

## APPENDIX G

### Forward Auction Clock Phase

#### 1 Introduction

This appendix provides a final version of Appendix G of the *Auction 1000 Comment PN* detailing the first part of the forward auction procedure adopted by the Commission in the *Auction 1000 Bidding Procedures PN*: the clock phase. Overall, this clock auction is designed to share some major features with the simultaneous multiple round auction (SMRA) format, but to run to completion in a fraction of the time that an SMRA would require. Like an SMRA, the clock phase of the forward auction proceeds through a sequence of ascending prices for the licenses. Also, like an SMRA with no bid withdrawals, once there is demand for a license in the auction, the license will not then go unsold. The clock auction design, however, includes three features that allow it to run in less time than the corresponding SMRA.

The first of these features is that the clock auction aggregates demand within each category of generic licenses, rather than treating each license as a distinct item for bidding. In a traditional SMRA, if during the auction, there were five units of demand for four very similar licenses, then at each round of the bidding, only one of the four licenses would have a new bid to raise its price. With that pattern of bidding it would take four rounds for all the license prices to rise by one bid increment. In a clock auction, by treating all four licenses as a single product, a single price increment applies to all, so the same price increase takes just one round, instead of four.

The second feature that is different in the clock auction design is the assignment phase, details of which are described in Appendix H. This feature is made necessary by the generic licenses structure, and highlights another important advantage of generic licenses in the incentive auction context. If the incentive auction used an SMRA with individually identified licenses, the auction rules would need to specify which of those licenses would be eliminated whenever the auction moves into a new stage. Uncertainty about not just the number of blocks that will be available, but also about which particular frequencies will be associated with the available blocks, would complicate bidding in the forward auction. By having a separate assignment phase to determine which particular frequencies each bidder will acquire, the auction allows each phase of the auction to perform a function for which it is best suited. Specifically, the clock phase identifies the number of licenses in each category that each bidder will acquire in a PEA, while the assignment phase determines the particular frequencies. This separation makes bidding much easier and, because it avoids solving the assignment problem except in the final stage, it reduces the time required for the auction.

The third feature that distinguishes this clock auction from the SMRA is *intra-round bidding*. This feature performs two important functions. First, it avoids price overshooting. If there were no intra-round bidding, the price for a category of blocks might rise so high in a round that a category with excess demand at the start of a round would have insufficient demand at the end of the round. With intra-round bidding, the price for a category stops rising as soon as demand falls to the level of supply, so there is no risk of overshooting. Second, intra-round bidding allows a clock auction to utilize larger bid increments than a corresponding SMRA, which helps bring the auction to a close more quickly. In an SMRA, the bid increments must be set small enough that a bidder who is willing to raise a price can afford to do so without exceeding its maximum price. In a clock auction with intra-round bidding, however, a bidder can specify the highest price between the beginning and end of round prices at which it wishes to maintain its

current demand, so that a bidder will not be deterred from further bidding when the full bid increment is larger than it is willing to pay.

In order for the clock auction design to achieve these benefits, it needs to include bid types that allow bidders to execute strategies similar to the ones they would use in an SMRA. This appendix describes three kinds of bidding plans that bidders commonly execute in an SMRA, and the corresponding three types of bids that facilitate those strategies in this clock auction. First, in an SMRA, when the price of a license becomes too high, a bidder can reduce demand by refraining from bidding again on that license. In the clock auction design, the *simple* bid performs that same function, that is, it allows a bidder to reduce demand for a category when its price rises above any price that the bidder may identify. Second, in an SMRA, when one license price rises too high compared to that of another license (in the same PEA), a bidder can stop bidding for the first license and start bidding for the second. In the clock auction, a bidder can do the same by making a *switch* bid, in which it specifies that it will shift demand from one category to the other when the price of the first category gets too high. Finally, suppose that for some category, a bidder wants to buy two blocks if the price is sufficiently low, but wants to avoid acquiring just one block of that type. In an SMRA, when the prices of a set of licenses are rising, the bidder can limit the possible outcomes by refraining from raising its bid on one license and waiting to see what happens, possibly using a waiver. If there is demand by other bidders for both of its licenses, it can then stop bidding on both. In this clock auction design, a bidder can accomplish the same by use of an *all-or-nothing* bid for a category. In the example, a bidder that is currently demanding two blocks of one category can specify that it will reduce its demand for that category to zero, but that it will not reduce its demand to just one block at the specified price.

The remainder of this document describes the procedures that accomplish all this in more detail, including technical descriptions of the various calculations.

## 2 Overview

The clock phase of the forward auction will consist of a series of timed bidding rounds. During each bidding round, bidders will place bids indicating demand for generic blocks in a particular license category in a particular PEA, at a price they specify between the start of round price and the end of round price (the *clock price*). After each bidding round closes, the bids are processed. Bid processing determines the quantity of a bidder's requested demand that is applied (the *processed demand*) and the start of round price of each product for the next round, if there is to be a next round (the *posted price*). After the bids are processed the system determines whether the next round will be a regular clock round or an *extended round*, or, if the final stage rule is met and there is no excess demand for blocks in any category in any PEA (indicating satisfaction of the closing conditions), the clock phase of the forward auction will end. Finally, the auction system sets up the next round, if there is to be one, including calculating the prices for each category in each PEA for the next round.

Section 3 describes several rules and definitions that are useful in understanding how the forward auction functions. Section 4 describes the bidding rules. Section 5 describes the calculations for the bidding information that is shown to bidders. Section 6 describes the types of bids bidders can place in the clock rounds of the forward auction. Section 7 describes bid processing in a regular clock round. Section 8 describes how the system checks whether the closing conditions have been met, and if not, determines the round type for the next bidding round. Section 9 describes how the system sets up that next round.

Section 10 describes the bid processing steps performed for an extended round. Finally, Section 11 describes how the system handles the mobile spectrum holdings reserve split.

### **3 Rules and Definitions**

This section describes several rules and definitions that are useful in understanding how the forward auction functions.

#### **3.1 Products**

A product is defined to be the pairing of a PEA and a license category. Before the spectrum reserve split, there are at most two products in each PEA. After the spectrum reserve split, there are at most three products in each PEA.

#### **3.2 Extended Round Products**

The *extended round products* are the Category 1 products in the 40 high-demand PEAs for which aggregate processed demand is equal to supply at the time that the extended round is triggered. The set of extended round products is denoted by “ER.”

If there are any Category 1 products in high-demand PEAs for which aggregate processed demand is strictly less than supply, those products will not be included for bidding in the extended round. Note that an extended round is not triggered unless the aggregate processed demand is less than or equal to supply for every Category 1 product in a high-demand PEA.

#### **3.3 Acceptable Bids**

*Acceptable bids* are ones that can be applied in full or in part when they come up for processing in a round. No bid will be applied that reduces the aggregate demand for blocks in a category below the available supply. This processing restriction ensures that once the final stage rule has been met, revenue cannot fall below what is required to meet the final stage rule. Specifically, by not allowing aggregate demand to fall below supply, the total proceeds of the forward auction can only stay the same or increase each round.

As a result of this restriction, some bids that request a reduction in the number of blocks in a category demanded by a bidder may not be applied in their entirety. Moreover, a bid that requests an increase in the number of blocks in a category demanded by a bidder will not be applied in its entirety if the bidder does not have sufficient bidding eligibility.

This section describes the circumstances under which a bid is applied either fully or partially.

##### **3.3.1 Fully Acceptable Bids**

A bid is *fully acceptable* if, at the time it is considered during processing, the following conditions both hold:

- (a) If the bid were applied in its entirety, the total number of bidding units associated with the bidder’s demand would not exceed the bidder’s eligibility in the current round;
- (b) If the bid were applied in its entirety, the aggregate demand would not be less than the supply for that product.

Only bids that are fully acceptable will be applied in their entirety during bid processing, with the following exception in the case that the auction transitions to a new stage:

In the first round of a new stage, a bid to reduce demand for a Category 2 product is considered fully acceptable even if condition (b) above is not satisfied. That is, such a bid will be applied in full during bid processing, even if there is no excess demand at the time the bid is considered during bid processing. This relaxation of the rule in the first round of a new stage allows bidders to adjust their demand for a Category 2 product if the supply and impairments of the blocks of that product have changed significantly as a result of lowering the clearing target and re-optimizing the location of impairing stations in the 600 MHz Band.

### 3.3.2 Partially Acceptable Bids

If a bid is not fully acceptable, it may be considered *partially acceptable* if, at the time it is considered during processing, the following conditions both hold:

(a') If the bid were applied *partially*, the total number of bidding units associated with the bidder's demand would not exceed the bidder's eligibility in the current round; and

(b') If the bid were applied *partially*, the aggregate demand would not be less than the supply for that product.

Examples of fully and partially applied bids are provided in Section 6.

### 3.4 Activity and Eligibility

A bidder's *processed activity* is equal to the total number of bidding units associated with the bidder's processed demand after the bid processing of the round.

An activity rule is used in the forward auction in order to require bidders to participate in each round of the auction. A bidder's eligibility in round 1 of stage 1 of the forward auction is determined by the bidding units associated with its upfront payment. A bidder's eligibility in subsequent rounds of any stage is calculated based on its eligibility in the previous round, its processed activity, and the activity requirement. A different calculation is used to calculate a bidder's eligibility in round 1 of a new stage if the last round of the prior stage was an extended round. See the calculations in Sections 9.1 and 9.2 for details.

## 4 Bidding

A bidder in the forward auction responds in each round by indicating its demand for blocks of the products it desires at current prices. When submitting a bid, the bidder specifies a quantity and a price. The price can be last round's posted price, this round's clock price, or any price in between (an "intra-round bid"). In each round, bidders may place multiple bids, including multiple bids for the same product. For example, a bidder that begins a round with processed demand of 4 units of some product might reduce its demand for that product from 4 to 3 at a price of \$5,500 and from 3 to 2 at a price of \$5,800.

In order to give bidders flexibility to express their demands, the forward auction includes three different types of bids: simple bids, all-or-nothing bids (with an option of "backstopping" the all-or-nothing bid), and switch bids. Section 6 provides a detailed explanation of each bid type along with examples to illustrate each of these bid types and how the auction system will process them.

## 4.1 Bidding Rules

In the first round of the auction, bidders may only submit a bid for a product at the *opening price* for that product. For all rounds subsequent to round one, bidders may submit a bid for a product at a price that is a whole dollar amount greater than or equal to the last round's *posted price* for that product and less than or equal to the current round's *clock price* for that product.

In every round, a bidder may only bid for a quantity that is greater than or equal to 0 and less than or equal to the supply for that product.

A bidder will *not* be allowed to submit a bid or collection of bids if the bidder's *activity* for the round would exceed its *current eligibility*.

A bidder may submit a bid on a reserved product only if the bidder is reserve-eligible in the PEA associated with that product.

In any round after the spectrum reserve has been triggered, a bidder that is reserve-eligible in a PEA subject to the small market bidding cap cannot bid for 3 (or more) blocks of the reserved product in that PEA.

In an extended round, a bidder may only bid on extended round products (see Section 3.2 for the definition). Also in an extended round, a bidder may only submit a simple bid for a quantity equal to either its current processed demand for that product or one block less.

In any regular clock round, a bidder may only submit one of the three types of bids for a given product: simple bids, all-or-nothing bids, or switch bids. However, it can submit multiple bids of the same type for a given product. For example, if a bidder places a simple bid for product A, then it cannot submit an all-or-nothing bid for product A nor can it submit a switch bid that involves product A in the same round.

A bidder may *not* submit two switch bids with the same "from" product and different "to" products in the same round.<sup>1</sup>

A bidder may *not* submit two different bids that involve the same product at the same price. For example, the bidder cannot submit a simple bid for 2 blocks of product A and a simple bid for 0 blocks of product A both at the same price. Similarly, if A and B are products in the same PEA, the bidder cannot submit a bid to switch one block from A to B and another bid to switch two blocks from A to B both at the same price<sup>2</sup>.

A bidder may *not* submit two bids for the same product that involve the same quantity at different prices. For example, the bidder cannot submit a simple bid for 2 blocks of product A at price \$1,050 and a simple bid for 2 blocks of product A at price \$1,070.

All of the bids submitted by a bidder in a round for a product must be *one-directional* in terms of price. That is, if all of the bids submitted by a bidder in a round for a product are put in ascending order by price, the corresponding quantities must all either increase or decrease starting from the bidder's

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<sup>1</sup> However, a bidder may submit two switch bids with the same "to" product and different "from" products in the same round.

<sup>2</sup> If the bidder were allowed to submit such bids, the system would need to randomly select which bid to process first.

processed demand from the previous round. The algorithm that determines *one-directionality* is described below.

#### 4.1.1 Algorithm for One-directionality

The following algorithm illustrates how one can check one-directionality for bidder  $i$  and a given product  $r$ . Let  $A$  denote the set of bids that the bidder has just requested to submit, and  $B$  denote the set of bids that the bidder has already submitted in this round.<sup>3</sup>

The algorithm looks at all bids for product  $r$  in  $A$  and  $B$ . It ranks them in price order, then checks the direction of the change and validates that all bids at higher prices maintain the same direction.

- Let  $A_r$  consist of all bids in  $A$  that involve product  $r$ . This includes switch bids for which  $r$  is the “from” product. Each element of  $A_r$  is represented by the pair (price, quantity for product  $r$ ).
- Similarly, let  $B_r$  consist of all bids in  $B$  that involve product  $r$ . Each element of  $B_r$  is represented by the pair (price, quantity for product  $r$ ).
- Let  $S$  denote the union of  $A_r$ ,  $B_r$  and the following element: (posted price of previous round for product  $r$ , processed demand from previous round for product  $r$ )
- Rank all elements of  $S$  in ascending order of price, and let  $q$  be the corresponding vector of quantities. That is,  $q(1)$  is the processed demand from the previous round,  $q(2)$  is the quantity associated with the lowest-price bid for product  $r$  in  $A \cup B$ , etc. Let  $N$  be the number of elements in  $q$ .
- Check whether one of the following conditions holds:
  - (i)  $q(2) \geq q(1)$  and  $q(k) > q(k - 1)$  for  $k = 3, 4, \dots, N$ .
  - (ii)  $q(2) \leq q(1)$  and  $q(k) < q(k - 1)$  for  $k = 3, 4, \dots, N$ .

If either (i) or (ii) is satisfied, bids in  $A$  are one-directional with the bids in  $B$  and the bidder’s processed demand from the previous round for product  $r$ . If the bids in  $A$  are one-directional with the bids in  $B$  and the bidder’s processed demand from the previous round for all products, then the system allows the bidder to submit the bids in  $A$ . Otherwise, the bids in  $A$  are not submitted.

#### **Example:**

Suppose that the bidder’s processed demand for product  $r$  from the previous round is 4, and the posted price is \$5,000. In the current round, the clock price is \$6,000. The bidder has already submitted the bids  $B_r = \{(\$5,300, 2), (\$5,400, 0)\}$  for product  $r$  in this round. The bidder is now trying to submit the bids  $A_r = \{(\$5,100, 3), (\$5,200, 1)\}$  for product  $r$ . Then,

$$S = \{(\$5,000, 4), (\$5,100, 3), (\$5,200, 1), (\$5,300, 2), (\$5,400, 0)\}$$

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<sup>3</sup> If the set of bids  $A \cup B$  includes at least one switch bid where product  $r$  is the “to” product, then one-directionality for product  $r$  is satisfied if and only if all bids in  $A \cup B$  that involve product  $r$  are switch bids with  $r$  as the “to” product. See Section 6.3 for details on switch bids.

The following table shows the prices and quantities of the elements of  $S$ , ranked in order of price:

$k$	Price	$q(k)$
1	\$5,000	4
2	\$5,100	3
3	\$5,200	1
4	\$5,300	2
5	\$5,400	0

Observe that  $q(2) < q(1)$  but  $q(4) > q(3)$ . Thus, the bidder will not be allowed to submit the bids in  $A_r$ .

## 5 Calculations for Bidding Information

In the following sections,  $N$  denotes the set of all products.

### 5.1 Activity – Regular Clock Round

When a regular clock round is open for bidding, the *activity* of a bidder is calculated as the total number of bidding units associated with the demand the bidder indicates it is willing to accept at the clock price, given all bids that the bidder has submitted. In other words, the activity of bidder  $i$  is given by the following sum:

$$\sum_r q_{i,r} \cdot b_r$$

Where:

- $q_{i,r}$  denotes the requested demand of bidder  $i$  for product  $r$  at the clock price, given all bids that bidder  $i$  has submitted so far in this round. In particular, if all the bids that are submitted by bidder  $i$  for product  $r$  are applied during bid processing, then its processed demand will be  $q_{i,r}$ .
- $b_r$  denotes the number of bidding units associated with product  $r$

At the beginning of a round, *i.e.*, before the bidder has submitted any bids in this round, the bidder's activity is equal to 0.

#### **Example:**

Product A has 10 bidding units and product B has 8 bidding units. For product A, the clock price is \$6,000, and the previous round's posted price is \$5,000. For product B, the clock price is \$4,800, and the previous round's posted price is \$4,000. Suppose that bidder  $i$  has submitted the following bids in the current bidding round:

- Product A: a simple bid for 4 blocks at price \$5,500, and a simple bid for 2 blocks at price \$5,700.
- Product B: an all-or-nothing bid for 2 blocks at price \$4,500.

After the bidder has submitted these three bids, its activity is:  $(2 \cdot 10) + (2 \cdot 8) = 36$  bidding units.

## 5.2 Activity – Extended Round

When an extended round is open for bidding, the *activity* of a bidder is calculated as the sum of (1) the total number of bidding units associated with the bidder's demand at the clock price, given all bids that the bidder has submitted so far for all *ER* products;<sup>4</sup> and (2) the total number of bidding units associated with the bidder's processed demand from the last round for all non-*ER* products (this component does not change during the extended round). In other words, the activity of bidder *i* is given by the following formula:

$$\sum_{r \in N \setminus ER} d_{\tau,i,r} \cdot b_r + \sum_{r \in ER} q_{i,r} \cdot b_r$$

Where:

- $d_{\tau,i,r}$  denotes the processed demand from the last round of bidder *i* for product *r*, i.e., its processed demand at the time that the extended round is triggered.
- $q_{i,r}$  denotes the requested demand of bidder *i* for product *r* in the extended round, given all bids that bidder *i* has submitted so far. In particular, if the bidder submitted a bid for its processed demand from the last round for product *r* at the clock price of the extended round, then  $q_{i,r}$  is equal to the bidder's processed demand from the last round for product *r*. If the bidder submitted a bid to reduce its demand by one block in the extended round, then  $q_{i,r}$  is equal to the bidder's processed demand from the last round for product *r* minus one. If the bidder's processed demand from the last round for product *r* is 0, then  $q_{i,r} = 0$ .
- $b_r$  denotes the number of bidding units associated with product *r*.

At the beginning of an extended round, i.e., before the bidder has submitted any bids in this round, the bidder's activity is equal to the total number of bidding units associated with (i) the bidder's processed demand from the last round for all non-*ER* products (the first term in the formula above) and (ii) one less than the bidder's processed demand from the last round for all *ER* products for which it has a positive processed demand. This is given by the following formula:

$$\sum_{r \in N \setminus ER} d_{\tau,i,r} \cdot b_r + \sum_{r \in ER: d_{\tau,i,r} > 0} (d_{\tau,i,r} - 1) \cdot b_r$$

## 5.3 Required Activity

A bidder's *required activity* in round *t* is the minimum total number of bidding units associated with the bidder's processed demand that the bidder should have after the bid processing of round *t* in order to maintain the same eligibility in round *t* + 1. The bidder's required activity in round *t* is calculated according to the following formula:

$$\text{Required Activity}(t) = \text{Eligibility}(t) \cdot \text{ActivityRequirement}$$

Where:

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<sup>4</sup> *ER* denotes the set of extended round products (see Section 3.2).

- *Eligibility*( $t$ ) denotes the bidder's eligibility in round  $t$ .
- *ActivityRequirement* denotes the activity requirement. This is a percentage (up to 100 percent) set by the FCC.

#### 5.4 Requested Commitment – Regular Clock Round

For the convenience of bidders, the auction software will provide the following additional information about the financial exposure created by bids during the course of the auction. A bidder's *requested commitment* during a regular clock round  $t$  is the total gross bid amount calculated at the round's clock prices, given the bids that the bidder has submitted so far in round  $t$ . During the round, bids for the round have not yet been processed, so the requested commitment is an estimate of a bidder's commitment, which is updated as bids are submitted. The requested commitment of bidder  $i$  in a regular clock round  $t$  is calculated according to the following formula:

$$\sum_{r \in N} q_{i,r} \cdot P_{t,r}$$

Where:

- $q_{i,r}$  denotes the requested demand of bidder  $i$  for product  $r$  at the clock price, given all bids that bidder  $i$  has submitted so far in this round. In particular, if all the bids that are submitted by bidder  $i$  for product  $r$  are applied during bid processing, then its processed demand will be  $q_{i,r}$ .
- $P_{t,r}$  denotes the clock price in round  $t$  for product  $r$

At the beginning of a round, *i.e.*, before the bidder has submitted any bids in this round, the bidder's requested commitment is equal to 0.

#### Example:

For product A, the clock price is \$6,000, and the previous round's posted price is \$5,000. For product B, the clock price is \$4,800, and the previous round's posted price is \$4,000. Suppose that bidder  $i$  has submitted the following bids in the current bidding round:

- Product A: a simple bid for 4 blocks at price \$5,500, and a simple bid for 2 blocks at price \$5,700.
- Product B: an all-or-nothing bid for 2 blocks at price \$4,500

By placing these bids, the bidder indicates that it is willing to buy 2 blocks of product A up to and including the clock price of \$6,000 per block, and 2 blocks of product B up to and including the clock price of \$4,800 per block. After submitting these three bids, the bidder's requested commitment is:

$$(2 \cdot \$6,000) + (2 \cdot \$4,800) = \$21,600$$

#### 5.5 Requested Commitment – Extended Round

In an extended round, the requested commitment of bidder  $i$  is equal to:

$$\sum_{r \in N \setminus ER} d_{\tau,i,r} \cdot p_{\tau,r} + \sum_{r \in ER} q_{i,r} \cdot Bid Price_r$$

Where:

- $\tau$  denotes the last round before the extended round
- $d_{\tau,i,r}$  denotes the processed demand of bidder  $i$  for product  $r$  after the bid processing of round  $\tau$ , *i.e.*, at the time that the extended round is triggered
- $p_{\tau,r}$  denotes the posted price for product  $r$  in round  $\tau$
- $q_{i,r}$  denotes the requested demand of bidder  $i$  for product  $r$  in the extended round, given all bids that bidder  $i$  has submitted so far. In particular, if the bidder submitted a bid for its processed demand from the last round for product  $r$  at the clock price of the extended round, then  $q_{i,r}$  is equal to the bidder's processed demand from the last round for product  $r$ . If the bidder submitted a bid to reduce its demand by one block in the extended round, then  $q_{i,r}$  is equal to the bidder's processed demand from the last round for product  $r$  minus one. If the bidder's processed demand from the last round for product  $r$  is 0, then  $q_{i,r} = 0$ .
- *Bid Price<sub>r</sub>* denotes the price in the bidder's bid for product  $r$  in the extended round. If in the extended round the bidder has not submitted a bid for a product  $r$  for which  $d_{\tau,i,r} > 0$ , then *Bid Price<sub>r</sub>* is set equal to the posted price from the previous round, *i.e.*, *Bid Price<sub>r</sub>* =  $p_{\tau,r}$ .

Note that the first summation is across all non-ER products, whereas the second summation is across all ER products. See Section 3.2 for the definition of extended round products (ER).

At the beginning of a round, *i.e.*, before the bidder has submitted any bids in this round, the bidder's requested commitment is given by the following formula:

$$\sum_{r \in N \setminus ER} d_{\tau,i,r} \cdot p_{\tau,r} + \sum_{r \in ER: d_{\tau,i,r} > 0} (d_{\tau,i,r} - 1) \cdot p_{\tau,r}$$

## 5.6 Bidding Credit Discounts on Requested Commitment

This section describes the calculations for requested commitment bidding credit discounts in a round  $t$ . All bidding credit discounts are rounded to the nearest dollar.

The following notation is used:

- $BC_i$  denotes the bidding credit percentage of bidder  $i$ .
- $RC_{t,i}$  denotes the requested commitment of bidder  $i$  in round  $t$ .<sup>5</sup>
- $S$  denotes the set of all products in *small markets* (*i.e.*, markets subject to the small market bidding cap)<sup>6</sup>

<sup>5</sup> Note that a bidder's requested commitment may change when the bidder submits or changes its bids.

<sup>6</sup> Markets that are subject to the small market bidding credit cap are those PEAs with a population of 500,000 or less, which corresponds to PEAs 118–416, excluding PEA 412. *Updating Part 1 Competitive Bidding Rules*, WT Docket No. 14-170, Report and Order, 30 FCC Rcd 7493, 7546, para. 127 (2015) (“[N]o winning DE bidder will be able to obtain more than \$10 million in bidding credits for licenses won in PEAs 118416, with the exception of PEA 412 (Puerto Rico), which exceeds the 500,000 pop threshold.”).

### 5.6.1 Rural Bidding Credit

If bidder  $i$  qualifies for the rural bidding credit, then in round  $t$

- Its *uncapped requested commitment discount* is:

$$BC_i \cdot RC_{t,i}$$

- Its *capped requested commitment discount* is:

$$\min\{\$10 \text{ million}, BC_i \cdot RC_{t,i}\}$$

This is equal to the bidder's requested commitment multiplied by its bidding credit and then capped at \$10 million.

### 5.6.2 Small Business Bidding Credit – Regular Clock Round

If bidder  $i$  qualifies for the small business bidding credit, then in a regular clock round  $t$

- Its *uncapped requested commitment discount in small markets* is:

$$BC_i \cdot \sum_{r \in S} q_{i,r} \cdot P_{t,r}$$

Note that the summation is across all products in small markets. The uncapped requested commitment discount in small markets is calculated by multiplying the bidder's requested commitment in small markets with its bidding credit.

- Its *uncapped requested commitment discount (across all markets)* is:

$$BC_i \cdot RC_{t,i}$$

- Its *capped requested commitment discount (across all markets)* is:

$$\min \left\{ \$150 \text{ million}, BC_i \cdot \sum_{r \in N \setminus S} q_{i,r} \cdot P_{t,r} + \min \left\{ \$10 \text{ million}, BC_i \cdot \sum_{r \in S} q_{i,r} \cdot P_{t,r} \right\} \right\}$$

This calculation first caps the bidder's discount in small markets at \$10 million, then adds the bidder's discount from all other markets (*i.e.*, markets that are not subject to the small market bidding cap) and caps the sum at \$150 million.

### 5.6.3 Small Business Bidding Credit – Extended Round

If bidder  $i$  qualifies for the small business bidding credit, then in an extended round  $t$ :

- Its *uncapped requested commitment discount in small markets* is:

$$BC_i \cdot \sum_{r \in S} d_{\tau,i,r} \cdot p_{\tau,r}$$

The summation is across all products in small markets. Note that products in small markets are not bid on in the extended round. The uncapped requested commitment discount in small markets is calculated by multiplying the bidder's requested commitment in small markets with its bidding credit.

- Its *uncapped requested commitment discount* (across all markets) is:

$$BC_i \cdot RC_{t,i}$$

This is just the bidder's requested commitment multiplied by its bidding credit.

- Its *capped requested commitment discount* (across all markets) is:

$$\min \left\{ \$150 \text{ million}, BC_i \cdot \left( \sum_{r \in N \setminus (ERUS)} d_{\tau,i,r} \cdot p_{\tau,r} + \sum_{r \in ER} q_{i,r} \cdot \text{Bid Price}_r \right) + \min \left\{ \$10 \text{ million}, BC_i \cdot \sum_{r \in S} d_{\tau,i,r} \cdot p_{\tau,r} \right\} \right\}$$

This calculation first caps the bidder's discount in small markets at \$10 million, then adds the bidder's discount from all other markets (*i.e.*, markets that are not subject to the small market bidding cap) and caps the sum at \$150 million.

## 5.7 Requested Net Commitment

A bidder's *requested net commitment* is equal to the difference between its requested commitment and its capped requested commitment discount.

## 5.8 Commitment (from previous round)

The bidder's *commitment* from the previous round is a dollar value that is calculated from the bidder's processed demand and the posted prices after the bid processing of the previous round.

The commitment of bidder *i* after round *t* is given by the following formula:

$$\sum_{r \in N} d_{t,i,r} \cdot p_{t,r}$$

Where:

- $d_{t,i,r}$  denotes the processed demand of bidder *i* for product *r* after round *t*.
- $p_{t,r}$  denotes the posted price of product *r* after round *t*.

## 5.9 Bidding Credit Discounts on Commitment (from previous round)

This section describes the calculations for commitment bidding credit discounts after a round *t*. All bidding credit discounts are rounded to the nearest dollar.

The following notation is used:

- $BC_i$  denotes the bidding credit percentage of bidder  $i$ .
- $C_{t,i}$  denotes the commitment of bidder  $i$  after round  $t$ .
- $S$  denotes the set of all products in *small markets* (*i.e.*, markets subject to the small market bidding cap).

### 5.9.1 Rural Bidding Credit

If bidder  $i$  qualifies for the rural bidding credit, then after round  $t$

- Its *uncapped commitment discount* is:

$$BC_i \cdot C_{t,i}$$

- Its *capped commitment discount* is:

$$\min\{\$10 \text{ million}, BC_i \cdot C_{t,i}\}$$

This is equal to the bidder's commitment multiplied by its bidding credit and then capped at \$10 million.

### 5.9.2 Small Business Bidding Credit

If bidder  $i$  qualifies for the small business bidding credit, then after round  $t$

- Its *uncapped commitment discount in small markets* is:

$$BC_i \cdot \sum_{r \in S} d_{t,i,r} \cdot p_{t,r}$$

Note that the summation is across all products in small markets. The uncapped commitment discount in small markets is calculated by multiplying the bidder's commitment in small markets with its bidding credit.

- Its *uncapped commitment discount* (across all markets) is:

$$BC_i \cdot C_{t,i}$$

- Its *capped commitment discount* (across all markets) is:

$$\min \left\{ \$150 \text{ million}, BC_i \cdot \sum_{r \in N \setminus S} d_{t,i,r} \cdot p_{t,r} + \min \left\{ \$10 \text{ million}, BC_i \cdot \sum_{r \in S} d_{t,i,r} \cdot p_{t,r} \right\} \right\}$$

This calculation first caps the bidder's discount in small markets at \$10 million, then adds the bidder's discount from all other markets (*i.e.*, markets that are not subject to the small market bidding cap) and caps the sum at \$150 million.

### 5.10 Net Commitment (from previous round)

A bidder's *net commitment* after round  $t$  is the bidder's commitment after round  $t$  minus its capped commitment discount.

## 6 Bid Types

The types of bids are:

**Simple Bids:** These bids indicate a desired quantity of a product at a price. During processing, if it is not possible to apply the simple bid in its entirety, it may be applied partially.

**All-or-Nothing Bids:** These bids indicate a desired quantity of a product at a price, just like simple bids. However, all-or-nothing bids are either applied in full or not at all. These bids are available for a bidder that does not wish to place bids that may only be applied partially. As described in more detail below, if a bidder's all-or-nothing bid is not applied (because it cannot be applied in full), the auction system allows a bidder to place a "backstop" bid if it is not willing to demand its current processed demand at the clock price of this round.

**Switch Bids:** These bids allow a bidder to request to switch its demand for a quantity of a product from one category of generic blocks to another category within the same PEA. Switch bids may be applied partially, but the increase in demand in the "to" category will always match in quantity the reduction in the "from" category.

Below, a more detailed explanation is provided along with examples to illustrate each of these bid types and how the auction system will process them.

### 6.1 Simple Bids

A *simple bid* requesting to reduce demand to a quantity  $q$  for a product  $r$  at price  $p$  in a round indicates that:

- (1) At all prices above  $p$  and less than or equal to the clock price (or the next price at which the bidder submitted a bid), the bidder is willing to buy an exact quantity equal to  $q$ ; and
- (2) At price  $p$ , the bidder is willing to buy any quantity between  $q$  and its previous demand for product  $r$ .<sup>7</sup>

By placing one (or more) *simple bid(s)* requesting to increase demand for a product  $r$  at one (or more) price(s) in a round, the bidder indicates that at all prices associated with this round (*i.e.*, prices that are greater than or equal to the last round's posted price and less than or equal to the clock price) it is willing to buy any quantity that is greater than or equal to its processed demand and less than or equal to the maximum quantity that it specifies in a bid for product  $r$ .<sup>8</sup>

A *simple bid* for a quantity equal to the bidder's processed demand for a product  $r$  at the round's clock price indicates that the bidder is willing to buy a quantity equal to the last round's processed demand at all prices in this round up to and including this round's clock price.

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<sup>7</sup> The bidder's previous demand for product  $r$  is either equal to its processed demand from the previous round or, if the bidder has placed a simple bid at a price below  $p$  for product  $r$ , the quantity in the bid for product  $r$  with the highest price below  $p$ .

<sup>8</sup> The auction system will not process the requested increase until bid processing reaches the price point at which the bid was made, but depending upon demand for the product relative to its supply and upon which bids to reduce demand for the product are applied, the posted price for the current round may be above or below the bid price of the requested increase. The posted price may be lower if, for example, applying the increase allows another bidder's requested decrease at a lower price point to be applied.

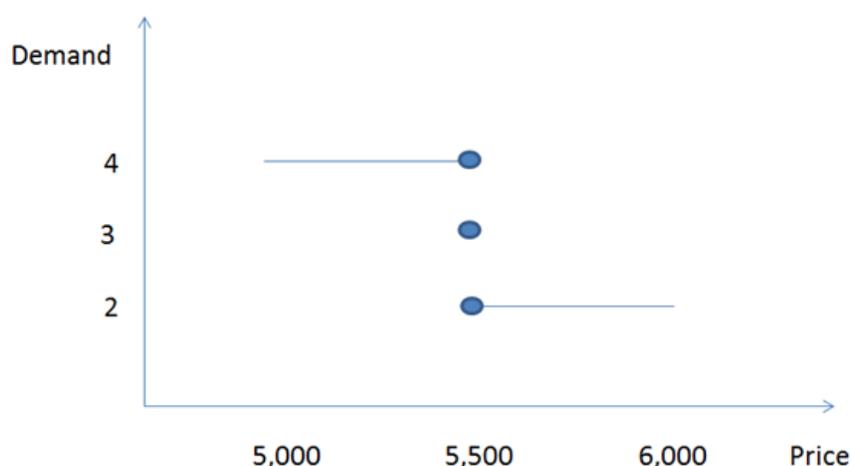
**Example: Bidder Places a Simple Bid Requesting to Reduce Demand to 2 Blocks at \$5,500**

Suppose that after the bids of the previous round are processed, the bidder's processed demand for a product is 4 blocks and the posted price is \$5,000. In the current round, the clock price is \$6,000, and the bidder places a single simple bid for the product requesting to reduce its demand to 2 blocks at price \$5,500.

To the auction system, this bid means the following:

- If the price is below \$5,500, the bidder is willing to purchase 4 blocks.
- If the price is exactly \$5,500, the bidder is willing to purchase 2, 3, or 4 blocks.
- If the price is above \$5,500, the bidder is willing to purchase only 2 blocks.

The graph below illustrates how the auction system interprets this simple bid:



If a simple bid is partially applied, then the processed demand of the bidder is a quantity that is strictly between the bidder's processed demand before the simple bid was applied and the quantity that the bidder specified in the bid.

When the auction system processes the bids at price \$5,500, the simple bid will be applied fully, partially, or not at all depending on the level of excess demand at that point in the bid processing.

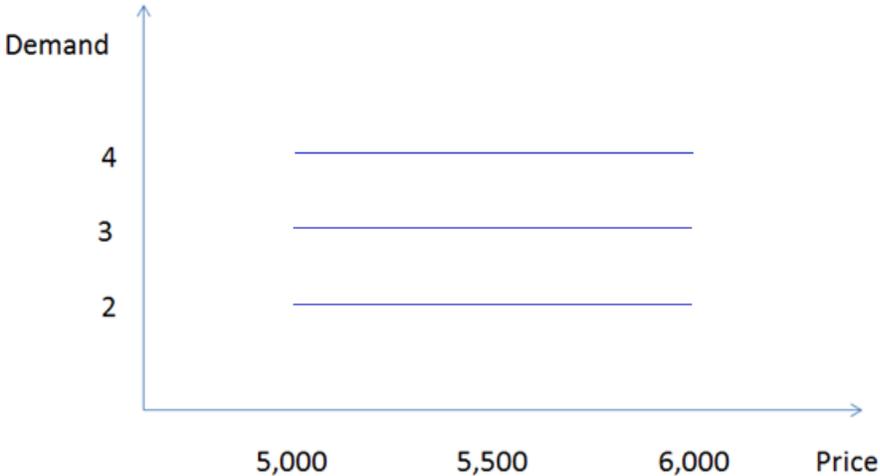
- (a) If demand exceeds supply by more than 2 blocks, the bid is fully applied. The bidder will hold 2 blocks.
- (b) If demand exceeds supply by exactly 2 blocks, the bid is also fully applied. The bidder will hold 2 blocks.
- (c) If demand exceeds supply by only 1 block, the bid is partially applied. The bidder will hold 3 blocks.
- (d) If demand does not exceed supply, the bid is not applied. The bidder will continue to hold 4 blocks.

Using the same bid, if no other bidder has submitted a bid requesting to change its demand for this product, then:

- In case (a), the posted price will be equal to \$6,000.
- In cases (b) and (c), the posted price will be equal to \$5,500.
- In case (d), the posted price will be equal to \$5,000.

**Example: Bidder Places a Simple Bid Requesting to Increase Demand to 4 Blocks at \$5,500**

Suppose that after the bids of the previous round are processed, the bidder's processed demand for a product is 2 blocks and the posted price is \$5,000. In the current round, the clock price is \$6,000, and the bidder places a single simple bid for the product requesting to increase its demand to 4 blocks at price \$5,500. This means that for all prices  $p$  such that  $5,000 \leq p \leq 6,000$ , the bidder is willing to buy 2, 3, or 4 blocks. The corresponding demand graph is shown in the following figure:

**6.2 All-or-Nothing Bids**

An *all-or-nothing bid* is a request to increase or reduce demand for a given product by two or more blocks. An all-or-nothing bid will be applied only if it is fully acceptable.

An all-or-nothing bid requesting to reduce demand to a quantity  $q$  for a product  $r$  at price  $p$  in a round indicates that:

- (1) If the bid is fully acceptable (see Section 3.3.1 for the definition), the bidder is willing to buy an exact quantity of  $q$  of product  $r$  when the price is greater than or equal to  $p$  and less than or equal to the current clock price (or the next price at which it submitted a bid).
- (2) If the bid is not fully acceptable, the bidder is willing to buy a quantity equal to its previous demand<sup>9</sup> for product  $r$  without applying this bid when the price is greater than or equal to  $p$  and less than or equal to the current clock price.

By placing one (or more) *all-or-nothing bid(s)* requesting to increase demand for a product  $r$  at one (or more) price(s) in a round, the bidder indicates that at all prices associated with this round (*i.e.*, prices that are greater than or equal to the last round's posted price and less than or equal to the clock price) it is willing to buy its processed demand and any quantity that it specified in an all-or-nothing bid for product  $r$ .

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<sup>9</sup> The bidder's previous demand for product  $r$  is either equal to its processed demand from the previous round or, if the bidder has placed an all-or-nothing bid at a price below  $p$  for product  $r$ , the bid quantity for product  $r$  with the highest price below  $p$ .

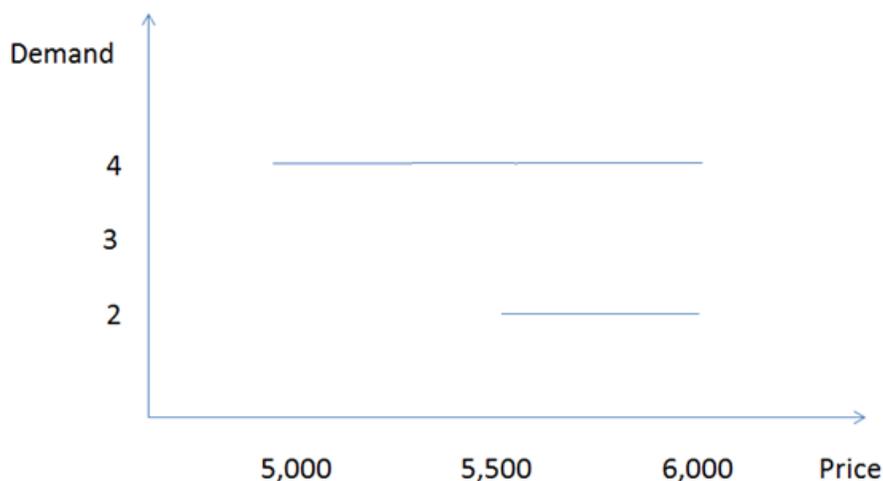
**Example: Bidder Places an All-or-Nothing Bid Requesting to Reduce Demand to 2 Blocks at \$5,500**

Suppose that after the bids of the previous round are processed, the bidder's processed demand for a product is 4 blocks and the posted price is \$5,000. In the current round, the clock price is \$6,000, and the bidder places a single all-or-nothing bid requesting to reduce its demand to 2 blocks at price \$5,500.

To the auction system, this bid means the following:

- If the price is below \$5,500, the bidder is willing to purchase 4 blocks.
- If the price is \$5,500 or higher, the bidder is willing to purchase either 2 or 4 blocks (depending on whether the all-or-nothing bid is fully acceptable), but not 3 blocks.

The graph below illustrates how the auction system interprets this all-or-nothing bid:



When the auction system processes the bids at price \$5,500, the all-or-nothing bid will either be applied fully or not at all depending on the level of excess demand at that point in the bid processing.

- (a) If demand exceeds supply by more than 2 blocks, the bid is fully applied. The bidder will hold 2 blocks.
- (b) If demand exceeds supply by exactly 2 blocks, the bid is also fully applied. The bidder will hold 2 blocks.
- (c) If demand exceeds supply by 1 block, the bid is not applied at all. The bidder will hold 4 blocks.
- (d) If demand does not exceed supply, the bid is not applied at all. The bidder will hold 4 blocks.

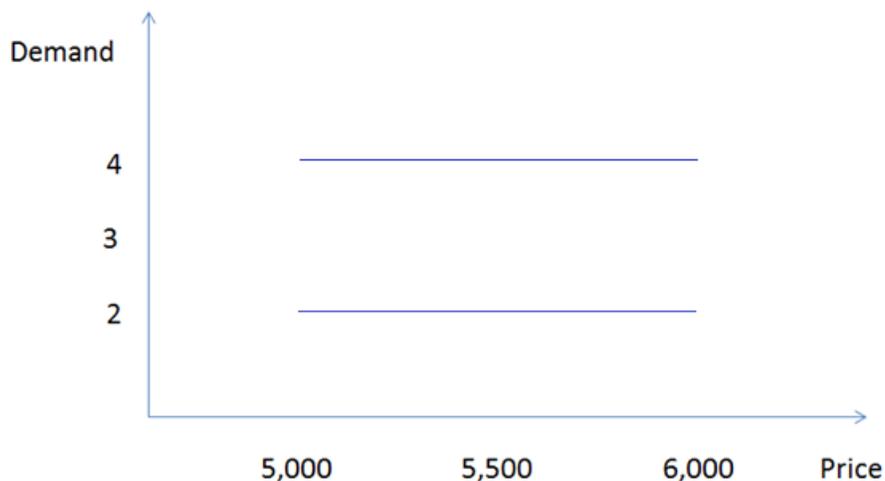
Continuing the same example, if no other bidder has submitted a bid requesting to change its demand for this product, then:

- In cases (a) and (c), the posted price will be equal to \$6,000.
- In case (b), the posted price will be equal to \$5,500.
- In case (d), the posted price will be equal to \$5,000.

**Example: Bidder Places an All-or-Nothing Bid Requesting to Increase Demand to 4 Blocks at \$5,500**

Suppose that after the bids of the previous round are processed, the bidder's processed demand for a product is 2 blocks and the posted price is \$5,000. In the current round, the clock price is \$6,000. By placing a single all-or-nothing bid for 4 blocks for the product at price \$5,500, the bidder is indicating that

it is willing to buy any quantity in {2, 4} at any price associated with this round. The graph below illustrates how the auction system interprets this all-or-nothing bid:



An all-or-nothing bid is either applied in full or is not applied at all; it is never applied partially. However, unlike a simple bid requesting a reduction, an all-or-nothing bid requesting a reduction will not stop the price if it cannot be applied. This leaves the possibility that the bidder may continue to hold its processed demand from the previous round as the price rises all the way to the current clock price. If the bidder wishes to prevent this, it has the option of associating a “backstop” with an all-or-nothing bid to reduce its demand.

### 6.2.1 Backstopping

If a bidder submits exactly one all-or-nothing bid for a reduction in quantity for a given product in a given round, the bidder has the option of *backstopping* at a higher price.<sup>10</sup> This means that, if the price reaches the specified backstop price, the bid may be applied in part (like a simple bid for the same quantity). If there is more than one all-or-nothing bid by a bidder for a given product in the round, backstopping is not permitted.<sup>11</sup>

#### **Example: Bidder Places an All-or-Nothing Bid Requesting to Reduce Demand to 2 Blocks at \$5,500 with a Backstop of \$5,700**

Suppose that after the bids of the previous round are processed, the bidder’s processed demand for a product is 4 blocks and the posted price is \$5,000. In the current round, the clock price is \$6,000, and the bidder places an all-or-nothing bid requesting to reduce its demand to 2 blocks at price \$5,500 with a backstop at \$5,700.

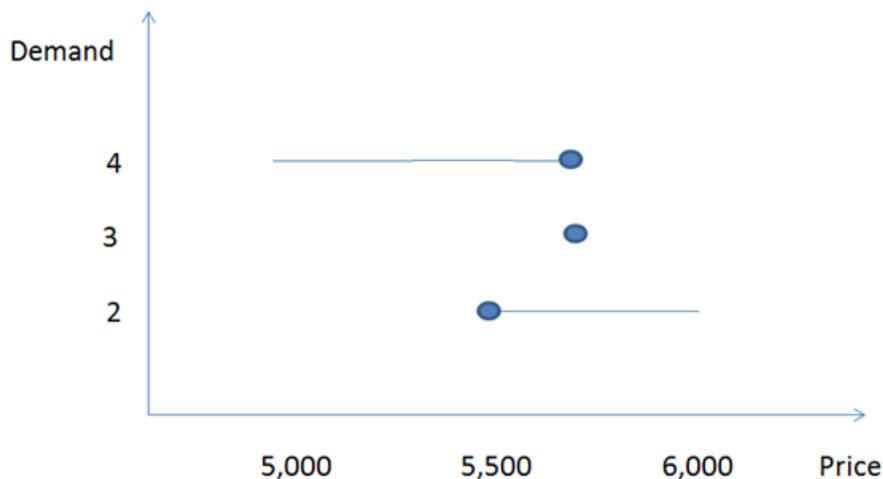
<sup>10</sup> Note that backstopping an all-or-nothing bid at the same price as the all-or-nothing bid is equivalent to submitting a simple bid at that price for the same reduction in quantity.

<sup>11</sup> Permitting bidders to submit multiple all-or-nothing bids for the same product along with one or more backstop prices would significantly complicate the bid processing algorithm and the bidding experience.

To the auction system, this bid means the following:

- If the price is below \$5,500, the bidder is willing to purchase 4 blocks.
- If the price is between \$5,500 and \$5,700, the bidder is willing to hold either 2 or 4 blocks, but not 3 blocks.
- If the price is exactly \$5,700, the bidder is willing to hold either 2, 3, or 4 blocks.
- If the price is above \$5,700, the bidder is willing to hold only 2 blocks.

The graph below illustrates how the auction system interprets this all-or-nothing bid with a backstop:



This all-or-nothing bid with backstopping is applied as described above, depending on the level of excess demand for the product at \$5,500. However, if the all-or-nothing bid was not applied at \$5,500 and the bidder continues to hold 4 blocks, the backstop indicates that at a price of \$5,700, the bidder would accept a partial reduction in demand if the full bid cannot be applied. Therefore, in the example without the backstop bid, depending on the amount of excess demand, the bidder could have ended the round with processed demand of 4 blocks at the clock price of \$6,000, but with the backstop bid, if the price rose to \$5,700, at least a partial reduction in demand would be applied.

### 6.3 Switch Bids

A *switch bid* is a request to move demand for up to  $n$  blocks in a given PEA from one category to another category. For instance, a bidder can request to switch up to two blocks from Category 1 to Category 2 in a given PEA. Switch bids may be partially applied.

For each switch bid, the bidder specifies two products within the same PEA (a “from” product and a “to” product), a price  $p$  for the “from” product, and a quantity  $q$  for the “from” category; the bidder does not specify a quantity or a price for the “to” category. In processing the switch bid, the auction system will determine the maximum number of blocks by which demand in the “from” category can be reduced (such that demand does not fall below supply) and will then switch an equal number of blocks to the “to” category.

Such a bid indicates that:

- (1) At all prices that are strictly greater than  $p$  and less than or equal to the clock price (or the next price at which the bidder submitted a bid involving the “from” product), the bidder is willing to buy an exact quantity of  $q$  of the “from” product;

- (2) At price  $p$ , the bidder is willing to buy any quantity between  $q$  and its previous demand for the “from” product;<sup>12</sup> and
- (3) The bidder is willing to buy up to a quantity of  $d_t + (d_f - q)$  of the “to” product at the clock price, where  $d_t$  and  $d_f$  denote the bidder’s previous demand for the “to” and “from” products respectively before the switch bid is applied.<sup>13</sup>

Regardless of whether a switch bid for  $n$  blocks from product A to product B is fully or partially applied, if the processed demand of the bidder for product A is reduced by  $m$  blocks, then the processed demand of the bidder for product B is increased by  $m$  blocks, where  $1 \leq m \leq n$ . A switch bid for 1 block cannot be partially applied.

**Example: Bidder Places a Switch Bid for 2 Blocks from Category 1 to Category 2 at \$5,500**

Suppose that after the bids of the previous round are processed, the bidder’s processed demand is 4 blocks in Category 1 and 0 blocks in Category 2 in some PEA and the posted price of the Category 1 product in that PEA is \$5,000. In the current round, the clock price for the Category 1 product in that PEA is \$6,000, and the bidder places a single switch bid involving that PEA requesting to switch its demand by 2 blocks from Category 1 to Category 2 at price \$5,500.

To the auction system, this bid means the following:

- If the price of Category 1 is below \$5,500, the bidder is willing to purchase 4 Category 1 blocks.
- If the price of Category 1 is exactly \$5,500, the bidder wishes to switch demand from Category 1 to Category 2 by up to 2 blocks.

Note that the bidder does not specify a quantity or a price for Category 2 blocks in its bid. By placing the bid, the bidder indicates a willingness to purchase up to 2 blocks of Category 2 at the current clock price.

When the auction system processes the bids at price \$5,500, this switch bid will be applied fully, partially, or not at all depending on the level of excess demand at that point in the bid processing:

- If demand exceeds supply by 2 or more blocks in Category 1, the bid is fully applied. The bidder will then hold 2 blocks in Category 1 and 2 blocks in Category 2.
- If demand exceeds supply by only 1 block in Category 1, the bid is partially applied. The bidder then will hold 3 blocks in Category 1 and 1 block in Category 2.
- If demand does not exceed supply, the bid is not applied at all. The bidder will continue to hold 4 blocks in Category 1 and none in Category 2.

In all cases, the bidder’s total processed demand across the categories is still 4. However, a switch bid may be applied partially in the sense that the number of blocks that are switched from Category 1 to Category 2 may be smaller than the maximum number of blocks that the bidder was willing to switch, depending on whether it is possible to reduce the bidder’s demand for Category 1.

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<sup>12</sup> The bidder’s previous demand for the “from” product is either equal to its processed demand from the previous round or, if the bidder has placed a switch bid at a price below  $p$  involving that product, the quantity in the bid involving that product with the highest price below  $p$ .

<sup>13</sup> The bidder’s previous demand for the “to” product is either equal to its processed demand from the previous round or, if the bidder has placed another switch bid involving that product, the quantity that has already been applied for this product during bid processing at the point this switch bid is considered.

## 7 Processing Bids for a Regular Clock Round

This section describes bid processing in the regular clock rounds. The purpose of bid processing is to determine at the conclusion of a round of bidding, the processed demands for all bidders and the posted prices for all the products. This section provides a definition of *price points* and the details of how bid processing is done in a regular clock round.

### 7.1 Missing Bids

For each product for which the bidder had positive processed demand in the previous round, if the bidder did not submit a bid for that product during the current round, it will be deemed to have bid a simple bid for that product with a quantity of 0 at a price equal to the last round's posted price. For example, if the last round's posted price for a particular product is \$6,000 and the bidder does not submit a bid in this round for that product, it will be deemed to have bid a quantity of 0 at \$6,000. Note that this does not necessarily mean that a bidder will receive 0 blocks at \$6,000. The missing bid is processed just as if a bidder submitted a simple bid for 0 blocks at \$6,000. All missing bids are subject to the same checks as those submitted by a bidder.

### 7.2 Price Points

The *price point* indicates the percentage of the distance between the posted price of the previous round and the clock price of the current round. For example, the 0 percent price point refers to the last round's posted price, the 100 percent price point refers to the clock price, and the 50 percent price point refers to the average of the last round posted price and the clock price of this round. As another example, if the last round's posted price is \$5,000 and the clock price of this round is \$6,000, the price \$5,100 corresponds to the 10 percent price point, and the price \$5,500 corresponds to the 50 percent price point.

### 7.3 Processed Demands

For processing bids after each round, bids are prioritized in the following order: price point (from lowest to highest) across all bids, and then a bid-specific pseudorandom number (from lowest to highest). The priority ordering of bids remains the same throughout bid processing of a round (that is, only one pseudorandom number is associated with a given bid in a round).

The bid processing algorithm described here maintains a *queue* of all bids from the round that have not been applied in their entirety.<sup>14</sup> The highest-priority bid that has not yet been considered is processed. The algorithm checks whether the bid is fully acceptable using the most-recently-determined aggregate demand.<sup>15</sup> If the bid is fully acceptable, then it is applied (in its entirety). If the bid is not fully acceptable, then it is placed in the queue. If the bid is a simple bid or a switch bid, then the algorithm checks whether the bid is partially acceptable using the most-recently-determined aggregate demand. If the bid is partially acceptable, then it is partially applied (to the maximum extent possible).

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<sup>14</sup> The implementation does not necessarily require a queue, but this description is used here for expository ease.

<sup>15</sup> Note that a bid may be found not acceptable because of insufficient bidding eligibility if another bid submitted by the bidder, requesting a reduction, is not processed due to insufficient aggregate demand, thereby not freeing up bidding units needed to support the requested bid to increase demand for another product. This can occur even when the bidder's activity overall does not exceed its eligibility.

Whenever a bid is applied either partially or in its entirety, the queue is re-tested to determine whether any bids in the queue have become fully acceptable and whether any simple bids or switch bids have become partially acceptable; if so, the highest-priority fully acceptable or partially acceptable bid is applied. When a bid has been applied in its entirety, it is removed from the queue; otherwise, it is kept in the queue so that the remaining part may be applied later. The re-testing of the queue is iterated until no bids remaining in the queue are fully acceptable and no simple or switch bids are partially acceptable. Then the next bid from the round is processed, until (1) all bids from the round have been processed, (2) no bids in the queue are fully acceptable and (3) no simple or switch bids in the queue are partially acceptable. At that point, all bids remaining in the queue are discarded.

The demands of a bidder following the processing of the bids for the round are referred to as its *processed demands*.

**Example 1:** Suppose that at the beginning of the round the bidder's processed demand for product A is 4 blocks and the bidder has submitted a simple bid for 0 blocks of product A. If the bid is not fully acceptable (because applying the bid in its entirety would lead to excess supply for product A), but it is possible to apply 1, 2, or 3 blocks of the reduction without creating excess supply for product A, then 3 blocks of the reduction will be applied. The bid for a quantity of 0 blocks for product A will be placed in the queue, so that the remaining one block may be applied later, if conditions permit after other bids have been processed.

If a bidder has backstopped an all-or-nothing bid, the bid processing algorithm uses a simple bid to represent the backstopped price. Therefore, an all-or-nothing bid with backstopping that is not fully acceptable is represented with two bids in the queue: an all-or-nothing bid at the price of the all-or-nothing bid and a simple bid at the backstop price.

**Example 2:** The bidder's processed demand at the beginning of the round is 4 blocks for product A. There are two other bidders, each with a processed demand of 4 blocks for product A at the beginning of the round. Thus, the aggregate demand for product A at the beginning of the round is 12 blocks. The supply for product A is 10 blocks. The bidder has submitted an all-or-nothing bid to reduce its demand for A to 0 blocks at price \$1,500 and has backstopped that bid at price \$1,700. The bid processing works as follows:

- The all-or-nothing bid is not fully acceptable (because it would lead to excess supply) and it thus placed in the queue.
- The system uses a simple bid for 0 blocks at price \$1,700 to represent the backstopping of the all-or-nothing bid.
- The simple bid is partially acceptable. The maximum extent to which it can be applied is for 2 blocks, since then the aggregate demand is equal to supply for product A. The simple bid is placed in the queue.
- If there are no other bids involving product A, then the bidder's processed demand for product A is 2 blocks when bid processing ends.

**Example 3:** There are three bidders (bidders 1, 2 and 3), each with a processed demand of 4 blocks for product A at the beginning of the round. Thus, the aggregate demand for product A at the beginning of the round is 12 blocks. The supply for product A is 10 blocks. The following bids are submitted in the round:

- Bidder 1 has submitted an all-or-nothing bid to reduce its demand for A to 0 blocks at price \$1,500 and has backstopped that bid at price \$1,700.
- Bidder 2 has placed a bid to increase its demand to 6 blocks at price \$1,800.

The bid processing works as follows:

- The all-or-nothing bid is not fully acceptable (because it would lead to excess supply) and it is placed in the queue.
- The system uses a simple bid for 0 blocks at price \$1,700 to represent the backstopping of the all-or-nothing bid.
- The simple bid that represents the backstop is considered next. It is partially acceptable. The maximum extent to which it can be applied is for 2 blocks, since then the aggregate demand is equal to supply for product A. The simple bid is placed in the queue. At this point there is no excess demand for product A, and the processed demand of bidder 1 is 2 blocks.
- The bid of bidder 2 is processed, creating 2 units of excess demand for product A. The all-or-nothing bid of bidder 1 is considered, because it is the highest priority bid in the queue (the bid that is associated with the lowest price). The all-or-nothing bid is now fully acceptable, because it is possible to reduce the demand of bidder 1 to 0 blocks. It is applied and removed from the queue. The simple bid representing the backstop is also removed from the queue at this point.
- Bid processing ends and the bidders' processed demands for product A are:
  - o Bidder 1: 0 blocks
  - o Bidder 2: 6 blocks
  - o Bidder 3: 4 blocks

If the auction transitions to a new stage, it is possible that for some bidders and some products, the bidder's processed demand at the end of the previous stage is strictly greater than the supply of that product in the new stage. In that case, the bidder's processed demand for that product is set to be equal to the product's supply at the beginning of the first round of the new stage, and the bidder is not allowed to increase its demand for that product because a bidder cannot demand more blocks than are available. However, the bidder maintains its eligibility and can increase its demand for other products.

#### 7.4 Posted Prices

Let  $P_{t,r}$  denote the clock price for product  $r$  in round  $t$ . After the bids of a regular clock round  $t$  have been processed, the *posted price*  $p_{t,r}$  for product  $r$  in round  $t$  is set as follows:

- If aggregate demand (evaluated using the processed demands) exceeds supply, the posted price will be set equal to the clock price for the round ( $p_{t,r} = P_{t,r}$ ).
- If aggregate demand (evaluated using the processed demands) is equal to the supply and at least one bid that included a reduction in the quantity demanded of that product was applied (either entirely or partially), the posted price ( $p_{t,r}$ ) will be set to be equal to the product price associated with the bid that has the highest price for product  $r$  among all bids from round  $t$  that included a reduction in demand for the product and that were applied (either entirely or partially). That is, the *posted price* will be the price at which a reduction caused demand to equal supply.
- If either of the following two conditions holds:
  - o The aggregate demand (evaluated using the processed demands) is less than the supply<sup>16</sup>

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<sup>16</sup> For example, because of insufficient demand at opening prices.

- The aggregate demand (evaluated using the processed demands) is equal to the supply and no bid that included a reduction in quantity for that product was applied (either as a whole or partially)

Then the posted price will be set to be equal to the posted price of the previous round ( $p_{t,r} = p_{t-1,r}$ ).

These rules ensure that the posted price of a product will not be higher than the price of a simple bid or a switch that requested a reduction for that product and was not applied (either entirely or in part). However, the posted price can be higher than the price of an all-or-nothing that was not applied.

For each all-or-nothing bid with backstopping that was applied either partially or in full, the price  $p$  associated with the reduction for the purposes of setting the posted price is set as follows:

- If the all-or-nothing bid was applied (in full), then  $p$  is set equal to the all-or-nothing price
- If the all-or-nothing bid was not applied and the backstop was applied partially, then  $p$  is set equal to the backstop price

Therefore, in Example 2 of Section 7.3, the posted price is \$1,700. On the other hand, in Example 3 of Section 7.3, the posted price is \$1,500.

## 8 Checking Closing Conditions and Determining Next Round Type

As part of processing for a round, once bid processing is complete, the auction system must determine what happens next:

- (1) If the last round was a regular clock round and the final stage rule has not previously been met:
  - After bid processing, the auction system will determine if bidding will continue in the current stage and if so whether the next round will be a regular clock round or an extended round. Bidding will not continue in the case where the final stage rule is met and there is no excess demand for any product;
- (2) If the last round was an extended round:
  - After bid processing the auction system will determine if the final stage rule has been met and thus if bidding continues or if the auction moves to a new stage; or
- (3) If the last round was a regular clock round and the final stage rule has previously been met:
  - After bid processing the auction system will determine if the closing conditions for the auction have been met or if bidding will continue with a regular clock round.

This flow is illustrated in Figure 1 below:

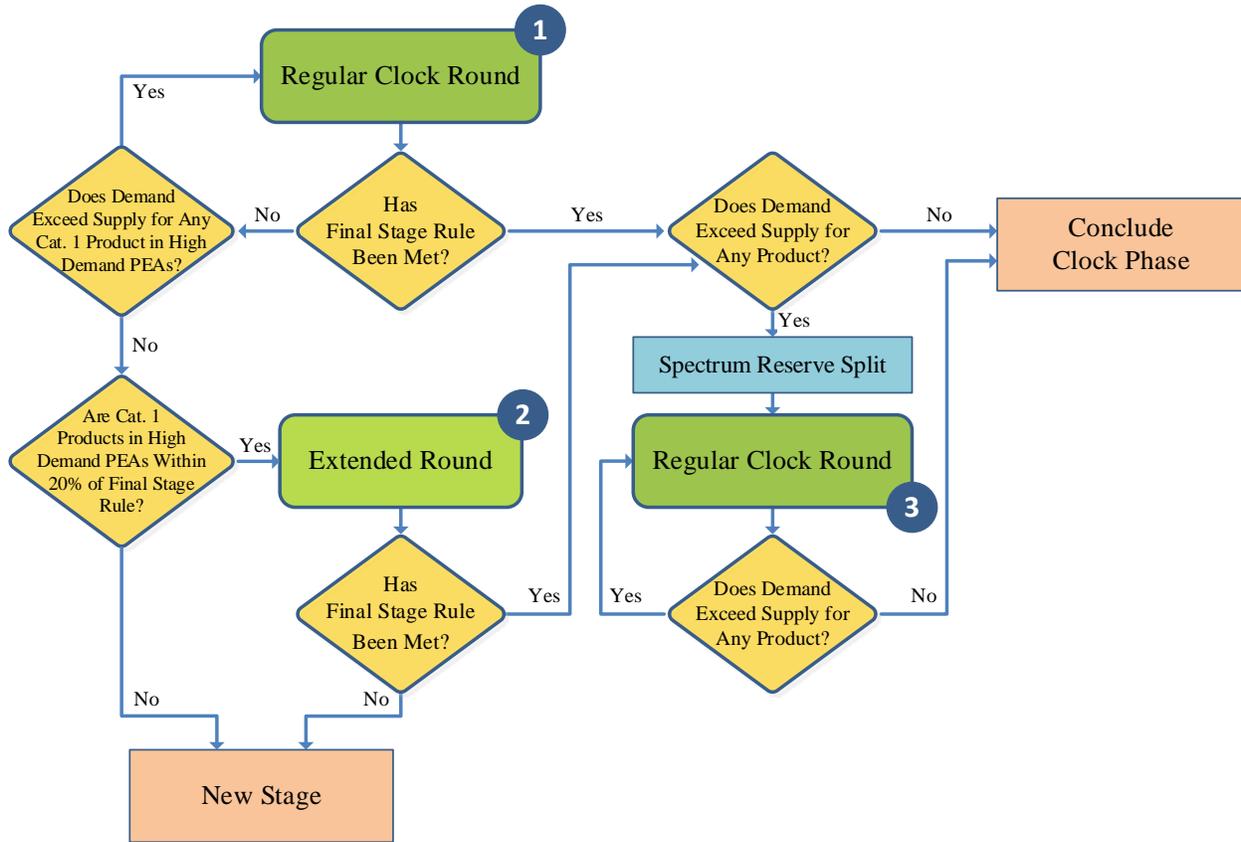


Figure 1: Forward Auction Clock Phase Flow

### 8.1 Notation

Sections 8.2 and 8.3 use the following notation:

- $X$  is the price per MHz-pop benchmark.
- $T$  is the licensed spectrum benchmark.
- $F$  denotes the set of Category 1 high-demand PEA products.
- $N$  denotes the set of all products.
- $p_r$  is the posted price for product  $r$ .
- $s_r$  is the supply (number of blocks) for product  $r$ .
- $d_r$  is the aggregate processed demand for product  $r$ .
- $q_r$  is the smaller of aggregate processed demand and supply for product  $r$ .
- $pop_r$  is the population of the PEA that corresponds to product  $r$ .

## 8.2 Final Stage Rule Calculations

The final stage rule is based on two benchmarks: the price per MHz-pop benchmark  $X$  and the licensed spectrum benchmark  $T$  (in megahertz). In the *Auction 1000 Procedures PN*, the Commission set  $X$  to \$1.25 per MHz-pop and  $T$  at 70 megahertz (corresponding to an 84 megahertz clearing target).<sup>17</sup>

In each round, after all bids are processed, the current stage will be the final stage if both of the following two components are met:

### (1) Average / Aggregate Prices in Forward Auction Component:

- a) For licensed spectrum targets at or below  $T$ , the average price per MHz-pop for Category 1 high-demand PEA products is greater than or equal to  $X$ .

This clause of the first component of the final stage rule is satisfied if and only if the following inequality holds:

$$\frac{\sum_{r \in F} p_r \cdot q_r}{10 \sum_{r \in F} pop_r \cdot s_r} \geq X$$

OR

- b) For all spectrum clearing targets above  $T$ , the current total proceeds of the forward auction is greater than or equal to the product of  $X$ ,  $T$ , and the total number of pops for the high-demand PEAs with at least one Category 1 block in this stage.<sup>18</sup> In particular, this clause of the first component of the final stage rule is satisfied if and only if the following inequality holds:

$$\sum_{r \in N} p_r \cdot q_r \geq X \cdot T \cdot \sum_{r \in F} pop_r$$

Note that the sum on the left hand side includes all products whereas the sum on the right hand side only includes the Category 1 high-demand PEA products.

The sum on the right hand side is the sum of pops across all high-demand PEAs with at least one Category 1 block. If all high-demand PEAs have at least one Category 1 block, then that sum is simply equal to the sum of pops across all high-demand PEAs.

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<sup>17</sup> *Broadcast Incentive Auction Scheduled to Begin March 29, 2016; Procedures for Competitive Bidding in Auction 1000, Including Initial Clearing Target Determination, Qualifying to Bid, and Bidding in Auctions 1001 (Reverse) and 1002 (Forward)*, GN Docket No. 12-268, AU Docket No. 14-252, 30 FCC Rcd 8975, 9078, para. 216 (2015) (*Auction 1000 Bidding Procedures PN*).

<sup>18</sup> This clarifies the description of the calculation for the first component of the Final Stage rule for forward auction stages in which more than 70 megahertz of licensed spectrum is available in the *Auction 1000 Bidding Procedures PN*, 30 FCC Rcd at 9078 para. 216, 9080 para. 220.

## (2) Covering Costs Component:

The net forward auction proceeds, which is the total proceeds adjusted to take into account the discounts for impairments and bidding credits, is sufficient to meet the sum of the following expenses:

- Payments to winning bidders in the reverse auction
- The Commission's administrative costs of the auction
- An estimate of broadcaster relocation costs

Let  $C$  denote the sum of the aforementioned expenses.

The second component of the final stage rule incorporates both bidding credits and discounts for impairments (see Appendix H for details on impairment discounts), whereas the first component does not. Because winning bidders are not known when the final stage rule is evaluated, bidding credits and impairment discounts are incorporated with a worst case calculation in the second component.<sup>19</sup> In particular, the net revenue of a product will be calculated as the lowest possible revenue that could be expected given the bidders that currently have positive processed demand for that product, their associated bidding credits, and the impairment percentage of each block. This is the revenue that would result if bidders with larger bidding credits were assigned less impaired blocks, and any unsold blocks were the least impaired blocks.

To give specific formulas for the net revenue of product  $r$ , taking into account bidding credits and impairment discounts, the following notation is used (in addition to the notation in Section 8.1):

- $d_{i,r}$  is the processed demand of bidder  $i$  for product  $r$ .
- $y_i$  is equal to 1 minus the bidding credit of bidder  $i$ . For example, if bidder  $i$  does not qualify for a bidding credit discount, then  $y_i = 1$ . If bidder  $i$  has a 25 percent discount, then  $y_i = 0.75$ .
- $x_{l,r}$  is equal to 1 minus the impairment percentage for block  $l$  of product  $r$ . For example, if block  $l$  of product  $r$  is 10 percent impaired, then  $x_{l,r} = 0.9$ .

For the purposes of this calculation, if there are unsold blocks the FCC is included as a bidder with processed demand equal to the excess supply and bidding credit equal to 100 percent.

Now consider product  $r$ . Bidders with positive processed demand for product  $r$  are ordered in increasing order of  $y_i$ , or equivalently, in decreasing order of bidding credits. Suppose that there are  $m$  such bidders, including the FCC in the case of unsold blocks. Therefore, if there is excess supply, the first bidder corresponds to the FCC.

The blocks of product  $r$  are ordered in decreasing order of  $x_{l,r}$ , or equivalently in increasing order of impairments.

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<sup>19</sup> Bidder credits are not capped in the calculation of the second component of the final stage rule, because this is a worst case calculation.

The estimated worst case net revenue from product  $r$  is equal to  $\delta_r$ , where  $\delta_r$  is defined as follows:

$$\delta_r \equiv p_r \cdot \sum_{i=1}^m y_i \cdot \sum_{l=1+\sum_{k=1}^{i-1} d_{k,r}}^{\min(s_r, \sum_{k=1}^i d_{k,r})} x_{l,r}$$

The second component of the final stage rule is satisfied if:

$$\sum_{r \in N} \delta_r \geq C$$

To explain the formula above, first consider the case that for product  $r$  supply is greater than aggregate demand. In this case, the formula assumes that the bidder with the smallest bidding credit (bidder  $m$ ) gets the  $d_{m,r}$  most impaired blocks, the bidder with the second smallest bidding credit (bidder  $m - 1$ ) gets the  $d_{m-1,r}$  next most impaired blocks, etc. Moreover, the formula assumes that the  $s_r - d_r$  least impaired blocks are retained by the Commission; in other words, any unsold blocks are the least impaired blocks.

**Example: Calculation of worst case net revenue from product with excess supply**

Consider a product  $r$  with blocks  $\{A, B, C, D, E, F\}$ , where:

- Block A is 0 percent impaired
- Block B is 5 percent impaired
- Block C is 2 percent impaired
- Block D is 6 percent impaired
- Block E is 10 percent impaired
- Block F is 10 percent impaired

The aggregate demand is  $d_r = 4$ , and the supply is  $s_r = 6$ . There is excess supply of 2 blocks. Thus, the FCC is considered as a bidder (bidder 1) with processed demand equal to 2. There are two bidders with positive processed demand for product  $r$ : bidder 2 has processed demand  $d_{2,r} = 2$  and bidding credit 25 percent, and bidder 3 has processed demand  $d_{3,r} = 2$  and bidding credit 0 percent. The posted price is  $p_r = 10$ . To compute the estimated worst case net revenue from product  $r$ , assume that:

- Bidder 1 (the FCC) is assigned blocks A and C
- Bidder 2 is assigned blocks B and D
- Bidder 3 is assigned blocks E and F

That is,  $\delta_r = 10 \cdot (1 - 25\%) \cdot (0.95 + 0.94) + 10 \cdot (1 - 0\%) \cdot (0.9 + 0.9) = 32.175$

The worst case assignment is shown in the following table. Note that blocks are listed in increasing order of percent impairment, and bidders are ordered in decreasing order of bidding credits.

<b>Block (impairment)</b>	A (0%)	C (2%)	B (5%)	D (6%)	E (10%)	F (10%)
<b>Bidder (credit)</b>	Bidder 1: FCC (100%)		Bidder 2 (25%)		Bidder 3 (0%)	

In the case that supply of product  $r$  is strictly smaller than aggregate demand, then the formula above indicates that the bidder with the largest bidding credit (Bidder 1) gets the  $d_{1,r}$  least impaired blocks, the bidder with the second largest bidding credit (Bidder 2) gets the  $d_{2,r}$  next least impaired blocks, etc. It stops “assigning” blocks to bidders when there are no more available blocks.

**Example: Calculation of worst case net revenue from product with excess demand**

Consider a product with supply of 10 blocks. There are 3 bidders each with a processed demand of 4 for that product. Bidder 1 has a bidding credit of 25 percent, Bidder 2 has a bidding credit of 15 percent and Bidder 3 has no bidding credit (*i.e.*, 0 percent). To compute the estimated worst case net revenue from product  $r$ , assume that:

- Bidder 1 gets the 4 least impaired blocks
- Bidder 2 gets the 4 next least impaired blocks
- Bidder 3 gets the 2 most impaired blocks

Note that in this example all 10 blocks are assigned, because there is no excess supply.

The calculations for the net revenue will be truncated at the bidder product level to the nearest \$1. In particular, the previous paragraphs explain how to compute  $\delta_r$ , the estimated worst case net revenue from product  $r$ . The calculations will be done in following way. The quantity:

$$p_r \cdot y_i \cdot \frac{\min(s_r, \sum_{k=1}^i d_{k,r})}{\sum_{l=1+\sum_{k=1}^{i-1} d_{k,r}} x_{l,r}}$$

is computed for every bidder  $i$  and each of these numbers is truncated to the nearest dollar. The summation of these numbers (across all bidders with positive processed demand for the product) will give the worst case net revenue from the product.

If it has been determined that the current stage is final (that is, if the final stage rule was met in a previous round), then the system does not check again whether the final stage rule is satisfied. In particular, the final stage rule calculations are not conducted after the split into reserved and unreserved products.

**8.3 Triggering an Extended Round**

An extended round is implemented when all of the following conditions hold:

- (i) Aggregate demand does not exceed supply for any Category 1 high-demand PEA products;
- (ii) The final stage rule has not been met;
- (iii) There has been no extended round so far in this stage of the auction; and
- (iv) The minimum extended round increment required to meet the final stage rule (assuming that no bidder reduces its demand in the extended round) is less than or equal to 0.2.<sup>20</sup>

If conditions (i)–(iii) above are satisfied, then the auction system checks whether condition (iv) holds. Let  $g$  denote this minimum extended round increment required to meet the final stage rule. Then condition (iv) holds if  $g \leq 0.2$ .

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<sup>20</sup> Condition (iv) clarifies the description of the same condition in the *Auction 1000 Procedures PN*, 30 FCC Rcd at 9084, para. 228.

For the purposes of this section, let  $E$  denote the set of Category 1 products in the 40 high-demand PEAs for which aggregate processed demand is equal to supply. If conditions (i)–(iv) hold and thus the extended round is implemented, the set of extended round products will be equal to  $E$ .

The minimum increment  $g$  will be the greater of the minimum extended round increment needed to meet the Average / Aggregate Prices component ( $z_1$ ) and the minimum extended round increment needed to meet the Covering Costs component of the final stage rule ( $z_2$ ). Specifically:

$$g \equiv \max\{z_1, z_2\}$$

Where  $z_1$  and  $z_2$  are defined as follows:

- If the Average / Aggregate Prices component is satisfied, then  $z_1 = 0$
- If the Average / Aggregate Prices component is not satisfied and the clearing target is at or below  $T$ , then

$$z_1 = \frac{X \cdot 10 \sum_{r \in F} p_r \cdot s_r - \sum_{r \in F \setminus E} p_r \cdot q_r}{\sum_{r \in E} p_r \cdot q_r} - 1$$

- If the Average / Aggregate Prices component is not satisfied and the clearing target is above  $T$ , then

$$z_1 = \frac{X \cdot T \sum_{r \in F} p_r - \sum_{r \in N \setminus E} p_r \cdot q_r}{\sum_{r \in E} p_r \cdot q_r} - 1$$

- If the Covering Costs component is satisfied, then  $z_2 = 0$
- If the Covering Costs component is not satisfied, then

$$z_2 = \frac{C - \sum_{r \in N \setminus E} \delta_r}{\sum_{r \in E} \delta_r} - 1$$

(Note that  $\delta_r$  is the estimated worst case net revenue from product  $r$  defined in Section 8.2.)

## 9 Setting Up the Next Round

If the auction system determines that the closing conditions have not been met in a round, then the system sets up the next round. For each round the system must calculate for each bidder its eligibility for the round based on the activity associated with its processed bids in the previous round. The clock prices for the new round must also be calculated. This section provides the details of these calculations.

### 9.1 Next Round Eligibility – After a Regular Clock Round and After an Extended Round in Which the Final Stage Rule Was Met

In most cases, after round  $t > 1$ , the bidder's eligibility for the next round is set to be equal to:

$$\min \left\{ \text{Eligibility}(t), \frac{\text{ProcActivity}(t)}{\text{ActivityRequirement}} \right\}$$

Where:

- $\text{Eligibility}(t)$  denotes the bidder's eligibility in round  $t$

- *ProcActivity*( $t$ ) denotes the bidder's *processed activity* from round  $t$ , that is, the total number of bidding units associated with the bidder's processed demand after the bid processing of round  $t$ . Using the notation of Sections 5.1 and 5.8,  $ProcActivity(t) = \sum_{r \in N} d_{t,i,r} \cdot b_r$
- *ActivityRequirement* denotes the activity requirement. This is a percentage (up to 100 percent) set by the Commission.

## 9.2 Next Round Eligibility – After an Extended Round in Which the Final Stage Rule Was Not Met

If an extended round was triggered in stage  $u - 1$  and the final stage rule was not met during the extended round, then the auction proceeds to stage  $u$ . In this case, the round after the extended round of stage  $u - 1$  is round 1 of stage  $u$ , and the eligibility of bidder  $i$  in round 1 of stage  $u > 1$  is set to be equal to:

$$\min \left( Eligibility(t), \sum_{r \in ER} d_{i,r} \cdot b_r + \frac{1}{Activity\ Requirement} \sum_{r \notin ER} d_{i,r} \cdot b_r \right)$$

Where:

- $d_{i,r}$  denotes the processed demand of bidder  $i$  for product  $r$  after the extended round of stage  $u - 1$  (for products that are not part of the extended round, this is just the processed demand after the last round before the extended round)
- $b_r$  denotes the number of bidding units associated with product  $r$ .
- $ER$  denotes the set of extended round products (see Section 3.2 of this Appendix).
- $t$  denotes the extended round and thus *Eligibility*( $t$ ) is the bidder's eligibility in the extended round.

## 9.3 Clock Prices for Regular Round

Once the posted prices for a round are calculated and the system has determined that the next round will be a regular clock round, the clock price for each product in the round is calculated as the product's posted price from the previous round multiplied by an increment.

Specifically, the clock price  $P_{t,r}$  for product  $r$  in round  $t$  is calculated as:

$$P_{t,r} = (p_{t-1,r}) \cdot (1 + y)$$

rounded up to the nearest \$1,000.

Where:

- $y$  denotes the price increment for round  $t$ .
- $p_{t-1,r}$  denotes the posted price for product  $r$  after round  $t - 1$ .

Note that this calculation applies to every product, irrespective of whether the product is in excess demand.

## 9.4 Clock Prices for Extended Round

If the auction system has determined that the next round will be an extended round, the system will calculate the clock price for each product in the extended round. Similar to a regular round, the clock price for a product in an extended round is calculated as the product's posted price from the previous

round multiplied by an increment. However, the price increment in an extended round is set so that the price increase is some amount greater than the amount needed to reach the final stage rule. In the *Auction 1000 Procedures* PN, the Commission set this amount to be 33 percent greater than the amount needed.<sup>21</sup> The same percentage of price increase will be applied to all products that are part of the extended round.

The increment for the extended round will be set to be equal to:

$$y \equiv 1.33 \cdot g$$

Where  $g$  is the minimum extended round increment required to meet the final stage rule assuming that no bidder reduces its demand in the extended round.<sup>22</sup>

## 10 Processing Bids for an Extended Round

### 10.1 Special Bidding Rules

In an extended round, a bidder can only bid on extended round products,<sup>23</sup> and will be permitted to accept the clock price for the blocks it demands or to submit an intra-round bid that requests a reduction of one block at a price less than or equal to the clock price and greater than or equal to the last round posted price. Only bidders with positive processed demands for extended round products from the previous round will be permitted to bid in the extended round.

### 10.2 Missing Bids

For extended round products, if the bidder has positive processed demand after the bid processing of the previous round and it does not submit a bid during the extended round for that product, it will be deemed to have submitted a bid to reduce its demand by 1 unit at a price equal to the last round's posted price for that product.

### 10.3 Processing Bids

Bids are processed sequentially in the following order: price point (from lowest to highest) across all bids,<sup>24</sup> and then a bid-specific pseudorandom number (from lowest to highest). At the lowest price  $p$  at which the auction system encounters a bid for a product  $r$ , the uniform price applying to that product will stop increasing and will be equal to  $p$ . The prices of products for which no bid has been processed so far continue increasing. During the extended round, processing ends if, at any time, the final stage rule is met given the current prices and the processed demand at the beginning of the round. The prices at which the final stage rule is met do not necessarily correspond to a price point with a bid.

For purposes of calculating whether the final stage rule is met, non-ER products are factored in using the aggregate demand and the posted prices from the previous round.

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<sup>21</sup> *Auction 1000 Procedures PN*, 30 FCC Rcd at 8084–85, para. 231.

<sup>22</sup> See Section 8.3 for how  $g$  is calculated.

<sup>23</sup> See Section 3.2 for the definition of extended round products.

<sup>24</sup> See Section 5.1 for the definition of price point.

If the final stage rule is met, the prices at which the final stage rule is met are called the *extended round clearing prices*.

If the final stage rule is not met, the prices that arise after having processed all bids of the extended round are called the *extended round processed prices*. In particular, for a product for which a reduction bid was processed during the extended round, the extended round processed price is equal to the price of the bid associated with the reduction. For a product for which there was no reduction bid during the extended round, the extended round processed price is equal to its clock price.

**Example 1:** There are three products (A, B, and C). For all three products, in the extended round the last round's posted price is \$1,000 and the clock price is \$1,200. There is a bid to reduce demand for product A by one at price \$1,050 (*i.e.*, the 25 percent price point), and a bid to reduce demand for product B by one at price \$1,150 (*i.e.*, the 75 percent price point). There is no reduction bid for product C. If 50 percent is the lowest price point at which the final stage rule is met, then the extended round clearing prices are: \$1,050 for product A, \$1,100 for product B and \$1,100 for product C (corresponding to the 50 percent price point). If the final stage rule is not met during the extended round, then the extended round processed prices are \$1,050 for product A, \$1,150 for product B, and \$1,200 for product C.

If the final stage rule is met during the extended round, then:

- The processed demand of each bidder is set to be equal to its processed demand at the start of the extended round (reductions in demand are not applied)
- For every *ER* product, the posted price is set to be equal to its extended round clearing price
- For every non-*ER* product, the posted price for the extended round is equal to the posted price of the previous round
- If there is still excess demand for any products, the market-based spectrum reserve is applied for Category 1 products and the forward auction is run until completion after the extended round. In this case, in every round after the extended round, bidding will be open on all products (including the Category 1 high-demand PEA products).

If, after the bid processing of the extended round, the final stage rule is not met, a new stage commences and the reductions of bids that were processed during the extended round are applied and carry over to the first round of the next stage. Note that this means that for a given product, only one bidder's demand reduction will be processed and thus carried over to the next round. If multiple bidders bid for a reduction at the same price for the same product, the determination of which bidder's reduction is accepted is based on pseudorandom numbers. For an *ER* product, the posted price is set to be equal to its extended round processed price. For non-*ER* products, the posted price is equal to the posted price of the last regular round before the extended round.

**Example 2:** In the extended round, for product A, the clock price is \$1,200 and the last round posted price is \$1,000. At the beginning of the extended round, the processed demand of bidder 1 for product A is 2 blocks and the processed demand of bidder 2 for product A is 3 blocks. Bidder 1 had submitted a bid to reduce its demand by one at price \$1,050 and bidder 2 had submitted a bid to reduce its demand by one at price \$1,075. Bidder 2's bid can never be applied, because demand cannot fall by more than one unit in the extended round. Suppose that bidder 1's bid is processed. Then, the price of product A will stop increasing, so the posted price for product A in the extended round will be \$1,050. If the final stage rule is met during the extended round, then the processed demand of bidder 1 will be 2 blocks and the processed demand of bidder 2 will be 3 blocks. If the final stage rule is not met during the extended round, then the processed demand of bidder 1 for product A is 1 block, the processed demand of bidder 2 will be 3 blocks, and the auction proceeds to a new stage.

## 11 Reserve Spectrum Split

The *spectrum reserve trigger* occurs if after a round, the final stage rule is met and there is still excess demand for at least one product. If at least one reserve-eligible bidder in a PEA has positive processed demand for the Category 1 product of that PEA when the spectrum reserve is triggered, that product is separated in two products: reserved and unreserved. A bidder can bid on both the reserved product and the unreserved product if it is reserve-eligible for that PEA. Bidders that are not reserve-eligible for the PEA can only bid on the unreserved product.

### 11.1 Maximum Reserved Spectrum Amounts

Let  $M_{u,j}$  denote the maximum number of blocks of reserved spectrum for stage  $u$  in PEA  $j$ . The following table is used to determine  $M_{1,j}$  for every PEA  $j$ :

Licensed Spectrum In the Initial Clearing Target (in megahertz)	100*	90	80	70	60	50	40
Minimum Unreserved Spectrum	70	60	50	40	40	40	30
Maximum Reserved Spectrum	30	30	30	30	20	10	10

\*The maximum amount of reserved licensed spectrum is 30 megahertz for initial clearing targets with more than 100 megahertz of licensed spectrum.

Given the amount of total spectrum in a PEA (*i.e.*, both Category 1 and Category 2) in stage 1, the first line is used to determine the correct column. Then, the last line of that column gives the maximum amount of reserved spectrum in that PEA in stage 1. Recall that 10 megahertz corresponds to one block. For example, according to the table above:

- If in some PEA  $j$  there are 9 blocks offered in stage 1 of the auction, then  $M_{1,j} = 3$ , *i.e.*, at most 3 of the Category 1 blocks in that PEA can become reserved in stage 1.
- If in some PEA  $j$  there are 6 blocks offered in stage 1 of the auction, then  $M_{1,j} = 2$ , *i.e.*, at most 2 of the Category 1 blocks in that PEA can become reserved in stage 1.

If the total spectrum in a PEA is less than 40 megahertz, then the maximum amount of reserved spectrum in that PEA in stage 1 is set to be equal to 0, that is,  $M_{1,j} = 0$ .

In later stages of the forward auction, the maximum number of blocks that can become reserved in a given PEA will generally be equal to the smaller of (1) the maximum amount in the previous stage, and (2) the total processed demand of reserve-eligible bidders for the Category 1 product in that PEA at the end of the previous stage – unless the supply in the previous stage for Category 1 in that PEA was 0 or 1 blocks. Specifically, in stage  $u > 1$ , the maximum number of blocks of reserved spectrum for PEA  $j$ ,  $M_{u,j}$ , is set as follows:

- If  $s_{u-1,j} = 0$ , then  $M_{u,j} = M_{u-1,j}$
- If  $s_{u-1,j} = 1$  and  $d_{u-1,j} > 0$ , then  $M_{u,j} = M_{u-1,j}$
- In all other cases,  $M_{u,j} = \min(M_{u-1,j}, d_{u-1,j})$

where  $d_{u-1,j}$  denotes the total processed demand for Category 1 in PEA  $j$  across reserve-eligible bidders at the end of stage  $u - 1$ , and  $s_{u-1,j}$  denotes the supply for Category 1 in PEA  $j$  in stage  $u - 1$ .

## 11.2 Supply of Reserved and Unreserved Products

If the spectrum reserve is triggered in stage  $u$ , the supply for each reserved product in PEA  $j$  is set to be equal to the minimum of (1) the quantity demanded for the product by reserve-eligible bidders for that PEA at the time the spectrum reserve is triggered, (2) the maximum number of blocks that can become reserved in PEA  $j$  and stage  $u$ , and (3) the supply of the pre-split product. Moreover, if there is only one reserve-eligible bidder with positive processed demand for the pre-split Category 1 product in a PEA, then the supply of the reserved product is capped at 2.

To give a formula for how to calculate the supply of the reserved product at the split, the following notation is used:

- $D$  denotes the total processed demand across all reserve-eligible bidders for Category 1 in PEA  $j$  at the time of the split.
- $k$  denotes the number of reserve-eligible bidders with positive processed demand for Category 1 in PEA  $j$  at the time of the split.
- $s_{u,j}$  denotes the supply in stage  $u$  for Category 1 in PEA  $j$ .

If the final stage rule is met in stage  $u$ , then the supply of the reserved product in PEA  $j$  is set equal to:

- $\min(D, M_{u,j}, s_{u,j})$ , if  $k > 1$
- $\min(D, 2, M_{u,j}, s_{u,j})$ , if  $k = 1$
- 0, if  $k = 0$

**Example:** The final stage rule is met in stage  $u$ . In stage  $u$ , there are six Category 1 blocks and two Category 2 blocks in PEA  $j$ , and  $M_{u,j} = 3$ . One reserve-eligible bidder has processed demand equal to 4 for Category 1 of PEA  $j$  at the time of the split, and all other reserve-eligible bidders have processed demand equal to 0 for that product. Then the supply of the reserved product in PEA  $j$  is equal to 2.

The supply for an unreserved product is equal to the difference between the supply of the corresponding pre-split product and the supply of the corresponding reserved product. Reserved and unreserved products will be considered as separate products for the purpose of setting clock and posted prices and checking whether a bid is partially or fully acceptable.

## 11.3 Distributing Demand at the Split (between Reserved and Unreserved)

Until the reserve is triggered, all bidders for Category 1 blocks, whether reserve-eligible or not, will be bidding on a single category (*i.e.*, Category 1). Right after the reserve is triggered, the processed demand for the pre-split (Category 1) product is distributed between the reserved and unreserved product according to the following algorithm:

- (1) All demand of bidders that are not reserve-eligible is assigned to the unreserved product.
- (2) A pseudo-random number is assigned (by product) to each reserve-eligible bidder with positive processed demand for the pre-split product.
- (3) Starting with the bidder with the highest number, assign one unit of its processed demand to the reserved product, proceeding with the next highest number until demand equals supply for the reserved product. In this step, the algorithm may re-cycle across reserve-eligible bidders if demand is less than supply for the reserved product at the time that each reserve-eligible bidder has been assigned one block of the reserved product.

- (4) Once the processed demand for the reserved product is determined for all reserve-eligible bidders in that PEA, the processed demand of a reserve-eligible bidder for the unreserved product is set to be equal to the difference between the bidder's processed demand for the pre-split product and the bidder's processed demand for the reserved product (which is determined by step (3) above).
- (5) If at this point a bidder's processed demand for the unreserved product exceeds the supply of the unreserved product, then the bidder's processed demand for this product is set to be equal to its supply. The bidder will then not be allowed to increase its demand for that unreserved product because a bidder cannot demand more blocks than are available. However, the bidder will maintain its eligibility and can increase its demand for other products.

Note that:

- The processed demand for the unreserved product of a bidder that is not reserve-eligible in that PEA is equal to the minimum of its processed demand for the pre-split product and the supply of the unreserved product.
- The processed demand for the reserved product of a bidder that is not reserve-eligible in that PEA is equal to 0 (since the bidder cannot bid on that product).
- If the supply of the reserved product is equal to the total of all reserve-eligible bidders' processed demands for the pre-split product in that PEA, then right after the split the processed demand of each reserve-eligible bidder in that PEA for the reserved product is equal to its processed demand for the pre-split product.
- If the supply of the reserved product is strictly smaller than the total of all reserve-eligible bidders' processed demands for the pre-split product in that PEA, then the supply of the reserved product is distributed evenly among reserve-eligible bidders, while avoiding excess supply of both the reserved and the unreserved product (unless there is excess supply for the pre-split product).

**Example:**

Suppose there are two reserve-eligible bidders each with a processed demand of 2 blocks for the pre-split product.

- If the supply of the reserved product is 2 blocks, then right after the split:
  - o The processed demand of each reserve-eligible bidder is equal to 1 block for the reserved product and 1 block for the unreserved product.
- If the supply of the reserved product is 3 blocks, then right after the split:<sup>25</sup>
  - o The processed demand of one reserve-eligible bidder (the bidder with the larger pseudo-random number) is equal to 2 blocks for the reserved product and 0 blocks for the unreserved product
  - o The processed demand of the other reserve-eligible bidder is equal to 1 block for the reserved product and 1 block for the unreserved product
- If the supply of the reserved product is 1 block, then right after the split:
  - o The processed demand of one reserve-eligible bidder (the one with the larger pseudo-random number) is equal to 1 block for the reserved product and 1 block for the unreserved product
  - o The processed demand of the other reserve-eligible bidder is equal to 2 blocks for the unreserved product (and 0 blocks for the reserved product)

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<sup>25</sup> In this case, the algorithm will proceed by first assigning one block of reserved to each bidder, and then assigning a second block of reserved to the bidder with the larger pseudorandom number.