PAUL MILGROM

June14, 2000

Mr. Evan Kwerel
Federal Communications Commission
445 12th Street SW
Washington, DC 20054

RE: PUBLIC NOTICE DA 00-1075

Dear Evan:

Only a few days remain to finalize the Commission's rules for a possible combinatorial auction for the 700 MHz band. Furthermore, the Commission has not yet determined whether to adopt such an auction and, if it does so, whether to base it on the design proposed in Public Notice DA 00-1075 or to use an alternative design.

To make my remarks as useful as possible in this short time frame, I divide this letter into two main parts. The first part discusses a sophisticated combinatorial design, unconstrained by considerations of bidder experience and the FCC's auction history. My discussion of the sophisticated design is intended to serve two purposes. First, in the unlikely event that the Commission does seek to implement a highly sophisticated new design on a short time frame, this section can be used as a sketch of the required rules. More importantly, however, a benchmark design is useful for guiding the refinement of the Public Notice design. The second part of this letter aims to do that, refining some aspects of the design using insights gleaned from the benchmark analysis.

SOPHISTICATED COMBINATORIAL DESIGNS: A BENCHMARK

Combinatorial auctions can be designed to allow bidders complete flexibility to bid different amounts for different license combinations. To achieve such flexibility, it is necessary and sufficient that each bidder can make mutually exclusive bids on sets of licenses. Adding to mutually exclusive bids the possibility of non-exclusive bids does not add to the effective number of bids that can be made, but it does permit many bids to be expressed compactly with just a few numbers. For example, in the (non-combinatorial) simultaneous multiple round auction, making individual bids for 12 individual licenses implies bids for the full package of 12 licenses and for every sub-package. There are 4095 sub-packages among the twelve licenses, so twelve numbers are implicitly expressing bids for 4095 distinct packages. Any system that allows non-exclusive bids achieves a similar flexibility.

The flip side is that FCC's traditional simultaneous multiple round (SMR) auction system *forces* bidders who wish to bid on, say, a package of twelve licenses, to make 4094 additional bids, some or all of which may be bids they do not want to make. This is not a problem when the licenses are mutual substitutes, because it is then a mathematical fact that a bidder whose most profitable package bid is on the twelve license package and who makes the necessary minimum bids is necessarily also willing to pay the implied amounts for each of the 4094 other sub-packages. With mutual substitutes, the SMR permits a tremendous economy in expressing many bids and provides lots of information to other bidders. However, when licenses are not mutual substitutes, bidders face the "exposure problem" that they may win a sub-package that they would not want to buy at the prices determined by the auction.

The exposure problem is avoided entirely when no combinatorial bid is ever combined with another bid

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by the same bidder to imply a value about some larger package. When bidders are free to place as many mutually exclusive bids for different packages as they wish, the bidding language can express any pattern of bids that a bidder could want. In principle, a bidder can bid a different amount for every possible package. Allowing additional kinds of bids provides additional ways to express the same values, sometimes with economy of expression. However, it does not add any new combinations that were absent with mutually exclusive package bids. To summarize: *allowing a bidder to make any number of mutually exclusive package bids is necessary and sufficient to provide bidders with complete bidding flexibility*.

A system allowing complete flexibility would be practicable alternative for the 700 MHz auction if history were no issue, because just twelve licenses are being offered. A benchmark auction system based on this idea would work as follows. Each bidder at each round can bid on any combination of licenses. As in all the multi-round combinatorial auction proposals, the provisionally winning set in this auction at each round would be the set of non-overlapping bids that maximize total revenue. However, in this auction, bids by any single bidder are interpreted as mutually exclusive, so the revenue is maximized subject to the additional constraint that each bidder can have only one provisionally winning bid. The minimum bid on each package is the highest previous bid on that package, plus a suitable increment. All bids, once made, remain in the system until the end of the auction.[1]

"Straightforward bidding" in such an auction means that each bidder who can profit by a change in the provisionally winning set at the current minimum bids makes the minimum bid(s) at the next round for the most profitable set(s) of licenses, and only for those sets. I have argued elsewhere that the result of straightforward bidding in such a scheme with a private values environment would be an allocation that maximizes total value to within a single bid increment. For example, if all the final increments (at which bidding stopped) are 5%, then, even in the worst case, the allocation is surely optimal to within 5%.

Of course, straightforward bidding by all bidders is hardly likely and there are important common value elements in any spectrum auction. Nevertheless, the criterion that the auction performs well with straightforward bidding in a private values environment is useful for evaluating alternative auction proposals. Rules that cannot achieve optimal allocations with straightforward bidding in such environments are unlikely to replicate the successes of combinatorial designs found in FCC-sponsored laboratory experiments.

Strategic analysis of combinatorial bidding points to an incentive for bidders to postpone bidding and park their bids. Indeed, if everyone bids straightforwardly, then the longer one waits before beginning to bid, the greater the profit obtained in the auction. Activity rules are a partial solution to this problem, but bidders can get around many simple activity rules by "parking"—a strategy that has already been seen in the FCC spectrum auctions. Excessive parking needs special consideration in combinatorial auctions, because there are so many packages on which bidders could potentially park.

The "threshold problem" is a close cousin of the parking problem. A bidder may be inclined to refrain from raising its bid on a non-winning package in the hope that other bidders will raise their bids enough to convert its existing bid to a winning bid. That pattern provides an advantage to bidders for larger packages, who need not coordinate their bids with as many other bidders. As I have demonstrated elsewhere, this provides an incentive for bidders to exaggerate their relative values for larger packages—I call this the "*large package problem*."

Thus, to implement this system effectively, several details need to be gotten right. Those proposed here are constructed with particular attention to the incentives for parking, its cousin, the so-called "threshold problem," and the large package problem. At the same time, the modified rules should not significantly restrict a bidder's ability to bid straightforwardly.

[1] Of course, as more bids are received, some bids may become irrelevant, since they are too low ever to become part of the winning set.

Experienced consultants know that bidders consider only a few business plans sufficiently carefully to determine accurate bids, so straightforward bidding is unlikely to be prevented by limiting any one bidder to bid on no more than a dozen different packages. To make such problems even more unlikely, the benchmark specifies that: *no bidder is allowed to bid on more than 24 different combinations of licenses during the full course of the auction.*

Setting minimum bids sufficiently high to exclude frivolous bids mitigates parking, but setting them too high may exclude potentially valuable bids. Professor John Ledyard's RAD system is designed to exclude frivolous bids, but its stringent requirements and non-monotonicity can create difficulties for straightforward bidders. Rather than propose a whole new design on such short notice, I suggest building on the RAD proposal: *the minimum bid on any package in the benchmark design to receive activity credit would be the greater of previous high bid plus x% or the average of the current high bid on the package plus the RAD minimum bid.*[2]

To facilitate straightforward bidding, *the activity rule would give credit for new bids and for provisionally winning bids from the prior round, and the activity requirement would be one active bid per round.* A bidder who fails to maintain the required activity loses all eligibility to make new bids in future rounds. Its previous bids remain in the system and may later become provisionally winning bids, but that event does not restore the bidder's eligibility.

The details of the proposed benchmark should not significantly constrain straightforward bidding. The limit on the number of combinations bid is highly unlikely to be a practical constraint. The potential non-monotonicity of the minimum bid merely changes the relevant bid increment that applies to the theorem about straightforward bidding: the auction remains efficient to within "one increment."

REFINING THE PUBLIC NOTICE DESIGN

The preceding auction design provides a *de novo* benchmark. The design that I proposed and that was incorporated in the Public Notice is intended to be a much smaller departure from current practice and one that minimizes the information processing demands on bidders. The intention was to suggest a mechanism that could be digested and implemented on short notice.

Despite the seemingly different structure of the Wye River proposal compared to the benchmark, attempts to modify the proposal benefit from the benchmark analysis. One lesson is that a general system does not require unlimited complexity. The benchmark auction itself is simpler than the alternatives that commenters have proposed. Nevertheless, as author of the Wye River proposal, I take seriously the criticism that my quest for simplicity may have gone too far in restricting the bidding patterns of the participants.

With that in mind and in the interest of clarifying some points raised by the commenters, I offer the following replies. These are treated in four sections below:

1. XOR bids and bid cancellation restrictions.
2. Pacing the auction: increments & activity rules
3. Unbid licenses
4. Tie bids

1. "XOR" BIDS AND BID CANCELLATION RESTRICTIONS

Analysis of the benchmark auctions suggests that mutually exclusivity of bids submitted in different rounds should be the rule, not the exception, for combinatorial auctions. While bids in other forms may be acceptable or even useful within a round because of the compact expression they allow, that justification does

[2] The auction may also allow bids that do not receive activity credit, though this does not appear to improve the worst-case properties of straightforward bidding.

not extend to bids submitted in different rounds. Consequently, the FCC should treat bids submitted in different rounds by one bidder be treated as mutually exclusive. A bidder who wishes the bids to be treated otherwise can simply repeat its retained bid at the current round. It should be permitted to do so at the same price as its current provisionally winning bid, perhaps by adding a check-box option to renew each existing bid.

A major advantage of this treatment is to obviate the need for changes to the bid cancellation restriction. The sole cogent argument against the restriction is that it prevents straightforward bidding. The argument in favor is that it facilitates the progress of the auction and deters frivolous bids. The proposed solution is easy to implement in this case and completely accommodates both concerns.

2. PACING THE AUCTION

As described above, my analyses of strategic opportunities in combinatorial auctions show that bidders have much to gain by delaying serious bidding and by adopting parking strategies. This threatens to slow the progress of the auction. That time-to-completion is a greater problem in combinatorial auctions than in the traditional FCC design is confirmed by the Cybernomics report to the FCC, in which the combinatorial auctions routinely took more than three times as long to reach completion as the simultaneous multiple round auction in the same experimental treatments. While such process costs are secondary to the hoped-for efficiency gains, it is nevertheless prudent and valuable to mitigate them.

In a simultaneous ascending auction with straightforward bidding by participants, the expected percentage inefficiency on account of an x% bid increment is on the order of x^2%.[3] The reason is that the inefficiency itself is at most one bid increment and the probability of any inefficiency at all is roughly proportional to the percentage bid increment. In sample calculations, a 10% bid increment implied an efficient loss of only about 0.5%. While the calculation for combinatorial bidding is subtler, a qualitatively similar argument applies: the efficiency loss is roughly proportional to x^2%. The FCC should not be reluctant to use 20% increments early in the auction and 10% late in the auction to bring the auction to a smooth close.

I have previously proposed for evaluation a minimum bid rule that imposes larger increments for bids with low bid/point ratios. One possibility integrates ideas suggested by Professor Robert Weber at the FCC-SIEPR-NSF combinatorial auction conference. To describe it, define the "*shortfall*" associated with a license combination be the difference between the total provisional winning bid in the auction and the maximum total revenue associated with packages of bids that include that particular license combination. The "*deficit*" for a combination is the shortfall multiplied by the proportion of points associated with that combination. For example, if there are 60 points and a particular combination encompasses 20 points, then the deficit is 1/3 of the shortfall. A rule that sets the minimum increment on any combination at the larger of 50% of the deficit or *x*% would significantly limit opportunities to delay the auction by parking.

Another suggestion that also seeks to speed the auction by reducing the role of parking is Professor Charles Plott's suggestion for stage-dependent activity credits. This suggestion has the advantage of simplicity and is likely to be effective in speeding the auction. However, the benchmark analysis suggests that bid increment policies are the preferred device for controlling the pace of the auction.

3. UNBID LICENSES

Professor Ronald Harstad's comment proposes that the FCC count zero for licenses on which the FCC is the provisional winner ("unbid licenses") in assessing the provisionally winning bids. This proposal should be rejected.

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[3] Ausubel and Milgrom have determined, however, that the excess of the expected revenue from equilibrium bidding in an auction with a vanishingly small increment and one with an x% increment is roughly ½x%.

The objectives of the auction program include the efficiency of the allocation (contribution to the economy) and the creation of revenue for the Treasury. Those objectives call for assigning some estimate of the opportunity value of the licenses in computing the winners. Although this cannot be done with precision, that hardly recommends setting those license values to zero. To the extent that the minimum bids reflect either the FCC's initial reserve value or actual bids that have been made, they represent better estimates of the opportunity value than the proposed zero estimate. If the FCC is uncertain concerning its initial minimum bids, then allowing those bids to be reduced later in the auction is reasonable.

4. TIE BIDS

As a practical matter, the rule for the resolution of ties is highly unlikely to affect the ultimate allocation in the auction and, when it does, the change will have only a barely perceptible effect on either revenues or efficiency. The issue of ties is, in practice, entirely a matter of user satisfaction. Because time stamps may create an unwanted coordination problem among bidders, satisfaction is likely to be increased by switching from the use of time stamps to random tie breaking.

Sincerely,

From: Paul Milgrom <paul@milgrom.net>
To: <ekwerel@fcc.gov>
Date: 6/15/00 8:45PM
Subject: Fwd: RE: Combinatorial bidding at the FCC

FYI

>From: "R. Preston McAfee" <mcafee@eco.utexas.edu>
>To: "Paul Milgrom" <paul@milgrom.net>
>Subject: RE: Combinatorial bidding at the FCC
>Date: Thu, 15 Jun 2000 14:50:56 -0500
>X-Mailer: Microsoft Outlook IMO, Build 9.0.2416 (9.0.2910.0)
>Importance: Normal
>
>Hi Paul:
>
>That is a very nice letter.
>
>My only comment is that I agree with Larry that the bid increment should be
>
> Max{5% of bid, 30% of shortfall}.
>
>I do think that FCC bids equal to 75% of the RAD prices might improve the
>efficiency and greatly improve the speed.
>
>Preston