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

Wireless radio spectrum is a limited resource. The U.S. uses a fixed spectrum allocation policy, determined according to national priorities and policies, technical characteristics, and international agreements. Because of the increase in demand for wireless internet, conventional license-based spectrum allocation policies are being expanded through unlicensed spectrum access operations. These unlicensed operations include opportunistic use of the spectrum channels by secondary users, i.e., wireless service providers (SPs) when they are not being used by the licensed users of the spectrum. Since availability of these channels for secondary usage varies geographically and temporally, the capacity available to the SPs vary stochastically. This creates novel challenges for SPs when determining optimal pricing for a customer’s use of internet. In this paper, we study the dynamic pricing of wireless internet access when capacity (i.e., available bandwidth) and demand are both stochastic.

Methodology and Assumptions

We consider a network in which an SP monitors the availability of channels and posts prices to the arriving customers based on the current number of customers of each class that are currently in the system, as well the current available bandwidth. If an arriving customer is willing to accept the posted price, he starts his internet connection; otherwise, he departs. We consider a system with multiple classes of customers, where the classes have different bandwidth requirements (e.g., video streaming, web surfing) and different price sensitivities. The total connection fee paid by an arriving customer depends on the posted price at the time of arrival and the length of the internet connection. Since the available bandwidth is a
stochastic process, it may decrease at random; thus, customers that are in service may need to be dropped off by the SP. A key challenge in managing the network is to maximize the revenue earned from admitted customers, while limiting the cost of dropped customers.

We study the dynamic pricing problem faced by the SP using a Markov Decision Process (MDP) model in which customers are posted dynamic prices based on the current status of the system. We also study the optimal drop-off policy, which determines the number of customers of each class to be dropped when total capacity falls below the total demand.

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, in addition to having stochastic inter-arrival and service times, our MDP model also has stochastic capacity availability, as well as customer drop-off related issues.

**Summary of Results and Managerial Implications**

For this problem setting, we characterize the structure of the optimal pricing policy and the optimal drop-off 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. 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.

When the total capacity drops below total demand, some customers need to be dropped off. We find that, in most cases, it is optimal to drop the customers with the highest
bandwidth requirements first. However, in some cases, it is optimal to drop a customer requiring a lower bandwidth if that customer’s expected service time is relatively long.

Since it is impossible to solve this MDP 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 pricing policy relative to the static myopic policy. We also study a heuristic bandwidth-based drop-off policy, which drops customers according to their bandwidth requirements, i.e., customers with larger bandwidth requirements are dropped first. We demonstrate that the bandwidth-based drop-off policy and the optimal drop-off policy always drop the same number of customers. However, the classes of the dropped customers may not be the same.

The literature has studied systems with fixed capacity and characterized conditions under which static pricing policies perform well. In contrast, our setting has stochastic capacity, and our state-dependent heuristic pricing policy achieves a significant performance improvement relative to the myopic pricing policy when capacity is scarce, a condition that holds for the practical setting which motivated this research. Also, the performance degradation from the use of the heuristic bandwidth-based drop-off policy in place of the optimal drop-off policy is very small. Our heuristic policies are computationally more tractable, and easier to implement in practical settings, than the optimal policies.

References
