Chapter 15

Game Theoretic Approaches for Wireless Cooperative Content-Sharing

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ABSTRACT

This chapter provides an overview of game theoretic solutions in a wireless application of particular interest for multimedia and social interactions in modern telecommunication systems. In particular, coalitional games, bargaining solutions and fairness and stability issues will be investigated within wireless cooperative content-sharing. According to this paradigm, users download portions of data of common interest over long-range cellular links while exchanging the downloaded portions over short-range radio links. Expected benefits, which are natural incentives to cooperation, may be in terms of content price, energy consumption, and transfer delay reduction. Significant research activity has been conducted to design strategies that simultaneously exploit the multiple radio interfaces of modern wireless devices and maximize the gain. A valid solution for the cooperative content-sharing application should be based on fairness in the utility distribution among the involved nodes which can be eased by exploiting the game theoretic approaches presented in this chapter.

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INTRODUCTION

Wireless cooperative networking, guaranteeing performance enhancements to handheld devices (e.g., smartphones, PDAs), is a well investigated research field (Iera, Militano, Romeo, & Scarcello, 2011). More specifically, cooperative content sharing is gaining momentum in the wireless communication arena thanks to its easy implementation in modern multi-interface mobile devices and the many applications for social and multimedia services. According to this paradigm, users download portions of data of common interest over costly long-range cellular links while exchanging the downloaded portions over short-range radio links. Significant research activity has been conducted to design strategies that simultaneously exploit the multiple radio interfaces of modern wireless devices and maximize the gains. As an example, the beneficial effects of integrating cellular and Wi-Fi networks are shown in Bhatia, Li, Luo, & Ramjee (2006) and Cavalcanti, Agrawal, Cordeiro, Xie, & Kumar (2005). The rewards of cooperation in terms of energy consumption and transfer delay are demonstrated in Militano, Fitzek, Iera, & Molinaro (2011) and Campolo, Iera, Militano, & Molinaro (2012) while the advantages of evolutionary theory and network coding techniques applied to cooperative scenarios are studied, e.g., in Militano, Fitzek, Iera, & Molinaro (2010a) and Militano, Fitzek, Iera, & Molinaro (2010b). Expected benefits, which are natural incentives to cooperation, may be in terms of content price, energy consumption, and transfer delay reduction. However, different file-sharing and cost-sharing policies may result in dissimilar performance levels experienced by the cooperating entities. Therefore, approaching the problem by relying on conventional tools based on analytical computation and linear programming to maximize the performance according to one key parameter only (e.g., energy or delay) could be unsatisfactory or too simplistic for some applications. The reason is that such tools distribute service costs disregarding any fairness among cooperating users. On the other hand, even a fair cost distribution could be unsatisfactory, in case a node (or a group of nodes) realizes that its reward increases by leaving the proposed cooperating group to form alternative cooperative groups making the solution unstable. A valid solution for the cooperative content-sharing application should indeed be based on fairness in the utility distribution among the involved nodes. The achievement of an agreement among cooperating users can be eased by exploiting game theory (GT). In fact, game theory is an analytical framework that attempts to analyze the behavior of rational entities with their own interests in reciprocal interactions. By starting from the economic field, during the last decades it has found successful applications to several other areas such as wireless networking. In Han, Niyato, Saad, Basar, & Hjørungnes (2011) a survey of GT-related studies is reported, which gives the reader an idea of the significance that game theory is gaining within the research community. Among others, fields of application of GT-based models are: Call admission control (Zhang & Fang, 2007), flow control (Tang & Andrew, 2008), radio resource management (Militano, Condoluci, Araniti, & Iera, 2013; Militano, Condoluci, Araniti, & Iera, 2012), content distribution (Goemans, Li, Mirrokni, & Thottan, 2006), malicious node detection in sensor networks (Yenumula, 2009), green networking (Militano, Molinaro, Iera, & Petkovic, 2013) and cooperation in wireless ad hoc networks (Srinivasan, Nuggehalli, Chiasserini, & Rao, 2003). Special attention to the fairness aspect in communication scenarios is given in Aram, Singh, & Sarkar (2009) and Cai & Pooch (2004), among others. Moreover, contributions can be found in the literature, which deal with coalitional games that are of particular interest for the problem discussed in this chapter: In Saad, Hjørungnes, Han, Niyato, & Hossain (2011) the focus is on vehicular networks, in Mathur, Sankaranarayanan, & Mandayam (2008)
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