Incentive Auction Design Alternatives: A Simulation Study

NEIL NEWMAN and KEVIN LEYTON-BROWN, University of British Columbia
PAUL MILGROM and ILYA SEGAL, Stanford University

ACM Reference Format:
Neil Newman, Kevin Leyton-Brown, Paul Milgrom, and Ilya Segal. 2020. Incentive Auction Design Alternatives: A Simulation Study. In *Proceedings of the 21st ACM Conference on Economics and Computation (EC '20), July 13–17, 2020, Virtual Event, Hungary*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3391403.3399499

In 2016–17 the US Federal Communications Commission (FCC) conducted an "incentive auction" to repurpose radio spectrum from broadcast television to wireless internet. The result of the auction was to remove 14 UHF-TV channels from broadcast use and sell 70 MHz of wireless internet licenses for $19.8 billion. With fewer UHF channels remaining for TV broadcast, the TV spectrum was also reorganized. Each station was either "repacked" in the leftover channels or voluntarily sold its broadcast rights, either going off the air or switching to a different band. The volunteers received a total of $10.05 billion to yield or exchange their rights and make repacking possible.

This paper uses a computational lens to revisit part of the incentive auction design: the descending clock "reverse" auction used to procure broadcast rights. We investigated the quantitative significance of various aspects of the design by running extensive simulations, leveraging a reverse auction simulator and realistic models of bidder values. Because the incentive auction design was both novel and extremely complex [1, 2], it was not possible to thoroughly consider every potential design variation before the auction was run. Our goal is to understand how well the auction design performed after the fact, particularly asking which elements of the design were most important and which variations of the design might have led to even better outcomes.

Roughly, the reverse auction worked by approaching stations one at a time with a series of decreasing price offers for their broadcast rights. When a station refused an offer, it exited the auction irrevocably and was guaranteed a spot in the leftover channels. As prices fell and more stations declined offers, the leftover channels "filled up". Before processing any station's bid, a "feasibility checker" ensured that the station could still fit in the leftover channels alongside the exited stations without causing undue interference; if it could not, that station "froze". Frozen stations were not asked to bid and their prices were not lowered. Stations that were frozen when the auction concluded were paid according to their most recently accepted offers. The auction included a provision to allow stations to exchange their broadcast rights for cash plus a channel in a less desirable (VHF) band and also a procedure to determine how many channels to repurpose, or "clear" (referred to as the auction's *clearing target*) in case the cost of clearing many channels proved to be too high. A "forward" ascending clock auction followed the reverse auction to sell licenses in the cleared spectrum to mobile carriers.

Our retrospective analysis is based on computational simulations. Our general simulation methodology involves six steps: (i) Build an auction simulator (choosing an appropriate level of abstraction,

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
EC '20, July 13–17, 2020, Virtual Event, Hungary
© 2020 Copyright held by the owner/author(s).
ACM ISBN 978-1-4503-7975-5/20/07.
https://doi.org/10.1145/3391403.3399499

as auction rules are often incredibly complex). (ii) Create a bidder model with parameters that control both valuations and behavior. (iii) Establish a probability distribution over the bidder model parameters. (iv) Draw many samples from the bidder distributions. (v) Run paired simulations holding sampled parameters fixed while varying some facet of the auction design. Lastly, (vi) compare outcomes across paired samples using predetermined metrics.

We built the simulator used in this paper; it is available online at https://github.com/newmanne/SATFC. For the bidder modeling step, we both (1) leverage a model from the empirical economics literature and (2) contribute a new model to rationalize bid data; we contrast the results obtained from both models as a robustness check. For the comparison step, we identify two key metrics to minimize when simulations clear the same amount of spectrum: the total value of the stations removed from the airwaves (value loss) and the cost paid to stations. When assessing design elements that affect the amount of spectrum cleared, we assume that clearing more spectrum is preferable, following public statements made by the FCC about the auction's goals. We then consider four questions: three concerning economic design and one concerning algorithmic design.

(1) *How much value was added by including the VHF option for broadcasters?* Adding this option substantially increased the complexity of the auction and undermined some of its desirable theoretical properties, but could have reduced the number and value of stations taken off the air and the cost of buying those stations' broadcast rights.
(2) *How much were costs reduced by offering lower prices to stations that reached smaller populations of viewers instead of just offering the same price to all and letting head-to-head competition set the prices?* The reduced price offers, called "pops scoring", were politically contentious and condemned by some opponents as price discrimination.
(3) *How was the auction's performance affected by the auctioneer's procedure for deciding the number of channels to clear, compared to what it might have been if the number of channels to be cleared were predetermined?* The actual clearing mechanism was novel and received little comment from participants.
(4) *Was auction performance significantly improved by the FCC's use of a customized feasibility checker to determine whether a station could be repacked alongside the set of stations continuing over-the-air broadcasting? How large might that effect have been?* This question is important because the design of customized feasibility checkers requires a nontrivial effort; such efforts should only be made in the future if they yield gains.

Our main findings are that repacking VHF led to significantly lower costs and potentially more efficient outcomes, that pops scoring lowered costs as intended, that the multiple stage clearing rule substantially both increased costs and reduced the efficiency of the auction, that a simple amendment to the clearing algorithm could both speed up the auction and nearly completely eliminates the multi-round inefficiency, and that the specialized feasibility checker developed for the auction significantly improved both cost and efficiency. We believe our analysis demonstrates that large-scale statistical analysis of the simulated behavior of candidate market designs in highly complex settings—requiring substantial, but not unrealistic computational resources—is a practical tool for understanding and evaluating alternative market designs.

A full version of this paper is available at https://www.cs.ubc.ca/~kevinlb/papers/2020-EC-IA.pdf.

REFERENCES

[1] Kevin Leyton-Brown, Paul Milgrom, and Ilya Segal. 2017. Economics and computer science of a radio spectrum reallocation. *Proceedings of the National Academy of Sciences* 114, 28 (2017), 7202–7209. https://doi.org/10.1073/pnas.1701997114

[2] Paul Milgrom and Ilya Segal. 2020. Clock Auctions and Radio Spectrum Reallocation. *Journal of Political Economy* 128, 1 (2020), 1–31. https://doi.org/10.1086/704074