FCC Technical Advisory Council (TAC)

IPv6 Working Group

Benchmarking Recommendations

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# Introduction

IPv4 resources depleted on a global level with IANA in February 2011, Regional Internet Registries (RIR) will follow. APNIC depleted their IPv4 resources in April 2011. The remaining RIRs are expected to follow suit throughout 2011 and into 2012. Refer to the following links respectively:

|  |  |
| --- | --- |
| IANA | <http://www.nro.net/news/ipv4-free-pool-depleted> |
| APNIC | <http://www.nro.net/news/apnic_announces_its_ipv4> |

As such the deployment of IPv6 remains a critical aspect of the Internet’s future. Encouraging the deployment of IPv6 and measuring the success and progress of the same are both essential. The Internet ecosystem consists of many moving parts, each of them different from the other. The delay or absence in one area can have a significant impact to the overall adoption of IPv6.

As part of the FCC TAC IPv6 Working Group several key topics are being addressed related to the adoption of IPv6. They are as follows:

1. Recommendations and Guidelines
2. Benchmarking
3. Cost benefit analysis

The purpose of this document is to outline the key areas where IPv6 must be adopted, specifically related to benchmarking. Metrics and measurements for each of the key benchmarks are specified below. Where possible existing data sources are recommended to support the documented metrics and measurements, however, in some cases the definition and creation of new techniques will be defined.

# Network

The term computer network has many different flavors and meanings. For the purpose of this document, a computer network will be a reference to an Internet Network with a unique autonomous system number (ASN). Each network will have ingress and egress locations layers which will the demark points for benchmarking. Also each network will have additional layers, which will need to be considered for enabling IPv6.

In the following diagram, a typical network is broken into the following layers.

* Border Layer – Connections to other networks.
* Core Layer – The central devices which all information flows
* Edge Layer – A spur or remote segment of a network
* Access Layer – The routing device a CPE (cell phone, cable modem, ONU, etc.) connects to.



An analogy to be referenced throughout the document will be similar to road and bridge building. Computer networks are the roads and bridges connecting different locations together. Computer networks are not the vehicles on the roads (computers, tablets, phones, etc.) nor are computer networks the locations (applications) people travel to and use.

Computer networks today are built to carry IPv4 traffic. Computer networks will have to be built to carry IPv6 traffic. Each element along the path will need to be upgraded to enable IPv6 vehicle and applications to function. Each element in the border, core, edge, and access layers will have to be upgraded with hardware, software, or both to enable IPv6 functionality. All layers must be IPv6 enabled to allow IPv6 to function.

At the time of drafting this document, there are ~38,938 ASNs connected to the Internet. By analyzing route table announcements, ~4,622 ASNs are announcing IPv6 space. Which translates to ~11.8% of the Internet is IPv6 compatible.

The proposal for benchmarking network readiness is to monitor IPv6 route announcements. The proposal allows for simple metric to track when each network is actually functioning with IPv6. We will avoid logistical pitfalls associated with status checkpoints for all 38,938 ASN owners as well as future ASNs.

One company, Hurricane Electric, has already begun tracking the route announcements. The efforts are tracked via the following web page:

<http://bgp.he.net/ipv6-progress-report.cgi>

Also have another reference web site, Tracking IPv6 via BGP FIB:

<http://bgp.potaroo.net/v6/as6447/>

# Consumer Electronics

Consumer electronics support for IPv6 is essential to ensure end users, or consumers, have the ability to leverage IPv6 when accessing the Internet. Support for IPv6 is different for each type of consumer electronic device. Following is a minimal list of consumer electronics that must support IPv6:

1. Small office (SOHO) or home networking equipment, including routers and customer home gateways
2. Personal computers
3. Operating systems
4. Tablets
5. Smart phones
6. Internet enabled televisions
7. Internet enabled media players, i.e. Blue Ray and DVD players
8. Internet enabled webcams

The following are measurement opportunities for consumer electronics:

* Home or SOHO router support for IPv6
  + % devices that are tested to support IPv6
  + – # devices sold or deployed
* Internet-­‐enabled TVs, tablets, game consoles
  + % devices that are tested to support IPv6
  + # devices sold or deployed
* Popular operating system support for IPv6, includes percentage and penetration
  + Windows 2000/XP/2003/Vista/7
  + Mac OS X
  + Linux (kernel 2.2 and higher)
  + BSD – Free, Net, & Open BSD

The following resources reflect global operating system distribution:

1. <http://www.w3schools.com/browsers/browsers_os.asp>
2. <http://www.netmarketshare.com/>
3. <http://en.wikipedia.org/wiki/Usage_share_of_operating_systems>
4. <http://gs.statcounter.com>

Other aspects of the above may be attainable through collaborative efforts with the Consumer Electronics Association (CEA), specifically the CEA IPv6 Working Group. Profiles for IPv6 may be defined to ensure devices manufactures have sufficient guidelines to ensure support for IPv6 meets minimum requirements and most importantly is interoperable.

Support for IPv6 with regards to consumer electronic devices come generally falls into two primary categories:

1. Devices that have already been purchased and are is use today
2. New devices that are soon to be released

For both categories of devices it seems important to have a mechanism to determine and track which devices are capable being software upgraded to introduce support for IPv6. With existing devices the challenge will remain how to incent or notify end users that an upgrade is available and to ensure the same is applied successfully to the device. Further it is important that after being enabled to support IPv6, support for the same should be enabled by default. This will help to ensure devices that are connected to a broadband service that supports IPv6 automatically begin taking advantage of IPv6.

More importantly it is critical that newly developed devices support IPv6 and meet the minimum requirements to ensure interoperability. As in the case of existing devices it is important to ensure these devices are IPv6 enabled by default.

To ensure support for IPv6 meets minimum requirements and is interoperable the adoption of a third party label or logo program, which can be used to test and verify IPv6 functionality by device manufacturers and those procuring the same.  This program would provide for independent testing to ensure devices meet the minimum requirements through a series of generic, well-defined tests. A suitable certification or testing program is currently being evaluated.  
  
Finally, a label or logo program for IPv6 will simplify the process of identifying IPv6 capable devices.  This will allow retailers and others who procure devices to easily identify devices that support IPv6 when making purchasing decisions.  Since most consumers do not and should need to be familiar with the detailed inter-workings of IPv6 it is important that retail channels only stock products that support IPv6.

# Applications

Applications are the main drivers for using the Internet. Applications are items such as web browsers, e-mail clients, over the top videos, file transfers, instant messaging, social networking, etc. Referencing the road analogy, these are the destinations people leave their homes to go to and go do on the Internet.

Since the destinations vary greatly for many reasons ranging from popularity to usefulness, the recommendation is to create major categories and the top applications per category for tracking. For example:

|  |  |  |
| --- | --- | --- |
| Web Browser | IPv4 Compliant | IPv6 Compliant |
| Microsoft Explorer | Yes | Yes |
| Google Chrome | Yes | Yes |
| Apple Safari | Yes | Yes |
| Opera | Yes | Yes |

In the case of web pages and/or domains, using the domain name system (DNS) records as a source of truth we can collect stats rather quickly and effectively. For example, using Hurricane Electric’s tracking page we find:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Top Level Domains | Domains | A Records (IPv4) | % domains with IPv4 | AAAA Records (IPv6) | % domains with IPv6 |
| .COM | 97,054,298 | 86,815,053 | 89.45% | 826,459 | 0.85% |
| .NET | 14,123,452 | 12,092,885 | 85.62% | 177,052 | 1.25% |
| .ORG | 9,416516 | 8,270,159 | 87.83% | 110,075 | 1.17% |

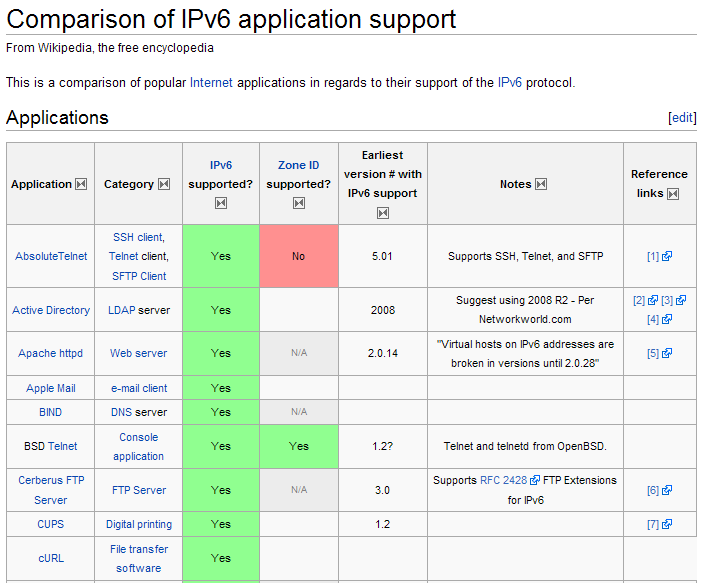
The conclusion of this table points to 89.45% of domains using the .COM extension have actual IPv4 hosts and can be found on the Internet. Meanwhile a mere 0.85% of web domains are using IPv6 today.

In the case of web browsing both the web browser and host server must use IPv6 to complete the experience over IPv6. If ether is broken or does support IPv6 the experience is direct affected. Web browsing will be the simplest of the applications to track due to DNS. While other applications such as online gaming will prove to be extremely difficult to track results.

Wikipedia has started a collection point for people to update as applications start to support IPv6.

<http://en.wikipedia.org/wiki/Comparison_of_IPv6_application_support>

Below is a sample of the webpage[[1]](#footnote-1):



As for the categories, we recommend to start with:

* Web Browsing
* Email
* Voice (Skype, Vonage)
* Video Services (Netflix, Hulu)
* Gaming (Consoles, PCs, Handhelds)
* Instant Messaging
* File Transfers
* Back Office and Provisioning (DNS, DHCP, TFTP)

# Content and Services

Another important variable to ensure that IPv6 is universally available and usable by end-users is to ensure content and services are openly enabled to support IPv6. There is no specific reference made with regards to IPv4, however, state of the art suggests that IPv4 support will remain for sometime while support for IPv6 is added. Discussions related to deprecating or disabling support for IPv4 are out of scope for this document.

Support for content and services over IPv6, particularly that which is popular or essential from an end-users point of view is an important step to support and encourage the adoption of IPv6. Following are the categories of content and services that are critical to measure where content refers mainly to websites and online Internet content like Internet properties, etc. Following is a list of critical sectors as defined by the FCC TAC IPv6 Working Group:

1. Government – includes local, state, and federal government agencies.
2. Education – includes K-12 and university educational institutions.
3. Commercial – includes commercial organization of varying types. Subsequent break out by industry may follow to allow for granular measurements.
4. Not for profit – includes all forms of not-for-profit organizations. Subsequent break out by industry may follow to allow for granular measurements.

For each of the categories above the content and services are defined to minimally include the following:

1. Main Internet properties and web sites
2. Services that include and are not limited to the following:
   1. Electronic mail (e-mail)
   2. Domain Name System (DNS)
      1. Caching and Authoritative
      2. Presence of IPv6 DNS resource records (AAAA) in the authoritative DNS infrastructure
      3. Presence of IPv6 DNS glue records for authoritative DNS infrastructure
   3. Internet video
   4. Internet voice

For content and service by type of organization or sector the following metrics are the primary focus. These metrics can be detected and measured independently using well known techniques and tooling.

1. % content and service supporting IPv6 by category
2. % traffic that each category represents of all traffic

Several organizations measure the enablement and availability of content over IPv6. The top web sites and domains as published by Alexa ([www.alexa.com](http://www.alexa.com)) is the typical source for these measurements. Further one or more of the below are examples of measurements that are actively being collected across the Internet:

1. <http://www.vyncke.org/ipv6status>
2. <http://www.mrp.net/IPv6_Survey.html>
3. <http://bgp.he.net/ipv6-progress-report.cgi>
4. <http://mnlab-ipv6.seas.upenn.edu/>
5. <http://www.caida.org/research/topology/as_core_network/>
6. <http://atlas.ripe.net/>
7. <http://www.worldipv6day.org/other-measurements/index.html>

# End to End

For the purpose of this document the end-user measurement is intended to represent the intersection of a number of IPv6 attributes. The goal for this metric is to represent the actual or effective IPv6 usage opportunity. There is a material difference between being capable, enabled, and actively using IPv6. This measurement is focused on determining active IPv6 usage and focuses largely on end user capabilities and connectivity. The following metrics will be minimally considered:

1. Service provider support for IPv6
2. Customer premise support for IPv6
3. Consumer electronics capabilities in the premise
4. Content and service availability over IPv6

The intersection of these attributes will determine effective support for IPv6, meaning truly whether IPv6 is available and being used. The absence of support for IPv6 in one of these key areas represents a gap in the IPv6 communications path that will prevent end users from fully utilizing IPv6. It is essential that the adoption of IPv6 occur across all areas to systematic adoption and utilization of the same.

# Traffic Levels

Prior to IPv6, all Internet traffic was using IPv4. As IPv6 is adopted and deployed in the networks, the traffic demographic will start to shift. While a device, network, and application might be IPv6 compliant, this does not mean the experience is IPv6. The thought behind measuring the traffic mix between IPv4 and IPv6 is to track the adoption of IPv6. As IPv6 is adopted, the percentage of traffic will grow to be even with IPv4 and then eventually become the dominant protocol.

One key to measuring the traffic demographic will be the border layer between the ASNs. Each network owner will be able to measure their own traffic flow on and off their network. One such mechanism could be NetFlow 9 which is enabled on wide range of network devices. The data is collected and presented via a different application such as MRTG.

Another possible location will be the Internet gateways / exchange locations where the Tier 1 providers share connectivity. In 2009, Martin Levy from Hurricane Electric presented information at NANOG 45 using the technique mentioned above.

Example of MRTG Graph from Martin Levy’s Presentation at NANOG 45[[2]](#footnote-2):



# Conclusion

Since IPv6 was ratified in 1999 the adoption of the same has not taken the course expected. Multiple techniques have been deployed to conserve IPv4 such as in home private NATs. These techniques modified the depletion rate and ultimately delayed adoption of IPv6. Meanwhile, the CPE market (smart phones, tablets, PCs, game consoles, etc) across the world has triggered a rapid consumption of the limited IPv4 resource.

In fact, it is arguable that the depletion of IPv4 reserves of IANA on Feb 3, 2011 was in the fact the turn point for the adoption of IPv6. Over the past several years interest and activity related to IPv6 has dramatically increased. During the transition to IPv6 organizations from around the world will have to employ a wide range of techniques to ensure their business and networks can grow and more importantly offer a consistent end user experience. While the objective is noble, there are a number of technical challenges related to IPv4 extension that complicate maintaining the existing user experience.

As such the benchmarking efforts of the FCC TAC IPv6 Working Group is important to not only motivate and facilitate the adoption of IPv6 but also to measure and track the progress of the transition as it unfolds. Ultimately, the long-term goal across the Internet community is to divorce from the IPv4 Internet and fully migrate to the use of IPv6.

1. http://en.wikipedia.org/wiki/Comparison\_of\_IPv6\_application\_support [↑](#footnote-ref-1)
2. <http://www.nanog.org/meetings/nanog45/presentations/Tuesday/Levy_traffic_level_hurricane_N45.pdf> [↑](#footnote-ref-2)