Games Between Competing ISPs Employing Different Pricing Schemes

Alexandros Kostopoulos, Antonis Dimakis, Costas Courcoubetis,
Department of Informatics, Athens University of Economics and Business, Athens, Greece,
{alexkosto, dimakis, courcou}@aueb.gr

***Abstract*— In this paper, we investigate and model interactions and incentives between competing ISPs employing different pricing strategies (dynamic congestion-based pricing vs. volume pricing). We focus here on a scenario where all users are considered to be multihomed.**

Keywords- multihoming; pricing; congestion marks; future Internet

I. INTRODUCTION

Nowadays, the socioeconomic impacts on future Internet architectures remain a great challenge for researchers. Due to the large number of new applications, users' demand for resilience and more bandwidth is increasing. Resilience seems to be sufficiently addressed by multihoming solutions. Nevertheless, the increased congestion within networks still remains a significant problem. Economic mechanisms that internalize these negative externalities (congestion) have been proposed by economists [1]. However, such mechanisms should be also technologically supported.

New protocols for future Internet architectures, such as ECN [2], Re-Feedback [3] and Congestion Exposure [4] aim at providing information about the network congestion caused by Internet users. Based on this information, ISPs are able to:

- apply new pricing schemes (i.e. congestion charging) to give users the incentive to act in a mutually beneficial manner, and
- develop cost-effective mechanisms to achieve operational costs reduction and continue being competitive in the Internet market.

Therefore, the consideration of socioeconomic and business-related aspects could be a useful input for designing successful future Internet architectures.

In this paper, we present a model to investigate the interactions and incentives between two ISPs who compete to attract traffic from multihomed users, employing different pricing schemes. Based on the applied charges, multihomed users are able to choose which one ISP out of the two will serve their traffic. The one ISP employs volume-based pricing, while the second one congestion-based. For congestion notification, the latter ISP uses *ECN marks*.

Each ISP aims at maximizing his revenues, while minimizing his costs; the maximization of his profits is achieved by selecting the optimal price for charging users. On the other hand, each multihomed user tries to minimize his cost by selecting the lowest price for sending his traffic.

II. THE MODEL

Consider a number of multihomed users who can send their traffic towards a destination through two different paths. Each path belongs to a different ISP. We assume that users' total demand for traffic D is an exponential variable. We further assume that there is a reservation price R, which is the maximum price per bit that a user is willing to pay. Figure 1 presents the basic idea our model.

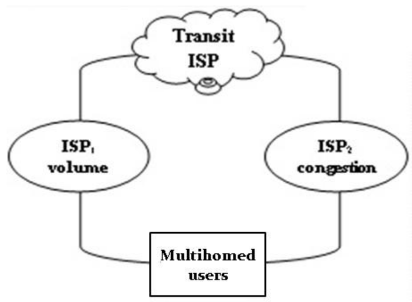

Figure 1. The total traffic of multihomed users is split between the two ISPs

Multihomed users can send their traffic exclusively through ISP_1 or ISP_2. Still, a portion of the total traffic will be distributed to both links: y throughput in ISP_1 and x throughput in ISP_2, so $y + x = D$. Users' decisions depend on the prices announced from both ISPs.

Furthermore, we assume that both ISPs route the received traffic to a higher-Tier transit ISP. The transit cost is considered to be the only cost for both ISPs to deal with. We study two different scenarios. In the first one, we assume that the transit ISP charges based on the traffic volume received from the two ISPs. The second more interesting scenario assumes that the transit ISP charges based on 95th percentile rule, which is a widely used approach to estimate the usage level of resources for long timescales (i.e. a month) when demand is bursty[1].

[1]In that case, the bandwidth used by a customer during a specific period (i.e. 10 minutes) is estimated and divided by the time period (in seconds) resulting in a single bps (bits per sec.) transfer measurement. At the end of the billing cycle period, all measurements are sorted in decreasing order and the top 5% of these measurements are thrown out. The next highest measurement is the 95th percentile, and the customer will be billed based on that rate.

As aforementioned, ISP_1 applies charges based on the traffic volume and announces a price per bit p_1, which is constant and does not depend on the throughput *y*. On the other hand, ISP_2 uses ECN markings to charge based on the congestion within its network and announces a price per mark p_2. In particular, we assume that the number of congestion marks created per period based on rate *x* is an exponential function.

We formulate the interaction between the two ISPs as a best response game in which each ISP repeatedly chooses his optimal price p_i that maximizes his profits.

In order to make our model more realistic, we assume that users have a *reservation price R*, which represents the maximum price per bit that users are willing to pay. In this case, we can assume that having a reservation price is similar to having another competing ISP (i.e. ISP_3) that announces a constant price per bit identical to a user's reservation price, namely $p_3 = R$.

Consequently, the total traffic will be allocated based on the price per bit announced by each ISP.

III. Discussion

We have calculated ISPs' revenues, as well as their costs for the two scenarios mentioned above, in order to investigate ISPs' behavior and find possible equillibria.

Preliminary results reveal that the ISP who employs congestion pricing is more competitive; even for lower values of the reservation price, he has positive profits. On the other hand, the ISP that employs volume charging has negative profits, and therefore is forced to leave the market. An interesting observation is also that the reservation price is a constraint that will probably lead the game in an equilibrium.

Future work includes the investigation of how other parameters introduced in this model affect the outcome of the aforementioned game. As a next step, we intend to study the described scenario for other types of dynamic pricing. Finally, we aim at developing a generalized game-theoretic framework for the investigation of ISPs' interactions, employing different pricing schemes.

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