Migrating to IPv6: A Game-Theoretic Perspective

Tuan Anh Trinh, László Gyarmati, Gyula Sallai
Department of Telecommunication and Media Informatics
Budapest University of Technology and Economics
Email: {trinh,gyarmati,sallai}@tmit.bme.hu
http://netecon_group.tmit.bme.hu

***Abstract*—The rate of deployment and adoption issues of new network technologies, IPv6 in particular, have recently been hotly debated in the research community. However, the question of how protocols migrate, especially the dynamics of migration, to new paradigms is still largely open. In this paper, we address the issue from a game theoretic point of view. We model and analyze the profit maximizing strategies of Autonomous Systems (ASes); both the properties of ASes and the topology of the Internet is considered. The contribution of our work is threefold. First, we propose an economic model of the ASes and their relations from the IPv4-IPv6 migration viewpoint. Second, we apply the findings of evolutionary dynamics on the problem of migration by incorporating Internet-specific properties to the evolutionary model, namely the size of the ASes and the cost of migration. The analyses show that even if IPv6 has higher payoff than IPv4, the whole migration does not happen always fast. Finally, extensive simulations are carried out based on the proposed models to illustrate the impacts of different parameters on the IPv6 migration dynamics in realistic scenarios.**

I. Introduction

The development of IPv6 protocol was carried out more than a decade ago and became an Internet standard in 1998 [1]. Since then numerous additional features have been designed including security extensions, mobility management and tunneling methods. Despite all its benefits, its necessity (as the number of unallocated IPv4 addresses rapidly decrease), and widespread supports [2]–[6], the widespread deployment of IPv6 is still yet to be seen. According to some recent reports [7], [8], the occurrence of IPv6 is still dwarfed by IPv4. One question arises from these facts: what cause hinders the spread of IPv6?

A recent effort [9] tried to tackle this issue by using adoption modelling analysis. It showed that overly efficient converting tools can hinder the protocol adoption. However, in practice, only ASes are large enough to influence the architecture selection of the whole population, i.e. upgrading from IPv4 to IPv6. As a result, we believe that the case of IPv6 is more a migration issue than an adoptability issue as the entire protocol is deprecated; the newly deployed system is not even necessarily able to interconnect with the older one.

The decision about migration is straightforward if only one entity has to select the best solution based on its own interests. However, it gets complicated if more than one stakeholders are involved in the migration. Not only strategic analyses of game-theory help the modelling and investigation of migration. The dynamic aspect of the migration can be handle using tools of evolutionary dynamics [10], which extends game theory to describe stable and dynamic properties of populations, where the individual utilities depend on the structure of the population.

The history of technology provides examples of migration related to communication, including the migration from analog to digital telephony. Contrary to previous telecommunication related migrations, the economic relations between the stakeholders of the Internet are much more complex [11], therefore, the modelling of the IPv6 migration problem is challenging. Models that include the most important aspects of the IP migration problem, such as different sizes and properties of the ASes and the Internet topology itself, have not been proposed yet. In this paper, we model and analyze the IPv4-IPv6 migration using methods of game theory dealing with strategic and evolutionary aspects. We believe the principal contributions of our work are as follows:

- We propose an economic model of the ASes which includes their revenues, expenditures, and also their growth rate. The economic model is applied throughout the paper in the analytical investigations of migration.
- We apply evolutionary dynamics, an extension of game-theory, to create a model of IPv6 migration where the protocol versions—IPv4 and IPv6—represent the competing genes in a population created out of ASes. The concept of games in finite population is adapted to include properties of the Internet such as the structure of the topology, the size of the ASes, and the cost of migration.
- We present simulation results based on the findings of the analytical analyses. In addition, we quantify the impact of IPv4 address resell on the dynamics of migration to IPv6.

The paper is structured as follows. We present our economic model in Section II. Afterwards, we apply the proposed economic model in evolutionary (Section III) analyses. Extensive simulation results are presented on real-world AS topologies, both at the level of individual decisions and populations in Section IV. The paper concludes in Section V.

II. Economic model

The migration from IPv4 to IPv6 has multiple stakeholders, including ASes, end-users, site operators, governments and even Internet registries. All of them impact the migration process, however, the effects of their decisions are diverse. While governments and registries can only motivate the migration,

978-1-4244-8389-1/10/$26.00 ©2010 IEEE

Tecnologies Avançades d'Internet **ACTIVITY**
Id: XX **IPv6**

NIUs: _____

Llegiu la primera pàgina de l'article que us han passat sobre la migració d'IPv6. Contesteu les següents qüestions per parelles.

1. Què proposen els autors?

2. Tenim antecedents històrics?

3. Son equivalents aquests antecedents?

4. Quins son els actors del model proposat?