Chapter 11
Bargaining Solutions for Resource Allocation Problems

ABSTRACT

The first unified and systematic treatment of the modern theory of bargaining is presented together with many examples of how that theory is applied in a variety of bargaining situations. This chapter provides a masterful synthesis of the fundamental results and insights obtained from the wide-ranging and diverse bargaining theory literature. Furthermore, it develops new analyses and results, especially on the relative impacts of two or more forces on the bargaining outcome. Many topics—such as inside options, commitment tactics, and repeated bargaining situations—receive their most extensive treatment to date.

NASH BARGAINING BASED BANDWIDTH MANAGEMENT (*NBBM*) SCHEME

Bandwidth is an extremely valuable and scarce resource in wireless networks. Therefore, efficient bandwidth management plays an important role in determining network performance. For multimedia cellular networks, S. Kim proposed a new Nash Bargaining based Bandwidth Management (*NBBM*) scheme, which consists of adaptive bandwidth reservation and borrowing algorithms (Kim, 2011). Based on the well-known game theoretic concept of bargaining, wireless bandwidth is controlled as efficiently as possible while ensuring QoS guarantees for higher priority traffic services. Under dynamic network condition changes, control decisions in the developed algorithms are made adaptively to strike a well-balanced network performance.

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Development Motivation

Nowadays, mobile networking technology needs to support an increasing range of services and the remarkable growth in the number of users. However, in spite of the emergence of high network infrastructures, wireless bandwidth is still an extremely valuable and scarce resource. Therefore, an efficient bandwidth management is very important and an active area of research over the last decade (Pati, 2007). A promising approach for the efficient wireless bandwidth usage is through the cellular concept. Cellular technology has greatly enhanced the network capability; the same bandwidth can be reused as much as possible by employing a collection of cells. This bandwidth reuse planning is an effective engineering task to improve the overall network performance (Kim, & Varshney, 2004).

Usually various multimedia data can be categorized into two classes according to the required QoS: *class I* (real-time) traffic services and *class II* (non real-time) traffic services. *Class I* data traffic is delay sensitive and *class II* data traffic is rather tolerant of delays. Based on different tolerance characteristics, *class I* data type has higher priority than *class II* data type. For next-generation multimedia cellular networks, the main challenge is to improve bandwidth efficiency while ensuring QoS for higher priority traffic services. To satisfy this goal, extensive research on bandwidth reservation and borrowing techniques has been carried out. Bandwidth reservation is a well-known strategy to enhance the network QoS. This strategy partitions available bandwidth and reserves some parts for higher priority services. To alleviate the traffic overload condition, bandwidth borrowing algorithms are developed. These algorithms migrate available bandwidth to approach perfect load balancing in cellular networks. The benefit of bandwidth reservation and borrowing strategies is to increase network QoS while maximizing the overall network performance (Kim, 2004).

Performance optimization is one of the most important issues in control problems. Until now, a lot of research dealing with performance optimization has been conducted. In 1950, John Nash introduced the fundamental notion of the Nash Bargaining Solution (NBS) to allocate the resource fairly and optimally. The NBS is a field of cooperative game theory and an effective tool to achieve a mutually desirable solution with a good balance between efficiency and fairness. In addition, the NBS does not require global objective functions unlike conventional optimization methods such as Lagrangian or dynamic programming (Park, & Schaar, 2007). Due to its many appealing properties, the basic concept of NBS has become an interesting research topic in a wider range of real life situations, such as economics, political science, sociology, psychology, biology, and so on.

In the *NBBM* scheme, effective bandwidth management algorithms are designed for multimedia cellular networks. Based on the concept of NBS, the developed algorithms effectively allocate the bandwidth among multiple services while providing the required QoS. Usually, the NBS has some attractive features to model the interactions among independent decision-makers and enforce collaborative behavior. However, due to some reasons, the classical NBS method cannot be directly applied to wireless network management. First, it is not amenable to complex non-convex problems; the utility space for the bandwidth allocation problem is not always convex (Suris, DaSilva, Han, & MacKenzie, 2007). Second, the traditional NBS was derived in the context of economics, so it is not appropriate for communication systems. Especially, a static one-shot game model is an impractical approach to justify realistic system operations. Third, due to the complexity of wireless network situations, mathematical modeling and numerical analysis have met with limited success.

The *NBBM* scheme was developed based on the NBS and would employ a dynamic online methodology for wireless network management, which can improve control adaptability and flexibility under widely different and diversified network situations. In the *NBBM* scheme, the traditional NBS method is modified to support dynamic network situations. By using the basic concept of NBS, the wireless bandwidth can be adaptively reserved and migrated to approximate the optimal network performance. The *NBBM* scheme consists of bandwidth reservation and borrowing algorithms. To strike an appropriate network performance, bandwidth reservation and borrowing strategies are incorporated in the *NBBM* scheme.

Nash Bargaining Solution

Traditionally, games can be divided into non-cooperative and cooperative games. In non-cooperative games, players are in conflict with each other and do not communicate or collaborate. Their preferences can be expressed as a utility function; players try to ensure the best possible consequence ac-