Chapter 5
Game Theory for Collaboration in Future Networks

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ABSTRACT

Cooperative strategies have the great potential of improving network performance and spectrum utilization in future networking environments. This new paradigm in terms of network management, however, requires a novel design and analysis framework targeting a highly flexible networking solution with a distributed architecture. Game Theory is very suitable for this task, since it is a comprehensive mathematical tool for modeling the highly complex interactions among distributed and intelligent decision makers. In this way, the more convenient management policies for the diverse players (e.g. content providers, cloud providers, home providers, brokers, network providers or users) should be found to optimize the performance of the overall network infrastructure. The authors discuss in this chapter several Game Theory models/concepts that are highly relevant for enabling collaboration among the diverse players, using different ways to incentivize it, namely through pricing or reputation. In addition, the authors highlight several related open problems, such as the lack of proper models for dynamic and incomplete information games in this area.

1. INTRODUCTION

Game Theory (GT) techniques have recently emerged in many engineering applications, notably in communications and networking. With the emergence of cooperation as a new communication paradigm, alongside the need for self-organizing, decentralized, and autonomic networks, it has become imperative to seek suitable GT tools to analyze and study the behavior and interactions of nodes in Future Networks (FNs). The final goal is to find low-complexity distributed algorithms

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that can efficiently manage the highly-complex future network environment formed by heterogeneous technologies, enhancing collaboration among players and punish selfish or misbehaving nodes. In addition, the new management solutions should reduce the unwanted effects of stale information (e.g. oscillation around a specific network status) by choosing the proper values, namely, for both sampling rate of network status and delay associated to the dissemination of status information amongst the network nodes. This chapter fills a hole in existing communications literature, by providing a comprehensive review about GT models/concepts that are highly relevant for enabling collaboration in FNs environments.

In FNs, incentive mechanisms should be applied to the network infrastructure as distributed and intelligent management algorithms, forcing players to cooperate instead of pursuing their own interest. This novel player's behavior aims to efficiently use the available network resources and to satisfy the heterogeneous requirements of data flows. Broadly speaking, the current literature highlights two different ways to encourage cooperation (collaboration) among the players: one with a short-term control effect and the other with a long-term control effect. The first approach makes use of virtual payments (credit-based games) to relieve costs for relaying traffic, and the second approach is related to community (or group) enforcement to establish long-term relationships among the nodes (reputation-based games). Cooperation is sustained in reputation-base games because defection against a specific node causes personal retaliation or sanction by others. In the limit, nodes that do not cooperate will not be able to use the network themselves. Effective corrective actions against cheating nodes are also required with either permanent or temporary measures. In addition, there is also a relatively new and a very interesting set of games designated by evolutionary coalitional games that can enable more intelligent, self-adjustable, and robust algorithms for the management of FNs. Furthermore, the social networks like Facebook or Flickr currently have a large popularity, and following very recent work (Apicella, 2012) (Bond, 2012), these networks could rapidly disseminate the positive impact of collaborative actions among the users of FNs. This fast dissemination will be anchored by the convergence of distinct wireless access technologies, and the deployment in large scale of vehicular networks as well as wireless sensor networks. Finally, it should be also interesting to investigate the deployment of hybrid solutions combining credit-based and reputation-based methods to enhance collaboration amongst players.

The current chapter reviews the literature to find and discuss the more promising GT proposals that can incentivize the collaboration among the diverse players to use more intelligently and efficiently the available resources of FNs. This chapter is organized as follows. Section 2 introduces and discusses important GT aspects for FNs. Section3 gives the background and highlights collaborative strategies in FNs. It also presents our vision about FNs. Then, section 4 describes how GT can enable and enhance collaboration in FNs. In particular, section5 offers a broad GT literature survey in wireless networking. Section6 discusses some relevant research work on how GT can be used to address the more significant operational or functional aspects we expect to be present in FN environments. Several guidelines to apply game theory on future networks using different application examples are given in this section. Finally, Section 7 concludes and discusses relevant GT open problems to support collaboration in FNs.

2. DISCUSSING GAME THEORY

The current section introduces and discusses relevant aspects of GT, which can be very useful to model the emergent network environments of FNs.