Hurdles in Implementing IPv6 in Pakistan

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Abstract
IPv4 addresses are almost consumed and IPv6 adoption has increased in recent years. Migrating to IPv6 needs transition from IPv4 to IPv6 but this process is facing challenges. Stakeholders like ISPs and ICPs seem divided on immediate migration as they use different options rather than moving to IPv6. This paper investigates obstacles and complications in completely moving towards IPv6. These include identifying key factors that are still supporting IPv4 and contribute towards delay. The Pakistani market is specifically targeted and analysis is given about root causes delaying IPv6 adoption

Index Term
Adoption in Pakistan, IP networks, IPv6 Protocols, IPv6 transition

1. Introduction

In Feb 2011, Internet Assigned Numbers Authority (IANA) announced that free pools of IPv4 addresses have been depleted[1][2]. The proposed solution to this problem is to migrate towards IPv6. Recent studies also show that IPv6 is becoming more widespread and proving to be a better alternate for IPv4[2][4]. But some hurdles are holding back its evolution even though these hurdles are not (any longer) of a technical nature. IPv6 has been available since 1996 and despite scarcity of IPv4; its adoption seems to be very slow. In the past few years, growth rate of IPv6 is between 1% to 4 % from 2012 to 2015 [5] and current IPv6 world total traffic in 2017 approximately is 20.55% as shown in figure 1.

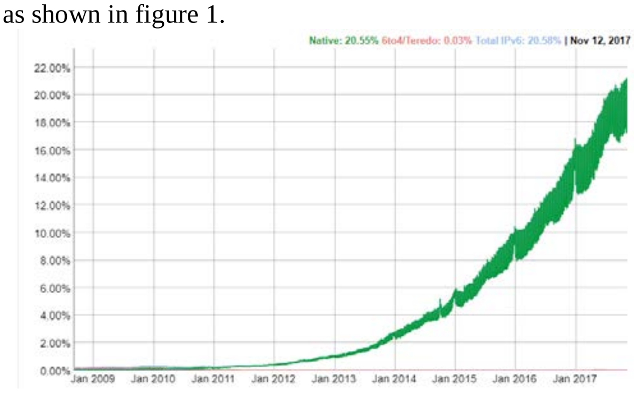

Fig.1 Google Statistic of Worldwide IPv6 Adoption.

IPv4 is unable to cope with the rapidly increasing number of internet users, IoT devices, commercial online businesses, tons of websites etc. This also indicates that Internet is entering a new paradigm, where connected devices are increasing day by day. Concepts like bring your own device (BYOD) and technologies like Internet of things (IoT) signal shift to an era where each device requires an IP address to communicate to the world[6]. Different authors have highlighted the incredibly high number of nodes predicted when devices interconnect using IoT[6][8], where each node will produce relevant data that should be accessible by any authorized user[7]. To address these nodes and users, IPv4 will no longer be able to support these massive numbers of devices. This is putting pressure on users for transition from IPv4 to IPv6 which has a much larger address space.

Number of studies have supported migrating to IPv6[5], [9][11], which raises the question as to what is holding back its evolution. Compared with IPv4, IPv6 has a large address space and IPv6 addresses are less costly than IPv4 addresses. It has been also proven 10% faster than IPv4 and deliver better user experience via low latency[2].

This paper analyzes the issues that have been hoding back IPv6 adoption and is organized as follows: Section 2 of the paper explains IPv4, IPv6 and exhaustion of IPv4 addresses. Section 3 of the paper identifies factors that are causing hindrances in adoption of IPv6 which is delaying the whole migration process. Section 4 of the paper analyzes IPv6 adoption progress in Pakistan and provides recommendation to expedite the adoption process while Section 5 concludes the paper.

2. Literature Review

2.1 IPv4 and IPv6

IPv4 and IPv6 are protocols that operate on layer 3, known as network layer, of the Open Systems Interconnection Model (OSI Model). Network layer is responsible for delivering data packets from source to destination. IP addresses perform two basic functions: an address function and a routing function. An IP address is assigned to each device as a unique identifier on the Internet to perform "who" function [1]. IP addresses are used by the routers to performs "how" function to send data packets from the source to the destination. The uniqueness of IP address for every host enables data packets to be delivered at right

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destinations. An IPv4 address comprises of 32 bit address field
and provides 4.3 billion unique addresses, of which 3.7 billion are usable. This is due to various reserved IP addresses for special purposes like reserved for broadcast, multicast, for local communications within a private network, loopback addresses and others. Since, the number of devices is increasing due to increased connectivity, IPv4 addresses are on the verge of exhaustion. In 1990s, Internet Society predicted the possibility of exhausting this resource which is a reality nowadays. In 1995, IPv6 was developed with 2^{128} unique addresses which provide an incredibly large address space.
It is generally believed that the transition from IPv4 to IPv6 will be slow and consequently both protocols will coexist for a long period[12]. The deployment of IPv6 is one of the biggest challenges for IPv4-based architectures[13] as both technologies are not interoperable[14]. Previous studies also suggest that adoption of the new IPv6 protocol will not happen overnight regardless of the apparently increasing passion for IPv6[13].
For both protocols to coexist, different transition mechanisms are required. These can be classified as dual stack, tunneling and translation[5][13]. None of these methods are fully compatible, efficient and resources proficient [12]. These mechanisms also incur a higher cost with low functionalities and therefore, constitute a disincentive for first-movers to IPv6[5]. Nevertheless, stake holders have realized that the growing number of internet users can only be accommodated with IPv6.
Policy initiatives to promote IPv6 have been taken by different public agencies and organizations. These initiative are soft in nature as it is still not possible to make this transition mandatory[5]. On June 8th 2011, several Internet operators and participants like Google, Facebook, Microsoft and others agreed to enable IPv6 support on their network on “IPv6 World Day” [11] [15]. Several countries and organizations have since joined this initiative and shifted their networks.

2.2 IPv4 exhaustion

Compared to last decade, allocation of IPv4 address is faster than ever due to intensification in the number of internet users, online businesses etc. IPv4 exhaustion was predicted by various authors in 2010 and 2011[16][17] which has come true. Exhaustion of IPv4 addresses is affecting entire world but on different scales as the distribution of IPv4 address blocks is not uniform[18].
The Internet Assigned Number Authority (IANA) distributes large IP address blocks to the Regional Internet registries (RIRs) which are five in number: ARIN, RIPE-NCC, APNIC, LACNIC, AFRINIC[18]. Currently only one of the five RIRs, APNIC handling Asia-Pacific region is facing severe IPv4 scarcity as the number of internet users and businesses are rising rapidly.
The purpose of RIRs establishment was to organize and distribute the IPv4 pools among network operators and ISPs within their specified region. Between 1980s and 1990s, due to absence of RIRs and polices, an imbalanced distribution of IPv4 addresses [19][20] occured. Around 33% to 45% of address were allocated prior to the establishment of registry system[16]. Thus, a huge portion of IPv4 address space is underutilized or unused. These addresses were distributed among different US authorities[18] and effort to reclaim them from so-called legacy holders have been highlighted by various researchers[16][18][20]. Despite reclaimed IPv4 addresses, which provides short term relief, authors also emphasize that adoption of IPv6 is the only long term solution to Internet growth and new IP based technologies[18][21].
IPv4 address exhaustion has taken place in different stages and might happen in different order but the most likely order is given below[17]
- On Feb 2011, IANA exhausted its free IPv4 pool
- Unallocated pools of IPv4 address exhausted by RIRs (for e.g. APNIC (serving the Asia-Pacific region) the APNIC pool reached the last /8 of available IPv4 addresses[22]
- ISPs, businesses etc exhaust their unused IPv4 addresses

3. Factors delaying IPv6 progress

There are many factors that are affecting the progress of IPv6. Not all factors affect in the same magnitude; it vary with different models, and some factor impact more than others. In this paper, we highlight those aspects which seem to be regularly occurring and noticeable on many occasions

3.1 Network Address Translation

Network address translation (NAT) is an old method used by ISPs and network operators to preserve public IP addresses. It maps one public address to multiple private addresses[3] [10]. NAT also limits the network with single point of entry thus enhancing security and easing network management[3][5][10]. One of the biggest cause behind lingering of IPv6 is NAT as almost every home user is behind NAT which is delaying the exhaustion of IPv4 addresses [3][10].
NAT has several drawbacks[23]. Studies have shown that traffic originating behind the NAT works as per expectation but it’s not the same case when traffic initiates from the outside. For example, a VoIP call set up or remote session initiated from outside will have to go through additional steps[14]. It adds complications to bi-directional application[10] and creates problems for those application that depends on IP addresses such as FTP [23]. Research-

ers also indicate that it adds a layer of complexity while mapping from public IP to private IP and often increases costs for the design and maintenance of networks[10]. NAT also makes thing worse when it's come to IP-based authentication, geolocation accuracy and proof of identity [3].

Increase in IPv4 address demand triggered extensive deployment of NAT[14] which itself is not enough to halt the IPv4 exhaustion. After the transition to IPv6, NAT would no longer be required to preserve IP addresses. Although, NAT would not disappear during the transition phase.

3.2 Carrier-Grade NAT

A new trend has been observed in the industry that to mitigate IPv4 exhaustion, Carrier Grade NAT (CGN) or Large-scale NAT (LSN) has been used. Latest calculations suggest that at least 3% of IPv4 users log on to the Internet via carrier grade NAT[18]. For example, British Telecom adopted CGN in 2013[24], Plusnet adopted it in 2013[25] and Skymesh using A10 network CGN product[26]. CGN assigns private IPv4 address to clients, who connect to the internet, instead of public IPv4 addresses hence limiting use of public addresses[27]. Use of private IPv4 addresses allows ISPs to gain benefit by not requiring them to purchase new public IPv4 addresses and avoiding potential upgrade of their network to IPv6. CGNs are also required in case if ISPs offering IPv6 addresses to clients to communicate with public IPv4 addresses. However, managing private IPv4 addresses is much more convenient in terms of mature technology, operational familiarity and compatibility with current Internet[27].

Two drawbacks of adopting CGNs for private IPv4 address are: First, as users grow, cost of CGN will keep increasing independently of how many online content providers become IPv6 accessible[2] [27]. Second, the level of complexity of network with the inclusion of CGN i.e. scalability, security and reliability are at risk. Some peer to peer applications might also face difficulty. Law enforcement agencies would face problems in keeping records and it is almost impossible to track down cyber-criminal activities [2] [28].

With CGNs, ISPs and network operators are lingering IPv6 progress and will delay IPv4 exhaustion, but it does not eliminate the problem.

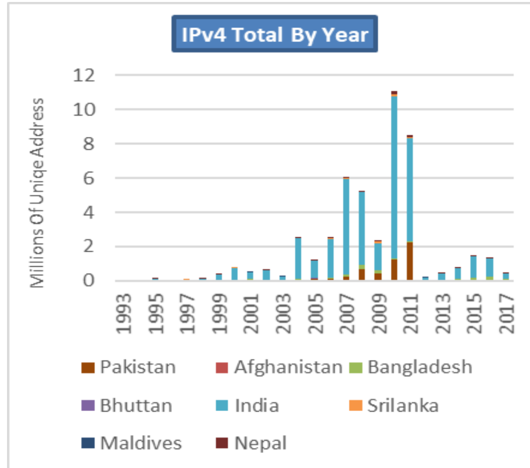

Fig. 2 Total IPv4 addresses acquired by South Asia Countries in millions

3.3 Purchasing of IPv4 address

IPv4 has the advantage of being fully compatible with current Internet technologies[9]. This keeps many organizations to opt for costly IPv4 addresses; for example, Microsoft acquired addresses from bankrupt Nortel Network in 2011 and purchased 666,624 IPv4 addresses for price of $7.5 million[29]. Another example is of bankrupt bookseller Borders Books which sold /16 IPv4 block (65,534 addresses) for a price of $786,432 to medical software firm [30]. Recently, MIT sold 8 million IPv4 addresses to Amazon due to underutilization [31]. Excess number of IPv4 addresses is part of early distribution of IPv4 blocks. Numerous government and private organizations are releasing IPv4 addresses as they are underutilized or out of business or upgrading to IPv6 (in case of MIT[31]). Organizations not willing to incur the cost of potential upgrade to IPv6, keep relying on purchasing new costly IPv4 blocks available at places like IPv4 Auction, Hilco Streambank, IP Trading, IPv4 Market Group. Transfer of IPv4 pools from other organization is a seamless process defined by respective RIRs like[32], [33]. Figure 2 depicts the IPv4 addresses purchased by South Asian countries in recent years.

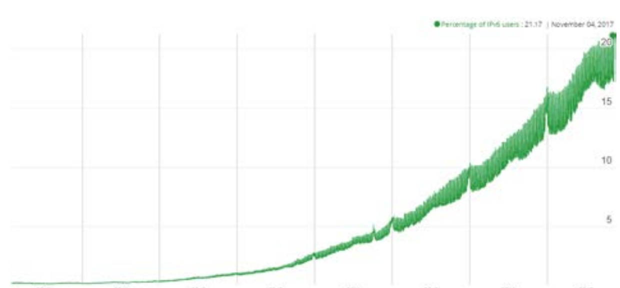

Fig. 3 Cisco Statistics of World User Data

3.4 Disagreement between ISPs to offer IPv6

Technology choices are controlled by ISPs as they are the providers of Internet connectivity. Deploying IPv6 is costly for early movers due to translation mechanism which has few solutions each with its shortcoming[34]. It also provides inferior services due to content unavailability. Without clear return on investment, it is very hard to question ISP's to invest in IPv6 with inferior services[23]. Despite this, a large number of ISPs have enabled IPv6 connectivity[35].
According to the current statistics, support for IPv4 is still greater but the growth of IPv6 is slow and steady[36]. World user adoption rate seems to be below 21%[37]. The increase in adoption of IPv6 is also shown in figure 3. It has been observed that independent decisions and no coordination between ISPs to provide IPv6 connectivity option, adds uncertainty and influences negatively on IPv6 adoption decisions[9].
ISPs plays major role in progress of IPv6. If they agree or make a collective effort to move towards IPv6, progression would become much easier and achievable. Let's consider two ISPs one of which is to start offering IPv6 but is not willing to acquire further IPv4 addresses while the other still relies on IPv4. The first one offering IPv6 would certainly require adding translation mechanism in their infrastructure as they need to communicate with IPv4 public Internet, being aware of the fact that transition towards IPv6 would not happen suddenly. Greater the number of users that use IPv6, greater will be the cost of translation mechanism. But this cost can decline as content providers adopt IPv6. Conversely, the second ISP does not incur any translation mechanism cost and rather opts for purchasing costly IPv4 address as this has the advantage of being fully compatible with current Internet technologies.
ISPs without both connectivity options highlight lack of consensus between ISPs, which ultimately affect market penetration and increase cost for first comers. ISPs must come up with better and coordinated plan which include both connectivity options with different packages. For example, For IPv4 connectivity, charge higher prices and charge for extra services while IPv6 is made available at discounted low price with free extra services that will attract users[9]. Defense Research and Engineering Network (DREN) was an early mover to IPv6. DERN experience recommends that, with planning, estimated expenses could be mitigated[38]. DERN include IPv6 in their regular lifecycle of upgrading network with keeping some additional money for migration to IPv6.

3.5 Configuration of IPv6

A commonly reported barrier to IPv6 deployment is expertise. Before deploying IPv6 to any organization: education, training and awareness must be the initial steps[14]. There are few network engineers with the available knowledge to manage IPv6 networks. IPv6 is a blessing for network administrators in terms of increased address space, ability to perform auto-configuration and efficient header processing[13]. But large address space also makes IPv6 a bit more complicated as compared to IPv4[39]. Configuration mistakes are one of the main sources of network disruption and network anomalies[39] [40]. Configuration errors can be avoided if administrators pay more attention and are careful as IPv6 addresses are hard to remember[39].
Another hurdle limiting IPv6 adoption is the presence of poorly managed IPv6 sites that negatively affect the quality of the IPv6 Internet[41]. When a IPv6 user communicates with IPv4 based system using a translation mechanism, mainly using dual stacked nodes, it encounters poor network performance[9]. The user assumes that the problem lies in IPv6 technology but in actual it's a poorly managed system due to lack of IPv6 expertise.

3.6 Content not available in IPv6

Amount of web content in IPv6 is still much less than IPv4. ISP's need to translate IPv6 connectivity at their end which increases their technical and management overhead. Availability of content in IPv6 will surge its adoption and costs will decline as translation need subsides. According to the stats available, IPv6 availability has increased in recent years but is still very low. For example, Alexa top 1000 websites which are accessible over IPv6 is 25.50% as of August 2017[42]. Thus, content availability rate is directly affecting user adoption rate. The percentage of users around the world that access google over IPv6 is 20.55% on Aug 2017[43]. In general, only seven countries have over 30% user using IPv6 in world[44] as given in table 1

Table 1: Estimated top countries using IPv6

Country	IPv6 Capable	IPv6 Preferred
Belgium	64.14%	62.63%
India	51.17%	49.96%
Germany	41.52%	40.56%
U.S	40.78%	38.93%
Switzerland	37.29%	35.76%
Greece	37.14%	36.40%
Luxembourg	34.11%	33.71%
U.K and Ireland	25.97%	25.60%
Portugal	25.51%	25.19%

3.7 End-User Hardware cost

With respect to the ISPs, upgrading their hardware is an ongoing process. ISPs have IPv6 enabled routers and some benefits from migrating to IPv6 with large address space. On the other side, enterprise networks are usually unconcerned by IPv4 depletion and have sufficient address space available through NAT. They do not have IPv6 enabled equipment and they won't change their premises equipment unnecessarily until hardware malfunction occurs. Further, there is no incentive for them to incur the burden and cost for adopting IPv6[2]. For many organizations, the strategy is to wait for everyone else to move first or wait until they have to move involuntary due to incompatibility with others[20].

4. Adoption in Pakistan

Pakistan is an emerging region with respect to technology. In 2006, three local ISPs Cybernet, Supernet, and Dancom acquired their IPv6 addresses and established national IPv6 task force to increase the pace of IPv6 activities in Pakistan[45]. To promote IPv6, National Task Force organized a technical summit in June 2007[45] and initiated the first IPv6 based project 6Core. This was a testbed network to start IPv6 research activities [45].

On 31st July 2007, Pakistan Telecom Authority(PTA) organized an Industrial Forum which was a gathering of academia, stakeholders, private sector and government functionaries[45]. The purpose of this forum was to make efforts to face future challenges in the field of information and communication technology. Adoption of IPv6 was one of the major agenda of the forum and it was decided that PTA shall articulate a consultation paper on “Transition from IPv4 to IPv6” to support the local industry to meet the upcoming challenges[45].

Despite early initiatives, IPv6 user adoption rate is still around 0.04% as of 2017 in Pakistan [43], [44] as shown in figure 4. These numbers are very low compared with other similar countries. To probe this discrepancy

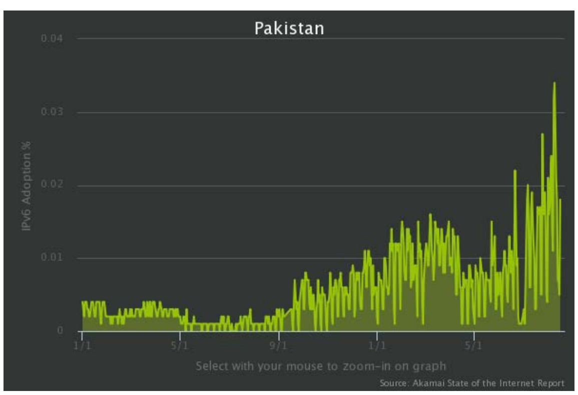

Fig. 4 IPv6 Adoption is Pakistan

, we have interviewed different decision makers working at various positions in major ISPs. Outcomes to this discussion reveal that all major ISPs provide IPv6 as a connectivity option but users on IPv6 are very rare. The main reason for such a low ratio is that very little local content is available on IPv6 as shown in figure 5. On the other hand, PTA, academic institutions and APNIC are continuously engaged in promoting IPv6 by conducting training session on IPv6 at major cities[46].

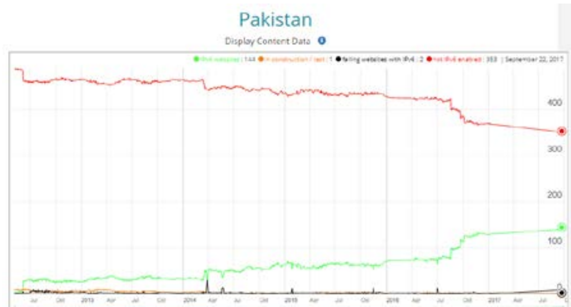

Fig. 5 Cisco Statistics of Content Data in Pakistan

The other reason that ISPs in Pakistan are not shifting to IPv6, are the IPv4 pools already available. The IPv4 exhaustion is impacting different organizations at different scale depending on the number of customers and the volume of IP addresses in reserve. Some ISPs have IPv4 pool available for next 10 years. Other organizations which are running out of IPv4 addresses and have high number of customers are planning to lease IPv4 pools. Leasing is a better option as investing large amount in buying IPv4 pools will have no benefits in future as eventually, IPv6 will be the last resort for everyone.

ISPs all around Pakistan are IPv6 enabled (hardware wise) though end user hardware will require upgrade. Some of the devices are IPv6 capable though not utilized at the consumer end. This is another reason why ISPs are not investing large amount in buying IPv4 pool and are opting for leasing. Policy for large organization is to buy some time by leasing IPv4 pools and wait until content is available and user demand increases for IPv6.

CGN option for ISPs are not feasible in Pakistan as mostly ISPs have corporate clients who host their devices directly over the internet i.e. VPN Servers, webhosting etc. Keeping track records of each home customer using CGN would require a huge bulk of data storage just to keep logs as is mandatory due to government regulations.

IPv6 configuration would be initially a challenge for the network administrators which can be overcome as familiarity increase with IPv6 addresses space. Big names on IPv6 are available but the local market still is on IPv4.

Fig. 6 IPv6 Adoption rate in Southern Asia region

IPv6 adoption has recently taken off in the region with India showing tremendous increase in a short period as shown in figure 6. Similar scenario is expected to happen in Pakistan once a critical mass is reached. This can be achieved through government regulation or thorough co-ordinated effort of industry.
Table 2 summarizes the the factors afftecting IPv6 adoption. It relates the factors discussed in this paper and their status in Pakistan. The main factors that have been identified are: content unavailability and lack of co-ordination. If these factors are overcome, then IPv6 adoption can see a major boost.

Table 2: Factors Affecting IPv6 Adoption in Pakistan

Factors	Status in Pakistan
Network Address Translation	Used extensively in private networks
Carrier Grade NAT	Not feasible due to corporate clients
Purchasing of IPv4	Preferred option, ISPs are buying or leasing IPv4 addresses
Disagreement between ISPs to offer IPv6	There is little co-orindation between ISPs or efforts from government
Configuration of Ipv6	IPv6 experties available but are limited
Content not available in IPv6	This is the major stumbling block as very little content exists
End-User hardware cost	Its not significant factor as IPv6 capable hardware is there

5. Conclusion

The paper highlights IPv4 address scarcity and increased demand for IPv6 in current and near-future. It also investigates the key factors that are affecting overall IPv6 adoption. It analyzes IPv6 progress in Pakistan and discusses the initiatives taken by groverment and private bodies. In our findings, these initiatives are still not enough to increase IPv6 adoption rate. Less local content availiblity and collective efforts by government and private bodies are the key factors that require attention to boost IPv6 in Pakistan.

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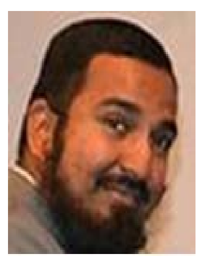

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