

STUDY ON THE QUALITY OF IPV6 ENABLEMENT OF US GOVERNMENT WEBSITES

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ABSTRACT

This paper presents the findings of the first large scale, quantitative study of the quality of IPv6 enablement of US government websites. A mathematical algorithm leveraging multiple sources of data was used to calculate the IPv6 effectiveness of government websites as far as user experience is concerned. The purpose of this study was to collect and analyze data representing the quality of the User Experience (UX) accessing US Government, public facing, websites over IPv6. A mathematical algorithm leveraging multiple sources of data was used to calculate QoS as a measure of the user experience, referred to in this study as “IPv6 effectiveness”. of these websites representing the user experience. The websites under study are all reported to have IPv6 Domain Name Services (DNS) and Web services accessible via IPv6 according to the National Institute of Standards Technology (NIST) USG IPv6 Statistics website.

KEYWORDS

IPv6 effectiveness, IPv6 implementation, US Government, Sonar

1. INTRODUCTION

As part of the 2010 OMB Memorandum titled “Transition to IPv6”, U.S government agencies were asked to upgrade their external public facing servers and services to operationally use native IPv6 by the end of September 2012 [1]. Although data exists on the National Institute of Standards Technology website as to the status of IPv6 enablement of US agency services, to date, no quantitative study of the quality of this enablement, as measured by the user experience, has been published.

V6Sonar©, a user experience monitoring platform developed by Nephos6©, was used to collect extensive data measuring the IPv6 effectiveness of US agency services. Web services of agency domains listed on the NIST USG IPv6 Statistics site were tested in terms of user experience as compared to IPv4. Sonar agents from various geographic locations in North America, Europe, and Asia were employed to poll each agency site at specified intervals for a period of 7 days.

The data collected in this study showed that while most of the US agencies in fact do have their external facing services enabled for IPv6, the IPv6 effectiveness of these services and the consistency of the IPv6 access vary widely between agencies, implementation approaches and access location. The implications of these findings are that citizens and business partners worldwide who use IPv6 to access the resources offered by the US Government may experience performance degradation, variability in performance and sometime no IPv6 connectivity at all. This paper also points to the impact that token yet unmonitored IPv6 implementation has on services and the brand of the organization.

2. BACKGROUND

On September 28, 2010; In an OMB Memorandum titled “Transition to IPv6”, U.S government agencies were asked to upgrade their external public facing servers and services to operationally use native IPv6 by the end of Fiscal Year(FY) 2012 [2]. The memo also included a deadline to implement IPv6 on internal agency networks by the end of FY 2014. In response to these mandates, the National Institute of Standards and Technology (NIST) Information Technology Laboratory (ITL) created the U.S. Government IPv6 (USGv6) Profile and Testing Program. In May of 2009 the Federal CIO Council published the first version of their "Planning Guide/Roadmap toward IPv6 Adoption within the U.S. Government." In July of 2012, the Federal CIO Council, in collaboration with the American Council for Technology (ACT) and the Industry Advisory Council (IAC), published the second version of this "Roadmap." It provides detailed step-by-step guidance to federal organizations for transitioning current networks to IPv6 compliant infrastructures. Also included in the guide are best practices for asset procurement and security threat mitigation [3].

In 2012, approximately 35 US government agencies, responsible for 1261 domains, had enabled IPv6 on many of their interfaces; however, this number has increased only slightly since. A review of the NIST web site shows a surge of IPv6 enablement in September of 2012 as shown in Figure 1. The figure clearly shows a substantial jump in the number of IPv6 enabled operational interfaces between July and September of 2012.

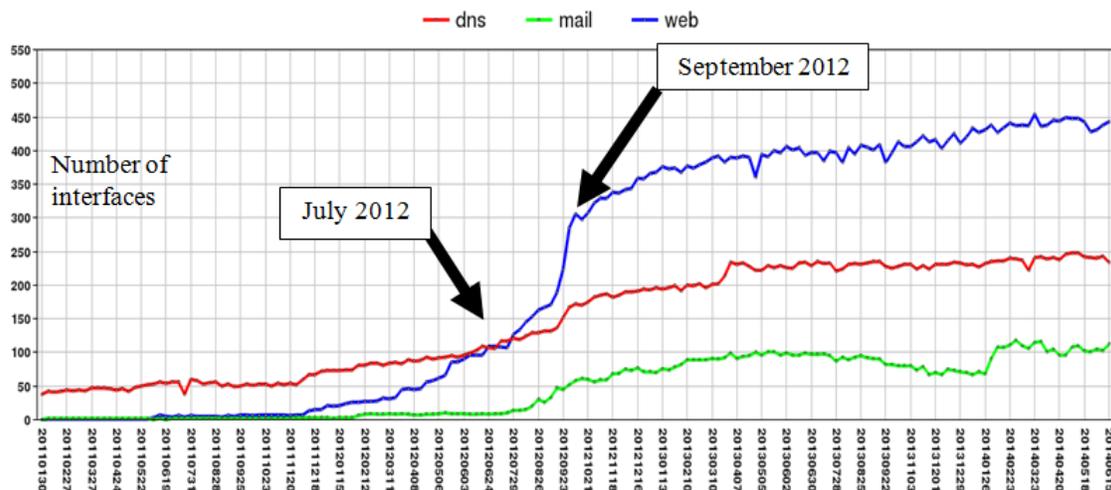


Figure 1. NIST Reported operational interfaces

Figure 2 represents similar data to Figure 1, but IPv6 enablement for each domain, rather than individual interfaces. An interface can be used to reach multiple domains which is why the number of IPv6 enabled domains shown in Figure 2 is greater than the number of IPv6 enabled interfaces shown in Figure 1. For the purposes of this study, the researchers focused only on the IPv6 effectiveness of enabled domains, and did not distinguish between individual interfaces.

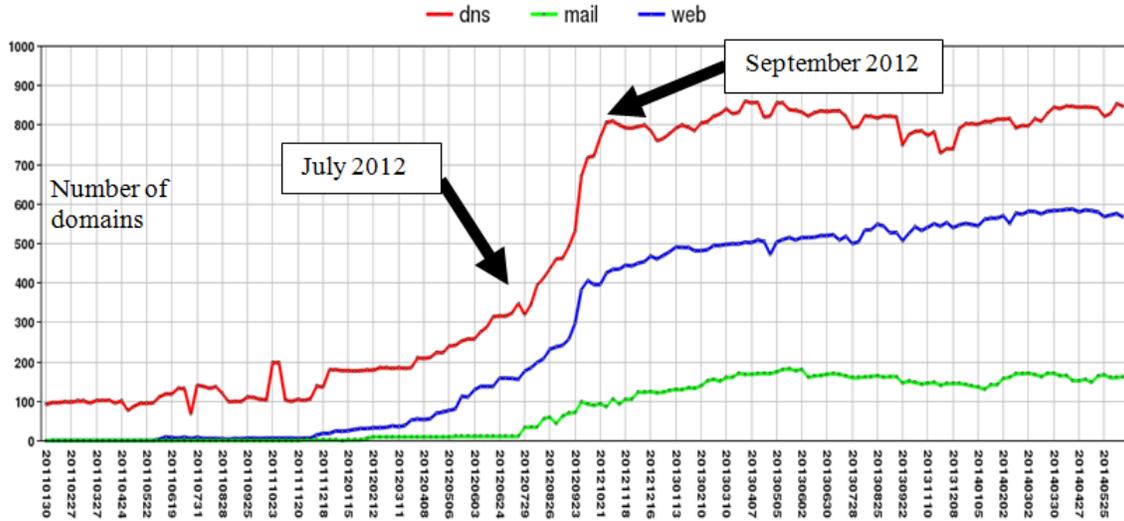


Figure 2. NIST reported operational domains

The surge in IPv6 enabled domains and interfaces that began in July of 2012 coincides with the publishing of Version 2.0 of the Federal CIO Council’s IPv6 planning roadmap [3] and ends approximately September 30th, 2012; which was the OMB deadline for upgrades of external services to IPv6. These graphs represent operational status only, not functionality. Operational capability is the implementation and configuration of IPv6 services, where functionality is the actual performance of those services. As of June 19, 2014; roughly 38% of all government web domains had DNS services and web services enabled for IPv6 [4]. The remaining 62% are expected to be externally and internally IPv6 operational by the end of 2014 to be in compliance the federal mandate.

3. METHODOLOGY

V6Sonar©, [5] a user experience monitoring platform developed by Nephos6©, was used to measure the IPv6 effectiveness, in terms of user experience compared to IPv4, the Web and DNS services of 193 U.S. Government agencies listed on the National Institute of Standards Technology (NIST) USG IPv6 Statistics site. The Hurricane Electric© BGP Toolkit was used to obtain detailed website information, including DNS, IP, and WhoIs information. This information was then used to determine the organization responsible for the domain and what web service providers were hosting domains.

193 websites identified as being DNS and Web enabled for IPv6 were monitored using the V6Sonar© platform. Six V6Sonar© agents located in various geographic locations as shown in Figure 3. Locations of the agents include Atlanta, Seattle, Hong Kong, Netherlands, Singapore, and Slovenia.

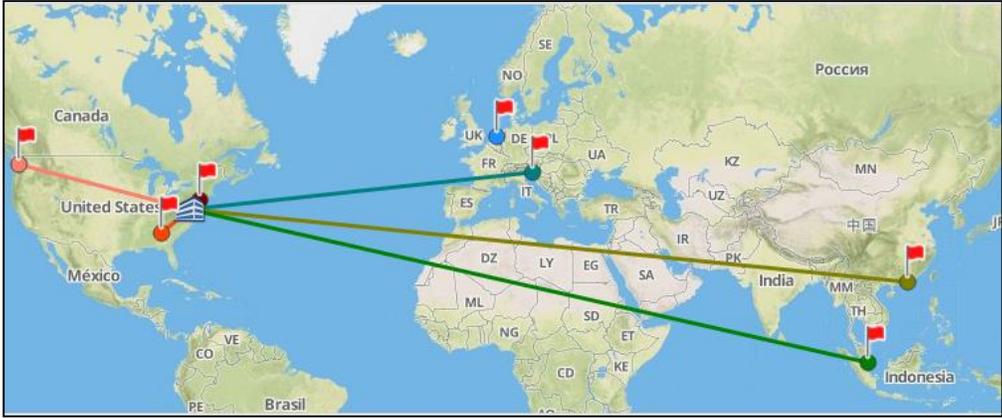


Figure 3. Map feature in V6Sonar© showing locations of agents

The agents were employed to poll each government agency website at 10 minute intervals for a period of six days. Agent polling tasks involved the following process:

- DNS query and answer
- IP TCP connection to web server established
- HTTP download times for all resources on the website

This process was attempted for each identified website over IPv4 and IPv6. The results were then recorded and calculated for IPv6 effectiveness by the V6Sonar© tool. Figure 4 shows an example of the output given by V6Sonar©. In the figure, IPv6 effectiveness scores are shown for each region (N. America, Europe, and Asia in this example) and globally. The measure of effectiveness is the multiplication of the probabilities of two conditional probabilities and is expressed by the formula:

$$\text{Effectiveness} = P1 * P2$$

With P1 = Probability that a user who has IPv6 access will connect over IPv6 according to Happy Eyeballs [6] and P2 = Probability that once connected over IPv6 the user will be as happy with the web download as with IPv4. Each probability is calculated using several data sets related to response times, Happy Eyeballs operation, browser types and IPv6 adoption.

Scores			
Global			
Score			
71% ▼			
North America			
Score	IPv6 Perf	IPv4 Perf	
42% ▼	808ms ▲	563ms ▼	
Europe			
Score	IPv6 Perf	IPv4 Perf	
100%	774ms ▲	847ms ▼	
Asia			
Score	IPv6 Perf	IPv4 Perf	
100% ▲	1.39s ▼	1.38s ▼	

Figure 4. Example of IPv6 effectiveness output from V6Sonar©

Each region also shows the difference in IPv6 effectiveness since the last measured instance, for this study every 10 minutes. For example, the global IPv6 effectiveness score for this website is worse than it was 10 minutes prior. But, the IPv6 effectiveness for Asia improved since the last measurement. Also seen in Figure 4, is the lack of importance of the websites performance, but rather the comparison of accessing that website over IPv6 services and IPv4 services. This particular website had a faster performance time in North America and had an IPv6 effectiveness score of 42%, but in Asia took longer and scored a 100%.

3.1 Website Selection Process

The NIST USG IPv6 Statistic website was used to select the websites used in this study. In Figure 5, a clip of the NIST website and the data available is shown. The colours assigned to each domain, per service are determined by the NIST Advanced Networks Technology Division in accordance with the following criteria:

- Red- if there appears to be no IPv6 addresses assigned, e.g. 0/0/0
- Yellow- if addresses are assigned but the application service cannot be reached, e.g., 1/0/0 or 3/3/0
- Green- if the service is fully supported over native IPv6, e.g., 4/4/4 or 1/0/1
- Gray- if the service is intentionally not assigned, i.e., [7] 0/0/0 [7]

The numbers in each cell play no factor in this study. These numbers are directly related to the number of interfaces associated with that domain. This study does not test individual interfaces, but domains as a whole. As long as the domain has a green status for DNS and Web, then it is considered operational and meets the requirements for this study.

Domain	Organization	DNS	Mail	Web	Links	DNSSEC
gov.404.	Securities and Exchange Commission	[8] 3/3/3 [0]	[0] 0/0/0 [-]	[3] 0/0/0 [I]	0%/0%	S/N/C
gov.9-11commission.	National Archives and Records Administration	[2] 2/2/2 [0]	[0] 0/0/0 [-]	[1] 0/0/0 [I]	0%/0%	S/N/C
gov.911.	Department of Transportation	[3] 3/0/3 [0]	[0] 0/0/0 [-]	[1] 1/1/0 [I]	0%/33%	S/N/C
gov.911commission.	National Archives and Records Administration	[2] 2/2/2 [0]	[0] 0/0/0 [-]	[1] 0/0/0 [I]	0%/0%	S/N/C
gov.aapl.	Department of Education	[4] 4/0/4 [0]	[0] 0/0/0 [-]	[1] 1/0/1 [I]	100%/100%	S/N/C
gov.abandonedmines.	Department of the Interior	[6] 4/4/4 [0]	[0] 0/0/0 [-]	[1] 1/1/1 [I]	100%/62%	S/N/C
gov.abilityvone.	Comm for People Who Are Blind/Severely Disabled	[2] 2/2/2 [0]	[1] 0/0/0 [I]	[1] 0/0/0 [I]	0%/0%	U/-/-
gov.abmc.	American Battle Monuments Commission	[2] 1/0/1 [0]	[1] 0/0/0 [I]	[1] 0/0/0 [I]	0%/67%	S/N/C
gov.access-board-members.	U. S. Access Board	[4] 4/4/4 [0]	[0] 0/0/0 [-]	[1] 0/0/0 [I]	0%/0%	U/-/-
gov.access-board.	U. S. Access Board	[2] 2/2/2 [I]	[2] 0/0/0 [0]	[1] 1/1/1 [I]	100%/83%	S/N/C
gov.af.	Department of Health And Human Services	[4] 4/4/4 [0]	[0] 0/0/0 [-]	[1] 0/0/0 [0]	0%/47%	S/N/C
gov.achp.	Advisory Council on Historic Preservation	[4] 2/0/2 [0]	[1] 0/0/0 [0]	[1] 0/0/0 [I]	0%/7%	S/N/C
gov.acquisition.	General Services Administration	[6] 2/0/2 [0]	[0] 0/0/0 [-]	[1] 0/0/0 [I]	0%/42%	S/N/C
gov.acus.	Administrative Conference of the United States	[6] 2/0/2 [0]	[2] 0/0/0 [0]	[1] 0/0/0 [I]	0%/22%	S/N/C

Figure 5. Detailed IPv6 and DNSSEC service interface statistics from NIST USG

The websites that were coded green, indicating that DNS and Web services are fully supported for IPv6, were selected for monitoring. In total, 193 websites were monitored.

3.2 Data Collection Process

A datasheet of domains (Figure 6) was created using domain name and agency responsible information available from the NIST website, ASN owner information available from the Hurricane Electric© BGP Toolkit, and AAAA Records obtained from the V6Sonar© DNS Tool. The following information was collected on each domain:

- Domain name

- Responsible agency or organization
- Source – where the services are hosted
- Autonomous System Number (ASN) owner
- AAAA record

ASNs provide unique identification of each routing domain on the internet and allow Border Gateway Protocol (BGP) routing to function properly [8]. If the ASN owner was identified as the Agency Responsible; or the ASN Owner was an organization of the Agency Responsible (i.e. the Federal Aviation Agency (FAA) belongs to the Department of Transportation), then a designation of internal (I) was given for the Source field. Any domains not meeting this requirement were designated as external (E) source . If multiple AAAA Records were available, the first record was input into the spreadsheet.

Domain	Organization	Source	(ASN) Owner	AAAA Record
gov.spaceweather.	Department of Commerce	E	NOAA	2610:20:8000:8c01::24
gov.spectrum.	Department of Commerce	I	DoC- ITA	2610:20:0:20:921a:110:225:147
gov.srs.	Department of Energy	E	Energy Sciences Network (ESnet)	2001:400:6000::22
gov.ssa.	Social Security Administration	I	SSA	2001:1930:e03::d
gov.standards.	Department of Commerce	E	AT&T Internet Services	2610:20:6005:13::115

Figure 6. Clip of domain datasheet

4. FINDINGS

The data collected in this study revealed that while most of the US agencies in fact do have their external facing services enabled for IPv6, the IPv6 effectiveness of these services and the consistency of the IPv6 experience and IPv6 access vary widely between agencies, implementation approaches and access location. Figure 7 shows the average level of IPv6 effectiveness (in increments of 10%) reported by agents located in North America (blue columns) and Globally (Orange Columns) and the number of agency sites that achieved that level of effectiveness averaged over a six day period.

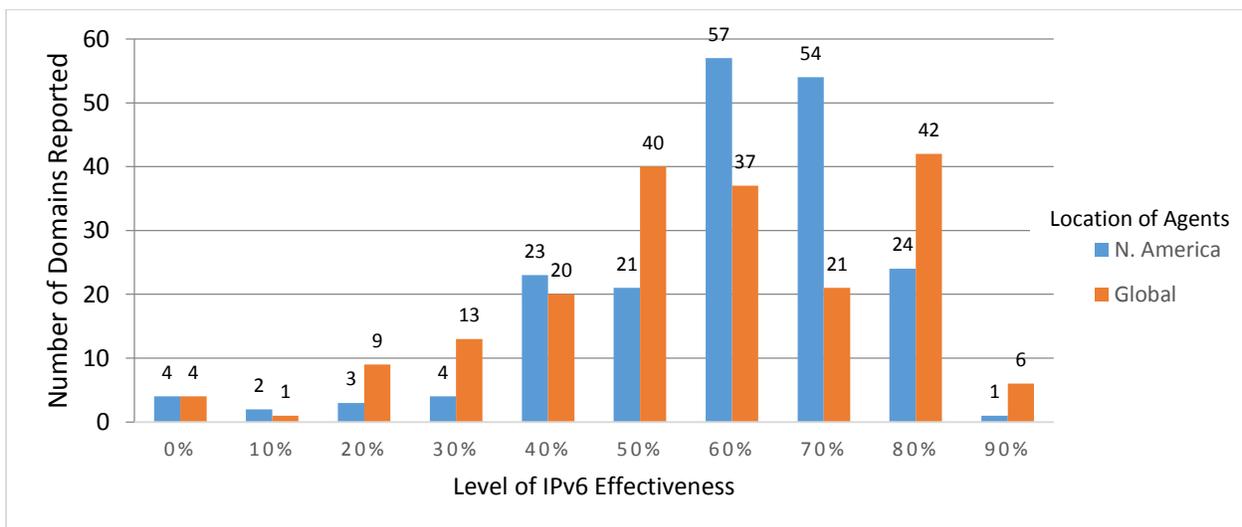


Figure 7. Average IPv6 effectiveness of USG agencies measured over six days

Above, Figure 7 shows an overview of the weekly average IPv6 effectiveness of all the websites tested. The IPv6 effectiveness ranged from 0% to > 90%. This graph shows how many websites had an average

weekly IPv6 effectiveness per 10% increments. The blue bar represents the number of websites with the specified IPv6 effectiveness or higher in the N. American region. (i.e. Only 1 website scored an IPv6 effectiveness of 90% or higher in N. America.) The orange bar represents the number of websites with the specified IPv6 effectiveness or higher globally. (i.e. six websites scored 90% or higher for a global IPv6 effectiveness.) The majority of the domains had an average weekly IPv6 effectiveness score between 50% and 80%.

Below in Table 1, the U.S. Government sites which returned an IPv6 effectiveness of greater than 80% as measured by V6Sonar© agents located in North America are listed.

Table 1. Sites with effectiveness >85% as measured by N. America agents

Domain	Organization	(ASN) Owner	Avg. N. America
gov.nvtc.	Department of Justice	DoJ	90.77%
gov.nic.	General Services Administration	VeriSign Infrastructure & Operations	89.14%
gov.fedcenter.	Environmental Protection Agency	EPA	88.08%
gov.employeeexpress.	Office of Personnel Management	L3 Communications, Inc.	87.41%
gov.ntis.	Department of Commerce	Qwest Communications Company	86.44%
gov.forfeiture.	Department of Justice	DoJ	86.24%
gov.nuclear.	Department of Energy	DoE	85.23%
gov.energy.	Department of Energy	Blackmesh Inc.	85.05%

Below in Table 2, are the U.S. Government sites which returned an IPv6 effectiveness of greater than 80% as measured by V6Sonar© agents located globally are listed.

Table 2. Sites with effectiveness >85% as measured by Global agents

Domain	Organization	(ASN) Owner	Avg. Global
gov.nvtc.	Department of Justice	DoJ	95.28%
gov.pubmedcentral.	Department of Health And Human Services	National Library of Medicine	89.76%
gov.nlm.	Department of Health And Human Services	National Institute of Health	90.19%
gov.genbank.	Department of Health And Human Services	National Institute of Health	90.81%
gov.its.	Department of the Treasury	FRIT	92.68%
gov.osmre.	Department of the Interior	DoI	89.16%
gov.govsales.	General Services Administration	GSA	91.93%
gov.nihseniorhealth.	Department of Health And Human Services	National Institute of Health	87.88%
gov.lacoast.	Department of the Interior	DoI	90.42%
gov.lca.	Department of the Interior	DoI	87.30%
gov.mrgo.	Department of the Interior	DoI	86.39%
gov.pay.	Department of the Treasury	FRIT	89.14%
gov.geoplatform.	Department of the Interior	DoI	88.53%
gov.onlinewbc.	Small Business Administration	AT&T Internet Services	88.03%
gov.regulation.	Environmental Protection Agency	EPA	86.43%

gov.rocis.	General Services Administration	GSA	85.23%
gov.spectrum.	Department of Commerce	DoC- ITA	88.45%
gov.hsa.	Small Business Administration	AT&T Internet Services	87.78%
gov.regulations.	Environmental Protection Agency	EPA	85.22%
gov.manufacturing.	Department of Commerce	AT&T Internet Services	85.16%
gov.greengov.	Environmental Protection Agency	EPA	86.41%
gov.wildlifeadaptationstrategy.	Department of the Interior	Dol	86.75%
gov.insurekidsnow.	Department of Health And Human Services	Hewlett-Packard Company	85.17%

Next, the data was analyzed to determine if there were any differences in IPv6 effectiveness between domains hosted internally by an agency as compared to domains hosted by a third party service provider external to the organization. Figure 8 shows the percentage of agencies hosting their own domains vs. those that outsource. Of the 193 domains under investigation, 56% were hosted internally (Internal) by the agency and 44% hosted by a web service provider (External).

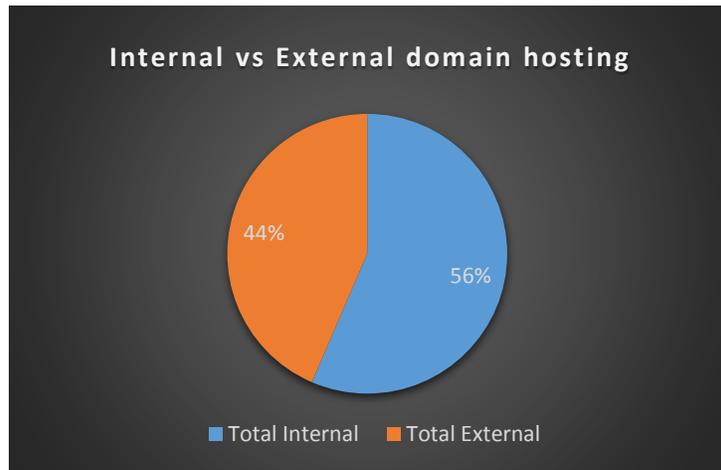


Figure 8. Percent of domains hosted internally and externally

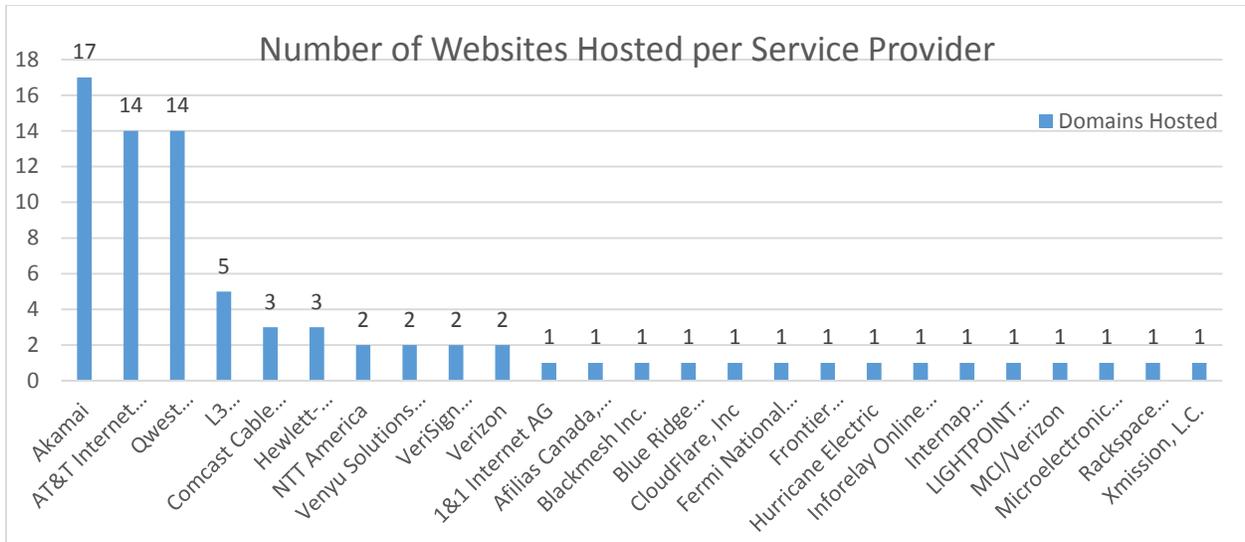


Figure 9. Domains hosted per Web service provider

To determine differences between internally and externally hosted domains, two analyses were performed. First, only data from agents located in N. America was analyzed (Seattle and Atlanta). Figure 9 shows a comparison of the IPv6 effectiveness of internally vs externally hosted domains from the perspective of V6Sonar© agents located in North America. As can be see in the chart, for domains with the highest levels of IPv6 effectiveness ($\geq 80\%$) the majority (72%) were hosted internally. The same was found true with the domains having the lowest levels of IPv6 effectiveness ($\leq 50\%$), most (64%) were hosted internally.

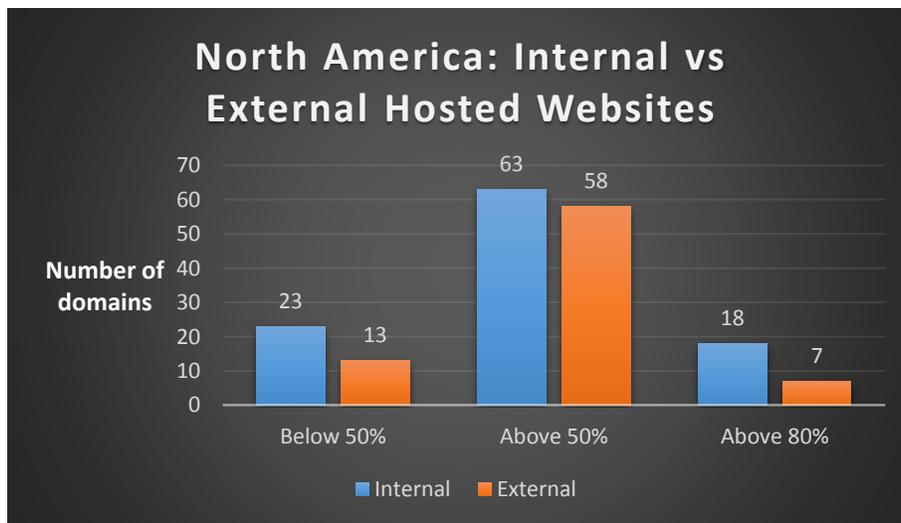


Figure 10. IPv6 effectiveness of internal vs externally hosted domains from N. America agents

Next, the data from all sonars globally (N.Ameria, Asia, Europe) was analyzed. Figure 10 shows the IPv6 effectiveness of the 193 domains from the perspective of V6Sonar© agents located globally. Again, from the gloably located agents, the highest levels of IPv6 effectiveness ($\geq 80\%$) were achieved by more internally hosted domains vs externally hosted. However, the same was not true with the domains having the lowest levels of IPv6 effectiveness ($\leq 50\%$), most (64%) were hosted externally.

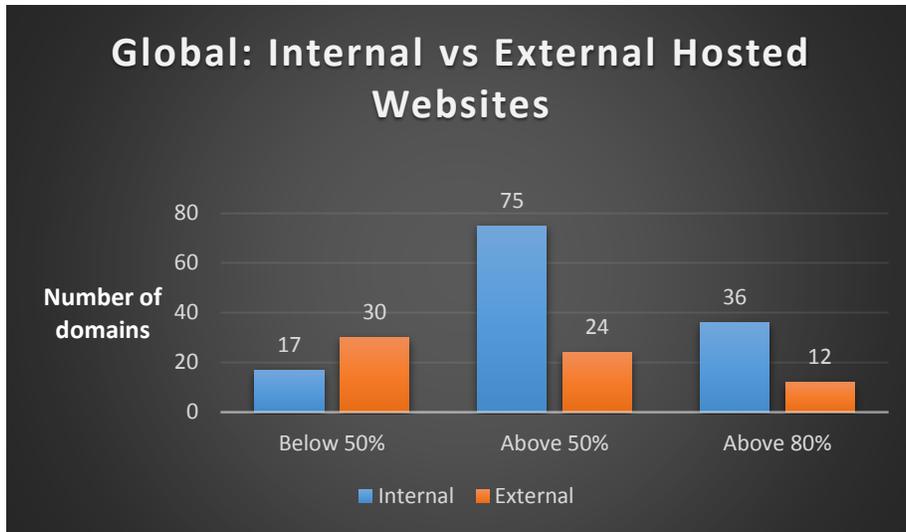


Figure 11. IPv6 effectiveness of internal vs externally hosted domains from global agents

Figure 9 and Figure 10 are not comparisons, but simply representations of the data collected. Because slightly more domains are hosted internally, the number of domains for internal websites is expected to be higher. Although, it is important to notice that internally hosted domains had less domains with a global IPv6 effectiveness score below 50%.

Figure 11 provides a representation of the third party companies are providing web services to government domains and how many domains they are hosting. Akamai, AT&T Internet Services, and Qwest Communications Company were the top 3 IPv6 web service providers.

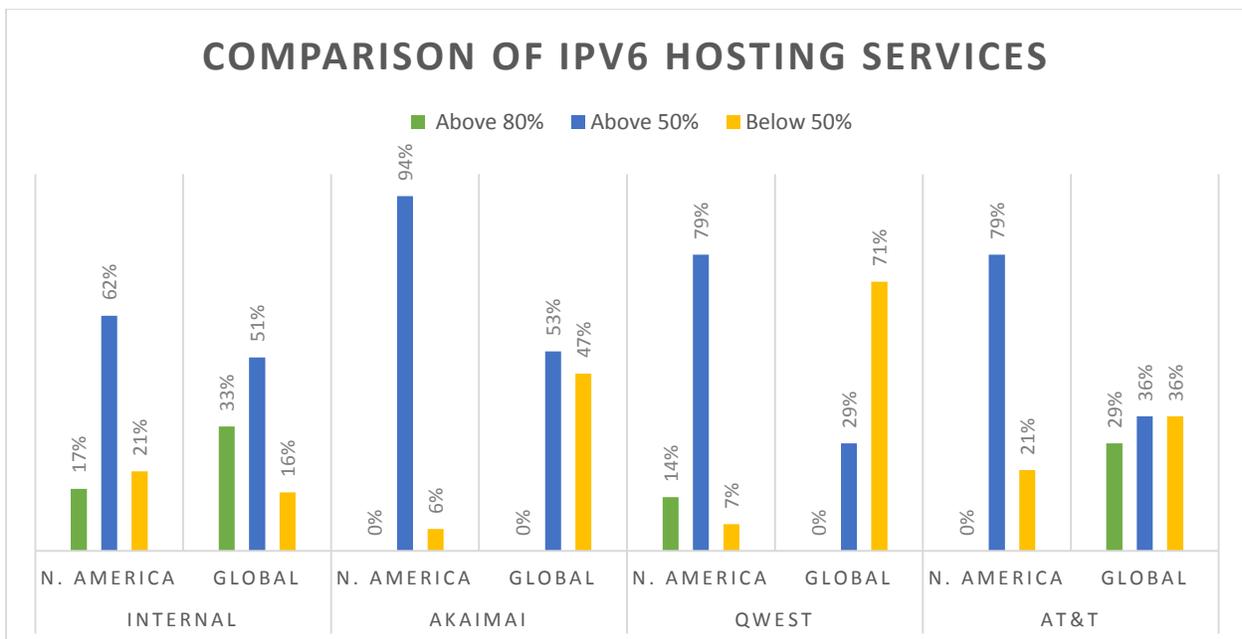


Figure 12. Comparison of IPv6 Hosting Services

Figure 12 shows a comparison between Internal domains, Akamai hosted domains, Qwest hosted domains, and AT&T hosted domains. The green bar represents the percent of the domains tested for that service provider scored above 80% IPv6 effectiveness. (i.e. 14% of the domains hosted by Qwest scored above 80% IPv6 Effectiveness in N. America.) The blue bar represents the percent of the domains tested for that service provider that scored above 50% and below 80% IPv6 effectiveness. The yellow bar represents the percent of the domains tested for that service provider that scored below 50% IPv6 effectiveness. Note: none of the external service providers perform as well as the domains that are hosted within the organization.

5. CONCLUSION

The data collected in this study showed that while most of the US agencies in fact do have external facing services enabled for IPv6, the IPv6 effectiveness of these services and the consistency of the IPv6 access varies widely between agencies, implementation approaches, and access location. The implications of these findings are that citizens and business partners worldwide who use IPv6 to access the resources offered by the US Government may experience performance degradation, variability in performance and sometime no IPv6 connectivity at all. This paper also points to the impact that token yet unmonitored IPv6 implementation has on services and the brand of the organization.

Future work will consist of testing the approximately 300 remaining websites reported as having IPv6 services enabled. Also, further analysis of IPv6 performance compared to IPv4 performance, and how the effectiveness and performance relate to network hop counts determined by traceroutes. Identifying domains with no IPv6 functionality will also be a priority.

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