A Game of Uncoordinated Sharing of Private Spectrum Commons

[Poster]

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1. CHANNEL ACCESS GAME

We consider secondary provisioning of radio spectrum where usage rights of a wireless channel are granted to secondary users without necessarily relying on the network of the primary license holder. In return, the secondary users pay the license holder per unit data transmitted on the channel. The rates that the secondary users achieve depend on the interference they create to each other, which also can vary temporally based on the activities of the users on the channel.

In this work, channel sharing is considered from the standpoint of a user that aims at fixing its *long-term average* rate at a utility maximizing value, without the need for predicting the behavior of other users. The problem is formulated as a non-cooperative game of channel access played in rounds, where, in each round, a user decides whether or not to access the channel based on the outcome of the game in the previous round. The single round payoff matrix of the channel access game of two users is shown in Figure 1. In each round, the users choose from a binary action space to transmit at a certain power level or at zero power. If one user accesses the channel, it will achieve rate R_1 for user 1 or R_2 for user 2. However, if the two users access the channel concurrently, they both achieve lower rates with $0 < \theta_1, \theta_2 < 1$.

User 1 \ User 2	Access	No Access
Access	$(\theta_1 R_1, \theta_2 R_2)$	$(R_1, 0)$
No Access	$(0, R_2)$	$(0, 0)$

Figure 1: The channel access game.

2. STRATEGIES FOR RATE FIXING

We analyze the previous channel access game as a discrete time Markov chain and devise strategies that allow users to achieve their rates regardless of the strategies of their opponents. In this regard, we describe the state of the game in any round by the actions of the users in that round. Let 1 denote *access* and 2 denote *no access*, and let $n_1, n_2 \in \{1, 2\}$ denote the actions of user 1 and user 2, respectively. Let $\mathbf{n}(t)$ denote the state of the game in round $t \geq 0$ and let Ω denote the set of all possible states, i.e.,

$$\Omega = \{(1,1), (1,2), (2,1), (2,2)\},$$

. We define the strategy of a user by the probability of choosing to access the channel dependent on the state of the game. Specifically, consider the game from the standpoint of user 1, a strategy is defined by the set of probabilities $(p^{1,1}, p^{1,2}, p^{2,1}, p^{2,2})$, where

$$p^{\mathbf{k}} = \mathsf{Pr}\left(n_1(t+1) = 1 \mid \mathbf{n}(t) = \mathbf{k}\right). \quad \forall \mathbf{k} \in \Omega,$$

Our main finding is that a user can fix the long term average rate at values in the range $[0, \theta_1 R_1]$, regardless of the access pattern of the opponent and without any coordination with the license holder. The strategies for achieving a value $\bar{R}$ in that range have the following structure

$$\left(1 + (1 - \frac{\theta_1 R_1}{\bar{R}})b,\ 1 + (1 - \frac{R_1}{\bar{R}})b,\ b,\ b\right),$$

where

$$0 < b \leq \min\left(\frac{\bar{R}}{R_1 - \bar{R}}, 1\right).$$

Our analysis extends an approach presented in [2]. The reader is referred to [1] for details of this extension. Namely, we identify structures of 2×2 games that allow a player to control its own payoff or that of the opponent, thus implying a broader application that is not restricted to the Prisoners' Dilemma game. For such games, we identify the strategies to achieve any feasible outcome. Furthermore, we present generalizations that include games of multiple players and games where opponents are not restricted to binary action space. We study some convergence properties of the resulting strategies and study their impact on power consumption of the users.

3. REFERENCES

[1] A. Al Daoud, George Kesidis, Jörg Liebeherr. An Iterated Game of Uncoordinated Sharing of Licensed Spectrum Using Zero-Determinant Strategies. *CoRR, arXiv:1401.3373v1*, 2014.

[2] W. H. Press and F. J. Dyson. Iterated Prisoner's Dilemma contains strategies that dominate any evolutionary opponent. *Proceedings of the National Academy of Sciences* Vol. 109, No. 26, pp. 10409–10413, June 2012.

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