NRO

IPV6

What is it, why is it important, and who is in charge?

... answers to common questions from policy makers, executive, and other non-technical readers.

October 2009

A factual paper prepared for and endorsed by the Chief Executive Officers of ICANN and all the Regional Internet Registries, October 2009.

What is IPv6? 1

"IP" is the Internet Protocol, the set of digital communication codes that underlies the Internet infrastructure. IP allows the flow of packets of data between any pair of points on the network, providing the basic service upon which the entire Internet is built. Without IP, the Internet as we know it would not exist.

Currently the Internet makes use of IP version 4, or IPv4, which is now reaching the limits of its capacity to address additional devices. IPv6 is the "next generation" of IP, which provides a vastly expanded address space. Using IPv6, the Internet will be able to grow to millions of times its current size, in terms of the numbers of people, devices, and objects connected to it.[1]

Just how big is IPv6? 2

To answer this question, we must compare the IPv6 address architecture with that of IPv4. The IPv4 address has 32 bits, allowing today's Internet to connect up to around four billion devices. By contrast, IPv6 has an address of 128 bits. Because each additional bit doubles the size of the address space, an extra 96 bits increases the theoretical size of the address space by many trillions of times. For comparison, if IPv4 were represented as a golf ball, then IPv6 would be approaching the size of the Sun.[2]

IPv6 is certainly not infinite, but it is not going to run out any time soon. Each of the RIRs has already been allocated at least one block of IPv6 addresses which is of itself bigger than the entire current IPv4 space. When subdividing and distributing addresses, generous allocations are preferable, as they provide greater flexibility and efficiency in network design, benefiting

1 ISOC Briefing Paper 1, "IPv6 and the Future of the Internet" http://www.isoc.org/briefings/001/

2 A golf ball occupies 0.04l, the Sun 1.4×10^{30}l; the ratio is $1:3.5\times10^{31}$, or $1:1.7\times2^{104}$

service providers and end users alike. However, these will also result in wastage of addresses, so a suitable balance must be maintained between a simple administrative framework and the need for ongoing conservation of addresses.

In developed countries today, the rate of utilization of IPv4 addresses is generally around 2 addresses per head of population.[3] If this rate of Internet penetration were replicated throughout the world, a total of 12 billion addresses would be needed, an impossible achievement since IPv4 provides a maximum of just 4 billion addresses. On the other hand, the same level of IPv6 penetration would require less than one billionth of the entire IPv6 address space.[4]

IPv6 provides an address space that is sufficient to provide addresses for any conceivable number of individuals, organizations, devices, or network-enabled objects in the foreseeable future (for a number of centuries, at least). Even assuming a uniform global Internet that is a million times denser than that of today's most advanced economy, IPv6, if properly managed, will be able to provide the required addresses.[5]

3 How are allocations made and to whom?

IP addresses are managed under a system which has been in operation for some 15 years and which has supported the successful growth of the Internet by a factor of over 100 in that time.[6] This system was established initially by the Internet Engineering Task Force (IETF),[7] a recognized international standards development organization that is the home of the Internet's core technical standards.

3 From http://resources.potaroo.net/iso3166/v4cc.html

4 A conservative calculation which assumes the equivalence of 1 IPv4 /32 identifier (of which 232 are available) and 1 IPv6 /64 identifier (of which 264 are available)

5 A calculation which follows directly from (4)

6 From the World Bank "World Development Indicators", Internet user population 1993 to 2007 (http://ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=135)

7 RFC1366 "Guidelines for Management of IP Address Space", http://www.ietf.org/rfc/rfc1366.txt

Today, organizations known as Regional Internet address Registries (RIRs)[8] receive IP addresses from a central global source, IANA (or the Internet Assigned Numbers Authority, which is operated by ICANN, the Internet Corporation for Assigned Names and Numbers).[9] The RIRs then make allocations directly to Internet Service Providers (ISPs) and network operators within their respective regions. This system achieves a balance between uniform resource management (which is critical to the maintenance of a single globally cohesive Internet) and the direct service needs of ISPs (namely, those who need and use Internet address space).

Each of the RIRs is a non-profit organization and acts in accordance with policies and practices that are established by the Internet community in its region.[10] These policies and practices govern the management, allocation, usage, and recovery of IP address space (both IPv4 and IPv6) according to the best current practices of the Internet, its industry, and stakeholders. At the global level, policies and practices are coordinated through the Address Supporting Organization (ASO)[11] of ICANN.

In some cases (currently 8 in total), National Internet address Registries (NIRs) provide services within a specific country or economy, in effect as an agent of the RIR.[12] Such registries operate under the policies and authority of their RIR and do not receive their own allocations of IP address space.[13] The operation of NIRs, where they exist, is specific to local needs and circumstances: for instance, some may be Governmental bodies while others may be independent.

---

8 http://www.nro.net

9 See http://www.icann.org

10 ISOC Briefing Paper 10, "The Regional Internet Registry Policy Development Process" http://www.isoc.org/briefings/010/

11 See http://www.aso.icann.org

12 See http://www.apnic.net/policy/nir-criteria

13 See http://www.apnic.net/policy/operational-policies-nirs

4 How are IPv6 addresses actually being allocated?

Like IPv4, IPv6 address space is allocated by the RIRs in line with the topology of the network itself, to the Internet Service Providers (ISPs and similar organizations) that require it. Allocations are made under a set of transparent address management policies, in accordance with the demonstrated technical needs of the recipients. When new technologies or applications are developed which may impact upon address management techniques, these are accommodated via open policy development processes that operate in each region. These formal processes are open to all interested stakeholders, through a total of 9 major policy development meetings that are held around the world each year.

In their policy-making to date the RIR communities have made a series of specific decisions to ensure that there are minimal barriers to IPv6 adoption by ISPs and others. At present the minimum size of an IPv6 allocation to any ISP is greater than the entire existing global IPv4 address space, yet each allocation is the equivalent of only a single IPv4 address on today's Internet (one four-billionth of the available address space).

At the end-user level, IPv6 addresses are also allocated in very substantial blocks rather than in single addresses or small blocks, as has been the case with IPv4. Under today's policies, each IPv6 user receives enough address space to allow the use of hundreds or thousands of separate segments within a home or business network. Depending on their service configuration, each end user has enough address space to address any conceivable number of devices (literally millions) that might be used. This will allow IPv6-enabled devices including appliances, sensors, and objects to be deployed easily and cheaply in the large numbers that are expected in coming years.

Why did such large IPv4 address allocations go to US organizations, including the US Government and its Department of Defense?

The Internet was developed by the US Defense Advanced Projects Research Agency (DARPA), and was originally used by the American Government and academic organizations. Until the late 1980s, the Internet was never expected to become a critical global infrastructure, and IPv4 address allocations were made in a liberal manner, not just in the US, but also to government and academic institutions throughout the world. This resulted in many large allocations of IPv4 address space and the early depletion of the IPv4 address pool (to the extent that in 1991, more IPv4 addresses were allocated than in any year since then).[14]

It was only in the early 1990s, when an Internet "boom" became apparent, that concerns arose about the rate and manner of address space distribution.[15] At this time, the RIR system was proposed[16] in order to ensure that addresses were managed by the Internet community itself, in the best possible manner. At the same time, work was started on the "next generation" of the Internet Protocol, which would be necessary to support long-term Internet growth. This was standardized in 1995 as IPv6.[17]

As described above, IPv6 allocations are made on a neutral and impartial "demonstrated need" basis, according to address management policies that can adapt as required to changing needs and circumstances. IPv6 allocations are made uniformly to any organization which demonstrates its requirement and there is no possibility of "special" allocations being made to any organization, whether Governmental, business, or otherwise.

---

14 See proceedings of APNIC 27: http://meetings.apnic.net/__data/assets/pdf_file/0011/8939/pan-nro-stats.pdf (slide 4), and APNIC 25: http://www.apnic.net/__data/assets/file/0013/12604/20080225-apnic25-igf2008.ppt (slide 16)

15 RFC1338 "Supernetting: an Address Assignment and Aggregation Strategy", http://www.ietf.org/rfc/rfc1338.txt

16 RFC1366 "Guidelines for Management of IP Address Space", http://www.ietf.org/rfc/rfc1366.txt

17 RFC1883 "Internet Protocol, Version 6", http://www.ietf.org/rfc/rfc1883.txt

6 How does this system change to meet evolving needs? What about developing countries and the changing face of industry?

Through the RIR policy processes, all stakeholders have the ability to bring concerns to light and to propose solutions for any problems that can be demonstrated. In this way a variety of issues affecting developing countries have been raised and addressed in the past, resulting in policy changes that have supported Internet deployment in those countries. Recently for instance, the size of the minimum IPv4 allocation has been reduced in some regions, allowing easier access to address space by those in disadvantaged circumstances.

It is notable that each of the RIRs, in accordance with its regional priorities and needs, has placed substantial resources into support for Internet development and capacity building in their regions and particularly in developing countries. This support has taken the form of targeted and subsidized training programs, conference scholarship support, discounted fees, online resources, remote participation facilities for RIR meetings, and many other measures. In future, as the IPv6 Internet evolves and grows, regional address policy processes will ensure that all relevant considerations are brought to bear on policy formation, in both developing and developed nations.

The current policy framework for address distribution operates on a needs-based framework, using a timeframe that is generally an annual cycle. For very large deployments that we anticipate with the continued growth of the Internet with IPv6 it may be appropriate for network operators to be able to plan address deployments over a longer timeframe of network deployment. One of the essential attributes of the address distribution system is the ability to adapt and change.

Proposals to change the parameters related to address distribution to meet the evolving needs of this industry at both local and global levels can be considered and endorsed within the respective regional and global policy development processes for address management.

7 Would it be better to set up a UN-based or other multilateral organization to manage IP address allocations?

The Internet today is a distributed, decentralized, multi-stakeholder enterprise, but one that is also reliable, efficient, and secure enough to carry trillions of dollars in value and investment worldwide. Indeed it is argued by many that the success of the Internet has not occurred **in spite of** its unique mode of coordination, but rather **because** of it.[18]

As the Internet has grown, some Governments and inter-Governmental organizations have sought to play a much stronger role in governing its use and ensuring that it is "properly" regulated. This approach has been resisted by the Internet community at large, which maintains the view that the imposition of governmental controls would inevitably stifle the currently highly effective network. It has been the experience of many diverse economies, in both developing and developed countries, that successful development of high-capacity, efficient, and cost-effective Internet infrastructures has followed from deregulation of the industry in favour of a more self-regulatory and competitive environment.

Industry, working in an environment of vibrant competition at national and global levels, has ensured that the network has grown in the most efficient and effective way, delivering the best content and applications to its users at the best possible price. Civil society has also acted, often at an international level, to ensure that the Internet is put to the best possible uses in serving human development, while being developed and governed in a way that is open, accessible, and secure. The multistakeholder, bottom-up policy making procedures developed by various non-governmental organizations, formal and informal, has proved to be a successful model which encourages the unique innovative capacity of the Internet, without the constraints which would be imposed by the heavier structures of the more traditional international organizations.

18 http://www.isoc.org/news/4.shtml

8 And what about the future?

IPv6 represents a turning point for the Internet, but one that will take another 5 to 10 years to fully materialize. Some may see this transitional period as an opportunity to propose alternative mechanisms for the management of either IPv6 address allocations or indeed, the Internet itself. However in the absence of any evidence or consensus that a new approach would be beneficial, or that challenges related to IPv6 adoption and transition cannot be managed through these systems, the RIRs will continue to operate as proven, open, and inclusive multi-stakeholder organizations; indeed as some of the best examples of effective Internet Governance which can be found in the world today.

NRO

AfriNIC APNIC ARIN American Registry for Internet Numbers LACNIC RIPE NCC

Number Resource Organization

www.nro.net