Ten years of the Venezuelan crisis - An Internet perspective

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ABSTRACT

The Venezuelan crisis, unfolding over the past decade, has garnered international attention due to its impact on various sectors of civil society. While studies have extensively covered the crisis's effects on public health, energy, and water management, this paper delves into a previously unexplored area – the impact on Venezuela's Internet infrastructure. Amidst Venezuela's multifaceted challenges, understanding the repercussions of this critical aspect of modern society becomes imperative for the country's recovery.

Leveraging measurements from various sources, we present a comprehensive view of the changes undergone by the Venezuelan network in the past decade. Our study reveals the significant impact of the crisis captured by different signals, including bandwidth stagnation, limited growth on network infrastructure growth, and high latency compared to the Latin American average. Beyond offering a new perspective on the Venezuelan crisis, our study can help inform attempts at devising strategies for its recovery.

CCS CONCEPTS

• **Networks → Network measurement**.

KEYWORDS

Internet Infrastructure, Venezuela

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1 INTRODUCTION

Over the past decade, the Venezuelan crisis has unfolded as a narrative of escalating challenges affecting every facet of civil society [22].

The magnitude of this situation has drawn international attention, and several studies have explored its impact on public health, energy, and water management, among other sectors [63, 74, 80, 81]. The collapse of Venezuela's public health system has yielded an estimated 40% increase in under-five mortality during the past decade. By 2022, the under-five mortality[1] estimates were as high as 29 deaths per 1000 live births with infants accounting for the majority of these deaths[2]; this rate is nearly twice that of Latin America as a whole, reported at 16/1,000 [14]. Other signals of the significant deterioration in the health conditions of Venezuela's population include the surge in vaccine-preventable diseases [80], such as diphtheria, mumps, and measles, with Venezuela accounting for 68% of the measles cases in South America by late 2018 [33]. The severe energy crisis, which began to present a deficit in electric power generation in 2009, has worsened over the last decade, causing the lack of electricity supply in large regions of the country for periods of >100 hours, further aggravating the country's economic crisis [81]. Today, estimates suggest that more than 7 million people – close to 25% of the country's population – have fled Venezuela [9, 47]

In this work, we consider a previously unexplored perspective – the impact of the Venezuelan crisis on the country's Internet infrastructure. In the face of multifaceted challenges, understanding the repercussions of the crisis on such a critical component of modern society as the Internet becomes imperative for charting a path to recovery [86].

We study this impact on the network from core infrastructure to access networks. We leverage a number of complementary datasets to capture a comprehensive view of the changes undergone by the Venezuelan network during the past decade, including bandwidth measurements from Measurement Lab (M-LAB) [70], changes to the submarine cable network infrastructure from Telegeography's Submarine Cable Map [90], and routes to root DNS servers from the RIPE Atlas built-in measurements, among others. To contextualize our findings, we draw comparisons with the rest of the Latin American countries.

Our study reveals the significant impact of the crisis on Venezuela's Internet, as captured by a range of metrics:

- **On network infrastructure.** While the region has quadrupled the number of submarine cables from 13 to 54 over the last 20 years, over the same period, Venezuela has added only one submarine cable connection to Cuba (ALBA). In addition, while the region experienced a three-fold growth in peering facilities over the last 6 years (from 180 to 552), Venezuela continues to host only 4 such facilities.

[1] The likelihood of a child dying before the age of five
[2] https://childmortality.org/all-cause-mortality/data?refArea=VEN

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- **On interdomain connectivity.** While networks in the rest of the region have increased interdomain connectivity through several IXPs over the last decade [23], Venezuela has not expanded its presence to Latin American or US IXPs. CANTV, the country's state-owned incumbent [24], was left with no US-based transits while it expanded its footprint over the domestic transit market.
- **On access network performance.** Download speed of access networks continues to improve around the world, with a median speed of 83.95 Mbps in 2023, a 19% improvement over 2022 [54]. Venezuela's download speed, on the other hand, has remained below 1 Mbps for over a decade. And, while most of the region experienced steady declines in RTT to Google Public DNS, taken as a proxy of Internet performance, Venezuela's RTT to this service has not changed over that time. In the last 6 months of our analysis, Venezuelan users experienced a latency 2.06x higher (36.56 ms) compared to the LACNIC average (17.74 ms).

We begin by providing a brief overview of the Venezuelan crisis (§2). We then describe the various datasets and methodologies we rely on for our analysis (§3). After introducing CANTV (§4), the incumbent state-owned ISP, the following sections explore the impact of the Venezuelan crisis on its network infrastructure (§5), its interdomain connectivity (§6), and the performance of its access networks (§7). We discuss the limitations of our study (§8) and put them in the context of related efforts (§9) before concluding.

We make available all datasets and code used in our analysis[3]. This work does not raise any ethical issues.

2 THE VENEZUELAN CRISIS

Once among Latin America's richest nations [46], Venezuela has taken a drastic turn during the last decade, facing significant challenges due to political unrest, economic decline, and shortages of vital resources including food, medicine, and electricity.

Venezuela is considered an example of a petrostate [26]. The country holds the largest proven conventional oil reserves globally [84], and the state-owned company, Petroleos de Venezuela S.A. (PDVSA), has monopolized oil extraction since President Carlos Andres Perez nationalized this resource in 1976 [83]. The government's income has been deeply reliant on oil and natural gas exports, financing over 60% of its budget on oil exports [10].

Without delving into the causes, Venezuela's downfall can be tied to the collapse of its oil exports, with a cascading domino effect manifesting across macroeconomic indicators and affecting the population at large. Utilizing data sourced from the International Monetary Fund (IMF) [40] and the Organization for Economic Cooperation and Development (OECD) [39], Figure 1 shows revealing key indicators.

The first graph shows the collapsing oil production (Fig. 1a). While not achieving the production peaks of the 1970s, Venezuela's production approached its maximum historical levels in the early 2000s. Starting around 2013, however, production plummeted by 77%! The consequences of this collapse in a petrostate are stark – a staggering ≈70% drop in GDP per capita in only 7 years (Fig. 1b), which is followed by a surge in inflation that peaked at 32,000% (Fig. 1c). The crisis has caused a mass exodus of ≈ 4.25 million people, about 15% of the population, since 2013, one of the largest displacements in a non-war zone context [6].[4]

[3]https://github.com/NU-AquaLab/2024-SIGCOMM-VE

3 DATASET

For our study, we leverage a number of complementary datasets related to network infrastructure (including peering facilities, submarine cables, and DNS servers), interdomain connectivity, and the performance of access networks. We rely on longitudinal data for Venezuela and the remaining countries in LACNIC, the Internet registry for the Latin American and Caribbean [62], to understand the evolving landscape and the long-term consequences of the crisis in context.

3.1 Network Infrastructure

We compile multiple datasets covering network measurements and infrastructure data that could reveal the deterioration of Venezuela's infrastructure over time compared to its Latin American peers. In the following paragraph, we describe each dataset, outlining its purpose, data source, and the timeframe it covers.

Peering facilities. We retrieve CAIDA's PeeringDB archive, which provides daily snapshots, to evaluate the growth of peering facilities in Venezuela and Latin America starting from April 2018[5]. PeeringDB offers public information about peering facilities, their locations, and network presence, the latter of which depends on reports from network operators. We download snapshots from the first day of each month to track the development of peering facilities in Venezuela and across the region.

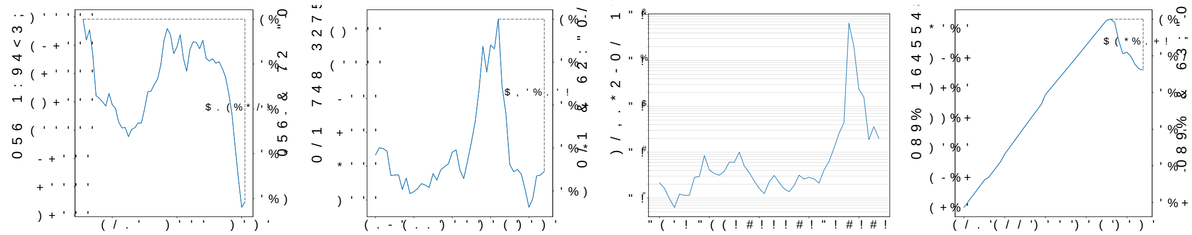
Submarine connectivity. Utilizing the Telegeography's Submarine Cable Map [90], we review the expansion of submarine connectivity in Venezuela and other Latin American countries using the cables' ready-for-service (RFS) dates. Telegeography's map offers a detailed list of the cables composing the submarine cable network along with their names, locations of landing points and their RFS dates.

IPv6 rollout. It has been argued that for network operators that need to grow, IPv6 adoption makes economic sense as it mitigates major constraints [55]. We study the adoption rate of IPv6 as an indicator of the impact of Venezuela's crisis on network growth. We use Meta's public dataset on IPv6 adoption [37] to examine Venezuela's IPv6 rollout in the context of the broader regional landscape.

Root DNS server coverage. Our analysis also aims to reveal the footprint of root DNS instances within the country. However, determining the location of these servers is a known challenge since root DNS are reachable through anycast. To address this challenge, we use RIPE Atlas' built-in measurements to retrieve CHAOS TXT records collected from Venezuela and the LACNIC region probes, targeting all root DNS servers since 2016. CHAOS TXT records enable network operators to identify specific anycast servers being accessed, typically codified with strings containing embedded

[4]Other sources have put the estimate at 7 million [9, 47].

[5]This is the starting date of version 2 of PeeringDB's data schema.



(a) Oil production **(b) GDP per capita** **(c) Inflation rate** **(d) Populaton**

Figure 1: The domino effect of Venezuela's economic catastrophe: Oil production collapsed (-81%), GDP per capita steep decline (-70%), Skyrocketing Inflation (peaking at 32,000%) and millions displaced (4.25M).

airport codes, as otherwise, each instance responds with the same address. Utilizing RIPE Atlas' built-in measurements, conducted every 30 minutes targeting all root DNS servers, our dataset includes measurements only from the first five days of each month. We develop regular expressions to extract these codes from each of the 13 different types of responses, and we then map these codes to their corresponding countries and cities.

Presence of off-nets. The evolution of deployments of Hypergiant (HG) replicas within local networks (i.e., *off-nets*) reflects Venezuela's lag in network infrastructure development. We leverage the artifacts published by Gigis et al. [41] to identify these off-net deployments between 2013 and 2021 in Venezuela and across the continent. This method utilizes subject names and domain names (`dnsNames`) in TLS certificates to reveal off-net replicas within external networks.

3.2 Interdomain Connectivity

To explore the impact of the crisis on interdomain connectivity, we include different datasets that can capture changes in the connectivity of networks operating in Venezuela.

We retrieved CAIDA's AS relationship files [2] starting in 1998 to investigate changes in the AS-level connectivity of CANTV-AS8048 due to its predominant position in the Venezuelan market. Our dataset also includes PeeringDB snapshots [3] to assess the presence of Venezuelan networks at major IXPs within the region and in the United States.

3.3 Performance of Access Networks

To capture potential changes in network performance, we rely on bandwidth (or throughput) collected from speed test measurement, and latency to public DNS infrastructure, in our case, to Google Public DNS.

Bandwidth. We leverage the measurement archive offered by the Measurement Lab (M-LAB) [70] to obtain a longitudinal understanding of the bandwidth evolution in Venezuela and the LACNIC region. M-Lab runs a globally distributed measurement platform comprising over 100 locations across various regions and offering a range of network performance tests, including the Network Diagnostic Test (NDT) [71] and WeHe [64, 73], among others. This platform uses a crowdsourced model, where users interact with it through high-level web interfaces, and the results of these tests later become publicly available. In our study, we focus specifically on downstream throughput values derived from NDT tests; despite these tests offering other throughput metrics, including upstream throughput, latency, and packet loss. We aggregate a month-country granularity from ≈447M speed tests from 28 countries in the LACNIC region, of which 3.9M are from Venezuela, that have been collected since July 2007.

Google Public DNS infrastructure. We use the latency measurement of Google Public DNS to proxy end-user performance. For this we leverage the extensive, longitudinal dataset collected by a RIPE Atlas platform-wide traceroute campaign (`MSM_ID = 1591146`). The campaign has been running since March 20, 2014, launching traceroutes every 30 minutes and amassing approximately 600,000 daily traceroutes by 2023. Our analysis focuses on the monthly changes within a 5-day window at the beginning of each month in the dataset.

4 THE ROLE OF THE INCUMBENT ISP

In the following paragraphs, we briefly discuss CANTV, the country's incumbent ISP [24].

The history of CANTV provides a valuable perspective for understanding the role of the Venezuelan state in the country's telecommunications market. The company known as *Compañía Anónima Nacional Teléfonos de Venezuela*, commonly referred to as CANTV, has changed ownership multiple times throughout its history. Initially established as a private company in 1930, it underwent its first nationalization in 1953 [85]. Subsequently, it was privatized once more in 1991 [35] and then re-nationalized during the administration of President Hugo Chávez in 2007 [87].

Over the past two decades, CANTV has continuously announced the largest portion of Venezuela's address space. To illustrate its dominance,[6] we conduct an analysis of the allocated address space in Venezuela and the visibility of these prefixes on BGP collectors. To that end, we download snapshots of CAIDA's AS prefix-to-AS files [4] and LACNIC delegation files [59] collected on the first of each month since 2008 to examine the structure of Venezuela's allocated and announced address space over time. We compare the footprint of CANTV with that of its closest peer, Telefonica de

[6]As of May 2024, CANTV's prominence in Venezuela's domestic market also extends to serving 21.50% of the country's Internet population, according to APNIC estimations [52]. See Appendix A for additional details on the leading eyeball networks in Venezuela.

Venezuela (also known as Movistar, AS6303), the local subsidiary of the homonymous Spanish conglomerate.

Figure 2 shows the fraction and the total address space held by both companies. CANTV has historically dominated most of Venezuela's address space, averaging around 43% and peaking at 69%. Telefonica de Venezuela, which began operations in 2005 [76], gradually narrowed the gap with CANTV, reducing it to only 11% before the company experienced a growth stall, coinciding with the beginning of Venezuela's economic collapse. Between 2014 and 2017, both companies maintained stability in the size of their address space. While their lack of growth may be partially the result of Venezuela's economic downturn, the period also aligns temporally with the implementation of phases 1 and 2 of LACNIC IPv4 exhaustion policies [60]. The most notable change in these time series is the contraction of Telefonica de Venezuela's address space between 2017 and 2023, which reinstated a clear lead to CANTV. We are unaware of the reasons behind it. Appendix C includes an analysis of the prefixes allocated to Telefonica but not announced for almost a decade.

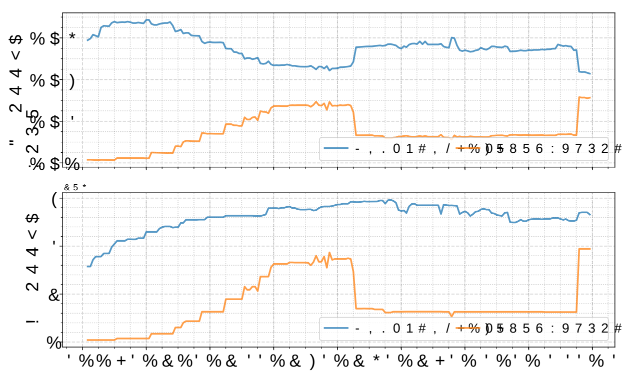


Figure 2: Evolution of allocated and announced address space in Venezuela originated with CANTV-AS8048 and Telefonica de Venezuela-AS6306. Telefonica was narrowing the gap with CANTV before Venezuela's economic collapse in 2013.

Although the overall importance of address space has been diminishing in the context of address pools' exhaustion, the analysis of Venezuela's address space clearly reveals the state's influence, particularly through CANTV, in shaping the domestic market structure.

5 ON NETWORK INFRASTRUCTURE

We begin our analysis focusing on Venezuela's network infrastructure. As networks constantly evolve to support increasing traffic and the demand for a better quality of experience [28, 38, 57], Venezuela's crisis likely impedes capital investments to match the pace of growth seen in its Latin American peers. In the following paragraphs, we explore a decade-long impact of the crisis on the countries' network infrastructure, focusing on key elements such as peering facilities (§5.1), submarine cable deployments (§5.2), IPv6 adoption (§5.3), the availability of Root DNS infrastructure (§5.4), and the deployment and adoption of Content Delivery Networks (§5.5). Throughout our analysis we place the observed trends in the context of other countries in the LACNIC region and, in particular, of five specific countries: Argentina, Brazil, Chile, Mexico and Uruguay. Appendix B presents a detailed explanation of similarities between Venezuela and this set of countries in terms of historical economic performances.

5.1 Proliferation of Peering Facilities

Peering facilities are physical infrastructures that enable direct internetwork connections, optimize traffic flow and reduce costs. The country-level availability of these facilities is a function of the size and diversity of its peering ecosystems, and partially determinant of the country's network resilience (e.g., against natural disasters).

We examine the development of peering facilities within the country and compare it to that of other countries in the region through an analysis of monthly snapshots from PeeringDB, starting in April 2018.

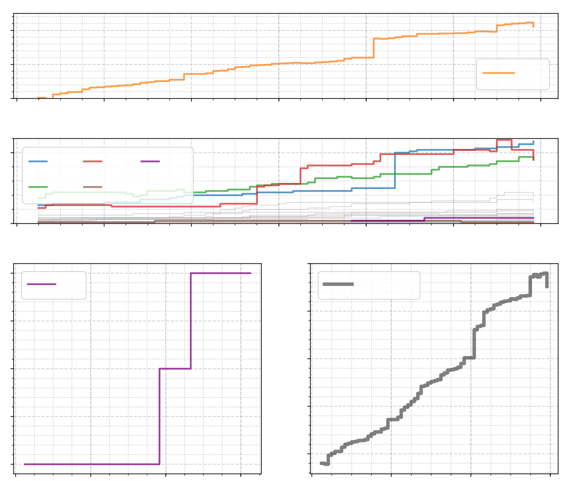


Figure 3: Evolution in the number of peering facilities in the LACNIC region since 2018. While the region experienced a three-fold growth from 180 to 552, Venezuela hosts only 4 peering facilities.

Figure 3 shows the evolution of peering facilities in the LACNIC region through four panels. The top two panels compare peering facility growth in Venezuela with other countries in the LACNIC region, with a separate panel for Brazil. We highlighted comparable peers in colors, with the remaining countries displayed in grey. The lower-left panel exclusively focuses on Venezuela, providing an in-depth view of its peering facilities, while the lower-right panel presents the aggregated number of facilities across the entire region.

The analysis reveals a notable lag in Venezuela in this regard – only 4 out of 600 facilities in the region are located within the country; two of them registered in 2021 and the rest in 2023. The difference is particularly stark when considering the corresponding growth in Brazil. The region's largest (8.5 million km^2) and most populated (214 million) country, Brazil shows unique growth from 102 to 311 facilities between 2018 and 2024. Other countries also experienced substantial growth during that period, including Mexico (from 11 to 45), and Chile (from 18 to 45).

Beyond the limited number of peering facilities in Venezuela, only Cirion's facility in La Uriba has attracted some networks, with 11 reported in the latest snapshot of our analysis. For a detailed analysis, Appendix D examines the evolution and presence of networks at these facilities in Venezuela.

While the limited growth of peering facilities in Venezuela may be due to the dominant market control of CANTV, Costa Rica, another country in Central America with a dominant state-owned provider ICE-AS11830 (24.1%), managed to expand its number of facilities from 3 to 8 during the same period.

5.2 Submarine Connectivity

Submarine cables enable international connectivity, critical from financial transactions to global communications and international scientific cooperation [15, 65, 93]. Given its importance, we now analyze Venezuela's efforts to expand its submarine infrastructure.

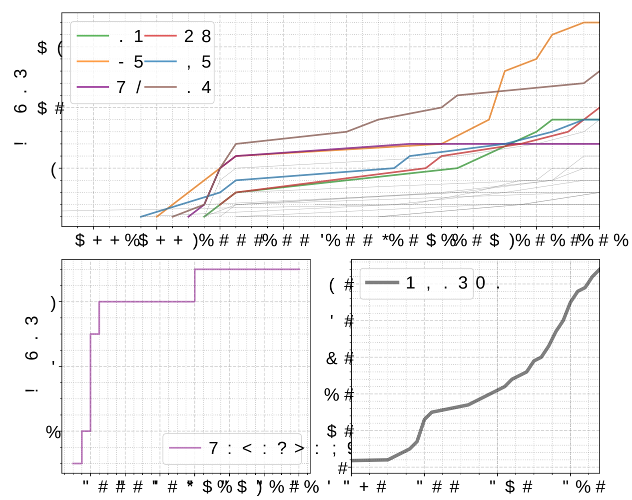


Figure 4: Expansion of Submarine Cable Networks (SCNs) in the LACNIC Region: From 2000 to 2024, the total number of SCNs increased from 13 to 54, while Venezuela only received the ALBA cable, which connects the country with Cuba.

We use Telegeography's dataset to explore the expansion of submarine connectivity in Venezuela and the region. Figure 4 presents three panels with the growth of the number of cables connecting countries in the region. The top panel provides a country-level comparison across countries in the LACNIC region, including Venezuela. The lower-left panel focuses specifically on Venezuela, zooming into the evolution of cable deployments within the country, while the lower-right panel shows the total number of cables reaching the shores of any country within the region.

The deployment of submarine cables in Latin America is characterized by two phases: pre and post the dot-com bubble [15]. While the region witnessed considerable growth before 2000, there has been an even more pronounced expansion of cables over the last 15 years. Over these period, Latin America experienced a significant economic bonanza due to the surge in commodity prices, which are the primary exports for all Latin American countries [45]. However, Venezuela did not participate in this second wave of expansion and ranked at the bottom of submarine cable deployment during this timeframe.

Between 2000 and 2024, the number of cables in the region underwent a substantial expansion, growing from 13 to 54. Notable examples include Brazil, growing from 5 to 17 cables, Colombia from 5 to 13, and the southernmost countries, with Chile expanding from 2 to 9 cables and Argentina from 3 to 9.

In contrast, during this period, only Nicaragua and Haiti did not expand their cable infrastructure, while Venezuela, along with Honduras, Aruba, and Belize, only added one cable. Venezuela, the wealthiest country in the region in 2001 [21, 46], stands out in the set. The only cable that landed in Venezuela in the past decade is the ALBA cable, connecting Cuba and Venezuela, specifically designed during Hugo Chavez's presidency to grant Cuba access to the Internet [18, 92].

5.3 IPv6 Rollout

For network operators that need to grow, IPv6 adoption makes economic sense as it mitigates major constraints, including the purchase of increasingly expensive IPv4 addresses allocations in the market and ever more intensive sharing of globally routed IPv4 address space [55]. On the other hand, one would expect a network experiencing limited growth to correspondingly have low adoption of IPv6.

To examine IPv6 adoption in Venezuela and the LACNIC region, we leverage Facebook's public dataset that reports the percentage of requests over IPv6 registered by Facebook (Meta) on a per-country basis.

Figure 5 shows the evolution of this percentage of requests over IPv6 received by Facebook. The top panel compares IPv6 adoption in Venezuela with other countries in the region, with highlighted comparable peers in vivid colors and the rest of the countries in the region in grey. The lower-left panel zooms in on Venezuela, providing a detailed examination of its IPv6 rollout, while the lower-right panel presents the mean value for the aggregated numbers of each country across the entire region.

The region shows a rapid uptake of IPv6, in an initial phase growing from under 5% in 2018 to ≈ 11% in early 2021, and with a second, more accelerated phase to 22% by 2023. Across countries, the analysis shows varying levels of IPv6 adoption, with most experiencing sustained growth and significant advancements in the group of large Latin American countries. Mexico and Brazil have had sustained IPv6 growth, surpassing approximately 40% in the latest snapshots, while Argentina, Chile, and Colombia are around the 20% mark. Chile and Colombia, in particular, stand out for their steeper growth trajectories, with Chile experiencing a notable surge in 2022. In contrast, Venezuela has not been part of this IPv6 surge within the region – the country recorded near-zero levels until 2021, only reaching 1.5% by mid-2023.

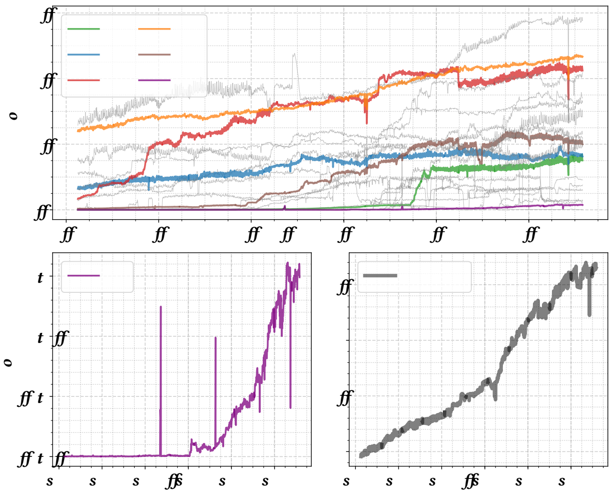


Figure 5: Percentage of requests over IPv6 registered by Facebook (Meta) from countries in LACNIC. While the region has rapidly grown to a level of adoption of 20%, Venezuela (VE) is significantly lagging at only 1.5%.

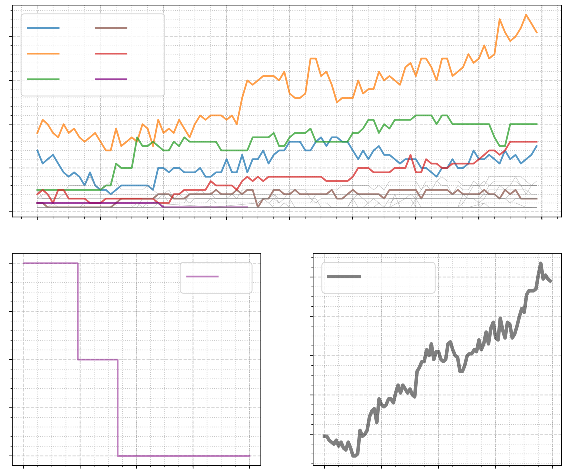


Figure 6: Growth in the number of root DNS servers hosted by each country in the LACNIC region. While hosting domestic replicas has proliferated throughout the region, RIPE CHAOS TXT measurements show that Venezuela has gone in the opposite direction.

5.4 Availability of DNS Infrastructure

To analyze the country's availability of infrastructure running critical Internet services, we use DNS as a representative example.

The proximity to root DNS servers is key in enhancing user experience by minimizing DNS resolution times [31]. Given the importance of DNS in Internet communications, various stakeholders have advocated for the expansion of the root DNS network [8, 29, 75].

As an example of this in Latin America, LACNIC leads this effort through the +Raices (+Roots) program [61], in which LACNIC intermediates between hosting sites and root DNS servers to deploy root servers in the region.

We analyze the country pace of deployment of local root DNS servers, in the context of other countries in the region.

We utilize RIPE Atlas' CHAOS TXT measurements to all root DNS servers to detect those deployed in the region. Figure 6 displays three sections showing the evolution of unique CHAOS TXT strings containing geolocation tags for countries in the region.

The top graph shows a country-level comparison, including Venezuela and the same subset of similar countries in colors and the remaining countries in the region in grey. The bottom left section focuses on Venezuela and the evolution of CHAOS TXT strings mapped to the country, while the bottom right section aggregates CHAOS TXT strings associated with the entire region.

Our analysis shows a notable increase in the hosting of domestic root DNS servers within the LACNIC region since the beginning of these measurements in 2016. Overall, during this period the region has seen a 2.34-fold rise in replicas, from 59 to 138. Individual countries, such as Mexico and Chile showed significant growth, with the number of replicas increasing from 4 to 16 and from 5 to 20, respectively. Brazil experienced a remarkable surge from 18 to 41 replicas, while Argentina only added one server to the count, starting from a relatively strong position of 14 servers.

In contrast, our latest data shows the absence of any root DNS servers in Venezuela. In fact, the country has seen a regression on this front. Our analysis found that initially, two root DNS servers, one L (`ccs01.l.root-servers.org`) and one F (`ccs1a.f.root-servers.org`), were geolocated in Caracas. These servers later disappeared from the measurements and were replaced by another L DNS server in Maracaibo (`aa.ve-mai.l.root`). While the LACNIC's +Raices report [58, 61] states that Venezuela hosts two L-root and one F-root servers, the current availability of these services in Venezuela remains uncertain.

Our recent measurements showed that Venezuela predominantly relies on overseas resources for DNS services. Most of these servers are located in the United States, followed by Great Britain, Germany, France, and the Netherlands. In Latin America, Brazil, Colombia, and Mexico are the primary alternatives for DNS services, with Panama, Chile, and Argentina serving as secondary options. Interestingly, Colombia emerged as a prevalent alternative when Venezuela's local DNS resources disappeared [7].

While our analysis is based on data collected by RIPE Atlas, the results cannot be attributed to a lack of coverage in Venezuela. Throughout this period, Venezuela consistently maintained between 10 to 20 probes, experiencing an increase from 10 to 30 in the last two years. In our latest assessments, Venezuela is ranked as the 6th highest country in the LACNIC region in terms of the number of RIPE Atlas probes. The platform's footprint in the country also spans other local networks beyond CANTV, which only

[7] A comprehensive analysis of these trends, including the specific locations and roles of these international root DNS servers serving Venezuela, is detailed in § E.

hosts 8 probes. We refer to Appendix F for a more in-depth analysis of RIPE Atlas' presence across the LACNIC region.

5.5 The role Content Delivery Networks

We conclude our analysis of Venezuelan network infrastructure by focusing on Content Delivery Networks (CDNs).

The rise of CDNs has reshaped the Internet landscape, with a few providers now generating the majority of Internet traffic [89]. To efficiently deliver content on a large scale, many of these networks have established replica servers within customer networks, or *off-nets*. These off-net deployments aim to reduce interdomain traffic and improve users' download times [41].

We leverage the artifacts of Gigis et al. [41] to assess the scale of off-net deployments by Venezuelan networks and compare it with those of other countries in the region.

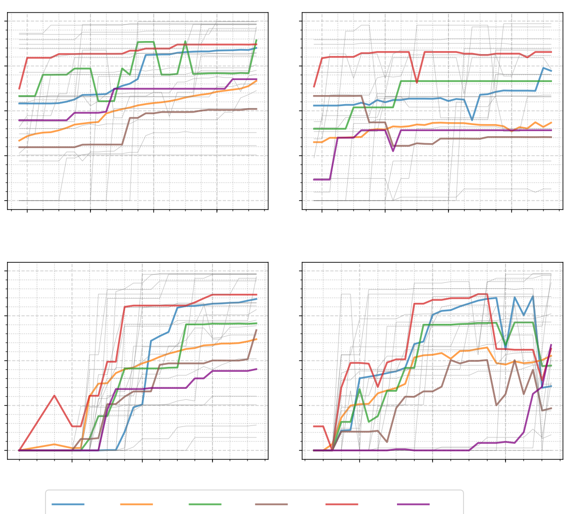


Figure 7: Evolution of the countries' Internet populations in providers hosting *off-nets*. Venezuela shows a dual trend where Google and Akamai established their presence prior to the country's downturn, whereas Facebook and Netflix, creating their infrastructures later, have had more modest deployments.

We use these artifacts to identify the presence of off-net deployments from major content providers within networks registered across Latin America. We consider these eyeball populations at the organizational level, using *as2org+* [12], to eliminate fluctuations in deployments across networks belonging to the same organization. We then combine these results with APNIC's estimates of Autonomous System (AS) populations [52] to calculate the percentage of a country's user base connected to networks with off-net hosts.

Figure 7 presents four time series for Google, Akamai, Facebook (Meta), and Netflix, which shows the percentage of the population in each country connected to networks hosting off-net servers over the period from 2013 to 2021.

Our analysis reveals a contrasting narrative for Venezuela compared to other countries in the region. Early in the observation period (2013), before Venezuela's crisis unfolded, Google and Akamai had established their presence in the country. Content providers that rolled out their networks later, such as Facebook and Netflix, have had more modest and delayed deployments in Venezuela.

When averaging the percentage of users in networks hosting off-net servers across each country during this 8-year period, Venezuela's ranking across providers varies but it is largely in the bottom set for the region: 19/27 (56.88%) for Google, 18/22 (35.74%) for Akamai, 21/25 (28.33%) for Facebook (Meta), and 23/25 (5.87%) for Netflix.

This pattern holds for other hypergiants, including Cloudflare, Microsoft, Limelight (now Edg.io), CDN Networks, Alibaba, and Amazon, which have minimal off-net presence in Latin America and no presence in Venezuela. For a complete examination of these content providers, refer to Appendix G.

We focus on the state-controlled network CANTV-AS8048 to examine if it has received off-net deployments during this period. Notably, Google and Akamai had already established a presence in the country, including CANTV, prior to Venezuela's decline. In contrast, networks with later deployments, such as Netflix and Facebook, took a different approach. Facebook, for instance, did not deploy servers within CANTV, and Netflix only began doing so in 2021, nearly a decade after its rapid expansion across the LACNIC region had started.

We also examine Venezuela's adoption of third-party providers for DNS, Certificate Authorities (CAs), and CDNs. Based on a snapshot collected in January 2024, the country's adoption rates for all these services fall below the regional average: 0.29 for DNS (regional average 0.32), 0.22 for CAs (0.26), and 0.37 for CDNs (0.46). The full analysis of Venezuela's adoption of these services can be found in Appendix H.

6 ON INTERDOMAIN CONNECTIVITY

The experience of Internet users is partially dependent on the quality of the path to the content they access. In this section, we look at Venezuela's interdomain Internet connectivity, focusing in particular on the connectivity of the state-owned provider, CANTV-AS8048, and the country's engagement in Internet Exchange Points (IXPs) within the country and across the region. Given its geographical proximity, we extend this analysis to include IXPs located in the United States.

6.1 CANTV's connectivity

Given CANTV's prominent position, we examine the network's upstream and downstream connectivity over time, shown in Fig. 8. Focusing on CANTV's upstream connectivity, we observe a steady increase until 2013, when there are 11 upstream providers. Subsequently, there was a decline to 3 providers in 2020, followed by a recent rebound. The sustained decline between 2013 and 2020 temporally correlates with Venezuela's economic implosion and numerous sanctions on the country [88].

During this period, CANTV significantly expanded its presence in the domestic transit market. Since its nationalization in 2007, the company has consistently grown its customer base, mostly with academic institutions and local banks.

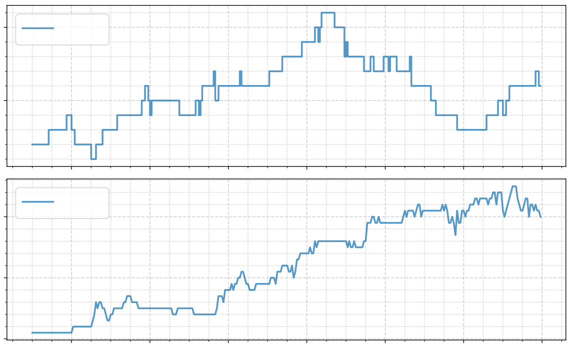


Figure 8: Variation in the upstream and downstream connectivity of CANTV-AS8048. The number of upstream providers significantly contracted since the beginning of the economic downturn in 2013.

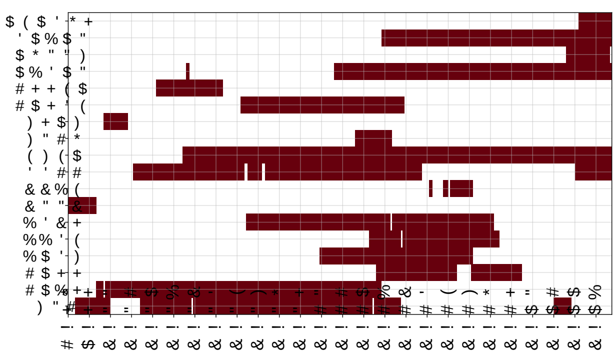


Figure 9: Changes over time in CANTV's upstream connectivity. Since 2013, excluding Columbus Networks (AS23520), all US-registered providers have ceased their services to CANTV, including Verizon (AS701), Sprint (AS1239), and AT&T (AS7018), GTT (AS3257 and 4436) in 2017, and Level3 (AS3356 and AS3459).

The ongoing crisis triggered tensions between the country and the United States, leading to economic sanctions that have reshaped Venezuela's connectivity landscape. Figure 9 extends the analysis of CANTV's upstream connectivity with a heatmap of the providers serving transit to CANTV for > 12 months since January 1998. This analysis reveals that Columbus Networks-AS23520 is the sole remaining US-based provider that continues to offer transit services to CANTV, following the departure of other US-based providers that started in 2013. Departures included Verizon-AS701, Sprint-AS1239, and AT&T-AS7018 in 2013, GTT (AS3257 and 4436) in 2017, and Level3 (briefly known as LUMEN and now as Cirion, AS3356, and AS3459) in 2018. During this period, Telefonica's backbone unit Telxius-AS12959 and the Swedish-based Arelion-AS1299 also stopped serving CANTV.

Despite the departures mentioned, CANTV's connectivity has been sustained in recent years by providers that existing submarine infrastructure reaching the shores of Venezuela. Notable among them is Telecom Italia-67672, a longstanding partner of CANTV, connecting through the South American Crossing (SAC) and Americas-II. Additionally, V.tal-AS52320 (formerly Brasil Telecom) utilizes the GlobeNet, while Orange-AS5511 (after a period of inactivity) and Columbus Networks-AS23520 leverage the Americas-II. A recent addition to this group of providers is Gold Data (AS28007 and AS394684), enhancing the diversity and stability of CANTV's connectivity landscape.

6.2 Venezuela at IXPs

We now turn focus on IXPs, which have reshaped local network domains over the past two decades. IXPs offer interconnection hubs, enabling direct network traffic exchange, reducing dependence on upstream providers, and lowering transit costs [5]. These direct network interconnections shorten path lengths and improve latency, thus enhancing users' Quality of Experience (QoE). While IXPs have flourished globally and in Latin America, remarkably in enabling local traffic exchanges between CDNs and networks [25], Venezuela remains one of the few countries without any deployed IXP up to 2024 [23]. This reflects the concentrated nature of its Internet ecosystem, which is dominated by CANTV and probably unattractive for new participants since the crises unfolded.

Next, we investigate the role of Latin American IXP connectivity in Latin America, considering both domestic and international connections.

We examine the impact of Latin American IXPs on domestic network structures and explore the prevalence of networks from one country traveling to another Latin American country to peer with networks not present domestically. Figure 10 shows a heatmap of the largest IXP in each country based on the domestic Internet population and the Internet population in Latin American countries served by the networks peering at these points.

The region has a wide variety of IXPs in terms of origin (e.g., state-sponsored in Bolivia), nature (e.g., federal networks of IXPs in Brazil and Argentina), and size (ranging from very few networks in Trinidad and Tobago to up to 2,000 in Sao Paulo) [23]. Several countries present success stories in keeping local traffic local, exemplified by Argentina, Brazil, and Chile. Notably, AR-IX (formerly known as CABASE) in Buenos Aires, IX.br (formerly known as Punto do Troca do Trafego, PTT) in Sao Paulo, and PIT Chile in Santiago connect networks with 62.4%, 45.53%, and 49.57% of the countries' Internet populations, respectively.

However, some countries, such as Uruguay and Venezuela, where state-owned Internet providers hold a significant footprint, have not seen the establishment of any IXPs. This might be attributed to the dominant size of the incumbent, leaving little room for the peering needs of the rest of the market or a neutral peering space to peer with CDNs. However, the figure reveals that Uruguay has a notable international presence in Argentina (AR-IX), Brazil (IX.br), Paraguay (IX.py), and Chile (PIT Chile).

Similarly, despite the absence of local IXPs, Venezuela's network could be at other prominent Latin American IXPs, such as IX.br Sao Paulo or the nearby AMS-IX exchange in Curacao, located only 295

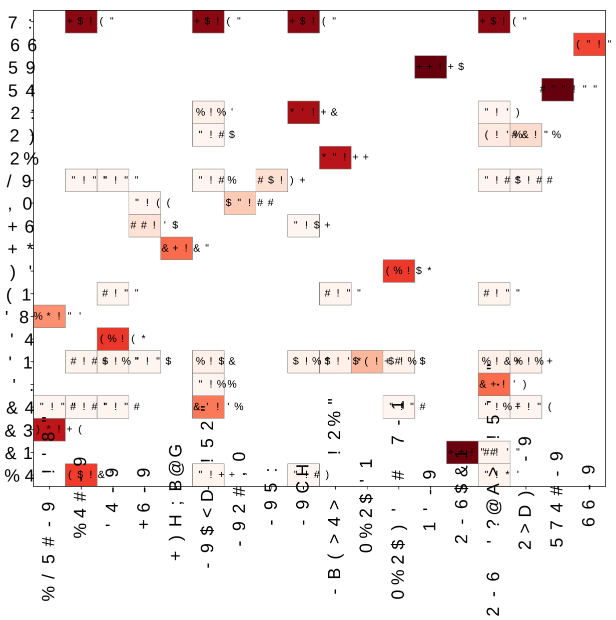


Figure 10: Percentage of countries' Internet population in networks peering at the largest IXP in each Latin American country. Venezuela (VE) is absent in this figure since no network with a presence in the country peers at any of these IXPs.

km from Caracas. However, our analysis reveals that Venezuela is notably absent from our heatmap, with a single network peering at Equinix Bogota in Colombia, which holds only 4% of Venezuela's Internet population.

Alternatively, geographic proximity might have encouraged networks serving Venezuelan Internet populations, such as their Mexican counterparts, to join IXPs in the United States. While some networks with a presence in Venezuela peer in the US, the presence is minimal, with only seven networks contributing to a mere 7% of Venezuela's Internet population. Appendix I provides a detailed analysis of the number of networks and their corresponding Internet populations present at IXPs in the US.

7 ON ACCESS NETWORKS PERFORMANCE

We close our analysis by assessing the impact of the observed deterioration and lag in Venezuela's network infrastructure on network performance. We evaluate how the crisis has affected the bandwidth growth in Venezuela compared to other countries in the region (§7.1). We also explore the consequences of the crisis on access networks relying on Google Public DNS (§7.2), offering a proxy of network performance.

7.1 Bandwidth

We examine the evolution of bandwidth in Venezuela and the rest of Latin America. Lagging behind other peer nations in these key aspects can indicate Venezuelans' impediment to properly interacting with the always-evolving bandwidth-intensive online services.

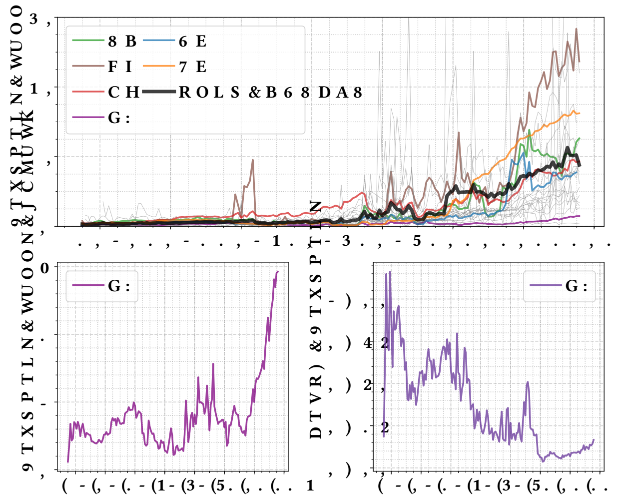


Figure 11: Evolution of the median download speeds in the LACNIC region. Venezuela (VE) stagnated most of the decade at below 1Mbps! and the current speed is 16% of the median regional speed.

We use throughput measurements collected by M-LAB to study the bandwidth evolution in Venezuela compared to the rest of the region. In Figure 11, three panels present the evolution of Venezuela's median download speeds. The top panel offers a country-level comparison of Venezuela with other countries in the LACNIC region (comparable peers highlighted in vivid colors) along with the mean value of the aggregated region. The lower-left panel zooms in on Venezuela, exclusively displaying the download speed for this country, while the lower-right panel presents Venezuela's download speed normalized by the mean value of the aggregated region.

The trends depicted in the three panels are clear: While download speeds have been steadily growing throughout the entire region, Venezuela's download speeds have experienced stagnation at levels of below 1Mbps over the past decade, with a slight recovery noted since 2022. The disparity is noteworthy, with countries such as Uruguay, Brazil, Chile, Argentina, and Mexico achieving download speeds (Mpbs) of 47.33, 32.44, 25.25, 15.48 and 18.66 in July 2023, In contrast, Venezuela's median speed lags significantly behind at 2.93 Mbps. To provide historical context, these download speeds are equivalent to the values achieved in Uruguay and Mexico in November 2013, Chile in June 2017, Argentina in April 2018, and Brazil in September 2019.

The normalized curve (lower-right) shows a glimpse of the impact of Venezuela's economic collapse on a relative decline in bandwidth over the past decade. Before entering the 2010s, Venezuela had near-average download speeds (89%). A decade later, the median download speed in the country dropped to 17% compared to the regional average.

Interestingly, Venezuela's median download speeds have significantly increased from 1 Mbps to nearly 3 Mbps since the end of 2021. This growth correlates with the introduction of new CANTV high-speed fiber optic plans of up to 300 Mbps [32] and the entry of new companies offering speeds of up to 50 Mbps [49]. However, these high-speed services remain unaffordable for most Venezuelans. CANTV's high-speed services are available only in East Caracas, the region historically with the highest income, and in 2022, they cost 100 VEB (bolívares), ten times the minimum wage [49]. Even CANTV's lower-capacity services (ranging from 4 to 22 Mbps) were beyond the reach of a minimum-wage worker, with costs ranging from 3 to 15 VEB per month, and they are typically unavailable for new subscribers [49].

7.2 Access to Google's Public DNS

Launched as an experimental component of Google's "Make The Web Faster" project [48], Google Public DNS (GPDNS) [42], the first public DNS service, debuted on December 3, 2009 [82]. Utilizing global anycast addresses 8.8.8.8 and 8.8.4.4, it processes DNS queries from clients, with requests routed through Google's autonomous system along the shortest announced path. The expansion and near pervasiveness of the GPDNS platform suggest that the quality of paths to this infrastructure can serve as proxy for Internet users' overall Quality of Experience (QoE).

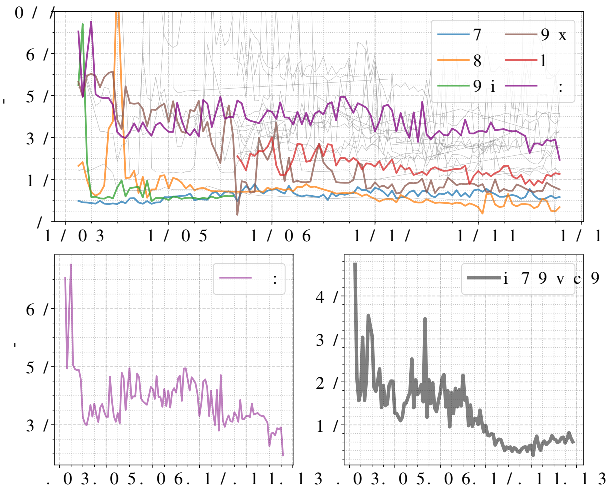


Figure 12: Median RTT for countries in the LACNIC region to Google Public DNS. In the last 6 months of our analysis, Venezuelan users experienced a latency 2.06 times higher (36.56 ms) compared to the LACNIC average (17.74 ms) .

We use RIPE Atlas' platform-wide traceroute campaign to examine the evolution of RTT latency values in Venezuela and the rest of the LACNIC region to GPDNS. We compute the minimum RTT from each probe in each monthly snapshot to remove any transient sources of noise (e.g., diurnal congestion). Figure 12 presents three panels with the evolution of median RTT in each country of the region. The top panel provides a country-level comparison, comparing Venezuela with other countries in the LACNIC region (with some comparable peers highlighted in vivid colors). The lower-left panel focuses specifically on Venezuela, zooming into the evolution of the RTT latency within the country, while the lower-right panel shows the aggregated RTT latency throughout the region.

We use RIPE Atlas' platform-wide traceroute campaign to examine the evolution of RTT latency values in Venezuela and the rest of the LACNIC region to Google's Public DNS. Figure 12 is divided into three segments, each showing the median RTT evolution. The top segment offers a comparative analysis at the country level, emphasizing Venezuela's latency to its LACNIC peers, with key comparable countries highlighted in bright colors. The bottom left segment focuses on Venezuela, providing a detailed view of its RTT latency trends. In contrast, the bottom right segment aggregates and displays the overall RTT latency trends across the LACNIC region.

Our analysis indicates a consistent reduction in RTT latency across most LACNIC region countries, which aligns with the ongoing expansion of GPDNS infrastructure. Since 2016, when the time series seemed to stabilize, latency values have been remarkably declining. Comparing the first half of 2016 with the latter half of 2023, minor fluctuations are observed in Argentina (from 12.27 ms to 11.36 ms) and Chile (from 11.25 ms to 11.87 ms), alongside notable declines in Colombia (from 48.48 ms to 16.10 ms), Brazil (from 18.12 ms to 7.52 ms), and Mexico (from 30.21 ms to 21.28 ms). While Venezuela also experienced a reduction in RTT latency to GPDNS during this period (from 45.71 ms to 36.56 ms), its progress lags behind those of these countries. In the latest measurements, Venezuela's latency values are still considerably higher, being 3.22 times that of Argentina, 4.86 times Brazil's, 3.08 times Chile's, 2.27 times Colombia's, and 1.72 times Mexico's. When we compare Venezuela with the region as a whole, Venezuelan users experienced a latency 2.06 times higher (36.56 ms) compared to the LACNIC average (17.74 ms).

We also analyze network-specific variations in RTT latency to client-facing GPDNS servers. Over the past two years, several networks have achieved RTT latencies between 10 and 20ms. Notably, these vantage points are predominantly located in Western Venezuela, near the Colombian border, including some around the Maracaibo region. The probes recording the lowest latencies, just under 10ms, are located right on the Colombian border, confirming that no GPDNS server is currently deployed within Venezuelan territory. Interestingly, these networks are primarily small access networks, none of which use CANTV-8048 (Venezuela's state-owned Internet provider) as their upstream provider. For a more detailed examination of how probe location affects RTT latency variations to GPDNS, refer to Appendix J.

8 LIMITATIONS

Our analysis has several limitations. A key set of limitations follows from the restricted coverage of some platforms we rely on, such as SpeedTest, RIPE Atlas, and PeeringDB. Although the platforms may introduce bias into these measurements, countries within the region will have comparable opportunities to host servers. For countries without local servers, the region's geographical proximity enables testing against servers in neighboring countries and may reduce testing disparities. The crowdsourced nature of the speed test data in this study may introduce another source of potential bias, as the number of tests per country, per day, and across networks may vary. While PeeringDB coverage has had a steadily growing adoption [12, 19, 66], it still draws a partial view of the network. This limited visibility could affect the completeness of our analysis regarding networks' presence at IXPs and the growth of peering facilities. However, while some networks might lack strong incentives to register or fully detail their profiles on PeeringDB, peering facilities are less likely to do so, given their role in the network ecosystem. Although RIPE Atlas coverage in Latin America may not be comparable with the US and Western European countries, Venezuela ranks among the best-covered countries in the region (refer to Appendix F for details). Beyond the coverage of platforms, drawing a conclusion about the footprint of root DNS servers through distributed CHAOS TXT queries may also introduce artifacts. To begin with, we are unaware of whether all roots use different strings to identify different client-facing servers. Moreover, we are unable to determine the entire coverage of roots in each country since our visibility is restricted to instances reached through anycast routes from probes in a fraction of all networks in each country.

9 RELATED WORK

The scale of the Venezuelan crisis has gained the attention of various research communities exploring its impact on different fronts, from health to energy. Several studies, for instance, have reported the consequences of the severely deteriorated health system, leading to increased child mortality, resurgence of vaccine-preventable diseases, shortages in medical supplies and personnel, and widespread undernutrition and mental health issues, among others [33, 67, 80, 91]. Others have investigated the sustained shortages in electric power generation, which have worsened over the past decade, have led to significant electricity supply outages, lasting over 100 hours in extensive areas of the country, exacerbating the economic crisis [81]. Our work considers a previously unexplored perspective – the impact of the crisis on the country's Internet infrastructure.

In our community, a large number of research studies have examined the network perspective of political events [17, 30, 78]. Among recent studies, Padmanabhan et al. [78] reports recurrent multi-hour network shutdowns during the 2021 Myanmar coup, while Bischof et al. [17] compares the characteristics of spontaneous outages and politically motivated shutdowns. Although political developments can result in persistent censorship practices, there are reports of network censorship in Venezuela [50, 51, 77], this work focuses on the impact of the Venezuelan crisis on network infrastructure. Investigating censorship within the country is beyond the scope of this paper and will be left for future work.

The research on the impact of large-scale externalities on the network is not only confined to political events. earthquakes [16, 27, 94], wildfires [7], weather-related events [1, 79], and the broader implications of climate change [34, 36]. The recent impact of COVID-19 lockdowns was examined from multiple angles, including the perspective of a large content provider [20], a large cellular network [69], shifts in user behaviors [38] and social distancing [13].

10 CONCLUSIONS AND FUTURE WORK

Over the last decade, Venezuela has undergone one of the most profound crises in modern history, probably the deepest crisis of any non-war-ridden country in recent times. The scale of it has drawn international attention and motivated several studies exploring its impact on different sectors. This work focused on a previously unexplored perspective: the impact of the crisis on the country's network infrastructure. While there may be a range of causes behind the state of any specific feature of Venezuela's network infrastructure, such as economic sanctions, the composed picture shown by our analysis clearly revels the significant impact of the crisis. In the face of multifaceted challenges facing the country's future, understanding the repercussions of the crisis on the country's Internet, as a critical component of modern society, is vital for charting a path to recovery.

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REFERENCES

[1] renesys [n. d.]. *Impact of hurricane Katrina on Internet infrastructure.* renesys.

[2] 2023. AS Relationships (serial-1). https://catalog.caida.org/dataset/as_relationships_serial_1. https://doi.org/dataset/as_relationships_serial_1 Dates used: 2023-12-08. Accessed: 2023-12-08.

[3] 2023. PeeringDB. https://catalog.caida.org/dataset/peeringdb. https://doi.org/dataset/peeringdb Dates used: 2023-12-08. Accessed: 2023-12-08.

[4] 2023. RouteViews Prefix to AS mappings. https://catalog.caida.org/dataset/routeviews_prefix2as. https://doi.org/dataset/routeviews_prefix2as Dates used: 2023-12-08. Accessed: 2023-12-08.

[5] Bernhard Ager, Nikolaos Chatzis, Anja Feldmann, Nadi Sarrar, Steve Uhlig, and Walter Willinger. 2012. Anatomy of a large European IXP. In *Proc. of ACM SIGCOMM.*

[6] Jorge A Alvarez, Marco Arena, Alain Brousseau, Hamid Faruqee, Emilio William Fernandez Corugedo, Jaime Guajardo, Gerardo Peraza, and Juan Yepez. 2022. Regional Spillovers from the Venezuelan Crisis: Migration Flows and Their Impact on Latin America and the Caribbean. *Departmental Papers* (2022).

[7] Scott Anderson, Carol Barford, and Paul Barford. 2020. Five alarms: Assessing the vulnerability of us cellular communication infrastructure to wildfires. In *Proc. of IMC.*

[8] APNIC. 2024. Host a root server - Expression of Interest. https://www.apnic.net/community/support/root-servers/apnic-call-for-expressions-of-interest-for-root-server-hosting/.

[9] Marco Arena, Emilio Fernandez Corugedo, Jaime Guajardo, and Juan Francisco Yepez. 2022. Venezuela's Migrants Bring Economic Opportunity to Latin America. https://www.imf.org/en/News/Articles/2022/12/06/cf-venezuelas-migrants-bring-economic-opportunity-to-latin-america

[10] Mayela Armas. 2022. Venezuela sees oil exports financing almost two-third of 2023 budget. REUTERS Americas.

[11] Michael Armbrust, Armando Fox, Rean Griffith, Anthony D Joseph, Randy H Katz, Andrew Konwinski, Gunho Lee, David A Patterson, Ariel Rabkin, Ion Stoica, et al. 2009. *Above the clouds: A berkeley view of cloud computing.* Technical Report. Technical Report UCB/EECS-2009-28, EECS Department, University of California âĂę.

[12] Augusto Arturi, Esteban Carisimo, and Fabián E. Bustamante. 2023. as2org+: Enriching AS-to-Organization Mappings with PeeringDB. In *Proc. of PAM.*

[13] Sana Asif, Byungjin Jun, FabiÃąn E. Bustamante, and John P. Rula. 2021. Networked Systems as Witnesses – Association Between Content Demand, Human Mobility and an Infection Spread. In *Proc. of IMC.*

[14] The World Bank. 2024. Mortality rate, under-5 (per 1,000 live births) - Latin America & Caribbean, Venezuela, RB. https://data.worldbank.org/indicator/SH.DYN.MORT?locations=ZJ-VE.

[15] Zachary S. Bischof, Romain Fontugne, and Fabián E. Bustamante. 2018. Untangling the world-wide mesh of undersea cables. In *Proc. of HotNets*.

[16] Zachary S. Bischof, John S. Otto, and FabiÃąn E. Bustamante. 2011. Distributed Systems and Natural Disasters – BitTorrent as a Global Witness. In *Proc. of CoNEXT Special Workshop on the Internet and Disasters (SWID)*.

[17] Zachary S Bischof, Kennedy Pitcher, Esteban Carisimo, Amanda Meng, Rafael Bezerra Nunes, Ramakrishna Padmanabhan, Margaret E Roberts, Alex C Snoeren, and Alberto Dainotti. 2023. Destination Unreachable: Characterizing Internet Outages and Shutdowns. In *Proc. of ACM SIGCOMM*.

[18] Zachary S Bischof, John P Rula, and Fabián E Bustamante. 2015. In and out of Cuba: Characterizing Cuba's connectivity. In *Proc. of IMC*.

[19] Timm Böttger, Félix Cuadrado, Gareth Tyson, Ignacio Castro, and Steve Uhlig. 2017. A Hypergiant's View of the Internet. *ACM SIGCOMM Computer Communication Review* (2017).

[20] Timm Böttger, Ghida Ibrahim, and Ben Vallis. 2020. How the Internet reacted to Covid-19: A perspective from Facebook's Edge Network. In *Proc. of IMC*.

[21] Callum Brodie. 2017. Venezuela was once South AmericaâĂŹs richest country. Here's what went wrong. https://www.weforum.org/agenda/2017/08/venezuela-economic-woes-2017-explained/

[22] Benedicte BUll and Antulio Rosales. 2020. The crisis in Venezuela: Drivers, transitions and pathways. *European Review of Latin American and Caribbean Studies* 109 (January-June 2020).

[23] Esteban Carisimo, Julán Martín Del Fiore, Diego Dujovne, Cristel Pelsser, and J. Ignacio. Alvarez-Halemin. 2020. A first look at Latin American IXPs. (2020).

[24] Esteban Carisimo, Alexander Gamero-Garrido, Alex C. Snoeren, and Alberto Dainotti. 2021. Identifying ASes of State-Owned Internet Operators. In *Proc. of IMC*.

[25] Nikolaos Chatzis, Georgios Smaragdakis, Anja Feldmann, and Walter Willinger. 2013. There is more to IXPs than meets the eye. *ACM SIGCOMM Computer Communication Review* (2013).

[26] Amelia Cheatham and Diana Roy. 2023. Venezuela: The Rise and Fall of a Petrostate. *Council on Foreign Relations* (December 2023). https://www.cfr.org/backgrounder/venezuela-crisis.

[27] Kenjiro Cho, Cristel Pelsser, Randy Bush, and Youngjoon Won. 2011. The Japan earthquake: the impact on traffic and routing observed by a local ISP. In *Proc. of CoNEXT Special Workshop on the Internet and Disasters (SWID)*.

[28] CISCO. 2020. CISCO Annual Internet Report (2018-2023). Whitepaper.

[29] Internet Systems Consortium. 2024. Hosting an F-Root Node. https://www.isc.org/froot-process/.

[30] Alberto Dainotti, Claudio Squarcella, Emile Aben, Kimberly C Claffy, Marco Chiesa, Michele Russo, and Antonio Pescapé. 2011. Analysis of country-wide internet outages caused by censorship. In *ACM SIGCOMM Computer Communication Review*.

[31] Ricardo de Oliveira Schmidt, John Heidemann, and Jan Harm Kuipers. 2017. Anycast latency: How many sites are enough?. In *Proc. of PAM*.

[32] Katherine Dona. 2022. Cantv ofrece plan de fibra optica a zonas del este de Caracas. https://elpitazo.net/gran-caracas/cantv-ofrece-plan-de-fibra-optica-a-zonas-del-este-de-caracas/

[33] Shannon Doocy, Kathleen R. Page, Charissa Liu, Hayley Hoaglund, and Daniela C Rodríguez. 2022. Venezuela: out of the headlines but still in crisis. *Bulletin World Health Organization* 100, 8 (August 2022).

[34] Ramakrishnan Durairajan, Carol Barford, and Paul Barford. 2018. Lights Out: Climate Change Risk to Internet Infrastructure. In *Proc. of ANRW*.

[35] EFE. 1991. Venezuela anuncia el comienzo de la privatización de su telefónica. *El Pais* (1991). https://elpais.com/diario/1991/02/03/economia/665535604_850215.html

[36] Brian Eriksson, Ramakrishnan Durairajan, and Paul Barford. 2013. RiskRoute: A framework for mitigating network outages threats. In *Proc. of CoNEXT*.

[37] Facebook. 2023. IPv6 adoption by country. https://www.facebook.com/ipv6/?tab=ipv6_country.

[38] Anja Feldmann, Oliver Gasser, Franziska Lichtblau, Enric Pujol, Ingmar Poese, Christoph Dietzel, Daniel Wagner, Matthias Wichtlhuber, Juan Tapiador, Narseo Vallina-Rodriguez, et al. 2020. The lockdown effect: Implications of the COVID-19 pandemic on internet traffic. In *Proc. of IMC*.

[39] Organisation for Economic Co-operation and Development. 2024. Crude oil production. https://data.oecd.org/energy/crude-oil-production.htm.

[40] The International Monetary Fund. 2024. IMF Data Mapper. https://www.imf.org/external/datamapper/NGDP_RPCH\spacefactor\@m{}WEO/OEMDC/ADVEC/WEOWORLD.

[41] Petros Gigis, Matt Calder, Lefteris Manassakis, George Nomikos, Vasileios Kotronis, Xenofontas Dimitropoulos, Ethan Katz-Bassett, and Georgios Smaragdakis. 2021. Seven years in the life of Hypergiants' off-nets. In *Proc. of ACM SIGCOMM*.

[42] Google. [n. d.]. Google Public DNS. https://developers.google.com/speed/public-dns/.

[43] Google. 2022. About CrUX. https://developer.chrome.com/docs/crux/about/

[44] Robert L Grossman. 2009. The case for cloud computing. *IT professional* (2009).

[45] Bertrand Gruss. 2014. After the BoomâĂŞCommodity Prices and Economic Growth in Latin America and the Caribbean. *IMF Working Papers* 2014, 154 (2014), A001. https://doi.org/10.5089/9781498363518.001.A001

[46] Ricardo Hausmann and Francisco R Rodríguez. 2015. *Venezuela before Chávez: Anatomy of an economic collapse*. Penn State Press.

[47] United Nations HCR. 2024. VENEZUELA HUMANITARIAN CRISIS. https://www.unrefugees.org/emergencies/venezuela/#:~:text=About%20the%20Crisis%20in%20Venezuela&text=The%20humanitarian%20crisis%20in%20Venezuela,Latin%20America%20and%20the%20Caribbean.

[48] Urs Hoelzle. 2009. Let's make the web faster. https://googleblog.blogspot.com/2009/06/lets-make-web-faster.html.

[49] Feedom House. 2022. Freedom of the Net: Venezuela 2022. https://freedomhouse.org/country/venezuela/freedom-net/2022.

[50] Feedom House. 2023. Freedom of the Net: Venezuela 2020. https://freedomhouse.org/country/venezuela/freedom-net/2020.

[51] Feedom House. 2023. Freedom of the Net: Venezuela 2023. https://freedomhouse.org/country/venezuela/freedom-net/2023.

[52] Geoff Huston. 2014. How Big is that Network? https://labs.apnic.net/?p=526.

[53] Shadi Ibrahim, Bingsheng He, and Hai Jin. 2011. Towards pay-as-you-consume cloud computing. In *Proc. of Conference on Services Computing*.

[54] Sylvia Kechiche. 2023. Ookla: The State of Worldwide Connectivity in 2023. https://www.ookla.com/articles/worldwide-connectivity-mobile-fixed-networks-digital-divide-2023.

[55] Brenden Kuerbis. 2019. Economic Factors Affecting IPv6 Deployment. ARIN Blog.

[56] Rashna Kumar, Sana Asif, Elise Lee, and Fabian E. Bustamante. 2023. Each at Its Own Pace: Third-Party Dependency and Centralization Around the World. *Proc. ACM Meas. Anal. Comput. Syst.* (2023).

[57] Craig Labovitz. 2019. Internet Traffic 2009-2019. NANOG Presentation.

[58] LACNIC. 2015. Venezuela installs the region's 15th root server copy. *LACNIC Blog* (2015). https://blog.lacnic.net/en/institutional/venezuela-installs-the-regions-15th-root-server-copy

[59] LACNIC. 2023. LACNIC Delegation files. https://ftp.lacnic.net/pub/stats/lacnic/.

[60] LACNIC. 2023. Phases of IPv4 Exhaustion. https://www.lacnic.net/1039/2/lacnic/phases-of-ipv4-exhaustion.

[61] LACNIC. 2023. +RAICES. https://www.lacnic.net/993/1/lacnic/+raices.

[62] LACNIC. 2024. Registro de Direcciones de Internet para AmÃľrica Latina y Caribe. https://www.lacnic.net.

[63] J.E. León-Vielma, F.J. Ramos-Real, and J.F. Hernández Hernández. 2022. The collapse of Venezulea's electricity sector from an energy governance perspective. *Energy Policy* (August 2022).

[64] Fangfan Li, Arian Akhavan Niaki, David Choffnes, Phillipa Gill, and Alan Mislove. 2019. A large-scale analysis of deployed traffic differentiation practices. In *Proc. of ACM SIGCOMM*.

[65] Shucheng Liu, Zachary S. Bischof, Ishaan Madan, Peter K. Chan, and Fabián E. Bustamante. 2020. Out of Sight, Not Out of Mind - A User-View on the Criticality of the Submarine Cable Network Conference. In *Proc. of IMC*.

[66] Aemen Lodhi, Natalie Larson, Amogh Dhamdhere, Constantine Dovrolis, and Kc Claffy. 2014. Using peeringDB to understand the peering ecosystem. *ACM SIGCOMM Computer Communication Review* (2014).

[67] Enrique S LÃşpez Loyo, Marino J GonzÃąlez, and JosÃľ Esparza. 2021. Venezuela is collapsing without COVID-19 vaccines. *The Lancet* (2021).

[68] LUMEN. 2022. Lumen Closes Sale of its Latin American Business to Stonepeak. *LUMEN* (2022). https://ir.lumen.com/news/news-details/2022/Lumen-Closes-Sale-of-its-Latin-American-Business-to-Stonepeak/default.aspx

[69] Andra Lutu, Diego Perino, Marcelo Bagnulo, Enrique Frias-Martinez, and Javad Khangosstar. 2020. A characterization of the COVID-19 pandemic impact on a mobile network operator traffic. In *Proc. of IMC*.

[70] M-LAB. 2023. Measurement Lab (M-Lab). https://www.measurementlab.net. Accessed: 2023-6-28.

[71] M. Mathis and M. Allman. 2001. *A Framework for Defining Empirical Bulk Transfer Capacity Metrics*. RFC 3148. IETF. http://tools.ietf.org/rfc/rfc3148.txt

[72] Michael Menzel and Rajiv Ranjan. 2012. CloudGenius: decision support for web server cloud migration. In *Proc. of the WWW*.

[73] Arash Molavi Kakhki, Abbas Razaghpanah, Anke Li, Hyungjoon Koo, Rajesh Golani, David Choffnes, Phillipa Gill, and Alan Mislove. 2015. Identifying traffic differentiation in mobile networks. In *Proc. of IMC*.

[74] Maria Alejandra Moreno-Pizani. 2021. Water Management in Agricultural Production, the Economy, and Venezuelan Society. *Frontier in Sustainable Food Systems* 4 (February 2021).

[75] RIPE NCC. 2024. Hosting a DNS node. https://hosted-dns.ripe.net.

[76] NBC News. 2004. Telefonica chases BellSouth assets. https://www.nbcnews.com/id/wbna4447681.

[77] US Department of State. 2022. 2022 Country Reports on Human Rights Practices: Venezuela. https://www.state.gov/reports/2022-country-reports-on-human-

rights-practices/venezuela/.

[78] Ramakrishna Padmanabhan, Arturo Filastò, Maria Xynou, Ram Sundara Raman, Kennedy Middleton, Mingwei Zhang, Doug Madory, Molly Roberts, and Alberto Dainotti. 2021. A multi-perspective view of Internet censorship in Myanmar. In *Proc. Workshop on Free and Open Communications on the Internet*.

[79] Ramakrishna Padmanabhan, Aaron Schulman, Dave Levin, and Neil Spring. 2019. Residential links under the weather. In *Proc. of ACM SIGCOMM*.

[80] Kathleen R. Page, Shaning Doocy, Feliciano Reyna Ganteaume, Julio S. Castro, Paul Spiegel, and Chris Beyrer. 2019. Venezuelas public health crisis: a regional emergency. *The Lancet* 393, 10177 (March 2019).

[81] Licia Pietrosemoli and Carlos Rodriguez-Monroy. 2019. The Venezuelan energy crisis: Renewable energies in the transition towards sustainability. *Renewable and Sustainable Energy Reviews* 105 (May 2019).

[82] Public DNS Team Prem Ramaswami. 2009. Introducing Google Public DNS: A new DNS resolver from Google. https://developers.googleblog.com/2009/12/introducing-google-public-dns-new-dns.html.

[83] Robert Rapier. 2019. Inside Venezuela's Contradictory Oil Industry. *Forbes* (2019). https://www.forbes.com/sites/rrapier/2019/01/29/charting-the-decline-of-venezuelas-oil-industry/

[84] Robert Rapier. 2023. Inside Venezuela's Contradictory Oil Industry. *Forbes* (2023). https://www.forbes.com/sites/rrapier/2023/02/21/inside-venezuelas-contradictory-oil-industry/?sh=2c351d277c13

[85] Gigliana Rivero Ramírez. 2000. EVOLUCIÓN DE LOS SERVICIOS DE TELEFONÍA EN VENEZUELA. *Academia de Ciencias Politicas y Sociales de Venezuela* (2000). https://www.forbes.com/sites/rrapier/2023/02/21/inside-venezuelas-contradictory-oil-industry/?sh=2c351d277c13

[86] Francisco Rodríguez. 2023. Can Venezuela Chart a Path Out of Crisis? *Foreign Affairs* (2023). https://www.foreignaffairs.com/united-states/can-venezuela-chart-path-out-crisis

[87] Simon Romero. 2007. Chávez Moves to Nationalize Two Industries. *The New York Time* (2007). https://www.nytimes.com/2007/01/09/world/americas/09venezuela.html

[88] Diana Roy. 2022. Do U.S. Sanctions on Venezuela Work? https://www.cfr.org/in-brief/do-us-sanctions-venezuela-work

[89] Brandon Schlinker, Hyojeong Kim, Timothy Cui, Ethan Katz-Bassett, Harsha V Madhyastha, Italo Cunha, James Quinn, Saif Hasan, Petr Lapukhov, and Hongyi Zeng. 2017. Engineering egress with edge fabric: Steering oceans of content to the world. In *Proc. of ACM SIGCOMM*.

[90] TeleGeography. 2023. Submarine Cable Map. https://www.submarinecablemap.com/.

[91] The Lancet. 2019. Venezuelans' right to health crumbles amid political crisis. *The Lancet* (2019).

[92] Yolanda Valery. 2011. Más internet para Cuba, cortesía de Venezuela. https://www.bbc.com/mundo/noticias/2011/01/110119_venezuela_cuba_cable_submarino_internet.

[93] Colin Wall and Pierre Morcos. 2021. Invisible and Vital: Undersea Cables and Transatlantic Security. https://www.csis.org/analysis/invisible-and-vital-undersea-cables-and-transatlantic-security

[94] Jian Wu, Ying Zhang, Z Morley Mao, and Kang G Shin. 2007. Internet routing resilience to failures: analysis and implications. In *Proc. of CoNEXT*.

APPENDICES

Appendices are supporting material that has not been peer-reviewed.

A COMPOSITION OF VENEZUELA'S INTERNET USER BASE

We employ APNIC's AS population estimates [52] to analyze the composition of Venezuela's Internet user base. Table 1 presents the ten largest Internet service providers in Venezuela, which together account for 77.18% of the market share as of May 2024.

Venezuela's state-owned Internet operator, CANTV-AS8048, dominates the market, holding 21.50% of the country's Internet users. This is nearly double that of its closest competitor, Telemic-AS21826, commonly known as *Inter*. The state's influence extends further through MOVILNET-AS27889 [24], a mobile carrier, which adds another 2.07% of users to the state's portfolio. Although the market is not entirely concentrated, CANTV maintains a leading position.

ASN	AS Name	Users	CC %
8048	CANTV Servicios, Venezuela	4,330,868	21.50
21826	Corporacion Telemic C.A.	2,490,253	12.36
6306	TELEFONICA VENEZOLANA, C.A.	2,110,464	10.48
264731	Corporacion Digitel C.A.	1,419,723	7.05
264628	CORPORACION FIBEX TELECOM, C.A.	1,316,463	6.54
61461	Airtek Solutions C.A.	1,092,514	5.42
263703	VIGINET C.A	962,781	4.78
11562	Net Uno, C.A.	896,094	4.45
272809	THUNDERNET, C.A.	515,761	2.56
27889	Telecomunicaciones MOVILNET	417,762	2.07
Summatory		15,552,683	77.18%

Table 1: Ten largest Internet service providers in Venezuela considering their estimated Internet populations.

B COMPARING VENEZUELA'S GDP PER CAPITA WITH THE REST OF THE REGION

We utilized the International Monetary Fund (IMF) public data on GDP per capita to compare Venezuela's economic growth over time with other countries in the LACNIC region. Figure 13 depicts these growth curves, using vivid colors to highlight the countries Argentina, Brazil, Mexico, Chile, Uruguay, and Venezuela, while the rest of the countries in the region are shown in light grey. Additionally, the figure annotates Venezuela's rank in this metric across the region every five years.

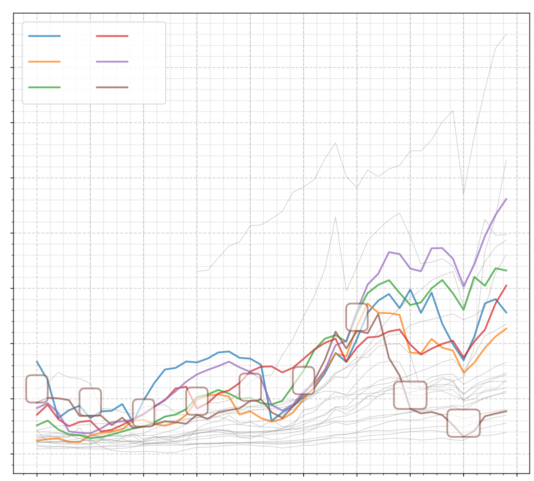

Figure 13: GDP Per Capita in the LACNIC Region since 1980 for Argentina, Brazil, Mexico, Chile, Uruguay, and Venezuela in vivid colors, with other regional countries represented in light grey. Annotations highlight Venezuela's ranking every five years.

Our results indicate that at the beginning of the time series in 1980, Venezuela was the third wealthiest country in the region, trailing only Argentina and Trinidad and Tobago and climbed to second place by 1985. From then until the early 2010s, Venezuela oscillated between the sixth and ninth positions, with values very close to those of the highlighted countries. However, when the economic crisis unfolded in 2013, Venezuela's rank rapidly declined, falling to 18^{th} by 2015 and 23^{rd} by 2020, leaving the group of leading economies in Latin America, a group to which Venezuela has historically belonged.

C TELEFONICA DE VENEZUELA PREFIX VISIBILITY

Our analysis of Venezuela's address space (detailed in §4) revealed that Telefonica de Venezuela (AS6306), a subsidiary of the Spanish conglomerate, reduced its footprint in the domestic address space for nearly a decade. Next, we closely examine Telefonica de Venezuela's prefix announcements since 2016, when this address space contraction became evident.

Figure 14 displays a heatmap of all prefixes announced by Telefonica de Venezuela (AS6306) from 2016 to 2024, with colored cells indicating routed prefixes. Our analysis reveals that around June 2016, several /17 prefixes, such as 179.23.128.0, 179.23.0.0, 161.255.0.0, and 161.255.128.0, were no longer visible in our dataset. Interestingly, many of these address blocks reappeared in June 2023, still under Telefonica's announcement, but now as part of larger address blocks, such as 179.20.0.0/14 and 161.255.128.0/16. The reasons behind Telefonica's address space contraction during this 7-year period remain unclear; however, it led to a more pronounced dominance of CANTV-AS8048 in the domestic address space.

D PRESENCE AT VENEUZELAN PEERING FACILITIES

While a thriving market of peering facilities may reveal a country's prosperity in terms of Internet connectivity, the number of networks present at each facility is key to understanding the impact of these infrastructures. Our analysis now investigates the growth trends in the number of networks connected to each peering facility in Venezuela over time. This examination offers valuable insights into the country's dynamic evolution of network interconnectivity.

To evaluate the number of networks connected to each peering facility in Venezuela, we utilize monthly snapshots from PeeringDB. Figure 15 illustrates the growth in the number of networks at each facility since November 2021, marking the emergence of Venezuela's first peering facility on PeeringDB. As findings in §5.1 show, Venezuela currently has only four peering facilities[8], with despair but mostly minimal presence of networks Since 2021, the distribution of network connections across these facilities has been uneven: GIGA POP has no network presence, DaycoHost and GlobeNet have a minimal presence (2 networks each), while Cirion has experienced a rapid but still moderate increase in network connections (peaking 11 networks in the latest snapshot). These numbers highlight that Venezuela still lacks a domestic market demanding peering locations, and the presence of foreign players at these facilities to serve domestic networks is also minimal.

Table 2 further expands the analysis by displaying the networks reported to be present at some point in VenezuelaâĂŹs peering facilities. As indicated in the table, neither hypergiants (e.g., Google, Cloudflare) nor large transit networks are present in these peering facilities.

[8]The facility in La Urbina underwent a name change following LUMEN's sale of its Latin American operations to Cirion [68].

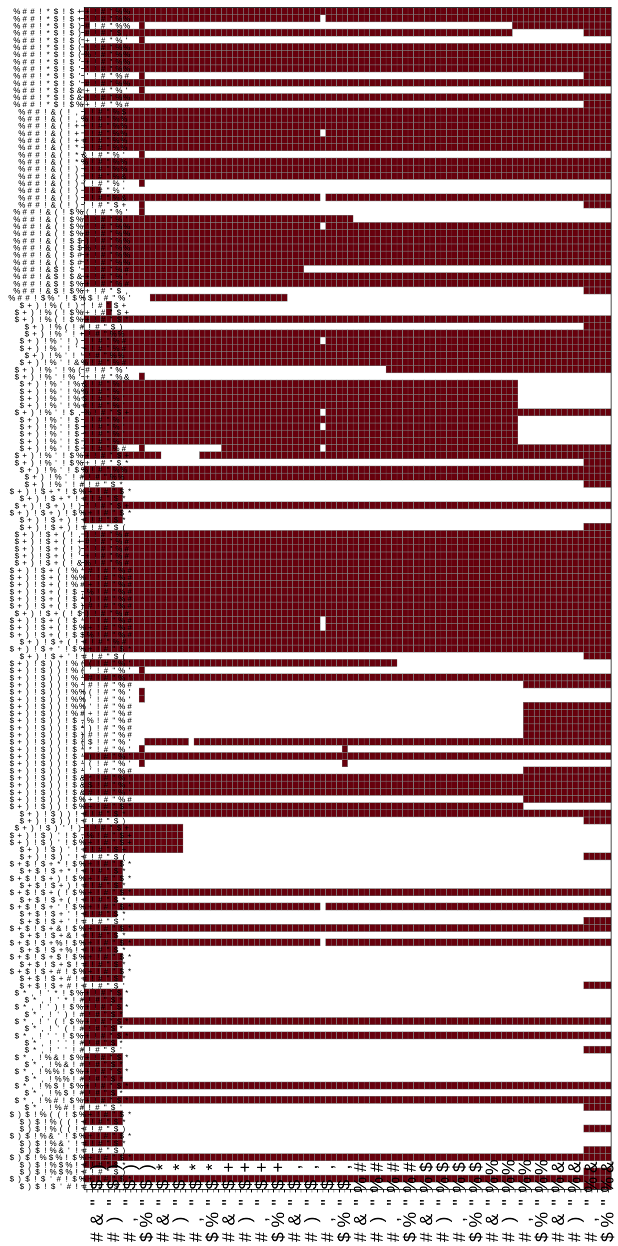

Figure 14: Prefix announced by Telefonica de Venezuela (AS6306) between 2016 and 2024.

E LOCATION OF ROOT DNS SERVERS SERVING VENEZUELA

As described in §5.4, Venezuela's absence of domestic root DNS servers renders it entirely dependent on overseas servers. Next, we

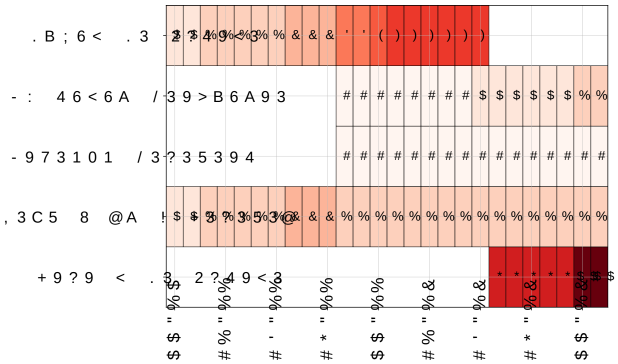

Figure 15: Number of networks present at Peering Facilities in Venezuela.

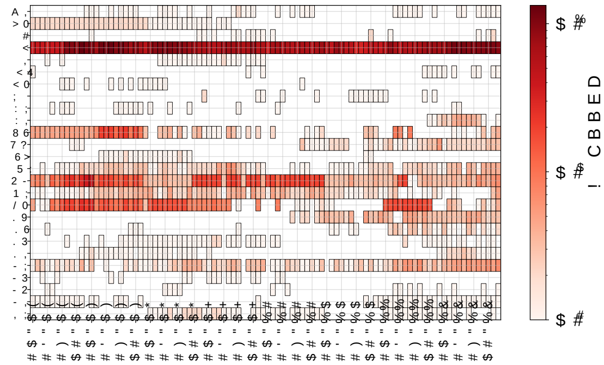

Figure 16: Number of Root DNS Servers per country detected in CHAOS TXT measurements using probes in Venezuela across our monthly snapshots.

Facility Name	ASN	AS Name
Lumen La Urbina	8053	IFX Venezuela
	265641	CIX BROADBAND
	269832	MDSTELECOM
	23379	Blackburn Technologies II
	270042	RED DOT TECHNOLOGIES
	269738	Chircalnet Telecom
	267809	360NET
Cirion La Urbina	8053	IFX Venezuela
	265641	CIX BROADBAND
	269832	MDSTELECOM
	23379	Blackburn Technologies II
	270042	RED DOT TECHNOLOGIES
	269738	Chircalnet Telecom
	267809	360NET
	19978	Cirion - VE
	21826	Corporación Telemic Network
	21980	Dayco Telecom
	269918	SISTEMAS TELCORP, C.A.
Daycohost - Caracas	8053	IFX Venezuela
	269832	MDSTELECOM
	270042	RED DOT TECHNOLOGIES
Globenet Maiquetia	272102	BESSER SOLUTIONS
	21826	Corporación Telemic Network

Table 2: Table of networks present at Venezuela's peering facilities.

expand our analysis to investigate the locations of root DNS servers serving Venezuela since 2016.

We use RIPE Atlas' built-in CHAOS TXT measurements, collected from probes in Venezuela, to determine the locations of DNS servers serving the country. Figure 16 presents a heatmap displaying the number of servers per country in monthly snapshots reached by probes in Venezuela. These findings, consistent with §5.4, indicate that servers previously deployed within Venezuela have disappeared from our data. Despite the significant impact of losing its domestic DNS root infrastructure, Venezuela has historically relied heavily on DNS servers in the US. However, there has been a shift away from distant servers located in countries like Germany, Great Britain, France, and the Netherlands towards closer resources in Latin America, particularly in Brazil — now the second DNS source — as well as Panama and Colombia. while Venezuela has experienced a setback in losing local DNS services, it continues to access DNS replicas from relatively nearby locations such as the US, Brazil, Panama, and Colombia.

F RIPE ATLAS' FOOTPRINT IN LATIN AMERICA

The coverage of RIPE Atlas in Venezuela is important in our capacity to detect root DNS servers deployed and operational in the country. To determine whether limited coverage could skew our observations, we now analyze the RIPE Atlas network's presence and evolution within Venezuela over time.

We examine the coverage of RIPE Atlas in LACNIC region through recurrent CHOAS TXT built-in measurements to all root DNS. Figure 17 shows the monthly evolution of the number of probes in each country involved in these measurements. The top panel offers a comparative view of the probe count in Venezuela against other LACNIC countries, with comparable peers emphasized in bright colors. The bottom-left panel exclusively focuses on Venezuela, while the bottom-right panel aggregates and displays the total number of probes across all countries in the region.

As the analysis reveals, Venezuela has one of the best coverages in Latin America despite facing challenges in maintaining network metrics comparable to the rest of the region. Notably, visibility has been significantly increased, with the number of probes in Venezuela rising from 10 to 30 in just the last few years. Given this extensive coverage, we assume that the lack of visibility of previously available root DNS servers in Venezuela is not due to a lack of coverage by the RIPE Atlas platform.

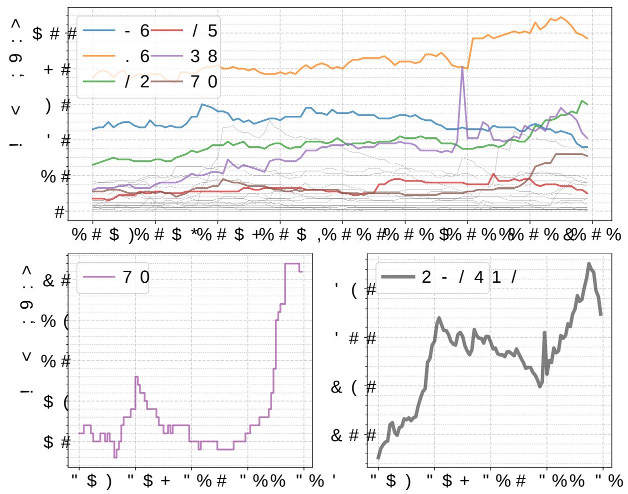

Figure 17: Number of probes per country involved in the CHAOS TXT measurements of our monthly snapshots.

G THE FOOTPRINT OF OFF-NET IN THE LACNIC REGION

Deploying *off-nets* to distribute content is a prevalent strategy numerous content providers employ. We now offer a full examination of the presence of all Hypergiants, as covered in Gigis et al. [41], across the LACNIC region. Our analysis aims to compare Venezuela with the rest of the countries in the region in terms of *off-net* deployments.

We repeat the methodology described in §5.5 to analyze the percentage of the Internet population within each country that is served by organizations hosting *off-nets*. Figure 18 displays this data, with each of the 10 panels representing a different content provider: Akamai, Google, Facebook, Netflix, Microsoft, Limelight, CDNetworks, Alibaba, Amazon, and Cloudflare.

As shown in §5.5, Google and Akamai had deployed *off-nets* before the beginning of Venezuela's crisis, while Facebook and Netflix, networks with later global expansions, have had modest and delayed deployments in the country. The articles of Gigis et al. [41] reveal that other content providers have a minimal presence throughout Latin America, with none having established a presence in Venezuela.

H PREVALENCE OF CDNS SERVING POPULAR SITES

The shift from on-premises to third-party content and cloud providers is a global trend. These providers offer a *pay you go* model [11, 44, 53], which allows for flexible allocation of computing resources, ensures service availability, and removes various capital and operational expenditures. However, this migration to the cloud also introduces new challenges, including technical aspects crucial for meeting Quality of Service (QoS) objectives [72]. Next, we conclude our analysis by investigating whether Venezuela's crisis impacted the adoption of third-party providers compared to other countries in the region.

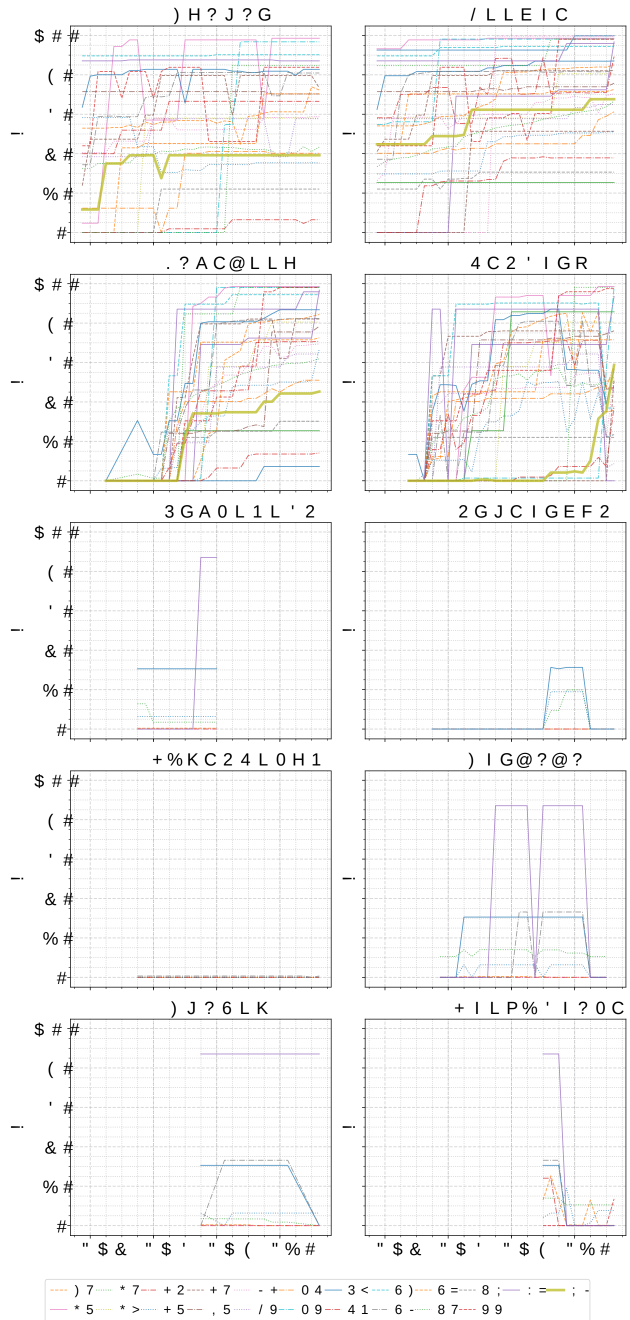

Figure 18: Evolution of the countries' Internet populations in providers hosting *off-nets*.

To identify third-party adoption, we leverage the methodology proposed Kumar et al. [56], and conduct a comparative analysis of Venezuela and other Latin American countries. This involves using a VPN service to obtain the perspective of a local user and retrieving a list of top 1,000 popular websites reported on Google's cRuX [43]. As a result of scraping each website, we identify the serving infrastructure for each component. Our analysis also compares HTTPS adoption growth in Venezuela relative to the rest of Latin America, aiming to determine any potential lag in this matter as well.

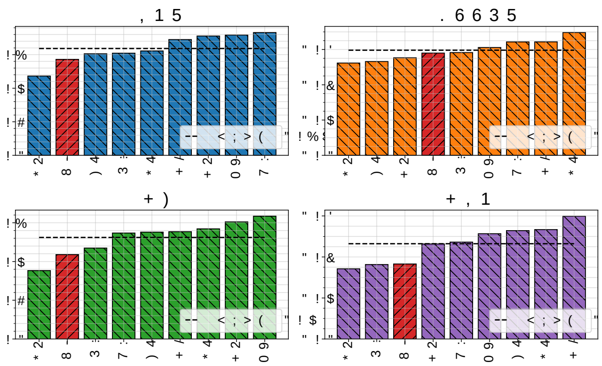

Figure 19: Analysis of adoption of third-party providers in topsites (1) DNS, (2) CA, (3) CDN, and (4) HTTPS adoption as well. Venezuela lags in the adoption of all these aspects except for HTTPS.

To assess the adoption of third-party providers, we examine four key variables identified in a prior work [56]: (1) HTTPS adoption, (2) Third-party DNS adoption, (3) Third-party Certificate Authorities (CA) adoption, and (4) Third-party CDN adoption. Considering that many top sites are common across countries and are often served by large third-party providers, our analysis only includes those top sites that are unique to the list of top sites in a single country. This focused methodology allows for understanding each country's adoption of third-party services.

Figure 19 illustrates the proportion of each country's unique top sites in the region that utilize HTTPS, DNS, CA, and CDN third-party providers. The analysis reveals that Venezuela ranks lower in adopting third-party DNS, CA, and CDN services, only ahead of Bolivia, which has the lowest GDP per capita in South America, with Venezuela excluded. Specifically, Venezuela's adoption rates stand below the average for DNS at 0.29 (regional average 0.32), CA at 0.22 (0.26), and CDN at 0.37 (0.46), but slightly above for HTTPS at 0.58 (0.60). This indicates that Venezuela's network infrastructure lags in yet another dimension, particularly in adopting third-party providers for content delivery.

I PRESENCE OF LATIN AMERICAN NETWORKS AT IXPS IN THE UNITED STATES

While establishing a presence in major regional IXPs within the LACNIC region, such as IX.br Sao Paulo or AR-IX Buenos Aires, can be appealing for networks in Latin American countries, establishing a presence in the United States emerges as an alternative, particularly for those countries geographically closer to Miami than Sao Paulo. Venezuela is within this latter group and Venezuelan networks might have had a presence in the US prior to escalating tensions between the two nations. Next, we analyze the eyeball population in networks connected to exchange points in the United States, comparing Venezuela with the rest of the region.

Figure 21 presents a heatmap showing the presence of Latin American networks at IXPs in the United States. The top panel of the figure shows the proportion of the Internet population in Latin American countries served by networks peering at these US IXPs, while the lower panel displays the number of Autonomous Systems (ASes) from each country present at these points. Our analysis indicates that, in general, IXPs in the US are not popular destinations for Latin American networks, with the exceptions being FL-IX, Equinix Miami, and DECIX New York. This trend differs for networks serving Brazilian and Mexican internet populations, which are present across most US exchanges. In contrast to Brazilian and Mexican networks, Uruguayan networks prefer establishing a presence at a few exchanges (Equinix Ashburn, Miami, and FL-IX), but connecting to a significant portion of the country's internet population. In the case of Venezuela, the presence of its network peering in the US is minimal, with just seven networks serving a mere 7% of Venezuela's Internet population.

J RIPE ATLAS' FOOTPRINT IN VENEZUELA AND RTT TO GOOGLE'S PUBLIC DNS

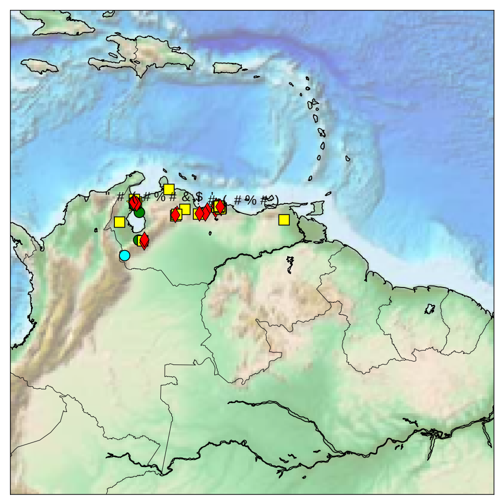

Figure 20: Geographical Distribution of Vantage Points Probing Google Public DNS: The markers represent the minimum RTT from each probe to GPDNS, color-coded as follows: below 10ms (Cyan circles), 10-20ms (Green circles), 20-40ms (Yellow squares), and above 40ms (Red diamonds).

Although country-level data indicates that Venezuela's median latency to Google Public DNS is higher compared to other LACNIC region countries, there is notable variability in latency among probes within Venezuela, including some with latencies comparable to peer countries. Next, we explore whether the geographic location of these probes in Venezuela could contribute to the observed differences in median latency.

To examine if there is a correlation between the geographical coordinates of each probe in Venezuela and their minimum latency to Google Public DNS, we analyzed data from the latest snapshot (December 2023). Figure 20 features a map that marks each probe's location, color-coded by their minimum latency to Google Public DNS: below 10ms (Cyan circles), 10-20ms (Green circles), 20-40ms (Yellow squares), and above 40ms (Red diamonds). The map reveals that the only probes achieving latencies under 10ms to Google Public DNS are located along the Colombian border, and slightly further, in the Maracaibo region, some probes exhibit latencies in the 10-20ms range. A noticeable trend of increasing latency with distance from the Colombian border suggests that no GPDNS server within Venezuela serves these probes.

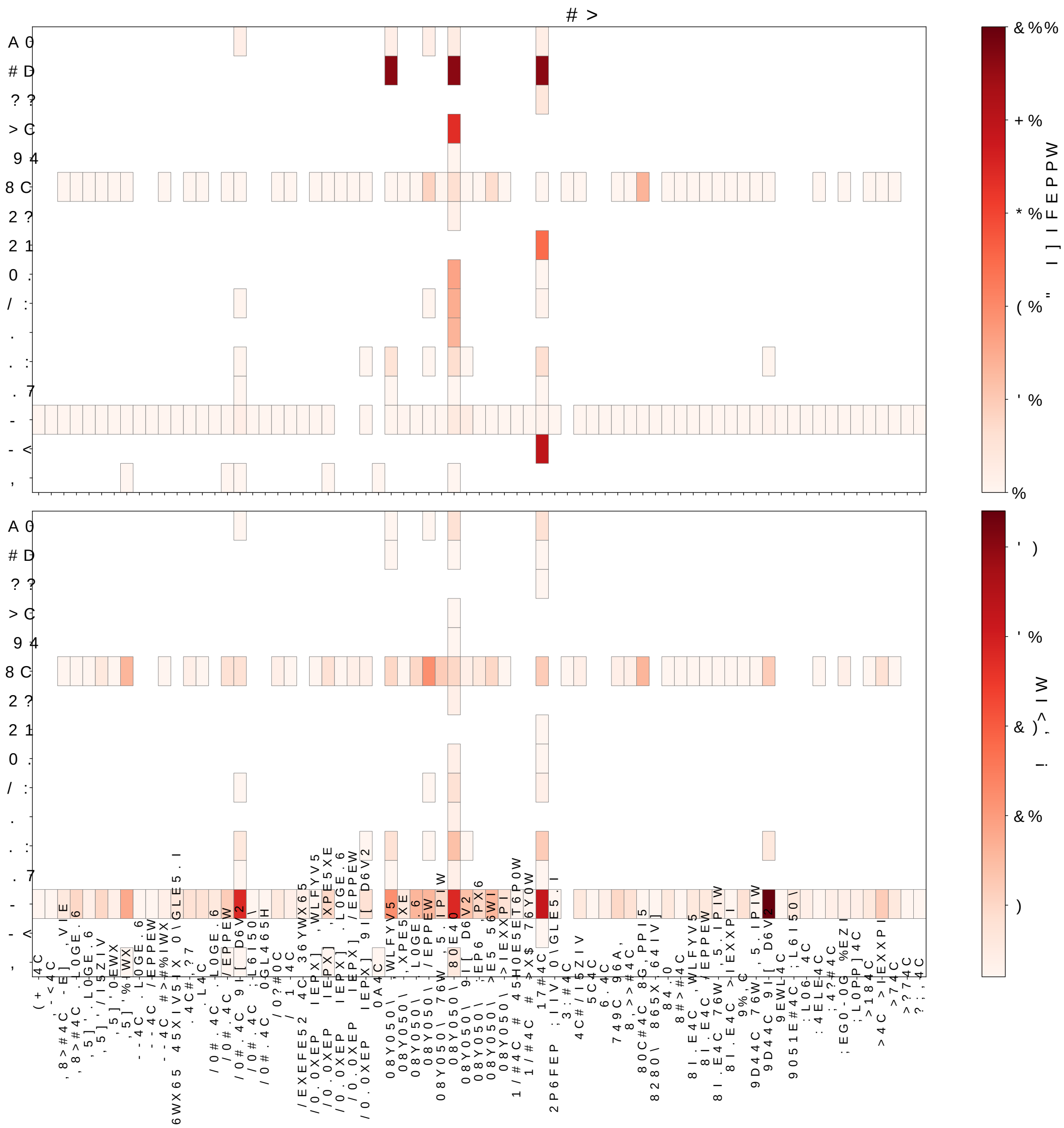

Figure 21: The percentage of countries' Internet population in networks is peering at IXPs in the United States. The presence of Venezuela's networks peering in the US is minimal, with just seven networks serving a mere 7% of Venezuela's Internet population.