Understanding the Impact of Network Infrastructure Changes using Large-Scale Measurement Platforms

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Abstract. A number of large-scale measurement platforms have emerged in the last few years. These platforms have deployed thousands of measurement probes at strategic locations within the access and backbone networks and at residential gateways. The primary goal of these efforts is typically to measure the performance of broadband access networks and to help regulators sketch better policy decisions. We want to expand the goal further by using large-scale measurement platforms to understand the impact of network infrastructure changes.

1 Research Statement

The curiosity to understand the performance of the Internet from the user's vantage point let to the development of techniques to remotely probe broadband access networks. Dischinger *et al.* in [3], for instance, inject packet trains and use the responses received from residential gateways to infer broadband link characteristics. This led to the development of a number of software-based solutions such as `netalyzr` [8], that require explicit interactions with the broadband customer. Recently, the requirement for accurate measurements, coupled with efforts initiated by regulators to define data-driven standards, has led to the deployment of a number of large-scale measurement platforms that perform measurements using dedicated hardware probes not only from within Internet Service Provider (ISP) networks but also directly from home gateways.

In a recent study, sponsered by the Federal Communications Commission (FCC), Sundaresan *et al.* [10] have used measurement data from a swarm of deployed SamKnows probes to investigate the throughput and latency of access network links across multiple ISPs in the United States. They have analyzed this data together with data from their own Bismark platform [11] to investigate different traffic shaping policies enforced by ISPs and to understand the bufferbloat phenomenon. The empirical findings of this study have recently been repraised by Canadi *et al.* in [2] where they use crowdsourced data from `speedtest.net` to compare both results. The primary aim of all these activities is to measure

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the performance (e.g., bandwidth, latency, jitter) and reliability of broadband access networks and facilitate the regulators with research findings to help them make policy decisions [9].

Using a large-scale measurement platform we want to take this further and study the impact of network infrastructure changes. We want to define metrics, implement measurement tests and data analysis tools that help us answer questions of the form:

– *How does the performance of IPv6 compare to that of IPv4 in the real world?*
– *Can we identify a Carrier-Grade NAT (CGN) from a home gateway?*
– *Can we identify multiple layers of NAT from a home gateway?*
– *How much do web services centralize on Content Delivery Network (CDN)s?*
– *To what extend does the network experience depend on regionalization?*

In the past, we have performed an experimental evaluation of IPv6 transitioning technologies to identify how well current applications and protocols interoperate with them [1]. We are now participating in the Leone[1] project, whose primary goal is to define metrics and implement tests that can asses the end-user's quality of experience by analyzing data collected from measurements running on SamKnows probes.

2 Proposed Approach

SamKnows[2] specializes in the deployment of hardware-based probes that perform measurements to assess the performance of broadband access networks. The probes function by performing active measurements when the user is not aggressively using the network. RIPE Atlas[3] is another independent measurement infrastructure deployed by the RIPE Network Coordination Centre (RIPE NCC). It consists of thousands of hardware probes distributed around the globe that perform round-trip time (RTT) and traceroute measurements to a number of preconfigured destinations alongside DNS queries to DNS root servers.

Measurement Lab (M-Lab) [5] is an open, distributed platform to deploy Internet measurement tools. The measurement results are stored on Google's infrastructure. The tools vary from measuring TCP throughput and available bandwidth to emulating clients to identify end-user traffic differentiation policies [4, 6] to performing reverse traceroute lookups from arbitrary destinations [7].

It will only be possible to answer the aforementioned research questions with access to a large-scale measurement platform. As partners of the Leone consortium, we will leverage the infrastructure of our partners. We will define metrics particularly targetted to our research questions and complement them by implementing subsequent measurement tests. The developed measurement tests will be deployed in our partner's networks, but may also become part of SamKnows

[1] `http://leone-project.eu`
[2] `http://www.samknows.com`
[3] `https://atlas.ripe.net`

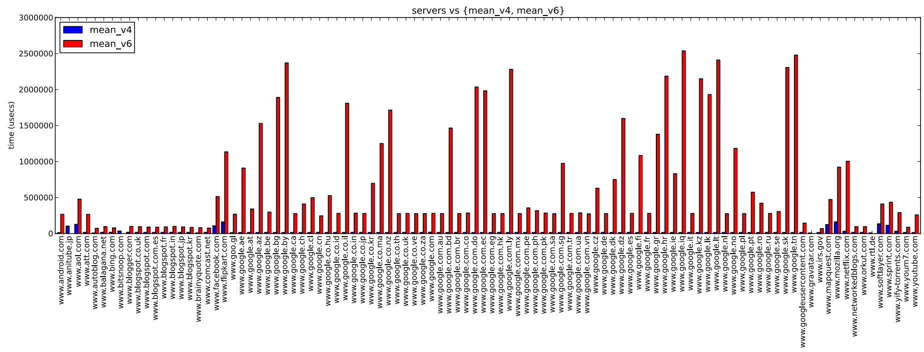

Fig. 1. Mean time to establish TCP connections to a list of web services. The measurement point is a virtual machine hosted at greatnet.de. It has IPv4 connectivity via LamdaNet Communications [AS13237] and IPv6 connectivity via Teredo.

global infrastructure. The SamKnows infrastructure already has several thousand deployed probes and will continue to grow during the project's lifetime. The collected data will be conglomerated from multiple measurement points and finally analyzed to uncover information needed to help us answer these questions. This requires to develop data analysis algorithms that can integrate data from different data sources such as address block allocations from Regional Internet Registry (RIR)s or prefix and path information from BGP route views. We have started with a study to assess how the user experience is effected by the deployment of IPv6.

3 Preliminary Results

A dual-stacked host with native IPv6 connectivity establishing a TCP connection to a dual-stacked web service prefers IPv6. This is because `getaddrinfo(...)` resolves a service name to a list of endpoints in an order that prioritizes an IPv6-upgrade path [12]. The dictated order can dramatically reduce the application's responsiveness in situations where IPv6 connectivity is broken, because the attempt to connect over an IPv4 endpoint will take place only when the IPv6 connection attempt has timed out, which can be in the order of seconds.

This noticeable degraded user experience can be subverted by implementing the happy eyeballs algorithm [13] in applications. The algorithm recommends that a host, after resolving the DNS name of a dual-stacked service, tries a TCP `connect(...)` to the first endpoint (usually IPv6). However, instead of waiting for a timeout, it only waits for 300ms, after which it must initiate another TCP `connect(...)` to an endpoint with a different address family and start a competition to pick the one that completes first. In this pursuit, to determine whether applications will use IPv4 or IPv6 on a dual stacked service, we developed `happy`, a simple TCP happy eyeballs probing tool. It uses non-blocking `connect(...)`

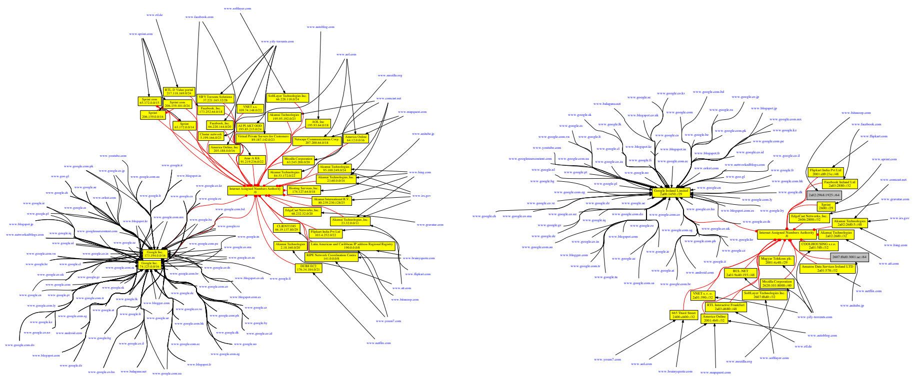

Fig. 2. An IPv4 (left) and IPv6 (right) aggregation cloud depicting how most of the services centralize on core content delivery networks and major cloud platforms (zoom in to see the details).

calls to concurrently establish connections to all endpoints of a service. We have cross-compiled `happy` for the OpenWrt platform, so that the tool can run on SamKnows probes. In order to develop data-analysis tools, we have prepared an internal test-bed of multiple measurement points. The measurement points have different flavors of IPv4 and IPv6 connectivity ranging from native IPv4, native IPv6, IPv6 tunnel broker endpoints, Teredo and tunnelled IPv4. We used the top 100 DNS names compiled by `he.net`[4] and ran `happy` on them.

A preliminary result comparing the mean time to establish a TCP connection to each of the services from one of the measurement points is shown in Fig. 1. The initial results show higher connection times over IPv6. Furthermore, on a Teredo IPv6 measurement point, an application will never use IPv6 except when IPv4 connectivity is broken, because the Teredo IPv6 prefix has a low priority in the address selection algorithm [12]. In addition, it appears, several services show very similar performance. These services either resolve to the same endpoint or a set of endpoints that belong to the same allocated address blocks. Digging through the `whois` information for each of the endpoints from their RIR seems to indicate that major portions of the services map to address blocks owned by organizations such as Google and Akamai Technologies as shown in Fig. 2.

4 Conclusion

Using our `happy` eyeballs probing tool we have performed a preliminary study on how IPv6 deployment may affect the quality of experience of Internet users. Using a large-scale measurement platform we want to take this further, and define new metrics, measurement tests and data analysis algorithms that help us uncover more insights into the impact of network infrastructure changes.

[4] `http://bgp.he.net/ipv6-progress-report.cgi`

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