Exploring the Realm of IPv6

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1 Introduction

1.1 Need For IPv6

As internet and related technologies increase in size everyday, our archaic allocation of IP addresses through IPv4 addressing scheme becomes more obsolete and difficult to handle. We have long exhausted our address space using IPv4 scheme and are delaying havocs by using NATs and CIDR. There is no debate on the fact that at the time IPV4 was introduced, it was a genuinely good way of IP allocation given the number of PCs, active users, and world population of the era. But we have come a long way ever since. During the deployment of IPV4 addresses in 1989 the world population was around 4 billion, and the addressing scheme provided 232 addresses, which could virtually supply one IP address to every person on the planet. It must be noted that this was just the dawn of internet and the kind of usage we have today, with every person (at least in developed countries) owning more than one internet connected devices (be it laptop, cell phone, tablets, etc) was an inconceivable idea. Naturally, at that time IPV4 seemed more than enough. But today, in the year 2017, the world population has almost doubled, reaching 7.5 billion in April. That is double the amount of address space in IPv4, with the constraint that each person gets just one IP address and ignoring the fact that there are a lot of reserved and private IP addresses in the pool too. But we somehow have managed to stretch the IPv4 life, using NATs. The basic idea behind NAT is rather simple, it just has internal and external network addresses. External addresses can be globally recognizable, whereas internal addresses need to be unique only within a network, meaning that several devices can be allocation same internal IP addresses as long as they are part of different globally identifiable networks. But even with this novel scheme of over utilizing the current IPv4 space, we will not be able to keep up the supply and demand chain in control for long. With the imminent arrival of Internet of Things, matters are bound to get worse. But we do have a solution sitting right under the rack for almost 20 years now- IPv6.

1.2 Constraints in the shift to IPv6

IPv6 basic protocol, also known as RFC 2460, was first published in 1998 with the introduction of a 128 bit addressing scheme (as opposed to its predecessor's 32 bit addressing scheme). It provides 2128 or 340 undecillion addresses, clearly more than enough for the entire human race carrying several ip-configured devices. At the first stance, IPv6 clearly looks like the immediate, effective, and long lasting solution to the IP address crisis and it should be implemented in the earliest possible manner. However, the growth of IPV6 addressing over the internet has seen a much staggering pace. The main obstacle is the hourglass structure of the OSI model with IPv4 acting as the biggest constraint at its waist. Deployment of IPv6 has been increasingly slow because of the economic overhead involved in the transition. Currently, all the components of our network are capable of utilizing IPv4 addresses and the cost of transferring them all to IPv6 is really high. Clearly, the key business players do not want to invest immediately in IPv6, at least till the point of absolute emergency. There is no pressure from the end user side either, as the very deployment of IPv6 has long been planned as a silent transition with efforts to minimize any effects the end user may feel.

1.3 The current Trends

In spite of this crippled growth, a lot of ISPs have already started supporting IPv6 and most devices today come equipped with a MAC, which incorporates IPv6 addressing. A lot of modern day devices come with a kind of a dual stack where they have both IPv4 and IPv6 addresses. The main problem lies in the fact that even though most end applications can support IPv6 today, there is just not enough incentive for the key players at the network layer to actually shift the major implementation and network traffic to IPv6. This has been the trend due to a variety of reasons, including but not limited to economic causes and the potential temporary drop in efficiency and user experience during the initial stages of the transition. Having said that it is not completely uncommon for new devices, specially the ones finding their spot on the network arena due to internet of things, to use IPv6 deployement from the very beginning of their introduction to the network. There have been numerous tunneling tehcniques through with IPv6 packets are tunelled through the pre existing IPv4 paths. Several different implementations are available for this kind of tunelling like 6to4, IPv6 Rapid deployment, Teredo etc. But the fact remains that the real efficient use of IPv6 would be if we had network stacks that downright supported IPv6 traffic at the basic level. The problem exacerbates with the fact that a lot of application level protocols like DHCP, ICMP and even DNS are fine tuned to work with IPv4. And introducing IPv6 at the network layer means upgrading these other layer protocols to an IPv6 compatible version too.

1.4 The need for Measurement

Evidently, the deployment of IPv6 is going to become a necessity, rather than an option in near future, and it is a good idea to actually check how far we have come in the deployment of IPv6 and what are the trends in this deployment. Measurements can give us a lot of insight not only to the current scenario but also to the possible reasons for the staggered growth; geographic, technical and financial influences and can open up realms for overcoming these constraints for a more wholesome deployment.

2 Literature Review

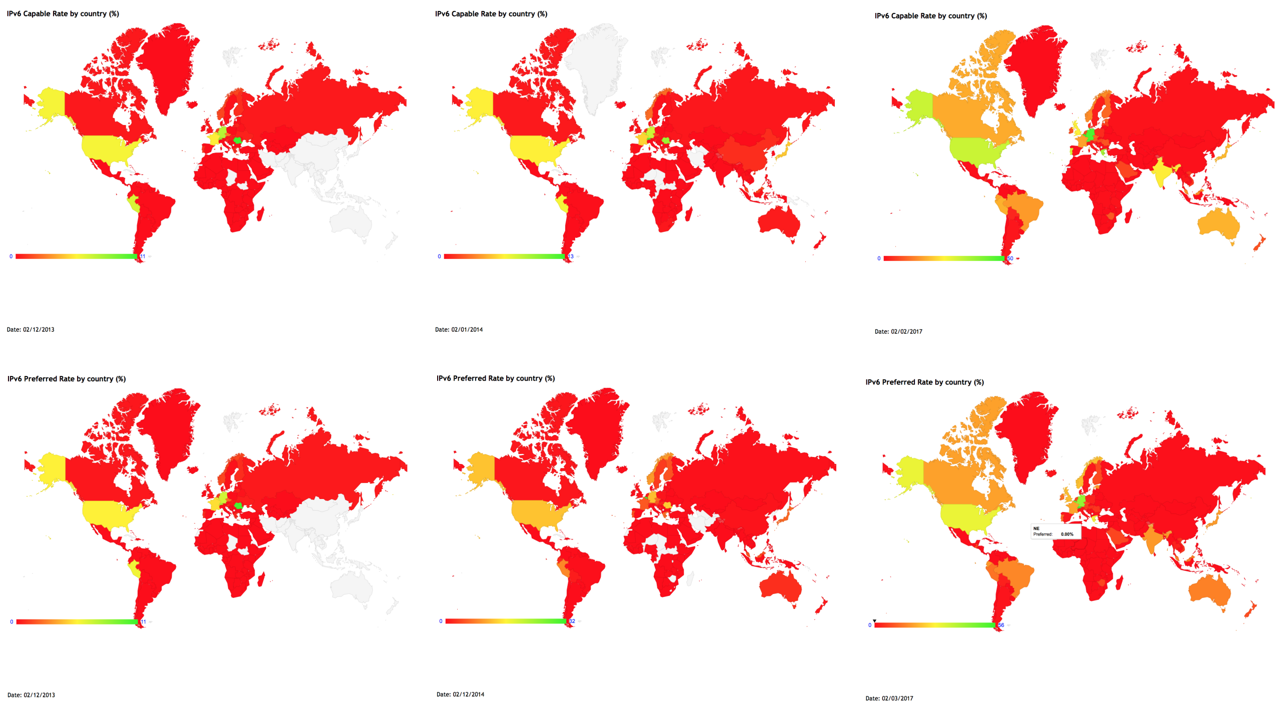
The approach and idea of this project has been backed up by many previous research works. A notable dissertation [5] in 2016, by John B. Southworth, has explored the deployment of IPv6 in 1000 colleges and universities of the United States. After careful research, his stance has been very clear; institutions that are readily deploying IPv6 are proactively saving themselves of an impending rush hour cost of immediate IPv6 deployment at an emergency state. A related work [3], by Jakub Czyz et. Al., measures IPv6 adoption rate and has discovered significant trends. For instance, while roughly 36 percent of new monthly (and 12 percent of cumulative) allocated prefixes are IPv6, we find just 0.63 percent of average traffic is carried over IPv6 (a two-order-of-magnitude difference) [3]. Clearly the problem lies in the network itself and not the end hosts, which motivated our research to be focused on measuring the network directly. As shown in [4], the measurements of performance we plan use (time to return a response and number of hops in the route) are reliable measures of network adaptability. In [4], authors discuss the methods of traceroute that we intend to use in our research and provide a backbone of their reliability. In [1], authors discuss their experience in using the ATLAS Ripe platform for probing servers through different hosts over the world. The authors have vouched for the platform's unbiased data outcomes and its ability to provide a large array of host choices through largely dispensed probes. The combination of the platform and our methods of analysis, served as a good starting point for our project.

3 Experimental Paradigm

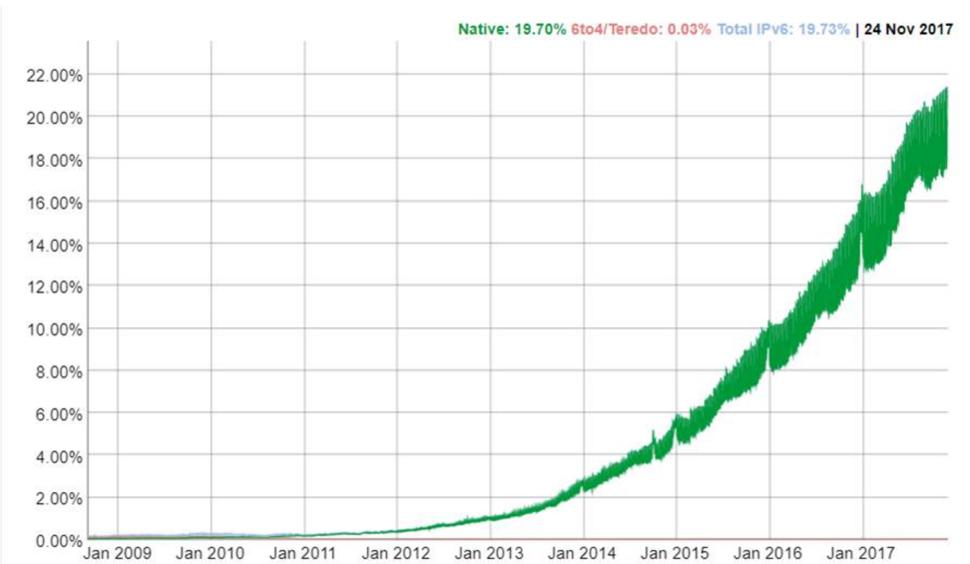
The approach we have chose was strongly influenced by the previous research in the field. The aim of this project was simple, we intended to analyze the development of IPV6 over different servers, networks and countries. We accomplished our goals in three main steps. First, we chose the fifteen most visited websites of the world (scored by www.alexa.com). Next, we will chose ten geographically diverse locations (we tried studying a few countries from every region of the world). Finally, we will measure the performance of IPv4 vs IPv6, by sending IPv4 and IPv6 requests from a host/client (in each of the locations) to a server (from each of the chosen websites). The performance will be measured based on two main parameters, the time taken to receive a response and number of hops in each version's route. The decision to use these particular parameters was influenced by previous research in this field and the availability of these parameters. The time taken to return a response can be a direct indicator of how many devices on the message's path were actually supportive of IPv6 as compared to IPv4. The number of hops in the route will be a strong indicator of the extent of deployment of IPv6 routing tables and their outreach.

4 IPv6 vs IPv4

The graphs below [2] show the growth of IPv6 over the past few years. Looking at the graphs from left to right, we see data representing February 2013, February 2014, and February 2017. There are two rows of data, the first row shows the percent of internet connected devices capable of using IPv6 and the second row shows the percent of internet connected devices willing to use IPv6. From the graphs, we can see how IPv6 has been deployed across the world and which regions have made the the strongest transition to IPv6 (Belgium, Germany, and Greece).



Further more in a graph by Google shown below, we can see the percentage of users accessing Google through IPv6 over the years. The graph definitely shows a steady increase in the number of users but the full fledged deployment of IPv6 still has a long way to go.



There are some major benefits from migrating to IPv6, aside from just having more global IP addresses. By including the device's MAC address (and other hierarchical prefixes) in the device's IP address, we are able to auto-configure IP addresses to devices and more efficiently route packets. With IPv6, we would be able to get rid of IP-level checksum because most link-layer technologies are capable of performing checksum and error-detection, along with the transport-layer's capabilities of using a checksum to perform error-detection. One of the major advantages of implementing IPv6 is the fact that it restores end to end transparency. With the widespread use of NAT with IPv4, the concept of end to end transparency had become non existent due to global and local ip addresses. With the widespread deployment of IPv6, the need for NAT is going to be eliminated and the network overhead due to address resolution will also vanish. Needless to mention the one most important advantage of IPV6 is the fact that the Internet of Things simply cannot be deployed without IPv6. It is also important to be aware of the problems that may arise during or after the implementation of Ipv6. One of the most obvious disadvantages is going to be the cyber security attack loophole by spoofing. Having such a large address space, IP attacks will be easier to carry out as the attacker can simply take a new address whenever needed and the need for masquerading is eliminated. Handling IPv6 address tables and subnetting for routing tables is also going to be a deployment and ongoing implementation challenge in IPV6.

5 Methodology

In order evaluate the difference in performance between IPv4 and IPv6, we looked at how well the two protocols performed in different settings. The goal of this project is to analyze the performance (i.e. latency and number of hops) of the two protocols when transmitting messages between a client and server. Since unknown factors (ie. sporadic overload on server or router, weather, etc.) could lead to an abnormally high latency, we used RIPE Atlas traceroutes since it measures the path between any two hops thrice, thus mitigating most erroneous measurements due to network abnormalities. We extract the mean and median latencies for the most accurate interpretations possible.

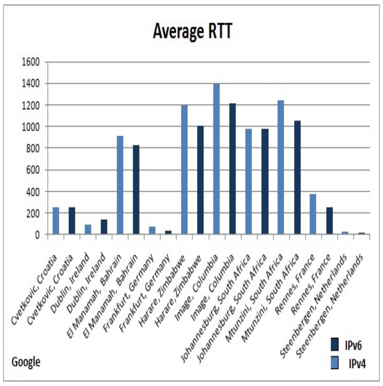
Connecting to servers from the most visited websites is significant to our approach because these servers are more likely to be IPv6 capable than choosing random websites (which may not have IPv6 capabilities or may only be physically located in one region of the world). The scope of this project is to analyze performance of IPv4/IPv6 around the globe. By varying the clients and servers which we probe, we are able to study the different/similar paths taken for each connection, which could foreshadow the development of networks in third world countries.

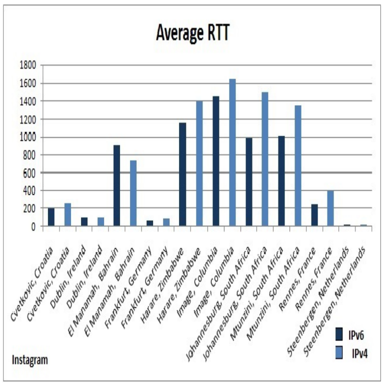
We took three main values into consideration- the number of hops, the average round trip time and the median round trip time. Graphs were plotted keeping two different perspectives- 1. with respect to the websites themselves and 2. with respect to countries. This helped us see how different tech giant websites are doing with respect to IPv6 deployment and also the general trend in different countries towards the acceptance of IPv6.

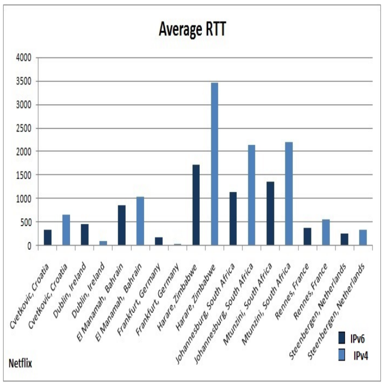
6 Results

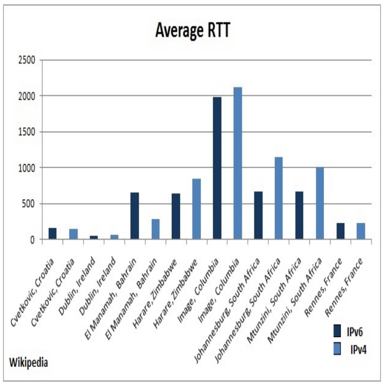
The initial result files that we obtained after conducting traceroutes through different probes and websites were multiple Json files, one for each probe- server pair. We analysed these Json files through our python parser and separated out the number of hops, average round trip time and median trip time. Each of these values was mapped to the particular website and the particular country of the probe.

The graphs below show some interesting trends in the deployment of IPv6 (Please note that the dark blue bars denote IPv6 and the light blue ones denote IPv4). We see that for all the major websites shown here, the avergae RTT is less for the IPv6 path as compared to the IPv4 path. Several conclusions can be drawn from this. First of all it becomes evident that most major tech giants have already deployed IPv6 to some extend. Secondly we can also see that in cases where IPv6 has been deployed successfully (like the websites shown below), it clearly outperforms IPv4 which is a clear indication of even more incentives to deploy IPv6. It is evident that not only is IPv6 need of the hour, it can actually enhance performance too. Another interesting point is how much IPv6 can be impacted by a country. While for all these graphs we can clearly see that IPv6 outperfroms IPv4 in case of proper deployment, the trend is opposite particularly in case of Bahrain. IPv6 is always slower. This strengthens our intuition that the deployment of IPv6 is technology, economically as well as geographically contrained too.

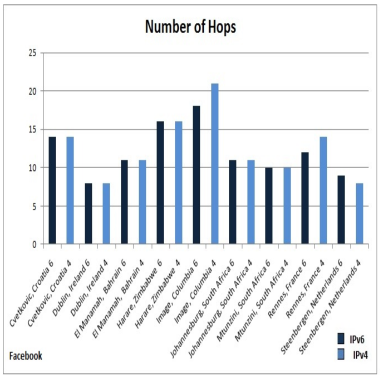


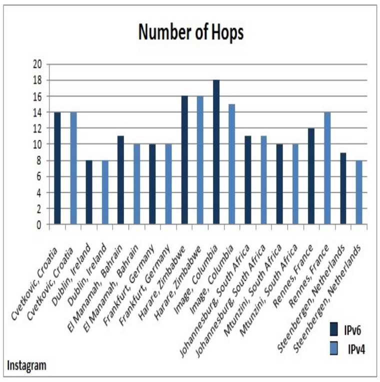


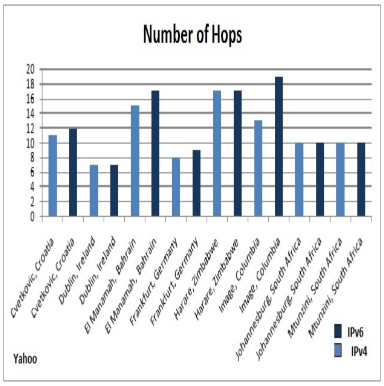




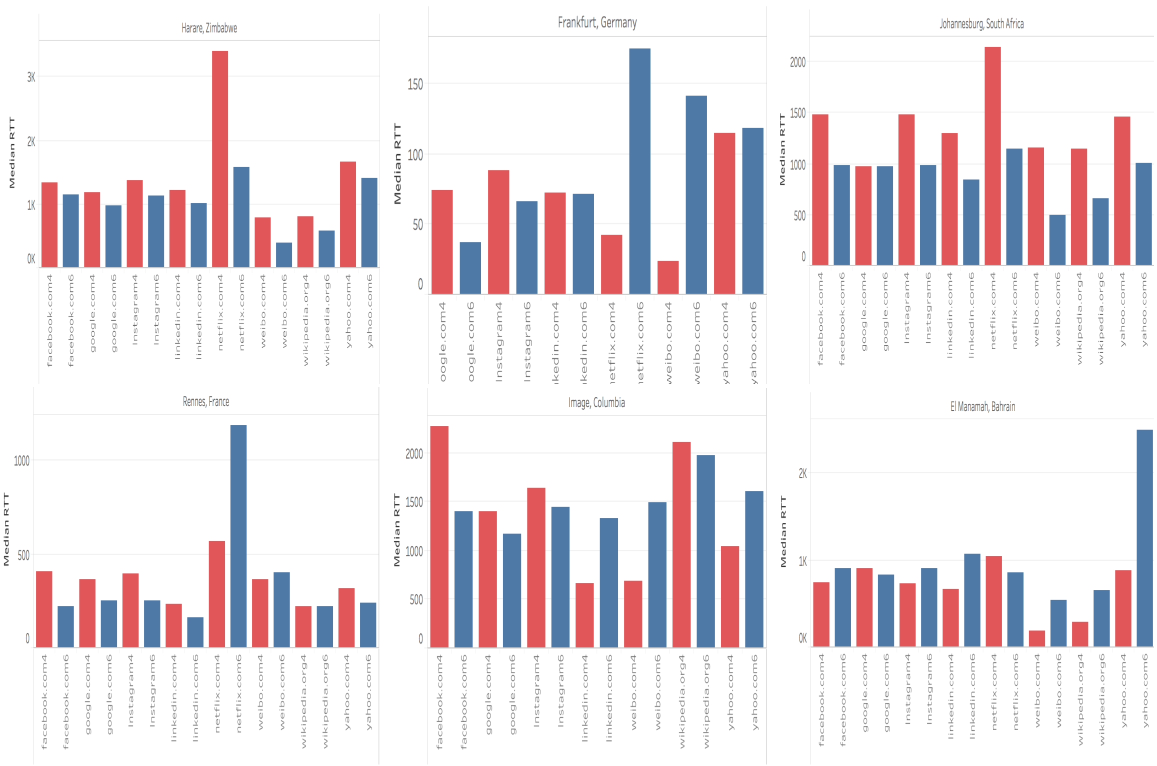
Next we have a look at the different traits in number of hops for some of the top websites for both IPv4 and IPv6 below. We observe thta for the cases of Facebook and Instagram the number of hops are almost equivalent for both Ipv4 and Ipv6. This is a strong suggestion that their Ipv6 deployement and networks have come at par with the IPv4 infrastructure. Interestingly, Yahoo doesn't show the same trend. Infact the RTT for yahoo's IPv6 packets was more than that of IPv4 too (Graph not shown here). This proves that Yahoo has not caught up with the serious deployment of IPv6. Bahrain is a bit of an outlier even in this case taking slightly more number of hops, confirming our hypothesis for less IPv6 support in that region.



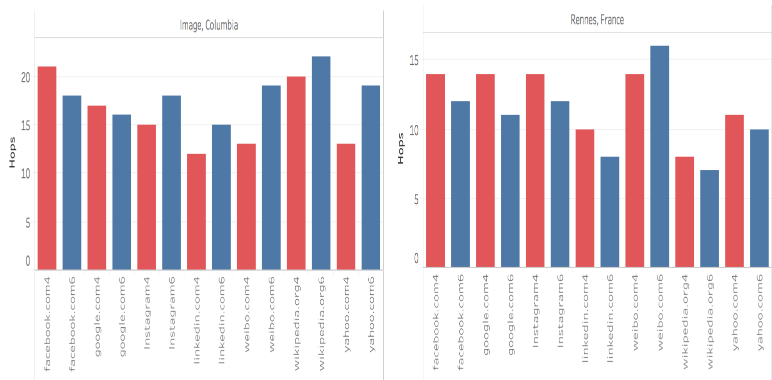




Now we shift our focus to county wise analysis of IPv6 deployment. The graphs below show the median RTT (we chose median in case of countries to protect false interpretations from inflated or deflated averages due to outlier values when considering multiple websites) for different websites comparing IPv4 and IPv6 times. We see that IPv6 has better performance overall in all countries chosen (Germany, South Africa, France, Columbia, Zimbabwe and Bahrain). Surprisingly enough, contrary to our expectations, Zimbabwe also has better performance and hence good support for IPv6. One thing to be noted in the case of all these countries is the fact that while overall IPv6 performs better with lower RTTs, performance is poor when concerned with websites like weibo, netflix and yahoo. This shows that these websites in particular have not committed enough to the deployment of IPv6. Again Bahrain stands out in these graphs as it has poor IPv6 performance on all website frontiers. This again strengthens our claim that the deployment is influenced by country wise factors too.



Finally we also haave a look at the number of hops countrywise. For this we present the two opposing trends notice that serve as a defining factor for the deployment of IPv6. For Columbia, the number of hops is greater for almost all websites for IPv6 whereas for France the trend is the exact opposite. This is yet another strong predisposition towards the fact that countries and regions have an important role to play in the deployment of IPV6 too.



7 Conclusion

Though our experiments and results in the preceding sections, we conclude that the realm of IPv6 is definitely expanding. A few tech giants (Google, Facebook, Instagram, etc) and some leading countries have served as vanguards of this deployment. And in places where IPv6 is indeed properly deployed, it is already outperforming IPv4 added to the protection against the IPv4 address space exhaustion. There are still some tech giants like Yahoo, Netflix and Weibo that seem to be lagging behind in catching up with IPv6 deployment. This also raises some concerns about the fact that if IPv6 has not been deployed properly by the top fifteen Alexa sites themselves, than the smaller websites have an even longer way to go. Some countries like Bahrain are also lagging behind in IPv6 support. Overall it can be said that there has been some measureable deployment that is significant but the job is far from over and we need more incentives in all possible ways for the companies and countries to support the much needed change to IPv6.

References

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