EURESCOM

Study Report

IPv4 address exhaustion: Issues and Solutions for Service Providers

D2bis: "P1952 Eurescom study results summary"

Editor: Pierre Levis, France Telecom

Abstract

The P1952 Eurescom study has investigated approaches to mitigate the problem of IPv4 address exhaustion. The objective of this study was to inform ISPs about the impact of the IPv4 address shortage, and to provide some recommendations and guidelines that help to identify solutions that best fit concrete network scenarios and business plans. This memo provides a summary of selected results of the P1952 study.

EDIN 0582-1952

Study P1952

For full publication

March 2010

Eurescom participants in study P1952 are:

- Isabel Borges, Portugal Telecom Inovação
- Olaf Bonness, Deutsche Telekom Laboratories
- Pierre Levis, France Telecom
- Lorcan Dillon Kelly, eircom

P1952 - IPv4 address exhaustion: Issues and Solutions for Service Providers

Editor: Pierre Levis, France Telecom

Project leader: Pierre Levis, France Telecom

Project supervisor: Dr.-Ing. Halid Hrasnica, Eurescom

Eurescom published project result; EDIN 0582-1952

List of Authors

- Mohammed Achemlal, France Telecom
- Olaf Bonness, Deutsche Telekom Laboratories
- Isabel Borges, Portugal Telecom Inovação
- Lorcan Dillon Kelly, Eircom
- Francisco Fontes, Portugal Telecom Inovação
- Jean-Luc Grimault, France Telecom
- Pierre Levis, France Telecom
- Pedro Neves, Portugal Telecom Inovação

Table of Contents

1 Introduction

Eurescom, the European Institute for Research and Strategic Studies in Telecommunications, was founded in 1991 by major European telecommunication network operators as a platform for collaborative R&D.

Eurescom performs multinational research projects on networks, services, applications and further aspects of telecommunications on behalf of its members, the European Union, and other customers. Among many activities, Eurescom manages private research for subscribing members in the so-called Eurescom Study Programme. A Eurescom study is a short (its results are delivered after only a few months) and focused project that aims to raise a topic for discussion, and bring it to the attention of decision-makers.

The P1952 Eurescom study was launched in June 2009 on the subject of "IPv4 address exhaustion: Issues and Solutions for Service Providers". The main study deliverable is exclusively available to Eurescom members. However, P1952 contributors consider that because of the gravity of the problem it is beneficial to publish a short summary of some selected results of the study. The purpose is to share experience with ISPs outside the Eurescom community, and more widely, with anyone affected by the IPv4 address shortage.

2 P1952 scope and assumptions

Over the last thirty years the Internet has developed from an education and research network to a mission critical infrastructure that is heavily involved in the global economy. All Internet communication is based on the IP addressability of communication partners - but current IP addresses (32 bits long) are becoming a more and more limited resource.

Public IP addresses are currently allocated and assigned by a set of organisations in a hierarchical way. In Europe, ISPs request new address blocks from RIPE NCC. The RIPE NCC should have no more addresses to deliver by the end of 2012, beginning of 2013 (see also http://www.potaroo.net/tools/ipv4/ for updates). This is a prediction based only on the current rate of consumption; no unknown killer application has been considered, which is why this exhaustion deadline is accepted by all actors as a final and unquestionable date.

The P1952 study is intended to:

- Alert all Internet stakeholders on the approaching exhaustion of the public IPv4 address space
- Provide in-depth knowledge of the issues created by this exhaustion, and of the appropriate solutions
- Propose practical guidelines and recommendations in order that all stakeholders can take the appropriate actions necessary to mitigate and survive the consequences of IPv4 address exhaustion

This study provides an ISP-centric point of view and makes the following assumptions:

- IPv4 shared addressing solutions are needed to ensure the continuity of ISPs business
- IPv4 shared addressing solutions are not meant to postpone IPv6 (which is by no means contradictory with the previous assertion)
- IPv6 is the only solution to solve the IP address depletion problem
- IPv6 is being deployed by the ISPs

The study does not try to devise new IPv4 shared addressing solutions, nor does it try to define how IPv6 deployment should occur.

3 ISPs challenges

At the IPv4 address exhaustion date the ISPs will be left with an address pool that cannot be increased anymore. Many services and network scenarios will be impacted by the lack of IPv4 public addresses. Only offering access to the (still limited) IPv6 Internet won't be sufficient for the needs of customers, as most of them will continue to access legacy IPv4-only services. ISPs will be forced to keep offering connectivity to the IPv4 Internet and will need public IPv4 addresses for that (even after the IPv4 address exhaustion date).

ISPs are confronted to three main challenges:

- To be able to continue offering access to the IPv4 Internet for existing and new customers when the number of customers exceeds the number of IPv4 public addresses in the ISP's pool
- To be able to continue offering legacy ISP services currently accessible through IPv4 (e.g. TV broadcast, web portal, search engine, etc.)
- To be able to enlarge their ability to meet customer demand as much as possible in order to sustain their business

Concrete situations may vary between ISPs according to country, network architecture, services and the way the ISP is involved in the global Internet business.

4 IPv4 address shortage solution scope

Identifying the most appropriate solutions to the IPv4 address exhaustion problem and deploying them in a real network with real customers is a very complex process for all ISPs. There is nothing like one solution, one architecture, one option, one way to implement, that would work for all situations. Each ISP has to take into account its own history, particularities, idiosyncrasies, policies, marketing views, and so forth.

The overall and future-proof ISP solution to tackle the limitations of IPv4 address exhaustion consists of three major components. All three solution components MUST be carried out in parallel.

4.1 IPv6

It is explicitly underlined that only a wide implementation and deployment of IPv6 by all Internet stakeholders can provide a fundamental and future-proof solution to the IPv4 address exhaustion problem. Such a general solution is urgently needed in order to ensure the dynamic growth of the global Internet based economy, and the continued development of the Internet itself.

4.2 IPv4 address pool management

Several actions are possible that allow ISPs to improve the way they use their existing address pool, such as: network renumbering and restructuring, moving internal services to private IPv4 addresses or better to IPv6, raising the efficiency of IPv4 address usage through centralised pools or right-sizing of pools and aggregates (e.g. for BRAS), and re-assignment of delegated but unused IPv4 addresses (a.k.a. time-multiplexing of public IPv4 addresses).

4.3 IPv4 shared addressing

The basic assumption of these so-called IPv4 shared addressing mechanisms is that, due to the IPv4 address shortage, it will no longer be affordable to allocate a unique public IPv4 address to each customer. For this reason, customers will have to share their addresses with other customers i.e. ISPs will have to allocate the same IPv4 address to several customers at the same time. In order to be able to differentiate customers who bear the same public address, the addressing space is extended by adding port information. The solutions differ in the way they manage the port value. In this new context, a public IPv4 address seen in an IP packet can refer to several customers. The three dominant IPv4 shared addressing approaches are NAT444, DS-lite, and A+P.

5 IPv4 shared address allocation strategy

When implementing IPv4 shared addressing solutions, ISPs will have to decide to whom they allocate shared addresses, and to whom they allocate unique public addresses, considering the availability of addresses. This choice will depend on several parameters such as those described in the following sub-sections.

5.1 Shared address technical feasibility

It may not be possible to provide a shared address to some customers because of technical constraints. For instance, some solutions will not be possible for customers with legacy CPEs.

5.2 Multiplicative factor

A key parameter for choosing the right IPv4 shared addressing solution is the factor by which ISPs want or need to multiply their IPv4 public address space.

The multiplicative factor is the factor by which an IPv4 address pool is virtually multiplied owing to the introduction of an IPv4 shared addressing solution. It is directly connected with the number of customers sharing the same public IPv4 address. For example the multiplicative factor is 10 if 10 customers share 1 public IPv4 address.

Potentially, an ISP with a pool of 15 million public addresses can see its pool double if it chooses to systematically allocate one address to two customers at the same time, and can therefore reach a pool of 30 million virtual addresses, and live happily for the rest of its life! Unfortunately, in practice, the gain will rarely be so impressive with a multiplicative factor of only 2 as in most cases, the multiplicative factor can only be applied to a small subset of the whole customer pool (for instance if the ISP cannot re-use the already allocated addresses).

Another constraint regarding the achievable multiplicative factor is given through the standard usage behaviour of the ISP customer base. Some draft investigations within a typical fixed-line network access scenario in Deutsche Telekom showed that the normal port distribution per user is very heavy tailed, that means that only 0.2 % of users use more than 100 TCP ports in parallel. 99.8 % of all customers use 100 ports or less. Of course this observed usage behaviour may change with the arrival of new networked applications or a general change in overall Internet usage. Nevertheless, from a current standpoint, a multiplicative ratio of about 1:650 may theoretically be reachable (possibly with specific allocation policy or service differentiation, to cope with the 0.2 % of users that are the biggest port consumers - see below).

5.3 Allocation Policy

Many policies can be envisaged for allocating public IPv4 addresses to customers, taking into account different soft and hard parameters such as: old vs. new customers, user profile, access type, geographic considerations, unique address as the preferred choice, shared address as the preferred choice, etc.

5.4 Service differentiation

Varied IPv4 address sharing strategies can also be used to create a certain service differentiation between different products or customer groups on the basis of shared versus non-shared IPv4 addresses.

For example, a straight-forward 3-level service differentiation could be realised by defining a "Premium service" without any IPv4 address sharing (multiplicative factor = 1), a "Standard service" with IPv4 address sharing on the basis of a small multiplicative factor (e.g. 10,000 ports per user; multiplicative factor = 6.5) and a "Best effort service" with IPv4 address sharing and a high multiplicative factor (e.g. 100 ports per user; multiplicative factor = 650).

5.5 Available IPv4 pool adjustment

ISPs may want to always keep their available IPv4 public address pool above a given threshold. ISPs can adjust the volume of available IPv4 public addresses by playing on the balance between shared and unique allocations.

- To increase the public IPv4 address pool: Increase the number of customers with shared address; increase the ratio of customers per shared address (multiplicative factor)
- To decrease the public IPv4 address pool: Decrease the number of customers with shared address; decrease the ratio of customers per shared address (multiplicative factor)

6 IPv4 shared addressing solutions guidelines

We provide in this section some high level orientation based on a fairly detailed assessment of each IPv4 shared addressing approach. The following recommendations should not be understood as imperative orders, but only as suggestions and guidelines.

6.1 NAT444

The P1952 study admits that the NAT444 approach may be a viable solution under proper circumstances. Nevertheless, the P1952 study does not encourage the implementation of the NAT444 approach:

- In many cases NAT444 forces the ISP to manage overlapping IPv4 private address zones
- NAT444 provides no synergy with IPv6 deployment

6.2 DS-lite

The P1952 study recommends deploying DS-lite if a solution has to be provided now, or within a short time range:

- DS-lite is available (regarding standardisation and implementation)
- DS-lite allows a high multiplicative factor
- DS-lite is in complete synergy with IPv6 deployment

6.3 A+P

The P1952 study encourages continuing work on A+P:

- A+P is not available yet (no standardisation and no operational implementation)
- A+P is considered to be less harmful to applications than CGN-based solutions
- A+P avoids CGNs that are complex and expensive devices
- In that direction the broad range of A+P's flavours to investigate should be narrowed to flavours that:
    - are in complete synergy with IPv6 deployment
    - are seen as an evolution of a DS-lite architecture (at least for fixed broadband access)

7 Conclusion

As a general conclusion of the P1952 Eurescom study, it can be stated that taking action to cope with the imminent IPv4 address shortage is a vital necessity for ISPs, and that deploying appropriate solutions and mechanisms is a complex process that has to take into account many technical, operational, commercial, and strategic aspects.

Furthermore, ISPs are deeply encouraged to exchange their views on this subject, in particular on the IPv4 shared addressing solutions to be deployed in full synergy with IPv6 deployment. This memo is intended to facilitate this discussion in that direction.

Finally, it is highly recommended that all actions regarding a mitigation of the IPv4 address exhaustion problem have to be decided by the ISPs in coherence with a clear IPv6 deployment strategy.

