Preference-Based Resource Allocation for Cognitive Radio Networks

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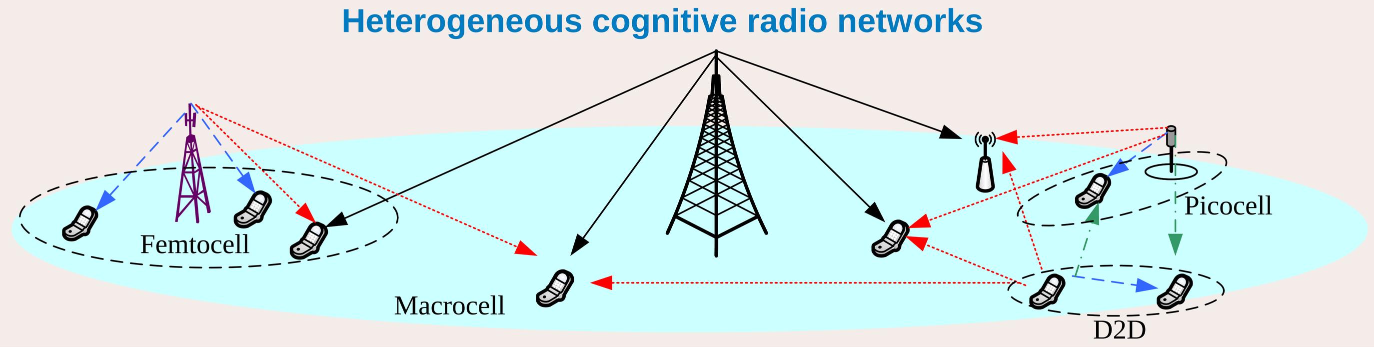
Cognitive Radio Networks

➢In current spectrum framework, most bands are exclusively allocated to some licensed users, leading to underutilization of spectrum bands.

➢To increase spectrum efficiency, **cognitive radio** technology has been proposed, where unlicensed users can use bands opportunistically without generating unacceptable interference to licensed users.

➢Practical cognitive radio networks may have heterogeneous structures, where the licensed network coexist with some small cells.

Heterogeneous cognitive radio networks



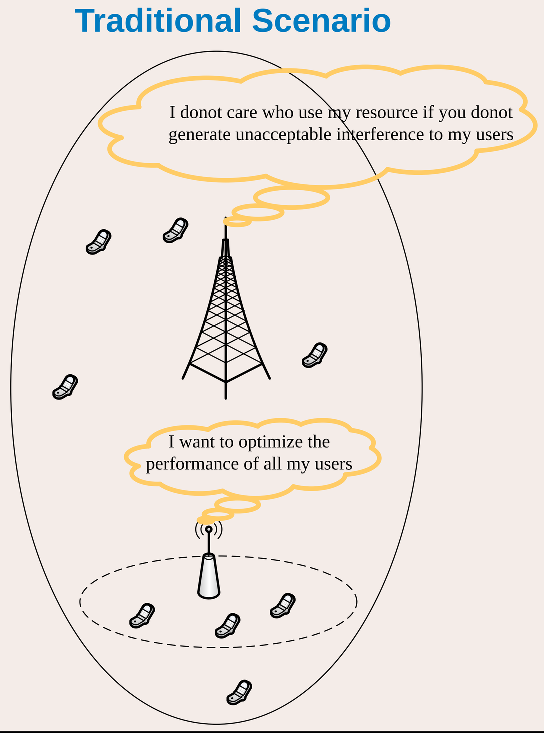
Preference-Based Resource Allocation

➢The most important issue for resource allocation in cognitive radio networks is interference control. Unlicensed users, also called as secondary users (SU), only can access the channels without generating unacceptable interference to the licensed users, also called as primary users (PUs).

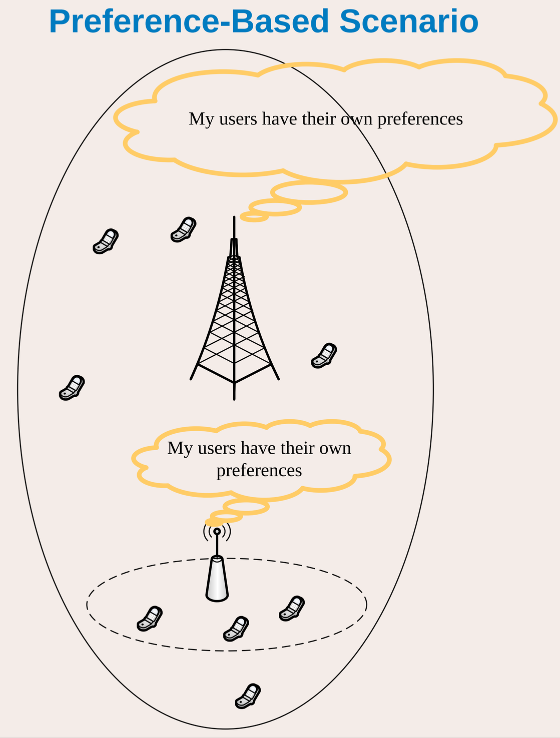
➢Resource allocation schemes traditionally aim at optimizing the performance of SUs under interference constraints at PUs.

➢We consider the design by taking both PUs and SUs preferences into account.

Traditional Scenario



Preference-Based Scenario

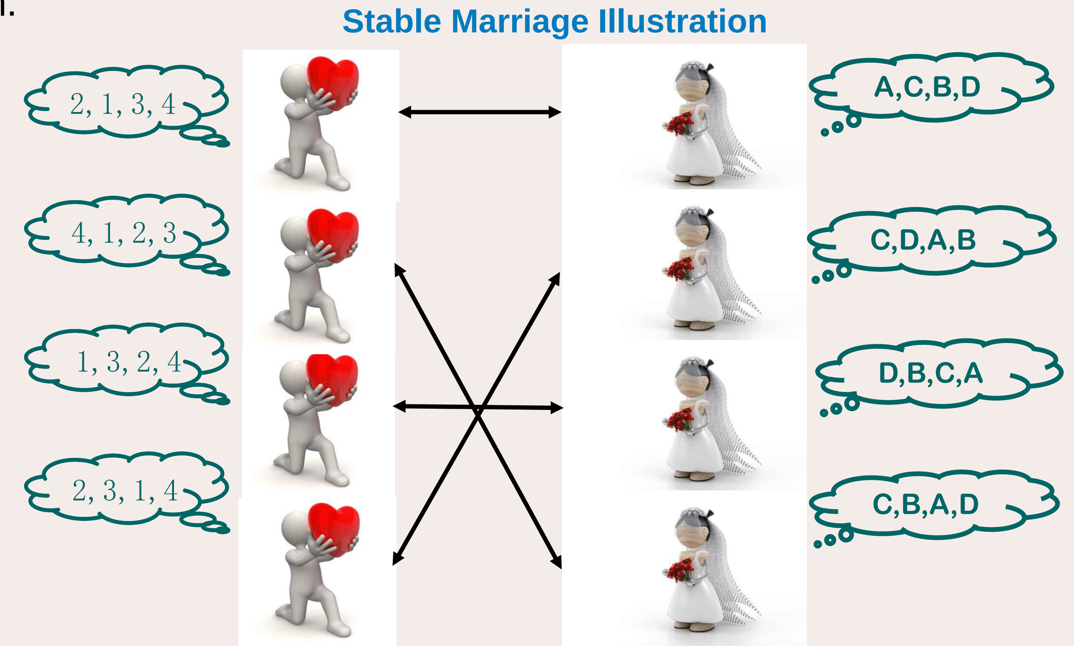


Graph-Based Stable Matching Algorithms

➢In graph theory, there is a traditional stable marriage problem, where a marriage is called stable if there does not exist a matched pair of man M and woman W such that (1) M prefers another woman over W, and (2) W also prefers some other man over M.

➢A well-known algorithm for finding stable marriage is called Gale-Shapley algorithm.

Stable Marriage Illustration



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Energy-Efficient Stable Allocation

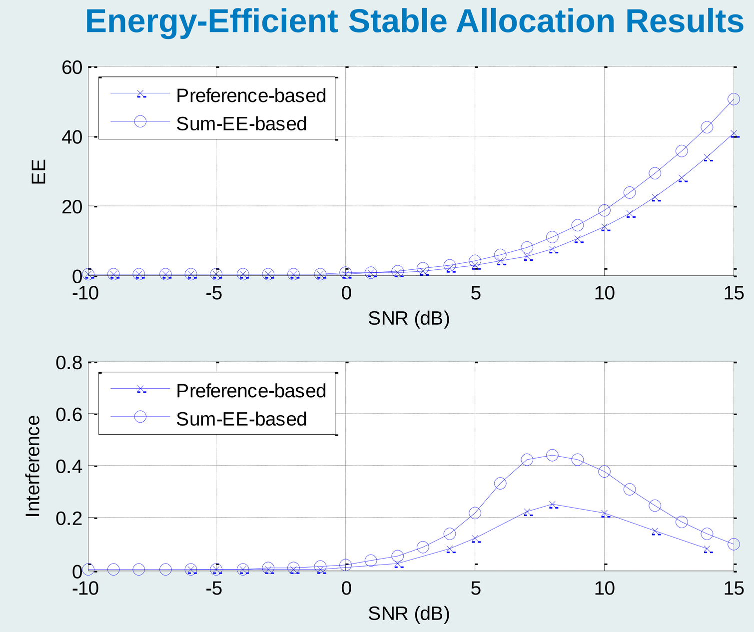
Lu Lu, Dawei He, Xingxing Yu and Geoffrey Ye Li, "**Energy-Efficient Resource Allocation for Cognitive Radio Networks**," to appear in IEEE Proc. Global Commun. Conf, Dec. 2013, Atlanta

➢Studied scenario for stable allocation: Each PU has its own channel. At most one SU is allowed at each channel.

➢PUs' preference lists are based on the interference generated by the SU they allowed. SUs' preference lists are based on its gained energy efficiency from the assigned channel.

➢Results: by taking PUs' and SUs' preference into account, the interference performance of PUs will be improved while the SUs' performance will be degraded a little bit.

Energy-Efficient Stable Allocation Results



Truncated Gale-Shapley Algorithm

➢The original Gale-Shapley algorithm is not robust that one tiny change of the network may affect the whole allocation results.

➢A truncated Gale-Shapley algorithm can improve the robustness. It stops after a certain number of rounds. The resulting matching may not stable, but "almost stability" can be guaranteed.

➢**Theorem:** Truncated Gale-Shapley algorithm can find an $(1+\varepsilon)$maximum-weight stable matching in rounds

$$\text{round} \le 2 + \frac{\Delta}{\varepsilon}$$

Maximum degree at the SU side

➢A change of the network only affect the matching in radius-(2*round) neighborhood around the point of change.

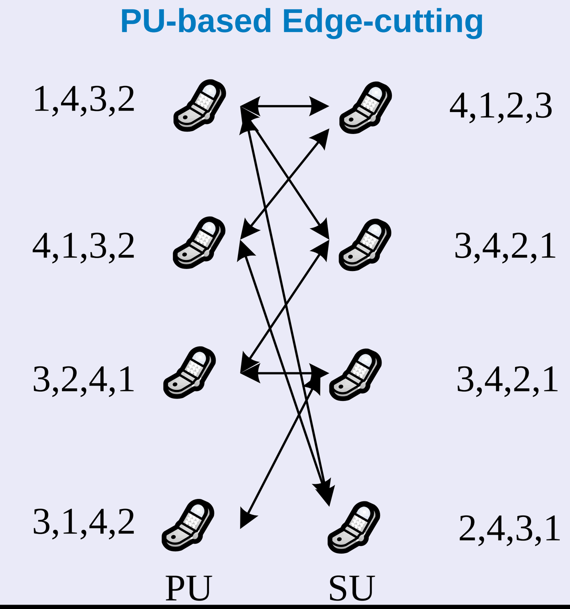
➢However, when the maximal degree is large or the required ε is small, the impact of changing one node may significant. We propose several edge-cutting algorithms to solve it.

Edge-Cutting Algorithms for Robust Design

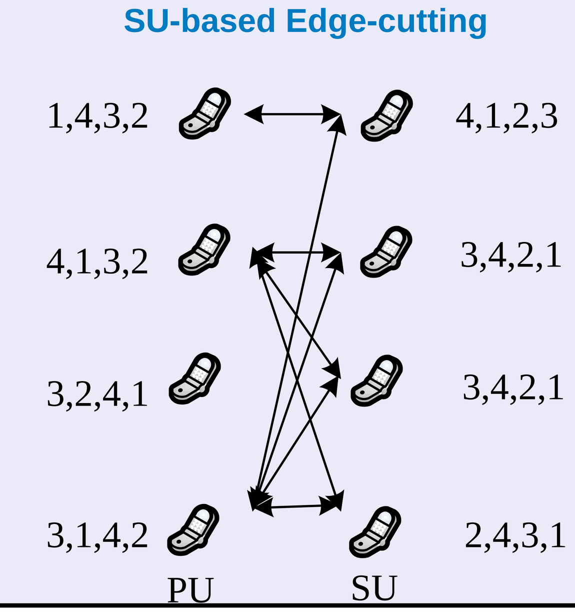
➢To design a robust system, we want to minimize the impact of a change in the network. From the proposed theorem, the maximum degrees at the SUs should be limited.

➢Edge-cutting algorithms can delete edges based on the preference of PUs' or SUs' or both PUs and SUs.

PU-based Edge-cutting



SU-based Edge-cutting



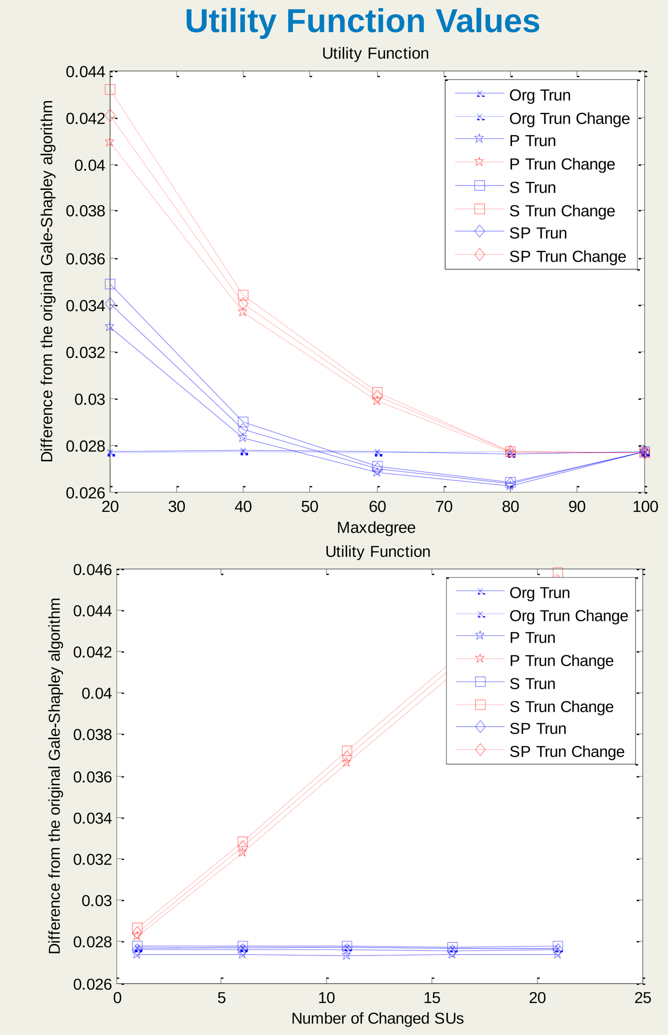
Performance Results

➢We simulate results for 100 PUs and SUs. For the truncated algorithm, when ε stable is satisfied, it stops. The utility function is the throughput of the SU can gain minus the interference generated by it.

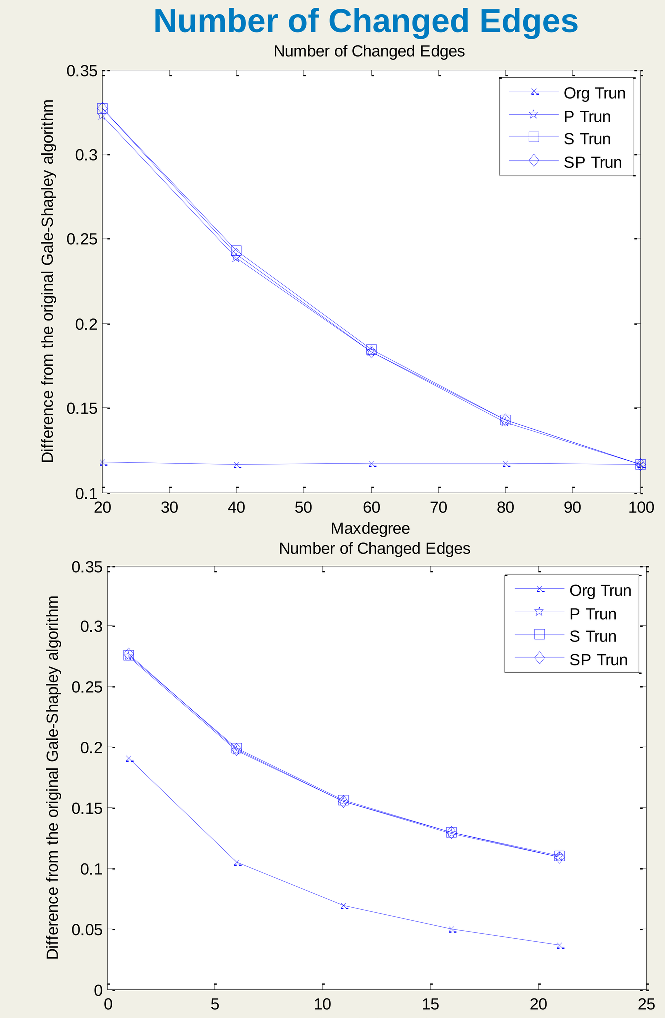
➢To test the robustness of the algorithms, we plot the change of the resource allocation results based on each algorithm by changing 5 SUs' channel conditions, including its own channels and the interference channels.

➢From our results, the results based on proposed algorithms can approach the results from the original Gale-Shapley while they are more robust to the change of the network.

Utility Function Values



Number of Changed Edges

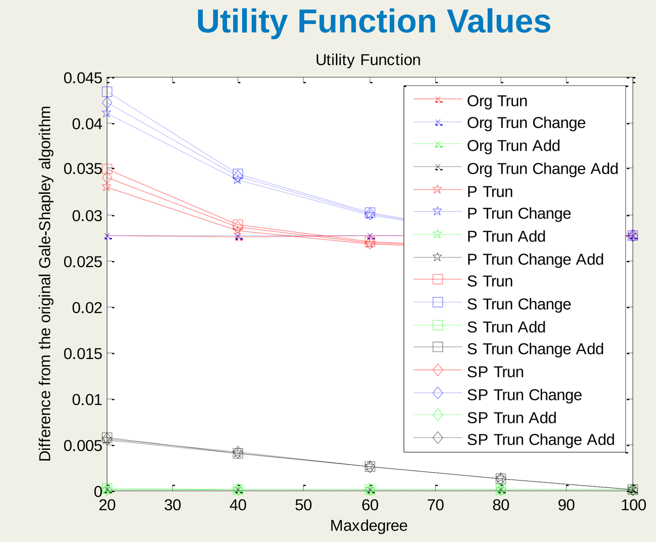


Revised Algorithms for Robust Design

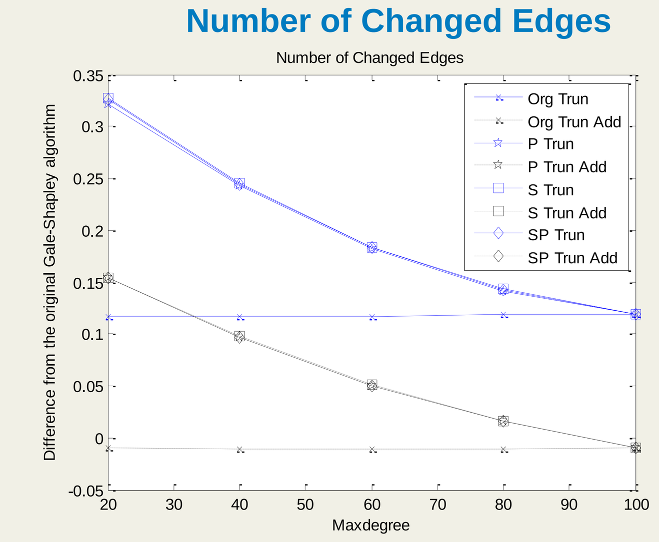
➢After edge-cutting, some SUs may cannot find suitable channels to transmit. In order to mitigate the problem, Gale-Shapley algorithm can be used again for unmatched SUs.

➢Compared to the truncated Gale-Shapley algorithm with edge-cutting, the revised algorithm reduce the utility function value gaps from the original Gale-Shapley algorithm while sacrificing some levels of robustness.

Utility Function Values



Number of Changed Edges



Conclusions

➢We study resource allocation problems in cognitive radio networks by taking both PUs and SUs preference lists into account.

➢Theoretical analysis is provided to show the performance of the truncated Gale-Shapley algorithm compared to the maximum-weight stable matching.

➢To improve the robustness of the resource allocation, edge-cutting algorithms are proposed.

➢In general, the use of graph theory can help to develop efficient algorithm in wireless communication systems. More work on it will be done in the future.