Chapter 14
Economic Approach for Network Management

ABSTRACT

It is not surprising that researchers in network technology are utilizing ideas from the field of economics since it provides the conceptual understanding of underlying constructs such as usage and resource allocation. Proper resource allocation plays a key role in improving network performance. There are two primary approaches to economic resource allocation: quantity limits and pricing. Economic approaches can provide principles in situations and provide valuable guidelines and analysis. A concerted effort is needed from academia, the computer industry, network service providers, and businesses involved in electronic commerce to design new mechanisms for network operations that will be suitable for a new generation network applications. This chapter explores this economic approach for network management.

STACKELBERG GAME BASED PRICE CONTROL (*SGPC*) SCHEME FOR WIRELESS NETWORKS

Recently, game-theoretic approaches for network price problem have attracted much attention. In 2011, S. Kim proposed a new Stackelberg Game based Price Control (*SGPC*) scheme for wireless networks (Kim, 2011). To provide the most desirable network performance, the *SGPC* scheme consists of two different control mechanisms; user-based and operator-based mechanisms. By using the hierarchical interaction strategy, control decisions in each mechanism act cooperatively and collaborate with each other to satisfy conflicting performance criteria. In addition, the developed dynamic online approach is practical for real network implementation.

Development Motivation

Nowadays, wireless/mobile networking is one of the strongest growth areas of communication technology. In view of the remarkable growth in the number of users, all performance guarantees in wireless networks are conditional on the current bandwidth capacity. However, in spite of the emergence of high network infrastructures, wireless bandwidth is still an extremely valuable and scarce resource. Therefore, efficient bandwidth management is very important for the wireless network performance (Niyato & Hossain, 2006)

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One of the central issues for bandwidth managements is pricing; it can be used as a viable solution to improve network efficiency. Pricing strategy can have strong influence on the behavior of the users and lead the network system into a desirable state (Feng, Mau, Mandayam, 2004). Therefore, an adaptive pricing algorithm is an effective tool to solve the network control problem. Generally, pricing algorithms can be classified as either user-centric or operator-centric approaches. These two approaches tend to result in qualitatively different network performance. From the viewpoint of users, a personal payoff is a very important factor; traditionally, users act independently and selfishly without considering the existence of other users. Therefore, the user-centric approach tries to maximize the interest of individual users. From the operator's point of view, main interests are total network revenue and collective user-satisfaction. To get the globally desirable network performance, the operator-centric approach attempts to optimize these metrics simultaneously. For the ideal network management, it is necessary to effectively mediate between two different control approaches (Feng, 2004).

In the *SGPC* scheme, the main challenge is to design a price control algorithm to use bandwidth as efficiently as possible. To achieve this design goal, the *SGPC* scheme has developed a control scheme by using the game theory. A game model has some attractive features to understand the behavior of self-regarding applications or independent network users. However, due to some reasons, classical game theory cannot be directly applied to the network price control problem. First, players have very limited information. Therefore, it is usually impossible to delineate all conceivable strategies. Second, it is not easy to assign a payoff value to any given outcome, and also difficult to synchronize the activities of the different players. Third, due to the complexity of network situations, the mathematical modeling and numerical analysis have met with limited success (Wang & Schulzrinne, 2005), (Xiao, Shan, Ren, 2005).

In 1934, H. V. Stackelberg proposed a hierarchical game model based on two kinds of different decision makers; a leader and followers. Decision makers have their own hierarchy level, utility function and strategies; they are forced to act according to their hierarchy level. One higher-level decision-maker, who is referred to as a leader, makes his decisions by considering the possible reactions of followers. Many lower-level decision-makers, who are referred to as followers, react dependently based on the decision of the leader while attempting to maximize their satisfaction (Wang, Han, & Liu, 2006), (Anandalingam, 1988).

While developing a price control scheme, there is a tradeoff between a network operator and users' objectives. To arbitrate this conflicting relationship, the adopted methodology is the Stackelberg game theory. In general, it may be concluded to be a proper method for the best compromise in the presence of conflicting objectives. In a realistic scenario, the network operator has more global network information and users make their reactions based on the network operator's decision. Therefore, in the *SGPC* scheme, the network operator plays the role of the leader and users become followers.

By employing dynamic online and distributed approach, the *SGPC* scheme is a new adaptive online price control scheme based on the Stackelberg model. The *SGPC* scheme consists of two different control mechanisms; operator-based and user-based mechanisms. In the operator-based mechanism, an appropriate performance balance is a critical issue; the network operator adaptively decides the price to optimize diverse performance criteria, simultaneously. In the user-based mechanism, a primary concern is the user's payoff. Therefore, to maximize their expected payoff, price sensitive users dynamically adapt their bandwidth requests in a distributed online manner. The outcome of users' decisions is the input back to the network operator to adjust the current price. By using this dynamic iterative feedback loop, network operator and users can

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