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Price Discrimination in Communication Networks

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ABSTRACT:

We study the best usage-based rating downside in an incredibly resource-constrained network with one increasing service supplier and multiple teams of surplus-maximizing users. With the idea that the service supplier is aware of the utility operate of every user (thus complete information), we discover that the entire value differentiation theme can do an over sized revenue gain (e.g., 50%) compared to no value differentiation, once the entire network resource is comparably restricted and therefore the high-willingness-to-pay users are minorities. However, the entire value differentiation theme could result in a high implementation quality. To trade off the revenue against the implementation complexity; we tend to any study the partial value differentiation theme and style a polynomial-time formula which will cipher the best partial differentiation costs. We tend to additionally think about the unfinished data case wherever the service supplier doesn't understand to that cluster every user belongs. We tend to show that it's still doable to comprehend value differentiation beneath this situation and supply the sufficient and necessary condition under that an incentive-compatible differentiation theme can do similar revenue as beneath complete data.

Index Terms—Network pricing, price differentiation, resource allocation, revenue management.

I. INTRODUCTION

P RICING is vital for the planning, operation, and management of communication networks. Rating has been used with 2 totally different meanings within the space of communication networks. One is that the “optimization-oriented” rating for network resource allocation: it's created standard by Kelly’s seminal work on network congestion control [2], [3]. as an example, the Transmission management Protocol (TCP) has been with success reverse-engineered as a congestion pricing-based resolution to a network improvement downside [4], [5]. A additional general framework of Network Utility Maximization (NUM) was later on developed to forward-engineer several new network protocols (see a recent survey in [6]). In varied NUM formulations, the “optimization-oriented” costs typically represent the Lagrangian multipliers of assorted resource constraints and square measure won’t to coordinate totally different network entities to realize the utmost system performance during a distributed fashion. The other is that the “economics-based” rating, that is employed by a network service supplier to numerous objectives as well as revenue maximization. The right style of such a rating becomes notably difficult these days owing to the exponential growth of knowledge volume and applications in each wire line and wireless networks. During this paper, we have a tendency to concentrate on learning the “economics-based” rating schemes for managing communication networks. Economists have projected several subtle rating mechanisms to extract surpluses from the shoppers and maximize revenue (or profits) for the suppliers. A typical example is that the best nonlinear pricing [7]–[9]. In apply; however, we frequently observe straightforward rating schemes deployed by the service suppliers. Typical examples embrace flat-fee rating and (piecewise) linear usage-based rating. One potential reason behind the gap between “theory” and “practice” is that the best rating schemes derived in political economy typically contains a high implementation complexness.

Besides a better maintenance cost, advanced rating schemes aren't “customer-friendly” and discourage customers from victimization the services [10], [11].Furthermore, achieving the best potential revenue typically with difficult rating schemes needs knowing the data (identity and preference) of every client, which may be difficult in giant scale communication networks. it's then natural to raise the subsequent 2 queries.1) a way to style straightforward rating schemes to realize the most effective trade-off between complexions and performance? 2) However will the network data structure impact the design of rating schemes? This paper tries to answer the on top of 2 queries with some stylist communication network models. totally different from some previous work that thought-about a flat-fee rating theme wherever the payment doesn't rely upon the resource consumption (e.g.[10], [12], and [13]), here we have a tendency to study the revenue maximization problem with the linear usage-based rating schemes, wherever a user’s total payment is linearly proportional to allotted resource. In wireless communication networks, however, the usage-based rating theme appears to become more and more standard owing to the ascent of wireless knowledge traffic. In Gregorian calendar month 2010, AT&T within the America switched from the flat-fee-based rating (i.e., unlimited knowledge for a hard and fast fee) to the usage-based rating schemes for 3G wireless knowledge [14]. Verizon followed up with similar plans in July 2011. Similar usage-based rating plans are adopted by major Chinese wireless service suppliers as well as China Mobile and China Unicom. Thus, the analysis on the usage-based rating is of nice sensible importance. In this paper, we have a tendency to contemplate the revenue maximization downside of a selfish person service supplier facing multiple teams of users. Every user determines its best resource demand to maximize the excess, that is that the distinction between its utility and payment. The service supplier chooses the rating schemes to maximize his revenue, subject to a restricted resource. We contemplate each complete data and incomplete data situations and style completely different} rating schemes with different implementational complexions levels.

Our main contributions are as follows

• ***Complete network information*****:** we tend to propose a polynomial algorithmic program to reason the optimum answer of the partial price differentiation downside, which has the entire value differentiation theme and therefore the single evaluation theme as special cases. The optimum answer encompasses a threshold structure, which allocates positive resources to high-willingness-to-pay users with priorities.

• ***Revenue gain beneath the entire network information:***

Compared to the one evaluation theme, we establish the 2 necessary factors behind the revenue increase of the (complete and partial) value differentiation schemes: the differentiation gain and therefore the effective market size. The revenue gain is that the most vital once high user's square measure minority among the full population and total resource is restricted however not too little.

• ***Incomplete network info:*** we tend to style an incentive compatible theme with the goal to realize identical most revenue which will be achieved with the entire information. We discover that if the variations of disposition to pay of users square measure larger than some thresholds, this incentive-compatible theme can do identical most Revenue. we tend to more characterize the required and enough condition for the thresholds.

We take into account 2 sorts of info structures.

1) Complete information: The service supplier is aware of every user's utility operate. Although the whole info could be a terribly sturdy assumption, it's the foremost oftentimes studied situation within the network evaluation literature .The Significance of learning the whole info is twofold. It is the benchmark of sensible styles and provides vital insights for the unfinished info analysis.

2) Incomplete information: The service supplier is aware of the entire range of teams, the quantity of users in every cluster, and also the utility operate of every cluster . It doesn't grasp that user belongs to that cluster. Such assumption in our separate setting is analogous to it the service supplier is aware of solely the users' sorts distribution during a time case. Such applied math info is obtained through semi permanent observations of a stationary user population. The interaction between the service supplier and users is characterized as a two-stage Stackelberg model shown in Fig. 1.The service supplier publishes the evaluation theme in Stage one, and users respond with their demands in Stage two. The users wish to maximize their surpluses by optimizing their demands consistent with the evaluation theme. The service supplier needs to maximize its revenue by setting the proper evaluation theme to induce fascinating demands from users. Since the service supplier features a restricted total resource, it should guarantee that the entire demand from users isn't any larger than what it will offer. The main points of evaluation schemes depend upon the knowledge structure of the service supplier. Below complete info, since the service supplier will distinguish completely different teams of users, it announces the evaluation and also the admission management choices to completely different teams of users. It will choose between the com

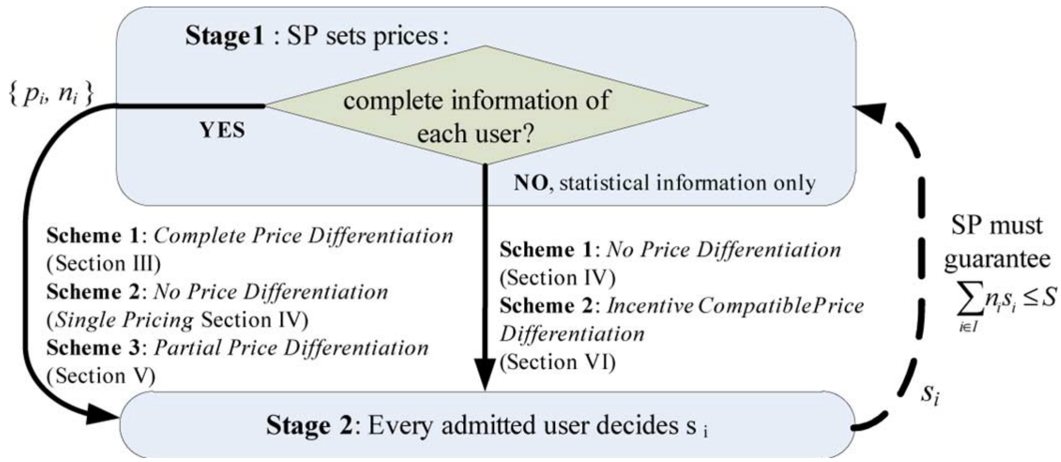

Fig. 1. Two-stage Stackelberg model.

III. ABSOLUTE PRICE DISCRIMINATION UNDER INCLUSIVE INFORMATION

We initial think about the whole data case. Since the service supplier is aware of the utility and also the identity of every user, it's attainable to maximize the revenue by charging a distinct value to every cluster of users. The analysis is supported backward induction, ranging from Stage two and so moving to Stage one.

A. User's Surplus Maximization drawback in Stage two

If a user in cluster has been admitted into the network and offered a linear value in Stage one, then it solves the subsequent surplus maximization problem:

(2) Which results in the subsequent distinctive best demand: wherever

(3)Remark 1: The analysis of the Stage two user surplus maximization drawback is that the same for all valuation schemes. The lead to

(3) Are conjointly utilized in Sections IV–VI.

B. Service Provider's valuation and Admission management drawback in Stage one In Stage 1, the service supplier maximizes its revenue by selecting the worth and also the variety of admitted users for every cluster subject to the restricted total resource. The key plan is to perform a whole value differentiation theme, i.e., charging every cluster with a distinct value rules one among the algorithm CP1 the best valuation theme to maximize the revenue underneath complete data.

Algorithm 1: Solving the Resource Allocation Problem CP_1

function $CP(\{n_i, \theta_i\}_{i\in\mathcal{I}}, S)$
  $k \leftarrow I$, $\lambda(k) \leftarrow \left(\frac{\sum_{i=1}^{k} n_i\sqrt{\theta_i}}{S+\sum_{i=1}^{k} n_i}\right)^2$
  while $\theta_k \leq \lambda(k)$ **do**
    $k \leftarrow k-1$, $\lambda(k) \leftarrow \left(\frac{\sum_{i=1}^{k} n_i\sqrt{\theta_i}}{S+\sum_{i=1}^{k} n_i}\right)^2$
  end while
  $K^{\mathrm{cp}} \leftarrow k$, $\lambda^* \leftarrow \lambda(k)$
  return K^{cp}, λ^*
end function

IV. DISTINCT PRICING METHOD

In Section III, we have a tendency to showed that the CP theme is that the optimum rating theme to maximize the revenue below complete data. However, such a sophisticated rating theme is of high implementational quality. During this section, we have a tendency to study the only rating theme. It's clear that the theme can normally suffer a revenue loss compared to the CP theme. We'll attempt to characterize the impact of varied system parameters on such revenue loss.

A. downside Formulation and resolution

Let us 1st formulate the only rating SP downside Compared to the matter in Section III, here the service provider charges one worth to any or all teams of users. When the same transformation as in Section III, we are able to show that the optimum single worth satisfies the subsequent the weighted water-filling condition

Algorithm 2: Search the threshold of the SP problem

function $SP(\{N_i, \theta_i\}_{i\in\mathcal{I}}, S)$
  $Sk \leftarrow I$, $p(k) \leftarrow \frac{\sum_{i=1}^{k} N_i\theta_i}{S+\sum_{i=1}^{k} N_i}$
  while $\theta_k \leq p(k)$ **do**
    $k \leftarrow k-1$, $p(k) \leftarrow \frac{\sum_{i=1}^{k} N_i\theta_i}{S+\sum_{i=1}^{k} N_i}$
  end while
  $K^{\mathrm{sp}} \leftarrow k$, $p^* \leftarrow p(k)$
  return K^{sp}, p^*
end function

B. Properties

Theme the SP theme shares many similar properties because the CP theme Section III-C, as well as the edge structure and admission management with valuation. Similarly, we are able to outline the effective marketplace for the SP theme. it's a lot of fascinating to note the variations between these 2 schemes. To differentiate solutions, we have a tendency to use the superscript "CP" for the theme, and "SP" for

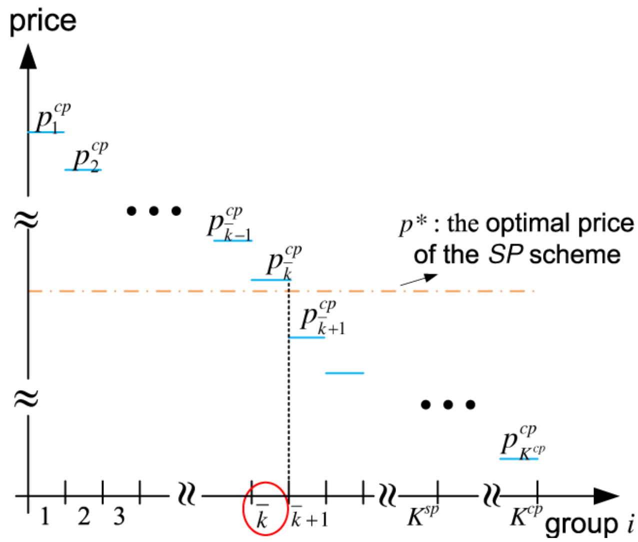

Fig. 2. Comparison of prices between the scheme CP and the SP scheme

IX. CONCLUSION

In this paper, we have a tendency to study the revenue-maximizing drawback for a monopoly service supplier below each complete and incomplete network data. Below complete data, our focus is to analyze the trade-off between the whole revenue and therefore the implementational quality (measured within the variety of evaluation decisions on the market for users). Among the 3 evaluation differentiation schemes we have a tendency to planned (i.e., complete, single, and partial), the partial value differentiation is that the most general one and includes the opposite 2 as special cases. By exploiting the distinctive drawback structure, we have a tendency to designed associate formula that computes the best partial evaluation theme in polynomial time and numerically segregated the tradeoff between implementational quality and total revenue. Below incomplete data, planning associate incentive-compatible differentiation evaluation theme is tough generally. We have a tendency to show that once the users are considerably completely different, it's doable to style a quantity-based evaluation theme that achieves identical most revenue as below complete data.

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