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June 11, 2015

EX PARTE VIA ECFS

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Room TW-A325
Washington, D.C. 20554

Re: ***Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268;**
***Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, AU Docket No. 14-252**

Dear Ms. Dortch:

T-Mobile USA, Inc.[1] and United States Cellular Corporation jointly submit the attached study, *Comments on the Assignment Round*, by Stanford University economists Dr. Gregory Rosston and Dr. Andrzej Skrzypacz, and Northwestern University economist Dr. Robert J. Weber, who propose using a deferred acceptance algorithm for the assignment round in the 600 MHz incentive auction.[2]

Once the forward auction ends, the incentive auction design must address how to assign specific licenses to the generic license winners. In its *Comment Public Notice*, the Commission proposed to optimize assignments for contiguity and other factors and then conduct a single-round, sealed-bid assignment round auction to allow bidders to express preferences for specific

[1] T-Mobile USA, Inc. is a wholly-owned subsidiary of T-Mobile US, Inc., a publicly traded company.

[2] Gregory Rosston is Deputy Director and Senior Fellow at the Stanford Institute for Economic Policy Research and Director of the Public Policy program at Stanford University. Andrzej Skrzypacz is the Theodore J. Kreps Professor of Economics at the Stanford Graduate School of Business and a Professor, by courtesy at the Department of Economics. Robert J. Weber is the Frederic E. Nemmers Distinguished Professor of Decision Sciences at the Kellogg School of Management, Northwestern University.

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license assignments not already addressed by the optimization phase.[3] As several commenters have explained, however, a single-round, sealed bid assignment auction is uncertain, risky, and potentially damaging to the auction.[4] First, there is no market for license assignments, so bidders have little guidance on the "proper" amount to bid during the assignment round. Second, a bidder's preference for any one license assignment may rest in part on information about hundreds and possibly thousands of other license assignments that will remain unknown. Third and perhaps most important, bidding during the assignment-round will remove revenue from the pool of funds used to clear broadcasters from the 600 MHz band, which could result in less spectrum available for broadband use.

To avoid these problems, several parties have proposed a variety of less risky, non-monetary alternatives to a single-round, sealed-bid assignment auction.[5] Indeed, the desirability of some type of revenue-neutral assignment round is one of the few areas in which there is widespread agreement by a wide variety of commenters.[6]

Building on prior submissions in the record, Professors Rosston, Skrzypacz, and Weber propose a three-step preference model or "deferred acceptance algorithm" to assign specific licenses to winning bidders. First, the Commission's auction system would ask all winning bidders to rank all geographic area licenses according to their preferences. The system would then randomly order bidders and pick the first bidder's first geographic license preference as the first geographic area to begin assigning licenses. Second, within the chosen geographic license

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[3] *See Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, Public Notice, 29 FCC Rcd. 15750, 15813-15 ¶ 199-209 (2014); *see also In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd. 6567, 6779-80 ¶¶ 513-518 (2014).

[4] *See, e.g.*, Robert Weber, *The Danger of Using a VCG-Style Auction for the Assignment Phase of the Forward Auction* (March 26, 2015), *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (March 26, 2015); *Bidding Procedures for the Broadcast Incentive Auction* (April 22, 2015), *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (April 22, 2015); Philip Haile, *Comments on U.S. Cellular's Assignment Phase* (May 15, 2015), *attached to* Letter from Christopher T. Shenk, Counsel to AT&T, to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (May 15, 2015); Reply Comments of T-Mobile USA, Inc., AU Docket No. 14-252, GN Docket No. 12-268 (March 13, 2015); Comments of Competitive Carriers Association, AU Docket No. 14-252, GN Docket No. 12-268 (February 20, 2015).

[5] *See id.*; *see also, e.g.*, Comments of Cellular South, Inc., AU Docket No. 14-252, GN Docket No. 12-268 at 6 (Feb. 20, 2015); Comments of Competitive Carriers Association, AU Docket No. 14-252, GN Docket No. 12-268 at 35-40 (Feb. 20, 2015); Comments of United States Cellular Corp., AU Docket No. 14-252, GN Docket No. 12-268 at 7-23 (Feb. 20, 2015); Reply Comments of Rural Wireless Association, Inc. and NTCA—the Rural Broadband Association, AU Docket No. 14-252, GN Docket No. 12-268 at 5 (Mar. 13, 2015); Reply Comments of T-Mobile USA, Inc., AU Docket No. 14-252, GN Docket No. 12-268 at 32 (Mar. 13, 2015).

[6] *See id.*

area, the system would assign the first-ranked bidder its bundle of preferences, which would reduce the set of feasible license assignments within that area for all other bidders. Third, the system would examine the second bidder's preferences within the same geographic licenses and choose the most preferred bundle given the constraints of the prior assignments. This process would continue until all of the licenses in the geographic license area were assigned. As Professors Rosston, Skrzypacz, and Weber explain, this type of deferred acceptance algorithm model is well established and widely used. This proposed mechanism can efficiently and equitably solve complex preference-ordering challenges without the risk and uncertainty of a single-round, sealed-bid assignment auction.

Pursuant to Section 1.1206(b)(2) of the Commission's rules, an electronic copy of this letter is being filed for inclusion in the above-referenced dockets.

Respectfully submitted,

/s/ Trey Hanbury

Trey Hanbury
Counsel to T-Mobile USA, Inc.

Comments on the Assignment Round

Gregory Rosston, Andrzej Skrzypacz, & Robert J. Weber[1]

Improvements to the design of the assignment round for the Federal Communication Commission's 600 MHz auction will help to increase revenues in the clock round and the chances of satisfying the Final Stage Rule ("FSR").[2] In addition, the assignment round can increase the efficiency of spectrum use. This submission builds on the submissions by Robert Weber (on behalf of United States Cellular Corporation ("US Cellular")), Philip Haile (on behalf of AT&T, Inc. ("AT&T")), T-Mobile USA, Inc. ("T-Mobile"), Competitive Carriers Association ("CCA") and other parties that discuss a variety of non-monetary mechanisms for awarding licenses in the assignment round.[3] These submissions raise important issues regarding revenue

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[1] Gregory Rosston is Deputy Director and Senior Fellow at the Stanford Institute for Economic Policy Research and Director of the Public Policy program at Stanford University. Andrzej Skrzypacz is the Theodore J. Kreps Professor of Economics at the Stanford Graduate School of Business and a Professor, by courtesy at the Department of Economics. Robert J. Weber is the Frederic E. Nemmers Distinguished Professor of Decision Sciences at the Kellogg School of Management, Northwestern University.

[2] As currently envisioned, the FSR has two components that must be satisfied. The first is an average price per MHz-pop benchmark; the second is a requirement that the proceeds be sufficient to cover certain costs to be funded from the proceeds of the auction. *See In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Order, 29 FCC Rcd. 6567, 6578 (2014); *Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 100, Including Auctions 1001 and 1002*, Public Notice, 29 FCC Rcd. 15750, 15769-15774 (2014) ("*Comment Public Notice*").

[3] *See, e.g.*, Robert Weber, *The Danger of Using a VCG-Style Auction (or any other revenue-generating procedure) for the Assignment Phase of the Forward Auction* at 5 (March 26, 2015) *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (March 26, 2015) (proposing to "allow bidders to express preferences without generating payments" by allocating a supply of points among the bidders); Bidding Procedures for the Broadcast Incentive Auction (April 22, 2015) *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (April 22, 2015) (proposing either a 100 point-based bidding system in which each winner in the clock phase would be allocated a budget of points for use in selecting assignments, or the use of random or quasi-random license assignments); Philip Haile, *Comments on U.S. Cellular's Assignment Phase* (May 15, 2015), *attached to* Letter from Christopher T. Shenk, Counsel to AT&T, to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (May 15, 2015) ("AT&T May 15 Ex Parte") (endorsing many aspects of a points system over other non-monetary alternatives, but awarding more points to those bidders with larger budgets); Reply Comments of T-Mobile USA, Inc., AU Docket No. 14-252, GN Docket No. 12-268 at iv (March 13, 2015) ("T-Mobile Reply Comments") ("using a quasi-random assignment process after applying

and efficiency and make relevant contributions to identifying the nature of the assignment problem that needs to be solved.

Background

Once the forward auction is complete, the auction system will attempt to maximize contiguity of spectrum assignments when a bidder wins more than one license in a PEA. The Commission has proposed an optimization approach that would pursue three objectives in the following order of priority: (1) maximize the number of multiple-block winning bidders that receive at least two contiguous blocks; (2) minimize the number of assigned blocks that are non-contiguous to the bidder's other blocks for bidders that won two or more blocks; and (3) maximize the number of bidders that are assigned only contiguous blocks.[4]

These optimization objectives are constructive, but incomplete in that not all preferences can be taken into account using any reasonable number of objectives. The ensuing assignment round should allow for an expression of these preferences, which arise because the licenses in a category in a PEA may not be perfectly homogeneous from the perspective of some bidders.[5] For example, there may be some divergence in the impairment levels of Category 1 licenses in a PEA. The Category 1 divergence in value is a maximum of 15% coverage differential; however, at least some of the differential in value will be accounted for by the automatic impairment

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limited frequency and geographic contiguity objectives could clear more spectrum for broadband use and result in a more equitable distribution of spectrum resources among auction participants than an assignment auction"); Comments of Competitive Carriers Association, AU Docket No. 14-252, GN Docket No. 12-268 at 38 (February 20, 2015) ("the Commission should establish a limited number of primary selection awards available to all carriers with provisionally winning bids: in essence, each carrier would receive ten or some other limited number of 'draft picks' to use on particular spectrum assignments").

[4] *Comment Public Notice* at 15814-15815.

[5] *See, e.g.,* Sprint Comment Public Notice Presentation at 3 (March 17, 2015) *attached to* Letter from Rafi Martina, Counsel, Sprint Corp., to Marlene H. Dortch, Secretary, FCC, AU Docket No. 14-252, GN Docket No. 12-268 (March 19, 2015). *But see* T-Mobile Reply Comments at 18-19 ("the [one-to-one impairment-to-price] discount . . . provides enough commonality among licenses to allow for generic license bidding").

discount of one percent from the winning bid price for every one percent of impairment. For Category 2 licenses, the divergence in coverage value could be greater, although the automatic impairment discount would still account for some of the differential in value.[6] In addition to percentage-impairment differentials, however, some parties may value specific licenses differently because of frequency and geographic adjacencies not already taken into account by the optimization objectives, or because of the detailed nature of the specific impairment. As a result, bidders may value the blocks as imperfect substitutes, even after application of the optimization objectives and payment adjustments.

Determining license assignments within PEAs

After the FCC has completed its initial assignments or constraints on assignments using its optimization objectives, we propose that every bidder submit a rank order for the package assignments for which it is eligible within each individual PEA (or PEA group).[7] The FCC would then run a form of a "deferred acceptance" algorithm within each PEA.[8] The FCC would determine a rank order of the winners in the given PEA. (We propose how to determine this

[6] We understand that while there is a wide band (15% - 50% impairment) for Category 2 licenses, the impairments may affect multiple licenses to a similar degree so that the licenses are unlikely to diverge in coverage value by the maximum amount.

[7] The Commission has proposed separately grouping "high-demand" PEAs with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks and non-high-demand PEAs within a Regional Economic Area Grouping ("REAG") that satisfy that same criteria. *Comment Public Notice* at 15813-15814. For simplicity, this proposal refers to the assignment of PEAs but could be applied equally to PEAs or groups of PEAs. However, the Commission could elect to forego the grouping process altogether to maximize the benefits of the deferred acceptance process described here.

[8] Deferred acceptance algorithms are well accepted and have been used in many different settings around the world. *See, e.g.*, Atila Abdulkadiroğlu & Tayfun Sönmez, *Matching Markets: Theory and Practice*, Paper Prepared for 2010 World Congress of Econometric Society, *available at* http://bit.ly/1Bnuz39. Since its initial formulation more than fifty years ago, this algorithm has been refined for use in everything from making student assignments in public schools to organizing kidney-exchange programs. *See id.* at 41. Indeed, the Royal Swedish Academy of Sciences awarded the 2012 Nobel Prize in Economic Sciences in recognition of the importance of this type of practical solution for complex matching problems. *See, e.g.*, THE ROYAL SWEDISH ACADEMY OF SCIENCES, *Stable Matching: Theory, Evidence, and Practical Design*, *available at* http://bit.ly/1esuEha.

order below). Then the algorithm would follow a straightforward sequential method to match bidders with their preferred license assignments.

First, the system would allocate to the rank-1 bidder its preferred bundle from the set of bundles that are feasible for that bidder subsequent to the FCC's contiguity optimizations. This assignment could reduce the set of feasible assignments remaining for other bidders. Next, the system would look at the rank-2 bidder's preferences and allocate the most preferred remaining feasible bundle to that bidder. The system would continue to make assignments through the ranks until all of the licenses in the PEA are allocated.[9]

Using this type of well understood and widely accepted deferred acceptance algorithm has the following positive properties, assuming that bidders care about their own allocation and do not want to make it worse for competitors:

1) There is no revenue left in the assignment auction.

2) The allocation will be Pareto-efficient in the ordinal sense. That is, there could be no reallocation of the licenses that would make the winners better off without payments to them.

3) Bidders optimize their assignments by reporting preferences truthfully, which should make the assignment round much less complicated.

4) The deferred acceptance algorithm is widely used in other applications; therefore, this algorithm is less risky to use than other possible mechanisms that have undergone far fewer practical tests and applications.

Determining Order within a PEA

We propose to determine the order in which the FCC allocates the rank order of choosing rights across all PEAs, and at the same time to determine the order in which PEAs will be

[9] This mechanism is equivalent to a so-called "serial dictatorship allocation" with a quasi-random order and with the FCC's constraints on allocations used to satisfy the objective of frequency contiguity. For the algorithm, if some PEAs were grouped, they would be treated as one PEA.

processed, in the following way. Each bidder would be asked to rank all the PEAs in which it has won some licenses in terms of how important the allocation in that PEA is to that bidder. Then, the FCC would randomly pick a rank ordering of all of the winning bidders, 1…N.

To begin, bidder 1's ordered list of PEAs would be consulted to choose the first PEA in which the FCC will allocate licenses. The assignment-selection ordering in that PEA would be that bidder 1 chooses first, bidder 2 chooses second, bidder 3 chooses third and so on.

Next, the FCC would remove that now-fully-assigned PEA from all the bidders' ordered lists, and choose the PEA ranked highest by bidder 2. In that PEA, bidder 2 would then choose first, bidder 3 would choose second and so on, with bidder 1 following bidder N. (In other words, bidder 1 would now be at the bottom of the stack.)

When the procedure reaches bidder N, the FCC would choose the first remaining PEA in that bidder's ordered list, and bidder N would choose a feasible assignment. Bidder 1 would choose second in that PEA and so on.

In the following round, the FCC again would allow bidder N's ranking to determine the next chosen PEA, with the successive choices of assignments being made by bidder N, bidder N-1, bidder N-2, and so on. Bidder N-1 determines the next chosen PEA, within which choices are made in turn by bidder N-1, bidder N-2 and so on. The process continues in this manner until bidder 1 determines the next chosen PEA. After that, the original process starts all over again.[10]

Sample Application of Deferred Acceptance Model

An example may assist in understanding how the proposed rule would apply to the assignment round. Assume that there are seven PEAs (A, B, C, D, E, F, G), each with four

[10] Giving bidder N two successive first choices, and then continuing to work backwards towards bidder 1, mimics the manner (known as a "snake draft") in which fantasy football leagues strive for equity while running their player drafts. As the choice of PEA moves backwards, the use of the reversed order for the within-PEA assignment selections equalizes the number of times either of any two bidders precedes or follows the other.

licenses. For simplicity, assume that each bidder wins a single license in any PEA; however, the same logic would apply with multiple licenses. Assume further that there are six winning bidders, ordered *i, j, k, l, m, n* by the FCC's initial randomization. The winners across the seven PEAs are listed in the following table, together with the "importance ordering" each assigns to the PEAs in which it has won licenses.

	i	***j***	***k***	***l***	***m***	***n***
A	1	1		2		4
B	2	2		3	2	
C	3	3	4			3
D	4	5	1	1		
E	5	7	2		1	
F	6	6	3			2
G	7	4	5			1

Note that both *i* and *j* have licenses in each PEA and the others have licenses in two or more PEAs.

Bidder *i* is the rank-1 bidder, and its top-ranked PEA is A. *i* would get first choice in A; *j* would get second choice; *l* would get third choice; and *n* would get the final choice (if a choice somehow remained). Next, the FCC would choose PEA B, bidder *j*'s top-ranked remaining PEA. *j* would get first choice in PEA B; *l* would get second choice; *m* would get third choice; and *i* would get the final choice. *k*'s preference for PEA D would mean that licenses in that PEA would be assigned next in the order, *k, l, i, j*. All of bidder *l*'s preferred markets will have been assigned by its turn so the FCC would move to bidder *m* and assign PEA E in the order, *m, i, j, k*. Since bidder *n* has PEA G as its first unassigned choice, licenses in that market would be assigned next, in the order *n, i, j, k*. The next assignment would look again to bidder *n* and assign PEA F, in the order *n, k, j, i*. The final assignment would be PEA C in the order *k, j, i, n*.

Discussion

The deferred acceptance algorithm has many favorable properties. The algorithm has been proven to work well in practice many times in a variety of settings.[11] Application of a deferred acceptance algorithm in this case should elicit truthful revelation and return a fair allocation of resources in a timely manner.

For bidders who win in many markets, the procedure of choosing the order within a PEA will result in getting a fair share of high-picks and low-picks. We think it will also be a fair procedure for bidders who win in a few markets, especially if these are markets that are outside the very top ones. We expect that bidders with many winnings will rank the largest (by population) markets the highest to increase their chances of getting the "first pick" in them. If so, even if a smaller winner is unlucky and receives a bad draw in the order of bidders, by the time the order reaches that bidder, it is unlikely that its most-preferred PEA would be already allocated.[12]

This ranking-PEAs method addresses the issue raised by Haile that bidders may vary in their strength of preference over allocations in different PEAs.[13] For example, if bidders A and B agree that in the Denver PEA license 1 is better than license 2 and in the Atlanta PEA license 1 is better than license 2, but for bidder A the allocation in Denver is more important while for

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[11] *See, e.g.,* Eric Gossett, *Discrete Mathematics with Proof* 7 (2009) (discussing use of deferred acceptance algorithms for college acceptances and medical residencies); Alvin Roth, *Deferred Acceptance Algorithms: History, Theory, Practice and Open Questions* at Table 1 (2007), *available at* http://bit.ly/1G0aJCr (listing the use of deferred acceptance algorithms in the labor market for a variety of professions, including pediatric dentistry, abdominal transplant surgeons, law firms, psychology, and other professions).

[12] At some additional cost of complexity, the Commission could augment the proposed algorithm to further reduce risk by, for example, increasing the chances that a bidder would choose second if given the selections so far, it had chosen second less often than expected based on the proposed algorithm.

[13] Philip Haile, *Comments on U.S. Cellular's Assignment Phase* at 8 (May 15, 2015), *attached to* AT&T May 15 Ex Parte.

bidder 2 the allocation in Atlanta is more important, the ranking PEAs method will allow them to express this preference and achieve more efficient allocation than choosing the order randomly.

As discussed above, deferred acceptance algorithms are widely used and adapted given their fast runtimes, broad applicability, and simplicity.[14] While bidders will need some amount of time to develop their preferences for all of the possible license combinations after the end of the clock round, this process can be accelerated. If the Commission were to release to each bidder the set of possible allocations after it has run its initial assignment process, for example, bidders would be able to focus on the set of licenses that are possible and to reduce the amount of time necessary between the end of the clock phase and the start of the assignment phase.[15]

It also may help bidders to know the outcomes of some of the PEA assignments before they submit preferences for subsequent licenses. For example, AT&T seems to view frequency contiguity over a geographic area as an important value.[16] As a result, knowing that it has frequency A in one PEA could change its preferences in adjacent PEAs.

In terms of timing, the algorithm we are proposing faces the same trade-offs as any other assignment procedure, including a point-based system and an assignment auction. On the one hand, it would be beneficial to perform the process quickly to reduce administrative costs. On the other hand, winners' preferences over allocations in a given PEA may depend on the allocations they receive in adjacent PEAs. The process we propose is flexible in responding to these concerns: the Commission could run the process sequentially, only asking the winners to provide rankings for the current PEA after the initial winners observe their own allocations in the

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[14] *See, e.g.,* Christian Haas, *Incentives and Two-Sided Matching: Engineering Coordination Mechanisms for Social Clouds*, 147 (1st ed. 2014), *available at* http://bit.ly/1ArW3tB.

[15] *See, e.g.,* Reply Comments of AT&T, AU Docket No. 14-252, GN Docket No. 12-268 at 4-5 (March 13, 2015).

[16] AT&T May 15 Ex Parte at 2-3.

previous PEAs. Conversely, bidders could be asked for all their rankings at once and then the system would run automatically in seconds. We support a sequential approach, but also recognize the possible efficiency advantages of a hybrid approach, which would allow sequential allocation in a few major PEAs to anchor preferences in different geographical regions and then ask winners to provide rankings simultaneously for multiple PEAs.

Conclusion

Matching theory as identified in deferred acceptance algorithms offers stable, well-developed mechanisms to efficiently and equitably solve otherwise complex preference-ordering challenges. The FCC should rely on this established body of literature to adopt a deferred acceptance algorithm such as the one proposed here. Doing so will allow the FCC to address the matching challenges posed by the 600 MHz Band in the incentive auction's assignment round.