Using Global Measurements to Understand the Evolution of the Internet

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Abstract. The abstract should summarize the contents of the paper and should contain at least 70 and at most 150 words. It should be written using the *abstract* environment.

1 Research Statement

An interest to understand the evolution of the Internet from the user' vantage point started with establishing techniques to remotely probe the broadband links. Dischinger *et al.* in [3] for instance, inject packet trains and use the responses received from gateway to infer the broadband link characteristics. This led to development of a number of software-based solutions, `netalyzr` [12], for instance, that require explicit interactions with the broadband consumer. Recently, the requirement for accurate measurements, coupled with Federal Communications Commission (FCC)' initiated efforts 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 the ISP' network but also directly from the home gateway.

In a recent study, sponsered by the FCC, Sundaresan *et al.* [14] have used such a 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 coupled this data with their own Bismark platform [15] to also investigate different traffic shaping policies enforced by the ISP and to understand the bufferbloat phenomenon [7]. The empirical findings of this study has recently been repraised by Canadi *et al.* in [2] where they use crowdsourced data from `speedtest.net` to compare both results. The primary aim is to measure the performance and reliability of broadband access networks and facilitate the regulators with research findings to help them make policy decisions that eliminate the ISP' monopoly [13]. As a result, the focus is on defining metrics and implement measurement tests that help achieve this goal.

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]. Using a large-scale measurement platform we want

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to take this further and study the IPv6 evolution and its repercussions. We want to describe metrics and implement measurement tests that help us answer questions of the form:

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

2 Proposed Approach

SamKnows [1] 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 less aggresively using the network. RIPE Atlas [2] is another independent measurement infrastructure deployed by RIPE Network Coordination Centre (RIPE NCC). It consists of thousands of probes distributed around the globe that perform round-trip time (RTT) and traceroute measurements to a number of preconfigured destinations alongside DNS queries to root DNS servers.

Measurement Lab (M-Lab) [5] is an open, distributed platform to deploy internet measurement tools and the resulting measurement data on Google' storage infrastructure. The tools vary from measuring TCP throughput and available bandwidth to emulating clients to identify end-user traffic differentiation policies [4, 10] to performing reverse traceroute lookups from arbitrary destinations [11]. All of the collected data is available in the public domain.

The answers to the aforementioned research questions will only materialize with access to an available large-scale measurement platform. We as partners of the Leone [3] consortium, will leverage the infrastructure of our partners: BT [4], TI [5] and SamKnows. The developed measurement tests will be deployed not only in our partner's ISP's network, but also in the already deployed SamKnows global infrastructure. The SamKnows infrastructure already has several thousand probes in the homes of broadband customers, and will continue to grow during the STREP lifetime.

3 Preliminary Results

A dual-stacked user when attempting to connect to a dual-stacked service traditionally prefers connecting over IPv6. This is because in POSIX systems, the

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

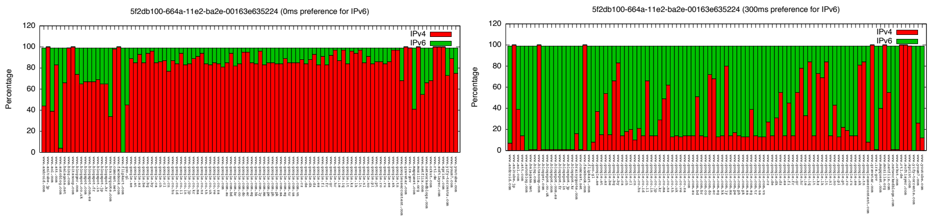

Fig. 1. IPv4 and IPv6 Happy Eyeball Competition

internal domain name resolution system call `getaddrinfo(...)` [8] returns the list of addresses in an order that prioritizes an IPv6-upgrade path [16]. The dictated order can dramatically reduce the application responsiveness in situations where IPv6 connectivity is broken. This is because, the attempt to connect over an IPv4 address 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 making applications apply the happy eyeballs algorithm [17]. The algorithm recommends that a dual-stacked application try resolving a dual-stacked service for both IPv4 and IPv6 addresses at once. If the resolver returns both addresses, the application must try a TCP `connect(...)` to both the resolved addresses and 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(...)` calls to establish concurrent connections to a number of possible endpoints of a service. The tool, however, does not check whether the endpoints of a given target all provide the same service. Hence, it is possible to impact the results by setting up fake servers that do not provide the service tested and which are designed and deployed with the only purpose to provide fast connection setup times.

We have cross-compiled `happy` for the OpenWRT [6] platform. As a result, the tool can now be run on widely deployed SamKnows probes [7], and the collected measurement data can be further analysed. In order to ascertain the value in this exercise, we 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 [6], Teredo [9] and tunnelled IPv4. We used the top 100 domains compiled by Hurricane Electric Internet Services [8] and ran `happy` on the set of dual-stack services represented by these domains.

A preliminary result comparing the preference of a happy-eyeballed application to IPv6 and IPv4 from one of our measurement points is shown in Fig. 1.

[6] `https://openwrt.org`
[7] `http://www.samknows.com`
[8] `http://bgp.he.net/ipv6-progress-report.cgi`

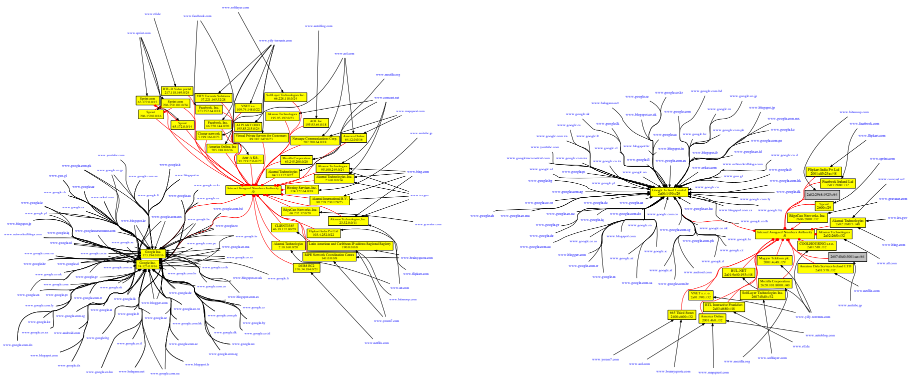

Fig. 2. IPv4 and IPv6 aggregation cloud

The measurement point represented in this plot is located at Braunschweig and has a native IPv4 and a IPv6 connection through the German Research Network [9]. The initial results show that happy eyeballs prevents IPv6 access to Facebook, with only a 20% chance to get to Google related services over IPv6. The plot looks very different if IPv6 endpoints are allowed a 300ms chance to succeed, but even then it appears the application will prefer to use IPv4 when reaching more popular web services. In addition, it appears, some of the related (and few of the unrelated) services show similar preferences. These services either resolve to the same endpoint or a set of endpoints that belong to an allocated block. Digging through the `whois` information for each of the endpoints from their Regional Internet Registry (RIR) seems to indicate that major portion of the services map to a cloud of an address block owned by popular organizations like Google and Akamai Technologies as shown in Fig. 2.

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[9] http://www.dfn.de

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