Resource Allocation in Wireless AdHoc Networks Using Game Theory

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Abstract

The purpose of this paper is to analyze the resource allocation problem in a self organizing network from the viewpoint of game theory. The main focus is to suggest the model and analyze a power control algorithm in wireless ad-hoc networks using non cooperative games. Our approach is based on a model for the level of satisfaction and utility a wireless user in a self organizing network derives from using the system. Using this model, we show a distributed power control scheme that maximizes utility of each user in the network. Formulating this as a non-cooperative game we will show the feasibility of such power control as well as existence of the Nash Equilibrium achieved by the non-cooperative game.

I. Introduction

Resource allocation is one of the most challenging and one of the most important aspects of modern wireless communication networks especially wireless ad-hoc networks which has emerged as an important part of the envisioned future ubiquitous communication because they do not require infrastructure support and can be quickly deployed with low cost. Wireless ad-hoc networks are finding a variety of applications such as disaster rescue, battlefield communications, environment monitoring and collaborative computing.

Since wireless ad-hoc network is totally decentralized in its nature as well as its application areas, it is important to allocate limited radio resource in an intelligent way for these networks. Thus system performance can be improved by applying decentralized, intelligent and adaptive radio resource management scheme in these networks [1].

Now a days decentralized resource allocation scheme in communication network has been studied from the view point of game theory [2]. Routing and flow control in communication networks have modeled as a non cooperative game [3]. The distributed approach of transmit power allocation [4] has been extended through game theory [5]. The game-theoretic approach allows the nodes to define their own QoS target. In self organizing wireless ad-hoc networks, decentralized solutions are necessary as the nodes are communicating each other in a decentralized distributed manner. The focus of this paper is on distributed power control in self organizing wireless ad-hoc network using non cooperative game approach. Applying non cooperative game to the networks we get Nash Equilibrium i.e. the steady state situation where power of each node is controlled and stable.

II. Game Theory

The fundamental component of game theory is the notion of a game, expressed in normal form as

$$G=\langle M,A,\{u_i\}\rangle$$

where G is a particular game, M is a finite set of players (decision makers) {1, 2, , m}, Ai is a set of action available to player i, $A = A1'A2' \quad 'Am$ is the action space, and $\{ui\} = \{u1, u2, \quad , um\}$ is the set of objective functions that the players wish to maximize. For every player i, the objective function ui, is the function of the particular action chosen by player i, ai, and the particular action chosen by all other players in the game, $a-i$. For this model, steady state conditions, known as *Nash Equilibria* are identified wherein no player would rationally choose to deviate from their chosen action as this would diminish their payoff, i.e. $u_i(a)\geq u_i(b_i,a_{-i})$ for all $i,j\in M$. The action tuples (a unique choice of each player) corresponding to the Nash Equilibria are then predicted as most popular outcomes. In a game the steady-state condition (Nash Equilibria) need not to be Pareto Efficient operating point. An example of a game expressed in normal form can be found in [6].

Ⅲ. Power control as Game

In this work, we consider a decentralized wireless ad-hoc networks of several nodes where each node is communicating with one another. We consider p_i the transmission power of node i and g_i the link gain of i. Then $y_i = p_i g_i$, $i = 1, 2, \ldots\ldots, m$ is the received power of each node i. The quality of service QoS of each node i is measured in terms of the signal to interference radio (SIR) of i. Thus the SIR for each node i is given by

$$SIR_i = \frac{y_i}{\sum_{j \neq i} y_j + e}$$

where e designates external noise power. It is presumed that self-interference is negligible or nonexistent. Each node of interest relays its SIR information back to the nodes transmitting to it. Each transmitting node then adapts its transmission parameters as a function of SINR at its node of interest constrained by a cost function that models the internal costs for a particular energy / waveform pair (battery life, complexity, distortion) and / or a cost function imposed by a network for a particular energy / waveform pair. This describes a game of power control. Let the action space for this game is defined as available power vector P where $P = \{P_1 \times P_2 \ldots\ldots \times P_m\}$ and each $P_i = \{p_1 \times p_2 \times \ldots\ldots \times p_m\}$. Thus power control game is $G = \langle M, P, \{u_i\} \rangle$ where M is the set of nodes in networks. The objective function u_i can be described in terms of SIR as

$$u_i = \left(\frac{y_i}{\sum_{j \neq i}^{M} y_j + e} \right) - c_i(p_i)$$

here $c_i(p_i)$ is the cost function of each node i which can be described in unit price of power p', i.e. $c_i(p_i) = p' * p_i$. In this power control game each node will try to increase its utility by choosing a power from available power vector rationally and finally reach a steady state condition i.e. *Nash Equilibria*.

Ⅳ. Simulation and Results

We consider a wireless ad-hoc network where M=7, external noise e=0.001 and unit power price=0.5. The available received power space P is a set of any real number between 0 to 10. Applying greedy algorithms to achieve maximum utility each node reach in a steady state i.e. Nash Equilibria point after some iteration as shown in Fig. 1 and 2.

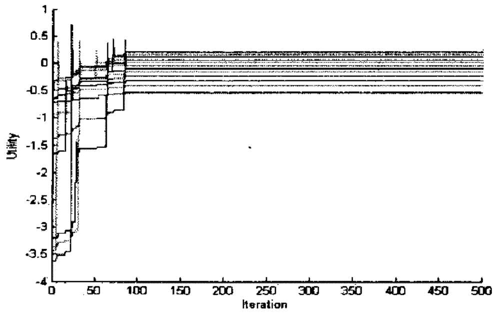

Fig.1. Utility meets Nash Equilibria.

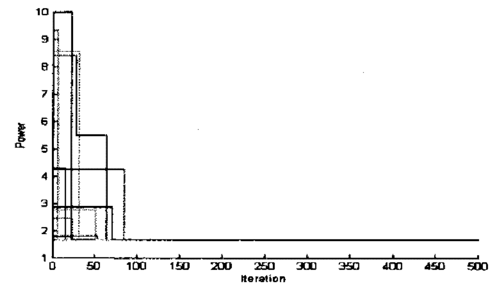

Fig.2. Power adjustments for Nash Equilibria.

Ⅴ. Conclusion

In this paper we have introduced game theoretical techniques for resource management especially power management in wireless ad-hoc networks. We showed that by applying non cooperative game theoretical techniques with greedy algorithm we got Nash Equilibria for wireless ad-hoc networks. Our future approach will be to extend this work to rate control as well as throughput maximization of a large self-organizing network.

Reference

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