Visualizing the Internet Topology

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1 Introduction

In this project, we explore the visualization of the Internet's topology, aiming to gain insights into its structure and organization. The Internet, a vast and interconnected network, plays a pivotal role in modern communication and information exchange. Our project focuses on presenting a visual representation of its topology to better understand its underlying architecture. All the related codes and documents can be found in this Github link

2 Network Sources and Destinations

To visualise the network topology we took the following sources and destinations ,

Index	Source
1	IITH WiFi
2	Mobile Hotspot
3	Japan (AS3258)
4	USA (AS212238)
5	NetherLands (AS43350)

(a) Sources

Index	Destination
1	BBC UK
2	Global Suzuki
3	Google
4	Hyundai
5	Rakuten
6	Orange-Networks
7	MICROSOFT
8	OpenAI
9	Zoom
10	HDFC

(b) Destination

Sources And Destination

3 Raw Data Collection

We have collected the raw data using `tracert` command in command prompt, which traces the route to the destination along with RTTs (Round Trip Time) at each intermediate router for 3 data packets, (look below for example)

```
  tracert www.google.com
Output :
1     3 ms     1 ms     1 ms  XiaoQiang [192.168.31.1]
2    10 ms     5 ms     3 ms  10.5.82.1
3     3 ms     2 ms     5 ms  192.168.41.149
4     2 ms     4 ms     1 ms  103.232.241.70
5     3 ms     1 ms     2 ms  noc-cr-in.comp.iith.ac.in [103.232.241.2]
6     3 ms     3 ms     3 ms  10.119.254.121
```

```
 7     *        *        *     Request timed out.
 8     *        *        *     Request timed out.
 9    29 ms    30 ms    30 ms  10.119.73.122
10    31 ms    31 ms    29 ms  72.14.195.128
11    31 ms    35 ms    30 ms  142.251.227.213
12    31 ms    28 ms    28 ms  142.251.55.221
13    28 ms    31 ms    30 ms  maa05s24-in-f4.1e100.net [142.250.193.100]
```

Using this command we got the ip addresses of each intermediate router from source to destination. This command is very useful as it gives us an idea about the traffic in the route and what different websites the packets are travelling to. The following are some key things we understood,

- In Linux, traceroute uses UDP which results in no response from some routers, but by using -I flag forces to use ICMP which helped in getting some hidden data.But in Windows, the command directly uses ICMP
- We observed some **Request timed out** responses even after using ICMP, this can happen when the packet is dropped due to more latency or when the organization choose to hide it's IP.
- When we took sources as Japan or US or NetherLands, first the packet went from IIT H to VPN location and then to destination which is different from general source (IITH wifi or Hotspot). So in our calculations we started from second route

To extract the command line output we used python `subprocess` which transforms data into `.txt` files.

You can find the python script to automate the `tracert` command here and all `.txt` files here .

4 Data Extraction

After getting the trace routes, to get deeper understanding about each ip address we used BGPview API to get key elements like AS Number, IP Range, AS Description, IP Country Code, etc. In doing so, we observed some key points,

- AS spans across continents but it is registered in a specific country and it can hold more than one IP block
  Ex : In case of `www.google.com`, when the source is changed the destination IP address that the packet took also changed but the AS number of the destination remained unchanged
- IP addresses fall into two categories: private and public. The attributes linked to an IP address significantly differ based on its classification. For public IP addresses, additional information like associated ASN (Autonomous System Number) is available. Furthermore, it's important to note that there are also designated private IP address ranges.

- 10.0.0.0 to 10.255.255.255
- 172.16.0.0 to 172.31.255.255
- 192.168.0.0 to 192.168.255.255

- In case of globalsuzuki.com, and some times openai.com there destination ip address is registered to akamai technologies, the reason we learnt by surfing through net is, akamai technologies acts like a proxy for above such organizations to maintain privacy.

Following are the features we extracted from ip address, here we added the ISP type of

Index	Feature
1	IP range
2	IP Name
3	IP description
4	IP Country
5	ASN Number
6	ASN description
7	ASN Name
8	ASN Country Code
9	ISP Type

the network device by considering the Host ID part of the ip address. As there is no sure way to decide whether the ISP is global/regional, we opted to label the ISP as **Global** if no. of free bits is > 8 (One of the characteristic of a global ISP), otherwise **Regional**.

To extract the above features we used BGPview API, to make api calls we used python `requests` library , to do operations on csv file we used `pandas` library, `re` module for identifying ISP, renaming the files and `os` module for streamlining the entire process. You can find the extracted data here and the relevant code here.

5 Visualization

We utilized the GraphViz library in Python for visualization purposes after preprocessing the extracted data. Here's a summary of our process:

- All distinct AS (Autonomous System) numbers along 50 paths were identified and treated as unique nodes in the graph.Paths were given colors based on the destination they reach to enhance clarity.

- Edges connecting the source and destination nodes in each path were rendered using the 'ortho' mode, strategically preventing clustering and enhancing clarity. The assignment of edge weights was guided by the disparity between the average latencies of the target and source nodes, providing a nuanced representation of network dynamics.

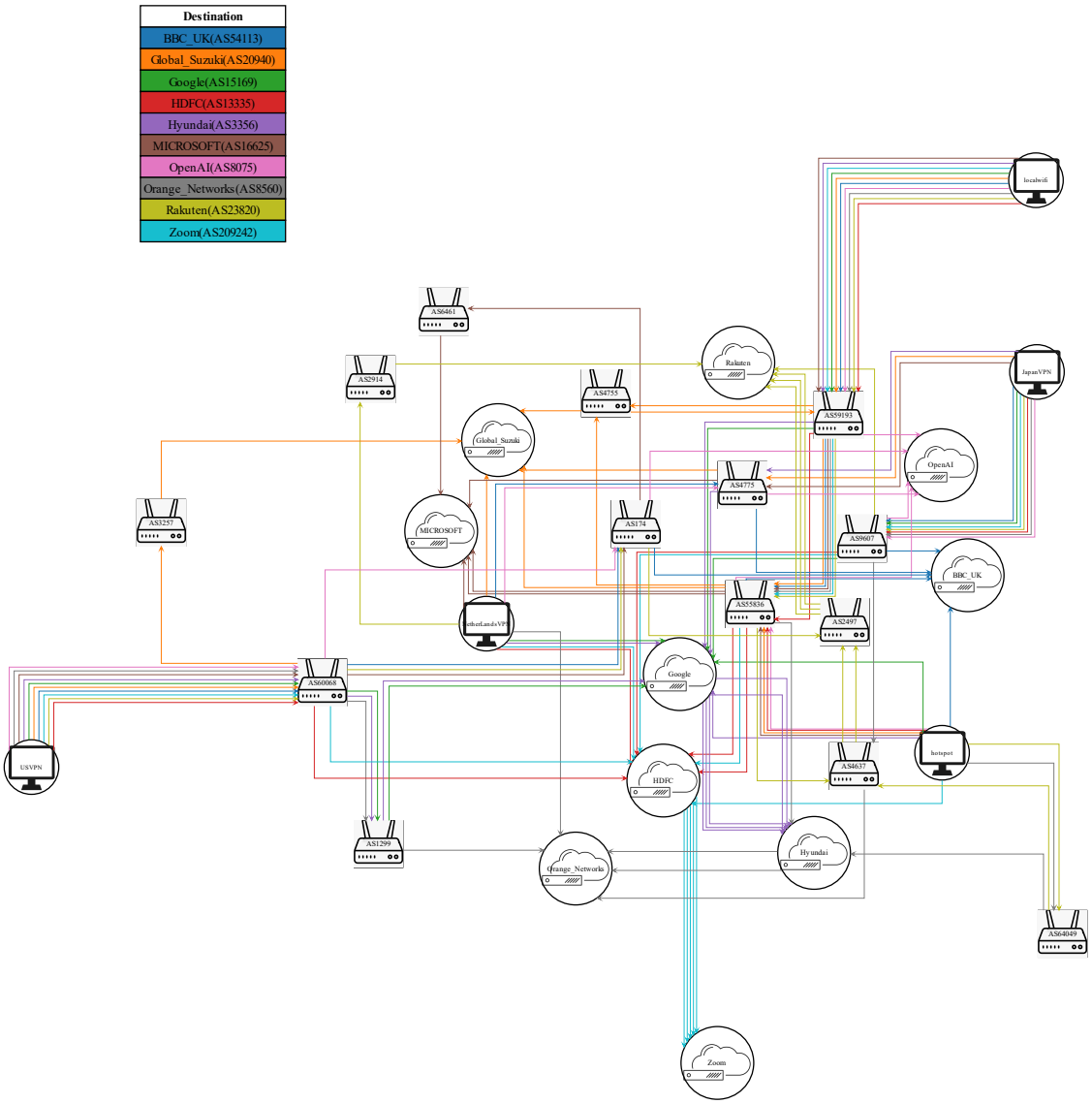
- In instances where negative edge weights arise from calculations, a default weight of 12ms is assigned. This pragmatic approach acknowledges that negative latency between ISPs is infeasible and often stems from complexities like network congestion or queuing delays. This corrective measure ensures network integrity by addressing unrealistic scenarios and aligning with the fundamental concept that latency cannot logically be negative.

- To achieve a visually appealing layout, we employed the force-directed placement (fdp) layout engine. The fdp algorithm positions graph nodes in a way that reduces edge crossings, balances node distribution, and attempts to preserve edge lengths.

The outcome of our efforts resulted in a graph visualization that effectively represents the connectivity and latency relationships between various AS numbers, sources, and destinations.Here is the link to graph's python code.

6 Conclusion

Throughout this project, we have delved into the intricacies of data transfer within a complex network of interconnected devices. Navigating the challenges of source and destination selection, extracting IP information from diverse databases and open-source APIs was integral to our journey. In its entirety, this endeavor has proven to be an exceptional learning opportunity, enriching our comprehension of network topology and its operational nuances.



Network Topology

We've consolidated vital data on Internet Service Providers (ISPs) within our network. This report summarizes the process and outcomes:

- **Data Collection**: Multiple destination folders containing ISP data were unified into a single CSV file.
- **Enhanced Dataset**: We eliminated duplicates and streamlined presentation by merging select columns in Excel for Multi-headed Layout.

This CSV compilation serves as a comprehensive resource for our network's AS landscape. Here is the link that provides details on the process we followed to generate a consolidated CSV file.

AS_Number	AS_description	AS_Country	IP	IP_range	IP_description	IP_Country	IP_Type
AS1299	Arelion, f/k/a Telia Carrier	SE	62.115.112.157	62.115.0.0/16		SE	Global
			213.248.70.121	213.248.64.0/18		SE	Global
			213.248.88.90	213.248.64.0/18		SE	Global
			62.115.191.217	62.115.0.0/16		SE	Global
			62.115.143.16	62.115.0.0/16		SE	Global
			62.115.113.21	62.115.0.0/16		SE	Global
			80.91.249.11	80.91.240.0/20	Telia Company AB	EU	Global
AS13335	Cloudflare, Inc.	US	172.70.120.2	172.70.120.0/24	Cloudflare, Inc.	US	Regional
			104.16.29.57	104.16.0.0/12	Cloudflare, Inc.	US	Global
			162.158.226.122	162.158.226.0/23	Cloudflare, Inc.	US	Global
			103.22.201.36	103.22.201.0/24	Cloudflare, Inc.	US	Regional
			104.16.115.21	104.16.0.0/12	Cloudflare, Inc.	US	Global
			172.70.108.4	172.70.108.0/24	Cloudflare, Inc.	US	Regional
			141.101.65.26	141.101.65.0/24	CloudFlare, Inc.	US	Regional
			162.158.152.5	162.158.152.0/24	Cloudflare, Inc.	US	Regional
			172.71.196.4	172.71.196.0/24	Cloudflare, Inc.	US	Regional
			172.69.176.5	172.69.176.0/24	Cloudflare, Inc.	US	Regional
			141.101.65.30	141.101.65.0/24	CloudFlare, Inc.	US	Regional
			172.71.100.2	172.71.100.0/24	Cloudflare, Inc.	US	Regional
			172.71.92.2	172.71.92.0/24	Cloudflare, Inc.	US	Regional
AS15169	Google LLC	US	142.250.56.39	142.250.0.0/15	Google LLC	US	Global
			74.125.242.145	74.125.0.0/16	Google LLC	US	Global
			216.239.54.159	216.239.32.0/19	Google LLC	US	Global
			142.251.64.7	142.250.0.0/15	Google LLC	US	Global
			142.251.35.164	142.250.0.0/15	Google LLC	US	Global
			108.170.242.129	108.170.192.0/18	Google LLC	US	Global
			216.239.54.92	216.239.32.0/19	Google LLC	US	Global
			142.251.60.195	142.250.0.0/15	Google LLC	US	Global
			142.250.196.100	142.250.0.0/15	Google LLC	US	Global
			142.250.234.37	142.250.0.0/15	Google LLC	US	Global
			72.14.204.154	72.14.192.0/18	Google LLC	US	Global
			72.14.195.128	72.14.192.0/18	Google LLC	US	Global
			142.251.227.213	142.250.0.0/15	Google LLC	US	Global
			142.251.55.221	142.250.0.0/15	Google LLC	US	Global
			142.250.193.100	142.250.0.0/15	Google LLC	US	Global
			216.58.214.4	216.58.192.0/19	Google LLC	US	Global
			209.85.148.162	209.85.128.0/17	Google LLC	US	Global
			216.58.200.132	216.58.192.0/19	Google LLC	US	Global
			108.170.248.202	108.170.192.0/18	Google LLC	US	Global
			74.125.51.166	74.125.0.0/16	Google LLC	US	Global
			209.85.168.26	209.85.128.0/17	Google LLC	US	Global
			209.85.253.143	209.85.128.0/17	Google LLC	US	Global
			142.250.63.91	142.250.0.0/15	Google LLC	US	Global
			172.253.71.201	172.253.0.0/16	Google LLC	US	Global
			216.239.47.175	216.239.32.0/19	Google LLC	US	Global
			142.251.55.243	142.250.0.0/15	Google LLC	US	Global
			108.170.241.161	108.170.192.0/18	Google LLC	US	Global
			142.250.224.213	142.250.0.0/15	Google LLC	US	Global
			108.170.242.97	108.170.192.0/18	Google LLC	US	Global
			108.170.231.79	108.170.192.0/18	Google LLC	US	Global
			74.125.37.7	74.125.0.0/16	Google LLC	US	Global
			108.170.241.225	108.170.192.0/18	Google LLC	US	Global
			142.251.227.211	142.250.0.0/15	Google LLC	US	Global
			142.250.224.133	142.250.0.0/15	Google LLC	US	Global
AS16625	Akamai Technologies, Inc.	US	104.122.217.246	104.122.216.0/22	Akamai Technologies, Inc.	US	Global
			23.60.109.172	23.60.108.0/22	Akamai Technologies, Inc.	US	Global
			104.123.41.162	104.123.40.0/22	Akamai Technologies, Inc.	US	Global
			23.47.169.232	23.47.168.0/22	Akamai Technologies, Inc.	US	Global

Table 1.1

AS174	Cogent Communications	US	154.54.30.114	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.0.54	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.5.217	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.44.86	154.48.0.0/12	African Network Information Center	MU	Global
			38.104.44.122	38.0.0.0/8	Fastly	US	Global
			154.54.3.125	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.27.118	154.48.0.0/12	African Network Information Center	MU	Global
			38.19.140.218	38.0.0.0/8	PSINet, Inc.	US	Global
			154.54.3.9	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.90.58	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.28.70	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.7.158	154.48.0.0/12	African Network Information Center	MU	Global
			154.54.40.106	154.48.0.0/12	African Network Information Center	MU	Global
			38.122.34.130	38.0.0.0/8	Microsoft Corporation	US	Global
			154.54.0.142	154.48.0.0/12	African Network Information Center	MU	Global
AS209242	Cloudflare, Inc.	US	170.114.52.2	170.114.52.0/24	Zoom Video Communications, Inc	US	Regional
AS20940	Akamai International B.V.	NL	69.192.23.106	69.192.0.0/16	Akamai Technologies, Inc.	US	Global
			23.9.64.150	23.0.0.0/12	Akamai Technologies, Inc.	US	Global
			104.71.158.210	104.64.0.0/10	Akamai Technologies, Inc.	US	Global
			2.16.43.59	2.16.0.0/13		NL	Global
			23.9.122.131	23.0.0.0/12	Akamai Technologies, Inc.	US	Global
			23.203.156.187	23.192.0.0/11	Akamai Technologies, Inc.	US	Global
AS212238	Datacamp Limited	GB	37.19.199.156	37.19.198.0/23	CDNEXT NYC	US	Global
			37.19.199.157	37.19.198.0/23	CDNEXT NYC	US	Global
AS23820	Rakuten Group, Inc.	JP	133.237.16.234	133.237.0.0/16	Rakuten Group, Inc.	JP	Global
			202.72.48.169	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.48.206	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.48.171	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.48.164	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.48.165	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.48.166	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.49.107	202.72.48.0/20	Rakuten,Inc.	JP	Global
			202.72.49.105	202.72.48.0/20	Rakuten,Inc.	JP	Global
AS2497	Internet Initiative Japan Inc.	JP	58.138.101.34	58.138.0.0/17	Internet Initiative Japan Inc.	JP	Global
			202.232.9.10	202.232.0.0/16	Internet Initiative Japan Inc.	JP	Global
			58.138.101.38	58.138.0.0/17	Internet Initiative Japan Inc.	JP	Global
			58.138.81.173	58.138.0.0/17	Internet Initiative Japan Inc.	JP	Global
			58.138.88.157	58.138.0.0/17	Internet Initiative Japan Inc.	JP	Global
AS2914	NTT America, Inc.	US	129.250.7.86	129.250.0.0/16	NTT America, Inc.	US	Global
			129.250.6.177	129.250.0.0/16	NTT America, Inc.	US	Global
			203.105.72.218	203.105.64.0/19	NTT Ltd Japan Corporation	JP	Global
			129.250.6.127	129.250.0.0/16	NTT America, Inc.	US	Global
			129.250.6.147	129.250.0.0/16	NTT America, Inc.	US	Global
			81.20.64.113	81.20.64.0/20	...	GB	Global
			129.250.4.143	129.250.0.0/16	NTT America, Inc.	US	Global
AS3257	GTT	US	98.124.184.66	98.124.128.0/18	GTT	US	Global
			213.200.121.6	213.200.64.0/18	...	US	Global
			209.120.246.61	209.120.128.0/17	GTT	US	Global
AS3258	xTom Tokyo	AU	91.200.240.8	91.200.240.0/24	...	DE	Regional
			103.125.235.1	103.125.235.0/24	ProtonVPN	JP	Regional
			91.200.240.12	91.200.240.0/24	...	DE	Regional
AS3356	Level 3 Parent, LLC	US	4.55.111.34	4.0.0.0/9	Level 3 Parent, LLC	US	Global
			62.67.23.38	62.67.0.0/16	...	GB	Global
			195.50.117.33	195.50.64.0/18	LUMEN TECHNOLOGIES UK LIMITED	GB	Global
AS43350	NForce Entertainment B.V.	NL	185.107.56.254	185.107.56.0/22	NForce Entertainment B.V.	NL	Global
			185.107.116.21	185.107.116.0/24	...	NL	Regional
			185.107.116.22	185.107.116.0/24	...	NL	Regional

Table 1.2

AS4637	Telstra Global	HK	134.159.129.18	134.159.0.0/16	Telstra Global IS Network Blocks	AU	Global
			202.84.178.54	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.249.10	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.141.1	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.148.69	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.127.69.134	202.127.69.0/24	Telstra Global IS Network Blocks	JP	Regional
			202.84.153.38	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.140.50	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			210.57.38.112	210.57.38.0/24	Telstra Global Internet Service	SG	Regional
			202.84.224.198	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.143.177	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
			202.84.173.22	202.84.128.0/17	Telstra Global IS Network Blocks	HK	Global
AS4755	TATA Communications	IN	121.244.3.222	121.244.0.0/17	Internet Service Provider	IN	Global
			115.110.206.73	115.110.128.0/17	Internet Service Provider	IN	Global
AS4775	Globe Telecoms	PH	193.239.118.116	193.239.116.0/22	Broadband Hosting B.V.	NL	Global
			101.203.88.173	101.203.88.0/22	BBIX, Inc.	JP	Global
			101.203.89.164	101.203.88.0/22	BBIX, Inc.	JP	Global
			101.203.89.177	101.203.88.0/22	BBIX, Inc.	JP	Global
			101.203.89.88	101.203.88.0/22	BBIX, Inc.	JP	Global
			193.239.117.16	193.239.116.0/22	Broadband Hosting B.V.	NL	Global
AS54113	Fastly, Inc.	US	151.101.156.81	151.101.0.0/16	Fastly	US	Global
			151.101.208.81	151.101.0.0/16	Fastly	US	Global
			151.101.228.81	151.101.0.0/16	Fastly	US	Global
			151.101.152.81	151.101.0.0/16	Fastly	US	Global
			151.101.36.81	151.101.0.0/16	Fastly	NL	Global
AS55836	RelianceJio Infocomm Limited	IN	49.45.4.86	49.45.0.0/16	Reliance Jio Infocomm Limited	IN	Global
			115.247.100.29	115.240.0.0/13	Reliance Jio Infocomm Limited	IN	Global
			49.44.129.66	49.44.128.0/17	Reliance Jio Infocomm Limited	IN	Global
			49.44.220.131	49.44.128.0/17	Reliance Jio Infocomm Limited	IN	Global
			49.44.183.1	49.44.128.0/17	Reliance Jio Infocomm Limited	IN	Global
			49.44.187.135	49.44.128.0/17	Reliance Jio Infocomm Limited	IN	Global
			49.44.187.157	49.44.128.0/17	Reliance Jio Infocomm Limited	IN	Global
AS59193	IIT Hyderabad	IN	103.232.241.70	103.232.241.0/24	IIT Hyderabad	IN	Regional
			103.232.241.2	103.232.241.0/24	IIT Hyderabad	IN	Regional
			103.232.241.237	103.232.241.0/24	IIT Hyderabad	IN	Regional
AS60068	CDN77	GB	185.229.188.172	185.229.188.0/23	Datacamp Limited	GB	Global
			185.229.188.174	185.229.188.0/23	Datacamp Limited	GB	Global
			45.134.215.17	45.134.215.0/24	CDN77 int	GB	Regional
			185.229.188.169	185.229.188.0/23	Datacamp Limited	GB	Global
			185.229.188.170	185.229.188.0/23	Datacamp Limited	GB	Global
AS64049	RelianceJio Infocomm Singapore	SG	103.198.140.43	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
			103.198.140.64	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
			103.198.140.249	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
			103.198.140.215	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
			103.198.140.176	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
			103.198.140.106	103.198.140.0/24	16-01 Raffles City Tower, Singapore	SG	Regional
AS6461	Zayo Bandwidth	US	64.125.28.111	64.124.0.0/15	ARIN	US	Global
			208.184.2.173	208.184.0.0/15	Zayo Bandwidth	US	Global

Table 1.3

AS8075	Microsoft Corporation	US	104.44.239.204	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.230.7	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.29.110	104.40.0.0/13	Microsoft Corporation	US	Global
			13.107.253.40	13.104.0.0/14	Microsoft Corporation	US	Global
			104.44.11.81	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.21.224	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.19.194	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.33.207	104.40.0.0/13	Microsoft Corporation	US	Global
			13.107.246.67	13.104.0.0/14	Microsoft Corporation	US	Global
			13.104.140.165	13.104.0.0/14	Microsoft Corporation	US	Global
			104.44.42.94	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.239.79	104.40.0.0/13	Microsoft Corporation	US	Global
			13.107.246.48	13.104.0.0/14	Microsoft Corporation	US	Global
			104.44.230.56	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.30.201	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.12.6	104.40.0.0/13	Microsoft Corporation	US	Global
			13.107.246.46	13.104.0.0/14	Microsoft Corporation	US	Global
			13.104.182.215	13.104.0.0/14	Microsoft Corporation	US	Global
			104.44.236.182	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.235.188	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.212.200	104.40.0.0/13	Microsoft Corporation	US	Global
			104.44.34.38	104.40.0.0/13	Microsoft Corporation	US	Global
			13.107.213.48	13.104.0.0/14	Microsoft Corporation	US	Global
AS8560	1&1 Internet SE.	DE	212.227.120.11	212.227.0.0/16	…	DE	Global
			212.227.117.208	212.227.0.0/16	…	DE	Global
			217.160.0.86	217.160.0.0/16	…	DE	Global
			212.227.117.207	212.227.0.0/16	…	DE	Global
			212.227.120.32	212.227.0.0/16	…	DE	Global
			212.227.117.4	212.227.0.0/16	…	DE	Global
			212.227.121.28	212.227.0.0/16	…	DE	Global
			212.227.116.221	212.227.0.0/16	…	DE	Global
			212.227.121.9	212.227.0.0/16	…	DE	Global
			212.227.120.40	212.227.0.0/16	…	DE	Global
			212.227.120.229	212.227.0.0/16	…	DE	Global
AS9607	BroadBand Tower, Inc.	JP	211.14.4.178	211.14.0.0/21	Japan Network Information Center	JP	Global
		JP	211.14.4.177	211.14.0.0/21	Japan Network Information Center	JP	Global
		JP	211.14.4.222	211.14.0.0/21	Japan Network Information Center	JP	Global

Table 1.4