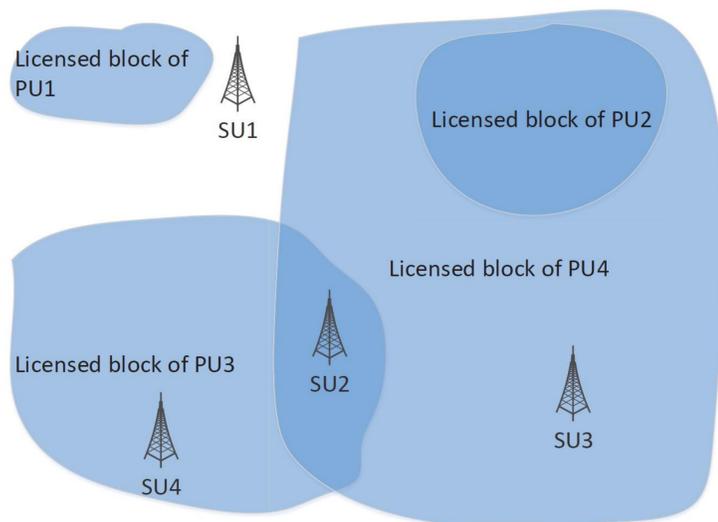


BACKGROUND

- Spectrum Sharing Using Economic Approaches
 - A hierarchical system, composed of primary users (PUs) and secondary users (SUs).
 - Idle channels of PUs can be traded as merchandise.
 - Channels of different PUs are differentiable products, providing different utilities.
- Related Work
 - Without geographical consideration, channel selection preference of each SU, channel selling preference of each PU, and channel prices of different regions cannot be handled.
- Motivation
 - We consider both the locations of SUs and the licensed blocks of PUs. By modeling the multi-price policy of the PUs and the price-elastic demand of the SUs, we want to specify the following issues.
 - ✓ Channel selling preferences of the PUs.
 - ✓ Channel selection preferences of the SUs.
 - ✓ Channel prices of the PUs in different regions.

SYSTEM MODEL



- Utility Model
 - The value assessment of a channel is price-related. Channel utility related to channel capacity and price sensitive function, i.e.,

$$U_{mn} = u_{mn} + \bar{\Xi}_{mn}$$
- Price-Elastic Demand Model
 - Our demand model is applicable to both oligopoly and monopoly markets.
 - Prevent the PUs from irrational high prices.

Problem Formulation

- We assume that each PU tries to achieve its maximum payoff. For a PU, the problem of interest is

$$\max_{\substack{(p_{m1}, \dots, p_{mN}) \\ (b_{m1}, \dots, b_{mN})}} \pi_m(p_{m1}, \dots, p_{mN}, b_{m1}, \dots, b_{mN})$$

ANALYSIS

- We design a quota transaction process, in which the PUs set the numbers of channels they would like to sell to particular SUs, or quotas.

- Channel transaction number should be under the quota, i.e.,

$$b_{mn} \leq k_{mn} \quad \sum_{n=1}^N k_{mn} = S_m$$

- Selling channels without reserve

$$\sum_{n=1}^N k_{mn} < S_m$$

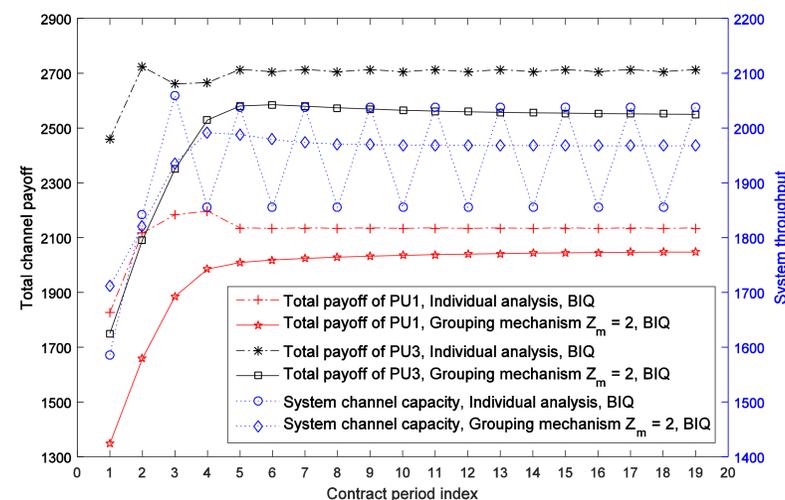
- We eliminate transaction situations that could not maximize the payoffs of the PUs.

- To sell more channels to the SUs that bring more payoff, the evolutionary procedure is defined as replicator dynamics. Specifically,

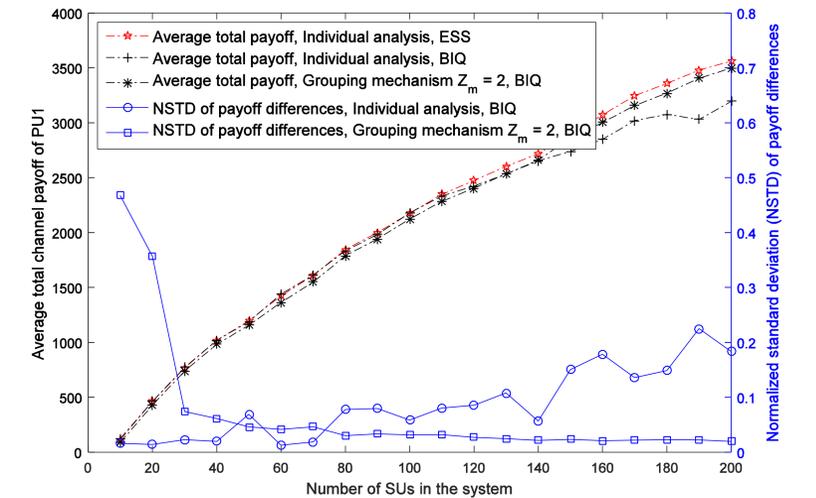
$$\Delta k_{mn}(\tau) = \mu_m [\bar{\pi}_{mn}(k_{mn}(\tau), k_{-mn}(\tau)) - \bar{\pi}_m(\mathbf{k}_m(\tau), \mathbf{k}_{-m}(\tau))] k_{mn}(\tau)$$

- We can determine a stable quota vector $\mathbf{k}_m^* = (k_{m1}^*, \dots, k_{mN}^*)$
- We prove that k_{mn}^* is asymptotically stable.

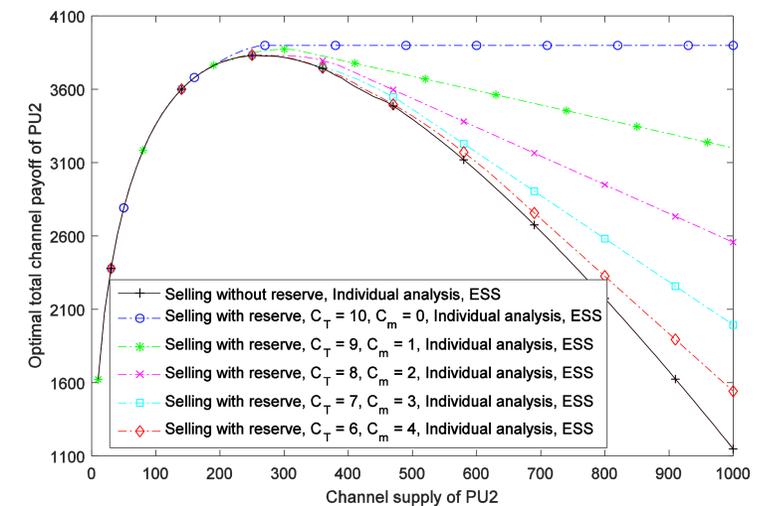
SIMULATIONS



- Total channel payoffs for selected 2 PUs and system throughput in individual analysis and grouping mechanism.



- Average total channel payoff of PU1, and normalized standard deviation (NSTD) of the payoff differences between BIQs and ESS quotas.



- Total channel payoff of PU2 when selling channels with reserve.

CONCLUSIONS

- We develop a model where geographic information, including licensed areas of PUs and locations of SUs, plays an important role in the spectrum sharing system.
- The value assessment of a channel is price-related and the demand from the SUs is price-elastic.
- We prove the existence and uniqueness of the evolutionary stable strategy quota vector of each PU, which leads to the optimal payoff for each PU selling channels without reserve.
- In the scenario of selling channels with reserve, we predict the channel prices for the PUs leading to the optimal supplies of the PUs and hence the optimal payoffs.