Special Section on Pricing and Incentives in Networks and Systems: Guest Editors' Introduction

Costas Courcoubetis, SUTD, Singapore
Roch Guérin, Washington University in St. Louis, USA
Patrick Loiseau, EURECOM, France
David Parkes, Harvard University, USA
Jean Walrand, UC Berkeley, USA
Adam Wierman, Caltech, USA

This paper describes the content of the special section on "Pricing and Incentives in Networks and Systems."

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1. INTRODUCTION

Today's communication networks and networked systems are highly complex and heterogeneous, and are often owned by multiple profit-making entities. For new technologies or infrastructure designs to be adopted, they must be based not only on sound engineering performance considerations but also present the right economic incentives. Recent changes in regulations of the telecommunication industry make such economic considerations even more urgent. For instance, new concerns such as network neutrality have a significant impact on the evolution of communication networks.

At the same time, communication networks and networked systems support increasing economic activity based on applications and services such as cloud computing, social networks, and peer-to-peer networks. These applications pose new challenges such as the development of good pricing and incentive mechanisms to promote effective system-wide behavior. Similarly, the security and privacy of these applications are

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themselves heavily dependent on economic considerations, which therefore need to be fully understood.

To address these questions, this special section brings together a relevant set of state-of-the-art research contributions on complementary topics including communication networks, wireless, web content and security, and using multi-disciplinary approaches ranging from game theory and economic modeling to algorithms and mechanism design, and including empirical studies.

2. PAPERS DESCRIPTION

In the first paper, "Distributed Content Curation on the Web," Abbassi, Hegde and Massoulié consider an economic model for content curation in the Internet, where content aggregators with finite capacity compete for increasing the total value of the content they provide to their readers, which also determines their payoff. Each reader in turn is a customer of multiple aggregators. The strategy of an aggregator is the set of content items to store assuming that he knows the value of a content item to each of his customers. The authors prove that distributed content curation based on selfish behavior of publishers converge to a pure equilibrium, compute the price of anarchy, discuss the rate of convergence to the equilibrium, analyze the performance of approximation algorithms and investigate cases when readers are also strategic.

The next paper, "Influence of search neutrality on the economics of advertisement-financed content" by Coucheney et al., proposes a model to analyze search neutrality issues regarding the ranking methods implemented by search engines: when a search is performed, should the search engine display the web pages ordered according to the quality-of-experience (relevance) of the content? The paper analyzes that question in a setting when content is offered for free, content providers generate revenue through advertising and hence the amount of advertising to add to their content is a strategic decision. There are interesting game-theoretic results indicating under what conditions on its revenue model the search engine prefers a neutral from a non-neutral ranking method, and the effects on the net utility and content quality.

Still in the neutrality topic, the next paper, "Regulation of off-network pricing in a nonneutral network" by Altman, Hanawal and Sundaresan, studies a non-neutral regime where a content provider (CP) may have to pay the last-mile ISP a side payment in addition to the ISP that connects the CP to the Internet. A first goal is to propose and study possible ways of implementing such payments and of regulating their amount. The authors propose a model that includes the users behavior, the utilities of the ISP and of the CPs, and the monetary flow that involves the content users, the ISP and CP, and the CPs revenues from advertisements. The results include the analysis of various game models and discover some interesting properties of the structure of the resulting equilibria.

The next paper, "Economic Viability of Paris Metro Pricing for Digital Services" by Chau, Wang and Chiu, is about Paris Metro Pricing (PMP). Because of its relative simplicity, the PMP scheme for offering different service classes has received significant attention over the past few years. Earlier studies typically assumed one type of congestion function, with differences in the congestion function often resulting in diverging conclusions regarding the scheme's efficacy in terms of welfare or profit maximization. The paper's main contribution is in offering a general framework that teases out how different properties of congestion functions such as utilization, loss, latency, outage, etc., affect the viability of PMP when it comes to maximizing welfare or provider's profit; in the process, elucidating why earlier studies reached different conclusions. In spite of limitations inherent to modeling, the paper makes a meaningful contribution to our understanding of what makes PMP desirable or not when it comes to achieving maximum welfare and/or profit.

In the next paper, "Adoption of bundled services with network externalities and correlated affinities," Guérin, de Oliveira and Weber study the problem of adopting technologies in the presence of network externalities, and how bundling of services can improve incentives for adoption when the users have positive correlations in value across services. They show through a careful analytic model that equilibrium adoption can go either way depending on conditions such as the strength of network effects and degree of value correlation.

The next paper, "Understanding Quota Dynamics in Wireless Networks" by Andrews et al., develops models of user pricing sensitivity for two types of contracts: prepaid quota without end date and postpaid quota with an end date. The authors first fit parametric models of call rates to actual call detail records. They then develop user utility models that explain these call rates. These utility models may be useful in developing pricing schemes.

The next paper is "Demand-Invariant Price Relationships and Market Outcomes in Competitive Private Commons" by Kavurmacioglu, Alanyali and Starobinski. This paper studies a promising new paradigm for spectrum sharing: Private Commons, which allows a license holder to maintain ownership of spectrum while providing access to secondary users for a fee. The paper studies this situation in detail, focusing on characterizations of the break-even price and the market-sharing price for license holders. A key result in the paper is that the break-even price is always less than the market-sharing price, which highlights that there always exists an interval in which the license holder is willing to share the market.

The next paper, "Approximation Algorithms for Secondary Spectrum Auctions" by Hoefer, Kesselheim and Vöcking, studies a general class of allocation problems that are suitable for the design of secondary spectrum markets, in which bidders compete for short-term licenses. Approximation algorithms with rigorous guarantees are developed for physical and binary interference models and oracle access to a bidder's valuation. Different bidder models can be handled, including bidders looking to broadcast from a particular location and connecting two devices along a path. Truthfulness-in-expectation is achieved through LP-based randomized meta-rounding, providing incentives for truthful bidding.

The next paper, "Revenue guarantees in the generalized second price auction" by Caragiannis et al., provides revenue guarantees over all Bayesian Nash equilibria (BNE) of the Generalized Second Price (GSP) auction, which is used by major search engines to sell advertisement slots. Prior work has established that the expected revenue in every BNE of a GSP auction, with valuations drawn i.i.d. from a distribution that satisfies a regularity condition, is at least 1/6th of the expected revenue of an optimal auction design. This paper improves the constant from 6 to 4.73, and establishes a bound of 3.47 for a class of distributions that satisfy a Monotone-Hazard-Rate (MHR) condition. The revenue guarantees are obtained by carefully arguing about profit inequalities implied by equilibrium conditions on infinitely many deviating bids.

The next paper, "Is Price of Anarchy the right measure for Load-Balancing Games?" by Doncel et al., analyzes the gap between the performance of a centralized scheduler and that of a decentralized scheme where each dispatcher independently tries to reduce its delay. In a large data center, it is hard to imagine a completely centralized scheduler and having the dispatchers do their independent load balancing seems to be a reasonable heuristic. The paper provides a bound on the price of anarchy as a function of the number of dispatchers and servers.

In the last paper, "Secure Team Composition to Thwart Insider Threats and Cyberespionage," Laszka *et al.* propose a game-theoretic model of insider threats. The game captures the strategic interaction between a project manager (defender) who has a secret she wants to protect but must share with employees selected from within

her organization, and an attacker who chooses an employee to bribe to obtain the secret. The employee reveals the secret if the bribe is larger than her trustworthiness modeled as a random variable whose distribution is common knowledge. The paper characterizes Nash equilibrium (existence and uniqueness in most cases) for general distributions and provides closed-form expressions for the uniform distribution. A few general conclusions are drawn from the analysis, such as that the defender must randomize her selection with a non-zero probability for each potential employee, unless she has a perfectly secure strategy. Overall, the paper provides a reasonable game-theoretic model to discuss a relevant security problem (insider threats).