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A projected gradient based game theoretic approach for multi-user power control in cognitive radio network

Key words: Cognitive radio networks; Multi-user power control; Non-cooperative game; Nash Equilibrium; Projected gradient

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Motivations

1. The limited spectrum resources are wasted by the static and rigid spectrum management regimes which are currently in use. Therefore, it is important to consider possible improvement in spectrum utilization by employing latest technologies such as cognitive radio.

2. In cognitive radio networks power control research, most works only considered a single primary user or a single-channel scenario. However, the real network is usually much more complex. It is more realistic to consider multi-PU and multi-channel scenarios in cognitive radio networks.

3. Given the complex multi-PU multi-channel CR network, the corresponding power control problem becomes a more interesting and complicated problem that is not solved yet.

Main ideas

1. We formulate the multi-PU and multi-channel power control problem in CR network as a non-cooperative game with coupled constraints. The existence of Nash Equilibrium (NE) for the game is proved.

2. A projected gradient based dynamic model is proposed to find the NE of the power control game.

3. To obtain the equilibrium points of the proposed model, we derive a centralized power control algorithm based on projected gradient, which achieves the NE of the non-cooperative power control game.

Methods

1. We propose a projected gradient based dynamic model whose equilibrium points are equivalent to the NE of the original game. Thus, pursuing NE of the original game is converted to solving the equilibrium points of the dynamic model.

2. To solve the equilibrium points of the proposed model, we then devise a centralized power control algorithm based on projected gradient which is converged to the equilibrium points. A centralized gradient projection (CGP) power control algorithm is proposed.

Simulation results

1. The convergence of each SU's power strategy over each channel.

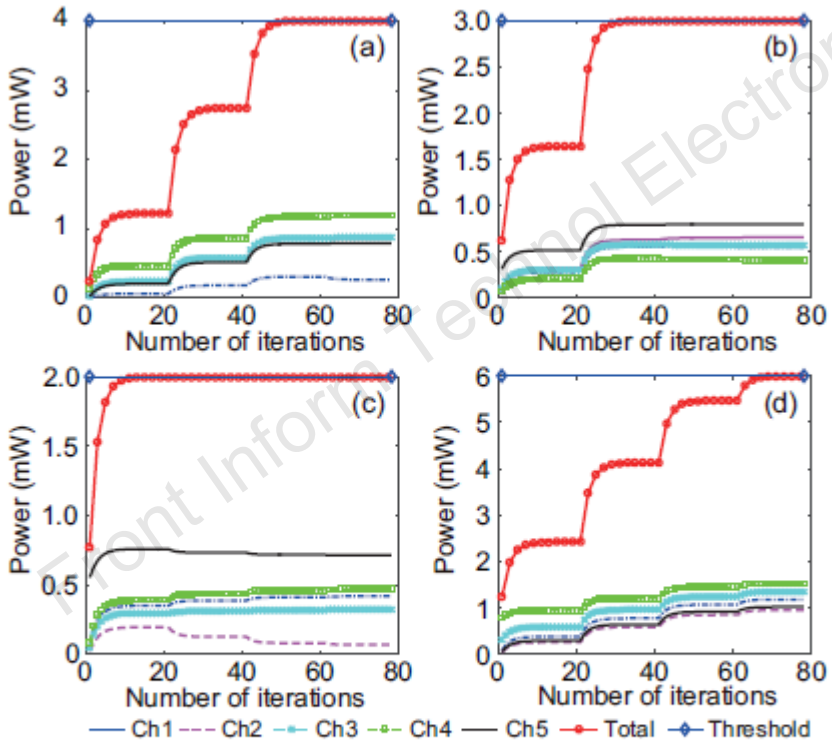

Fig. 2 Convergence of four SUs' power strategy over five channels: (a) SU1; (b) SU2; (c) SU3; (d) SU4 (SU: secondary user)

Simulation results

2. Comparison of the two algorithms (CGP and DMPA) in terms of the interference created for PUs.

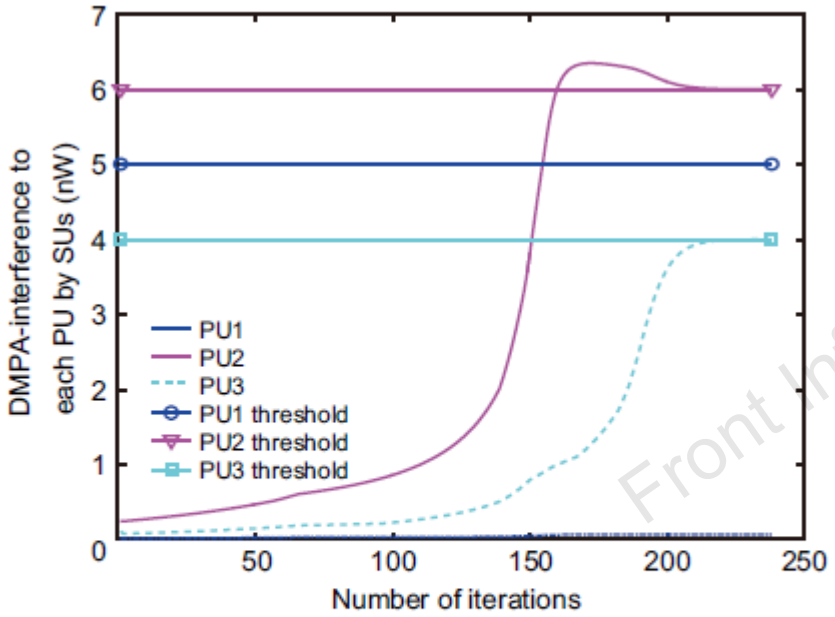

Fig. 6 DMPA convergence of interference created for PUs by SUs

DMPA: distributed multichannel power allocation; PU: primary user; SU: secondary user

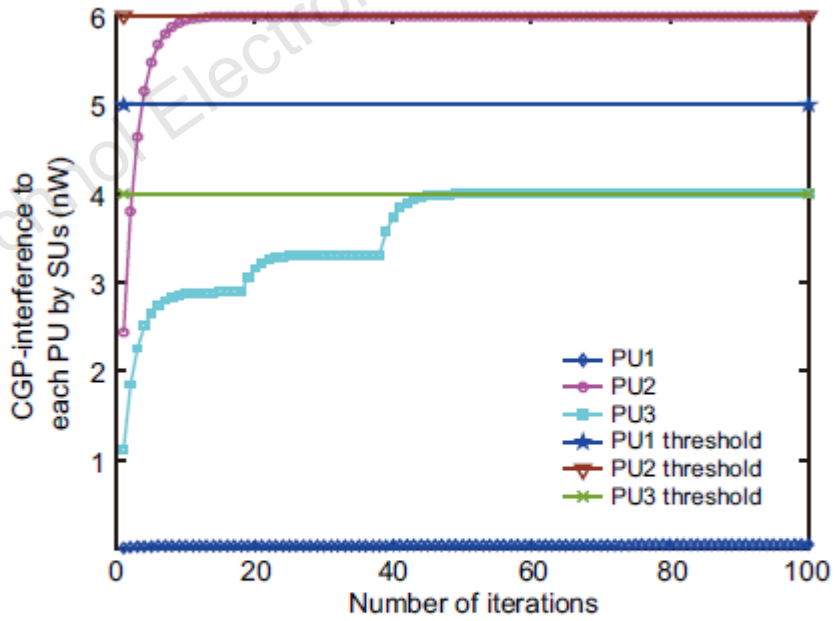

Fig. 7 CGP convergence of interference created for PUs by SUs

CGP: centralized gradient projection; PU: primary user; SU: secondary user

Simulation results

3. Complexity analysis of the CGP.

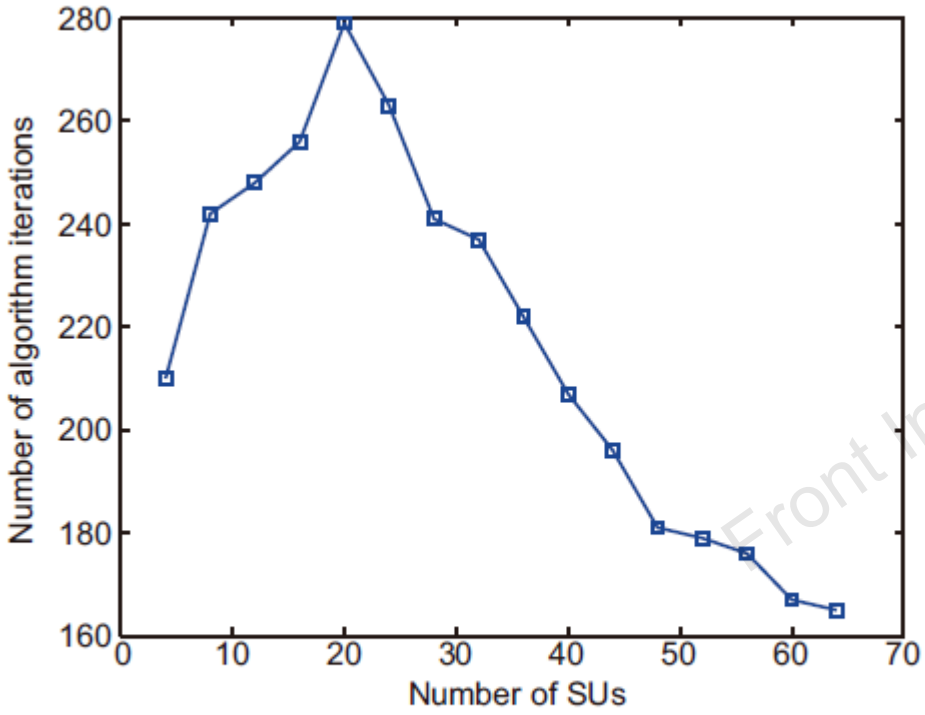

Fig. 9 Required number of iterations vs. number of SUs (SU: secondary user)

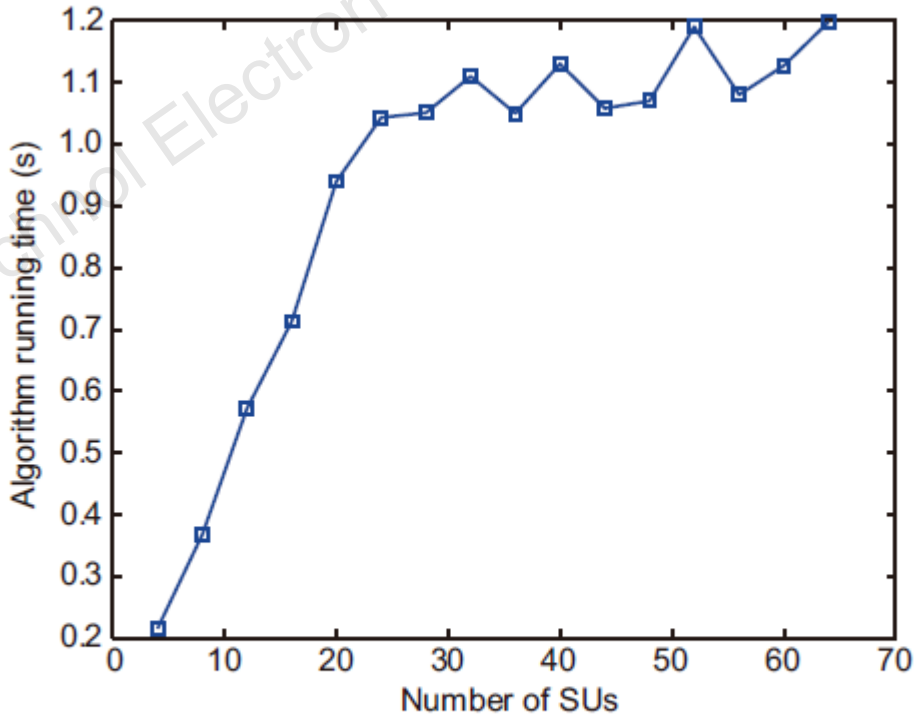

Fig. 10 Running time vs. number of SUs (SU: secondary user)

Conclusions and future work

1. We investigated the power control problem for SUs in a CR network with multi-PU and multi-channel. The problem is formulated as a non-cooperative game with coupled constraints. Due to the complexity of finding the NE of the original game, we proposed a projected gradient based dynamic model and converted the problem into finding the equilibrium points of the proposed model. A CGP algorithm is proposed to obtain the points.

2. The centralized power control scheme may not be suitable for fast time-varying channels. The effective distributed algorithm is an interesting topic. Furthermore, it is also interesting to guarantee the optimality of the proposed algorithm.