FCC License Auction Design: A 12-Year Experiment

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I. Introduction

Recent policy discussions regarding broadband Internet access have revived debates about various methods for allocating electromagnetic spectrum rights and the appropriateness of spectrum auctions (Telecomm. Rep. 2007). Debates over the assignment of spectrum rights via auction are hardly new (e.g. Herzel 1951; Coase 1959). Economists have long argued that auctions would promote efficiency in various ways, including the reduction of rent seeking and the avoidance of transaction costs used to reassign licenses in secondary markets (Kwerel & Felker 1985). Still, auctions have attracted vigorous opposition from defenders of traditional "public interest" licensing, who have argued that competitive bidding was not even feasible,[1] and that it would undermine the government's ability to regulate broadcasters. When this market-oriented approach was actually implemented in the United States in the early 1990s, these debates ceased being purely theoretical. Twelve years of actual experience with spectrum auctions now allow us to look back and assess what lessons can be learned from the adoption of this approach.

This short article provides a glimpse at the auction process's evolution, from its initial design to the rules governing the Advanced

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[1] Among those who argued that it was not feasible, is a former FCC Chief Economist, Dallas Smythe (1952).

Wireless Services (AWS) auction held from August 9, 2006 to September 18, 2006. It also provides observations about the strengths and weaknesses of various auction designs, and it proposes ways to improve future auctions. Section II briefly describes the political environment that lead to the first electromagnetic spectrum auction in 1994 and the nature of the rights that are auctioned. Section III explains the basic auction design that the Federal Communications Commission (FCC) adopted, while sections IV and V discuss the rules that were implemented to accommodate that initial design and the bidding strategies that arose to take advantage of those rules. Sections VI and VII describe the rules FCC adopted for later auctions in order to put boundaries around that strategic behavior. Section VIII concludes with observations about the shortcomings of FCC's chosen auction design, and it proposes an alternative design that should lead to more efficient use of the electromagnetic spectrum.

II. Background

From the 1927 Radio Act until the mid-1980s, "comparative hearings" (distributing transmission rights by political fiat) constituted the sole license assignment method (Hazlett 1998). In 1981, federal legislation authorized the FCC to use lotteries for spectrum allocation – a compromise that stopped short of auctions. However, the lotteries, which the FCC used to assign hundreds of cellular licenses starting in 1984, made visible what had previously been hidden: Failure to employ competitive bidding left billions of dollars of potential revenue on the table. Consequently, economists, who promoted auctions for efficiency reasons, had their advice bolstered by political demands to capture additional revenues.

Political realignment in the 1992 elections gave the Democratic Party control of the executive branch and both houses of Congress. This change in presidential administrations was accompanied by a fresh outlook, and the shared party affiliation allowed new accommodations to be reached between Congress and the White House that enabled the FCC to begin selling licenses to high bidders. The actual reform was included within the federal Omnibus Budget Reconciliation Act passed in the summer of 1993. The Commission was given one year to initiate auctions, and auctions did indeed begin, as mandated, in July 1994.

Before discussing auction design issues, however, a word should be said about the rights that are to be auctioned. The licenses awarded in spectrum auctions do not grant full property rights to a certain spectrum frequency. Rather, they give purchasers only those use or access rights that are defined in the license. For example, the 1993 legislation specifically authorized the award of bandwidth licenses for use by Personal Communications Service (PCS) networks – which include such items as mobile telephones, personal digital assistants, and similar devices. Thus, because the auctions were for licenses, and not broader rights to the spectrum frequency, they defined one, and only one, use to which the specified bandwidth could be put. However, the best use, in terms of highest value, for any spectrum frequency will always be subject to changing technology and economics. In a dynamic world, it is unwise to build in constraints on how any resource may be used; otherwise, today's efficient allocation may quickly become obsolete.

Consider another example. Digitalizing analog frequencies can greatly increase information transmittal capacity, but early allocations of certain spectrum bands to defined analog transmission – such as television – have locked that bandwidth into a comparatively low value use. Thus, television stations (channels 50 to 100) that were originally awarded rights in the 900 MHZ band have an asset that would be more valuable if digitalized and assigned to other uses. This is an argument for allowing previous winners at auction to enter new FCC auctions as sellers in a two-sided exchange. Doing so would allow any earlier property rights to be reassigned to higher value uses when technological innovations expand the ways in which the bandwidth can be used.

III. **Basic Auction Design**

Use of auctions was authorized by the federal budget statute enacted in 1993. However, the statute did not specify what form the auctions should take, so scholars and policymakers quickly began an investigation to resolve this issue. In the summer of 1993, a conference was held at the California Institute of Technology at which the merits of various proposals were discussed and demonstrated. Most of the main contributors to the academic auction literature attended the conference, and participants discussed three potential auction forms.

Participants first considered an initial proposal for a sequential auction in which licenses would be auctioned one-by-one, using either an English

auction[2] format or a first-price sealed-bid[3] process.[4] This structure appeared easy to conduct and implement, but it had important shortcomings. Most of the license areas that would be auctioned were small relative to the area needed for efficient scale of operations, exactly the situation that obtained in mobile phone services. It is typical in PCS license auctions to have hundreds of non-overlapping franchise areas for blocks of spectrum with potential bidders having strong economies (in both consumption and supply) generated by regional or national networks. Sequential auctioning would not allow for the assembly of many interrelated (complementary or substitute) area licenses that could make most efficient use of the spectrum. It would be akin to trying to solve a general equilibrium pricing problem one market at a time.

A second auction format proposal suggested that large groups of licenses be auctioned simultaneously, so that bidders could see all of the prices forming and move their bids accordingly. This would at least acknowledge the area assembly problem posed by a sequential auction format, but it too fails to maximize auctioning's full potential. Because

[2] In an English auction, bids are taken in real time, each successively higher, until only one bidder remains. The price paid is the last price bid.

[3] In a first-price sealed-bid auction, bidders submit the price they are willing to pay. The highest bidder wins, paying the price offered.

[4] There was also a discussion on the use of Vickrey, or second price, auctions. However, it was noted that these auctions have poor political appeal because they leave the impression that money has been left on the table. Thus if the highest sealed bid is $2 million and the second highest is $1 million the high bidder wins the item and pays $1 million leaving the superficial appearance that a million dollars was foregone by the seller. If, however, these were indeed the maximum amounts that the two highest bidders were willing to pay, then in the English progressive auction the bidding would have stopped the moment the most eager buyer raised the bid to $1million because the second most eager bidder would have declined to raise the bid. It follows that no one would have known that the winner of the auction was willing to go as high as $2 million. The second price rule was actually used in the New Zealand spectrum auctions in part because it was supported—in fact recommended—by auction theory and theorists as the favored rule in sealed bid auctions. Hence, this first meeting of theorists at Caltech was informed by earlier experience based on what had been thought to be a straight forward application of (private values) auction theory. This, in microcosm, is the first in the long sequence of reappraisals of the state of understanding of auction theory, based on experience, as it has been applied to the auctioning of spectrum rights.

participants must bid on licenses without knowing whether they will also be able to acquire complementary licenses, they are likely to enter lower bids for any given license than they would be willing to enter if they could be assured of assembling a larger, contiguous license area.

Finally, there was a call to accomplish area assembly more directly in the auction process itself, by allowing a more integrated auction form in which bids could be placed in packages with various restrictions – what are known as combinatorial auctions.[5] The need for this type of auction arose because bidders argued that grouping licenses together into packages (to create regional networks) would be worth more than the sum of licenses bid a la carte.[6] When such possibilities arise, auctions that do not take into account these complementaries can result in financial losses to bidders (see Cull et al. 2000; Banks et al. 2002). However, combinatorial auctions have been thought to face difficult computational issues, sometimes referred to as the 2^N bogyman or NP-completeness.[7] Critics have also argued that combinatorial auctions would make it more difficult for new entrants to

[5] Combinatorial auctions were first invented by Rassenti, see Stephen Rassenti, 0-1 Problems with Multiple Resource Constraints: Algorithms and Applications (1981) (PhD. thesis, on file with Univ. of Arizona), and subsequently published in Rassenti et al., *A Combinational Auction Mechanism for Airport Time Slot Allocation*, 13 BELL J. OF ECON. 402 (1982). For more information on these types of auction see CRAMTON ET AL., COMBINATORIAL AUCTIONS (2006).

[6] For example, bidder's valuation for one license in a market might depend on "who" will be the winner of the licenses in neighboring markets. A bidder might care what type of service its neighbor provides if roaming agreements are required. For PCS, there are three competing technologies: Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), and Global System of Mobile Communications (GSM). Thus, bids conditional on which technology would be implemented in adjacent areas would be an important means by which all such information could be incorporated into the set of submitted bids, and taken into account in the awards. Failure to do this carried the potential of leaving lots of unrealized gains from exchange on the table, and creating financial uncertainty for the bidders.

[7] If there are bids for combinations of items and there are *N* items, then to completely enumerate all of the possible combinations (if there were bids submitted for all possible packages) then the computations grow exponentially but computational resources do not. Specifically, computationally easy problems can be solved by computer algorithms that run in polynomial time; *i.e.,* for a problem of size *N*, the time or number of steps needed to find the solution is a polynomial function of *N*. Algorithms for solving such difficult problems require times that are exponential functions (Non-Polynomial (NP) time) of size *N*.

compete in auctions with incumbents, which we address in Section VIII below.

Erring on the side of conservatism, and without benefit of any laboratory testing in this early phase, the FCC decided to implement the second proposal, a simultaneous auction informed by what economists had learned from auction theory applied to simpler environments. The auction form FCC used is typically called the Simultaneous Multi-Round (SMR) Auction or the Simultaneous Ascending Auction (SAA) (see Milgrom 2000). However, one needs more than a name to implement an auction; specific rules are required.

While various types of wireless licenses would be auctioned, the initial interest was dominated by the assignment of PCS licenses.[8] These would enable additional competition in the mobile phone market, then structured as a duopoly with each U.S. market having two licenses allocated 25 MHz of bandwidth (50 MHz total). The FCC had allocated another 120 MHz for use by mobile carriers, with the bandwidth spread across six new license types (three allotted 30 MHz, three allotted 10 MHz). The country was divided into 51 non-overlapping license areas for two of the 30 MHz license types (PCS A and PCS B), and into 493 markets for the other four license types (C, D, E, and F). Hence, there were some 2,074 total licenses ([2*51] + [4*493]) to assign by auction.[9] This highly disaggregated

[8] While the FCC was required to begin holding auctions by the end of July 1994 – and met that deadline with its auction for Interactive Video Data Service (IVDS) licenses – the first PCS auctions (PCS A and PCS B) did not begin until December 1994, concluding March 1995.

[9] The FCC actually pulled three licenses out of the PCS A and B license auction, awarding them to companies the Commission determined had made notable contributions to advancing PCS technology. This was under the "pioneers' preference" policy, later discontinued. The three awardees were charged

licensing scheme stands in stark contrast to global markets, where the great majority of countries award nationwide licenses for mobile telephony. It adds complexity to the bidding process, as mobile operators attempt to construct regional or national networks by winning multiple licenses.[10]

IV. **Specific Auction Rules**

In order to implement its chosen auction scheme, the FCC had to make many decisions about rules that would govern the auctioning itself. The general structure of the SAA auction is that participants submit a series of single-item, sealed bids for desired licenses. Following the submission of such bids, the high bids for each license are posted. These high bids then become the standing bids for the next round of bidding. Still, this basic design left many questions unresolved. For example, how long should a round last? Since the auctions were allocating highly valuable assets, some suggested that each round should be an entire day long, so that bidders would have plenty of time to digest the information from the auction and make intelligent bids.[11] Whatever the length, rounds should be long enough for firms and their consultants to peruse the data from each round in order to make informed bids.[12]

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license fees that were based on a formula using the winning bids paid for other licenses and that incorporated a discount for the pioneers' preference.

[10] Of course, networks can be (and are) pieced together via roaming agreements, such that it is not necessary for a single entity to own each license. Yet roaming agreements are not perfect substitutes for ownership, as seen in U.S. wireless networks where operators have made pointed efforts to aggregate licenses.

[11] The FCC did however, use an open out-cry auction for the IVDS auction in 1994.

[12] It should be noted that many of the participants in the design of the FCC auction rules were also at some point consultants to bidders in the actual auctions. The FCC auctions have created a cottage industry for consulting firms in assisting bidders through the myriad rules and strategies in the SAA. Critics have remarked that this is akin to a new "Military-Industrial complex" – call it the "FCC-Consultant complex." Many of the consultants argue, on the other hand, that much of their billing time was spent familiarizing the bidders with the complexities of the rules.

On the other hand, some observers believed that a set of rules to help speed-up the auction and allow for flexibility of the bidders was required. In particular, the FCC and its advisors were worried that participants would not bid on the cadre of licenses in which they were interested, but would hold back and wait to see what others were bidding on to gain an informational advantage. To discourage this type of strategy, a set of rules was designed to force the pace of the auction. First, for a bid to be *acceptable* in any round, it had to be greater, by a pre-specified *increment*, than the standing bid for that license. The FCC had to determine the increment size (this was listed in percentage amounts over the standing bid) and had the right to change the size of the increment during the auction for any license. Obviously, changing the amount of the increment can affect the speed of the auction and its allocative efficiency.

Second, the FCC introduced an *eligibility* requirement for bidding after the first round. Each license was assigned a numerical value in terms of *activity units*. This number is typically derived from the MHz and population (referred as MHz-Pops) associated with the license territory. For example, if a license consisted of 20 MHz of spectrum and within the boundary of that license there were one million people, the license would be assigned 20 million activity units. At the beginning of a bidding round, a participant would be eligible to bid only on a number of activity units that was related to the number of activity units on which he bid in prior rounds. The exact amount of a participant's *free eligibility* was equal to (1) the sum of the activity units of licenses for which he submitted acceptable bids in the previous round and for which that participant did not have the standing bid,

plus (2) the sum of the activity units of licenses for which the participant had the standing bid two rounds previous, but no longer has the standing bid. Given this total eligibility budget, a participant is then constrained to bid on licenses for which he has the standing bid and additional licenses whose sum of activity units is less than his free eligibility.[13] Thus, if a bidder is interested in obtaining a license or set of licenses totaling 20 million activity units, he must actively bid on licenses totaling that level of activity or he will not be able to obtain that license set at the end of the auction. This rule obviously forces bidders not to lay in wait.

Given that the activity rules push the pace of the auction, the FCC created several rules to provide flexibility to bidders. First, eligibility for all participants would be adjusted within each round by the FCC's choice of a numerical activity rule factor to apply in each auction *stage*. The auction begins in stage one, and a factor $0 < \alpha_1 < 1$ is selected, so that if a bidder has X amount of current eligibility he is required to bid on licenses totaling only $X \cdot \alpha_1$ of activity units to maintain X. Thus, if the stage factor is .8 and a participant bids on licenses totaling 16 million activity units, then his eligibility for the next round can be as high as 20 million units. As the auction proceeds, the FCC has the right to move the auction to different stages with $0 < \alpha_1 < \alpha_2 < \ldots < 1$.

The FCC also created a limited number of *waivers* for each bidder, each of which allowed a bidder to advance to the next bidding round at his current level of bidding eligibility without bidding in the current round. This

[13] This sounds complicated, and it is. Consulting firms and the FCC have created special software programs to assist bidders in tracking and managing their eligibility.

rule was implemented to provide bidders flexibility to respond to either a computer hardware or software problem or an unexpected need to consult on bidding or financing matters with senior management or paid advisors. For example, a bidder could use one of his waivers to sit out a round while he sought additional budget authority.

Because a bidder may value a combination of licenses more than the sum value of the individual licenses alone, there is a possibility of a "failed aggregation." To provide flexibility to bidders for this possibility, bids on provisionally winning licenses at the beginning of a round could be *withdrawn*. After a withdrawal, the FCC becomes the standing bidder for the withdrawn license and replaces the bid with one that is less than or equal to the withdrawn bid (typically the previous high bid for the license). An individual who withdraws a bid pays a *penalty* equal to the greater of zero or the difference between the amount of the bid he withdrew and the highest bid submitted by a participant other than the FCC after his withdrawal.[14] Thus, a bidder desiring both license X and Y may decide to withdraw a standing bid on X because he no longer wants to stay in the bidding for Y (and X), and vice versa. Of course, in a combinatorial auction, the bidder will only send a bid message for X and Y together, and he will not bid on X or Y separately unless he is also willing to buy X or Y without its complement. Unfortunately, the FCC rejected the combinatorial auction design.

[14] Because a standing bid on a license may be withdrawn multiple times, the highest bid after a withdrawal need not be the final bid on a license.

An auction would come to a close when all bidders have no free eligibility remaining – that is, when the amount of their eligibility is equal to the amount of their standing bids. Licenses are awarded to the participants with the standing bids, and any withdrawal penalties are computed and paid at that time. However, to ensure that participants are committed to paying for the licenses on which they bid – or, as the FCC puts it, to "help deter frivolous or insincere bidding" – an upfront payment deposit must be placed with the FCC in order to be qualified to bid in the auction. The size of the upfront payment determines a bidder's initial activity unit budget. The larger the upfront payment made, the larger the initial eligibility of the bidder. At the end of the auction, the upfront deposit is returned if the bidder does not win any licenses. If a winner of a license fails to pay for any of the licenses on which he placed the standing bids at the end of the auction, he forfeits his upfront deposit.

In addition to the rules listed above, the FCC provides all information (including bidder identities, bids, eligibility amounts, etc.) to all participants during every round. The full information rule was justified for two reasons. First, the FCC believed full transparency was necessary because it was allocating rights to what is considered a public good. Second, because spectrum licenses have important common and affiliated value, knowing what others have bid can increase auction revenue. The hypothesis here is that, if some bidders are better informed about values, an open auction can allow this information to be revealed and reflected in the bidding; other

bidders would update their value assessments and, thus, what they would bid.[15]

Every rule in the above list was implemented based on intuitions from the theory of auctions for allocating a single unit, however. At no time were these rules tested in a scientific manner, and the problem was far too complex to admit of formal modeling. Nevertheless, armed with this set of rules, the FCC began its experimental journey.

V. **Strategic Use of the Rules**

After several auctions, a variety of bidding strategies started to arise (see Cramton and Schwartz (2000) for a detailed list of some of these strategies). New terminology was created to describe these emergent behaviors.

1. *Jump Bidding*: Bidding above the prescribed minimum increment to stay active. The use of jump bidding has been associated with a strategy to signal strength to "scare" away bidders from a license. It is also associated with an attempt to secure a license for which the bidder may not have the highest value, but, because of the size

[15] Since the full information characteristics of the auction force revelation of value by the better-informed bidders, this undermines the original incentive to invest in acquiring information. To the extent, then, that there is under-investment in information that is not firm specific, this feature diminishes the importance of common values as an assumed feature of the auction environment, i.e., the form of the auction provides disincentives to invest in acquiring the information whose postulated existence is what justifies the form of the auction.

of the bid increment, the highest valued bidder would lose if he tried to bid after the jump.[16]

2. *Up Yourself*: Increasing one's bid despite being the standing bidder on a license. Ordinarily, this is viewed as a patently irrational action in auction theory, but, in FCC license auctions, it has been associated with the same signaling strategies as those associated with jump bidding.

3. *Retaliatory Bids*: Placing bids on the licenses bid upon by rivals to force them not to bid on the licenses the bidder desires. For example, if a bidder is interested in license A and another bidder is interested in licenses A and B, the first bidder can drive up the price of B, signaling that the second bidder should cease bidding on A.

4. *Parking*: Bidding on a license one does not want, but which is in high demand (many bids on the license), in order to stay active without revealing interest in the licenses the bidder does want. This allows a bidder to not drive up the price on an item he wants and still maintain eligibility, a tactic intended to mislead other bidders.

5. *Eligibility Management*: Bidding on a license that has a higher eligibility point total to have the option value to return to it if bids change later in the auction.[17]

6. *Lateral Hand-Off*: Bidding on a license, then withdrawing and bidding at a lower level, in order to signal that a bidder is not

[16] Jump bidding is also used to ensure that one's bid is not tied, in which case, one of the tied bids is randomly selected to be the provisionally winning bid, and the others are discarded.

[17] Banks et al., *Theory, Experiment and the Federal Communications Commission Spectrum Auctions*, 51 J. OF ECON. BEHAVIOR & ORG. 303 (2001), shows that the asymmetric eligibility points on licenses can have a significant effect on revenue obtained in the auction.

interested in the license, but will punish bidders on other licenses in which the bidder is interested.

7. *Bid and Waive*: Combining jump bidding on a license with the use of a valuable waiver in order to signal a strong desire for a license and ensure that other bidders "get the message." In each round of the auction, bidders tend to examine four important statistics on each bidder because of their costliness: reduced eligibility, jump bids, withdrawals, and waivers.

8. *Trailing Digits*: Attaching market numbers in the last three digits of a bid to tell another bidder where it would be punished if it continued its bidding on a certain license, or on which license the rival should back off if it wants to avoid further punishment.[18]

9. *Budget Bluffing*: Bidding above one's budget to fool rivals into believing the budget is larger than it is. Each bidding team is typically provided a budget from its corporate management to use in the auction. Bidders normally track the *bid exposure* for other bidders in every round (the sum of the other bidders' previous round provisionally winning bids plus new round provisionally winning bids plus non-winning new bids in a round), because the maximum of any participant's bid exposure during the auction provides some insight into that competitor's potential budget. With this in mind, a bidder could bid above his budget, knowing that he will likely be outbid on some licenses, thus sending a false signal about his budget.

[18] Market numbers are two or three digits, and bids are typically six figures or more. So, a bid could contain, at negligible cost, the market number as its last few digits, prefaced by leading zeroes to make the trailing digits stand out.

The behaviors observed in these auctions may have been surprising to the FCC and some economists, but they had been observed many times in laboratory experiments. McCabe et al (1988) found jump bidding behavior in their attempts to test Vickrey's proposal to use English auctions for multiple units. They found that allowing bidders to announce bid prices from the floor is not a good design feature in multiple unit auction environments – a problem that does not arise in simple, single-unit auctions. This may explain why one does not typically observe the simultaneous auctioning of multiple units in other fields. Rather, what typically occurs is a market, such as the Australian wool markets, in which multiple units are auctioned sequentially, one lot at a time.

Using clocks that move price based on bidder demands eliminates jump bidding and is more effective in yielding efficient outcomes.[19] Porter (1999) found that the ability to withdraw bids leads to worse outcomes due to a false security from "getting out" and to retaliatory bidding. Experimentalists have long known that, as one adds more information to the auction results, outcomes can, counterintuitively, get worse because the ability to signal becomes greater. Sometimes less information yields more efficient awards. In addition, adding more rules to fix or fine-tune a process tends to create a new series of unanticipated problems. As noted in the introduction by Smith in Cramton, Shoham and Steinberg (2006):

[19] In a single-unit English auction with strictly private (or strictly common) value, jump bidding cannot lead to an inefficient allocation since the award must be to the highest value bidder. If the high bidder jumps past the value of the second highest value bidder it just means that he pays more than he needed to. When multiple identical units, say $Q > 1$, are auctioned simultaneously, jump bids can raise the price so much that only $q < Q$ units are sold. Similarly, in the FCC auctions, if the efficient allocation is to a bidder who wants both license A and license B, the aggregation attempt may fail if someone jumps the bid for A so that the combined price of A and B is out of reach of the bidder trying to efficiently combine A and B.

> "The ideal incentive mechanism design should lead managers to a two-step procedure: (1) an estimation of the value of the auctioned item(s), followed by (2) a readiness to reveal this value in the form of a bid, if necessary, such action being a fair approximation to that which serves the interest of the bidder. Market design should focus on how to facilitate this procedure. Very complex market allocation problems for runway rights, gas in pipeline networks, energy on a high voltage grid, and so on, can be made simple for the participants. Humans make the value judgments, and smart markets handle the complexity. Participants are not required to be experts in anything except their own business uses of the auctioned items, and must apply what they know to determine the private values of those items. That must be their specialty and their focus, and strategizing should not be plainly required of them. Privacy is essential: public information on who is bidding for what, how much, and when, fosters manipulation, gaming, collusion, and inefficiency…."

VI. **New Rules to Reduce Strategic Bidding**

Many of the strategies summarized above are used in an attempt to reduce the amount a bidder pays and potentially reduce the efficiency and/or revenue of the auction. The FCC imposed new, untested rules to overcome some of these practices. In 1997, the FCC imposed the following rules:

1. *Click-box Bidding*: This form of bidding only allows the bidder to increase his bid in integer multiples of the identified increment. Thus, if the increment amount were 10 percent for a particular license, any bid submitted for that license was restricted to be equal to the Standing Bid times $(1 + .10\pi)$, where π is a positive integer greater than or equal to 1. This was used to eliminate

trailing digits and typos after learning that trailing digits were used to signal intentions. Note, however, that any given rule potentially maps into many behavioral effects, not just the effect the rule was designed to control. There are no assurances that 'Undesirable Behavior X is controlled if and only if rule R is imposed.' This is why rule changes should be tested in the laboratory to determine if there are unintended consequences whose costs may exceed the presumed benefits. For example, the Vickrey rules for multiple unit English auctions, although logically unassailable, in practice led to jump bidding and, in some cases, inefficient rewards – an unintended consequence that may have been foreseen if they had been tested prior to adoption.

2. *Limit Withdrawals*: Bidders were limited to two withdrawals in an auction. This rule was implemented to reduce the lateral hand-off problem, but it obviously could interfere with assembling complementary items and may reduce efficiency and/or revenue.
3. *Increment Smoothing*: The FCC now changes the percentage bid increment from round to round based on the number of new bids received on a particular license. This was adopted in order to speed-up the auction.

In addition to the observations that spurred these rule changes, there were other lessons learned from conducting the auctions. In particular, the C Block auction lasted approximately six months.[20] While this was a boon for

[20] The C block auction, completed in May 1996, extended bidding credits to Designated Entities (DEs), small businesses or rural telephone companies determined by the FCC to be handicapped in accessing credit markets. DE bidders winning licenses were extended long-term (10-year) credit on extremely favorable terms (U.S. Treasury debt interest rates), paying for licenses via installments. The two largest

consultants, it created high transaction costs for participants – costs not part of the design criteria. In the early FCC auctions, the system averaged two rounds each day. Recently, this has been increased to an average of nine rounds each day in later rounds. Finally, the Justice Department has shown a willingness to pursue bidders they believe are fostering collusive bidding, such as retaliatory bidding or bid signaling. Thus, bidders are becoming more sensitive to the type of bids they will submit.

VII. **New Rules on the Horizon and the AWS Action**

There have been two specific proposals to increase the efficiency and revenue from the FCC auctions: a change in the auction form and a change in the informational structure of the auction.

A. **Combinatorial Auctions**

An important concern for bidders in FCC auctions is the inability to bid for packages of licenses. That is, bidders are not able to make bids such as "I want License B AND C together or neither." Not allowing "AND" bids handicaps bidders who have regional or national business plans. Combinatorial auctions allow for such bidding possibilities. In addition to

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bidders defaulted on their payments, leading to court battles resolved by the U.S. Supreme Court in 2003. F.C.C. v. NextWave Personal Commc'ns Inc., 537 U.S. 293, 123 S.Ct. 832 (2003) (Bankruptcy Code prohibits FCC from revoking licenses held by a debtor in bankruptcy upon the debtor's failure to make timely payments owed for purchase of the licenses). Eventually, however, the licenses were re-auctioned. *US FCC announces NextWave settlement agreement*, INT'L. TELECOMMUNICATIONS INTELL., Apr. 21, 2004 (Pg. Unavail. Online) 2004 WLNR 6953743. For more details on the use of bidding credits and their effects see Thomas Hazlett & Robert Munoz, *What Really Matters in Spectrum Allocation Design* (AEI-Brookings Working Paper 04-16), available at http://www.aei-brookings.org/publications/abstract.php?pid=821.

AND bids, combinatorial auctions allow for "OR," "ONLY IF" and other logical bid constraints.

In 2000, the FCC held its first combinatorial auction conference to begin looking at ways to implement a combinatorial auction for future licenses. Software was designed and redesigned to be used for combinatorial bidding, and two additional conferences were held in 2001 and 2003.[21] To date, no such auction has been used by the FCC. Such auctions, however, have been used effectively in various other public and private venues (see Ishikida et al. (2001), Ledyard et al. (2002) and Porter et al. (2006)). A new, improved design has been proposed in Porter et al. (2003). It remains to be seen if such auctions will be adopted by the FCC.

For the AWS auction held from August 9 to September 18, 2006, the FCC sought comment on "the feasibility and desirability of allocating the AWS-1 licenses among two auctions, run concurrently, with one of the auctions using the standard SMR format and the other using the FCC's package-bidding format ("SMR-PB"). Under the SMR-PB format, bidders can place bids on groups of licenses they wish to win in combination, with the result that they win either all of the licenses in a group or none of them, in contrast to the license-by-license bidding in the FCC's SMR format. In the SMR-PB auction format, each bidder can have, at most, a single winning bid, so that, in order to win any particular license combination, the bidder must have placed a package bid on that license or specific group of

[21] A potential combinatorial design, based on a similar rule structure as the SMR was tested, and though it performed better than the SMR, it took many more rounds to complete.

licenses."[22] Given the complexity of participating in two concurrent auctions and the overwhelming negative comments, the FCC opted to not try any combinatorial auction designs for the AWS auction.

B. **Information Provided to Bidders**

The bidding strategies outlined in section V require that bidders have access to full information on bidder identities, bids submitted, and other information. Thus, the FCC also sought comments on potential rules concerning limitations on the specificity of information provided to bidders about the identities and actions of other bidders during the AWS auction.[23] Specifically, The FCC initially proposed "not to reveal until the close of the auction: (1) bidders' license selections on their short form applications and the amount of their upfront payments; (2) the amounts of non-provisionally winning bids and the identities of bidders placing those bids; and (3) the identities of bidders making provisionally winning bids." After each bidding round, the FCC would reveal the number of bidders who placed bids for each license and the amount of the current highest bid.

Both the Federal Trade Commission and the Department of Justice submitted *ex parte* comments supporting the no information condition and noting that providing full information would "likely result in a loss of competition with lower government auction revenues and less efficient allocations of markets among bidders." However, the FCC opted for a

[22] Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments and Other Procedures for Auction No. 66 AU Docket No. 06-30.

[23] Federal Communications Commission, Auction of Advanced Wireless Services Licenses Scheduled for June 29, 2006 Comment Sought on Reserve Prices or Minimum Opening Bids and Other Procedures, AU Docket No. 06-30, 71 Fed. Reg. 6486 (Feb. 8, 2006) ("Public Notice").

modified rule that examined the "competitiveness" of the auction. Competitiveness was defined by the upfront payments of the participants, so that, if the amount of eligibility obtained from the upfront deposit was three times the aggregate level of the license offered in the auction, then all information would be provided; otherwise the rule identified above would be used.[24] FTC provided no explanation why the competition defined by three-times the aggregate level is enough to not worry about collusion, and it remains to be seen whether this is true. Note, though, that each of theses rules is testable, and they can be compared with alternative variations.

VIII. **AWS Auction Results and Conclusion**

Based on the upfront payments of the bidders, the modified eligibility ratio in the August-September 2006 AWS auction was 3.04, just barely above the require 3.0 amount to make the auction open. Interestingly, though, the amount of eligibility shed after round one of bidding pushed the modified eligibility ratio well below 3.0. The auction lasted 29 days, with 161 rounds of bidding. There were 168 qualified bidders, and 104 bidders ended up winning at least one license (35 licenses went unsold). The auction raised $13.7 billion in revenue, which translates into a price of 54.34 cents per MHzPop. This is significantly below the amounts paid in previous international Third Generation (3G)[25] auctions and below the prices in the

[24] Specifically, the eligibility ratio is defined as the sum of the bidding units from the upfront payments divided by the total number of bidding units on licenses in the auction. Each bidder's total eligibility was capped at 50 percent of the total bidding units in the auction. This capped amount was used in calculating the "modified eligibility ratio."

[25] The most advanced PCS devices are considered to be "Third Generation" technologies, which combine high-speed mobile access with Internet protocol based services.

PCS C and F block auctions ($4.00 MHzPop) or recent private transactions of spectrum ($1.70 MHzPop).[26]

One interesting insight from the AWS auction arose from the observation that there were at least two clearly identified bidders who would be new nationwide entrants, a consortium of the Cable companies (SpectrumCo) and a partnership of the satellite TV companies (Wireless DBS). The incumbent national wireless operators (Verizon, Cingular, and T-Mobile) were also participants. There was a fear that the incumbents would bid to keep the new entrants out, or at least raise their entry costs. Given the structure of Simultaneous Multi-Round auctions, an incumbent could keep a national entrant out by bidding on just a handful of licenses to cripple any attempt to assemble a national aggregation of licenses. If, instead, a combinatorial auction were to be used, an incumbent would have to keep out a new entrant by potentially outbidding a nationwide package of licenses, which would be costly if the incumbent actually won the licenses. This is precisely the opposite argument from the one that suggests a combinatorial auction hinders entry.

In view of this experience, we think a fresh reexamination of the FCC auction design protocols is overdue. An important objective of redesign should be to find auction procedures that reduce the participation and transactions costs of the bidders, and that make it easier for bidders who desire packages of the elemental rights to assemble those packages by expressing their willingness-to-pay, with minimum incentive for strategic behavior. We think the likely features of an improved auction design

[26] In the appendix, a history of the revenue and rules for the FCC auctions is provided.

include: English clock procedures for advancing the price on each offered item; publicity of those items on each round that are or are not still actively bid; bid privacy; and efficiency (not revenue) optimization algorithm support, as needed, after bidding on the last item(s) becomes inactive. Whatever the proposed redesign, it should be thoroughly tested first in the laboratory. After shakeout, that testing should be further refined with industry and government professionals, using environments that are thought to be both relevant and challenging to the design. We think it is also time to consider two-sided auctions, in which incumbent rights holders can offer their rights for sale in combination with new rights being offered.

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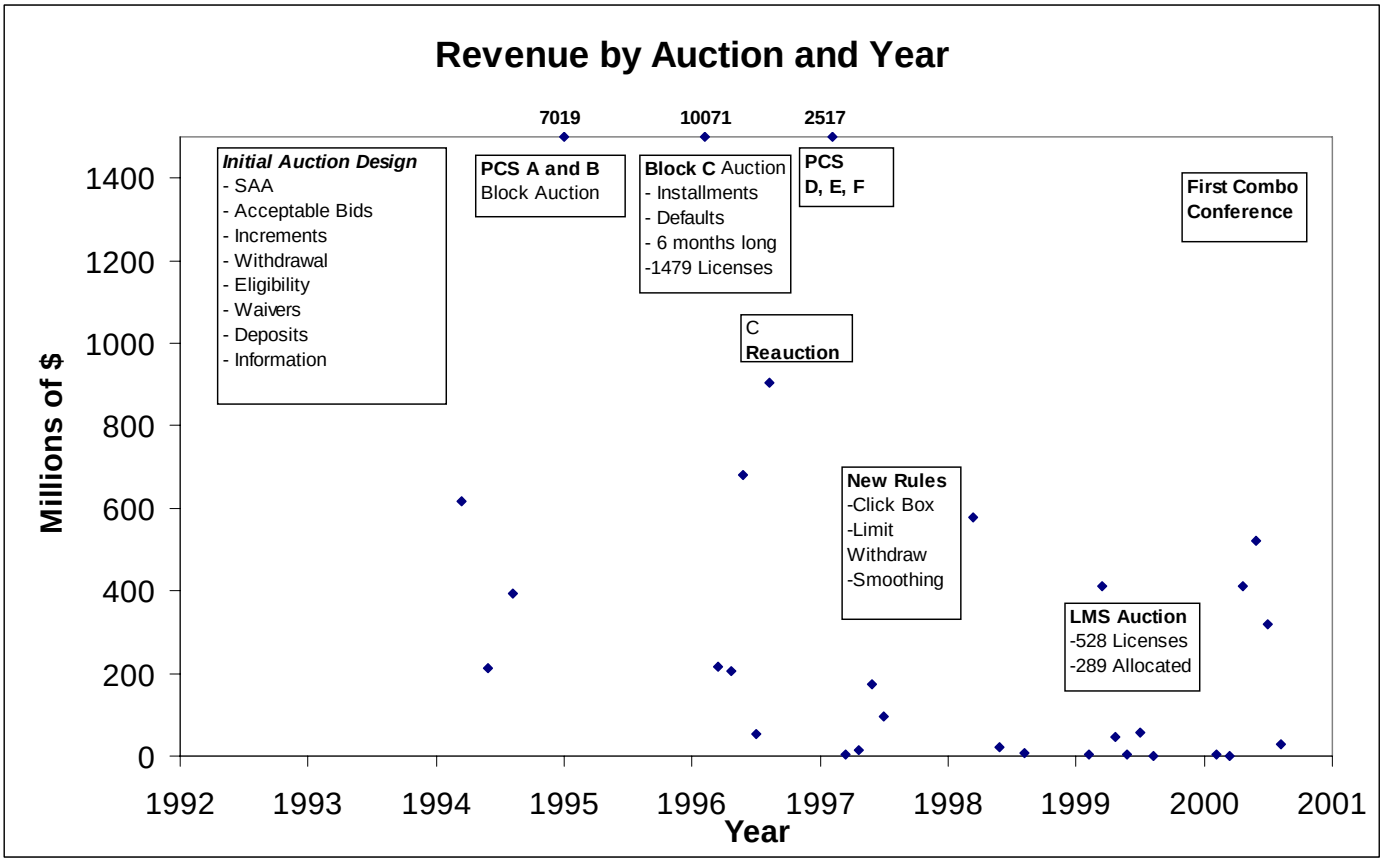
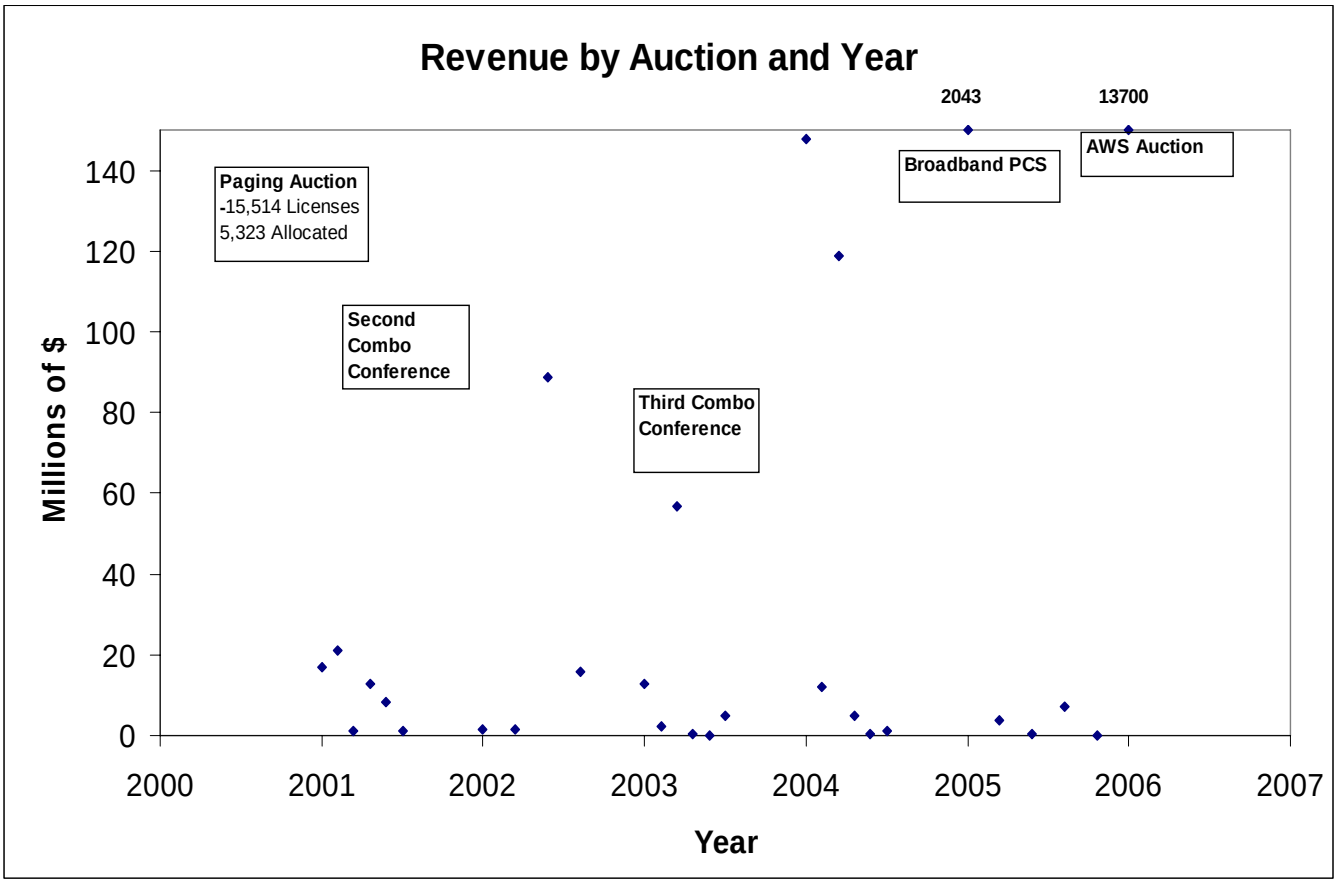
Appendix

The Figures below chart the revenue from each FCC Spectrum auction by year. The first figure tracks the revenue and major results and design decisions for the auctions from 1993 to 2000. The second figure does the same for 2001 to 2006. However, the vertical scale is decreased by a factor of 10 since the revenues are much lower in these later auctions.[27]

[27] The figures show the reported revenues from each auction. The aggregate winning bids per auction as reported by the FCC total $45.118 billion (1994-2006). However, approximately $8 billion has proven to be uncollectible in Auction 5 (the PCS C Bloc). In addition, the approximately $16.9 billion for Auction 35 (Jan. 2001), has resulted in virtually zero actual revenues when the federal courts overturned the FCC's ownership of the licenses in the Nextwave case. (The uncertainty concerns licenses other than Nextwave's that may have been legally sold in the auction.). Roughly, this means that $20 billion of the reported $45 billion has gone uncollected, for a grand total of about $25 billion in actual revenues over 12 years, a little more than $2 billion per year.


Revenue by Auction and Year
7019
10071
2517
Initial Auction Design
- SAA
- Acceptable Bids
- Increments
- Withdrawal
- Eligibility
- Waivers
- Deposits
- Information
PCS A and B
Block Auction
Block C Auction
- Installments
- Defaults
- 6 months long
-1479 Licenses
PCS
D, E, F
First Combo
Conference
C
Reauction
New Rules
-Click Box
-Limit
Withdraw
-Smoothing
LMS Auction
-528 Licenses
-289 Allocated
Millions of $
0
200
400
600
800
1000
1200
1400
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


Revenue by Auction and Year
2043
13700
AWS Auction
Broadband PCS
Paging Auction
-15,514 Licenses
5,323 Allocated
Second
Combo
Conference
Third Combo
Conference
Millions of $
140
120
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
2006
2007
Year