

Towards Large-Scale Economic-Robust Spectrum Auctions



LINK LAB

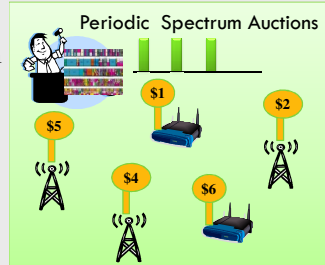
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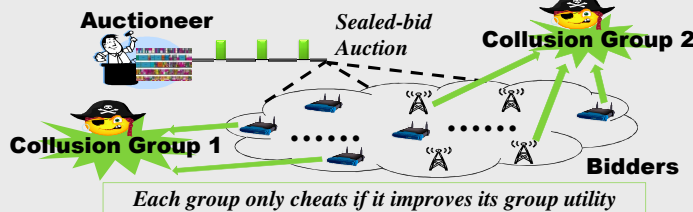
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Dynamic Spectrum Auctions

- 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



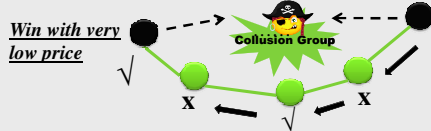
Collusion is a Serious Threat in Large-Scale Spectrum Auctions



- 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

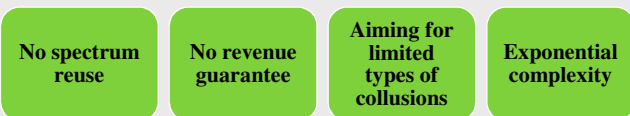
But, Small-Size Collusion is the Bottleneck!

- 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.

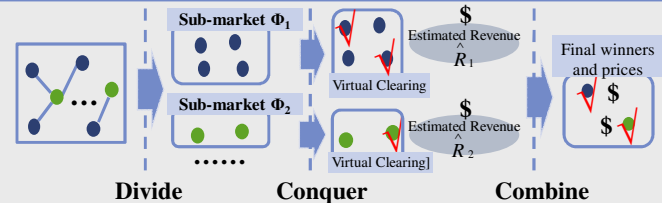
Limitations of Existing Solutions



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.

$$DC^2 \text{ achieves the } (t,p)\text{-truthfulness with probability } p = \log_{\frac{t_{\max}}{t_{\min}}} \left(\frac{1 - \beta t}{(l_{\min} - t)} \right)$$

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 $\geq R^{OPT} / (C^{\max} \alpha_{CP})$

Sum of the optimal revenue by treating each of the V sub-markets separately

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)

