

Capacity and Fairness Analysis of Game Theoretic Power Controlled Wireless Access Network

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Abstract—In wireless networks, transmission power has adverse effects. With low transmission power, the received signal may be eclipsed by the noise and interference from other transmitters, resulting in low SINR. On the other hand, with high transmission power, the interference seen at other receivers could be too large, also resulting in low SINR. This paper aims to address this problem by using the game theory. Particularly, the scenario of wireless access network with two transmitters, each with two intended receivers, is considered. Selection of transmission power of the two transmitters is modeled as the two-person game, which would lead to a Nash Equilibrium in a non-cooperative scenario. However, with a proper power control, the scenario can become a cooperative game, with a possibility of operating at a Pareto optimum. Three utility functions are investigated, and the trade-off between capacity and fairness is analyzed.

Keywords—Wireless access network; power control; two-person game; utility function; fairness

I. INTRODUCTION

Performance of wireless networks is restricted by the channel capacity. Based on Shannon's capacity, it can be found that the two factors that govern the limitation are bandwidth and signal power. With limited spectrum, multiple transmitters and receivers usually share a bandwidth. Thus, signals from a transmitter can be seen as interference at unintended receivers. However, for a successful communication, transmission power also has to be high enough so that the signal can overcome noise and reach its intended receiver. Under this circumstance, game theory is a remarkable mathematical tool to deal with many conflicting functions or conflicting resources in this case.

With this ability of game theory, it has been utilized in many research works to tackle wireless network problems. Wireless network with flat-fading interference channel is analyzed as two-person games [1]. Game theory is applied to change uplink CDMA network into N-person non-cooperative game and controls transmission power of all users for better overall network performance [2]. Application of game theory also yields optimal transmission power that maximizes bit rate-to-power consumption ratio [3]. Bayesian game and Stackelberg game are adopted to

allocate transmission power in decentralized cognitive radio networks [4], [5]. Algorithms for updating transmission power in the distributed wireless ad hoc networks using asynchronous pricing game have been proposed for optimal power allocation [6].

In this work, only the effect of transmission power is concerned. Game theory is adopted to change wireless access networks into game models so as to solve the games and find optimal transmission powers of the networks.

The outline of this paper is organized as follows. In Section II, basic concepts of game theory are introduced. In Section III, the network model and its game models are presented. Numerical results are shown in Section IV and Section V concludes the paper.

II. GAME THEORY CONCEPTS

Generally, a game G in game theory consists of 3 components:

$$G = (\{1, \dots, K\}, S, \{R_1, \dots, R_K\}),$$

where the first component $\{1, \dots, K\}$ is a set of player 1 to player K that are involved in the game. S is a strategy space or a set of all possible strategies that each player can choose. The last component $\{R_1, \dots, R_K\}$ is a set of utilities or payoffs resulted from the strategy that the K players choose. The space formed by all possible utilities is called the utility region.

Pareto optimum is defined as a feasible point on the boundary of the utility region that optimizes the utilities of all players. At this point, in order to increase the utility of any player, there must be some other players getting a lower utility. A set of all Pareto optimal points forms a Pareto boundary.

Nash equilibrium is defined as a feasible point in the utility region where no players can get a higher utility from changing a strategy unless other players also change their strategies.