Measuring the Impact of Local IXPs: Understanding Hosting Trends in the Asia-Pacific Region From the Regional Domain Perspective

Australia, Bangladesh, Indonesia, India, Japan, Malaysia, Nepal, Philippines, Singapore, and Thailand

By Terry Sweetser

Internet Society

Abstract

The technical objective of this study is to measure the impact of local Internet exchanges across the Asia-Pacific region. Data was gathered from locally hosted machines in ten countries using a complete list of local ccTLD[1] domains. Performance data for latency and hop counts was gathered from the ten locations as IPv4 and IPv6 addresses of the remote servers, providing HTTPS for each domain. Further data was generated to geolocate the remote IP addresses and check the Resource Public Key Infrastructure (RPKI) (secured routing) status of each address. Analysis and visualization of the data set is presented alongside commentary and interpretation of the technical and business impact of those observations.

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1 Country code top level domains (Wikipedia, 2021)

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List of Acronyms

ASN: Autonomous system number

AS path: Autonomous system path

ccTLD: Country code top-level domain

BGP: Border Gateway Protocol

CDN: Content Delivery Network

DNS: Domain Name System

HTTPS: Hypertext Transfer Protocol Secure

IP: Internet Protocol

IPv4: Internet Protocol Version 4

IPv6: Internet Protocol Version 6

ISP: Internet Service Provider

IXP: Internet Exchange Point

ROA: Route Origin Authorization

ROV: Route Origin Validation

RPKI: Resource Public Key Infrastructure

RSA: Encryption Standard

SQL: Structured Query Language

TCP: Transmission Control Protocol

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Introduction

This is an analysis of country code top-level domain (ccTLD) web-server presence and performance in the Asia-Pacific region. ccTLD is specifically (but not exclusively) reserved for use by individuals, organizations, or companies registered and/or residing in a particular country, sovereign state, or dependent territory. For example, .au is for Australia, .us is for the United States, .eu is for Europe, .fr is for France, and so on.

We initiated a research project to find how the presence of one or more local Internet exchange points (IXPs) aid content hosted locally? With IXP hubs increasingly playing a critical role in making local Internet faster and more affordable, the project wanted to explore their impact on content hosting in the Asia – Pacific region.

While there are currently 308 country-code top level domains, the project only examined the ten from the Asia-Pacific region.[2]

2 https://en.wikipedia.org/wiki/Country_code_top-level_domain#:~:text=There%20are%20308%20delegated%20ccTLDs.

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This report covers the following countries, including the provider and location of test machines and availability of IPv6:

	CC	Country	Locale	Provider	IPv4	IPv6
	AU	Australia	Sydney	Choopa AS20473	Yes	No
	BD	Bangladesh	Dhaka	Fiber@Home AS10075	Yes	No
	ID	Indonesia	Jakarta	Zenlayer AS4229	Yes	Yes
	IN	India	Mumbai	Zenlayer AS4229	Yes	No
	JP	Japan	Tokyo	Zenlayer AS4229	Yes	No
	MY	Malaysia	Kuala Lumpur	Zenlayer AS4229	Yes	Yes
	NP	Nepal	Kathmandu	NREN AS45170	Yes	Yes
	PH	Philippines	Manila	Zenlayer AS4229	Yes	No
	SG	Singapore	Singapore	Zenlayer AS4229	Yes	Yes
	TH	Thailand	Bangkok	Zenlayer AS4229	Yes	No

The project was not able to obtain a suitable test machine in Fiji.

Additional information on technical methodology:

The testing process consists of three steps:

1. Obtaining useful IP Address information for each domain[3];
2. Performing single test ping[4] to any found IP addresses, for the round-trip time; and
3. Performing TCP traceroute[5] to the HTTPS[6] port is performed to obtain hop count.

3 https://linux.die.net/man/1/dig (domain information groper) does DNS lookups.
4 https://linux.die.net/man/8/ping sends requests to echo datagrams back to the source.
5 https://linux.die.net/man/1/tcptraceroute traces to the destination showing each network hop.
6 https://en.wikipedia.org/wiki/HTTPS is used for secure web communications.

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Data Summary

Being Served	Number of
Unique Domains	3,506,351
Unique Networks	15,618
Unique Autonomous Systems	4,763
IP Address (v4) Hosting Web Sites	524,611
IP Address (v6) Hosting Web Sites	128,459
Country Codes	10
Remote Hosting Country Codes	97
Average Latency	73.9 ms
Average Hops	12

Data Quality

Figure 1. Geographic coverage of the report data by number of domains, source: Terry Sweetser, Tableau Visualization.

Provider Peering

A major question is to examine the effects of peering in the local region on the hosting of ccTLD content.

Connectivity (count) to local Internet exchange points:

	AU	BD	ID	IN	JP	MY	NP	PH	SG	TH
Zenlayer	0	0	4	6	4	1	0	1	2	3
Choopa	3	0	0	0	1	0	0	0	1	0
Fiber@Home	0	0	0	1	0	0	0	0	1	0
Nepalese Research Education Network	0	0	0	0	0	0	1	0	0	0

By far, the best-connected test sites were hosted by Zenlayer, with excellent in-country and regional connectivity.

The nature of the network connectivity for the Bangladesh and Nepal tests required more thoughtful treatment in the analysis.

The Australian-hosted test server was well connected within Australia; however, regional connectivity was absent, possibly leading to a bias in data for sites hosted outside the country. Appendix 4 contains information about the connectivity of each test-site provider.

Hop Counts

During analysis, it became obvious that IPv6 hop counts were missing. This is due to a bug in the scripts dealing with executing a “IPv4 only” test for hop count.

The nature of the hop count tests also shows that some sites and providers have issues carrying TCP traceroute[7] probes. Data analysis showed that the use of the hop count was not relevant or useful for determining if content is local. Statistical correlation between the two variables was very low.

7 https://linux.die.net/man/1/tcptraceroute

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Latency

Latency is the round-trip response time of a user request, for example, the time required to send an Internet Control Message Protocol (ICMP), a ping request from your computer to a server IP and get a response back. One of the major reasons of network latency is because of distance between the client (your computer) and the server it is trying to access.

If your computer is in Sydney (Australia) and trying to access a server which is in San Francisco (U.S.), then the point-to-point distance between the 2 locations is more than 11,000 kilometers (KM) and the request has to go through multiple networks to reach the destination and get the response.

In the data gathered, latency has become the main measure of content presence locally or abroad. With several million rows in the data set overall, and many thousand rows per country, the measure proved far more useful for this analysis.

Multi-modal analysis (Benaglia et al., 2009) of latency also made it clear if content was in-country or not.

Latency is important as it is a good geographical indicator. Light latency on optical fiber is around eight microseconds per mile (Quigley, 2011).

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Geolocations

MaxMind, a geolocation tool, is not accurate for geolocating the hosts of content. The data more fairly aligns with ownership of address space. Distinguishing between where space is owned and how far away it is (in terms of latency) has provided insight into the technical operations of several hosts.

RPKI

We have a professional interest in routing security[8], so Route Origin Authorization[9] data has been combined with network and autonomous system numbers[10] (ASN) data to measure uptake in the hosting community. Testing RPKI uptake is an important trend to analyze (Testart and Clark, 2020).

This data set specifically uses a point-in-time capture from February 9, 2021. No time-series analysis has been performed. Two possible malicious events were captured.

8 https://www.manrs.org/

9 https://help.apnic.net/s/article/Resource-Public-Key-Infrastructure-RPKI

10 https://blog.stackpath.com/autonomous-system-number/

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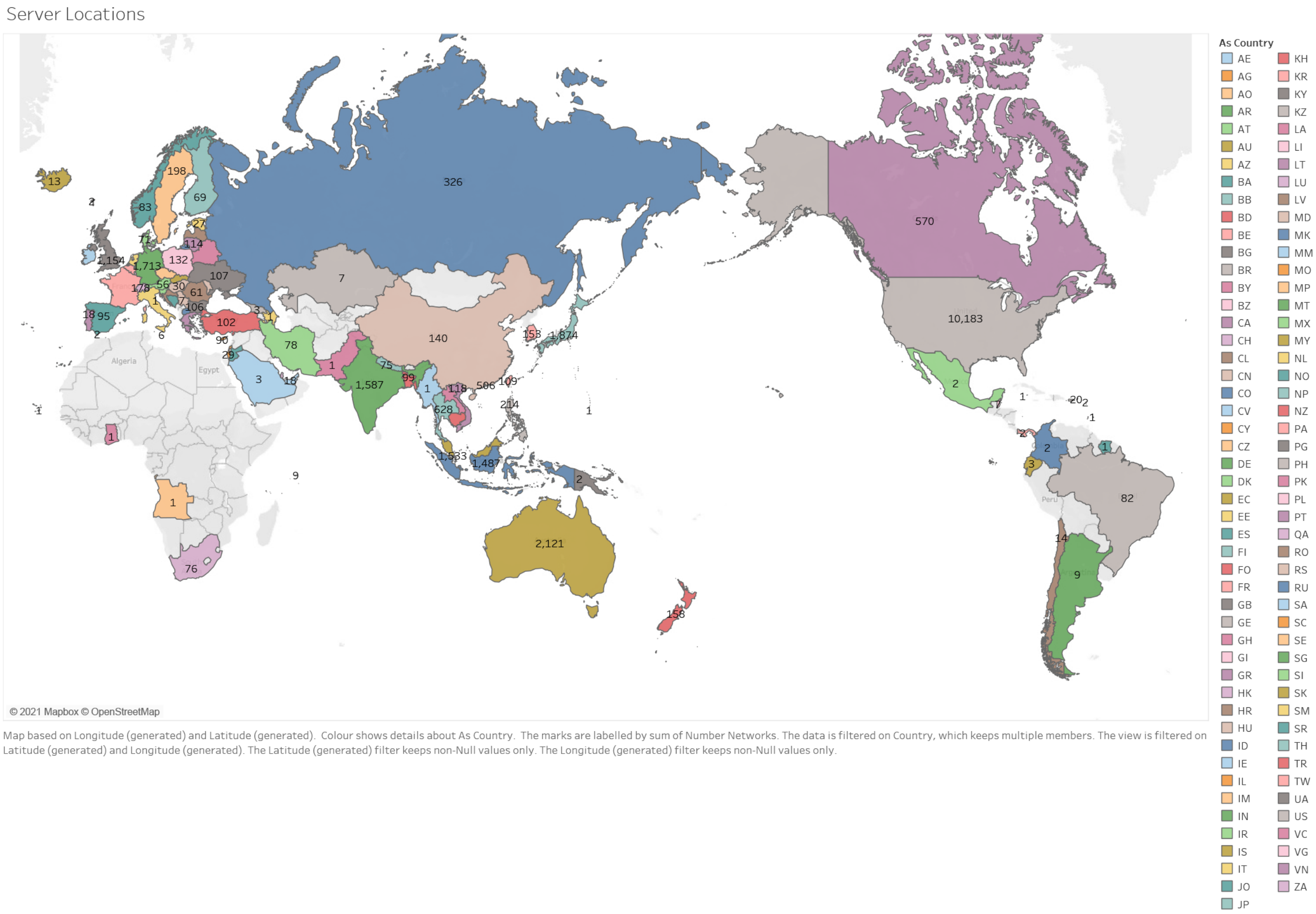
Visual Analysis

Hosting Locations (Nations)

Figure 2. Hosting locations around the globe by number of server networks, source: Terry Sweetser, Tableau visualization



One of the more surprising trends was the "location" of the hosted content.

As the data quality section of this report suggests, there are "locations" on the map that represent the location of the organization, not the network edge being used for content delivery.

For instance, nine domains are supposedly hosted in the Seychelles, but in fact the hosting provider is registered there only as an organization.

While the United States (U.S.) features many networks in the visualization, analysis of network metrics made it obvious that those organizations were using ARIN[11] address space around the globe and not in their U.S.-registered headquarters.

11 https://www.arin.net/

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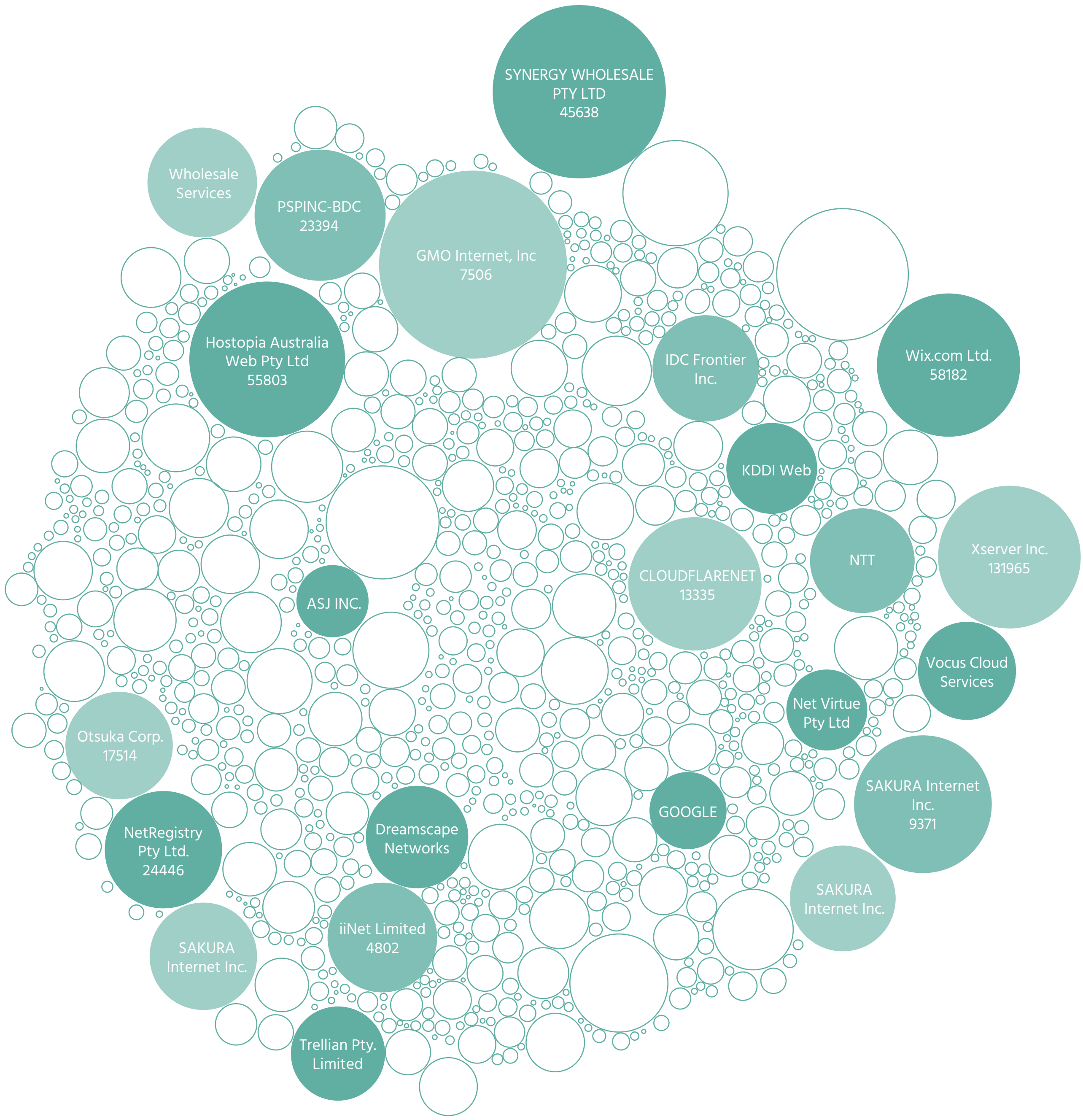
Hosting Organizations

Figure 3. Hosting numbers as a bubble map of domains per ASN, source: Terry Sweetser, Tableau visualization



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The hosting[12] market is very well served by small and large firms from across the globe.

There are 224.5 domains per unique network and 736.2 domains per autonomous system number.

The top network from the data is Cloudflare, with 177,733 domains hosted and an average latency of 13.7ms.

Again, latency surfaces as a major metric, so that will be examined in detail.

12 https://en.wikipedia.org/wiki/Web_hosting_service

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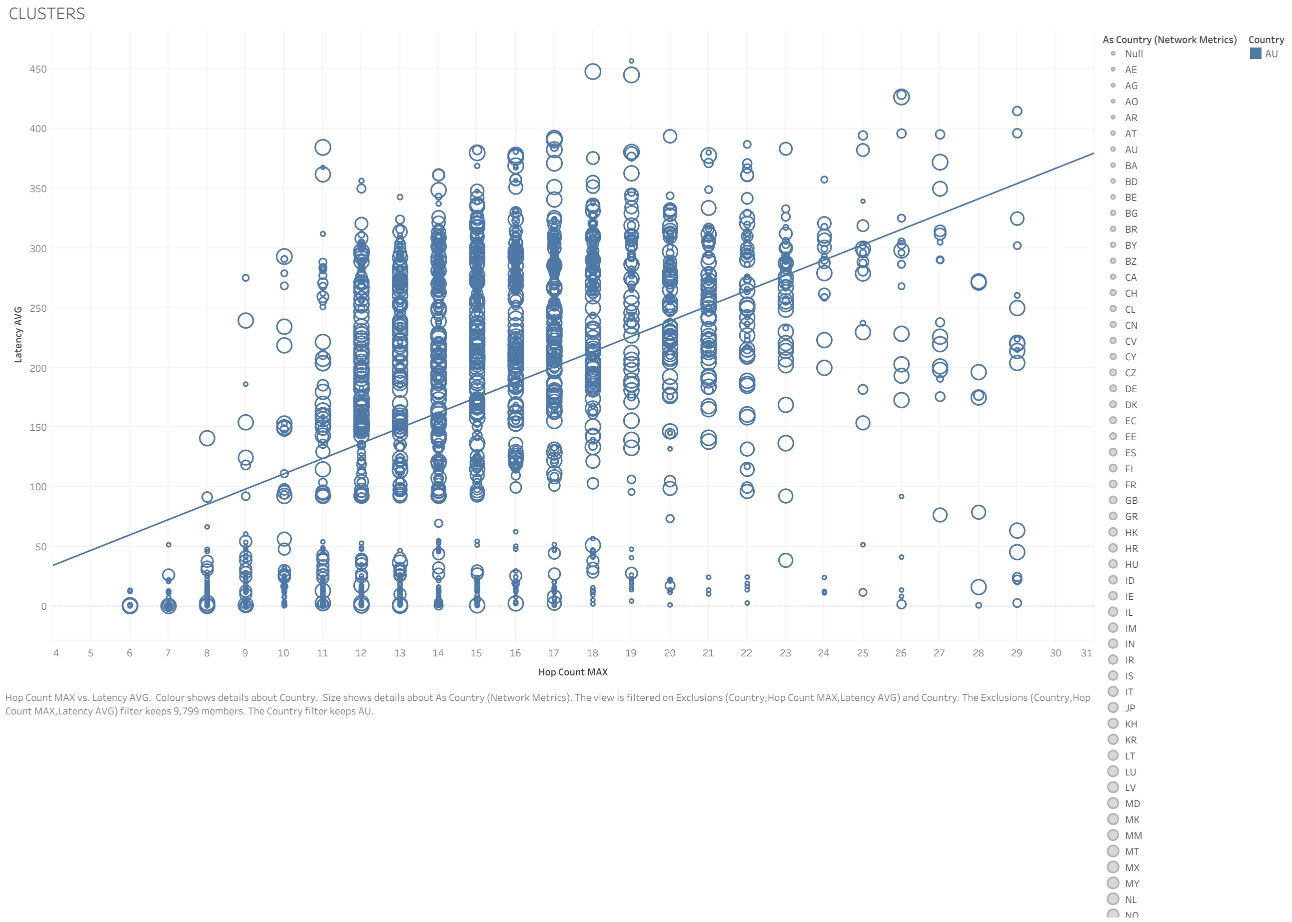
Hop Count Versus Latency (Australia)

Is latency determined by hop count?

Figure 4. Average latency versus hop count for Australian domains. source: Terry Sweetser, Tableau visualization



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Trend Line

P-value:	< 0.0001
Equation:	Latency AVG = 12.7694*Hop Count MAX + -16.981

Coefficients

Term	Value	StdErr	t-value	p-value
Hop Count MAX	12.7694	0.504086	25.3319	< 0.0001
Intercept	-16.981	8.04546	-2.11063	0.0349164

Statistically, the conclusion is that hop count does not predict latency. It follows that **hop count is not a proxy measure for the locality of hosting.**

Hop count, on pure speculation, would be indicative of the number of different networks on the route between source and end user. Data gathered did not include routing information, so no specific conclusion should be drawn on hop count.

Visually, this strongly suggests clusters or multi-modal data (McLachlan et al., 2019).

Visuals for all countries show these same clusters (see Appendix 3).

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Multi-Modal Analysis[13]

If we take a multi-modal approach on the data by country, trends clearly emerge to indicate where hosted content is located in a country.

Noteworthy is Japan with nine out of ten ccTLD sites located within the country in the latency range of zero to twenty milliseconds at a confidence level of 99.8 percent. Follow the λ_1 column:

	μ1	μ2	σ1	σ2	λ1	λ2
Japan	6.17 ms	110.03 ms	4.84 ms	59.25 ms	91.34%	8.66%
Indonesia	10.78 ms	201.86 ms	6.41 ms	90.39 ms	89.62%	10.38%
Malaysia	5.40 ms	157.86 ms	4.91 ms	86.35 ms	81.59%	18.41%
Singapore	1.98 ms	165.82 ms	0.68 ms	67.17 ms	68.00%	32.00%
Thailand	1.63 ms	73.73 ms	0.65 ms	85.31 ms	62.60%	37.40%
Nepal	35.39 ms	224.80 ms	36.66 ms	68.37 ms	59.54%	40.46%
Bangladesh	60.66 ms	272.86 ms	55.48 ms	21.50 ms	59.09%	40.91%
Philippines	21.58 ms	212.14 ms	24.64 ms	53.20 ms	42.94%	57.06%
Australia	0.80 ms	154.67 ms	0.36 ms	84.12 ms	42.78%	57.22%
India	9.95 ms	142.53 ms	10.11 ms	90.66 ms	22.53%	77.47%

σ_1 is substantially higher for Nepal and Bangladesh, indicating a much higher statistical error.

Doing more iterations on the Bangladesh data yielded better results for "near," "intermediate," "far," and "very far" modals.

Bangladesh	μ	σ	λ
Modal 1	7.79 ms	7.88 ms	18.36%
Modal 2	56.87 ms	8.68 ms	21.97%
Modal 3	132.52 ms	71.98 ms	21.22%
Model 4	274.22 ms	20.14 ms	38.45%

13 μ is mean, σ is standard deviation, λ is probability/density.

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In Appendix 3, the attached routing data indicates that the chosen test site on AS10075 is up streamed via India and Singapore only.

Nepal has a very active local Internet exchange (NpIX - Bgp.He.Net, n.d.). A three-way split for modal analysis has far more confidence and fit.

Nepal	μ	σ	λ
Modal 1	1.23 ms	0.40 ms	28.93%
Modal 2	67.67 ms	20.70 ms	31.27%
Modal 3	227.39 ms	66.03 ms	39.80%

Network Performance

Comparing the network metrics of the top ten hosts:

AS NAME	Unique Domains	Average Latency	Served Countries
Cloudflarenet	177733	13.72	AU,BD,ID,IN,JP,MY,NP,PH,SG,TH
Google	164802	56.98	AU,BD,ID,IN,JP,MY,NP,PH,SG,TH
Sakura Internet Inc.	132389	8.97	AU,ID,IN,JP,MY,PH,SG,TH
GMO Internet,Inc	113085	3.24	AU,ID,IN,JP,MY,PH,SG,TH
AS-26496-GO-DADDY-COM-LLC	108045	150.15	AU,BD,ID,IN,JP,MY,NP,PH,SG,TH
Synergy Wholesale PTY LTD	99357	2.65	AU,BD,IN,JP,MY,NP,PH,SG
Hostopia Australia Web Pty Ltd	92040	2.98	AU,BD,ID,IN,JP,MY,PH,SG,TH
Dreamscape Networks Limited	81442	48.76	AU,ID,IN,JP,MY,NP,PH,SG,TH
Wix.com Ltd.	80158	158.66	AU,ID,IN,JP,MY,NP,PH,SG,TH
Unifiedlayer-AS-1	75102	211.76	AU,BD,ID,IN,JP,MY,NP,PH,SG,TH

As discussed above, one of the major reasons for latency is distance between the host (your computer) and destination server (content). While the speed of light (in case of optical fiber cables) is constant, the only thing which can reduce the latency is if we can bring the content closer to the host by reducing the physical distance. If you are accessing content with lower latency, then it is easy to assume that the content is hosted in close vicinity but if the latency is very high then content is faraway, while “close” and “faraway” are relative terms to explain the phenomenon.

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In the data for large-scale hosting operators, the first notable feature of the data is the extremes in the measures of latency. For some, it is consistently “local,” or low, in measure. For some, it is very high—so high as to indicate the content is on another continent: They are far from the local region.

Cloudflare has been using a combination of technologies in its content delivery network (CDN) service (Third Time’s the Cache, No More, 2021) to speed up site access across the globe. AS13335 is also reachable on 37 different public Internet exchanges across the region, 16 of which are in Australia alone (AS13335 Cloudflare, Inc. - bgp.he.net, n.d.).

In comparison, Wix has a presence in only three locations: San Jose (U.S.) Ashburn (U.S.), and Dublin (Ireland). All sites resolved to 29 unique IPv4 addresses, suggesting that no CDN scheme was being used. Wix is not on any public Internet exchange list.

This report used Tableau to deep dive into metrics for Cloudflare, Google, and Wix.

Cloudflare

Figure 5. Cloudflare network metrics, source: Terry Sweetser, Tableau visualizationPays en italique gras = pays des études de cas

Network Metrics - CLOUDFLARENET

		Country									
As Country ..		AU	BD	ID	IN	JP	MY	NP	PH	SG	TH
AU	Hop Count (MIN)	6.0		7.0	8.0		6.0				
	Hop Count (AVG)	6.2		7.0	8.5		6.0				
	Latency [ms] (MIN)	0.4		15.9	24.1		5.4				
	Latency [ms] (AVG)	0.9		15.9	27.8		5.4				
CA	Hop Count (MIN)	2.0		7.0	7.0	8.0	6.0	7.0	6.0	7.0	7.0
	Hop Count (AVG)	6.2		7.5	7.3	8.6	6.6	7.0	6.5	7.1	7.4
	Latency [ms] (MIN)	0.3		14.2	1.3	1.2	5.3	168.6	0.9	1.3	27.6
	Latency [ms] (AVG)	1.0		15.3	7.4	1.8	5.5	168.6	1.0	2.3	29.6
US	Hop Count (MIN)	6.0	3.0	7.0	7.0	6.0	6.0	7.0	6.0	7.0	7.0
	Hop Count (AVG)	6.3	4.0	7.8	8.4	6.1	9.0	7.2	6.5	7.2	7.8
	Latency [ms] (MIN)	0.3	0.2	13.3	1.4	0.8	5.4	71.8	0.9	0.8	27.2
	Latency [ms] (AVG)	1.0	22.2	30.1	63.7	1.5	17.8	91.1	1.1	12.5	43.3

Hop Count (AVG), Hop Count (MIN), Latency [ms] (AVG) and Latency [ms] (MIN) broken down by Country vs. As Country (Network Metrics) on page 1 northfields av. The view is filtered on As Name (Network Metrics) and As Country (Network Metrics). The As Name (Network Metrics) filter keeps multiple members. The As Country (Network Metrics) filter keeps AU, CA and US.

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Google

Figure 6. Google network metrics, source: Terry Sweetser, Tableau visualizations

Network Metrics - GOOGLE

		Country									
As Country ..		AU	BD	ID	IN	JP	MY	NP	PH	SG	TH
AU	Hop Count (MIN)	15.0									
	Hop Count (AVG)	15.0									
	Latency [ms] (MIN)	1.6									
	Latency [ms] (AVG)	2.1									
BE	Hop Count (MIN)	20.0		23.0	21.0	23.0	24.0		28.0	22.0	23.0
	Hop Count (AVG)	24.4		24.5	25.9	25.9	25.0		28.0	23.3	23.5
	Latency [ms] (MIN)	131.7		55.7	96.5	47.4	48.9		243.6	42.2	68.5
	Latency [ms] (AVG)	214.9		178.4	207.6	111.3	105.8		243.6	161.1	174.2
CH	Hop Count (MIN)			20.0	19.0		21.0			18.0	
	Hop Count (AVG)			20.0	20.2		21.0			18.5	
	Latency [ms] (MIN)			257.8	120.7		252.9			241.0	
	Latency [ms] (AVG)			257.8	121.5		252.9			242.8	
DE	Hop Count (MIN)	16.0			18.0						
	Hop Count (AVG)	16.0			18.0						
	Latency [ms] (MIN)	270.1			121.6						
	Latency [ms] (AVG)	289.9			121.7						
GB	Hop Count (MIN)	12.0	19.0	19.0	19.0	22.0	23.0			18.0	19.0
	Hop Count (AVG)	15.3	19.0	21.9	22.1	24.2	23.3			21.1	21.2
	Latency [ms] (MIN)	0.8	74.0	14.1	56.4	74.1	9.1			1.9	30.3
	Latency [ms] (AVG)	11.8	74.0	18.7	177.7	144.6	30.5			53.4	143.3
HK	Hop Count (MIN)								9.0		
	Hop Count (AVG)								17.9		
	Latency [ms] (MIN)								16.8		
	Latency [ms] (AVG)								49.0		
ID	Hop Count (MIN)			13.0							
	Hop Count (AVG)			14.7							
	Latency [ms] (MIN)			1.4							
	Latency [ms] (AVG)			26.2							
IN	Hop Count (MIN)	8.0	20.0	10.0	3.0	8.0	11.0	16.0		9.0	10.0
	Hop Count (AVG)	14.4	20.0	20.9	17.0	14.5	18.7	16.6		12.8	21.4
	Latency [ms] (MIN)	0.2	51.9	13.2	1.4	1.2	6.6	41.1		0.7	26.8
	Latency [ms] (AVG)	22.4	52.6	42.5	8.4	12.7	19.2	66.2		11.8	46.6
JP	Hop Count (MIN)								21.0		
	Hop Count (AVG)								24.1		
	Latency [ms] (MIN)								35.0		
	Latency [ms] (AVG)								92.2		
SG	Hop Count (MIN)	12.0	18.0	18.0	16.0	14.0	19.0	15.0	11.0	17.0	17.0
	Hop Count (AVG)	21.1	22.3	21.5	24.4	22.7	22.7	21.4	23.2	20.2	21.3
	Latency [ms] (MIN)	0.7	62.7	13.5	54.3	2.5	6.6	83.9	21.5	0.9	26.6
	Latency [ms] (AVG)	78.9	202.8	29.1	80.9	78.2	17.1	113.3	74.9	9.0	42.6
TW	Hop Count (MIN)	19.0		23.0	21.0	10.0	24.0		17.0	19.0	23.0
	Hop Count (AVG)	23.8		24.0	23.6	15.2	25.2		22.3	22.2	23.8
	Latency [ms] (MIN)	114.3		58.2	100.0	2.1	47.5		18.9	42.0	68.7
	Latency [ms] (AVG)	193.2		119.3	192.2	12.4	67.0		78.2	75.9	102.6
US	Hop Count (MIN)	2.0	6.0	2.0	2.0	8.0	11.0	8.0	9.0	9.0	10.0
	Hop Count (AVG)	13.8	7.8	10.5	13.3	16.7	18.0	8.3	15.8	19.7	15.6
	Latency [ms] (MIN)	0.2	23.4	13.0	1.3	1.1	6.4	37.9	16.6	0.6	26.4
	Latency [ms] (AVG)	63.5	67.5	16.5	55.8	56.8	82.5	47.0	82.8	127.1	73.0

Hop Count (AVG), Hop Count (MIN), Latency [ms] (AVG) and Latency [ms] (MIN) broken down by Country vs. As Country (Network Metrics) on page 1 Click Services Limited. The view is filtered on As Name (Network Metrics) and As Country (Network Metrics). The As Name (Network Metrics) filter keeps multiple members. The As Country (Network Metrics) filter keeps 12 of 98 members.

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Wix

Figure 7. Wix network metrics, source: Terry Sweetser, Tableau visualization

Network Metrics - Wix.com Ltd.

As Country ..		Country: AU	BD	ID	IN	JP	MY	NP	PH	SG	TH
US	Hop Count (MIN)	2.0		11.0	3.0	2.0	13.0	16.0	13.0	10.0	11.0
	Hop Count (AVG)	12.0		11.0	12.0	11.0	13.5	16.5	13.0	10.0	11.0
	Latency [ms] (MIN)	150.0		175.1	123.5	104.3	170.2	266.8	167.6	162.5	191.8
	Latency [ms] (AVG)	165.1		178.9	126.8	107.0	172.8	310.4	172.3	165.5	193.1

Hop Count (AVG), Hop Count (MIN), Latency [ms] (AVG) and Latency [ms] (MIN) broken down by Country vs. As Country (Network Metrics) on page 1&1 Ionos Se. The view is filtered on As Name (Network Metrics) and As Country (Network Metrics). The As Name (Network Metrics) filter keeps multiple members. The As Country (Network Metrics) filter keeps US.

Discussion

Between the modal analysis and visualizations of the data, there is more than sufficient evidence of both the need and the good use of peering in country for ccTLD content.

The data contains raw latency and not route paths. Each hosting firm in the region will have its own network build and peering strategy, none of which is contained in the data. Low latency is not a guarantee that the nearest Internet exchange point is in use.

Japan is by far the most successful at hosting ccTLD content in country, closely followed by Indonesia and Malaysia

ccTLD Hosted In-Country:

	In Country[14]	Notes
Japan	91.34%	
Indonesia	89.62%	
Malaysia	81.59%	
Singapore	68.00%	
Thailand	62.60%	
Philippines	42.94%	
Australia	42.78%	All Peering in Australia
Bangladesh	40.33%	Quad-Modal; see discussion
Nepal	28.93%	Tri-Modal
India	22.53%	

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Nepal

NP-IX is the one and only IXP listed on PeeringDB in Nepal (NpIX - Bgp.He.Net, n.d.)..14

After matching data to BGP.HE.NET for Nepal, a clear example of placing ccTLD content on highly populated Internet exchange points emerges as a good technical strategy. Of the 40 networks in Nepal serving content under the ccTLD with good latency metrics, we can trace a direct relationship with NP-IX as a direct participant of the exchange and/or a downstream customer of a direct participant.

Nepal's data exhibited a tri-model fit. Examining the central modality points to hosting providers like Digital Ocean, Google, Linode, and Cloudflare, we can see they are serving Nepal from data centers located in India and Singapore.

Bangladesh

The Sustainable Development Networking Program operates BD-IX in Dhaka. However, the test host was not connected to this local exchange (BDIX - Bgp.He.Net, n.d.)

(AS10075 Fiber@Home Global Limited - Bgp.He.Net, n.d.). Fibre@Home has upstream transit with Bangladesh Submarine Cable Company Limited (BSCCL) and Bharti Airtel. Those providers peer in Singapore and India.

As a result, in the data:

- 80 domains are hosted by BD-IX connections with an average latency of 57.84 milliseconds (ms).
- 195 domains are hosted via transit in country with an average latency of 64.89 ms.
- 489 domains are hosted abroad with an average latency of 189.13 ms.
- Foreign country hosting by ISO two-letter code:
  AU, CA, DE, FI, FR, GB, IN, MY, NL, PL, SG, TH, US, VG

The data analysis found distinct modals at 51.163 ms (bi-modal) and 7.79 ms and 56.87 ms latency (quad-modal), so local hosting has been classified to fit those second findings in the data.

14 The lowest mean latency that matches traffic patterns can be easily deemed "local."

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Australia

Australia still operates with the gang of four paradigm (Newton, 2017). That situation continues to make business models "interesting" for local Internet providers lacking knowledge of peering.

Despite several good IXP offerings from IX Australia, Equinix, Megaport, and EdgeIX, Australians continue to host a lot of dot-AU sites outside the country.

Canada, India, Europe, Singapore, and the United States are the most popular hosting locations for ccTLD content. This very likely aligns with Australia's cultural bias towards Singapore, the United Kingdom, and the United States (Ng & Taneja, 2019).

Australia also has a significant number of "parked" domains in the data set, where no glue exists to a website for the domain (see Appendix 7: Is There Any Glue?).

India

India has an actively developing peering ecosystem (PeeringDB, n.d.), yet ccTLD hosting is concentrated outside the country.

In the analysis, almost four of five .in domains were in the second model at 142.5 ms average latency. In distance terms, that places most ccTLD web sites outside the continent. Seventy-six foreign nations host ccTLD content for .in.

In comparison with Japan and the Philippines, India has no dominant local hosting firms or public service operators assisting to host .in locally.

Philippines

ccTLD content served from within the nation applies to two out of five websites in the data. Distinctively, the majority of those sites fall within the 22 ms latency band (50 percent of the primary modal) and are hosted on two provider networks: Cloudflare (AS13335) and PH ccTLD (AS23660).

PH ccTLD (AS23660) hosts more than 500 websites from .ph on 32 unique IPv4 addresses with a single upstream provider. Infinivan Incorporated (AS135607) is that provider, and it is present on GetaFix, PHOpenIX, HKIX, Equinix Singapore, and BBIX Tokyo, which provides good coverage for those .ph clients in the region.

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Thailand

Data for Thailand's ccTLD is most notable due to the low second modal mean latency in the data, indicating that ccTLD hosting outside the country is not "far away" via regional networks.

A closer look into the data reveals a large amount of ccTLD hosting concentrated in Singapore and India. While Thailand has hosting in 42 other countries, these instances are substantially small.

Singapore

This small Southeast Asian nation is a very popular place for hosting content of all varieties, especially within the region. Many submarine cable systems land in the nation (submarine cable map, n.d.).

Singapore's own ccTLD is 68 percent hosted in country. Malaysia and Germany appear in the data as popular locations abroad for hosting ccTLD content.

Only two local firms feature in the data for ccTLD hosting: Vodian Internet Solutions and USONYX (which also promotes .sg for hosted sites).

Malaysia

Only three nations have more than 80 percent of their ccTLD content hosted locally: Malaysia, Indonesia, and Japan. Malaysia is at 81.59 percent.

Of the top ten ccTLD hosting operations in the country, eight are Malaysian-registered firms:

CC	Firm Name	Domains Hosted	Latency (ms)
MY	Exa Bytes Network Sdn.Bhd.	14,696	1.01
US	Cloudflarenet	4,644	13.90
MY	IP ServerOne Solutions Sdn Bhd	3,165	2.16
MY	Gigabit Hosting Sdn Bhd	2,730	1.33
MY	Shinjiru Technology Sdn Bhd	2,191	2.39
MY	AIMS Data Centre Sdn Bhd	2,135	5.78
MY	Bigband Sdn Bhd	1,534	2.46
MY	TM-VADS DC Hosting	1,513	9.87
MY	SKSA Technology SDN BHD	1,166	2.12
SG	Digital Ocean-ASN	980	40.79

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Indonesia

Indonesia has a strong local presence in the hosting industry for .id.

Seventy-five foreign AS names in country serve ccTLD content, for 34,986 domains; however, more than 600 local AS names serve up content from 42,909 domains.

The internationals are well-known operators: Hostinger International Limited, Cloudflare, Google, Digital Ocean, Linode, Amazon Web Services (AWS), and Choopa.

The leading firm in Malaysia has a local subsidiary named PT. Exabytes Network Indonesia. Otherwise, there is very little overlap between the two adjacent markets.

Japan

Japan tops the list, with 91.34 percent of ccTLD content hosted locally.

The outstanding feature of the data is the local hosting industry that dominates the .jp space:

- Sakura Internet Inc. hosting 132,062 domains.
- GMO Internet Inc hosting 112,361 domains.
- Xserver Inc. hosting 69,099 domains.
- NTT Communications Corporation hosting 25,567 domains.
- IDC Frontier Inc. hosting 17,351 domains.

Localization

The analysis of data from Indonesia, Japan and Malaysia clearly indicates that local firms that host specific content for ccTLD domains do so in country as close as possible to end users.

At the start of the project, we didn't foresee that this would be a factor in the data. It is surprising to have found that a robust local hosting industry becomes a major facet of the ccTLD/IXP thesis.

While local IXP operators are a necessity to ensure that traffic takes a low latency route between users of the Internet and providers of content, those IXP operators are only a part of a larger business environment supporting local content delivery.

The data set strongly suggests that localization in respect of content, technical operations, and cultural factors are interdependent. This area should be examined in future research.

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IPv6 Adoption

The project was not able to gather IPv6 data for all parts of the data set. Several providers and several hosts were not IPv6 capable. Some comparison to global IPv6 adoption data is possible (IPv6 – Google, n.d.).

The three ccTLDs that stand out in the limited data are:

- Indonesia: far above the national rate of adoption.
- Malaysia: far below the national rate of adoption.
- Nepal: above the national rate of adoption.

Country	IPv4 hosts	IPv6 hosts	ccTLD	Google
AU	1,512,323	0		23.51%
BD	870	0		0.25%
ID	118,799	21,373	17.99%	0.99%
IN	472,042	0		57.29%
JP	531,525	0		38.64%
MY	58,209	11,097	19.06%	51.33%
NP	12,136	2,850	23.48%	13.80%
PH	25,122	0		12.74%
SG	50,101	6,697	13.37%	14.63%
TH	37,381	0		39.51%

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Routing Security

During data collection for the other analysis tasks on the project, Route Origin Authorization (ROA) and Route Origin Validation (ROV) were checked against gathered data and compared with the ROA snapshot.

Country	Not Found	Valid	Invalid
AU	2,300,593	496,963	
BD	1,159	523	
ID	122,324	34,597	
IN	581,113	78,433	
JP	570,012	201,295	
MY	48,287	28,862	
NP	18,625	398	
PH	31,122	2,452	1
SG	49,613	16,879	
TH	39,964	9,512	1

Neither of these issues were malicious, just the result of misconfiguration (RPKI Portal, n.d.).

Business Models

For some content networks, using Internet exchange points is a key part of their business model (Cuadrado et al., 2018). Internet exchanges in general have moved from being "transit to transit" connections to "content delivery" to "eyeballs" (Carisimo et al., 2019). The way in which various hosting providers fulfill the needs of their customers is evidenced in the network metrics.

For some operators, an emphasis on technical metrics is clearly a goal of their operation, with largely distributed and very well-connected networks. Cloudflare emerges in the data for these reasons, especially for low latency. The services it offers are designed to be highly distributed and available (AS13335 Cloudflare, Inc. - Bgp.He.Net, n.d.; How Cloudflare Rocket Loader Redefines the Modern CDN, 2011).

For others, infrastructure is highly centralized in a few locations globally. Wix, with 180 million customers, has chosen to serve its content from just three discrete locations (AS58182 Wix.Com Ltd. - Bgp.He.Net, n.d.; Free Website Builder | Create a Free Website | Wix.Com, n.d.).

The large cloud providers all feature one attribute "ubiquity": Google, Digital Ocean, and Amazon Web Services all have global presence. Their "footprint" is mid-range on metrics and distributed across different locations. A common factor for all of the larger firms is the strategic technical priority to be well connected to the global Internet. They will peer with "eyeball" providers willingly as doing so suits their business model (Carisimo et al., 2019).

These various business models impact the metrics and the placement of the ccTLD hosting. Content placement is not actually driven by these business models but can be displaced because of the differing products purchased from each firm.

The data presented in this report shows clear evidence that a vibrant hosting industry is more likely to drive uptake of content hosting in country for any ccTLD.

Cultural Contexts

Taneja et al (2017) discuss cultural proximity and language in Internet use patterns (Ng & Taneja, 2019; Taneja, 2017):

> "We had web traffic rankings available at the level of web domains. Most companies, such as Google, Amazon, eBay, Yahoo, and Microsoft, have country specific domains, but some, such as Wikipedia.org, are available worldwide as one domain, with different language subdomains. Thus, a user in Germany accesses de.wikipedia.org and a user in the United Kingdom accesses en.wikipedia.org. … Thus, we might have overestimated web use similarities between some countries, which, in turn, would mean we underestimated the role of language similarity."

For instance, Thai websites are hosted in or near the country maybe because of differences in language and culture across borders.

While Taneja et al (2017) were able to establish patterns of usage, they were not specifically examining or testing a hypothesis on ccTLD usage. Cluster analysis did find that nations like Indonesia were alone in their cluster, but India, Sri Lanka, Maldives, Bhutan, and Bangladesh are clustered together. Interestingly, specific language groups became clusters because of their language: Brazil, Portugal, and Cape Verde, all countries where Portuguese is spoken, were a cluster (Ng & Taneja, 2019).

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Conclusion

The project concluded successfully with a useful data set.

A few bugs and differences in the data and methodology have led to some key learnings:

1. Data on hop count is not a useful metric for determining local hosting.
2. Latency is a key metric; however, in the future AS Path, the autonomous systems that routing information passes through to get to a specified router should be analyzed. This will formally locate the content in the global routing table.
3. Not all hosting environments are friendly toward traceroutes and other network probing.

The developed data set has clearly demonstrated that local content for ccTLD domains is best served by an ecosystem of local and international operators attached to local Internet exchange points.

In the case of Thailand, the data also supports that ccTLD operations target local populations and businesses, with the added factors of language and culture.

Comparing the top three ccTLD hosting nations and the other seven, the contrast is clear: Active IXP operations alone do not foster good local ccTLD content, and active local firms are needed to do so.

Future research needs to explore issues of culture and industry development and how they link to ccTLD and IXP utility.

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Appendix 1: Project Brief

Measuring the Impact of Local IXPs: Understanding Hosting Trends in the Asia-Pacific Region From the Regional Domain Perspective

Background

IXPs provide an alternative to the expense of sending domestic Internet traffic abroad, only to have to return that traffic via an expensive international link. Basically, IXPs help keep local traffic local and help with cheaper, better, faster local Internet traffic exchange. The cost and quality of service that IXPs make can help ISPs (Internet service providers) and content delivery networks see the benefit of supporting IXPs.

The impact of an IXP is dynamic and can be instrumental in developing the local Internet ecosystem. IXPs can attract a range of local and international operators, which then can trigger innovation and more business opportunities. In addition, IXPs can improve local users' quality of access by providing more-direct network connections for local content producers and consumers.

To measure the impact, we need to check if the local content is actually hosted locally and, if not, then look into the details. The first step is to measure what is hosted locally and what is not.

Because ccTLDs are used mostly by local businesses, it is safe to assume that they are targeting local audiences and should be hosted locally. For example, a local state government website for New South Wales (Australia) is targeting the residents of the state, and it is beneficial for that government entity to host it locally.

```
URL: https://nsw.gov.au
A Records: 99.83.133.180, 75.2.117.83
whois -h whois.cymru.com 99.83.133.180
AS | IP | AS Name
16509 | 99.83.133.180 | AMAZON-02, US
whois -h whois.cymru.com 75.2.117.83
AS | IP | AS Name
16509 | 75.2.117.83 | AMAZON-02, US
PING 75.2.117.83 (75.2.117.83) 56(84) bytes of data.
64 bytes from 75.2.117.83: icmp_seq=1 ttl=121 time=0.792 ms
--- 75.2.117.83 ping statistics ---
1 packet transmitted, 1 received, 0% packet loss, time 0ms
11
rtt min/avg/max/mdev = 0.792/0.792/0.792/0.000 ms
PING 99.83.133.180 (99.83.133.180) 56(84) bytes of data.
```

```
64 bytes from 99.83.133.180: icmp_seq=1 ttl=121 time=0.665 ms
--- 99.83.133.180 ping statistics ---
1 packet transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.665/0.665/0.665/0.000 ms
```

The above results suggest that the website is hosted with Amazon (AWS) but at Sydney node, as the ping results are from Sydney, and it is accessible locally with less than 1ms delay. If we are able to get the same data for all .au domains, then it is easy to understand the behavior at large scale.

Scope of work and deliverables:

- Study has to be conducted for the following countries in the Asia-Pacific region.
- Countries: Australia, Bangladesh, Fiji, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, Singapore, and Thailand .

Internet Society obligation:

- The Internet Society will provide the list of domains per selected ccTLD, and the list of domains will be taken from domain crawler zonefiles.io, which might contain old records with no A/AAAA[15] entries and/or stale data. Such records should not be included in the study, and subdomains must be removed from the list as well.

Service provider deliverable:

- The script to fetch the desired results per ccTLD is available at GitHub, and vendor has been added to the repository. In case of any problem with the script, please open an issue on GitHub.
- Vendor must run the script from a Virtual Machine (VM) within the country to fetch the results against the list of domains provided.
- In case of any ambiguity in results, the vendor will raise the concern through GitHub.
- Highlight the government and educational/university domains in particular, while tabulating results for the country.
- Tabulate the results on the basis of in-country and out-of-country domain hosting, and also mention the domains with only A[16] records and/or both A and AAAA records.
- Report should include country analysis as well as general regional analysis.

15 IP Version 6 Addresses (Hinden & Deering, 1995)

16 IP Version 4 Addresses

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Appendix 2: Technical Methodology

- Each ccTLD has a supplied list of domains to use.
- A virtual machine or a bare metal machine from a well-connected provider was used in each country.
- With the exception of blog derived domains across the sample, all domains were tested.
- The main DNS[17] records resolved and used were A and AAAA records.
- Using code supplied by the project sponsor (danishahmed90, 2020), the list is crawled in parallel.
- Data on hop count and latency is saved into a temporary SQLite3 database.
- As the scripts finish, consolidated data is dumped to CSV[18] format files.
- That raw data is loaded into a database on the PostgreSQL[19] data.
- The MaxMind database as of early February 2021 is used to geolocate the networks loosely in the data.
- A capture of the ROA data from February 9, 2021, is used to estimate the validity and uptake of RPKI amongst the hosts.

17 DNS https://www.cloudflare.com/en-gb/learning/dns/dns-records/

18 A Comma Separated Values (CSV) file is a plain text file that contains a list of data.

19 Programming language - usually used to write scripts that can pull data from databases. SQL stands for Structured Query Language, used to communicate with a database.

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Appendix 3: More Visualizations

BD

Figure 8 BD, Latency versus Hop Count, source: Terry Sweetser, Tableau Visualization .

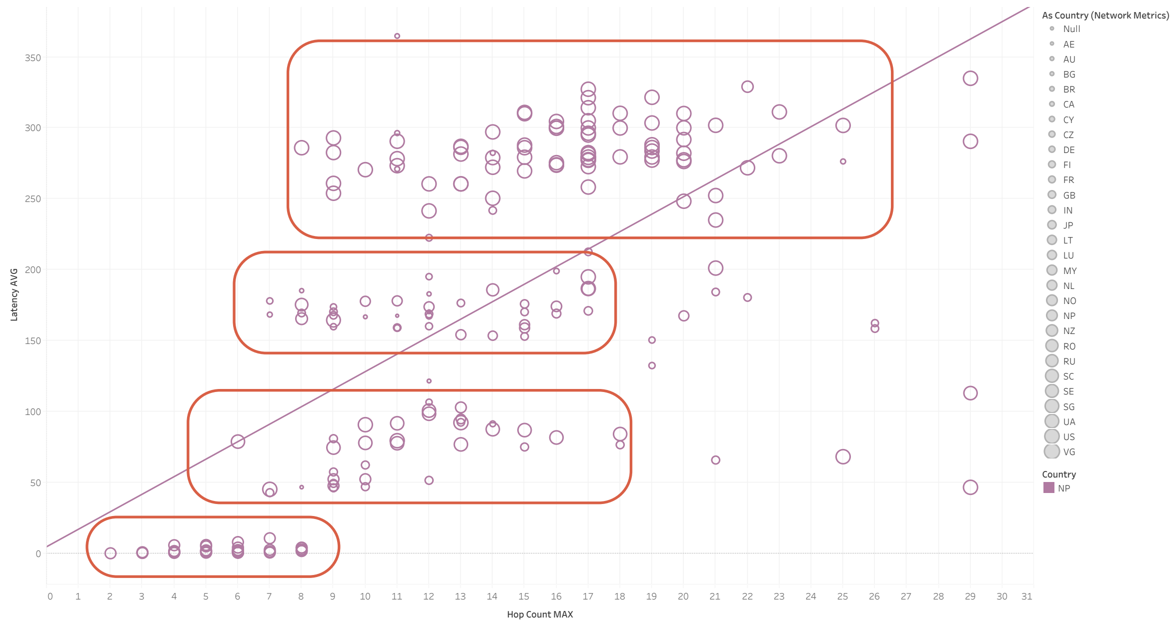
CLUSTERS

Hop Count MAX vs. Latency AVG. Colour shows details about Country. Size shows details about As Country (Network Metrics). The view is filtered on Exclusions (Country,Hop Count MAX,Latency AVG) and Country. The Exclusions (Country,Hop Count MAX,Latency AVG) filter keeps 9,799 members. The Country filter keeps BD.

NP

Figure 9. Nepal, latency vs hop count, source: Terry Sweetser, Tableau visualization

CLUSTERS



Hop Count MAX vs. Latency AVG. Colour shows details about Country. Size shows details about As Country (Network Metrics). The view is filtered on Exclusions (Country,Hop Count MAX,Latency AVG) and Country. The Exclusions (Country,Hop Count MAX,Latency AVG) filter keeps 9,799 members. The Country filter keeps NP.

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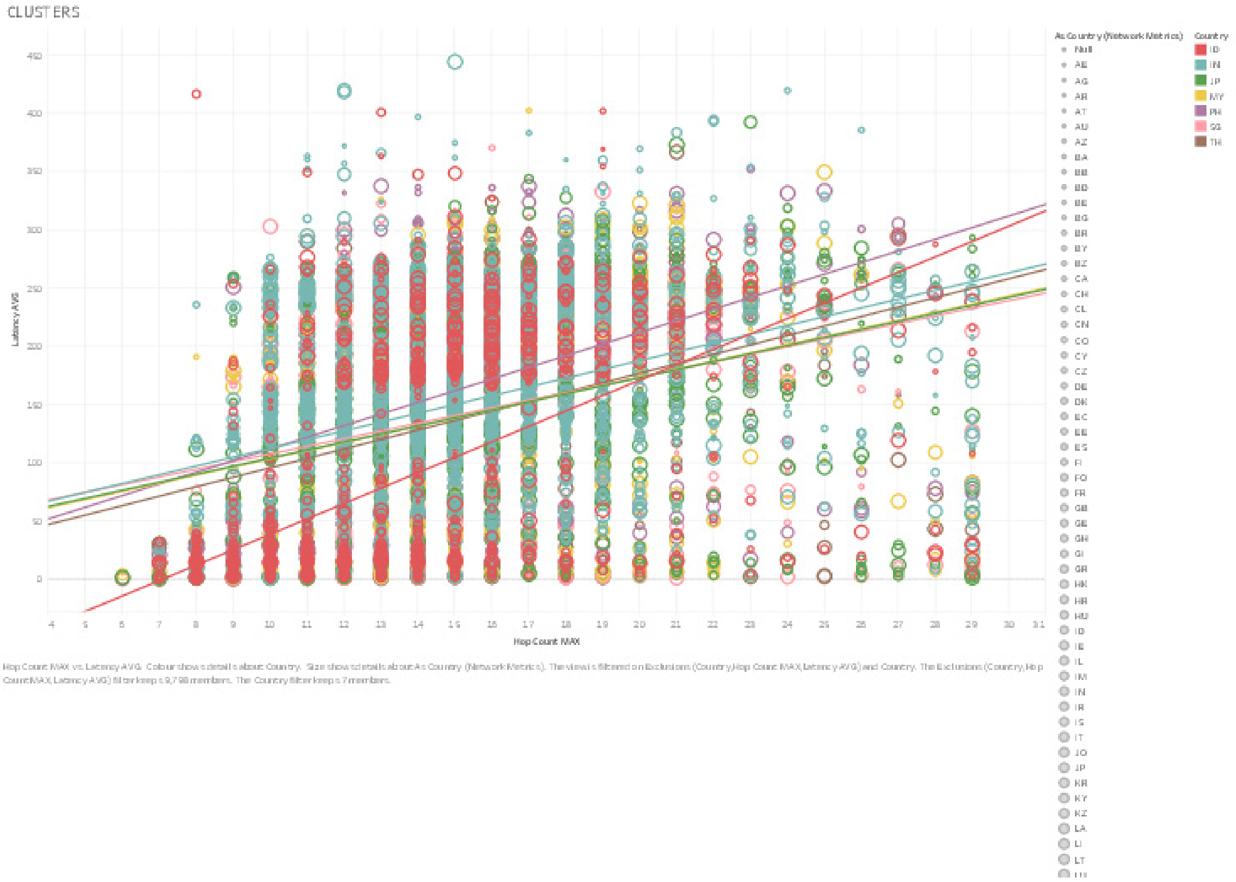
Others

Figure 10. Other latency vs hop count, source: Terry Sweetser, Tableau visualization



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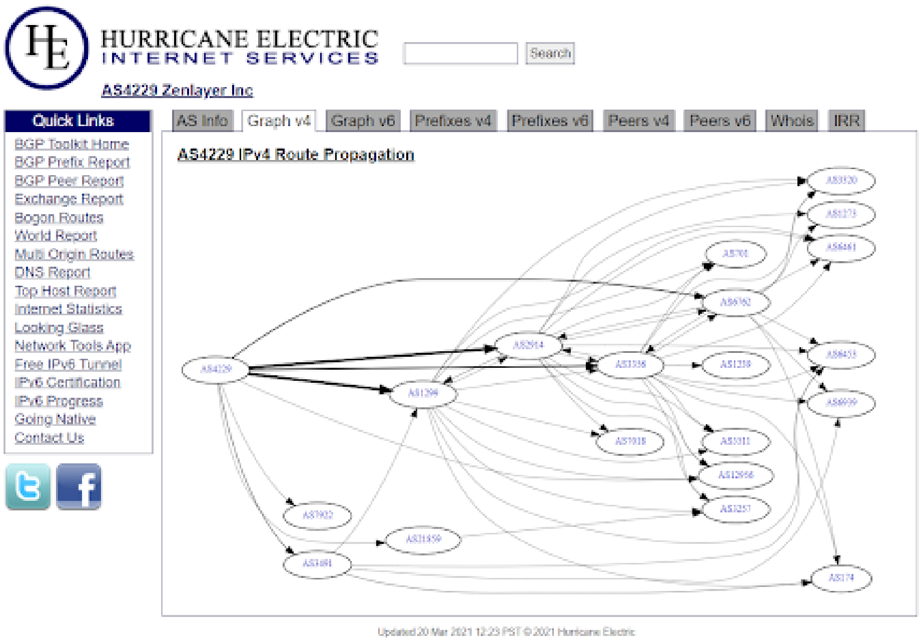
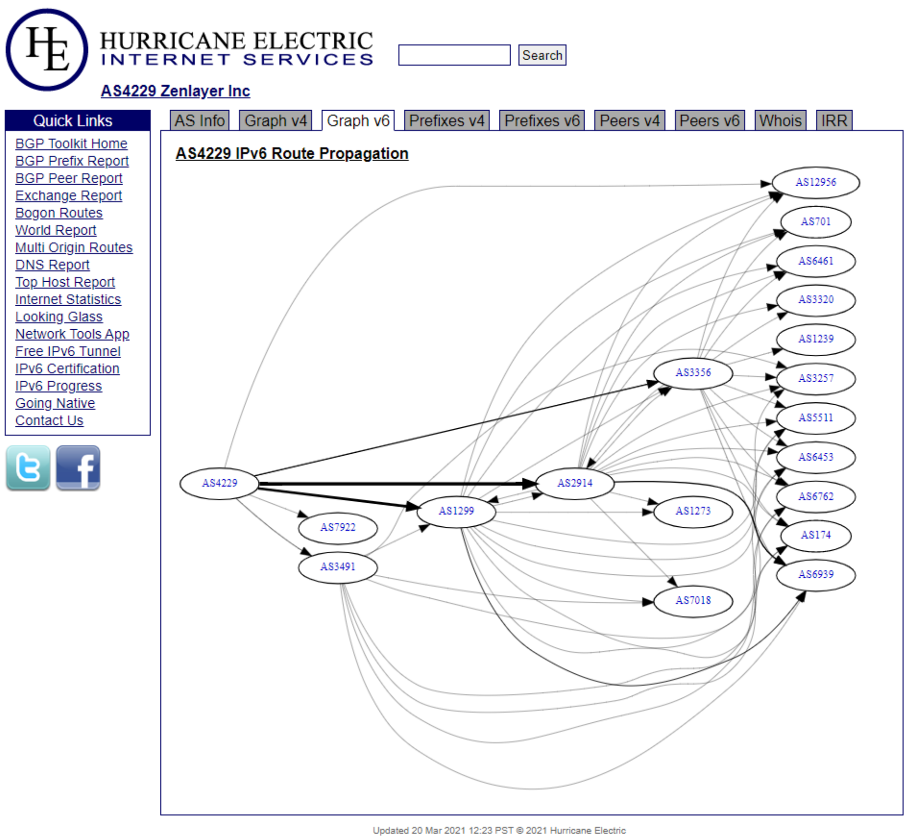
Appendix 4: Provider Connectivity

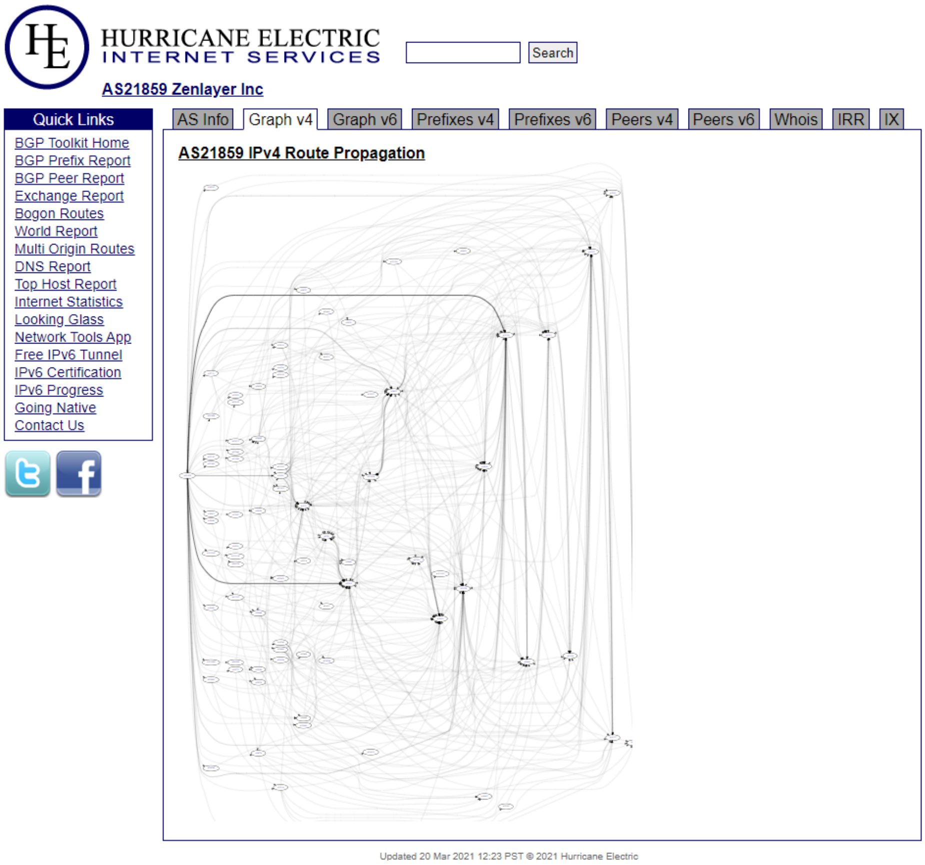
Captured below is the routing (or map) of the Internet from the provider's network to the greater Internet. Both address families are captured: IPv4 and IPv6.

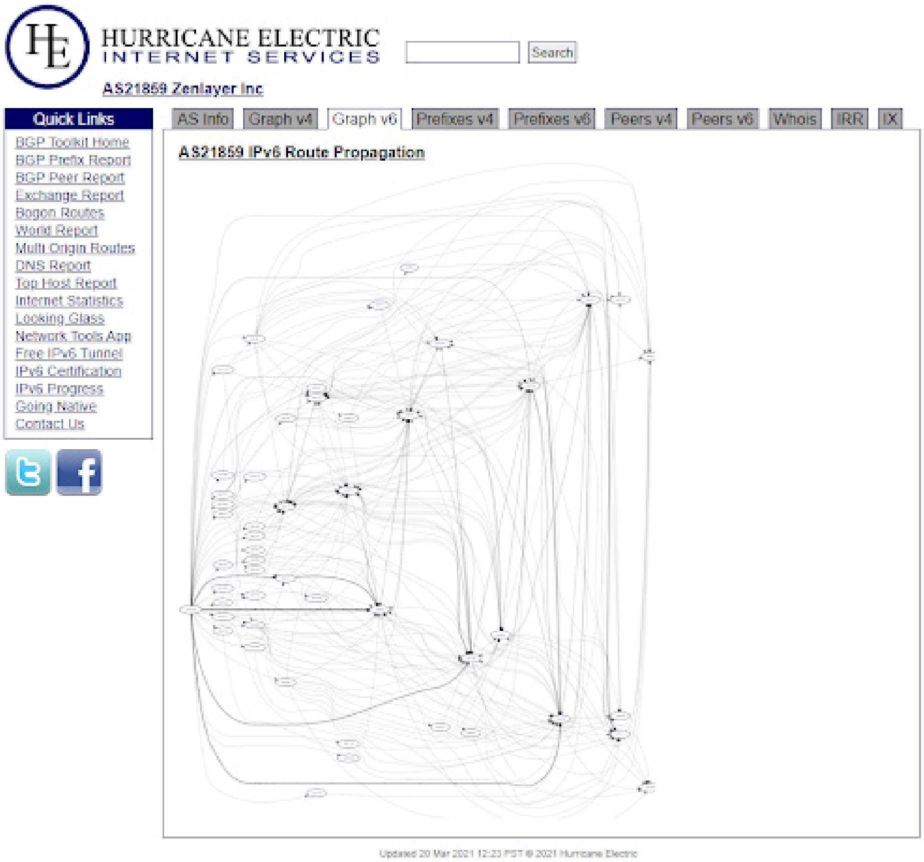
AS4229





AS21859





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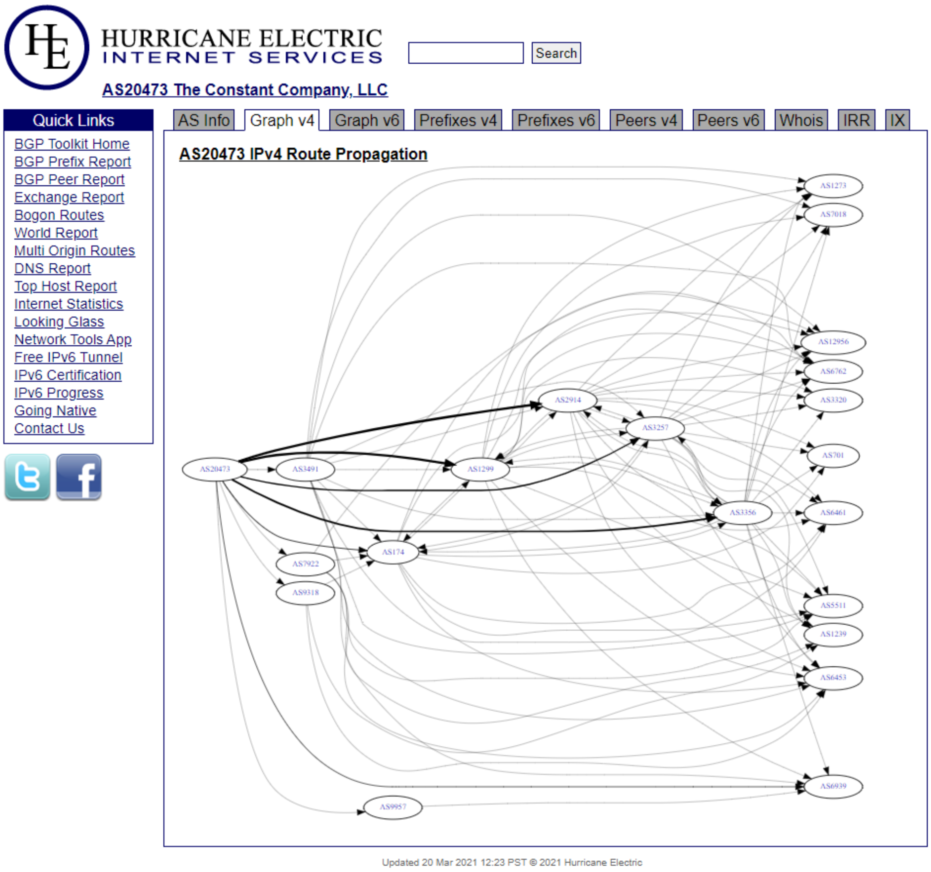
AS20473


HURRICANE ELECTRIC
INTERNET SERVICES
Search
AS20473 The Constant Company, LLC
Quick Links
BGP Toolkit Home
BGP Prefix Report
BGP Peer Report
Exchange Report
Bogon Routes
World Report
Multi Origin Routes
DNS Report
Top Host Report
Internet Statistics
Looking Glass
Network Tools App
Free IPv6 Tunnel
IPv6 Certification
IPv6 Progress
Going Native
Contact Us
AS Info
Graph v4
Graph v6
Prefixes v4
Prefixes v6
Peers v4
Peers v6
Whois
IRR
IX
AS20473 IPv4 Route Propagation
AS1273
AS7018
AS12956
AS6762
AS3320
AS2914
AS3257
AS701
AS20473
AS3491
AS1299
AS3356
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AS9318
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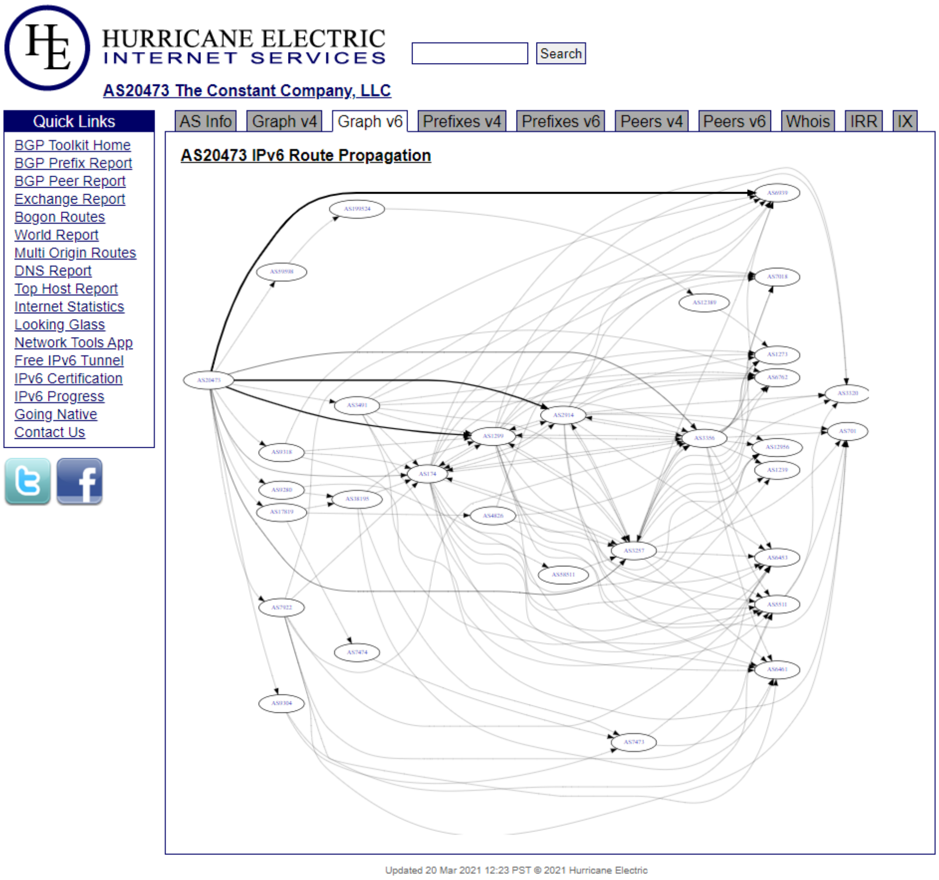
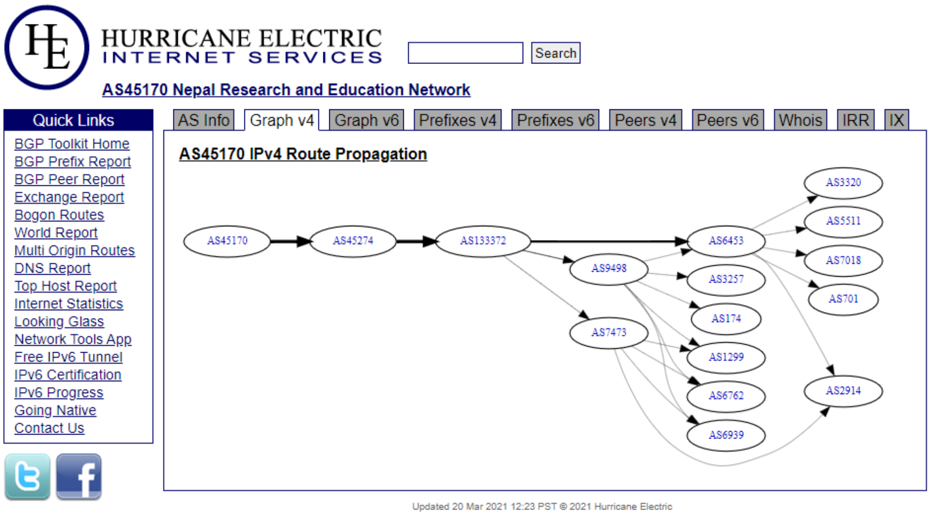
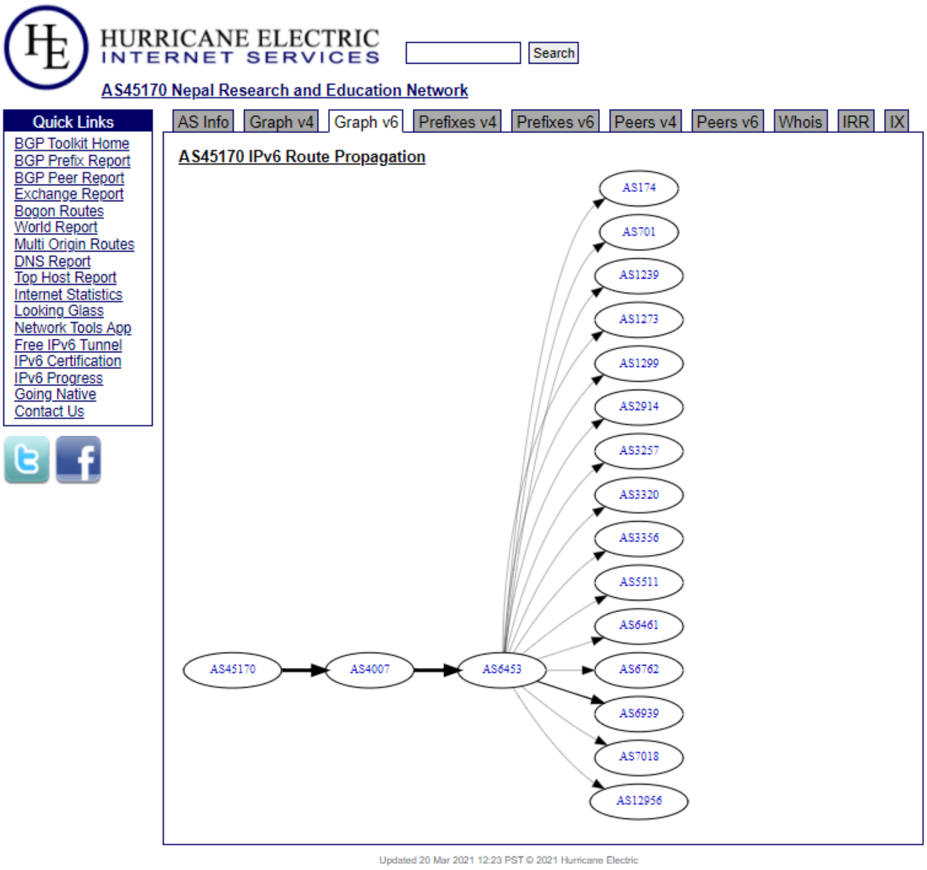
AS1239
AS6453
AS6939
AS9957
Updated 20 Mar 2021 12:23 PST © 2021 Hurricane Electric


HURRICANE ELECTRIC
INTERNET SERVICES
Search
AS20473 The Constant Company, LLC
Quick Links
BGP Toolkit Home
BGP Prefix Report
BGP Peer Report
Exchange Report
Bogon Routes
World Report
Multi Origin Routes
DNS Report
Top Host Report
Internet Statistics
Looking Glass
Network Tools App
Free IPv6 Tunnel
IPv6 Certification
IPv6 Progress
Going Native
Contact Us
AS Info
Graph v4
Graph v6
Prefixes v4
Prefixes v6
Peers v4
Peers v6
Whois
IRR
IX
AS20473 IPv6 Route Propagation
Updated 20 Mar 2021 12:23 PST © 2021 Hurricane Electric

AS45170





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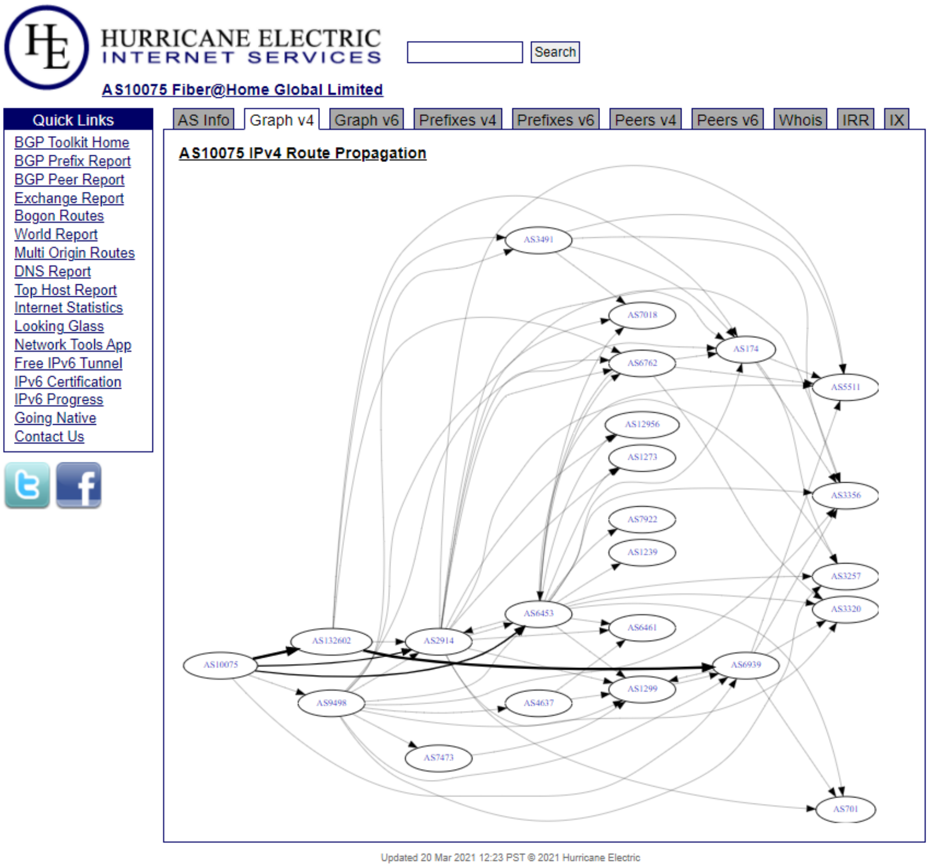
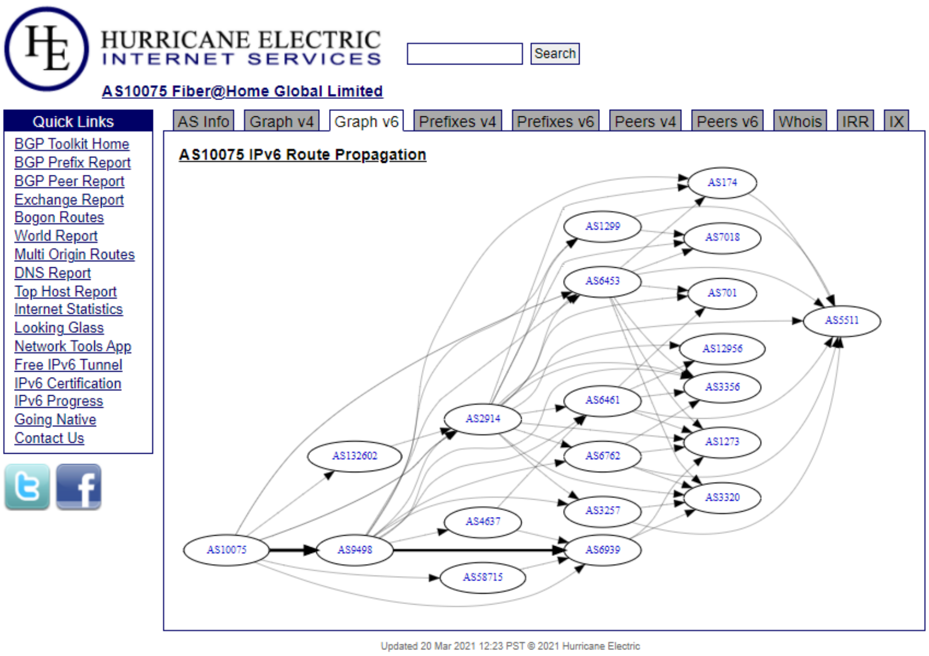
AS10075


HURRICANE ELECTRIC
INTERNET SERVICES
Search
AS10075 Fiber@Home Global Limited
Quick Links
BGP Toolkit Home
BGP Prefix Report
BGP Peer Report
Exchange Report
Bogon Routes
World Report
Multi Origin Routes
DNS Report
Top Host Report
Internet Statistics
Looking Glass
Network Tools App
Free IPv6 Tunnel
IPv6 Certification
IPv6 Progress
Going Native
Contact Us
AS Info
Graph v4
Graph v6
Prefixes v4
Prefixes v6
Peers v4
Peers v6
Whois
IRR
IX
AS10075 IPv4 Route Propagation
Updated 20 Mar 2021 12:23 PST © 2021 Hurricane Electric


HURRICANE ELECTRIC
INTERNET SERVICES
Search
AS10075 Fiber@Home Global Limited
Quick Links
BGP Toolkit Home
BGP Prefix Report
BGP Peer Report
Exchange Report
Bogon Routes
World Report
Multi Origin Routes
DNS Report
Top Host Report
Internet Statistics
Looking Glass
Network Tools App
Free IPv6 Tunnel
IPv6 Certification
IPv6 Progress
Going Native
Contact Us
AS Info
Graph v4
Graph v6
Prefixes v4
Prefixes v6
Peers v4
Peers v6
Whois
IRR
IX
AS10075 IPv6 Route Propagation
AS174
AS1299
AS7018
AS6453
AS701
AS5511
AS12956
AS3356
AS6461
AS2914
AS1273
AS132602
AS6762
AS3320
AS3257
AS4637
AS10075
AS9498
AS6939
AS58715
Updated 20 Mar 2021 12:23 PST © 2021 Hurricane Electric

Appendix 5: Regional Latency Data (Singapore)

From Ping Time between Singapore and Other Cities, n.d.

Ping "times" are a metric relied on by providers and users across the Internet, also known as latency. The time taken for Internet traffic to traverse networks is directly proportional to distance and therefore makes for a good measure of distance.

City	Distance	Average	Min	Max	Mdev
Jakarta	898km	13.30ms	13.04ms	14.61ms	0.33ms
Bangkok	1423km	27.22ms	26.57ms	31.15ms	1.00ms
Manila	2395km	52.08ms	51.99ms	52.28ms	0.30ms
Dhaka	2871km	54.08ms	53.37ms	56.62ms	0.73ms
Mumbai	3897km	54.34ms	54.02ms	55.56ms	0.43ms
Tokyo	5325km	69.15ms	68.97ms	69.70ms	0.34ms
Sydney	6314km	92.97ms	92.50ms	94.36ms	0.61ms

Appendix 6: Trends in the Data Using SQL

Looking for specific insights into the data and how that impacts conclusions and discussion in the report.

Data Using SQL

Top 25 Networks (IPv4)

The most popular IP address ranges for content in the project.

```
ccTLD=# select network(set_masklen(ipv4,24)), count(*) from data
where ipv4 is not null group by 1 order by 2 desc limit 25;
   network      | count
------------------+--------
185.230.63.0/24 | 214023
198.185.159.0/24 | 85509
198.49.23.0/24  | 81995
157.7.107.0/24  | 44151
23.227.38.0/24  | 38525
202.124.241.0/24 | 25070
103.224.182.0/24 | 22430
```

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```
34.102.136.0/24 | 21540
23.236.62.0/24  | 16186
192.0.78.0/24  | 15799
157.7.44.0/24  | 15419
103.18.109.0/24 | 14437
103.42.110.0/24 | 13710
199.34.228.0/24 | 13129
103.27.32.0/24  | 13116
103.27.34.0/24  | 13030
184.168.131.0/24 | 11642
211.13.196.0/24 | 11616
198.71.232.0/24 | 11179
43.250.140.0/24 |  9947
103.42.108.0/24 |  9013
100.24.208.0/24 |  7458
203.170.80.0/24 |  7212
103.9.171.0/24  |  7073
157.7.144.0/24  |  6378
(25 rows)
```

Top 25 Networks (IPv6)

The most popular IP address ranges for content in the project.

```
ccTLD=# select network(set_masklen(ipv6,32)),count(*) from data
where ipv6 is not null group by 1 order by 2 desc limit 25;
  network     | count
----------------+--------
2606:4700::/32 | 239131
2404:8280::/32 | 30482
2600:9000::/32 | 11976
2400:b800::/32 | 10240
2403:1400::/32 |  6752
2405:3f00::/32 |  5358
2a00:fd80::/32 |  3980
2001:4860::/32 |  2928
2407:e700::/32 |  2647
2403:3a00::/32 |  2135
2404:6800::/32 |  1573
2403:bc00::/32 |  1141
2001:e42::/32 |  1080
2a05:d014::/32 |  860
```


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```
2001:df0::/32 |  798
2001:19f0::/32 |  770
2402:1f00::/32 |  734
2620:12a::/32 |  649
2406:da1c::/32 |  624
2407:d600::/32 |  616
2401:2500::/32 |  509
2a07:7800::/32 |  423
2400:6180::/32 |  405
2404:9400::/32 |  348
2401:fc00::/32 |  332
(25 rows)
```

Top 25 Hosting ASNs

Where are the bigger sources of ccTLD content in the data?

```
ccTLD=# select count(*),array_accum(distinct country) as
"Serving",network,asn,as_name,as_city,as_country,latitude,
longitude from data where network is not null group by
network,asn,as_name,as_city,as_country,latitude,longitude
order by 1 desc limit 25;
```

```
count | Serving | network | asn | as_name | as_city | as_country | latitude | longitude
------+---------+---------+-----+---------+---------+------------+----------+-----------
214079 | {AU,JP,MY,TH} | 185.230.60.0/22 | 58182 | Wix.com Ltd. | Ashburn | US | 39.018 | -77.539
165690 | {AU,BD,JP,MY,TH} | 104.16.0.0/12 | 13335 | CLOUDFLARENET | | US | 37.751 | -97.822
85509 | {AU,BD,JP,MY,TH} | 198.185.159.0/24 | 53831 | SQUARESPACE | | US | 37.751 | -97.822
81995 | {AU,BD,JP,MY,TH} | 198.49.23.0/24 | 53831 | SQUARESPACE | | US | 37.751 | -97.822
40191 | {AU,BD,JP,MY} | 101.0.64.0/18 | 55803 | Hostopia Australia Web Pty Ltd | | AU | -37.8159 | 144.9669
38525 | {AU,JP,MY,TH} | 23.227.38.0/23 | 13335 | CLOUDFLARENET | | CA | 43.6319 | -79.3716
29657 | {AU,JP,MY} | 116.90.0.0/18 | 55803 | Hostopia Australia Web Pty Ltd | | AU | -33.494 | 143.2104
27652 | {AU,JP,MY} | 103.27.32.0/22 | 45638 | SYNERGY WHOLESALE PTY LTD | | AU | -33.494 | 143.2104
25136 | {AU,JP} | 202.124.240.0/21 | 24446 | NetRegistry Pty Ltd. | | AU | -33.494 | 143.2104
25062 | {AU,JP,MY} | 103.42.108.0/22 | 45638 | SYNERGY WHOLESALE PTY LTD | | AU | -33.494 | 143.2104
22430 | {AU,JP,MY} | 103.224.182.0/23 | 133618 | Trellian Pty. Limited | | AU | -33.494 | 143.2104
21579 | {AU,BD,JP,MY,TH} | 34.102.0.0/15 | 15169 | GOOGLE | Kansas City | US | 39.1028 | -94.5778
20563 | {AU,JP,TH} | 157.7.128.0/17 | 7506 | GMO Internet,Inc | | JP | 35.6897 | 139.6895
17367 | {AU,JP,MY} | 103.18.108.0/22 | 132680 | Net Virtue Pty Ltd | Sydney | AU | -33.8591 | 151.2002
16741 | {AU,JP} | 203.170.80.0/21 | 38719 | Dreamscape Networks Limited | | AU | -33.494 | 143.2104
16228 | {AU,JP,MY,TH} | 23.236.48.0/20 | 15169 | GOOGLE | Council Bluffs | US | 41.2619 | -95.8608
15829 | {AU,JP,MY,TH} | 192.0.64.0/18 | 2635 | AUTOMATTIC | | US | 37.751 | -97.822
15433 | {AU,JP,MY,TH} | 157.7.40.0/21 | 7506 | GMO Internet,Inc | | JP | 35.6897 | 139.6895
13655 | {AU,JP,MY,TH} | 199.34.228.0/22 | 27647 | WEEBLY | | US | 37.751 | -97.822
```

```
13012 | {AU,BD,JP,MY,TH} | 198.71.128.0/17 | 26496 | AS-26496-GO-DADDY-COM-LLC | Ashburn | US | 39.0481 | -77.4728
12975 | {AU} | 103.9.168.0/22 | 45638 | SYNERGY WHOLESALE PTY LTD | | AU | -33.494 | 143.2104
11914 | {AU,JP,MY}  | 122.201.64.0/18 | 38719 | Dreamscape Networks Limited | | AU | -33.494 | 143.2104
11827 | {AU,JP,MY,TH} | 13.232.0.0/13 | 16509 | AMAZON-02 | Sydney | AU | -33.8591 | 151.2002
11808 | {AU,BD,JP,MY,TH} | 184.168.128.0/17 | 26496 | AS-26496-GO-DADDY-COM-LLC | | US | 37.751 | -97.822
11326 | {AU,JP,MY,TH} | 54.248.0.0/13 | 16509 | AMAZON-02 | Sydney | AU | -33.8591 | 151.2002
(25 rows)
```

Appendix 7: Is There Any Glue?

Is there a website or anything hosted on a domain?
Some of the answers is this question are "no glue" or nothing is present.

Essentially, the domain is registered and then parked. No website or any other service is being listed in the global DNS for the domain, so the registrant is just obtaining the domain name and no other service with it.

```
country | Domains | IPv6 Glue | IPv4 Glue | Non-IP Glue | No Glue  | Total
--------+---------+-----------+-----------+-------------+----------+-------
AU | 2,035,511 | 289,210 10.34% | 1,718,239 61.42% | 14,499 .52% | 775,608 27.72% | 2,797,556
JP | 683,137 | 25,684 3.33% | 710,829 92.16% | 1,445 .19% | 33,349 4.32% | 771,307
IN | 497,969 | 72,085 10.93% | 545,705 82.74% | 4,693 .71% | 37,063 5.62% | 659,546
ID | 106,671 | 21,710 13.83% | 125,519 79.99% | 621 .40% | 9,071 5.78% | 156,921
MY | 57,007 | 11,182 14.49% | 63,496 82.30% | 180 .23% | 2,291 2.97% | 77,149
SG | 48,350 | 6,803 10.23% | 57,669 86.73% | 175 .26% | 1,845 2.77% | 66,492
TH | 37,738 | 6,279 12.69% | 41,148 83.17% | 162 .33% | 1,888 3.82% | 49,477
PH | 25,129 | 3,916 11.66% | 29,110 86.70% | 137 .41% |  412 1.23% | 33,575
BD | 1,368 |  136 8.09% | 1,194 70.99% | 43 2.56% |  309 18.37% | 1,682
(9 rows)
```

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