Dynamic Pricing of Relocating Resources in Large Networks

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Abstract

Motivated by applications in shared vehicle systems, we study dynamic pricing of resources that relocate over a network of locations. Customers with private willingness-to-pay sequentially request to relocate a resource from one location to another, and a revenue-maximizing service provider sets a price for each request. This problem can be formulated as an infinite horizon stochastic dynamic program, but is quite difficult to solve, as optimal pricing policies may depend on the locations of all resources in the network. We first focus on networks with a hub-and-spoke structure, and we develop a dynamic pricing policy and a performance bound based on a Lagrangian relaxation. This relaxation decomposes the problem over spokes and is thus far easier to solve than the original problem. We analyze the performance of the Lagrangian-based policy and focus on a supply-constrained large network regime in which the number of spokes ($n$) and the number of resources grow at the same rate. We show that the Lagrangian policy loses no more than $O(\sqrt{\ln(n)/n})$ in performance compared to an optimal policy, thus implying asymptotic optimality as $n$ grows large. We also show that no static policy is asymptotically optimal in the large network regime. Finally, we extend the Lagrangian relaxation to provide upper bounds and policies to general networks with multiple, interconnected hubs and spoke-to-spoke connections, and to incorporate relocation times. We also examine the performance of the Lagrangian policy and the Lagrangian relaxation bound on some numerical examples, including examples based on data from RideAustin.

Joint work with David B. Brown (Duke University) and Chen Chen (University of Chicago)


Bio:
Santiago R. Balseiro is the Daniel W. Stanton Associate Professor of Business in the Decision, Risk, and Operations division at the Graduate School of Business, Columbia University. He teaches the core MBA class Business Analytics and the core Ph.D. class Foundations of Optimization. He also holds a part-time Research Scientist position at Google Research.

His primary research interests are dynamic optimization, stochastic systems, and game theory with applications in revenue management and internet advertising. His work studies the design and operation of online advertising markets. His research has been recognized by the 2014 George B. Dantzig Dissertation Award, an honorable mention in the 2017 Junior Faculty Interest Group Best Paper Award, an honorable mention in the 2014 George Nicholson Student Paper Competition, the 2019 Revenue Management and Pricing Student Paper Award, the 2015 Google Faculty Research Award, the 2012 Networks, Electronic Commerce and Telecommunications Institute Summer Grant, the 2011 Deming Doctoral Fellowship, and the 2010 Google Engineering
Professor Balseiro is a graduate of the University of Buenos Aires and received his Ph.D. from Columbia University’s Graduate School of Business in 2013. Before joining Columbia, he was on the faculty at the Fuqua School of Business, Duke University.