IPv6 protocol adoption in the U.S.: Why is it so slow?

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1 Introduction

In 1981, IPv4 became the de facto standard in the Internet routing world. In the early 1980s, the advantages of IPv4 were unmistakable and therefore, its adoption rate skyrocketed. In the early 1990s, due to increase in demand for the internet from end users, this adoption increased exponentially which raised concerns among the Internet Engineering Task Force (IETF) and other internet governing organizations. At this juncture, it was realized that running out of IPv4 addresses was inevitable. The previously presumed, $2^{32}$ i.e. 4.3 billion large address space, now seemed to be exhaustible. This brought up the need for a better technology that would be able to accommodate the need for a bigger address space and also provide enhanced services [1].

In September 2005, Cisco predicted that the remaining pool of IPv4 addresses would exhaust in about 7-8 years [2]. Policy building process for U.S. started in 2008 [3]. Although, the last block was sold out in early 2011, there are some addresses with major ISPs which have not yet been utilized, for example, according to a review site published by MIT; the United States has 1.5 billion IPv4 addresses of the total 3.7 billion IPv4 addresses. As a result, the U.S. has many of those IPv4 blocks unused and this has led to a slower transition to IPv6 [4].

This paper will proceed in 7 sections. The first two sections introduced the research topic and our research methodology. Section 3 talks about the need to increase this adoption rate. Section 4 sheds some light on why the IPv6 adoption rate is slow in the United States. Section 5 and 6 focus on what is the approach of other countries in regard to IPv6 and what is the United States' approach. Finally section 7 will conclude this paper by providing suggestions to improve the deployment rate of IPv6 in the United States.

2 Research Methods

Discussion with faculty members, industry sources, and information from academic literatures were the starting points of our research. A thorough review and analysis of academic literatures – whitepapers, journals, and conference proceedings provided a greater understanding of the IPv6 technology as well as the current deployment scenario. The facts researched from whitepapers and industry news provided strong information.

Another research method we used was researching the earlier facts and verifying the same through a sample of industry professionals/students. This was done by creating surveys specific to expert industry professionals working in the IP networking industry as well as specific to current/former students studying IPv6. These surveys helped in quantifying the research results from other sources and finding the key parameters.
Interviewing IP industry experts on the key findings of research and preparing a comprehensive analysis report was the final research method that helped us in finding the results.

3 Need to increase the IPv6 adoption rate

Statistics show that by the end of 2012, there will be approximately 3.6 billion devices that require an IP address all over the world [5]. Many of these devices would need more than 1 IP address. Therefore, 4.3 billion addresses are less than sufficient for the whole networking world to function properly. Also, Network Address Translation (NAT), a technology used for translating multiple private addresses to one or more public addresses has limited scalability. NAT limits an end user from creating a peer to peer session between them. This proves a disadvantage for some of the applications such as VoIP, IPsec and also affects some application layer protocols [6]. Moreover, RTI predicts the cost to the application vendors to support NAT transversal to be as high as 500 million dollars per year [7]. On the other hand, IPv6 allows end users to create an end to end session between them and hence do not need a central server to communicate between them.

IPv6 addresses assignment is organized and provides route aggregation i.e. network layer IP addresses are assigned in a hierarchical way which makes them geographically significant. In addition, route aggregation allows summarization of routes in an orderly fashion. This reduces the size of the routing table which, in turn, reduces the load on network devices and minimizes the consumption of system resources. On the other hand, IPv4 use a mixture of flat and hierarchical architecture for the address assignment which would result in large routing tables on the routers and also increase the memory utilization.

As the availability of IPv4 addresses are declining; a need for a better technology arises. One of the most important features in IPv6 is that it provides enormous expansion of IP addresses as compared to the traditional IPv4. IPv6 can be truly called virtually inexhaustible at this point of time. Some calculations show that every square inch of the earth could get approximately 3.6 million IP addresses and each square feet of the Milky Way galaxy can get an IP address [8].

Apart from its huge address blocks there are many other advantages of IPv6. Some of them are:

- Mobility: This is a feature that helps in providing multiple IP addresses to each network interface. A good example to illustrate this is the international roaming feature of a mobile phone. When the subscriber goes to a foreign country the device automatically acquires the most suitable IP address. This application is a big advantage to the wireless cellular and broadband industry as compared to IPv4. IPv6 mobility provides seamless roaming and therefore, finds many applications. Wireless Sensor devices used in health and medicine is a great example of IPv6 mobility.

- Security: IPv6 has inbuilt security features i.e. IPSec. This is an added field in the IPv6 packet header. This eliminates the need for NAT as well as implementing IPSec separately. Although, IPv6 has its unique security risks, it is considerably secured than IPv4.

- No broadcast feature: One of the major advancements in IPv6 is that it has completely phased out broadcasting. It supports multicast, unicast and anycast. This is helpful because it reduces the excess broadcast traffic and only multicast messages are sent.
4 Reasons for slow growth of IPv6

After the last IPv4 block was sold, the United States had 42% of the total IPv4 addresses i.e. 1.5 billion IPv4 addresses. In the fourth quarter of 2011, there were about 508 million internet users all over the U.S.; simply stating there are sufficient unused IPv4 addresses in the U.S. [4]. Apart from the abundance of addresses there are many other reasons slowing the rate of IPv6 adoption and deployment which are discussed below.

On the basis of a survey conducted by us among industry professionals working in the IP network industry in both ISPs and Enterprise network companies, we found out that according to most professionals, the “transition cost” involved in migrating to IPv6 is the biggest hurdle in deploying IPv6 in their networks.

![Figure 1: Biggest hurdle for IPv6 adoption](image)

The above graph shows findings from the survey which is in coherence with our findings from various research papers. Some of the hurdles are elaborated below.

4.1 Transition costs

Cost is one of the main reasons for the slow adoption rate of IPv6 in the United States. Craig Labovitz, the chief scientist at Arbor Networks says that the United States Department of Commerce estimates the cost of US $25 billion for ISPs in the United States to upgrade to an end to end native IPv6 network.

4.2 Technical and design hurdles

IPv6 is a very complex technology and compared to IPv4, needs considerably high processing power and memory allocation to support all the applications. Most of the ISP routers are more than capable of supporting IPv6 but not all companies have networking devices, capable enough to support IPv6. Kevin Epperson from Microsoft corroborated this finding and said that “many companies which are not too focused on technology have a large amount of legacy devices which do not support IPv6. Therefore, they are not willing to adopt IPv6.”[9]. Many of the operating systems also need significant enhancements to support the IPv6 adoption [10].

IPv4 addresses are still operational only because of the Network Address Translation (NAT) tool; without NAT all IPv4 addresses would have exhausted a long time ago. Apart from
NAT there are lots of other technologies that have helped in keeping IPv4 alive, for example, tunneling mechanisms such as GRE, Teredo, and 6-to-4. These tunnels are not always efficiently deployed and are poorly structured, unorganized, raising the cost of IPv4 traffic while degrading the quality of service and delaying the overall IPv6 deployment [11].

Another major issue of concern is Voice over IP (VoIP), according to Vikas Saraswat, Senior IP Architect at CableLabs, “Mainly in VoIP, all the codes written are for IPv4 message formats. By default it is not for IPv6; the code written is stable for IPv4 but not for IPv6. Therefore, there are problems in VoIP while using it with IPv6.” [12].

4.3 Lack of IPv6 content

According to a study conducted by Arbor Networks in October 2010, IPv6 traffic just represents one-twentieth of 1% of the entire internet traffic. This data was compiled from the management statistics from 110 ISPs. Another interesting fact found by Arbor Networks was that majority of the IPv6 traffic was via tunneling mechanisms, i.e. the native IPv6 traffic was minimal [14]. Additionally there is also lack of IPv6 content.

![Figure 2: Percentage of native IPv6 traffic as compared to the total IPv6 traffic [15]](image)

This graph shows the percentage of native IPv6 traffic as compared to the total IPv6 traffic [15]. The above graph implies that there are less content providers of native IPv6 traffic. Even though the IPv6 traffic is increasing, it is just the traffic over the tunnels. As more and more content providers step up the growth of IPv6, the transition will be inevitable. Kevin Epperson from Microsoft also said that “less IPv6 traffic as a result of less IPv6 content as well as the ability to rent or buy IPv4 addresses from ISPs are two major reasons stalling IPv6 adoptions.” [9].
5 How are other countries approaching IPv6?

The government plays an important role in the deployment of IPv6 throughout the nation. The American government had setup mandates to successful demonstrate their IPv6 capability by June 30th 2008, but it was never completed. Major ISPs in the U.S. already have a lot of unused IPv4 addresses spaces which will be sufficient for a couple of more years to come. However, other countries, who had limited IPv4 addresses to begin with, had to find other alternatives to overcome this shortage. Some of the countries have been mentioned below along with the approach they have taken.

5.1 Japan

Japan has the highest IPv6 adoption rate. Japan had started IPv6 adoption back in 1999, the very next year the RFC for Internet Protocol Version 6 (RFC 2640) was made. In comparison to other countries Japan was way ahead in IPv6 deployment which we can be seen from the diagram given below.

![IPv6 adoption timeline](image)

**Figure 3: IPv6 adoption timeline [16]**

Japan was the first country to start IPv6 deployment with support from their government. The Japanese government had started an initiative to support IPv6 deployment (e-Japan initiative) and went a step forward to promote IPv6 as a national mission. One of the main driving forces to start the initiative was because Japan was lagging behind in Internet reachability even in the Asia-pacific region. E-Japan initiative was started from January 2001, it had well-defined goals with sole aim was to make Japan the “Worlds most advanced IT nation within 5 years” [17].
In addition to the government initiatives Japan is heavily driven by a strong consumer market. Sony, one of the Japanese multinational decided to produce all its products IPv6 enabled from 2005. In addition to this, there were several other projects initiated and funded by the government for promoting IPv6. The Japanese government had also provided tax incentives and subsidies to those companies which had promoted and integrated IPv6 in their company [18]. Japan had a consumer driven market and makers understood the importance of IPv6 and knew that IPv4 did not have the address capacity to support their network they had envisioned. Japan is a strong participant in IPv6 forum since it was formed in 1999 and also has contributed and funded to the IPv6 forum ready logo program with sole aim to promote IPv6. This was proved when around 47% of Japanese products had IPv6 logo during phase I (e-Japan initiative) which had aimed for interoperability and more than 29% of Japanese products during the phase II which aimed for professional use; thus, giving Japan a head start in the IPv6 market [19].

With this movement Japan has made an estimate that a US $1.5 trillion market will be created by the end of 2010 [20]. And by the end of year 2010, the Ministry of Information and communication had already set their goals to get IPv6 deployed with several technologies.

5.2 China

China had implemented the Internet from 1994, almost ten years after the developed countries. The Chinese government realized the fact that with their increasing population they will not have enough IPv4 address. Hence, the Chinese government initiated a program CNGI (China Next Generation Internet) in 2001. This was a government supported initiative and was sponsored by the top eight ministries in China [21].

The CNGI initiative was divided in two phases. The first phase was from 2003 to 2005, its motive was to provide a platform for advanced networking technologies and build the backbone network, whereas the second phase started from 2006 to 2010 which aimed to deploy the large scale IPv6 network throughout 38 Giga POP’s. China demonstrated its success in IPv6 at the coveted Beijing Olympics. The surveillance cameras which were deployed within the Olympics facilities had IPv6 sensors and controllers. 'The large-scale remote visual system has been the technical highlight in the Beijing Olympic games,' said Liu Dong, Chief Technology Officer (CTO) of the Beijing Internet Institute. It supplied the visual surveillance system for the games.

Being the early adopters of IPv6 helped China to showcase their growth. At the same time they also unveiled their next initiative CNGI-CERNET2 which provided a test-bed for Chinese students, researchers and professionals and also interconnected around 60 Chinese institutions. In their next initiative the CNGI-CERNET2 they had gone to build the World’s largest native IPv6 research backbone. They could not get with dual stack because again dual stack would require IPv4 address which the Chinese ISPs were lacking. The IPv6 and IPv4 services are closely related i.e. a occurrence of fault in the IPv6 infrastructure will affect the IPv4 infrastructure and in total affecting the company’s service level agreement. Any kind of loophole or weakness in the IPv6 architecture would be the entry point for an attacker to also exploit the IPv4 architecture because they are inter-related. And lastly dual stack is just a transition mechanism and does not promote IPv6 [22].

Hong-Kong Shanghai Banking Corporation like many other multinational banks has increased their IPv6 adoption rate to compete in the global market. In the mid 2010 they had planned to upgrade their entire backbone infrastructure in order to successfully compete in Asian markets where it has half of its market [23].
5.3 European Union

RIPE (European Union RIR) has always been allocating the maximum IPv6 address. In December 2004, RIPE had 56% of IPv6 allocated address spaces and 47% in December 2011[24]. European Commission had initiated several projects for successful deployment of IPv6. i2010 and the Digital agenda was one of them which aimed to provide the European citizen with high-speed internet by 2013. Similar to Chinese initiative, The European Union had deployed IPv6 within the academic network for testing purposes. GEANT project is a pan-European data network dedicated for academic and research purpose. Currently it has successfully connected more than 40 million users spread over 40 countries [25]. Due to this initiative European Union has an operational IPv6 backbone network. There were several other projects like 6NET, Euro6IX, SEINIT and many more which are funded by the government which continue to contribute to the growth of IPv6 deployment.

6 What is the United States’ approach?

Contrary to approach of the other countries, the United States has not yet shown an active interest in the adoption and deployment of IPv6. Some of the major factors that affect this decision are:
- The United States still has a lot of unused IPv4 blocks.
- Content providers are still focused on IPv4 services. A customer demands for basic internet connectivity and they are not concerned if it is delivered via IPv4 or IPv6. Therefore, enterprise networks and Internet service providers are moving very slowly towards the transition to IPv6 due to lack of demand from customers [26].
- There has been no strong regulatory decisions been made in regard to the deployment of IPv6. This lack of enthusiasm is reflected in the following graph which shows the percentage of IPv6-enabled Autonomous Systems (AS) registered in each RIR [27].

![Figure 4: Percentage of IPv6-enabled Autonomous Systems (AS) registered in each RIR [26]](image_url)
IPv6 protocol adoption in the U.S.

This chart clearly shows that among the 5 RIRs the American Registry for Internet Numbers (ARIN) is lagging behind the others.

6.1 IPv6 deployment and approach

The Obama Administration released a plan to upgrade all the federal websites and governmental services in the next 2 years. This mandate has received a positive reception from various policymakers and industry leaders. This mandate also projects a secondary goal with a deadline of September 2014 for federal agencies to upgrade applications and internal networks to support and establish connectivity with the public internet. Any and all hardware and software upgrades during this period are necessary [28]. One of the key aspects of this plan was to upgrade the federal website of the Department of Commerce to an all IPv6 compatible website.

![Figure 5: NIST document showing the IPv6 enabled domains of the Department of Commerce [29]](image)

NIST conducted extensive tests on the public domains of the Department of Commerce and results are shown in the graph above. It shows the combined IPv6 service results for all the agencies of the Department of Commerce. A total 131 DNS services were measured and for this cycle the Department of Commerce had 29 Operational services depicted in green, 1 service was under progress and 104 showed no progress, depicted in red. In regard to the Mail services all 55 services showed no progress. Similarly in regard to the Web services offered by the Department of Commerce only 3 were operational and 113 showed no progress [29].

However, this is the second time when the Office of Management and Budget (OMB) has sent out a mandatory memo for federal agencies in regard to IPv6. A similar mandate was released by the Bush administration back in 2005 with a deadline of June 2008 [30]. Ram Mohan, executive vice president, Afilias, which operates .info and a dozen other Internet domains stated that simply aiming for a date will not create a thorough implementation of IPv6 as there are several technical issues with the deployment of IPv6 that need to be addressed.

In 2011, Comcast pioneered IPv6 deployment in the market with IPv6 services and applications [31]. Other major ISPs and content providers, for example: T-Mobile, Time Warner
Cable and AT&T are also joining in the race for IPv6 deployment. However, most of their IPv6 deployment strategies are still in the beta testing phase. In the United States one of the heavyweights in the IPv6 deployment is Hurricane Electric. With a fully functional IPv6 network and Autonomous System (AS6939), Hurricane Electric, was one of the early adopters of IPv6 technology. As of 2008 they maintained one of the largest native IPv6 backbones in the United States. Hurricane Electric’s teredo tunnels provides IPv6 connectivity to users worldwide [32]. Another California-based ISP, Sonic.net, offers IPv6 addresses which are tunneled through the 6to4 tunneling mechanism [33]. Vikas Saraswat, Senior IP Architect at CableLabs, states that CableLabs is IPv6 ready and they have accounted for IPv6 network scenario from the start. He mentions that DOCSIS 3.0 (2003) DOCSIS 2.0 (1997) both are IPv6 ready and there are many test projects going on [12].

6.2 Recommendations

The United States should follow the example set by the other countries, such as Japan and China, and mandate incentives and subsidies for the IPv6 early adopters. This would highly benefit the rate of IPv6 deployment and adoption in the United States. The data compiled from the survey sent out to the professionals working in the industry shows a list of recommendations which will play an important role in the adoption of IPv6. Although, with the limited scope of our survey some of the key factors that would influence the adoption rate are:

· Creating mandatory policies for the adoption of IPv6.
· Push the enterprise ISPs and networking giants towards an IPv6 environment.

Professor Dale Hatfield, in an interview, suggested that “even the state government should step in with an effort to promote IPv6.” [34]. Unless the government, enterprise networks or service providers find enough incentives to transition and modify their current IPv4 network to support IPv6, it is unlikely that the deployment rate in the United States will increase. In another interview, Kevin Epperson, reinforced that a functional incentive for economic investments is required for the adoption rate of IPv6 to increase and flourish [9].

7 Conclusion

The IPv4 addresses have now been exhausted and therefore network planners should begin planning for an organized approach towards IPv6 deployment. The United States should follow the example set by the other countries in the deployment of IPv6 and form concrete policies that mandate the adoption of IPv6 networks. Such a network should seamlessly transition to interconnect with the existing IP world. Organizations stepping into the IPv6 world will be regarded as the early adopters of a newer and superior technology.

Although, the transition costs may be an initial hurdle towards the end goal, but this transition is inevitable. As the costs for implementing NAT will increase significantly, soon, the maintenance cost of IPv4 will far exceed the transition costs towards IPv6. Above mentioned recommendations would facilitate faster IPv6 adoptions.

IPv6 provides a world full of business opportunities and a complete technical solution to many Internet problems faced today. An investment today will save a lot of resources in the future.
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References:

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[34] D. Hatfield, private interview, April 5, 2012.