only. The technopolitics of ASN assignment is also related to IXP deployment and should be included in future regulation discussions.

Conclusions

At the crossroads of internet governance studies and science and technology studies, this article contributes to the study of internet infrastructure in the global South. Its original contribution includes reframing engineering definitions to further investigate internet technopolitics. Conceptually, an IXP can be finally defined as a shared interconnection facility and key internet governance arena where players with myriad goals and functions mesh in interlaced technical and political dy-

namics for designing the online flow of information. Negotiations are continuous, strengthening or weakening IXP equilibrium; the internet that arises is a result of these dynamics where law, infrastructure, and actors' purposes interact.

By mediating interconnection, IXPs have a crucial role in internet competition. In line with previous findings, this research shows that Tier-2 ISPs are unlikely to be IXP supporters. Large CDNs who already have agreements with the main country's ISPs (Tier 2), will also be unlikely to fully support an IXP, unless new players not otherwise reachable, such as small ISPs (Tier-3), are there. Access to passive infrastructure, transport links, and ASNs has an impact on how Tier-3 players will be able to interconnect, though, as lack of access to infrastructure prevents that from happening. On the other hand, Tier-1 networks may be favoured by a dysfunctional IXP, as transit services are the best option for incumbent competitors to reach the incumbent's network as they refuse to peer.

The study of internet infrastructure with an ethnographic lens in Mexico exposes the dynamics of pro-competition laws otherwise unseen with top-down and institution-focused research approaches. Further research on the politics of infrastructure is necessary, particularly the relation between ASN assignments and internet interconnection, and how infrastructure affordances play a role in regulatory outcomes. Players with substantial market power are often supported by underlying layers of infrastructure and how they are distributed. Non-attention to such context and spaces of mundane internet governance limits the comprehension of internet policies and the internet in the global South.

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