Towards Large-Scale Economic-Robust Spectrum Auctions

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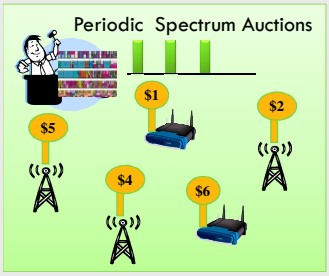
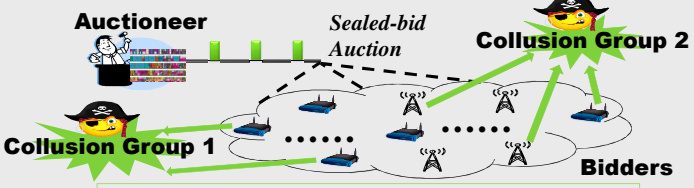
Dynamic Spectrum Auctions

- Manage spectrum efficiently via ***dynamic, on-demand*** spectrum auctions
  - -- **Auctioneer** auctions spectrum
    - Discover price on the fly
  - -- **Bidders** request spectrum
    - Match to traffic dynamics
- **Spectrum reuse** → multiple winners for one channel



Collusion is a Serious Threat in Large-Scale Spectrum Auctions

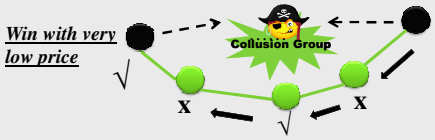


Each group only cheats if it improves its group utility

- Bidders tend to coordinate bids as a group, illegally gaining unfair advantages yet harming others
- Combating individual's cheating by truthfulness is not enough against collusion
- **Spectrum reuse opens up more vulnerabilities in spectrum auctions**
- Addressing collusion of *any* group size is hard even in conventional auctions

But, Small-Size Collusion is the Bottleneck!

- A fact observed in practical auctions[1][2] and deployed systems (2-4 players per collusion group)[3]
- Easy to form, yet hard and expensive to detect
- More effective in spectrum auctions via "Chain Effect"



[1] P. Bajari and J. Yeo, "Auction design and tacit collusion in FCC spectrum auctions," National Bureau of Economic Research, Working Paper 14441, October 2008.
[2] P. Cramton and J. Schwartz, "Collusive bidding in the FCC spectrum auctions," Papers of Peter Cramton, Dec. 2002.
[3] Q. Lian, Z. Zhang, M. Yang, B. Y. Zhao, Y. Dai, and X. Li, "An empirical study of collusion behavior in the maze P2P file-sharing system," in Proc. of ICDCS, 2007.

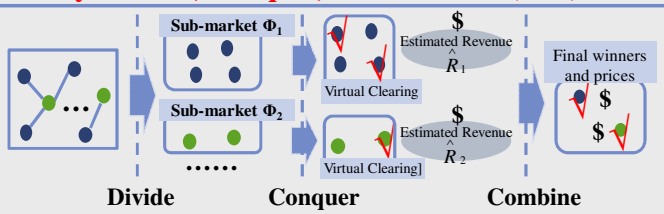
Limitations of Existing Solutions

No spectrum reuse	No revenue guarantee	Aiming for limited types of collusions	Exponential complexity

Our goal: enable spectrum reuse, address any type of collusion, w/ tractable complexity and revenue bound

Collusion-Resistant Spectrum Auctions

Integrating collusion-resistance and spectrum-reusability by "Divide, Conquer, and Combine (DC²) "



Divide: Partition bidders into *sub-markets*
- Bidders in one sub-market do not conflict with each other

Conquer: Conduct *virtual clearing* in each sub-market Φ_m
- Use collusion-resistant scheme tCP to set virtual clearing price Γ_m and mark potential winners
- Apply randomized rounding function to compute estimate revenue $\hat{R}_m$ so that $\hat{R}_m$ is insensitive to collusive bid changes

Combine: Determine final winners and prices
- Treat Φ_m as a super-bidder with bid $\hat{R}_m$, determine final winners and prices

DC² Achieves Soft Collusion-Resistance

- Ensuring **(*t*,*p*)-truthfulness** via randomization

(*t*,*p*)-truthfulness: With a probability $\geq p$, no collusion group of size $\leq t$ can improve its group utility by rigging the bids.

DC² achieves the (*t*,*p*)-truthfulness with probability $p = \log_{c_{\min}}(1 - \lambda t/(l_{\min} - t))$

Auction parameters; #of winners in the smallest sub-market

DC² Provides Revenue Bound

While satisfying the (*t*,*p*)-truthfulness, DC² with *V* sub-markets running tCP achieves a revenue $\geq R^{OPT}/(c^{\max}\alpha_{tCP})$

Sum of the optimal revenue by treating each of the *V* sub-markets separately; Auction parameters

DC² Runs in Polynomial Time to Configure

DC² takes $O(n \log(n))$ complexity for configuration

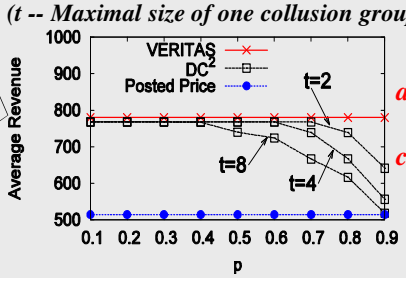
#of bidders

Tradeoff between Economic-Robustness and Revenue

- **VERITAS**: a truthful design w/o collusion resistance
- **DC²**: proposed design w/ *soft* collusion-resistance
- **Posted price**: auction design w/ *perfect* collusion-resistance

(t -- Maximal size of one collusion group)

Assume no collusion actually occurs



Allowing the auctioneer to adjust the auction's collusion-resistance level based on its preference