Using Large-Scale Measurement Platforms to Understand the Evolution of the Internet

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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 probes at strategic locations within the Internet Service Provider (ISP) and at the residential gateways to perform measurement tests. The primary goal of these efforts is typically to measure the performance of broadband access networks and to provide regulators with insights to help sketch better policy decisions. Using a large-scale measurement platform, we want to expand this goal further by designing metrics and measurement tests that help us understand the evolution of the Internet. We have started with a preliminary study to assess the growth of IPv6 and the repurcussions that it brings.

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 access network. Dischinger *et al.* in [3], for instance, inject packet trains and use the responses received from residential gateway to infer the 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 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.* [10] 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 [11] to investigate different traffic shaping policies enforced by the ISP and to understand the bufferbloat phenomenon. 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 of all these

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activities is to measure the performance and reliability of broadband access networks and facilitate the regulators with research findings to help them make policy decisions [9]. As a result, the focus is on defining metrics and implement measurement tests that help achieve this goal.

Using a large-scale measurement platform we want to take this further and study the evolution of the Internet and its repercussions. We want to define 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 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].

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 not aggressively using the network. RIPE Atlas[2] 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' 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]. All of the collected data is available in the public domain.

The answers to the aforementioned research questions will only materialize with access to a large-scale measurement platform. We as partners of the Leone[3] consortium, will leverage the infrastructure of our partners. 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 project' lifetime.

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

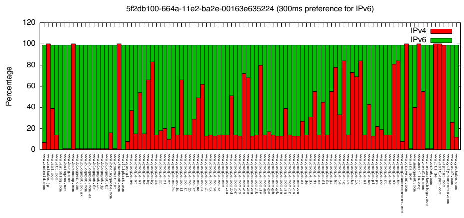

Fig. 1. Native IPv4 and Teredo Tunnel

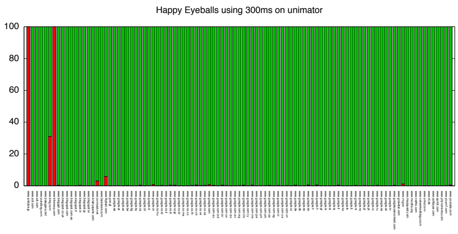

Fig. 2. Native IPv4 and Native IPv6

Fig. 3. IPv4 and IPv6 Happy Eyeball Competition

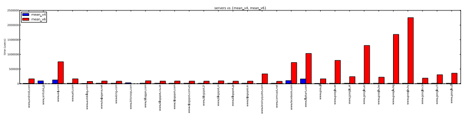

Fig. 4. Native IPv4 and Teredo Tunnel

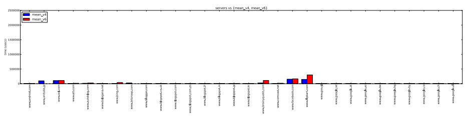

Fig. 5. Native IPv4 and Native IPv6

Fig. 6. Mean and Standard Deviations for IPv4 and IPv6

3 Preliminary Results

A user when attempting to connect to a dual-stacked web service prefers connecting over IPv6. This is because in POSIX systems, the domain name resolution system call `getaddrinfo(...)` returns a list of endpoints in an order that prioritizes an IPv6-upgrade path [12]. 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 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 making applications apply the happy eyeballs algorithm [13]. The algorithm recommends that a dual-stacked application resolves the DNS names of a dual-stacked service for both IPv4 and IPv6 endpoints at once. If the resolver returns both endpoints, the application must try a TCP `connect(...)` to both the endpoints pick the one that completes first. The connection attempt does prefer the first resolved address family (usually IPv6) by the order of 300ms though.

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 concurrently establish connections to all the endpoints of a service. We have cross-compiled `happy` for the OpenWRT[4] platform, so that the tool can now be run on widely deployed SamKnows probes. In order to ascertain the value in this approach and develop

[4] `https://openwrt.org`

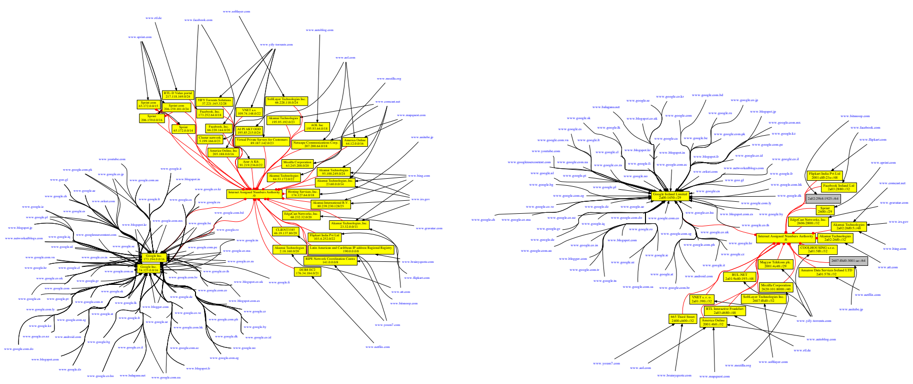

Fig. 7. An IPv4 and IPv6 aggregation cloud depicting how most of the services centralize on core content delivery networks and major cloud platforms

data analysis tools, 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, Teredo and tunnelled IPv4. We used the top 100 DNS names compiled by Hurricane Electric Internet Services[5] and ran `happy` on the set of dual-stack services represented by these DNS names.

A preliminary result comparing the preference of a happy-eyeballed application to IPv6 and IPv4 from two measurement points is shown in Fig. 3. The initial results show that happy eyeballs prevents IPv6 access to Facebook, with only a 20% chance to get to Google related services over a Teredo Tunnel. The results look more promising on a native IPv6 connection. It is important to note that adhering to the happy eyeballs recommendation, IPv6 endpoints are allowed a 300ms chance to succeed. A result comparing the time (mean and standard deviation) to establish a TCP connection to each of the services from the same measurement points is shown in Fig. 6. The initial results show higher time variances when connections are made over IPv6. In addition, it appears, some of the related (and few of the unrelated) services show very similar performances. These services either resolve to the same endpoint or a set of endpoints that belong to the same allocated prefix. 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 allocated prefixes owned by popular organizations like Google and Akamai Technologies as shown in Fig. 7[6]

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

[6] A full resolution image is available at `https://gist.github.com/vbajpai/4730696`

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