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Some Measurements on World IPv6 Day from End-User Perspective
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Abstract

During the World IPv6 Day on June 8th, 2011, several key content providers enabled their networks to offer both IPv4 and IPv6 services. Hundreds of organizations participated in this effort, and in the months and weeks leading up to the event worked hard on preparing their networks to support this event. The event was largely unnoticed by the general public, which is a good thing since it means that no major problems were detected. For the Internet, however, there was a major change on such a small timescale. This memo discusses measurements that the authors made from the perspective of an end-user with good IPv4 and IPv6 connectivity. Our measurements include the number of most popular networks providing AAAA records for their service as well as delay and connection failure statistics.

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1. Introduction

Many large content providers participated in World IPv6 Day on June 8, 2011. On that day, IPv6 [RFC2460] was enabled by default for 24 hours on numerous networks and sites that previously supported only IPv4. The aim was to identify any remaining issues with widespread IPv6 usage in these networks. Most of the potential problems associated with using IPv6 are, after all, of a practical nature, such as: ensuring that the necessary components have IPv6 turned on; that configurations are correct; and that any implementation bugs have been removed.

Some content providers have been reluctant to enable IPv6. The reasons for this include delays for applications attempting to connect over broken IPv6 links before falling back to IPv4 [RFC6555], and unreliable IPv6 connectivity. Bad IPv6 routing has been behind many of the problems. Among the causes are broken 6to4 tunneling protocol [RFC3056] connectivity, experimental IPv6 setups that are untested and unmonitored, and configuration problems with firewalls. The situation is improving as more users and operators put IPv6 to use and fix the problems that emerge.

World IPv6 Day event was largely unnoticed by the general public, which is a good thing since it means that no major problems were detected. Existing IPv4 connectivity was not damaged by IPv6 and also new IPv6 connectivity worked as expected in vast majority of cases. For the Internet, however, there was a major change on such a small timescale. This memo discusses measurements that the authors made from the perspective of an end-user with well-working IPv4 and IPv6 connectivity. Our measurements include the number of most popular networks providing AAAA records for their service as well as delay and connection failure statistics.

The rest of this memo is structured as follows. Section 2 discusses the goals of our measurements, Section 3 describes our measurement methodology, Section 4 gives our preliminary results, and Section 5 draws some conclusions.

2. Motivation and Goals

Practical IPv6 deployment plans benefit from accurate information about the extent to which IPv6 can be used for communication, and how its characteristics differ from those of IPv4. For instance, operators planning to deploy dual-stack networking may wish to understand what fraction of their traffic would move to IPv6. This information is useful for estimating the necessary capacity to deal with the IPv6 traffic and impacts to the operator's IPv4

infrastructure or carrier-grade NAT devices as their traffic is reduced. Network owners also wish to understand the extent to which they can expect different delay characteristics or problems with IPv6 connectivity. The goals of our measurements were to help with these topics by answering the following questions:

o What fraction of most popular Internet sites offer AAAA records? How did the World IPv6 Day change the situation?

o How do the traffic characteristics differ between IPv4 and IPv6 on sites offering AAAA records? Are the connection failure rates similar? How are RTTs impacted?

There have been many measurements about some of these aspects from a service provider perspective, such as the Google studies on which end users have broken connectivity towards them. Our measurements start from a different angle, by assuming good dual-stack connectivity at the measurement end, and then probing the rest of the Internet to understand, for instance, how likely there are to be IPv6 connectivity problems, or what the delay differences are between IPv4 and IPv6. Similar studies have been performed by the Comcast IPv6 Adoption Monitor [IPv6Monitor] and RIPE NCC [RIPEv6Day].

3. Measurement Methodology

We used the top 10,000 sites of the Alexa 1 million most popular sites list [Alexa] from June 1st 2011. For each domain name in the list, we performed DNS queries with different host names. For IPv4 addresses (A records) we used host name "www" and also performed a query with just the domain name. For IPv6 addresses (AAAA records) we used also different combinations of host names that have been used for IPv6 sites, namely "www6", "ipv6", "v6", "ipv6.www", "www.ipv6", "v6.www", and "www.v6".

All DNS queries were initiated in the order listed above (first "www" and just the domain name for A-records, then "www", domain name, and different IPv6-host names for AAAA records) but the queries were done in parallel (i.e., without waiting for the previous query to finish). The first response for A and AAAA records and the corresponding host names were recorded. The queries had 3 second re-transmission timeout and if there wasn't any response for 10 seconds, all remaining queries for the site were canceled. We used a custom-made Perl script and the Net::DNS [net-dns] module for the DNS queries.

The measurement script used a bind9 DNS server running on the same host as was performing the measurement. The DNS cache of the server was flushed before each measurement run in order to detect the

changes in the DNS records in real-time. The host, and thus the DNS server, was not part of DNS IPv6 whitelisting agreements.

The local network where the host performing the measurements was has native IPv6 (dual-stack) connectivity. The IPv6 connectivity to the local network was provided by an IPv6-over-IPv4 tunnel from the network's default router to the ISP's IPv6 peering point.

After obtaining IP addresses for the site, if a site had both A and AAAA records, a simple C program was used to create TCP connections to the port 80 (HTTP) simultaneously using both IPv4 and IPv6 to the (first) IP addresses discovered from the DNS. The connection setup was repeated up to 10 times, giving up after the first failed attempt (but only after normal TCP re-transmissions). The connection setup delay was measured by recording the time immediately before and after the connect system call. The host used for measurements is a regular Linux PC with 2.6.32 version kernel and dual-stack Internet connection via Ethernet.

The measurements were started one week before the World IPv6 Day (on Wednesday, June 1st, 17:30 UTC) and were running until July 11th, once every three hours. One test run takes from two to two and a half hours to complete.

The accuracy and generality of the measurement results is limited by several factors. While we ran the tests in three different sites, most of the results discussed in this document present snapshots of the situation from just one measurement point, the Ericsson Research Finland premises, near Helsinki. Also, since one measurement run takes quite a long time, the network characteristics and DNS records may change even during a single run. The first DNS response was used for the TCP connectivity tests and this selection may result in selection of a non-optimal host; yet, a slight preference is given to the "www" and only-domain-name records since their queries were started before the others. While the host performing the measurements was otherwise idle, the local network was in regular office use during the measurements. The connectivity setup delay is collected in user space, with regular, non real-time, kernel implementation, resulting in small inaccuracies in the timing information.

4. Measurement Results

4.1. DNS AAAA Records

The number of top 10,000 sites with AAAA DNS records before, during, and after the World IPv6 Day, is shown in [DNS-top10k]. The

measurements performed during the World IPv6 Day are shown on the light gray background.

When the measurements began on June 1st, there were 245 sites (2.45%) of the top 10,000 sites with both A and AAAA record. During the following days the number of such sites slowly increased, reaching 306 sites at the measurement that was started 22:30 UTC on June 7th, the evening before the World IPv6 Day. When the World IPv6 Day officially started, the following measurement (1:30 UTC) recorded 383 sites, and the next one 472 sites. During the day the number of sites with AAAA records peaked at 491 (4.91% of the measured 10,000 sites) at 19:30 UTC.

When the World IPv6 Day was over, the number of AAAA records dropped nearly as fast as it had increased just 24 hours earlier. However, the number of sites stabilized around 310 and did not drop below 300 since, resulting in over 3% of the top 10,000 sites still having AAAA records at the end of our measurements.

While 274 sites had IPv6 enabled in their DNS for some of the tested host names one day before the World IPv6 Day, only 116 had it for the "www" host name that is commonly used when accessing a web site. The number of "www" host names with AAAA records more than tripled during the World IPv6 Day reaching 374 sites for 3 consecutive measurement runs (i.e., for at least 6 hours). Also the number of AAAA records for the "www" host name dropped steeply after the day and remained at around 160 sites since.

Similar but more pronounced trends can be seen if only top 100 of the most popular sites are taken into considerations, as show in [DNS-top100]. Here, the number of sites with some of the tested host names having an AAAA record was initially 14, jumped to 36 during the day, and eventually dropped to 13. Also, while none of the top 100 sites apparently had an AAAA record for their "www" host name before and after the World IPv6 day, during the day the number peaked at 30. Thus, roughly one third of the 100 most popular sites had IPv6 enabled for the World IPv6 Day.

Two other test sites in Sweden and Canada experienced similar trends with the DNS records. However, one of the sites used an external DNS server that was part of whitelisting agreements. There the number of sites with AAAA records before the World IPv6 Day was already higher (above 400) and hence the impact of the day was smaller as the amount of sites increased to same numbers as seen by the test site in Finland. With the whitelisted DNS server the level of sites remained above 450 after the day.

4.2. TCP Connection Setup

To test whether the IP addresses given by the DNS actually provide connectivity to the web site, and if there is any difference in the connection setup delay and failure rates with IPv4 and IPv6, we attempted to create TCP connections for all domains that contained both A and AAAA DNS records. The fraction of sites for which the first DNS response gave addresses that were not accessible with TCP to port 80 over IPv4 or IPv6 is shown in [TCP-fails].

There is a baseline failure rate with IPv4 around 1-3% that is fairly static throughout the test period. For hosts with AAAA records, the fraction of inaccessible sites was much higher: in the beginning up to one fourth of the tested hosts did not respond to TCP connection attempts. Much of this was likely due to the various test sites with different "IPv6 prefixes" (as discussed in Section 3); in the first run more than half of the tested sites with AAAA records used them for the first DNS response. Also, some of the hosts may not even be supposed to be accessed with HTTP but provide AAAA records for other purposes while some sites had clear configuration errors, such as localhost or link-local IPv6 addresses.

As the World IPv6 Day came closer, the number of inaccessible IPv6 sites decreased slowly and the number of sites with AAAA records increased at the same time, resulting in the failure ratio dropping to roughly 20% before the day. During the day the number of IPv6 sites increased rapidly but also the number of failures decreased and hence, at the end of the day, the failure ratio dropped to just above 10%. After the World IPv6 Day when many of the participating IPv6 hosts were taken off-line, the fraction of failed sites for IPv6 increased. However, since there was no increase in the absolute number of failed sites, the fraction of inaccessible sites remained at a lower level, between 15% and 20%, than before the day.

4.3. TCP Connection Delays

For sites that were accessible with both IPv4 and IPv6, we measured the time difference between establishing a TCP connection with IPv4 and IPv6. We took the median (as defined in Section 11.3 of [RFC2330]) of the time differences of all 10 connections, and then median and mean (of the median) over all sites; the result is shown in [timediff].

In general, the delay differences are small: median of medians stays less than 3ms off from zero (i.e., IPv4 and IPv6 delays being equal) and even the mean, which is more sensitive to outliers, stays most of the time within +/- 5ms; with the greatest spikes reaching to roughly -15ms (i.e., mean of median IPv6 delays being 15ms larger than for

IPv4 delays). Closer inspection of the results shows that the spikes are often caused by only one or a handful of sites with bad connectivity and multiple re-transmissions of TCP SYN and ACK packets resulting in connection setup delays an order of magnitude larger.

Surprisingly the median delay for IPv6 connections is in most cases equal to or smaller than the IPv4 delay, but during the World IPv6 Day, the IPv6 delays increased slightly and became (as median) slower than their IPv4 counterparts. One reason for such an effect was that some of the sites that enabled IPv6 for the World IPv6 Day, had extremely low, less than 10ms, IPv4 delay (e.g., due to Content Delivery Network (CDN) provider hosting the IPv4 site), but "regular", over hundred millisecond, delay for the IPv6 host.

More detailed analysis of the TCP connection setup delay differences, and the reasons behind them, is left for future work.

5. Conclusions

The World IPv6 Day had a very visible impact to the availability of content over IPv6, particularly when considering the top 100 content providers. It is difficult to find other examples of bigger one day swings in some characteristic of the Internet. However, the impact on end users was small, given that when dual-stack works correctly it should not be visible at the user level and that IPv6 availability for end users themselves is small.

The key conclusions are as follows:

o The day caused a large jump in the number of content providers providing AAAA DNS records on that day.

o The day caused a smaller but apparently permanent increase in the number of content providers supporting AAAA.

o Large and sudden swings in the relative amount of IPv4 vs. IPv6 traffic are possible merely by supporting a dual-stack access network and having a few large content providers offer their service either globally or to this particular network over IPv6.

o Large fraction of sites that published AAAA records for a name under their domain (be it "www" or "www6" or something else) were actually not responding to TCP SYN requests on IPv6. This fraction is far higher than that which we've seen in our previous measurements, and we are still determining why that is the case. Measurement errors or problems on our side of the network cannot be ruled out at this stage. In any case, it is also clear that as

new sites join, incomplete or in-progress configurations create more connectivity problems in the IPv6 Internet than we've seen before. Other measurements are needed to verify what the general level IPv6 connectivity is to addresses publicly listed in AAAA records.

- Even if the overall level of connection failures was high, activities on and around the IPv6 day appear to have caused a significant permanent drop in the number of failures.

- When IPv6 and IPv4 connectivity were both available, the delay characteristics appear very similar. In other words, most of the providers that made IPv6 connectivity available appear to provide a production quality network. TCP connection setup delay differences due to RTT differences between IPv4 and IPv6 connections are in general low. In the remaining differences in our measurements, random packet loss plays a major role. However, some sites can experience considerable differences simply because of different content distribution mechanisms used for IPv4 and IPv6 content.

It is promising that the amount of most popular Internet content on IPv6 was surprisingly high, roughly one third of top 100 sites (during the IPv6 day or with whitelisting enabled). However, other content on the Internet forms a long tail that is harder to move to IPv6. For instance, only 3% of the 10,000 most popular web sites provided their content over IPv6 before the IPv6 day. On a positive note, the top 100 sites form a very large part of overall Internet traffic [Labovitz] and thus even the top sites moving to IPv6 could represent a significant fraction of Internet traffic on IPv6. However, this requires that users are enabled to use IPv6 in their access networks. We believe that this should be the goal of future global IPv6 efforts.

6. Security Considerations

Security issues have not been discussed in this memo.

7. IANA Considerations

This memo has no IANA implications.

8. References

8.1. Normative References

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Appendix A. Acknowledgments

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