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Analytical Analysis and Mitigation Strategies for Catalyzing the Adaption of IPv6

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ABSTRACT

Internet Protocol version 6 popularly known as IPv6 has been in existence for almost two decades now. However, the adaption, implementation and use of IPv6 across the world has been very slow. Infact the adaption and explosion of IPv4 networks was better if not faster than the rollout of IPv6 networks. IPv6 which is a future networking protocol has many advantages and is much superior than its predecessor, the IPv4 – yet the rollout is not only sluggish, the full-fledged enablement of the IPv6 functionality is still far off. This paper trying to identify the reasons for the slow adaption of the IPv6 protocol across networks, devices and applications and how to overcome them.

Keywords: Internet Protocol version 6 (IPv6), Dual Stack, Migration to IPv6, Implementing IPv6

INTRODUCTION

It is a well-known fact that the Internet that we see and use today, and which has become an integral part of our life with a potential to facilitate and control our surroundings, once the Internet of Things (IoT) devices get deployed was never conceptualized or imagined even by the founders of the Internet Protocol. Internet or the collection of many networks across the world interconnected together has been an offshoot of the invention or development of a simple yet powerful communication Protocols TCP/IP, initially meant for making it easy to connect two or more computing devices together with the sole purpose of making them accessible across a distance within the same building.

Internet Protocol basically relies to identifying each device connected on the network with a unique number configured on the device to make it part of that network. Therefore each device connected on the Internet will have a unique number based on the format of the IP number system. The International Standard Organization has a well-defined model for Communication Systems known as Open System Interconnection, or the OSI Model. This layered model is a conceptualized view of how one system should communicate with the other, using various protocols defined in each layer. Further, each layer is designated to a well-defined part of communication system. The IPv4 format has four octets each having numbers ranging from 0 to 255, thus allowing about 4.2 billion unique numbers. However, since the IP based networks were supposed to serve different requirements and therefore some of these numbers were reserved for different uses, thus bringing down the usable unique numbers on the Internet to about 3.6 billion.

As the world of networking devices grew in the American continent and Europe, the number of devices from these continents took away about 1.5-2 billion unique IP addresses leaving very little scope for the rest of the world. Expanding regions in Asia with its two big giants India & China, Latin America and the Australian continent were constrained with the shortage of available unique IP numbers. Therefore, the need was felt that the present system of IP numbers need to be modified to enhance the number of IP numbers to cater to the need of the growing regions and the Internet world as a whole. Advancement in the Internet device technologies resulting in the advent of IoT devices is estimated to have about 20 billion devices hooked onto the Internet in the next 3-5 years.

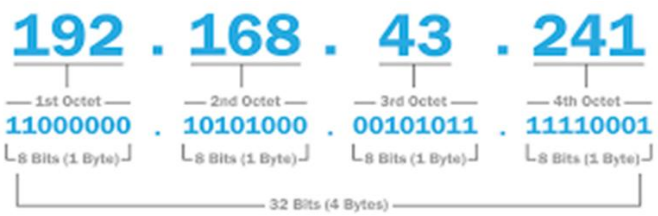
With the above scenario, it is amply clear, that the present IPv4 numbering system will not be able to cater to the requirement of the exploding Internet world and the new format of larger IP numbers offered by the IPv6 Protocol is the only way forward.

LITERATURE REVIEW

IPv4

The initial Internet Protocol was over the years enhanced to cater to the different needs of the network and the final version as we use today is version 4. This was the first and only version of the Internet Protocol to be widely deployed outside the experimental domain before the version 6 came into existence. Still around 80% of the internet traffic uses version 4.

Figure 1 IPv4 Address Format



Data based Communications which rides on the Internet Protocol suite and helps in transfer of vital information from one source to another has almost replaced the primary communication method of analogue voice communication. All new networks and technologies today try to leverage the advantages of the flexibility and ease of deployment of IP based networks.

This has resulted in the explosive growth of the Internet devices in the past one and a half decade.

IPv6

However, the above attraction of using IP based networks for all forms of communications between devices, between humans etc. have also stressed the IPv4 to its limit both in terms of the unique IP numbers as well as the efficiency and security provided by the protocol. This necessitated the need of developing a new version of the protocol having more unique IP numbers as well as taking care of the different security and efficiency challenges that will keep on growing as the internet devices boom including smartphones and other futuristic IoT devices keep adding to the network. Thus, the IP version 6 was born.

IPv6 uses the hexadecimal format instead of the decimal format used by its predecessor. This implies that instead of the number being in numeric form, the version 6 will have alfa-numeric format consisting of digits 0-9 & A-F.

Since most of the people around the globe were born with IPv4, the ease and comfort in using

Figure 2- Network Routing Overview

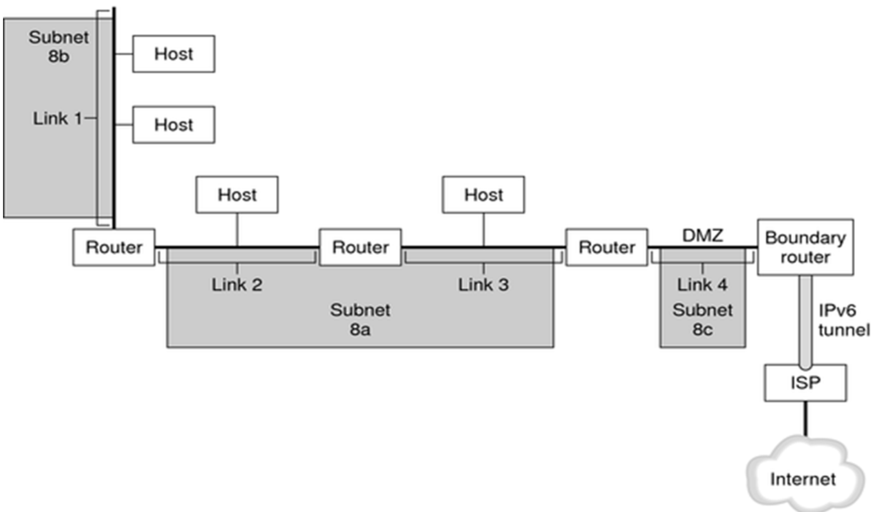


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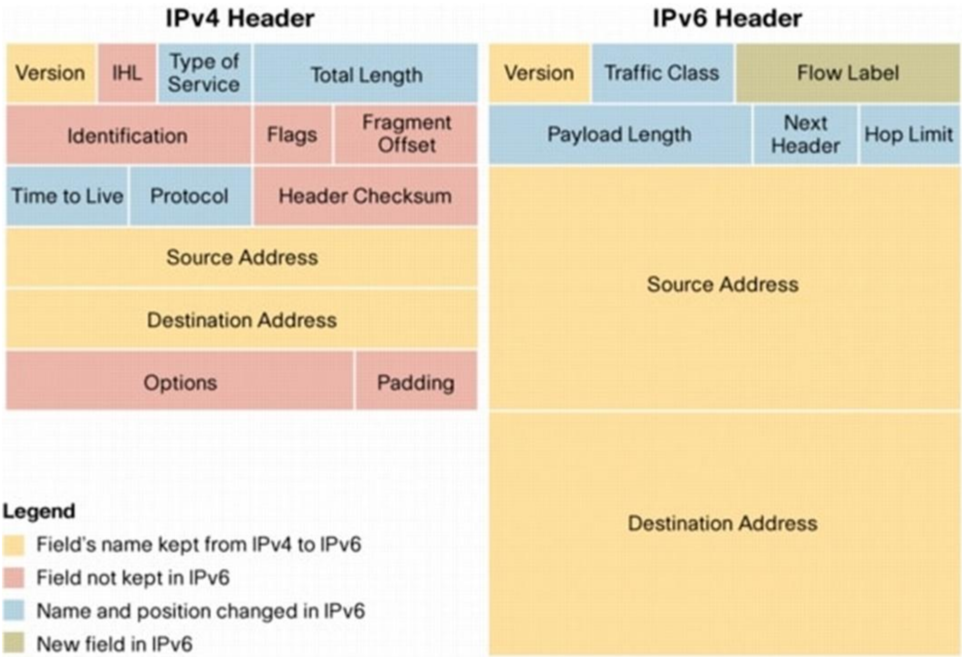
Figure 3-IPv4 and IPv6 Header comparison



As can be seen above, the new generation Internet Protocol is much lighter, more flexible and designed to cater to new future applications which can be accommodated in the extension header without impacting the efficiency, stability and security of the protocol itself. The previous generation protocol was never meant to cater to wide area networks when initially designed by its founders and had no flexibility of accommodating future application. The success of the internet however resulted in the organic expansion of the networks with the protocol offering no security or flexibility. This resulted in patching the protocol and the resultant was an inefficient, patchy and less secure protocol.

Figure 4- IPv6 address availability

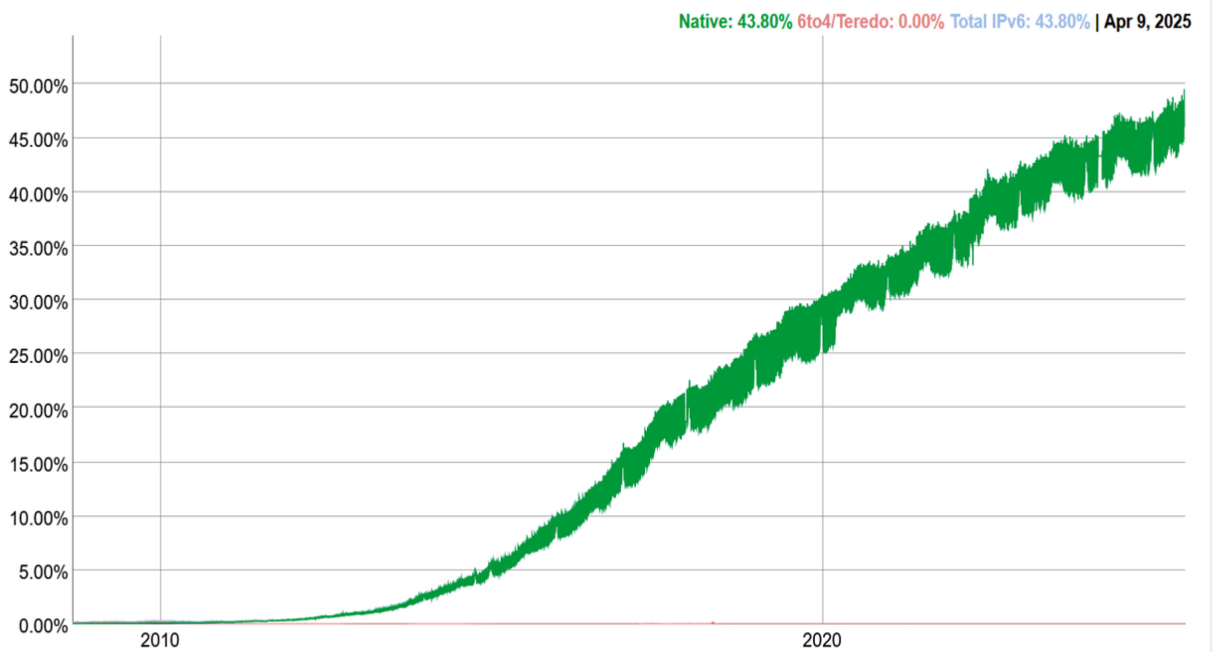
2^x	10^x	Decimal	IP Quantity	Short Scale	SI Prefix
2^8	$\approx 10^2$	256	Single IPv4 interface (/24)		
$\approx 2^{10}$	10^3	1,000			kilo
2^{16}	$\approx 10^5$	65,536	IPv4 Class B (/16)		
$\approx 2^{17}$	10^5	100,000			
$\approx 2^{20}$	10^6	1,000,000		million	mega
2^{24}	$\approx 10^7$	16,777,216	IPv4 Class A (/8)		
$\approx 2^{30}$	10^9	1,000,000,000		billion	giga
2^{32}	$\approx 10^9$	4,294,967,296	Entire IPv4 space		
$\approx 2^{40}$	10^{12}	1,000,000,000,000		trillion	tera
$\approx 2^{50}$	10^{15}	1,000,000,000,000,000		quadrillion	peta
$\approx 2^{60}$	10^{18}	1,000,000,000,000,000,000		quintillion	exa
2^{64}	$\approx 10^{19}$	18,446,744,073,709,551,616	Single IPv6 interface (/64)		
$\approx 2^{70}$	10^{21}	1,000,000,000,000,000,000,000		sextillion	zetta
$\approx 2^{80}$	10^{24}	1,000,000,000,000,000,000,000,000		septillion	yotta
2^{80}	$\approx 10^{24}$	1,208,925,819,614,629,174,706,176	IPv6 Site (/48)		
$\approx 2^{90}$	10^{27}	1,000,000,000,000,000,000,000,000,000		octillion	
2^{96}	$\approx 10^{29}$	79,228,162,514,264,337,593,543,950,336	IPv6 ISP/Large enterprise (/32)		
$\approx 2^{100}$	10^{30}	1,000,000,000,000,000,000,000,000,000,000		nonillion	
$\approx 2^{110}$	10^{33}	1,000,000,000,000,000,000,000,000,000,000,000		decillion	
2^{116}	$\approx 10^{35}$	83,076,749,736,557,242,056,487,941,267,521,536	IPv6, RIR (/12)		
$\approx 2^{120}$	10^{36}	1,000,000,000,000,000,000,000,000,000,000,000,000		undecillion	
2^{125}	$\approx 10^{37}$	42,535,295,865,117,307,932,921,825,928,971,026,432	IPv6 GUA (2000::/3)		
2^{128}	$\approx 10^{38}$	340,282,366,920,938,463,463,374,607,431,768,211,456	Entire IPv6 space		
$\approx 2^{130}$	10^{39}	1,000,000,000,000,000,000,000,000,000,000,000,000,000		duodecillion	

Recall that the character ≈ means *approximately equal to.*

It is estimated that there are around 170 trillion galaxies with an average of 400 billion stars in each of them. With this calculation, the estimated number of stars in the universe would result in a total of 6.8x1025 stars. This would be almost 5 trillion times fewer than the number of available IPv6 addresses! This gives the pool of the number of IPv6 address that exist and which will never get exhausted whatever may come and with the worst address allocations, thus assuring the numbers are always available and will never get exhausted.

Although there are enormous advantages of adapting the next generation protocol, one wonders that inspite of facing challenges and bottlenecks in the old, inefficient and insecure IPv4, the migration to the next generation efficient, secure and flexible protocol is still less than 50% which forces us to analyze the causes for this slow rate of adaption and find ways of providing a catalyst for increasing the adaption of IPv6.

Figure 5-Global IPv6 Adaption



Comparitive Table of the important differences between IPv4 and IPv6.

IPv4	IPv6
Addresses are 32 bit length.	Addresses are 128 bit length.
Addresses are binary numbers represented in decimals.	Addresses are binary numbers represented in hexadecimals.
IPSec support is only optional.	Inbuilt IPSec support.
Fragmentation is done by sender and forwarding routers.	Fragmentation is done only by sender.
No packet flow identification.	Packet flow identification is available within the IPv6 header using the Flow Label field.
Checksum field is available in IPv4 header	No checksum field in IPv6 header.
Options fields are available in IPv4 header.	No option fields, but IPv6 Extension headers are available.
Address Resolution Protocol (ARP) is available to map IPv4 addresses to MAC addresses.	Address Resolution Protocol (ARP) is replaced with a function of Neighbor Discovery Protocol (NDP).
Internet Group Management Protocol (IGMP) is used to manage multicast	IGMP is replaced with Multicast Listener Discovery (MLD) messages.

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group membership.	
Broadcast messages are available.	Broadcast messages are not available. Instead a link-local scope "All nodes" multicast IPv6 address (FF02::1) is used for broadcast similar functionality.
Manual configuration (Static) of IPv4 addresses or DHCP (Dynamic configuration) is required to configure IPv4 addresses.	Auto-configuration of addresses is available.

Rate Of Ipv6 Adaption

Despite the fact that IPv6 deployment started happening from mid 2000s and more than two decades have passed, the Global IPv6 adoption is still hovering around less than 50% compared to IPv4. With its enhanced capabilities and efficiencies, IPv6 has still not been the preferred protocol for most users. Surprisingly, wit the exhaustion of IPv4 having happened almost a decade back in the early 2010-15 period, even new users are preferring to acquire IPv4 addresses at much higher costs instead of using IPv6. This is an alarming situation and needs to be analysed for future corrections.

Rate of adaption measurement using the DNS Queries

Some of the causes for the urgency of using IPv6 as anticipated earlier have not meterialised or users have found way around the problems and so are not deterred away from using IPv4.

NAT : The Network Address Translation although hides the users behind virtual IPs and disrupts realtime end to end communication, has significantly helped in the multiplication of IPv4 resources.

DHCP : Reusability of IPv4 addresses has been another factor reducing the shortage of IPv4 addresses

IPv6 supported Devices : Many devices still does not fully support IPv6 natively and in case where support is available, it is not by default. IPv4 is the default configuration in majority of devices

Skill Gap : IPv6 is still cumbersome from the complex and large address length as well as its configuration on different devices. Added to this, the use of link local and Global address confuses users

Security : Use of encryption, IPsec, VPN technologies have to some extent addressed the security concerns of IPv4 users

Larger Processing resources : IPv6 due to its larger bit length requires more processing power at routing devices. Although it is not true if you look at the composite networks IPv6 carries in the routing table instead of the large amount /24 address networks being routed in IPv4, but till we have significant IPv6 routes, this comparison is not possible.

Technical Complexity: For existing IPv4 setups, it may require system upgrades for routers, switches, and other network infrastructure as well as topological changes which may involve redesign of billing and monitoring systems.

Lack of backword compatibility with IPv4 : Since it is not a patching and the new protocol has followed a completely different architecture, there is no compatibility between both the protocols. Hence both need to work independently on each device.

Lack of Perceived immediate Benefits: Organizations do not see immediate benefits from migrating to IPv6, leading to delays in adoption.

CONCLUSION

Despite the challenges, IPv6 adoption will continue to grow as devices become more IPv6 friendly and the load on the IPv4 protocol makes it more inefficient and complex. The policymakers and governments need to create a conducive capacity building roadmap not only for the network administrators but also keeping the developer community in sight for application development with native and default IPv6 support. This would enhance the embracement of next generation protocol and would lead to the enablement of IPv6 by default in the entire ecosystem and create a catalyst effect in the usability of IPv6 protocol. The awareness and expertise in this next generation protocol would go a long way in addressing the cyber security needs since the future wars would see less missiles and more cyber warriors. The corporates also need to be sensitized that the cost of development of products and services on next generation protocol would not add any significant financial burden but would provide them the cutting edge USP to enhance their reputation and business bringing them great returns on their skilling initiatives in this future area. Even the cloud providers also do not see much demand and usability of IPv6 today but would be forced to provide it as a unique advantage once users start demanding and seeing benefits out of using this future ready protocol.

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