Real World RTT Performance Comparison of IPv4 and IPv6

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ABSTRACT

To compare the real world RTT performance of IPv4 and IPv6, 150 `RIPE Atlas` nodes have been randomly selected to execute a series of `traceroutes` to distinct hosts in the Netherlands, Switzerland and Russia. The resulting measurements have then been analyzed to find out if there is a statistically significant difference in RTT performance between `IPv4` and `IPv6`. The study finds that there is no statistically significant difference between the two versions of the Internet Protocol in the Swiss host. The Dutch host exhibits a slight predilection towards `IPv6`, whereas the Russian host shows better performance via `IPv4`. These differences in IP performance can be attributed to peering agreements between providers.

Keywords

IPv4, IPv6, RTT, comparison, performance, real world, RIPE Atlas

1. INTRODUCTION

`IPv4` exhaustion is a topic that has gotten quite some attention after the announcement of APNIC (Asia Pacific Network Information Centre) in February 2011 that it had been allocated the last two /8 address blocks from the IANA (Internet Assigned Numbers Authority). Two consecutive IPv6 events were then organized to further promote the usage of `IPv6`. The first event was the World IPv6 Day on June the 8th and the second event was held roughly one year later on June 6th 2012: World IPv6 Launch Day. The main topic of these events was `IPv6` adoption, but not if migration to `IPv6` could have any adverse effects in e.g. connectivity performance.

Early scientific research suggests that `IPv6` may have a higher RTT (Round-Trip-Time) between two hosts, paired with higher packet-loss during transit, whereas newer research suggests that these values are now more similar to `IPv4`. The goal of this paper is to validate the more recent claims.

Contrary to the currently existing research though, this paper will employ a novel method which has not yet been used to answer the question of performance difference in IPv4 and IPv6. In 2005 [7] Wang, Ye and Li used `ping` and `traceroute` from three different locations in Japan and Spain. Whereas in 2016 [4] just a single node within `CERNET2` (China Education and Research Network) was used.

The new method presented in this paper will make use of the `RIPE Atlas` platform. `RIPE Atlas` consists of roughly 8000 active small nodes, spread world wide, which are capable to run `ping` and `traceroute` commands. The nodes can be hosted in data centers, but also in the homes of volunteers. This allows the user of `RIPE Atlas` to not just measure data center performance, but real world end-user scenarios.

In 2013 German ISP Unitymedia [5] decided to only assign IPv6 addresses to new customers, and to NAT IPv4 connections with a technology called Dual-Stack Lite (RFC6333). Anecdotal evidence[2] suggests that the IPv4 NAT service is often "overloaded" or "slow".

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2. RELATED WORK

2.1 2005: Hopcount and E2E delay: IPv6 versus IPv4

This study by Zhou and Mieghem[8] used a precursor of `RIPE Atlas`, the so called `RIPE Test Traffic Measurement Service` (TTM). Measurement nodes as well as endpoints come from within the TTM. In 36% of their test cases `IPv6` RTT seems to be substantially slower than for `IPv4`. While no exact measurement numbers are provided one can infer these numbers from a supplied graph. While most `IPv4` RTTs are between 1 and 50 ms, the same route seems to be four times slower via `IPv6`. They conclude that:

> Concerning the IP delay variation, our results suggest that compared to IPv4, IPv6 paths suffer from a larger delay variation, which has a significant impact on the real-time application since it might increase the cost of buffering in the end host.

An explanation for those variations comes in the form of badly configured `IPv6` tunnels as well as a lower commitment to `IPv6` infrastructure.

2.2 2006: Evaluating IPv6 on a large-scale network

Shiau et al.[6] have created a comparative study between `IPv4` and `IPv6` by using bandwidth throughput, delay jitters, packet loss rate and RTT in two different environments. The first environment is a testbed, two computers connected with a point-to-point gigabit Ethernet connection.

The second environment is a real large-scale network. Here two computers were each connected to Cisco 3750 gigabit Ethernet switches and then to Cisco 7609 routers. Both routers are connected to the Taiwan Advanced Research and Education Network (TWAREN).

`Iperf` has been used to measure throughput, jitter and packet loss, while `ping` was used to measure RTT. Particularly relevant for this study, are the RTT results of Shiau et al.:

In their testbed environment `IPv6` RTT was always slower than `IPv4`, by less than 0.1 ms, whereas in the real environment `IPv6` was always slower by about 0.4 ms. They conclude their paper by saying that higher RTT times are expected in `IPv6` due to higher header overhead.

2.3 2008: Empirical performance of IPv6 vs. IPv4 under a dual-stack environment

In this research[3] measurements were taken from the Hongkong Advanced Research Network (HARNET) to roughly 2000 worldwide spread dual-stack end-points. `ping` and `ping6` were used to measure RTT. According to their data `IPv6` had an average RTT of 403.36 ms whereas `IPv4` had an average RTT of 272.78 ms. They assume that `IPv6` packets have to take longer routes, because there are fewer `IPv6` routers attached to Internet exchanges. This in turn also, they say, explains why the hop count for `IPv6` routes is often shorter than for `IPv4` routes.

2.4 2012: Measuring the Deployment of IPv6: Topology, Routing and Performance

Dhamdhere et al.[1] used five different nodes to measure the performance to 544 end-points. While they do not supply raw measurement values they present that in 79% of all cases, the performance op `IPv6` was within 10% of `IPv4`, occasionally even faster, if the forward AS-level path was the same in both protocols. On the other hand this number drops down to 63% if the forward AS-level paths were different. They conclude though that considering AS-path length might be skewed in favor of a single provider, Hurricane Electric (HE). HE predominates the `IPv6` topology significantly more than the most predominant AS in the `IPv4` topology, the researchers say. Ultimately though, while currently only 40-50% of AS paths are identical, this number could rise up to 95% if current `IPv6`-capable ASes established equivalent peerings in `IPv4` and `IPv6`.

2.5 2016: Packet delay, loss and reordering in IPv6 world: A case study

This research[4] by Li, Wang, Pan and Yang uses a purpose written software, namely `OneProbe`, to collect measurement data. The developers of `OneProbe` describe it as:

> [...] a new method for measuring a non-cooperative path's quality. The measurement is conducted in one or more concurrent TCP connections by an endpoint of the path under measurement. The main novelty is the capability of measuring, in addition to round-trip time, unidirectional packet loss rate, packet reordering rate and capacity from the same packet-pair probes.

Their measurement node is located within the China Education and Research Network (CERNET2) and endpoints have been chosen randomly from the top 1M entries of Alexa. Furthermore the endpoints are sorted in in terms of the five Regional Internet Registries (RIRs), i.e., APNIC, ARIN, AFRINIC, LACNIC, and RIPENCC. Their comparison of the average `IPv4` and `IPv6` RTT data across all

Nodes per country							
DK	1	EE	1	AT	2	RU	4
ID	1	IN	1	BY	2	NL	6
IT	1	MU	1	HU	2	NO	8
MV	1	MZ	1	LU	2	GB	9
NC	1	NZ	1	CZ	3	FR	11
PL	1	RO	1	SE	3	US	11
RS	1	SG	1	CH	3	CA	27
SI	1	VU	1	FI	3	DE	32
ZA	1	JP	2	UA	3		

Table 1. All nodes

RIRs shows, that only a difference of 3.23 ms exists (`IPv4`: 244.48ms - `IPv6`: 247.71 ms).

Just as in the 2012 study by Dhamdhere et al.[1] they conclude that if AS-paths are similar between the two Internet Protocol versions, then the performance is also similar.

3. METHODOLOGY

The measurement data collection has been designed as follows:

3.1 RIPE Atlas Nodes

Via the web-interface of the `RIPE Atlas` platform new measurements have been created. These measurements will use the same 150 randomly selected `RIPE Atlas` nodes to guarantee consistency among the measurements. These 150 nodes will then run `traceroute` commands in a periodic fashion for one week to three end-points. `RIPE Atlas` uses a credit system to pay for these measurements and credits can be earned by hosting a node. For this research 1,000,000 credits were available. The projected costs for all measurements are roughly 800,000 credits.

Within this pool of 150 nodes, there are also a few non-responders. Some of those nodes have never generated any measurement data, while others only errored a few times. The nodes with no data have been fully excluded from the statistical analysis which follows in 3.5. Additionally nodes which haven't atleast participated in 75% of all measurements, will also be excluded. The cut-off point of 75% has been arbitrarily chosen.

Reasons for failed measurements are plenty. The node might temporary be offline, or permanently after being selected for this study. Furthermore there could be firewalls or BGP routing issues. Roughly 80% of all nodes though have participated in 100% of the measurements.

As can be seen from table 1 there is an over-representation of Germany (DE) and Canada (CA). This might have several reasons, e.g. `RIPE Atlas`' randomize function is biased, in addition to Germany and Canada both supplying a larger number of nodes (DE = 2000, CA = 400) compared to less inter-connected and possibly less developed countries like Afghanistan or African Samoa (AF = 8, AS = 0 [2 offline]).

3.2 Measurement End-Points

The endpoints are a server in each of the following locations:

- Enschede, The Netherlands
- Hünenberg, Switzerland
- Moscow, Russia

Contrary to other studies where the endpoints often consist of entries from Alexa's top 1 million visited domains this study uses general purpose Servers for this measurement. The reason for this decision is that high traffic websites often deploy path optimization techniques which could alter the results of the study. Two examples for this are Anycast IPs and Content Delivery Networks (CDNs).

In Anycast an IP address is announced on multiple routers at the same time and due to the way BGP announcements work, a measurement node will choose the router which is closest. Similarly, a CDN might have several websites cached in close proximity to one largely consumer oriented ISP, whereas another ISP has no such agreement.

In this study it can be guaranteed that for each of the above mentioned servers the same ethernet adapter has been assigned a static IPv4 and IPv6 address. Furthermore CDNs or Anycast have not been used.

3.3 Measurement Time-Points

The periodic measurements have been set up to be run four times per day for one week. The exact times are: 07:00, 13:00, 19:00 and 01:00 CEST.

Data collection started on Tuesday the 13^{th} of June *2017* at 07:00 and ended on Tuesday the 20^{th} of June *2017* at 01:00.

These measurement time-points have been chosen for the following reasons:

Firstly because some of the `RIPE Atlas` nodes might be hosted on a residential internet connection, they are prone to random restarts (a common end-user practice is to restart the modem and router if one experiences "internet problems").

Secondly these values roughly correspond with the maximum and minimum internet usage in Europe. Consulting the two largest internet exchanges in Europe, the `AMS-IX` and `DE-CIX` shows that data throughput is at its lowest during the hours of 03:00 and 08:00 a small plateau can be seen between 11:00 and 17:00 with its peak finally between 19:00 and 01:00.

3.4 Data Parsing

Every successful `traceroute` consists of three RTT values. The average of these RTTs will be reported as final measurement for a given time stamp. A small `Java` program has been written to parse the `JSON`-files which contain the measurement data. The `Java` program will then output the measurement data in a format which can be used by SPSS for further statistical analysis.

As can be seen in 2, `Node 20` and `Node 93` have each tried to create a measurement at 01:00 on the 15th of June. The third column represents IPv4 measurements, where apparently `Node 93` had a faulty measurement.

Node	Date-v4	RTT	Date-v6	RTT
20	2017/06/15-01	60.1	2017/06/15-01	59.9
93	2017/06/15-01	NaN	2017/06/15-01	318.0

Table 2. Sample output to be used by SPSS

3.5 SPSS

For the statistical analysis of the data SPSS 24 will be used. Because every `traceroute` has two measurements (IPv4, IPv6) on the same node during different times of the day a *Paired Samples T-Test* may be used. Further exploration of the data however reveals that we may not assume a normal distribution of the RTT values. What can be inferred though, is that collected `IPv4` and `IPv6` data is non-parametric. As a result of this exploration a *Wilcoxon signed-rank test* will be used instead. All tests will be run with $\alpha = .05$. This means that the general null-hypothesis, as well as alternative-hypothesis will be:

Significant Measurements		
CC	Pair	Sig.
NL	V13 - V11	.042
	V53 - V51	.035
	V73 - V71	.004
	V89 - V87	.033
	V109 - V107	.018
CH	None	None
RU	V5 - V3	.050
	V17 - V15	.005
	V49 - V47	.001
	V61 - V59	.000
	V65 - V63	.017
	V73 - V71	.020
	V77 - V75	.000
	V81 - V79	.037
	V89 - V87	.028
	V93 - V91	.026
	V105 - V103	.034

Table 3. All measurements where $\alpha = .05$ has been applied

$$H_0 : \mu_{IPv4} = \mu_{IPv6}$$
$$H_1 : \mu_{IPv4} \neq \mu_{IPv6}$$

H_0 and H_1 will be applied to all measurement time-points within the same measurement end-point.

4. RESULTS

Figure 5, 6 and 7 show 27 measurement pairs per endpoint and their corresponding significance levels. Table 3 will list all significant measurement pairs from all three endpoints. Table 4 will then show to which time stamps the measurement pairs resolve. What can be immediately seen is that for the Swiss end-point all measurements seem to support H_0, that is there is statistically speaking no difference between `IPv4` and `IPv6`. The Netherlands shows five significant measurements while in Russia there are eleven.

Pair	Time Stamp
V65 - V63	2017/06/13 - 13:00
V105 - V103	2017/06/13 - 19:00
V81 - V79	2017/06/14 - 01:00
V93 - V91	2017/06/14 - 07:00
V17 - V15	2017/06/14 - 13:00
V49 - V47	2017/06/14 - 19:00
V5 - V3	2017/06/15 - 01:00
V53 - V51	2017/06/15 - 13:00
V109 - V107	2017/06/15 - 19:00
V89 - V87	2017/06/16 - 01:00
V13 - V11	2017/06/19 - 07:00
V73 - V71	2017/06/19 - 13:00
V61 - V59	2017/06/19 - 19:00
V77 - V75	2017/06/20 - 01:00

Table 4. Significant Time Stamps

Looking at the Dutch pairs first, we find that the five measurements can be split into two groups. Firstly three

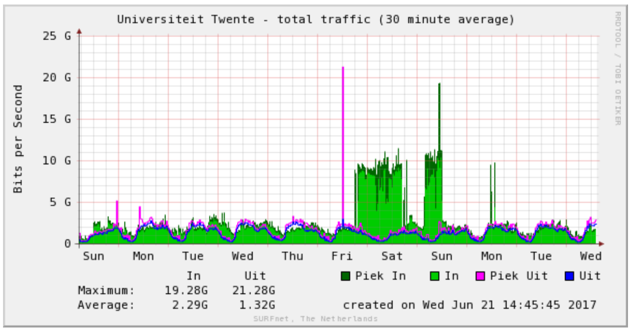

Figure 1. All in and outgoing traffic of the data-center which hosted the Dutch end-point

continuous measurements over the course of Wednesday the 15^{th} (13:00, 19:00) and partly Thursday 16^{th} (01:00). The second group belongs to Monday the 19^{th} (07:00, 13:00). Figure 1 shows that the University which hosted the Dutch end-point has sustained some high traffic flow during the measurements, but this seems to have been of no influence on the measurements.

The Russian pairs are dividable into three groups. The first group contains seven continuous measurements, during Tuesday the 13^{th} (13:00, 19:00), Wednesday the 14^{th} (01:00, 07:00, 13:00, 19:00) and partially Thursday the 15^{th} (01:00). This is interrupted by a single measurement on Friday the 16^{th} (01:00). Lastly three continuous measurements were recorded on Monday the 19^{th} (13:00, 19:00) and Tuesday the 20^{th} (01:00).

Additionally the average RTTs of all measurements per end-point and protocol have been calculated and plotted against each other in a scatter plot. Figure 2 shows the scatter plot of the Swiss end-point.

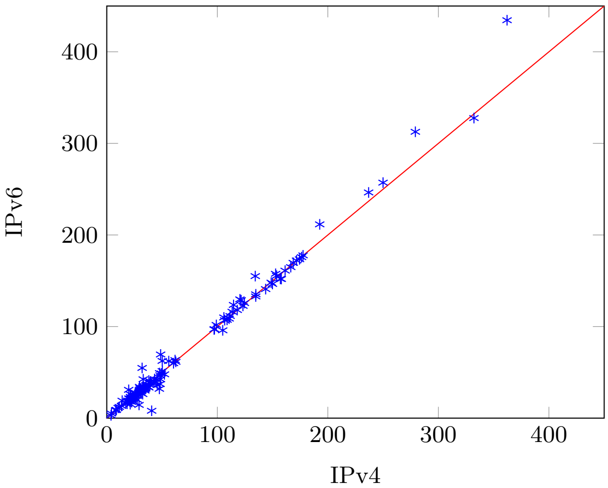

Figure 2. Scatter plot of the Swiss IPv4/IPv6 RTT distribution

There are three distinct clusters visible. Firstly the cluster under 100 ms: It consists of European nodes only. The second cluster from 100 to 200 ms consists of mostly US and Canadian nodes bar three exceptions, Indonesia, Mozambique and South Africa. The last cluster, from 200 ms onward are Japan, New Zealand, New Caledonia, Vanuatu and the Maldives.

We can also see that only very few values stray from the ideal line, if they do they tend to favor `IPv4`.

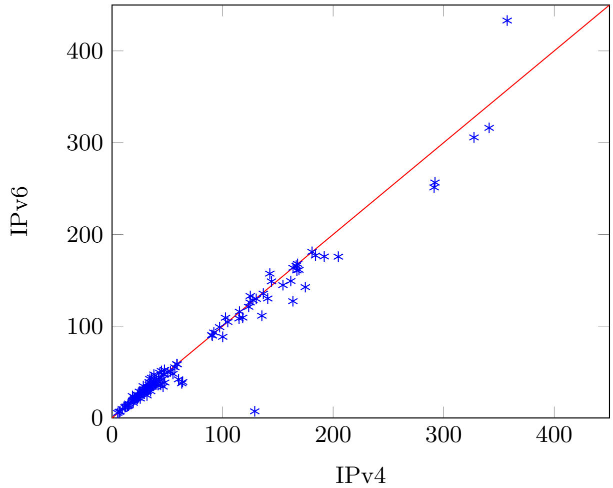

Figure 3. Scatter plot of the Dutch IPv4/IPv6 RTT distribution

The same clusters as mentioned before are also visible in figure 3. A general difference though is that if nodes stray from the ideal line they favor `IPv6`.

The plot of figure 4 depicts the Russian measurement results. In this graph there is still a stark contrast between cluster one and cluster two, but the difference between cluster two and cluster three is less pronounced. Additionally this graph very clearly shows the strong predilection towards `IPv4`.

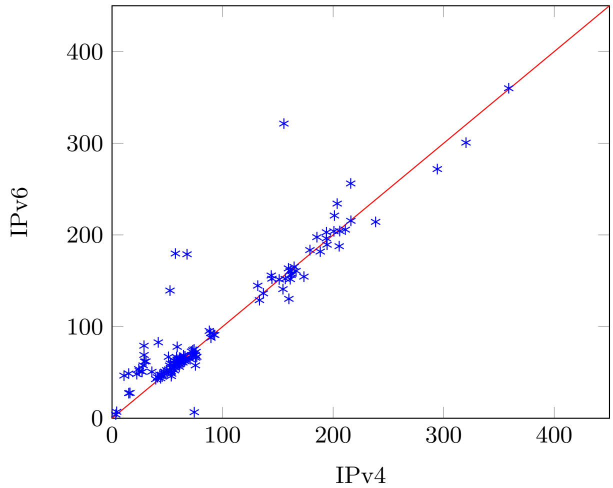

Figure 4. Scatter plot of the Russian IPv4/IPv6 RTT distribution

The Russian end-point exhibits some strange pathing rules. Looking at node `3628` for example: Its `IPv4` RTT is 10 ms for a connection within Russia, but 47 ms for the `IPv6` route. An inspection of both routes shows that the `IPv4` route is rather direct, from Saint-Petersburg to Moscow. `IPv6` on the other hand first travels to Stockholm, while then traveling back the same path.

Something similar happens for node `12291` from Finland. The `IPv4` path travels via Saint-Petersburg to Helsinki in 15 ms. `IPv6` takes roughly three times as long, 49 ms, by first traveling to Frankfurt and from there further to Helsinki.

This behavior can be found in other Russian nodes as well.

To investigate a possible relation between RTT and pathing the average RTT has been plotted against its average hop count. This has been done for the Swiss as well as the Russian end-point. The results can be seen in figure 8, 9, 10 and 11.

Figure 8 and 9 exhibit a very similar design which is also visible in the average hops per protocol: 10.3 for `IPv4` and 10.2 for `IPv6`.

The Russian end-point on the other hand shows significant differences. While the `IPv4` plot (10) is similar to the Swiss `IPv4` plot (8), the Russian `IPv6` plot (11) shows an elongated form of the clusters. The average hops for `IPv4` are 9.5 and for `IPv6` 10.9 .

5. DISCUSSION

All of the significant measurements, bar one, were continuous measurements, this makes it less likely that these measurements were a random occurrence. Plausible reasons for the significance of the measurements are a broken core router or an increase in Internet traffic due to a popular (online) event. But something that seems more likely would be temporary routing issues. While compiling the results for this paper, we have occasionally tracerouted connections with a big difference in RTT. In some cases the RTTs were very similar, contrary to the measured data. In other cases, such as the previously presented path from Moscow to Helsinki the problems persist. We assume that sub optimal peering agreements between providers are at play. This is further supported by the fact that the Swiss end-point exhibits a very similar hop count for its `IPv4` and `IPv6` paths, whereas the Russian end-point

6. CONCLUSION

The goal of this study was to find out if there is any discernible difference between `IPv4` and `IPv6` RTT performance. According to the results presented in this paper supporting evidence has been only found in cases of sub optimal pathing due to peering agreements.

7. FUTURE WORK

Because the Internet is very dynamic and routes between hosts aren't static one should also look at the underlying AS paths that make up a single route from one host to another. Many routes use a shared intermediate AS path and diverge only at the end.

According to this study the Swiss end-point found no difference between `IPv4` and `IPv6`. Even though the Netherlands and Switzerland are both neighboring countries to Germany it could be investigated if connectivity from Germany is better to Switzerland, than to the Netherlands (As a large fraction of the nodes came from Germany). For this study the `RIPE Atlas` platform could be used to only employ nodes from within Germany.

Another possible research could be done on the effects of "`IPv6`-only" ISPs, such as Unitymedia mentioned in the introduction. Again `RIPE Atlas` may provide nodes from the corresponding `AS` of the ISP.

8. REFERENCES

[1] Dhamdhere, A., Luckie, M., Huffaker, B., claffy, k., Elmokashfi, A., and Aben, E. Measuring the deployment of ipv6: Topology, routing and performance. In *Proceedings of the 2012 Internet Measurement Conference* (New York, NY, USA, 2012), IMC '12, ACM, pp. 537–550.

[2] kuhnikuehnast. *Internetgeschwindigkeit über IPV4 viel langsamer als über IPV6?*, 2016 (accessed May 16, 2017). `https://www.computerbase.de/forum/showthread.php?t=1574641`.

[3] Law, Y.-N., Lai, M.-C., Tan, W. L., and Lau, W. C. Empirical performance of ipv6 vs. ipv4 under a dual-stack environment. In *Communications, 2008. ICC'08. IEEE International Conference on* (2008), IEEE, pp. 5924–5929.

[4] Li, F., Wang, X., Pan, T., and Yang, J. Packet delay, loss and reordering in ipv6 world: A case study. In *2016 International Conference on Computing, Networking and Communications (ICNC)* (Feb 2016), pp. 1–6.

[5] Schamberg, J. *Unitymedia: Neukunden erhalten nur noch IPv6-Adressen*, 2013 (accessed May 16, 2017). `https://www.onlinekosten.de/news/unitymedia-neukunden-erhalten-nur-noch-ipv6-adressen_190258.html`.

[6] Shiau, W.-L., Li, Y.-F., Chao, H.-C., and Hsu, P.-Y. Evaluating ipv6 on a large-scale network. *Computer communications 29*, 16 (2006), 3113–3121.

[7] Wang, Y., Ye, S., and Li, X. Understanding current ipv6 performance: a measurement study. In *Computers and Communications, 2005. ISCC 2005. Proceedings. 10th IEEE Symposium on* (2005), IEEE, pp. 71–76.

[8] Zhou, X., and Van Mieghem, P. Hopcount and e2e delay: Ipv6 versus ipv4. In *International Workshop on Passive and Active Network Measurement* (2005), Springer, pp. 345–348.

Test Statistics - NL[a]

	V5 - V3	V9 - V7	V13 - V11	V17 - V15	V21 - V19	V25 - V23	V29 - V27	V33 - V31	V37 - V35	V41 - V39	V45 - V43	V49 - V47	V53 - V51	V57 - V55
Z	-1,108[b]	-1,500[b]	-2,032[b]	-,502[b]	-1,811[b]	-,904[b]	-,656[b]	-1,112[b]	-1,874[b]	-1,391[b]	-,721[b]	-1,095[b]	-2,108[b]	-1,209[b]
Asymp. Sig. (2-tailed)	,268	,134	,042	,616	,070	,366	,512	,266	,061	,164	,471	,273	,035	,226

	V61 - V59	V65 - V63	V69 - V67	V73 - V71	V77 - V75	V81 - V79	V85 - V83	V89 - V87	V93 - V91	V97 - V95	V101 - V99	V105 - V103	V109 - V107
Z	-,789[b]	-1,248[b]	-,925[b]	-2,845[b]	-,229[b]	-,340[c]	-1,165[b]	-2,130[b]	-,367[b]	-1,501[b]	-1,847[b]	-1,421[b]	-2,367[b]
Asymp. Sig. (2-tailed)	,430	,212	,355	,004	,819	,734	,244	,033	,714	,133	,065	,155	,018

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Figure 5. Paired Samples Test - Enschede

Test Statistics - CH[a]

	V5 - V3	V9 - V7	V13 - V11	V17 - V15	V21 - V19	V25 - V23	V29 - V27	V33 - V31	V37 - V35	V41 - V39	V45 - V43	V49 - V47	V53 - V51	V57 - V55
Z	-,313[b]	-,876[b]	-,674[b]	-1,499[b]	-,291[b]	-1,227[b]	-,036[b]	-,958[b]	-,984[b]	-,782[b]	-1,528[b]	-1,205[b]	-1,337[b]	-,873[b]
Asymp. Sig. (2-tailed)	,754	,381	,500	,134	,771	,220	,971	,338	,325	,434	,127	,228	,181	,383

	V61 - V59	V65 - V63	V69 - V67	V73 - V71	V77 - V75	V81 - V79	V85 - V83	V89 - V87	V93 - V91	V97 - V95	V101 - V99	V105 - V103	V109 - V107
Z	-1,435[b]	-1,760[b]	-,620[b]	-1,598[b]	-1,097[b]	-,540[b]	-,739[b]	-,908[b]	-1,070[b]	-,069[b]	-,481[b]	-,164[c]	-,556[b]
Asymp. Sig. (2-tailed)	,151	,078	,535	,110	,273	,589	,460	,364	,285	,945	,630	,869	,578

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Figure 6. Paired Samples Test - Hünenberg

Test Statistics - RU[a]

	V5 - V3	V9 - V7	V13 - V11	V17 - V15	V21 - V19	V25 - V23	V29 - V27	V33 - V31	V37 - V35	V41 - V39	V45 - V43	V49 - V47	V53 - V51	V57 - V55
Z	-1,962[b]	-1,332[b]	-,098[c]	-2,800[b]	-,965[b]	-1,716[b]	-,658[b]	-1,897[b]	-1,381[b]	-1,941[b]	-1,133[b]	-3,245[b]	-1,072[b]	-1,569[b]
Asymp. Sig. (2-tailed)	,050	,183	,922	,005	,335	,086	,511	,058	,167	,052	,257	,001	,284	,117

	V61 - V59	V65 - V63	V69 - V67	V73 - V71	V77 - V75	V81 - V79	V85 - V83	V89 - V87	V93 - V91	V97 - V95	V101 - V99	V105 - V103	V109 - V107
Z	-6,794[b]	-2,388[b]	-1,059[b]	-2,324[b]	-5,384[b]	-2,087[b]	-1,473[b]	-2,191[b]	-2,225[b]	-1,779[b]	-1,802[b]	-2,116[b]	-1,865[b]
Asymp. Sig. (2-tailed)	,000	,017	,290	,020	,000	,037	,141	,028	,026	,075	,072	,034	,062

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Figure 7. Paired Samples Test - Moscow

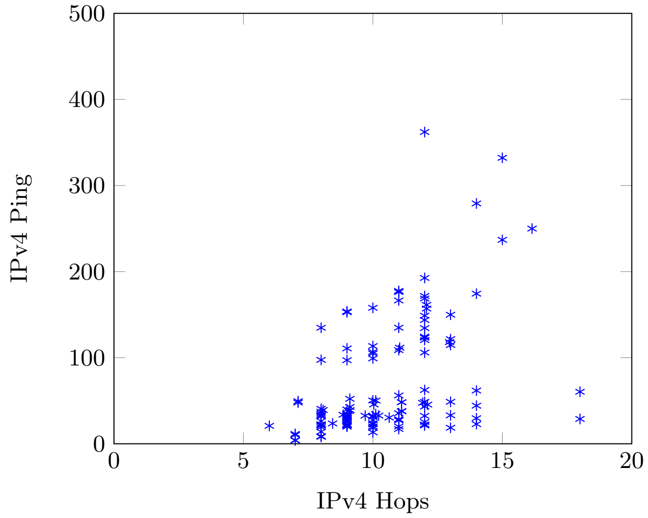

Figure 8. Scatter plot of the Swiss IPv4 Hops/RTT distribution

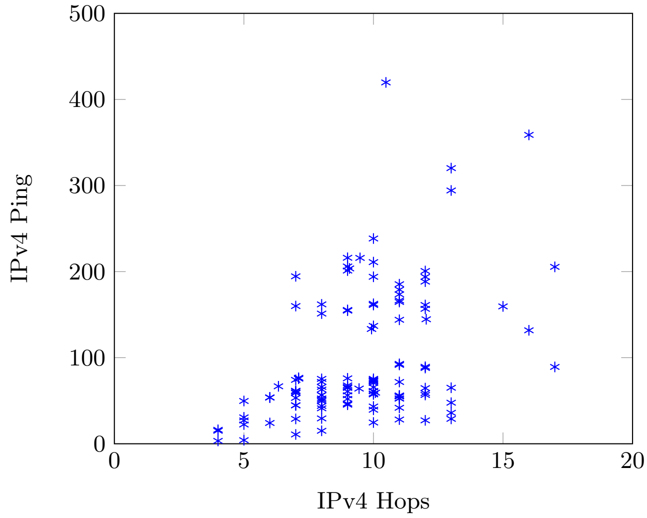

Figure 10. Scatter plot of the Russian IPv4 Hops/ RTT distribution

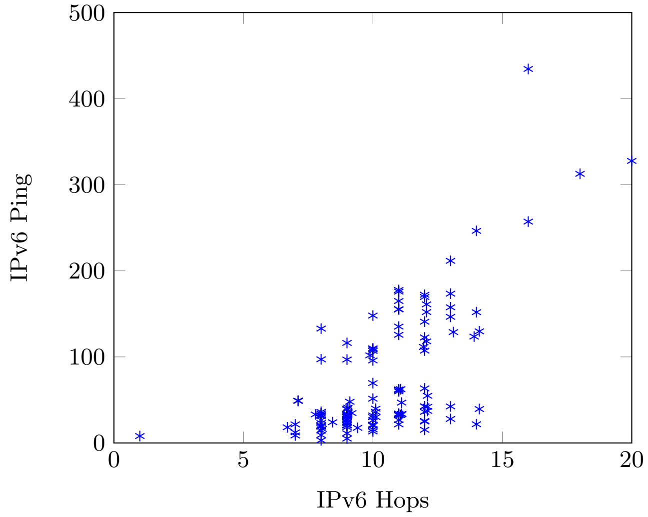

Figure 9. Scatter plot of the Swiss IPv6 Hops/ RTT distribution

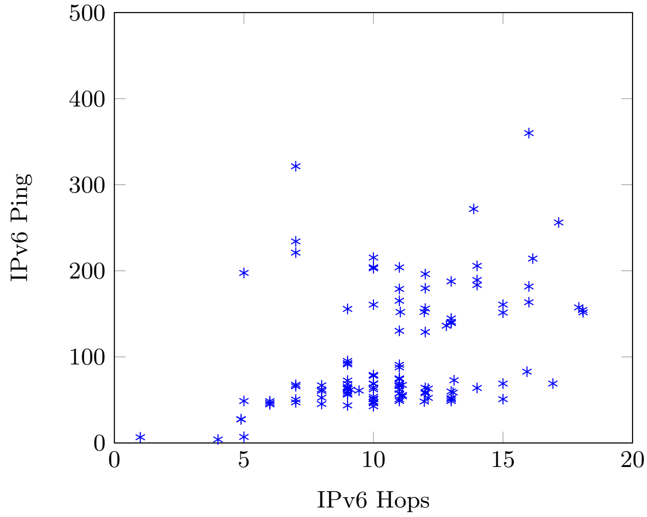

Figure 11. Scatter plot of the Russian IPv6 Hops/ RTT distribution