Pricing Residential Broadband Internet

[Extended Abstract]

Humberto T. Marques-Neto
Federal University of Minas Gerais (UFMG)
Belo Horizonte, Brazil
31270-010
hmarques@dcc.ufmg.br

Virgilio A. F. Almeida (Advisor)
Federal University of Minas Gerais (UFMG)
Belo Horizonte, Brazil
31270-010
virgilio@dcc.ufmg.br

Jussara M. Almeida (Co-Advisor)
Federal University of Minas Gerais (UFMG)
Belo Horizonte, Brazil
31270-010
jussara@dcc.ufmg.br

ABSTRACT

Pricing could be used to promote a fair use of Internet resources and to control backbone congestion. This paper presents a mechanism of pricing residential broadband Internet based on user subscription, historic data about Internet Service Provider backbone usage, and estimated future consume of each user. Our proposal mixes concepts from flat rate pricing, usage based pricing, and time based pricing models. This is ongoing work and we are now simulating the proposed pricing model to analyze its performance.

Categories and Subject Descriptors

C.4 [**Performance of Systems**]: Modeling techniques.

General Terms

Performance, Economics.

Keywords

Pricing, Incentives, Residential Broadband Networks.

1. INTRODUCTION

The use of household Internet through broadband connections has grown over past recent years [3, 7]. Videoconferencing, interactive video and television, collaborative gaming, peer-to-peer applications, and grid-oriented computing are some potential services which could be used in residential broadband network [6].

The growth of residential broadband subscriptions forces the Internet Service Providers (ISPs) to understand user behavior and the impact of innovative applications, like peer-to-peer (P2P) systems, on theirs backbones. Some studies [3, 4] establish a relationship between the increase of P2P usage with the growth of broadband Internet adoption.

CoNext '06 Lisbon, Portugal

Normally, users pay a flat monthly rate with limited peak bandwidth to access residential broadband Internet services [1]. The flat rate pricing model is simple, but, it is not fair, because it encourages waste and light users subsidize heavy users [2]. One user could stay "always on" during all hours of every day of a month and will pay the same rate of another user who creates few short sessions on the same month.

In this paper, we propose a pricing mechanism to promote a fair use of Internet resources and to control backbone congestion. This mechanism is based on (i) users' budget, which depends on their subscription, (ii) historic workload of ISP's backbone, and (iii) estimated users' future consume. Like presented in [8], users' applications should be configured to decide if they will pay more for a better quality of service based on their own budget. Our pricing mechanism is described in the following section.

2. A MECHANISM TO PRICING RESIDENTIAL BROADBAND INTERNET

Let one ISP which provides residential broadband Internet access for N users, each ISP's user should choose one subscription plan offered by ISP, which will limit user's peak bandwidth. Let D^t the total demand generated by all ISP's users in time t ($D^t = \sum_{i=1}^{N} d_i^t$, where d_i^t is the demand of user i in time t) and B the total of bandwidth, if $D^t \geq B$, a backbone congestion could occur and, consequently, a delay in a response time and loss of packets would happen.

In a period $T = \{t_0, t_1, t_2, ..., t_w\}$, one price p^t is defined for each $t \in T$. Each p^t is proportional to past values of D^t. That is, $p^{t_x} < p^{t_y} \iff D^{t_x} < D^{t_y}$. The array $P = \{p^0, p^1, p^2, ..., p^w\}$ is based on the average of all D^t in a set of periods T and is published by ISP for all its users before the time t_0 of one T.

Thus, each p^t is determined by

$$p^t = \left(\theta^t + \frac{\mu^t}{B}\right) \quad (1)$$

where μ^t is the average of backbone use for past values of t and θ^t is a parameter for adjust the price proportional to backbone workload, also, in past values of t. The value of θ^t, for each t, is defined based on thresholds of B which indicate a congestion of ISP's resources.

The residential broadband user receives, for each period T, a budget to access the Internet. The user's budget is

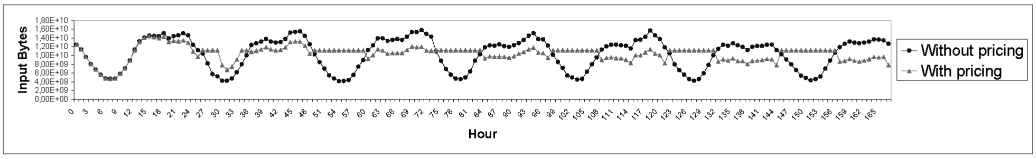

Figure 1: Used bandwidth per hour (typical week)

proportional to subscription and is defined by

$$\beta_i^T = q_i^T \Omega \tag{2}$$

where q_i^T is the peak bandwidth contracted by user i during the period T and Ω is a parameter which determines the percentage of q_i^T ensured by ISP. The value of β_i^T is only valid in T, that is, if $\beta_i^T > 0$ at the end of T, $\beta_i^T \leftarrow 0$.

A user spends units of his/her budget when uses the Internet. The cost of consumption is $d_i^t p^t$, where d^t is the amount of input bytes received by user's applications in time t. If $p^t > 1$, the user must pay more for each byte transferred. Otherwise, when $p^t < 1$, user accumulates $\left(1 - p^t\right) d^t$ units of budget. It is an incentive to move the backbone workload for periods with past small demand, where $p^t < 1$. Figure 1 shows the used bandwidth with and without our pricing mechanism. We consider for this initial simulation that all users' applications follow the proposed mechanism. We observe that differentiated price could redistribute the backbone workload over hours of the day.

Users' adaptive applications should look for information about the price p^t in P, verify user's budget (β_i) and calculate user's future consume (δ_i) before decide if t is a good moment to use the Internet with the demand (d_i^t).

The future consume (δ_i) is estimated through user's history of connections and the average price (m_i) payed by user. User's history of connections is stored in array H_i. Each element of H_i maintains the number of connections of user with ISP in t. The average price payed by user is calculated by

$$m_i = \left(\frac{\sum_{t=0}^{w} H_i^t \varphi_t}{\sum_{t=0}^{w} H_i^t} \right) \tag{3}$$

where φ_j is the average price of backbone usage in t, calculated with values of P, and $(w + 1)$ is the length of arrays P, T, and H. In our proposal, the average price for user i is the weighted medium of prices practiced by ISP and accepted by user's applications in the past. Thus, the future consume for a user i could be estimated by

$$\delta_i = \frac{(w+1) - t}{t} \left(\sum_{k=0}^{w} H_i^k \right) m_i \left(q_i^T \Omega \right) \tag{4}$$

where $(w + 1) - t$ is the time to next budget reload.

If user i has enough budget to consume his/her intention demand (d_i^t) and further accomplish the future consume (δ_i) until next budget reload, then $\beta_i \leftarrow \beta_i - p^t d_i^t$. If user's budget after intended consume (d_i^t) will be smaller than the future consume (δ_i), the demand d_i^t is recalculated and renamed as g_i^t, such as $g_i^t = \beta_i - \delta_i$ and $g_i^t \geq 0$. Hence, after this, the user's budget is updated, $\beta_i \leftarrow \beta_i - p^t g_i^t$. The third case occurs when $(\beta_i - \delta_i) \leq 0$ and there is no consume. In this situation user makes credits for the future. User makes credits if intends to consume, analyzes the environment and decides not consume at that moment.

The utility function for those users could be defined as

$$u_i = \sum_{t=0}^{w} d_i^t - \sum_{t=0}^{w} d_i^t p^t \tag{5}$$

To maximize the utility function, users should use the Internet in periods where there were little demand of ISP's backbone. That is, the use should happen when $0 \leq p^t < 1$, transferring the use of Internet from periods of small workload of ISP's backbone to periods of high demand.

3. FUTURE WORK

We are now simulating the proposed pricing model to analyze its performance. Our simulation uses the actual logs and the results presented in [5] and we will also compare the results with others pricing models proposed in the literature.

4. REFERENCES

[1] A. Chaudhuri and K. Flamm. An analysis of determinants of broadband access. *Telecommunications Policy*, 29:731–755, Sep. 2005.

[2] R. J. Edell and P. Varaiya. Providing internet access: What we learn from the index trial. Technical Report Index Project Report 99-010W, University of California, Berkeley, April 1999.

[3] K. Fukuda, K. Cho, and H. Esaki. The impact of residential broadband traffic on japanese isp backbones. *ACM SIGCOMM Computer Communications Review*, 35(1):15–21, January 2005.

[4] K. Lakshminarayanan, V. N. Padmanabhan, and J. Padhye. Bandwidth estimation in broadband access networks. In *IMC '04: Proceedings of the 4th ACM SIGCOMM conference on Internet measurement*, pages 314–321. ACM Press, 2004.

[5] H. T. Marques-Neto, J. M. Almeida, L. C. D. Rocha, W. Meira, P. H. C. Guerra, and V. A. F. Almeida. A characterization of broadband user behavior and their e-business activities. *SIGMETRICS Performance Evaluation Review*, 32(3):3–13, 2004.

[6] MIT. The broadband incentive problem. In *MIT Communications Futures Program (CFP) and Cambridge University Communications Research Network*, September 2005.

[7] OECD. Oecd broadband statistics, June 2005.

[8] X. Wang and H. Schulzrinne. Pricing network resources for adaptive applications. *IEEE/ACM Transactions on Networking*, 14(3):506–519, 2006.