A Base Station Congestion-Dependent Pricing Scheme for Cellular Data Network

[Extended Abstract]

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ABSTRACT

The increasing of the mobile Internet traffic generated in cellular networks has challenged Internet Service Providers (ISPs) to improve the management of their resources' usage, e.g. during hours of peak demand. Time-based pricing schemes could be used to address this problem. However, in this kind of scheme, the workload of each base station is not normally considered in the methodology for pricing definition. During network peak periods, different base stations do not have the same workload and, consequently, a time-based pricing can be unfair to users who are outside of a congestion area. This paper presents a pricing scheme that uses base stations' historical workload data to differentiate prices in order to control the geographical congestion in the ISP network. We are currently simulating the proposed pricing model and other models to perform a comparative analysis in terms of performance and feasibility.

Categories and Subject Descriptors

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

Keywords

Incentives; Time-Dependent Pricing; Congestion-Base Pricing; Mobile Data.

1. INTRODUCTION

The mobile Internet traffic generated in cellular networks, which has grown over the recent years [2, 6, 9], challenges Internet Service Providers (ISPs) to explore new mechanisms to control the operational costs and keep acceptable levels of revenue. The growing popularity of services like video streaming (YouTube, Netflix, etc.), and the increase of mobile applications that consume and generate huge amounts of data have led the demand of cellular network resources to high levels in some periods of the day. During these periods of congestion, delays in response time and/or packet losses may occur.

Some studies [3, 5, 8] have proposed the use of time-based pricing scheme to address the problem of high demand of Internet access during peak periods. Normally, this kind of pricing scheme provides mechanisms to deal with *when* users generate a network workload. That is, the price is determined by the time of the day in which users access the Internet with their mobile devices.

However, considering that cellular data networks have a set of geographically distributed base stations and that each one can have different workloads in a determined period (e.g. in a peak period) [4, 6, 7], a pricing scheme should also deal with *where* users access the Internet. If the access location is not considered by pricing schemes, an unfair situation may arise. For example, users who live or work in areas covered by base stations with high resource demands will pay the same rate as users who use base stations with low workload. We believe that ISPs could improve the usage of their resources by employing a pricing scheme which considers the historical workload of each base station.

In this paper, we propose a pricing scheme which allows ISPs to foster the usage of base stations with historically lower workload and distributing the demand of their resources among the greatest possible number of base stations. Our pricing scheme is based on the historic workload of base stations and the constant monitoring of users' sensitivity to applied prices.

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2. THE PROPOSED PRICING SCHEME

Let S be the set of base stations of an ISP, D_s^t be the total demand generated by n users connected to base station $s \in S$ at time t, $D_s^t = \sum_{i=1}^{n} d_i^t$, where d_i^t is the total demand generated by the user i on base station s at time t. Let B_s be the total bandwidth of base station s, when D_s^t is almost equal to B_s some congestion may occur and users in s perceive delays on their response time.

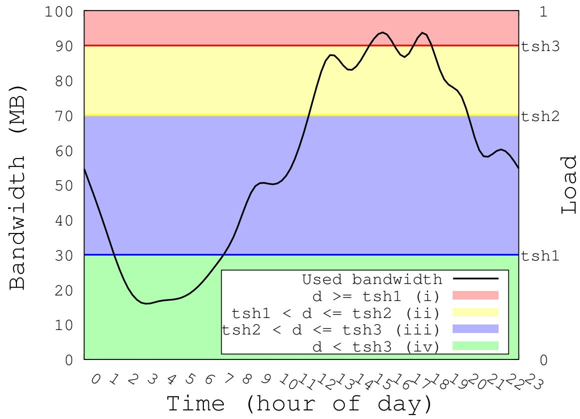

Figure 1: Usage bandwidth at a base station during one day with thresholds defined by a ISP.

In a period $T = \{t_0, t_1, t_2, \ \ldots, t_k\}$, each base station has a price p_s^t defined for each $t \in T$. Each p_s^t is defined considering the past values of D_s^t, if we consider the historical values D_x and D_y from periods x and y respectively, if the average values of D_x are bigger than the average values of D_y the price at x will be bigger than the price at y, i.e. $p_s^{t_x} < p_s^{t_y} \iff D_s^{t_x} < D_s^{t_y}$. Each $p_s^t \in P_s$ is based on the average of all d_s^t in a set of periods and is published by the ISP for all its users before the time t_0 of each T.

In our pricing scheme, as proposed in [5], there is a set of thresholds for each base station. These values will be used to limit or even to encourage the usage of ISPs resources in certain periods of the day. In a first moment, we propose the usage of four thresholds which indicate, respectively, (tsh_1) high demand with congestion levels, i.e. $(D_s^t/B_s) \geq tsh_1$, (tsh_2) high demand without congestion levels, i.e. $tsh_1 < (D_s^t/B_s) \leq tsh_2$, ($tsh_3$) regular demand, i.e. $tsh_2 < (D_s^t/B_s) \leq tsh_3$, and ($tsh_4$) under-utilization of base station resources, i.e. $(D_s^t/B_s) < tsh_3$. Figure 1 shows these thresholds with a curve of the bandwidth usage during a typical day.

Observe that the four thresholds should not divide uniformly the points of high, regular, or low demand. That is, ISP may define discounts or overcharges for each limit which will discourage or motivate the mobile Internet access. For instance, ISP may use higher discounts under the threshold tsh_4 which could encourage users to watch movies or perform software updates without compromise their budget.

When base station demand is at levels tsh_3 or tsh_4 ISPs may define a range of discount $[\theta_{min} : \theta_{max}]$ which will be used to encourage the mobile Internet access. Thus, ISPs have a simple way to define the discount θ_s^t at periods of lower demand by

$$\theta_s^t = \left(\frac{d_s^t - ths_{min}}{ths_{max} - ths_{min}} \right) \times (\theta_{max} - \theta_{min}) + \theta_{min} \qquad (1)$$

where ths_{max} and ths_{min} represent the upper and lower limits at threshold range respectively. When one base station demand is at high levels, ISPs can easily use Equation 1 increased by 1 to overcharge users and discourage mobile Internet access.

The price p_s^t can be calculated by $\theta_s^t \times P_{byte}$, where P_{byte} is the base value per byte that ISPs charge the users during periods without discounts or overcharges. When users demand d_s^t bytes they are charged by $p_s^t \times d_s^t$. Thus, a user's daily bill μ_i can be calculated by

$$\mu_i = \sum_{s \in S_i} \sum_{t \in T} p_s^t \times d_s^t \qquad (2)$$

where S_i is the set of base stations visited by user i during the day and T is the set of periods defined by the ISP to differentiate the prices. The user's monthly bill is basically the sum of all daily bills.

If a user wants to save money, they can postpone their Internet access to a period of low price. This postponement can be acceptable for applications that do not have real time restrictions, like software updates and movie downloads [3]. The monetary discount offered by ISPs must be large enough for the user to decide to wait for a lower price before using these kinds of applications.

The news that Youtube will allow mobile users to watch videos when they are offline was recently published at Youtube Creators Blog [1]. That news points out that ISPs can control the traffic at peak periods with our pricing scheme, so that users may be able to download their preferred videos at out-of-peak periods, paying less, and watch them whenever they want. Moreover, the proposed scheme could be used by ISPs to reduce the network workload in areas with high demographic density, such as downtown areas, touristic places, and during large scale events.

The proposed pricing scheme can be useful for both ISPs and their users. For ISPs this scheme could reduce the operational costs with the overload management and could also increase the total revenue by stimulating the use of the network at out-of-peak periods. On the other hand, users could significantly reduce their monthly bills by moving their heavy traffic to out-of-peak periods.

3. ONGOING WORK

We are simulating the proposed pricing scheme to analyze its performance and feasibility. Our simulations uses the actual characterization results presented in [7]. We also intend to compare the results with other pricing and priority models proposed in the literature, like [3].

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