Analyzing Package Bidding in the FCC Auction No. 31: Upper 700 MHz Band

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1 Introduction

Since 1994, the Federal Communications Commission (FCC) has conducted 43 auctions of the electromagnetic spectrum used for wireless telecommunication. All but two of the FCC spectrum auctions have been administered using a simultaneous ascending auction design (Cramton 2002), where bidders bid on similar spectrum licenses over many rounds of bidding. In each round, bidders can submit higher bids on some or all of the licenses. The auction ends when a round passes without any new bids. The auction uses pay-as-bid pricing, where winning firms pay the price of their winning bids.

In "Auction No. 31: Upper 700 MHz Band", the FCC will implement a new type of simultaneous ascending auction design that allows package bidding. Bidders will be allowed to submit bids not only for individual licenses but also for groups of licenses. In Auction No. 31, the FCC will auction off twelve different licenses, consisting of two different bandwidths (10 MHz and 20 MHz) from each of six United States regions. Under the current proposal, possible packages include: (1) both bandwidths in a particular region, (2) a nationwide package across one or the other bandwidth, or (3) a global package including all twelve licenses.

There are several strategic differences between the simultaneous ascending auction (SAA) and the simultaneous ascending auctions with package bidding (SAAPB). One main issue is the exposure problem that occurs with the SAA auction (Cramton 2002). This happens with complementary goods when bidders try to assemble their own packages, bidding higher on each license that it is worth without its complements. Another main strategic issue is the threshold problem created by the package bidding, which favors bidders seeking large aggregations of goods (Cramton 2002).

The remaining sections of this paper analyze these and other strategic factors as they relate to the FCC Auction No. 31. Sections 2 and 3 discuss the methods of data collection and provide an overview of the pertinent data, respectively. Section 4 analyzes each of the strategic factors relevant to SAA and the SAAPB auctions in detail. Section 5 concludes with some remarks about how the FCC should proceed with the auction design in light of this analysis.

2 Method

Since the auction has not yet been conducted, there exists no empirical data; the majority of the publications on this topic cover a speculative analysis of the strategic factors. This will be the first auction with package bidding implemented by the FCC.

As a result, the majority of the research for this paper comes from publications and commentary about the auction design. The sources for this paper include both theoretical publications and publications specific to the FCC Auction 31. Some of the major players in the design analysis are academics, auction design consultants, and telecommunications companies. The following section outlines some of the most relevant resources used in this paper.

3 Data

The data for this paper comes from a variety of primary and secondary sources relevant to the FCC spectrum auctions and to package bidding auction theory.

The FCC web site[1] contains the official information regarding the Auction No. 31: Upper 700 MHz Band. In addition to administrative and logistical information, the site contains substantial discussion of the strategic factors behind the switch to the SAAPB.

One of the more relevant areas of the FCC web site is the coverage of the Combinatorial Bidding Conference in May, 2000. Auction experts were invited to the conference in order to "develop and evaluate the best combinatorial auction mechanism" for Auction No. 31. Several conference papers and publications are especially pertinent to this paper.

A presentation by Paul Milgrom titled, "Selections from the FCC Combinatorial Bidding Reports and Subsequent Developments" outlines some of the strategic advantages and disadvantages of the SAAPB versus the SAA. He argues that the main advantage of the SAAPB is the elimination of the exposure problem and that the main disadvantage is the creation of opportunities for collusion and strategic manipulations of the auction.

Another presentation by John Ledyard titled, "A Brief History of Combinatorial Auction Mechanisms: Theory and Practice" reviews the history of auctions with package bidding,

[1] The Federal Communications Commission web site is located at http://wireless.fcc.gov/auctions/31/

including both theory and practice. He explores some of the main strategic issues of the auction including the exposure problem, the threshold problem, contingent bidding, etc..

A paper submitted to the FCC by Charles River Associates is also directly pertinent. The paper, "Package Bidding for Spectrum Licenses" reviews the strategic issues of the exposure problem and the demand reduction problem of simultaneous ascending auctions without package bidding.

The FCC web site also provides a link to one of the few empirical studies of ascending auctions with package bidding. In a report submitted to the FCC titled, "An Experimental Comparison of the Simultaneous Multiple Round Auction and the CRA Combinatorial Auction", a company called Cybernomics reviews an empirical comparison between the SAA and the SAAPB. They analyze issues of efficiency, revenue generation, and number of rounds.

In addition to the FCC web site, there are several other significant web resources that directly focus on the strategic features of package bidding. Spectrum Exchange Group, LLC has published a document online called, "Frequently Asked Questions about Ascending Auctions with Package Bidding?" that addresses some of the fundamental questions about how package bidding affects strategic behavior.

Also relevant is a publication authored by Lawrence Ausubel and Paul Milgrom called, "Ascending Auctions with Package Bidding". Ausubel and Milgrom's theoretical analysis of ascending auctions with package bidding is referenced extensively in this paper. Ausubel and Milgrom address the most up-to-date theories behind Vickrey auctions, SAA's, SAAPB's, and an ascending package auction with proxy bidding.

Finally, Professor Peter Cramton of the University of Maryland has provided some primary source material regarding the proxy bidding system. Several emails written by Lawrence Ausubel and Peter Cramton outline important ideas for implementing such a system[2]. These email focus on defining a structure for bidder value functions used by the ascending auction with proxy bidding.

[2] Two emails authored by Lawrence Ausubel on March 6, 2003 and March 7, 2003 discuss the proxy bidding system structure and the transition path of the auction format, respectively. Two emails authored by Peter Cramton on March 16, 2003 and March 25, 2003 also comment on the proxy bidding system structure.

4 Analysis

There are notable advantages and disadvantages of the FCC's decision to switch to the simultaneous ascending auction with package bidding. This section identifies the major strengths and weaknesses of the SAAPB and the standard SAA and evaluates each strategic issue with respect to the Auction No. 31: Upper 700 MHz Band auction.

4.1 Demand Reduction in SAA

One problem prevalent in standard simultaneous ascending auctions is demand reduction. A firm with sufficiently large demand will have an incentive to reduce demand (Ausubel and Cramton 2002), especially when items are substitutes. The intuition behind demand reduction is as follows: if a firm can lower the clearing prices across many goods by exerting market power and reducing demand, they can increase their profits by winning fewer items at lower prices than by winning many items at higher prices.

Consider the following example. Let there be two firms competing for two identical licenses. Firm A values the first license at $50 million and the second license at $40 million. Firm B only desires one license, valuing it at $30 million. In a simultaneous ascending pay-as-bid auction, the efficient outcome would be for Firm A to outbid Firm B on both licenses, winning them both at $30 million. Firm A would receive $30 million in total profits.

However, Firm A could deviate from this behavior to increase profits. Firm A would rather reduce demand to one license; as a result, both firms would win licenses and pay nothing (or pay the research price). Firm A would receive $50 million in profits, and Firm B would receive $30 million.

Introducing package bidding would allow Firm A to bid slightly above $30 million for both licenses. Firm B would have no incentive to outbid Firm A in this case. Firm A would receive $60 million in profits, making this allocation more desirable than the demand reduction allocation.

The use of standard simultaneous ascending auctions by the FCC has made their auctions vulnerable to demand reduction. By switching to an auction with package bidding, the FCC is protecting itself from the demand reduction strategy. In the FCC Auction No. 31, licenses in the same geographic region are likely to be substitute goods to some extent, as will licenses of the same band in different geographic regions.

While introducing package bidding reduces the incentive for demand reduction in the traditional sense, it can create another demand reduction problem. Firms may try to reduce demand in a "negotiation process" in order to split up the licenses evenly and obtain below market prices. This strategic issue is discussed in further detail in section 4.6.

4.2 Exposure Problem

The most notable strength of the SAAPB is the elimination of the exposure problem. The exposure problem occurs in the SAA when goods have significant synergistic value; that is, the goods are strong complements.

In the simultaneous ascending auction, firms are capable of assembling their own packages by bidding on items individually, but they run the risk of paying synergistic prices for singular goods. They "expose" themselves to the risk of not completing their package.

Consider the following example with two firms competing for two spectrum licenses. Suppose there are two identical nationwide licenses, each specified for 10 MHz bandwidth. Also suppose there are two firms, who value the licenses as follows. Firm A values a single license at $40 million; it has no value for the second license due to technological constraints of production. Firm B is free of these constraints but only values the licenses in a monopoly situation; that is, Firm B holds no value for a single license, but the combination is worth $60 million.

In the standard simultaneous ascending pay-as-bid auction, Firm B would have to bid at least $80 million to win both licenses. Otherwise, Firm A would continue to drive the price of each license to at least $40 million. This would make it impossible for Firm B to win any licenses at a profit. It is clearly inefficient for Firm A to win any licenses. The FCC would like to award Firm B both licenses for $60 million.

Also consider a scenario where Firm B begins to bid on one or more of the licenses, trying to assemble the desirable package of both licenses. When Firm B finally realizes that it cannot win both items (this will occur when the price of each license reaches $30 million), it will already be committed to purchasing a single license for some price greater than their value (which equals zero for a single license). This is an illustration of the exposure problem.

The exposure problem can be eliminated by the implementation of package bidding (Milgrom 2000). In the previous example, consider the case where Firm B were allowed to submit a bid for both licenses together. Firm A would not try to beat any package bid over $40 million. This would lead to an efficient allocation and an elimination of the exposure problem.

The FCC Auction No. 31 is an example where the exposure problem would be substantial in a standard SAA. The structure of the twelve licenses creates two types of synergies. One type of complementary value is across bandwidth. A firm may have a synergistic value of obtaining both licenses in a particular geographic region. This value might come from market advantages, technological flexibility, or previously existing licenses.

The other type of complementary value comes from geographical synergies. A firm might add value to two licenses in adjacent geographical regions. Also, firms wishing to offer nationwide service would have large synergistic value to obtaining licenses in every geographic region.

Package bidding will eliminate the exposure problem, allowing bidders to bid more aggressively (Spectrum Exchange Group, LLC 2000). Without package bidding, bidders adjust their bidding strategy to avoid the exposure problem; they bid lower to avoid the risk of obtaining only a partial package. The introduction of package bidding eliminates this risk and makes it a better strategy to be more aggressive.

For Auction No. 31, the FCC has preliminarily decided to introduce a limited amount of package bids. Since the auction consists of six regions and two bands, possible packages include both bands in one geographic region or nationwide licenses in one or both bands. While these packages will cover the most likely license synergies, the FCC will not completely eliminate the exposure problem if they do not allow unrestricted package bidding. This issue is discussed in more detail in section 4.4.

Experimental data also indicates that package bidding encourages efficient allocation. In an experimental study submitted to the FCC by Cybernomics, Inc., auctions with combinatorial bidding were "more efficient than [auctions without combinatorial bidding] in all environments, with the biggest difference coming in high synergy case" (Cybernomics, Inc. 2000). So using a simultaneous ascending auction with package bidding minimizes the exposure problem and improves efficiency.

4.3 Threshold Problem

While package bidding reduces the exposure problem, it raises a new issue called the threshold problem. The threshold problem occurs when small bidders cannot raise their bids enough to beat out a large bidder, even though the aggregate value of the small bidders may be greater than the large bidder's value.

Consider an extension of the previous example of an auction for two identical nationwide licenses at different bandwidths. Suppose there is a third bidder, called Firm C. Firm C is identical to Firm A; that is, it values one license at $40 million but has no marginal value for a second license. So this example has three firms with the following valuations:

	Winning one license	Winning both licenses
Firm A	$40 million	$0
Firm B	$0	$60 million
Firm C	$40 million	$0

The efficient outcome in this example is to award one license to Firm A and one license to Firm C. But the allocation is not efficient in a simultaneous ascending auction with package bidding. Firm B will win both licenses if they submit a package bid greater than $40 million. Neither Firm A nor Firm C will want to bid above $40 million on one or both licenses if values are privately known[3]. This is an example of the threshold problem.

The threshold problem is a relevant and significant issue with the Auction No. 31. The threshold problem tends to favor large bidders bidding on large packages. With such strong synergies in a nationwide package, it will be difficult for smaller bidders to outbid a large bidder bidding on the entire set of licenses. The threshold problem can also create an incentive for collusion among smaller bidders (see section 4.6).

The FCC originally thought that the threshold problem and the complexity issue (section 4.4) were worse than the exposure problem (Cramton 2002). However, after further research on package bidding, the FCC has decided to switch to package bidding.

[3] Note that if values are public (or made public by value discovery from the ascending bidding process), Firm A or Firm C could profitably deviate by bidding above $60 million for the package and selling one license to the other firm.

4.4 Increased Complexity with SAAPB

Another issue raised by introducing package bidding is increased complexity. Consider a simultaneous ascending auction with n distinct items. Each bidder is restricted increasing the winning bid in exactly n different ways (by bidding higher on any of the n items). However, allowing package bidding with the same number of items increases the number of possible bids exponentially. With n items, a simultaneous ascending auction with package bidding generates $(2^n - 1)$ possible packages on which to bid[4].

It is costly for bidders to evaluate such large numbers of package bids. The more packages the bidders have to consider, the more time and money they have to invest in valuing items. This may limit entry to the auction and give an advantage to large bidders.

Experimental results have also shown that allowing package bidding may make the auctions longer and thus more costly for the bidders. In the Cybernomics, Inc. experiment, the SAAPB "took about 3 times longer to finish than the [SAA]" (Cybernomics, Inc. 2000). In other words, the SAAPB took about 3 times as many rounds as the standard SAA.

In the FCC Auction No. 31, there are 12 licenses to be auctioned. This means that there would be $2^{12} - 1 = 4095$ possible package bids to consider. Therefore, the FCC has decided to limit the package bidding to 12 pre-defined packages. This will reduce the complexity and computational difficulty of the package bidding process.

Package bidding also introduces another issue. With package bidding, the provisionally winning set of bids can change drastically from round to round. A bid that might have been a losing bid in a previous round might become a winning bid in a later round (Ausubel and Milgrom 2002). This is not an issue with the SAA; once a bid becomes a losing bid, it can never become a winner. The FCC needs to decide whether or not bidders will be held to their bids if they become winners in a later round. By holding bidders accountable for their previous round bids, bidders may be less likely to bid aggressively with the fear that one of their losing bids may come back to win. One way to reduce this problem is by making bids in different rounds mutually exclusive; that is, bidders are not held to their provisionally losing bids in previous rounds.

[4] $(2^n - 1)$ is calculated by treating each item as either included in the package or not included in the package. We subtract 1 to exclude the package bid of zero items (all items are in the not included state).

So the FCC may reduce auction complexity by allowing only 12 possible packages, but they still run the risk of not entirely eliminating the exposure problem. An efficient allocation failure could result if a bidder is unable to bid on a desired package. This is the tradeoff that the FCC faces in Auction No. 31 and all of its spectrum auctions.

The FCC's decision to limit the auction to 12 possible packages is probably a good one for the first SAAPB. The limited set of packages will permit most of the benefits of package bidding allow, while reducing enormous complexity issues for the first auction of this type.

4.5 Proxy Bidding

Another strategic consideration with package bidding that the FCC is considering for spectrum auctions is whether to use a type of bidding called proxy bidding. In proxy bidding, each bidder inputs valuation information to a "proxy agent", which bids on their behalf. The proxy agents bid straightforwardly against other proxy agents to determine the optimal auction solution (Ausubel and Milgrom 2002).

In their recent publication, Lawrence Ausubel of the University of Maryland and Paul Milgrom of Stanford University examine the theoretical results behind proxy bidding in ascending auctions with package bidding. Ausubel and Migrom defend that a big advantage of the proxy system is that, given the reported preferences, the final allocation produced by the proxy system is in the core; that is, the final allocation is feasible and will not be blocked by any coalition of bidders. So under this auction design, no group of bidders will want to renege on the auction assignment (Ausubel and Milgrom 2002).

It is not clear yet if and when the FCC will incorporate proxy bidding into their auctions. Some ideas about how to implement proxy bidding have been provided by Ausubel:

> "1. A dynamic auction with single-item bids, followed by a single final round with mandatory proxy bidding.
>
> 2. A dynamic auction with a few FCC-selected packages and single-item bids, followed by a single final round with mandatory proxy bidding.
>
> 3. A dynamic auction with an expressive bidding language, followed by a single final round with mandatory proxy bidding.
>
> 4. Multiple rounds of mandatory proxy bidding." (email by Ausubel 3/7/03)

Proxy bidding is clearly more complex than any auction design used by the FCC thus far. Consequently, options (1)-(3) above are designed to make the transition process from the older auctions as smooth as possible.

Proxy bidding is an extension of the SAAPB. It is a more automated process designed to minimize strategic manipulation of the auction and provide the most optimally efficient outcome. More research and experimental studies will need to be done on this type of auction before it can be implemented as a standard in FCC spectrum auctions.

4.6 Strategic Manipulation and Collusion

One concern regarding the SAAPB is the increased opportunity for strategic manipulation and collusion in the auction. It is clear from past auctions that collusion between bidders is a threat that must be taken seriously. Cramton and Schwartz point out the evidence of such collusion in the DEF-block PCS spectrum auction (Cramton & Schwartz 2003).

Following the DEF-block auction, the FCC implemented a system to minimize collusion where bidders can only submit bid increments of whole numbers (typically 1 to 9) times the minimum bid increment (Cramton & Schwartz 2003). This change reduces the effectiveness of bid signaling as a strategy for collusion. Unfortunately, discrete bid increments still do not protect against retaliatory bidding strategies, where bidders bid against rivals who have outbid their provisionally winning licenses.

The incorporation of package bidding opens up new opportunities for bid signaling, since there are more “legal” opportunities to convey information to other bidders. Bidders can send signals to other bidders through their bids on any combination of packages, which gives them much more flexibility than the SAA. The auction is especially vulnerable in the case when all bids are transparent.

Furthermore, package bidding opens more doors for “license negotiation” among bidders. Two large bidders might submit package bids as a negotiation tactic to divide up the spectrum licenses evenly without driving up the price. This sort of demand reduction and negotiation is made easier with package bidding since there is no risk of getting stuck with unfavorable packages of licenses.

The implementation of package bidding also introduces another problematic incentive for bidders. According to Milgrom, the SAAPB "creates an incentive for strategic bidding on large packages" (Milgrom 2000). Due to the threshold problem, bidders will be more likely to bid on the nationwide and global packages since they may be able to pay below market prices for them. Bidders may also have a greater incentive for collusive bidding to collectively bid on large packages. In other words, bidders may form implicit "coalitions" that collectively determine the outcome of the auction (Spectrum Exchange Group, LLC 2000).

Strategic manipulation and collusion are legitimate concerns in the switch to package bidding. However, since the FCC has never used package bidding in spectrum auctions, there is no historical evidence that collusion will increase in the SAAPB. The only sure thing is that incentives are different under SAAPB and firms will adapt strategies to maximize profits. Whether bid signaling and collusive strategies will actually be more problematic under the SAAPB has yet to be seen.

5 Conclusion

The FCC's decision to switch to a simultaneous ascending auction with package bidding is a good one. The exposure problem is significant and needs to be mitigated; allowing package bidding is the best solution.

The major disadvantage of introducing package bidding is auctions with package bidding favor larger bidders relative to the standard ascending auction, (Spectrum Exchange Group, LLC 2000). Smaller bidders will find it difficult to outbid large package bids due to the threshold problem. As a result, the FCC may be more likely to encounter strategic bidding and collusion by both large and small bidders.

Strategies under the ascending auction with package bids have been fundamentally altered. Large bidders have an increased incentive to bid on large packages. Large bidders will be less likely to engage in demand reduction, leaving fewer opportunities for smaller bidders. Small bidders will be forced to try to coordinate with other small bidders to overcome this problem.

It would not be surprising to see the FCC Auction No. 31 result in one or two bidders winning all of the licenses. The incentive for bidding on the nationwide packages is large, and difficult to overcome by smaller bidders. Whether or not this allocation of licenses is desirable will be something that the FCC will have to evaluate.

Auction No. 31 will be the FCC's first experiment with a simultaneous ascending auction with package bidding. While theory and empirical research support the switch, the true test will be the auction in practice. The performance of the FCC Auction No. 31 will inevitably set a precedent for the future of FCC spectrum auctions.

6 References

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