Hopcount and E2E Delay: IPv6 Versus IPv4

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Abstract. IPv6 provides an expanded address space to satisfy the future Internet requirements. In this paper we compare and analyze one-month measurements of the end-to-end IPv6 delay and hopcount between 26 testboxes of the RIPE TTM project with the corresponding parts in IPv4 network. By comparing IPv6 and IPv4 paths, we focus on problems that are only present in the IPv6 paths. In those poorly performing IPv6 paths, we run traceroute with the path maximum transmission unit (MTU) discovery to identify the problems and their causes.

1 Introduction

IPv6 is the next generation IP protocol to replace the current IPv4. IPv6 provides an expanded address space, and supports new Internet applications that require advanced features to provide services like real-time audio. However, IPv6 is still in its infancy and is rarely used. Because the network performance directly influences the user experience in many applications, such as online chatting and games, the poor IPv6 performance certainly limits its deployment. To qualify the IPv6 infrastructure, it is interesting to compare the IPv6 and IPv4 measurements under the current network situations. Specifically, for each source-destination pair, i.e. between 26 textboxes of RIPE NCC TTM project [1], we collect routing and one-way delay information using IPv4 and IPv6 versions of traceroute and delay measurements, and compare the routing and delay data on a path-by-path basis. By comparing IPv6 and IPv4 paths, we focus on problems only present in the IPv6 paths, and run traceroute with path MTU discovery to identify the causes.

2 Measurement results

2.1 Statistical results of delays, IP Delay Variation and hopcount

Statistical results of source-destination delays Real-time applications will not perform well if the end-to-end delays between the communicating parties exceed a certain QoS delay threshold. For example, in case of VoIP, to maintain the high quality of voice, packets need to be received within about 150 millisecond (ms). The importance of Internet delay for providing QoS triggered us to examine the congestion-free delay of each pair as a function of time. The congestion-free delay is computed as the minimum end-to-end IPv4 and IPv6 delay. We repeated the experiments to calculate the average delay of each pair. The delay can depend on the geographical distance. The results show that 37% of the IPv6 paths and 39% of the IPv4 paths have a minimal delay less than 10 ms, while 88% and 92% less than 50 ms, respectively. We also found that 25% of the IPv6 paths and 32% of the IPv4 paths have an average delay less than 10 ms, while 86% and 90% less than 50 ms, respectively.

IP Delay Variation The one way IP delay variation (ΔD) is defined in RFC 3393. Low IP delay variation is important for applications requiring timely delivery of packets. For each source-destination pair, we compute ΔD for both IPv6 and IPv4 paths, from which we constructed the pdf (probability density function) of the IPDV. We categorize four main classes: Class 1 is a typical distribution. It is a symmetrical distribution with short tails. Class 1 has 97.5% of the delay variation smaller than +/- 20 ms. To isolate high quality connections, a subclass 1b is introduced, which contains plots with less than +/- 1 ms of delay variation. Class 1 is characteristic for a good quality in transmission. Class 2 is similar to Class 1 except that there are many variations exceeding 20 ms; Class 3 is a symmetric distribution with more than one peak, which is mainly caused by path switching. We observed that only about 18% of IPv6 traffic are of class 1b, while about 31% in IPv4; about 60.2% of IPv6 traffic are of class 1, while about 69% in IPv4; about 34.7% of IPv6 traffic are of class 2, while about 24.4% in IPv4; about 5.1% of IPv6 traffic are of class 3, while about 6.7% in IPv4. The experiments confirm that compared to IPv4, IPv6 paths suffer from a larger delay variation, which has a significant impact on the real-time application since more buffering in the end host is required.

Statistical results of hopcounts The pdf of hopcounts (H) in Internet contributes to our understanding of the Internet's topological structure. All traceroute IP paths were converted to AS paths from the RIPE Whois database. In the traceroute data from the remaining boxes a total of 630 most dominant paths have been determined. From the pdf of the hopcount of those paths shown in Figure 1.a, we found that both IP hopcount and AS hopcount in IPv6 are alike their corresponding parts in IPv4. The interesting distinguishing factor between AS hopcounts and IP hopcounts lies in the ratio $\alpha = \frac{E[H]}{var[H]}$. For IPv6 and IPv4, we found approximately $\alpha \approx 1$ in the IP level, while $\alpha \approx 2$ in the AS level, respectively. These observations suggest that, to first order, the IP hopcount might be close to a Poisson random variable as explained in [2], while the AS hopcount behaves differently.

2.2 Comparison of IPv6 delays and IPv4 delays

For each source-destination pair, we compare the IPv6 and IPv4 delay data on a path-by-path basis. Figure 1.b shows the scatter plot of the IPv6 delays versus

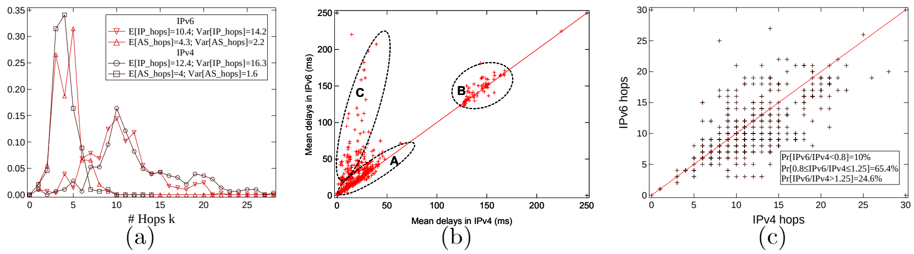

Fig. 1. (a) The hopcount distribution in the experiments; (b) Distribution of IPv6/IPv4 one-way delay; and (c) Distribution of IPv6/IPv4 hop

the IPv4 delays, where IPv6 delay is on the Y-axis while IPv4 delay on the X-axis. Each data point corresponds to a pair of peers. In Figure 1.b, following the idea from [3], the data points are approximately classified into three groups by R, the ratio of the IPv6 over the IPv4 one-way delay: group A for the European pairs with equal R ($0.8 \leq R \leq 1.25$) or small R ($R<0.8$); group B for the continent pairs (Europe-Japan, Europe-USA and USA-Japan) with equal or small R; and group C for the pairs with large R ($R>1.25$). The results indicate that compared with IPv4 paths about 54% of pairs are of group A, about 10% of group B, while about 36% of group C.

These poorly performing IPv6 paths (shown in the group C) consisted of several test-boxes located in different European counties (like UK, IT and NL). The large delay ratios might be a result of high level of IPv4 commitment and relatively low level of IPv6 responding in Europe. We repeat the experiments with the IP level hopcount. The results shown in Figure 1.c indicate that most IP level hopcounts are alike in IPv6 and IPv4.

2.3 Traceroute results

For those 229 selected IPv6 paths whose IPv6:IPv4 delay ratios R are large, we run traceroute to identify specific problems and their causes. Many IPv6 networks use tunnels. Traceroute6 is one of the many tools used to obtain the quality of connectivity in a route. The experiments show that it is common for IPv6 paths to traverse different ASes than their IPv4 counterparts. The results also suggest that many problems lie in routing (e.g., 20 paths suffered routing loops, where 10 are native paths, while another 10 went through tunnels). The poor performance in IPv6 might be due to some poorly configured tunnels that disregard the underlying topologies. Tunnels are useful during the early stages of IPv6 deployment, but poorly configured tunnels lead to performance problems. In addition to the traceroute measurements, we use path MTU discovery to identify IPv6-in-IPv4 tunnels in those poorly performing IPv6 paths. The Tunnel discovery Tool allows us to detect an IPv6 tunnel by measuring the MTU over an entire path, since a drop in MTU at an intermediate router indicates a possible tunnel entry point. About 48.8% of those selected IPv6 paths went through native paths, while about 26.2% went through IPv6-in-IPv4 tunnels, about 21.3% went throught Generic Routing Encapsulation tunnels; and about 3.8% used BSD tunnels. We expect that a decrease in the delay is possible because of the continuous improvements of IPv6 paths: the IPv6 in IPv4 tunnels are replaced with native IPv6 paths, and the IPv6 forwarding capability of routers in the path is improved. However, for those about 49% IPv6-native paths, we could not assert the precise causes of the poor performance.

3 Conclusion

Although IPv6 will replace IPv4 in the future, it is expected that IPv4 and IPv6 hosts will coexist for a substantial time during the steady migration from IPv6 to IPv4. To qualify the IPv6 infrastructure, it is interesting to compare the IPv6 and IPv4 measurements under the current network situations. Specifically, for each source-destination pair, we have collected the routing and delay information using both the IPv4 and the IPv6 versions of the traceroute and delay measurements, and have compared the delay data on a path-by-path basis. We have focused on problems that were only present in the IPv6 paths, and have run traceroute with path MTU discovery for identifying the causes. From our experiments, we can draw the following conclusions:

- 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;
- Compared with IPv4 paths, about 36% of the IPv6 paths are suffering from a significantly larger delay;
- The poorly performing IPv6 paths might be due to some badly configured tunnels that disregard the underlying topologies.

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References

1. RIPE Test Traffic Measurements, http://www.ripe.net/ttm
2. Van Mieghem, P., G. Hooghiemstra and R. W. van der Hofstad, "Scaling Law for the Hopcount", Delft University of Technology, report2000125, 2000
3. K.Cho, M.Luckie and B.Huffaker. Identifying IPv6 Network Problems in the Dual-Stack World. SIGCOMM'04 Network Troubleshooting Workshop, Portland, Oregon, September 2004