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IPv6

INTRODUCTION

News articles, presentations, and government documents, are all making an urgent appeal to adapt the Internet so as to cope with its growth. "The Internet is running out of IP addresses and if no immediate action is taken now, further growth will be impossible", they claim.

This alarming message must be taken seriously. But, there is no need to panic, the Internet is not at risk and will not stop working. There is no bug or threat that has to be fixed; however, changes are needed to guarantee the continuous steep growth of the global network.

This article explains why the changeover from IPv4 to IPv6 is needed and outlines the primary difficulties in this changeover.

SETTING-THE-SCENE:-INTERNET-GROWTH.01

The Internet has undergone exponential growth since it opened for commercial activities in 1992, and continues to grow relentlessly. By the end of 2011, almost 2.3 billion people already used the Internet which is a growth with 528% since the year 2000. However, the number of Internet users is still less than one third of the global population[1]. So this steep growth is expected to continue. More and more users are going online, since efforts are being taken to connect developing countries and rural areas and much money is being invested in increasing the broadband penetration of fixed and mobile networks.

A further development lies in the fact that more and more devices are being connected to the network. Today, using your mobile phone to access the Internet is no longer exceptional. We're all familiar with sharing a printer on our home or office network but there are also many other devices, such as TV sets, games consoles, etc. that can be connected and used over the network. The next step is that devices will be able to communicate with each other without human intervention. This evolution goes further and some of the plans that are currently on the table of engineers, go beyond even the wildest of imaginations, for example an indigestible chip which is activated by stomach acid and communicates via a patch on the skin with your smart phone.[2]

IP-ADDRESSES...THE-UNIQUE-IDENTIFIERS.02

Any device which wants to communicate with other devices on a network requires a unique identifier. This identifier tells other devices how to find the device they want to communicate with. Hence, this identifier is the 'address' of the device on the network. Without this address, it wouldn't be possible to communicate – send or/and receive information – with the device.

On the Internet, the numerical string used to identify devices is called an IP address. You'll also say that the Internet is an IP-based network. IP stands for 'Internet Protocol'. A protocol is a set of rules that describe how to communicate on the network. Every device using the Internet has an IP address.

The information that is sent over the Internet is divided when it leaves the sender and is assembled again when it arrives at the destination. So if you receive an email or download a picture from a website, this information does not come to you as one email or a full picture, but as a number of small chunks called packages each containing a small portion of the entire email or picture.

Each package of information contains a destination IP address and the IP address of the sender (or source IP address) so that it finds its way over the network to its final destination.

IPv4-AND-IPv4-EXHAUSTION.03

The current and much widely used version of the Internet Protocol was developed in the mid 1970's and is called IPv4, which stands for Internet Protocol version 4. IP addresses in IPv4 are written as four decimal numbers separated by dots. These

1 http://www.internetworldstats.com

2 Ipv6 inside everything and everybody, http://www.circleid.com/posts/20101115_ipv6_inside_everything_and_everybody/

numbers can range from 0 to 255. For example 188.93.97.197 is a valid IPv4 address[3].
The popularity of the Internet today, and as a result the high consumption of IP addresses, was certainly not foreseen in the 1970's. As explained above, an ever growing number of computers, laptops, mobile phones, all require IP addresses. And the development continues further with televisions, network printers, games consoles, etc. all using the Internet network.
How come that a protocol from the '70s is still so dominant? It is much cheaper and easier to embed the IP protocol into new applications when they are being developed than inventing and implementing a new communications protocol. Think for example of the time needed for testing and to roll out a new system, or the difficulties to communicate with the existing system.

It might come as a surprise but the major growth of the Internet happened AFTER the Internet "boom", so after 1999-2001. The number of Internet users continued to grow, and even more important new applications were invented and connected to the Internet.
For example, the world's IP address consumption peaked in 2010 at a new all-time high of an equivalent rate of 243 million addresses per year.[4] Since the total number of possible unique IPv4 addresses is limited to 4,294,967,2965[5] it is quite obvious that at such a consumption rate, the IPv4 address space is at risk of being depleted.

THE-IP-ALLOCATION-PROCESS.04

Who distributes the IP addresses? Initially all IP addresses are held by the Internet Assigned Numbers Authority (IANA) in the Unallocated Address Number Pool.
Large blocks of addresses are then allocated to the five Regional Internet Registries (RIRs), AFRINIC, APNIC, ARIN, RIPENCC and LACNIC, each of them responsible for a geographical area.
The allocation from IANA to RIRs, is carried out on the basis of demonstrated need: there is no pre-allocation. When the local pool reaches a low threshold size a further address block is allocated by IANA to the RIR.

IPv4 address consumption 2010	
AfriNIC	8.95 million
APNIC	126.22 million
ARIN	54.55 million
LACNIC	17.29 million
RIPE NCC	75.45 million

The RIRs in their turn, allocate the IP addresses in smaller blocks via the Local Internet Registries (LIR) to those who need them. A Local Internet Registry (LIR) assigns address space to the users of the network services that it provides. LIRs are generally Internet Service Providers (ISPs), whose customers are primarily end users and possibly other ISPs.

WHEN-WILL-IPv4-RUN-OUT?.05

The global reserve of IPv4 addresses is empty. On 3 February 2011 IANA allocated the last five blocks of IPv4 addresses, one to each RIR. It was agreed before that at the moment only 5 blocks of 16.7 million addresses[6] were left in the IANA pool, the remaining addresses would be equally allocated between the five regions.

IPv4 address expected exhaustion	
APNIC	April 2011
RIPE NCC	mid 2012
ARIN	mid 2013
LACNIC	early 2014
AfriNIC	late 2014

In April 2011 APNIC, as the first of the Regional Internet registries, reached a threshold of one remaining block of 16.7 million addresses and ceased performing general use IPv4 address allocations.[7] It is expected that by mid 2012 RIPE NCC, responsible for the allocation in Europe and the Middle East, will reach the last /8 block of IPv4 address space.[8] The other RIR's have relatively more time, as is shown in the table[9].
Even when IPv4 addresses can no longer be allocated, this does not mean that the Internet will stop working. An exhaustion of IPv4 addresses will not cause a breakdown of the Internet. The addresses already assigned will be used and will continue to work. It is the growth and also capacity for innovation that will be hindered by a shortage of IP addresses.

AFTER-IPv4-COMES-IPv6.06

As early as the beginning of the 1990's, Internet engineers realised that at one point in the future the total number of available IP addresses would be depleted. In January 1995, after having examined different proposals the IETF settled on a successor

3 188.93.97.197 is the IP address corresponding with www.centr.org
4 Geoff Huston, http://www.potaroo.net
5 This is theoretically the maximum number of unique combinations of 4 blocks of 3 figures between 000 and 255.
6 These are so called /8 blocks where the /8 refers to an 8 digit prefix for the block. As a result there are 24 bits left over to form the unique IPv4 host addresses, which makes 16,777,216 addresses per /8 block.
7 The ISP Column, Geoff Huston, January 2012, http://www.potaroo.net
APNIC Press release, 15 April 2012, http://www.apnic.net/
8 http://www.ripe.net/internet-coordination/ipv4-exhaustion
9 Based on the counter at http://inetcore.com/project/ipv4ec/index_en.html

to IPv4, the protocol called IPv6 (RFC1752)[10]. IPv6 addresses are longer so that more unique combinations can be made. In theory[11] there are 340,282,366,920,938,463,463,374,607,431,768,211,456 unique addresses possible using IPv6. An IPv6 address is represented by 8 groups of hexadecimal values separated by colons (:).
The IPv6 address size is 128 bits[12]. The preferred IPv6 address representation is: xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx where each x is a hexadecimal digit representing 4 bits. With x ranging for '0' to 'f'.[13] A typical example of an IPv6 address is 2a02:d08:1001:108:1880:9309:7197:1.[14]

A and AAAA records

The IPv4 address is stored in an "A" record while an IPv6 address is stored in an "AAAA" record. This name was chosen to clearly show that an IPv6 address is four times the length of an IPv4 address.
It is possible to publish both A and AAAA records. Systems with IPv6 connectivity will first check for an IPv6 AAAA record and try to connect and then fall back to an IPv4 record if IPv4 connectivity is available and IPv6 not.

Publishing an AAAA record is the last step once all other software is ready to serve content via IPv6. Otherwise the content will be inaccessible.

TRANSITION-TO-IPv6.07

Unfortunately the transition to IPv6 requires that the entire network and all devices linked to it be adapted to the use of IPv6. There is no so-called 'backward compatibility' between IPv4 and IPv6. Devices using IPv4 cannot communicate with devices using IPv6.
This creates major challenges because there is a transition phase during which both devices using IPv4 and devices using IPv6 will be operating simultaneously on the network. Without interim solutions it is not possible for these to communicate and the Internet will break up in two separate networks, one for IPv4 devices and one for IPv6 enabled ones.

Engineers have found ways to make it possible for IPv4 and IPv6 enabled devices to communicate over the Internet. There are different techniques. 'Dual-stack' techniques allow IPv4 and IPv6 to co-exist in the same devices and networks[15]; 'Tunnelling techniques' encapsulate IPv6 packets inside IPv4 packets[16]; 'Translation techniques' allow IPv6-only devices to communicate with IPv4 only devices.
However, such solutions all have their limitations; some techniques can only be used in very limited contexts. There seems, therefore, to be no other solution than to implement IPv6 across the entire network as soon as possible.

It is likely that when the IPv4 addresses become scarcer they will increase in value and a market to trade IPv4 addresses will arise. The higher the value of an IPv4 address, the higher the incentive to organisations to sell addresses they are not using. The RIRs, however, are rather sceptical about the emergence of such a secondary market.

The RIRs and IANA are working on a policy proposal to allocate returned IPv4 blocks to the RIRs. In the currently discussed plans[17] IANA would serve as a repository for IPv4 blocks returned by the RIRs. IANA would collect the returned addresses, put them in a pool and then redistribute them to the RIRs according to need.
However, it is merely a temporary solution since the changeover to IPv6 is inevitable. It is possible that the cost of such an operation would far outweigh the additional lifetime it would bring to the pool of available addresses.
Trading, recycling or other proposed solutions might extend the final deadline for the IPv4 exhaustion but will not alter the face of the problem. Adoption of IPv6 is not an 'if'-question but rather a question of when.

10 Note: IPv5 was used in the 1990's for an experimental version of the Internet Protocol (the Internet Stream Protocol, Version 2 (ST-II), RFC1190) intended to support sound, video and voice communication.
11 It is expected that the IPv6 space will encompass between 2^{50} to 2^{60} usable addresses which is still between 1 million and 1 billion times the size of the IPv4 address space.
12 A bit is a digit in the binary numeral system, the basic unit for storing information.
13 IPv6 addresses range from 0000:0000:0000:0000:0000:0000:0000:0000 to ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff.
14 This is the IPv6 address corresponding with www.centr.org
15 In fact with dual stack, a system has both a public IPv4 and IPv6 address and connects through a provider that makes both protocols available from the system all the way to the Internet
16 With tunnelling, a request is routed through a special server with access to both protocols. The server converts the request and also relies on the response back. Tunnelling is not an optimal solution because it adds a delay an overhead relying all communications trough a third party, put it permits connection between an IPv4 and IPv6 device.
17 Global Policy Proposal for the Allocation of IPv4 by IANA Post Exhaustion, http://www.icann.org/en/news/in-focus/global-addressing/proposal-allocation-ipv4-post-exhaust-14mar12-en.txt

ACTION-NEEDED!.08

The transition to IPv6 needs to be completed throughout the whole network. A billion end hosts, hundreds of millions of routers, firewalls and middleware units need to be verified and prepared. At the moment, most of the major server software support IPv6 (Apache, LiteSpeed, BIND, etc) . But, for example, hosting a website via IPv6 also requires IPv6 support in the underlying software. Without patches and adjustments from vendors and software developers, supporting software such as the email server may not be able to provide IPv6 functionality.

Are you ready?
Test IPv6 connectivity at:
http://test-ipv6.com/

According to NRO, the organisation of the RIRs, we are on track. 'Approximately 90% of end-users have computer operating systems that work seamlessly over IPv6. This means that many home and small business users are simply waiting for their service providers to offer IPv6 connections.'

WORLD-IPv6-LAUNCH:-6-JUNE-2012.09

On 8 June 2011 more than 1,000 websites, including Facebook, Google and Yahoo! turned on IPv6 for a successful global 24 hour trial. IPv6 day showed that nothing happened! The network didn't break down. World IPv6 day[18] was an important message to the operator community: the content providers are ready; so if you provide access over IPv6 on your network you'll have traffic.[19]

The launch of IPv6 is a task for all. The content needs to be accessible for IPv6, the networks need to allow traffic over IPv6 and the home networks and home equipment needs to be IPv6 ready. On 6 June 2012 major ISPs, home networking equipment manufacturers and web companies will join for the World IPv6 Launch[20]. This is a symbolic date by which an ever growing group of sites, vendors, providers etc will have permanently enabled IPv6 for their products and services.

ccTLD registries - IPv6 Ready!

ccTLD registries promote, raise awareness and inform their communities about the need of IPv6 deployment. Some take the lead with an own initiative while others support or cooperate in local projects with government, business associations or other relevant partners.

Most registries have started preparations for IPv6 already a few years ago. This was necessary since making the whole registry IPv6 ready takes a lot of planning and time. Not only the core function of the registry, the DNS infrastructure needs to be adapted, but also all the registry services such as the Whois, web and EPP interface and even the company's email system.

96% of the CENTR members are completely or almost IPv6 ready.

CONCLUSION.10

The transition to IPv6 is necessary and inevitable because the exhaustion of IPv4 addresses puts a burden on the growth of the Internet.

Since IPv4 and IPv6 are not compatible, the transition has to be complete. During the transition period measures are taken to enable IPv4 and IPv6 devices to communicate with each other. However at one point in the future, when a critical mass has changed to IPv6, IPv4 will no longer be supported.

For the end user, the transition should be seamless and unnoticeable.

FURTHER-READING.11

- INRO – the organisation of Regional Internet Registries http://www.nro.net/
- IPv6 Act Now, RIPE NCC's IPv6 portal: http://www.ipv6actnow.org/
- World IPv6 Launch: http://www.worldipv6launch.org/
- IPv4 Exhaustion Counter: http://inetcore.com/project/ipv4ec/index_en.html
- European Commission: http://ec.europa.eu/information_society/policy/ipv6/index_en.htm

18 http://www.worldipv6day.org/

19 'From World IPv6 Day to World IPv6 Launch: This time it's for real', Andrei Robachevsky (ISOC) at RIPE64, April 2012, Ljubljana

20 http://www.worldipv6launch.org/