BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION

Reply Comment on

Competitive Bidding Procedures for Auction 901

Mobility Fund Phase I

AU Docket No. 12-25

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I: QUALIFICATIONS AND PURPOSE

My name is David McAdams. I am Associate Professor of Business Administration and Economics at Duke University. My academic expertise is microeconomics, game theory and, especially, auction theory and market design. My theoretical and empirical auction research has been supported by the National Science Foundation and published in the leading journals of economics, including *Econometrica*, *American Economic Review*, *Journal of Political Economy*, *Review of Economic Studies*, *Journal of Economic Theory*, and *Journal of Econometrics*.

There is already quite a lot of commentary in this proceeding, but several of the key design issues facing the Commission still seem unresolved. My goal here is to help bring more clarity to these issues.
II: OUTLINE AND OVERVIEW

Several aspects of the Mobility Fund Phase I auction design appear to be largely settled, including: (i) all subsidies will be auctioned simultaneously; (ii) bidders will submit sealed bids; (iii) bidders will receive subsidies equal to their winning bids; and (iv) the Commission’s objective is to maximize the road-miles\(^1\) that will be newly served, subject to a total budget of $300 Million. However, other aspects of the auction design appear unresolved, including:

- Should the Commission restrict bidding to tracts, or allow bidding on blocks?
- Should the Commission allow package bids?
- How should winners be selected?

In my analysis, I will focus not on what auction design may be optimal in theory, but on what design will work well in practice for the bidders that the Commission would like to attract to participate in the auction. This leads me, in Part III, to propose a “Simplicity Principle” of auction design. Part IV then applies this principle to the geographic scope of bids and the related question of whether to allow package bidding, concluding:

1. If block-level bidding is allowed, then package bidding should also be allowed;
2. If the Commission plans to subsidize at most one provider per tract, then the Commission should restrict bidders to submit tract-level bids; and
3. Allowing limited packaging of tracts might offer substantial benefits.

Part V then considers how to select winners, concluding:

1. The Commission should not select winners according to a “Bang for the Buck” rule, whereby winners are those with the lowest cost per mile served; and

\(^1\) My recommendations can be easily translated to an alternative scenario in which the Commission seeks to maximize a different objective, such as road-passenger-miles and/or resident population.
2. The Commission should select winners according to a “Road-Mile Maximizing” rule, whereby the set of winners is selected to maximize the total number of miles served nationwide.

Finally, Part VI corrects a misunderstanding in AT&T’s February 24, 2012 comment, regarding the Milgrom-Eilat proposal.
III: THE SIMPLICITY PRINCIPLE

In many currently unserved areas, small rural carriers may be best positioned to expand service. Such small carriers are at a natural disadvantage in any auction, given their relative lack of bidding expertise and resources to devote to bid preparation. To attract such small players to the auction, the Commission ought to choose an auction design that is as simple as possible:

i.  *simple to understand*, so that bidders with little experience can easily grasp the rules;

ii. *simple to strategize*, so that unsophisticated bidders will not be disadvantaged; and

iii. *simple to prepare and submit bids*, so that minimal costs are imposed on bidders.

There can be trade-offs between these different aspects of simplicity, so there may not be a “simplest auction”. However, any auction design satisfying the following “Simplicity Principle” will be *simple enough* not to deter participation of unsophisticated bidders.

**THE SIMPLICITY PRINCIPLE: naïve bidding strategies are close to optimal.**

The notion of “ naïve bidding strategy” is meant to capture the sort of bidding strategies that unsophisticated bidders would choose to follow, if they were to participate. The Simplicity Principle can therefore be rephrased as saying, “Sophisticated bidding strategies allow one to squeeze only a small extra profit from the auction”.

For any given auction design, one can determine how unsophisticated bidders will behave by conducting interviews, dry runs, and so on. Without access to such information, I will proceed under the following (hopefully intuitive) *assumption* about naïve bidding.

**Assumption: Naïve bidding in Mobility Fund Phase I.** Any unsophisticated bidder who participates in the Mobility Fund Phase I auction will formulate its bid as follows. First, such a
bidder will identify a *target footprint* that it would like to serve. Then it will bid on this target footprint – as a package, if allowed, or as a collection of bids on the regions that comprise the footprint – at a per-mile price equal to its *per-mile cost plus a mark-up*.

Such naïve bidding could be far from optimal, depending on the auction design. For instance, suppose that package bidding is not allowed and a bidder only faces competition on half of its target footprint. Charging the same per-mile price could be disastrous, if it leads that bidder to win too little of its target footprint to achieve efficient scale. In such a scenario, a bidder could do much better by bidding a higher price on the uncontested part and a lower price on the contested part. (This approach increases its likelihood of winning the entire footprint while also guaranteeing a higher per-mile price should it win only half.) Of course, devising an optimal strategy in this context requires one to know which parts of one’s target footprint are more or less contested, which unsophisticated bidders may be unable to do.

This strategic complexity creates a *risk of naivete* can be alleviated by allowing package bidding, since an unsophisticated bidder could then just make an all-or-nothing offer on its target footprint. However, obviously, package bidding is not a panacea when it comes to simplicity! For one thing, an optimal strategy may entail bidding on numerous overlapping packages. Naïvely bidding on just one package could put an unsophisticated bidder at a substantial disadvantage. Formulating the packages that one wants to bid upon and submitting multiple package bids could also be costly.
IV: WHAT BIDS TO ALLOW?

In this section, I will apply the Simplicity Principle to the question of what sorts of bids to allow. First, how large should the minimal geographic area be for a bid: “one block” (on average ~1 square mile in unserved areas) or “one tract” (on average ~120 square miles)? Second, what if any package bids should be allowed? My conclusions will be as follows:

1. If block-level bidding is allowed, then package bidding should also be allowed;
2. If the Commission plans to subsidize at most one provider per tract, then the Commission should restrict bidders to submit track-level bids; and
3. Allowing limited packaging of tracts might offer substantial benefits.

A. BIDDING ON INDIVIDUAL BLOCKS

Suppose first that bids are allowed at the block-level, but that package bids are not allowed.\(^2\) Such a design would create serious concerns, given the important cost complementarities that service providers enjoy across adjacent blocks. Since a typical transmission tower can reach a service area of from 20 to 150 square miles (depending on terrain), and an average block is only about 1 square mile in currently unserved areas, serving one block allows one to automatically serve most (if not all) neighboring blocks. Given this important complementarity in the cost of serving contiguous blocks, any auction design that allows block-level bidding should allow bidders to submit package bids that reflect how they plan to expand their service areas.

\(^2\) Some readers will immediately appreciate the serious problems created by such a design. However, in discussion with FCC staff, I got the impression that an auction design like this might be under consideration.
Further, naïve bidding in this context can be far from optimal, violating the Simplicity Principle. To see why, consider a stylized example with just two bidders, \{A,B\}, who coincidentally decide to bid on blocks in the same tract. Each hopes to cover 40 blocks, but their planned service areas overlap with 20 blocks in common. Suppose that bidder A’s total cost is $300, bidder B’s total cost is $600, and that the “market-clearing price” in the national auction is $19/block. Finally, suppose that each bidder were (naively) to submit a bid that is marked up 20% above true cost, spread equally across all of the blocks in its planned coverage area. The result would be that (i) bidder A bids $9 on 40 blocks and wins all of those blocks for total subsidy $360 while (ii) bidder B bids $18 on 40 blocks but only wins 20, also for total subsidy $360. Note that bidder B is now obligated to build a transmitter that costs $600, at a substantial total loss.

Anticipating this “exposure problem”, bidders who face the risk of only receiving a subsidy on a portion of their service area will demand a higher price per block. Continuing the previous example, suppose that bidder B believes that (i) half of the time, bidder A will participate and win 20 blocks out of B’s 40-block service area and (ii) otherwise, bidder B will face no competition on the tract in question. How much subsidy per block must bidder B bid to avoid losing money? Bidding subsidy \( S \) per block will result in either (a) zero profit if \( S \) is too high to clear in the nationwide auction, (b) profit \( 40S - 600 \) if bidder A does not compete so that bidder B wins all 40 blocks, or (c) profit \( 20S - 600 \) if bidder A competes and wins half of B’s desired blocks.

To break even, bidder B must demand a subsidy of at least \( S^* = \frac{20}{\text{block}} \), where \( \frac{1}{2} (40S^* - 600) + \frac{1}{2} (20S^* - 600) = 0 \) is the break-even condition. However, by assumption, $20/block is too high to clear in the nationwide auction. So, due to the exposure problem, bidder B will
choose not to participate at all, even though half of the time it would have been efficient for bidder B to win.

**B. BIDDING ON PACKAGES OF BLOCKS VS. ON INDIVIDUAL TRACTS**

Suppose that packages of blocks are allowed, but that such packages are restricted to consist of blocks within a single tract. *Suppose further that the Commission restricts attention to allocations in which at most one bidder wins within each tract.*\(^3\) If so, bidding on a package of blocks within a given tract is equivalent to bidding on a portion of the road-miles contained in that tract. For example, suppose that a given tract has 10,000 unserved road-miles, 8,000 of which are contained within a package of blocks. A bidder willing to serve those 8,000 road-miles for total subsidy $X could (i) bid $X on the package of blocks containing those 8,000 road-miles or (ii) bid for 80% of the tract at per-mile subsidy $X/8,000.

Although these are equivalent formulations when there is at most one winner per tract, there are significant practical advantages associated with bidding on portions of a single tract rather than packages of blocks within that tract. In particular, when bidding on a portion of a tract, there is no need for a bidder to specify *exactly* which road-miles will be covered should it receive a subsidy. This simplifies bid preparation and, furthermore, provides flexibility should the bidder realize afterward that it could have served the same number of road-miles more cheaply in a different way. Knowing that they can finalize the exact details of their service-expansion plans after the auction will also economize on participation costs. This can encourage more bidders to participate.

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\(^3\) My understanding is that both such restrictions have been considered by FCC staff.
**One winner per tract, or more?** As I have argued, bidding on individual tracts is more attractive than package bidding on blocks *if* the Commission plans to subsidize at most one winner per tract. However, as the Commission has recognized, there could be benefits associated with having multiple winners on some tracts and, indeed, with allowing some duplicative service in which some blocks are served by multiple winners whose new service areas overlap:

“as a general matter, the Commission should not award Mobility Fund Phase I support to more than one provider per area unless doing so would increase the number of units (road miles) served, as is possible with partially overlapping bids” 316

So, there is a potential trade-off to be made between allowing bidding on packages of blocks within a tract, versus just bidding on portions of that individual tract. On some tracts in which allowing multiple winners could be important, this trade-off points toward allowing bids on packages of blocks. On other tracts in which only one winner is needed and/or inducing more participation is especially important, this trade-off points toward just allowing bids on portions of the tract. Overall, there is potentially a case to be made for a “mixed” design with block-package bidding on some tracts, but individual-tract bidding on others. In such a design, the Commission would pre-specify which tracts are of which kind.

**C. BIDDING ON PACKAGES OF TRACTS**

While cost complementarities for wireless providers are strong over nearby blocks, such complementarities are likely to be significantly weaker over nearby tracts. Average tract size is about 120 square miles in currently unserved areas, while a typical transmission tower can reach from 20 to 150 square miles, depending on terrain. Thus, very few wireless transmission towers
can reach more than a small portion of any two non-adjacent tracts. Of course, some transmission footprints will straddle adjacent tracts. Forcing bids to belong to a single tract could discourage the most efficient placement of new transmission facilities – away from tract borders and toward tract centers – an arbitrary and undesirable distortion. On the other hand, full-fledged package bidding on tracts could dramatically complicate the auction, deterring the participation of unsophisticated bidders.

Fortunately, there appears to be little economic justification for wireless providers to be able to bid on large packages of tracts. As noted earlier, most transmission footprints are likely to be contained within a single tract or pair of adjacent tracts. Providing new service in non-adjacent tracts therefore requires a wireless carrier to build or upgrade multiple transmission facilities, the cost of which seems unlikely to enjoy significant economies of scale or network benefits. If anything, there may be substantial diseconomies of scale for some bidders if, say, a bidder will employ its existing workforce to build the first tower but need to hire new workers for the second.

**Allowing packages of adjacent tracts.** Consider then an auction design in which bidders may submit bids on (i) single tracts and/or (ii) pairs of adjacent tracts, with each such bid specifying the number of road-miles to be covered in each tract in the package and a total price for such coverage. As discussed at the start of Section IV-B, there is no need to force bidders to specify which particular blocks they will serve within each tract, if the Commission plans to subsidize at most one winner per tract.

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4 “Adjacent tracts” are those that share an edge, or portion thereof. “Non-adjacent tracts” do not share any edge.

5 The “cost” of building a transmission facility is its net cost, accounting for the profitability of future operations. Such profitability undoubtedly depends on the bidder’s installed network and customer base in nearby service areas. However, the areas affected by the auction are “unserved areas”, and these unserved areas seem unlikely to generate substantial network effects among themselves. That is, the profitability of adding one unserved area to a given network seems unlikely to depend much on what other unserved areas are also added to the network.
Once bids can cover portions of multiple tracts, however, the Commission may find this restriction less palatable. For instance, imagine a tract with hills running north-south through the middle. The most efficient way to serve this tract might be with two transmission facilities, one to the west of the hills and another to the east. Neither of these facilities would cover 50% of the full tract, but each would likely cover a significant portion of an adjacent tract as well.

Fortunately, one can accommodate this sort of possibility in a relatively tractable way, without resorting to full-blown block-level package bidding, while also ensuring that the service footprints of all winners within the same tract have minimal overlap, by imposing the following sort of restrictions on winner determination. For each tract X,

1. if a bid on tract X alone wins, then no bid on a pair of tracts including X can win; and

2. at most two bids on pairs of tracts including X can win.  

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6 Given more detail about tract layout, one could sensibly add more restrictions to minimize service overlap of tract-level package bids, while still not needing to elicit block-level coverage information.
V: HOW TO SELECT THE WINNERS?

A key feature of the Mobility Fund Phase I auction design is that bidders must compete nationally for a piece of the Commission’s limited subsidy budget. However, since the Commission prefers not to subsidize duplicative service, bidders must also compete locally against others who are capable of expanding service in the same tract(s). This combination of local and national competition can lead to some unexpected and undesirable outcomes, depending on the rule that is used to select who wins.

For simplicity, I will focus on a setting like that discussed in Section IV-B, in which bidders submit tract-level bids specifying (i) the number of road-miles that they will serve in that tract and (ii) per-mile subsidy, and assume that package bidding is not allowed. (Bidders may bid on as many tracts as they please, and may submit multiple bids per tract.) My main conclusions will be as follows:

1. The Commission should not select winners according to a “Bang for the Buck” rule, whereby winners are those with the lowest cost per mile served; and
2. The Commission should select winners according to a “Road-Mile Maximizing” rule, whereby the set of winners is selected to maximize the total number of road-miles served nationwide.

A. BANG FOR THE BUCK RULE

One natural and intuitive-seeming way of evaluating bids is by the per-mile subsidy that they demand, what I will call the “Bang for the Buck Rule”.

**Bang for the Buck Rule.** First, for each tract, define the “tract-winner” as the bid on that tract with the lowest per-mile subsidy. Next, rank each tract by the per-mile subsidy demanded by its
tract-winner, and award the $300 Million budget in order according this to ranking (to those tract-winners with the lowest per-mile subsidies) until the budget is exhausted.

For monopolistic tracts where there is just one bidder, the Bang for the Buck Rule creates an incentive for the monopolist to propose an efficient service area. However, for competitive tracts with multiple bidders, the Bang for the Buck Rule can create an inefficient “race to the smallest” in which each bidder has an incentive to propose service areas that are too small.

**Example: “Race to the smallest”**: Consider a tract with 10,000 road-miles, in which any bid must cover at least 7,500 road-miles, and suppose that nationwide competition has established a “market-clearing price” $P^*$ of $10 per road-mile. Suppose further that there are two bidders, each having identical costs $C(q) = 10,000 + q^2/5,000$ of serving $q$ road-miles in the tract. Each firm’s average cost $AC(q) = 10,000/q + q/5,000$ and marginal cost $MC(q) = q/2,500$. Please note that, for all quantities $q$ in the relevant range $[7,500,10,000]$, $AC(q) < MC(q) < 10$.

Since marginal cost is everywhere below the $10 market-clearing price of procuring road-miles elsewhere in the nation, the efficient outcome is for all 10,000 road-miles to be served in this tract. However, the Bang for the Buck Rule creates a perverse incentive for each bidder to serve fewer road-miles and, in equilibrium, only 7,500 road-miles will be served. Why? Since the bidders have identical costs, competition between them to be the tract-winner will drive their demanded per-mile subsidy down to true average cost. However, since average costs are increasing, each bidder can gain an advantage over its competitor by offering a smaller service footprint, since then its average cost will be lower. In the end, in equilibrium, both bidders will offer the smallest service footprint permitted by the rules.
I should note that the Bang for the Buck Rule does not necessarily induce identical competing bidders to propose inefficient coverage plans. Table 1 illustrates four possibilities in which average cost (AC), marginal cost (MC), and the market-clearing price (P*) are ranked in different ways. As this Table illustrates, an inefficient “race to the smallest” only occurs when \( P^* > MC > AC \), as in the previous example.

<table>
<thead>
<tr>
<th>Case</th>
<th>Equilibrium outcome</th>
<th>Efficient?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case #1: AC &gt; P*</td>
<td>Serve 0%</td>
<td>Yes</td>
</tr>
<tr>
<td>Case #2: MC &gt; P* &gt; AC</td>
<td>Serve 75%</td>
<td>Yes</td>
</tr>
<tr>
<td>Case #3: P* &gt; MC &gt; AC</td>
<td>Serve 75%</td>
<td>No. Best to serve 100%</td>
</tr>
<tr>
<td>Case #4: P* &gt; AC &gt; MC</td>
<td>Serve 100%</td>
<td>Yes.</td>
</tr>
</tbody>
</table>

Table 1: Bang for the Buck Rule outcomes, given two identical bidders

Discussion of Table 1. Case #1: Neither bidder can profitably serve the tract. Neither receives a subsidy. This is efficient. Case #2: Since MC > AC, each bidder has an incentive to serve fewer road-miles, thereby lowering its average cost to gain a bidding advantage under the Bang for the Buck Rule. In equilibrium, bidders are driven to offer the least amount of road-miles allowed by the rules (75%). Since MC > P*, this is efficient. Case #3: Since MC > AC, bidders are again driven to offer the least amount of road-miles allowed by the rules (75%). Since P > MC, this is now inefficient. Case #4: Since MC < AC, each bidder has an incentive to serve more road-miles, thereby lowering its average cost to gain a bidding advantage. In equilibrium, bidders are driven to serve 100% of the roads in the tract. Since MC < P*, this is efficient.

7 In all of these cases, for simplicity, I assume that marginal cost, average cost, and the market-clearing price are ranked in the same way, for all quantities \( q \) in the relevant 75%-100% range.
B. ROAD-MILE MAXIMIZING RULE

The fact that equilibrium bidding can lead to inefficient outcomes under the Bang for the Buck Rule is not really so surprising. Suppose that one were to conduct a procurement in which quality matters, but only compare bids based on cost. Not surprisingly, such an auction design can induce bidders to submit low-quality bids, a problem that becomes even more acute when there is more competition. A similar dynamic can occur under the Bang for the Buck Rule, with “quality” corresponding to the size of the service footprint and how marginal cost (MC) relates to the marginal opportunity cost of service captured by the market-clearing price (P*).

Fortunately, this is an easy problem to solve: simply align the criteria by which bids are evaluated with the Commission’s true objective of maximizing total road-miles nationwide.8

Road-Mile Maximizing Rule. The set of winning bids is selected so as to maximize the total number of road-miles that are served nationwide, subject to the $300 Million budget.

Under this rule, bidders in competitive tracts are incentivized to submit bids that will provide the greatest social value, rather than to minimize average cost. In particular, on competitive tracts, bidders will now have an incentive to bid on an efficient service footprint, so as to gain an advantage by contributing more toward the Commission’s objective than their local competition. This efficiency benefit of the Road-Mile Maximizing Rule could be substantial.

That said, I should note that the Road-Mile Maximizing Rule is not as simple as it may seem at first glance. Faced with uncertainty about the nationwide market-clearing price P*, each

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8 If the Commission decides to seek to maximize a different objective, such as road-passenger-miles and/or resident population, then the following rule should be modified accordingly.
bider’s optimal strategy could be to submit numerous bids on each tract, for differently-sized service areas. Why? P* represents the opportunity cost of a marginal road-mile served within any given tract. If a bidder could correctly anticipate P*, then he would optimally bid to serve that tract up to the point where marginal cost equals P*. With uncertainty about P*, however, his optimal strategy is much more complex, with different bids targeted to be more or less attractive at different prices P*.  

\[ \text{(9)} \]

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\[ \text{9 This strategic complexity could be significantly reduced by revealing information about P* in an iterative process, allowing bidders to modify their bids depending on P*, until a fixed point is reached.} \]
VI: REPLY TO AT&T’S COMMENT ON MILGROM-EILAT PROPOSAL

Under the Milgrom-Eilat proposal, “[e]ach bid would specify a set of census blocks, a fixed amount of support to be paid if any of the census blocks identified in the bid are selected for an award, and a separate individual amount of support specific to each census block in the package” (Milgrom and Eilat, “The CAF Auction: Design Proposal”, at 13). AT&T argues:

“Mobile wireless providers … have to incur fixed costs associated with building (or upgrading) towers and backhaul, but they face no cost that is comparable to the cost of launching a satellite … As a result, if the Milgrom-Eilet [sic] proposal were adopted, AT&T expects that most wireless providers would specify a close-to-zero price for the overall fixed cost.” (AT&T Comment, pg 17-18)

This argument seems to reflect a misunderstanding of the Milgrom-Eilat proposal. Milgrom and Eilat allow for bids that encompass the entire nation, but also for bids that encompass smaller geographic areas such as the footprint of a transmission tower. The latter sort of bid would likely be utilized by a mobile wireless provider, with the fixed subsidy part of the bid corresponding to the fixed cost of building / upgrading the tower in question.

Indeed, the Milgrom-Eilat proposal includes quite a rich bid-space. For example, yet another possibility is to bid a fixed cost for a given footprint, demanding zero additional subsidy to serve each block within that footprint. Such a bid is very similar to a standard package bid – which specifies a fixed cost to serve all of a given footprint – with the twist that the bidder gives the auctioneer license to pay the same subsidy for any strictly smaller footprint. Since the Milgrom-Eilat proposal allows a very similar sort of bid as in a standard package auction, plus additional options, I see no reason why wireless providers will have more difficulty submitting bids that reflect their true cost structure.
Indeed, to the extent that wireless providers face a non-zero marginal cost (or non-zero marginal benefit) of serving more road-miles within a given transmission area, having the option to express that marginal cost directly will simplify their bidding problem. For example, suppose that a wireless provider can build a tower for $1 Million that can serve 100,000 road-miles, with $1 of additional cost to serve each road-mile. To express this cost structure in a standard package auction, the bidder would need to submit the following package bids: (i) $1,100,000 for all 100,000 road-miles, (ii) $1,099,999 for all combinations of 99,999 road-miles, (iii) $1,099,998 for all combinations of 99,998 road-miles, and so on, a truly ridiculous number of packages overall. By contrast, under the Milgrom-Eilat proposal, the bidder could express this cost structure with a single bid.

While the Milgrom-Eilat proposal is (arguably) simpler than standard block-level package bidding, it is still much more complex than the tract-level bidding design also under consideration for the Mobility Fund Phase I auction. (See Sections IV-B and IV-C for related discussion of tract-level bidding.) Such complexity in the design of the auction could create strategic complexity, if bidders’ optimal strategies are not to submit truthful bids reflecting their costs. Given the great richness of the bid-space in the Milgrom-Eilat proposal, there could be ways for sophisticated bidders to “game” the auction that no one has even thought of yet. Big bidders like AT&T might even hire game theorists to tease out such hidden sources of strategic advantage in the auction, potentially putting unsophisticated bidders at a disadvantage and/or inducing inefficient outcomes in ways that we cannot yet anticipate.

THIS CONCLUDES MY COMMENT.