Dynamic Pricing of Wireless Internet Based on Usage and Stochastically Changing Capacity

Demet Batur\textsuperscript{1}, Jennifer Ryan\textsuperscript{1}, Zhongyuan Zhao\textsuperscript{2}, and Mehmet Vuran\textsuperscript{2}

\textsuperscript{1}Supply Chain Management and Analytics, University of Nebraska-Lincoln
\textsuperscript{2}Computer Science and Engineering, University of Nebraska-Lincoln

Research Problem

Inspired by new developments in dynamic spectrum access, we study the dynamic pricing of wireless internet access when demand and capacity (i.e., available bandwidth) are both stochastic. The demand for wireless internet access has increased enormously in recent years. However, the spectrum available to wireless service providers is limited. The industry has thus expanded conventional license-based spectrum access policies through unlicensed spectrum operations. However, the additional spectrum obtained through these unlicensed operations has stochastic availability. This creates novel challenges for the service provider when determining the optimal pricing for this service. The dynamic pricing problem considered in this paper is therefore both of high practical relevance and new to the academic literature.

Methodology and Assumptions

We consider a network in which a service provider monitors the availability of unlicensed channels and posts prices to the arriving customers based on the available bandwidth. If an
arriving customer is willing to accept the posted price, he will start his internet connection; otherwise, he will depart from the system. We consider a system with multiple classes of customers, where the classes have different bandwidth requirements based on the type of activity to be performed, e.g., video streaming vs. web surfing vs. checking email, and different price sensitivities. The total connection fee paid by an arriving customer depends on the posted price at the time of arrival, the customer’s bandwidth requirement, and the expected connection duration. A key feature of this model setting is that the available bandwidth is a stochastic process due to the fact that unlicensed channels become available for usage when they are not actively being used by licensed users, and they become unavailable when licensed users start to use the channel.

For this model setting, we study the dynamic pricing problem faced by the service provider, who seeks to maximize his revenue, using a Markov Decision Process (MDP) model in which customers are posted dynamic prices based on the current number of customers of each class that are currently in the system, as well the current available capacity. The research presented in this paper has some similarities to the previous literature on dynamic pricing in MDP models, as well as admission control in systems with multiple demand classes and stochastic service times (Gans and Savin, 2007; Paschalidis and Tsitsiklis, 2000). However, a key distinguishing feature of our MDP model is that in addition to having stochastic inter-arrival and service times, our model also has stochastic capacity availability.

**Summary of Results and Managerial Implications**

For this problem setting, we are able characterize the structure of the optimal pricing policy as a function of the system state, which is defined as the number of customers of each class and
the number of available channels of each class, and of the key input parameters, such as the bandwidth requirements and the price sensitivities for each customer class. We demonstrate that customer classes requiring higher bandwidth are offered higher prices, and that more price sensitive customer classes are offered lower prices. Furthermore, we demonstrate that the optimal price is always at least as large as the myopic price, which is the price that maximizes the immediate expected discounted revenue for a given customer class.

Since it is impossible to solve this problem for practically large state-spaces, we propose a heuristic dynamic pricing policy that performs very well, particularly when the ratio of capacity to demand is low. We demonstrate the value of using this dynamic heuristic policy relative to the static myopic policy. The literature has studied systems with fixed capacity and has characterized conditions under which static policies perform well. In contrast, our setting has stochastic capacity, and we find that identifying good state-dependent heuristic policies is of greater importance. Our heuristic policy is computationally more tractable, and easier to implement in practical settings, than the optimal pricing policy. In addition, it provides a significant performance improvement relative to the myopic policy when capacity is scarce, a condition that holds for the practical setting which motivated this research.

References
