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From IPv4 to IPv6: Lost in translation?

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ABSTRACT

The paper examines the transition from IPv4 to IPv6 (Internet Protocol version 4 and 6). More specifically, the aim of the paper is to present an analysis of the status of the transition process and the drivers and barriers concerning this transition. This includes an update on the availability of IPv4 addresses and how far the adoption of IPv6 has come. It also includes a discussion on *what* but also *who* the drivers and barriers are, including an examination of the implications of implementing transfer markets for IPv4 addresses.

1. Introduction

The numbering space for IPv4 is very limited taking all the present and future applications of Internet into consideration. Already at the beginning of the 1990s, there was concern regarding the coming depletion of IP numbers. Some 20 years later, the last publicly available IPv4 addresses were allocated by ICANN (Internet Corporation for Assigned Names and Numbers) in February 2011, but still IPv6 has only developed very slowly.

IPv6 and its almost infinite numbering space has been available since 1996 and even though there are a lot of built-in advantages of IPv6 compared to IPv4, IPv6 traffic on the Internet is still in 2015 only app. 4% of total traffic (APNIC, http://stats.labs.apnic.net/ipv6). Even though there has been a considerable growth in adoption of IPv6 in the past three years, from less than 1% in 2012 to 4% in 2015, this begs the question what it is that holds back the development of IPv6 when taken into account that it is a long time ago that Internet was basically an American 'thing' used for a limited array of applications. Today, Internet is a world-wide set of technologies, and the kinds of usages of Internet have expanded tremendously. Internet of Things (IoT), for instance, will in the future potentially require an enormous mass of addresses.

From its outset, the allocation of IP addresses has been uneven, providing the economically developed markets, especially the US, with huge advantages when it comes to the number of available IP addresses. The poorer and emerging economies including China and India suffer from this and, therefore, have an incentive to promote a more rapid transition. This adds an additional issue to the IP address scarcity question, namely the uneven geographical distribution of IP address allocations.

The systems used to circumvent the problems of having two parallel systems in function at the same time are tunneling, dual stack, and translation (Network Address Translation – NAT). All three systems add to the costs and, therefore, constitute a disincentive for users to implement IPv6-based equipment and systems. The result is that first-mover advantages are bleak. The functionalities can be lower and the costs higher when deploying IPv6.

The most important reason, however, for the sustainability of IPv4 is the system of private addresses. Private addresses can accommodate more users than the number of IP addresses. This decreases the demand for public addresses. At the same

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time, it creates a kind of firewall system where the private addresses can be protected behind a single public point of entry. When implementing IPv6-based systems, another kind of firewall system may in some instances need to be installed.

The result of all this is a very slow implementation of IPv6 although the need for a larger addressing space is obvious with the increasing number of people using Internet and the steeply growing amount of applications and services. Internet institutions and public agencies have taken different policy initiatives to promote IPv6. These policies are 'soft' initiatives as it is not possible to order a mandatory transition. Internet is not like a national system of broadcasting, where a transition from analogue to digital technology can be decided centrally. The Internet is a complex international system of systems, and it will be the equipment and service producers – primarily the corporate ones – who decide on the transition.

Taking these issues into consideration, the purpose of the paper is to examine the following questions:

- What is the status of the allocation, assignment and advertisement of IPv4 addresses?
- How far has the adoption of IPv6 come?
- Which and who are the drivers and barriers of the transition from IPv4 to IPv6 and how do these factors and forces affect the transition processes? – This includes a discussion on corporate and policy initiatives and also includes an examination of the potential implications of IPv4 transfer markets.

The theory framework for the analysis is primarily concerned with the hysteresis of the complex Internet system, including the concepts of path-dependence, lock-in and switching costs (Arthur, 1989). The theory notion of network effects also comes into play (Katz and Shapiro, 1994). We are dealing with a system with strong direct network effects, where the two IP address standards are incompatible. Furthermore, theory on the characteristics regarding consumption rivalry and excludability (Ostrom, 2005) regarding IP addresses is important when discussing the possible implications of implementing market transfer mechanisms. In fact, the whole field of issues relating to the IP addressing system lends itself to a large array of social science approaches. In spite of this, only a smaller community of researchers including among others Mueller (2006, 2008, 2010), DeNardis (2009), Lehr et al. (2008), Levin and Schmidt (2014), and Howard and Sowell (2014) have worked with the IP addressing systems and the transition from IPv4 to IPv6 from a social science perspective. In the following section, a brief state-of-the-art is presented.

Empirically, the paper builds on secondary material from Internet organizations, primarily ICANN and the regional and local registries, the Internet Governance Project, and from OECD. The paper also builds empirically on a round of interviews with stakeholders, i.e. providers of IP equipment, service providers, institutional users, and representatives of Internet and public institutions. This provides the basis for the assessment of the processes of transition.

The following section presents a brief state-of-the-art concerning social science approaches to the IP address transition question and also includes a presentation of the theoretical framework for the analysis in the paper. Thereafter, there is a section on the status of the transition process and the actors – corporate and otherwise – affecting this transition. This is followed by a section discussing the transition process in light of the relevant theory approaches and a concluding section.

2. State-of-the-art and theory framework

One of the ways of dealing with IPv4 address limitation problems has been using Network Address Translation (NAT) that provides the possibility for reusing the private IPv4 addresses several times. Levin and Schmidt (2014), however, discuss a number of difficulties in relation to using NAT as a response to the exhaustion of IPv4 addresses mainly bound to the architectural and technical issues like altering the end-to-end character of the Internet, and problems of peer-to-peer applications to function properly. Howard and Sowell (2014) support the argument of NAT limitations with regards to applications that only work with two public IP addresses.

Howard and Sowell (2014), furthermore, point to other shortcomings related to the poor performance of NAT, e.g., limitations related to low enforcement and the fact that blocking one IP4 address may cause 'collateral damage for all the actors behind a single address, not just those engaging in abusive activities' (Howard and Sowell, 2014). This is also discussed and analyzed by Turiel (2011) who raises a number of security challenges bound to the lack of knowledge of IT professionals resulting in incorrect configurations of network devices, which will open up to vulnerabilities. Moreover, the article points to the necessity of using tunneling of IPv6 in some organizations, which 'may result in some of the communications being hidden from traditional protection systems' (Turiel, 2011).

In the discussion on driving forces for IPv6, Howard and Sowell (2014) appreciate the role of the market but indicate that '... without coordination the migration will be costly, error prone (hurried) and may potentially lead to islands of connectivity' (IPv4 and IPv6 islands without connectivity to each other). Another important barrier for the development of IPv6 is identified to be the knowledge issue: the firms are simply not informed about how a change to IPv6 will contribute to their value proposition.

Levin and Schmidt (2014) discuss remedies to cope with the problem of exhaustion of the addresses using policy measures at RIR (Regional Internet Registry) level like assigning smaller blocks of addresses to the network operators and implementing policies to reclaim unused IPv4 addresses. However, the paper states that 'the actual transition to IPv6 is the only suitable, long term solution to the growth of the global Internet and the exploding demand for IP addresses' (Levin and Schmidt, 2014).