Poster Abstract: CSP: Customer Satisfaction based Pricing for Advanced Cellular Networks

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***Abstract*—Pricing plays a major role in the efficient management of network resources as it can be used to manage congestion, enforce Quality of Service (QoS) guarantees and optimize revenue generation. Static, dynamic, and congestion-based pricing strategies have been proposed, but they have limitations when services with QoS guarantees are provided in LTE and 5G networks. We propose a pricing plan that is based on traditional commodity pricing where the user pays based on the quantity consumed. Additionally, the quality of the resources provided is also taken into consideration. The proposed pricing is flexible, as it handles QoS and pricing at the bit level, and allows users to dynamically demand additional quantity (bytes of data) as well as additional quality (higher QoS). Since the users pay based on the quality they actually achieve as opposed to the quality they requested, they are fairly charged in congestion situations.**

***Index Terms*—Quality of Service, Dynamic Pricing, LTE, 5G.**

ADVANCED cellular networks such as LTE and 5G are capable of providing QoS for supporting real-time applications as well as best effort services over a common platform. This has further led to an exponential growth in data traffic, driven by the increased popularity of machine-to-machine communications, Internet of Things (IoT) and other cloud-based services. To deal with the ever-increasing data traffic, efficient pricing plays an important role. By choosing an appropriate pricing strategy, network operators can motivate the users to optimally utilize network resources while deriving acceptable revenue.

Various static, dynamic and congestion pricing strategies have been proposed in the literature [1]. Static pricing schemes such as usage based pricing, priority pricing, paris metro pricing, incur minimal accounting overhead, but do not offer any incentive for users to dynamically adjust their demand for better utilization of network. Dynamic pricing strategies, such as proportional fair pricing, game theoretic pricing, etc., take current network conditions into account, resulting in higher responsiveness. However, most of these do not take QoS into consideration. A number of other alternatives, such as QoS-based pricing and congestion pricing have also been proposed. Most of these provide differential pricing, focused on exploiting the adaptability of users by increasing the prices during congestion to shift the usage to off-peak hours. However, such penalty-based pricing might be unfair to the customers since they may be paying more for services because the operator has failed to provide sufficient capacity.

In the present work, we propose a dynamic pricing scheme where users only pay for the achieved quantity and quality. Hence, although the operator may receive reduced revenue during congestion but improved customer satisfaction will result in less churn (one of major causes of lost revenue for operators) [2]. To illustrate the benefits of proposed approach, its comparison with congestion-based pricing is presented.

I. Proposed Pricing Framework

A. System Model

We consider the network like a utility and charge not only based on usage but also based on the QoS required for the users. If users' subscription requires a minimum throughput of r, a maximum latency of d and a maximum packet loss ratio of e, the cost per bit of such a subscription is denoted by $C(r, d, e)$. If we assume that the QoS guarantees are satisfied and B bits of data (upload and download) is consumed for the month, then their monthly cost would be $C(r, d, e)B$. It can be approached similar to class-based LTE QoS framework, where each bearer type (Guaranteed Bit Rate or Non-Guaranteed Bit rate) has an associated QCI (QoS Class Identifier) value. However, if due to congestion, users' QoS guarantees are not satisfied for some period of time, then the price charged will be lower for that period of time. For e.g., let $r = 2$ Mbps, $r = 1.5$ Mbps and $r = 1$ Mbps for Gold, Silver, Bronze plan, respectively. Suppose that the user's rate drops to 1.8 Mbps for x bits due to congestion. For these x bits, the cost would be $C(1.5, d, e)x$, instead of $C(2, d, e)x$. Note that the price reduction is only done under congestion. A user may fail to achieve QoS guarantee in very poor radio conditions (e.g. in the basement/tunnel), which does not reflect a capacity issue.

B. QoS and Congestion Detection

Given the desired QoS parameters for a subscription, we briefly describe a QoS based scheduling approach. If we consider an objective function F defined in terms of throughput and delay; jitter is not considered in LTE, and packet loss rate can be handled using Hybrid-ARQ. If k represents the number of active users competing for a channel with capacity C, then the scheduling problem can be formulated as:

$$\text{maximize} \quad F(\vec{r}, \vec{d}) \equiv \sum_{i=1}^{k} (T_i(r_i) + D_i(d_i)) \tag{1}$$

$$\text{subject to} \quad \sum_{i=1}^{k} r_i < C \text{ and } \quad r_i \geq r_{\min}, \quad d_i \leq d_{max} \tag{2}$$

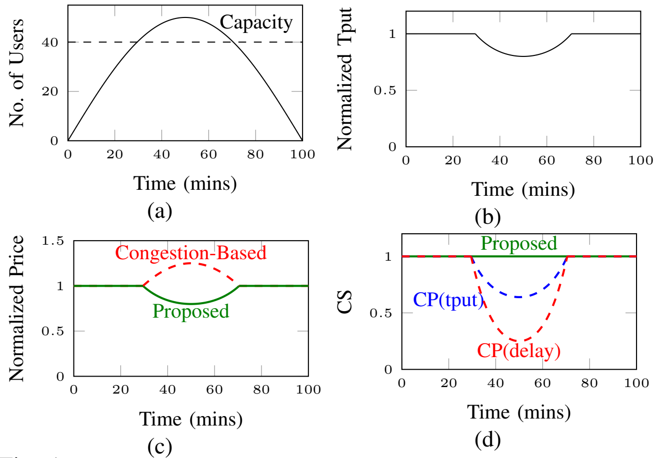

Fig. 1: (a)Variation of No. of Users over Time; (b)Variation of normalized User Throughput over Time;(c) Price Variation for Both Strategies; (d) Customer Satisfaction (CS) for Throughput Guarantees and Delay Guarantees.

over $r_i \geq 0, d_i \geq 0, 1 \leq i \leq k$, where, $T_i(r_i)$ is throughput-based utility function, r_i is the average throughput experienced by user i, $D_i(d_i)$ is delay-based utility function with average delay d_i, $r_{\min}$ is the minimum throughput constraint, and d_{max} is the maximum delay allowance. In wireless networks with mobile users and varying channel conditions, the optimal solution changes continuously, gradient ascent method can be used to make the scheduling decision. Based on the above framework, QoS guarantees can be provided using the concept of a barrier function [3]. For delay-sensitive applications, if d_{max} denotes maximum delay budget, then a delay based barrier function can be used:

$$D(d) = \frac{(d_{max} - d)^{(1-\alpha)}}{1-\alpha}, \quad \alpha > 0, \quad \alpha \neq 1 \qquad (3)$$

The value of α can be chosen based on subscription of the user. In addition, the above QoS framework can also be used to detect congestion based on the information from the scheduler.

II. Evaluation and Future Directions

In this section, we provide a simple illustrative example to demonstrate the customer satisfaction achieved by the proposed approach when compared to congestion based pricing (price charged is increased during congestion to discourage users from using the network during the congestion period) [4]. Consider a system with fixed capacity, evenly allocated among all users in the system. The number of users as a function of time is plotted in figure 1a. If we assume that beyond $n = 40$ users QoS throughput constraints cannot be satisfied, the throughput achieved by a single user as a function of time, normalized by their minimum QoS throughput guarantee is shown in figure1b. If we assume that the price per bit C is simply proportional to the throughput achieved, we normalize the price by the value paid when QoS guarantees are provided i.e. $P_{proposed} = r_{norm}$. For congestion-based pricing, we use the model proposed in [4], where price per bit is iso-elastic function of the system load and capacity. For an offered load L and capacity V, the price per bit is given by $(L/V)^k$ where $k \geq 1$ determines the degree of penalty when the offered load is greater than capacity. In our case, if we have n users each with a demand of r_{min} then the load is $L = nr_{min}$. The achieved rate of each user in congestion is $r = V/n$. Hence,

$$P_{congestion} = \left(\frac{L}{V}\right)^k = \left(\frac{nr_{min}}{nr}\right)^k = \left(\frac{1}{r_{norm}}\right)^k \qquad (4)$$

where r_{norm} is the normalized throughput plotted in Figure 1b. We use a value of k=1 and so the congestion-based price when in congestion is simply the inverse of the normalized throughput, as shown in Figure 1c. A new pricing plan is said to be adoptable if the users are at least as satisfied, and, at least one user is more satisfied, as compared to the existing *status quo* pricing [2]. In case of the mobile networks, it has been proven that the perceived QoS and pricing are two major determinants of user satisfaction. We assume that customer satisfaction is proportional to throughput achieved and inversely proportional to price paid [5], and can be calculated as ratio of normalized throughput and normalized price, as shown in Figure 1d. Similarly, for delay sensitive application such as VoIP, (assuming Poisson arrival process), the packets will be transmitted when the user is in favorable radio conditions, resulting in exponentially distributed waiting time (M/M/1 queuing model). The customer satisfaction for delay based guarantees is depicted in Figure 1d. In both the cases, customer maintains the same level of satisfaction throughout the congestion period for proposed pricing method.

The proposed CSP pricing results in higher user satisfaction and lower churn rate and is therefore beneficial for users as well as the operators. The analytical results presented in the paper clearly illustrate the advantages of the proposed approach. For future work, we plan to investigate the customer satisfaction by collecting real data through detailed survey and study its impact on the overall churn and operator revenue through in-depth analysis and simulation. The evaluation of proposed model for massive machine type communication for IoT use cases in 5G networks will also be considered.

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