"INCENTIVE AUCTIONS"
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EXECUTIVE SUMMARY

In February, President Obama signed into law the Middle Class Tax Relief and Job Creation Act of 2012 (Public Law 112–96 – Feb. 22, 2012) (the "Incentive Auction legislation"). The measure cedes the FCC authority to conduct reverse auctions for TV station exit, compensating low bidders with proceeds from the subsequent forward auction that will assign flexible use licenses. The purpose of this paper[1] is to examine the issues associated with the design and implementation of the reverse auction to reallocate spectrum from television licenses and the forward auction to assign the rights to use that bandwidth in new ways. The FCC is facing many auction design decisions and implementation procedure choices.

The reverse auction can be used to extract market information to assist regulators in selecting and compensating broadcasters to exit, either by ending off-the-air broadcasts or by agreeing to share a channel with another broadcaster. We examine two basic forms of auctions that could be used to obtain data on opportunity costs, a sealed-bid auction and a clock auction. In both formats, releasing the FCC repacking model prior to the reverse auction will allow stations to determine trade-offs and place informed bids in the reverse auction. For the sealed bid auction:

- Stations will submit sealed bids for releasing 6 MHz of spectrum by either exiting the market or channel-sharing.
- Bids could be bundled with multiple channel-sharing partners or exiting options within a market.
- Group station owners could submit package bids within and across TV markets (DMAs).
- An *as bid* compensation rule pays accepted bidders the amount they bid which results in price variation.
- *Vickrey pricing* encourages bidders to reveal their true exit costs, but is more complicated for bidders and creates potential political liabilities.

Sealed bids provide the FCC with a contingent price schedule, which they can use (as a supply curve) for cost-effective spectrum clearing.

For a clock auction:

- The payment to exit is posted in each TV market at a high starting price.
- Stations respond by revealing whether they will exit or channel-share at the posted clock price or not.
- Depending on how the bids are to be used in the auction process (see Section III), the clock will either fall until the target number of stations is reached (in the market in question) or until there are no more supply offers.
- The FCC optimization is conducted and winners are selected based on their clock bids.

[1] This paper was commissioned by Verizon Wireless. All views and analysis are solely those of the authors.

- All DMA winners are paid the same exit price – equal to the highest bid of the auction winners.

In the forward auction, the FCC must decide whether to use DMAs when allocating spectrum to the new flexible-use licenses, or to employ maps used previously for mobile services. The next option to consider is whether to impose a nationally harmonized band plan, or if bids in the reverse and forward auctions will be used to optimize the set of licenses offered in each market. For the forward market design, given a band plan, the format will either be a Simultaneous Multi-Round (SMR) or combinatorial clock auction.
In addition to auction design issues, there are many ancillary concerns. These policy choices may have important impacts on the efficiency of the auctions and resulting wireless sector activity. We suggest:

- There should be no (maximum) reserve prices in the reverse auction.
- All full-power, Class A U.S. TV stations should be invited to participate in the (one) reverse auction.
- Bidders should be given as little information as possible while participating in the auction.
- Promises restricting future reverse auctions could help participation, but would require tying regulators' hands in ways that could more than offset short-term gains.
- The FCC should set a date certain for the release of the spectrum to winners in the forward auctions, prior to the auctions.

I. INTRODUCTION

The Federal Communications Commission's (FCC) National Broadband Plan[2] (NBP) calls for providing an additional 500 MHz of spectrum for mobile broadband by 2020, of which 300 MHz is scheduled to be available to market participants by 2015. An integral part of this plan includes the reallocation of spectrum from broadcast over-the-air (OTA) television to mobile broadband services. Early in 2012, Congress passed – and President Obama signed – the Middle Class Tax Relief and Job Creation Act of 2012 (Public Law 112–96) (the "Incentive Auction legislation"). The measure grants the FCC authority to conduct reverse auctions for TV station exit, compensating low bidders with proceeds from a forward auction to assign flexible use licenses allocated from the repurposed TV band spectrum. These new licenses will provide increased capacity for mobile networks, a key priority in promoting broadband services and U.S. economic growth.

To achieve this outcome, a large number of broadcast TV stations will be relocated (in frequency space) by the FCC. Stations vacating higher UHF channels for lower UHF channels help to make contiguous TV band frequencies available for reallocation to the new licenses. It is not clear, at this point, how many channels will be "cleared" of TV broadcasting. Policy makers have often discussed targeting channels 31-51, and allocating

[2] Federal Communications Commission, *Connecting America: The National Broadband Plan* (March 2010) ["NBP 2010"].

120 MHz for TV service, however; the analysis in this paper assumes this 20-channel reallocation as the baseline. It is a challenging regulatory task, and time is of the essence. For this policy to be successful, the auction process needs to be transparent and simple, yet flexible, allowing efficient use of the repurposed spectrum. Appropriate policy design will encourage wide participation by both broadcasters and mobile service providers.

Currently, the envisioned process has five major steps:

(1) *Overall Plan.* The FCC establishes procedures for removing all television broadcasts using channels 31 to 51. (This constitutes 21 channels, 20 of which are currently used for TV broadcasting, and one – Channel 37 – that is allocated for radio astronomy but which may also be reallocated.[3] Each channel is allotted 6 MHz.) This band clearing process, which will take place in each of 210 TV markets (DMAs), moves stations to Channels 14-30, where possible, or pays stations to exit the market, either by completely abandoning terrestrial broadcasting or by sharing one digital television channel with another station.[4] (Two stations sharing one channel effectively removes one TV channel. Stations that share keep their 'must carry' rights, assuring carriage of their primary broadcast signal on cable and satellite TV services serving their geographic market. This protection does not appear to extend to stations that exit entirely, however.[5])

(2) *Reverse Auction*. TV station offer prices (to exit) are discovered in a reverse auction. Repacking compensation is agreed upon using an administrative process. This first stage is provisional.[6] No actual changes occur until after the forward auction establishes how much the new licenses are worth.

(3) *TV Spectrum Reallocation*. Depending on the bid prices to vacate the TV band, the estimated costs of relocation, and other allocation priorities established by the Commission, the FCC will reallocate an amount of TV Band spectrum to new flexible-use licenses.

(4) *TV Station Relocation*. Regulators then switch TV station broadcast assignments from channels that are to be reallocated to channels that will remain in the TV band. This involves a process to determine the compensation (up to $1.75 billion in aggregate) TV stations will receive for changing channels. (New towers and electronics are often needed for this, and over-the-air viewers must "find" the new signal.)

(5) *Forward Auction*. Finally, flexible-use licenses granting the opportunity to deploy the reallocated TV band spectrum are awarded via competitive bidding. An auction such as the FCC's standard Simultaneous Multi-Round process will be used for this purpose. This is labeled a "forward auction" because the new bandwidth rights

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[3] The enabling legislation allows relocation – to other frequencies – of parties using Channel 37 if that process can be achieved for under $300 million.

[4] A third option, which we note here, is that UHF stations can voluntarily agree to move to VHF channel assignments. We focus on the "exit" and "share" options in this paper.

[5] 47 USC 1452, (a) (4).

[6] We use the word *provisional* because the allocation and compensation funds are derived from a later step. If the funds from the forward auction do not cover clearing costs, the exit bid would not be accepted. We will discuss this in more detail in section III.

become available for use in the future, when winners are assigned licenses. This sale signals a transition wherein "television spectrum" will be reconfigured according to the demands of the market.

While the forward auction repeats an exercise that the FCC has been through numerous times, the reverse auction involves new regulatory procedures and presents numerous challenges not previously resolved. As such, it is critical for the Commission to consider the mechanism design options available and carefully weigh the trade-offs of each while understanding that delays are themselves costly to society.

This paper attempts a high-level outline of the costs and benefits of various FCC policy actions. Section II describes potential auction mechanisms to be used to conduct the reverse auction, considering how different rules will affect outcomes. Section III discusses the forward auction and the interplay between the forward and reverse auctions. In Section IV, we examine ancillary issues, such as transparency, timing, and bidding rules. We provide concluding remarks in Section V.

II. THE REVERSE AUCTION

The TV bandwidth to be reallocated to mobile licenses from the reverse auction mechanism was proposed in the FCC's National Broadband Plan released March 2010. That document laid out a goal of reallocating 120 MHz (or twenty TV channels). As noted, the scope of any actual reallocation has not yet been decided, but we will continue to use this baseline for illustrative purposes.

There are two basic sets of tasks the FCC must perform in clearing the spectrum, one technical[7] and one financial. The technical element is the repacking of broadcast stations from channels 31-51 into 2-30.[8] In some TV markets, one or more broadcast signals will have to be eliminated since 29 channels (available on 2-30) will not be enough to accommodate all stations. Some TV licensees will exit the market, either giving up an entire TV station license or by sharing a broadcast facility with another station. Some analysts suggest that stations will need to exit in only the largest markets, perhaps 30 DMAs (designated market areas) of 210 nationwide.[9] The estimated number of stations

[7] Technical details on repacking and associated costs are thin but some details can be found in FCC, *Spectrum Analysis Options for Broadcast Spectrum*, OBI Technical Paper Number 3, (June 2010) ["OBI 3"]. It should be noted that the "technical" nature of the task is defined by the operational approach adopted by the FCC. In fact, decisions to change the use of radio spectrum from one activity to another inherently involve economic judgments as to the value of the affected resources. For an excellent explanation of this basic reality, see Ronald Coase, William H. Meckling & Jora Minasian, *Problems of Radio Frequency Allocation*, RAND DRU-1219RC (Sept. 1995).

[8] The enabling legislation restricts the FCC from involuntarily relocating a station from the UHF band to the VHF band, and from high VHF to low VHF. This is due to concerns regarding diminished viewer reception when using certain frequencies for DTV broadcasting. These constraints presumably increase the number of broadcasting stations that the FCC will seek to remove entirely.

[9] CTIA – The Wireless Association ("CTIA") and Consumer Electronic Association ("CEA"), *Broadcast Spectrum Incentive Auctions White Paper*, (Feb. 2011).

that will need to exit ranges from 204 to 391.[10] Broadcast TV content will continue to be delivered for such stations via satellite, cable, telco TV and web distribution.
The financial element is to determine the compensation to TV stations for exiting and repacking. Repacking imposes relocation costs for those stations moved to the lower channels. The CTIA estimates that the average cost of a TV station transferring to a new channel (also referred to as *channel swapping*) would be $898,000. Such costs include new transmitters, new towers, various electronics, and installation. It is not clear that TV station owners will find this a reasonable number. In fact, we anticipate that the level of compensation offered from the swap will be vigorously challenged by stakeholders. Furthermore, due to differing physical locations, coverage areas, terrain, frequencies, and emitted power levels, there will be significant variance in repacking costs.[11]

Knowing how repacking will occur and the compensation that will be paid will help station owners form their preferences as to whether to exit from broadcasting. Therefore, the FCC should release their plans vis-à-vis these policies in advance, with an appropriate public comment period, so that TV stations can weigh trade-offs and make informed decisions.

One of the tenets of the Incentive Auction legislation is that station exits will be *voluntary*. This prompts the following questions:

1. Which TV stations should exit?
2. For those TV stations that exit, how should they be compensated and where will the funds be acquired?
3. What makes the process voluntary?

If the FCC had access to the minimum amount each station would be willing to accept to voluntarily leave a market, it would be straightforward to determine the least cost set of station exits. Yet those prices are unknown; hence, the FCC is now constructing a process to fill the information gap. The rest of this section examines the design and implementation of the chosen mechanism, a reverse auction. There are two basic formats, a Sealed Bid Auction and a Clock Auction.[12] While the specific format has yet to be determined by the FCC, we will introduce some relevant considerations here.

A. Sealed Bid (Reverse) Auction

A Sealed Bid Reverse Auction (SBRA) would ask each station licensee to state the price at which it is willing to release 3 MHz of spectrum through channel-sharing or 6 MHz of spectrum by exiting. These bids are submitted via a private (sealed bid) communication to the FCC. After all bids have been submitted, they are sorted and ranked. The FCC would then have the information needed (abstracting from relocation payments) to determine the

[10] The OBI 3 paper predicts 204 stations will need to end off-air broadcasts, while the National Association of Broadcasters, *Spectrum Impact Studies* (July 2011) ["NAB 2011"] estimates 391 stations. The actual figure depends upon the restrictions placed on which channels may be utilized and which stations are to be included in the auction.
[11] NAB 2011.
[12] Peter Cramton, Congressional Briefing, *Incentive Auctions* (May 23, 2011).

lowest cost of TV Band clearing. Using the bids submitted by stations, a set of stations would be selected to exit or channel-share, and their compensation would be based upon all the submitted bids.

Possible Bid Formats in the SBRA

There are two types of bids that would be accepted in an SBRA: A bid to exit and a bid to channel-share. A *bid to exit* is a dollar amount submitted by the bidder listing the minimum amount they would accept to release 6 MHz of spectrum and exit from OTA broadcasting in a particular market. A *channel-sharing bid* is more complicated and it is not yet clear how it will be implemented. One implementation would be for each station to independently submit a single channel-sharing bid, and then have the FCC decide which stations share a given transmitter.[13] The alternative is for stations to choose a multicasting partner, specifying this information in their offer bid. Each station that has agreed to channel-share can then submit separate bids (of 3 MHz each) for the total 6 MHz that would be released. However, both bids would have to be considered jointly to ensure they are accepted or rejected together.

Allowing TV stations to contract together on channel-sharing bids confers efficiency advantages over the FCC selection approach. There are reasons a TV station might prefer one partner over another. If both feature programming with relatively low data rates, such as pre-recorded sitcoms or talk-shows, the partners may be able to multicast two high-definition video streams. Additionally, some programming may be complementary, or could be operated by the same parent company – making cooperation easier. Channel-sharing prices may therefore be lower if pairings can be specified.

Table 1 lists possible paired bids in the case of a 4-station market where the FCC seeks to gain the exit of one station. The optimal outcome would be for Stations 1 and 3, and Stations 2 and 4, to share (shown in bold). This likely lowers band clearing costs relative to generic sharing bids where bidders allow for the possibility that they may win – but with an unfavorable pairing.

[13] To be specific, the "channel-sharing" option does not subdivide the spectrum allocated to the TV license, but has two TV stations sharing the same broadcast transmission facility. The 6 MHz channel would not be subdivided into two 3 MHz channels. The ATSC (digital television) standard provides that broadcasts emit across all 6 MHz and distribute a signal delivering 19.4 MBPS. Presumably, two stations would cooperate in running the transmission facility and each would then program 9.2 MBPS of the broadcast. This would allow stations to transmit about three standard definition digital video signals (depending on the type of programs broadcast).

Table 1: Hypothetical Channel-sharing Bids in a Market with 4 Stations

Station Pairing	Pairing Bids	Total Bid
1&2	100 - 100	200
3&4	600 - 600	1200
1&3	**150 - 150**	**300**
2&4	**200 - 500**	**700**
1&4	200 - 300	500
2&3	300 - 400	700

However, it is apparent that the optimal pairings are unlikely to be achieved if stations are limited to a single channel-sharing bid. In the example above, when limited to only one bid, Stations 1 and 2 would likely submit a bid together, as it would be the least expensive option for either of them. This would leave only Stations 3 and 4 to submit an alternative bid. Taken together, the cost of removing one station totals 1400, 400 higher than the optimal allocation. This indicates that to obtain the lowest cost combination for two stations to exit depends on the possibility of *multiple* linked bids for channel-sharing. These bids, in turn, require *XOR logic*.

XOR means that if an entity submits two bids in the auction, only one of the two bids can be part of the winning set of bids. In the case of the FCC auction, if Station 1 submits a bid to channel-share with Station 2 and another bid to channel-share with Station 3, just one of the bids placed by Station 1 can be accepted. This same logic would apply if a station submits a bid to exit (entirely) along with a channel-sharing bid.[14]

While these types of bids can be incorporated in an optimization to find the lowest cost arrangement, there are drawbacks. Specifically, the number of possible bids grows exponentially as the number of stations increases, and the optimization algorithm required to select the least expensive bids would be more complex than just accepting bids from lowest to highest. However, modern computing and the limited number of such possible bids would suggest that the computational complexity of this problem is not excessively challenging.

A greater challenge to the shared-channel bids would be whatever policy the FCC crafts with respect to bidder collusion. A shared-channel bid is, by its nature, the product of coordination between two stations in the same market. If the FCC imposes a blanket ban on pre-auction discussions between bidders, as it did in the 700 MHz auction in 2008, then such bids could not be formulated. The FCC should, at a minimum, consider potential efficiency losses from restricting voluntary pre-auction pairings when deciding on whether to impose such rules here.

In addition to the XOR bid logic suggested above, an extended bid format could allow bidders that own stations in multiple markets to submit one bid to release their MHz for

[14] Bidders may arrange their own alliances by contract. These are best left to marketplace negotiations.

multiple stations.[15] This *package bid* requires that all offers (stations) in the package bid be accepted or rejected. Package bids could result in reduced exit costs, as broadcasters could consolidate bids into a single, less risky offer. This would tend to lower band clearing costs.

Package bidding has been advocated for use in FCC auctions since 1996[16] but was not used until the 700 MHz auction - and then in only a very limited way. One of the main historical reasons for not using package bids is because it complicates the optimization problem (similar to XOR bids) and can result in indeterminate processing times. Again, modern computing can handle these types of problems more easily than in previous years.

Sealed Bid Auction Pricing Rule

The most common pricing rule used in sealed bid auctions is *as bid*. This rule has each participant being compensated exactly what they bid if their offer is accepted. This means that stations might, and most likely will, be paid differently for the same release of spectrum in the same market – which is called *discriminatory pricing*. With a discriminatory pricing rule, participants have an incentive to shade their offers, not revealing the true cost of exiting or channel-sharing. They will predictably bid higher than their actual value. A potential station bidding strategy would be to determine the expected value of the first rejected bid and bid just below that amount. This is risky, since the value of the rejected bid is not known with certainty.

The benefits of the sealed bid auction with *as bid* pricing are three-fold: it is easy for participants to understand, it is easy to implement, and it provides all the necessary information for the simultaneous approach that we will describe in Section III. However, economic experiments have found that both the efficiency and final prices of this pricing system are highly dependent on the specific values (opportunity costs) of the participants. In particular, the more elastic the supply curve, the higher the probability of an inefficient result.[17] That is, if the opportunity costs of sellers are clustered very closely, then there is a greater chance that a higher cost (less efficient) seller will have its bid accepted in lieu of a lower cost supplier simply due to more aggressive bidding. If seller opportunity costs are far apart, then there is less of a chance for this sub-optimal outcome to obtain.

An alternative to *as bid* pricing is *Vickrey pricing*. This rule is a bit more complicated given the possibility of XOR and package bids. The Vickrey pricing rule is designed to provide an incentive for bidders to truthfully reveal their minimum value to exit or channel-share. The amount that a winning bidder would receive is calculated by determining the

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[15] In fact, there is a natural package bid that occurs for channels which span multiple DMAs, which is common in more densely packed areas such as the Northeast or Southern California. For example, if KRCA in Riverside exits, 6 MHz will be freed in both Los Angeles and San Diego. This means the FCC will be forced to accommodate at least some package bidding.

[16] Jeffrey Banks, Mark Olson, David Porter, Steve Rassenti & Vernon Smith, *Theory, Experiment and the Federal Communications Commission Spectrum Auctions,* 51 JOURNAL OF ECONOMIC BEHAVIOR AND ORGANIZATION (2003): 303-350.

[17] David Porter, Stephen Rassenti, William Shobe, Vernon Smith & Abel Winn, *The Design, Testing and Implementation of Virginia's NOx Allowance Auction,* 69 JOURNAL OF ECONOMIC BEHAVIOR AND ORGANIZATION (2009): 190-200.

opportunity cost of their offer. This is done by finding the value of the offer(s) displaced when their offer is accepted. Suppose, for example, the offers submitted are those charted on the left side of Figure 1, which summarizes a situation where the FCC seeks to remove 5 TV stations from a given market. In this case, all of the 5 winning offers displace the 6th lowest offer of 600. Thus, each of the winning bidders would receive the same (uniform) price of 600. However, with package bids, a uniform price might not occur. Suppose our example shifted to what is illustrated on the right side of Figure 1, where Bidder 3 has placed a package bid. Bidders 1, 2, and 4 exit the market, and bidder 3 wins a package offer. Bidders 1, 2, and 4 each receive 500, while Bidder 3 receives a total of 1200 for the B3 package.

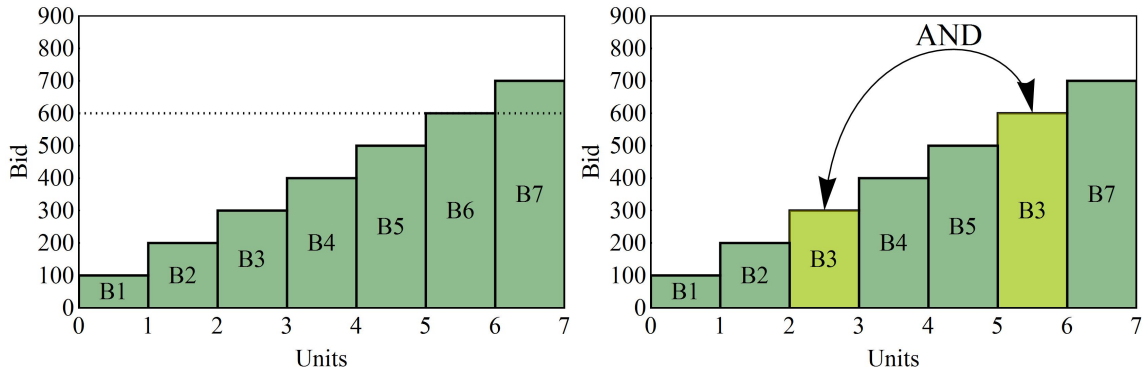

Figure 1: Vickrey pricing results in a uniform price when only single offers are involved; inviting package bidding allows for different outcomes. Left Side: A Vickrey auction without package bids. The sell price is 600 for all bidders. Right Side: Package bids accepted. Bidders 1, 2, and 4 are paid 500 to exit, while Bidder 3 is paid 1200 for its package offer – what it would cost to accept the single bids (together) of B5 and B6.

Even though this pricing rule has desirable properties, including incentives for truthful revelation and allocative efficiency, there are several issues. First, this rule is foreign to bidders and requires experience to know how to bid. Second, since the FCC will make the bids public after the auction, the information could be used against the bidders in future negotiations.[18] Third, to the extent the public sees "money left on the table," political backlash may result. In 1990, when New Zealand sold wireless licenses using a uniform price rule, a winning bid of $100,000 resulted in a sales price (revenue captured by the Government) of just $6. In another case, the winning bid was $7,000,000, but the uniform price was only $5,000.[19] This generated controversy over "windfalls."

Recap of the Sealed Bid Reverse Auction

- Releasing the FCC repacking model prior to the reverse auction will allow stations to determine trade-offs and place better informed bids.

[18] Lawrence Ausubel & Paul Milgrom, *The Lovely but Lonely Vickrey Auction*, in Peter Cramton, Richard Steinberg & Yoav Shoham,,eds., COMBINATORIAL AUCTIONS (MIT Press; 2005): Ch. 1.; Michael H. Rothkopf, Thomas J. Teisberg & Edward P. Kahn, *Why Are Vickrey Auctions Rare?* JOURNAL OF POLITICAL ECONOMY (Feb. 1990): 94-109.

[19] John McMillan, *Selling Spectrum Rights,* 8 JOURNAL OF ECONOMIC PERSPECTIVES (1994): 145-162.

- Stations will submit sealed bids for releasing 6 MHz of spectrum by either exiting the market or channel-sharing.
- Bids could be bundled with multiple channel-sharing partners or exiting options within a market.
- Group station owners could submit package bids within and across TV markets.
- An *as bid* compensation rule pays accepted bidders the amount they bid which results in price variation.
- *Vickrey pricing* encourages bidders to accurately reveal their exit costs, but is more complicated for bidders and creates political liabilities.
- Sealed bids provide the FCC with a contingent price schedule, which they can use (as a supply curve) for cost-effective spectrum clearing.

B. Descending Clock Auction

The descending clock auction is another design that the FCC can utilize to solicit TV stations' sale prices. Although different formats are possible, the most likely scenario is for the FCC to start the auction by posting a high price – a payment to cease broadcasting either in whole (exit) or in part (channel-sharing) in each TV market that requires (according to the FCC repacking model) a reduction in stations. Responding to these prices, stations submit their plans to stay, share, or exit.[20] Bidders that have a channel-sharing arrangement can submit that bundled offer.

If there are more offers to exit than desired in that market by the FCC, which should be the case as the FCC seeks to set the initial price at a sufficiently high enough to induce this outcome, the clock price is then reduced by a specified percentage. This is called *a tick of the clock*. The process continues under two separate cases depending on how the offers are to be used (see Section III):

1. Price falls until the target number of stations is reached.
2. Price falls until there are no station offers (this maps out a full supply curve).

The pricing rule used with the descending clock auction is a *uniform price* rule. This means each station in a DMA that wins (is selected in) the auction is paid the same amount per MHz to either exit or channel-share. This pricing rule has the property that each station should truthfully reveal their bid since what they are paid is not purely a function of their bid. Uniform price rules, while providing excellent incentive properties, have the same political pitfalls as the Vickrey pricing rule we mentioned earlier if we define the entire supply curve as in (2). Clock auctions can also use non-uniform price rules. In this case, winners are paid *as bid* at the point that the clock stopped. This format has the same theoretical properties as the sealed bid auction with as bid pricing (discussed above).

[20] The clock auction can also allow for XOR and package bids. The process is the same, except that participants are allowed to link their bids. See David Porter, Stephen Rassenti, Anil Roopnarine & Vernon Smith, *Combinatorial Auction Design*, 100 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES (2003): 11153 - 11157; Lawrence M. Ausubel and Paul Milgrom, *Ascending Proxy Auctions*, in Cramton, Steinberg & Shoham (2003).

Finally, there are two conditions where a descending clock auction produces lower exit costs than the SBRA[21]:

1. **Elastic supply.** The more elastic the true supply curve the more likely the total exit costs are lower in the clock auction.
2. **High participation.** The more stations that participate, the lower the revenue in the clock auction. (This is a corollary of (1).)

Recap of Clock Auction

- The payment to exit is posted in each TV market at a high starting price.
- Stations respond by revealing whether they will exit or channel-share at the posted clock price. The default is that they do neither (i.e., the station stays as is).
- Depending on how the bids are to be used in the auction process (see Section III), the clock will either fall until the target number of stations is reached (in the market in question) or until there are no more supply offers.
- The FCC optimization is conducted and winners are selected based on their clock bids.
- All DMA winners are paid the same exit price – equal to the highest bid of the auction winners.
- The descending clock auction has desirable revelation properties, but comes with political pitfalls similar to the Vickery price rule.

III. INCORPORATING REVERSE AUCTION DATA IN THE FORWARD AUCTION

Figure 2 shows a map of the 210 TV DMAs in the United States and the relative size of the audiences they cover.[22] Assuming that up to 120 MHz spectrum will be acquired through both the reverse auction and/or repacking in every TV market, the FCC will develop a band plan for the fraction of the 120 MHz to be allocated to flexible-use licenses. One of the challenges for the FCC is to decide whether to use DMAs when allocating spectrum to the new flexible-use licenses, or to employ the maps used previously for mobile services. These partition geographic markets into: Cellular Market Areas (CMAs); Basic Trading Areas (BTAs) and Major Trading Areas (MTAs); or Economic Areas (EAs) and Regional Economic Area Groupings (REAGs). This decision will impact how the FCC uses the bids in the reverse and forward auctions. There are two possible ways the FCC could incorporate the results of the reverse auction with the results of the forward auction: using a harmonized selection process or a variable selection process.

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[21] See Vernon Smith, *Experimental Studies of Discrimination Versus Competition in Sealed-Bid Auction,* 40 JOURNAL OF BUSINESS (1967): 56-8; and David Porter, Stephen Rassenti, William Shobe, Vernon Smith & Abel Winn, *The Design, Testing and Implementation of Virginia's NOx Allowance Auction,* 69 JOURNAL OF ECONOMIC BEHAVIOR AND ORGANIZATION (2009): 190-200.

[22] The graph was constructed using Nielson, *2010-2011 TV Household DMA Rank* (Sept. 2010).

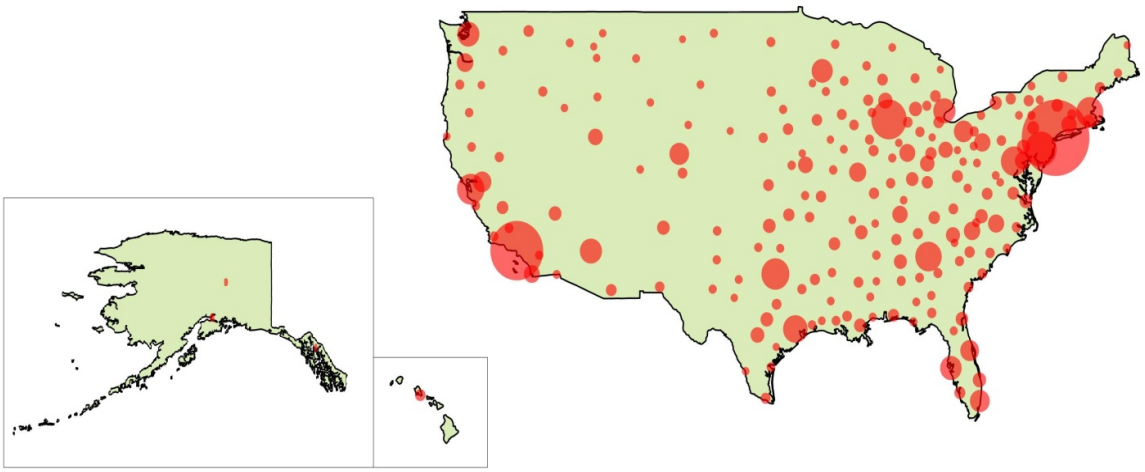


Figure 2: The map indicates each television market as a red circle. The size of each circle indicates the proportion of US population served by that market. Although each market is defined to have a distinct geographical boundary, many stations can be received by viewers in multiple markets.

The variable approach would not, in all likelihood, collect bids from both the TV broadcasters and mobile service providers at the same time.[23] Rather, the FCC conducts an optimization to determine how much spectrum is repurposed that uses bids from both the reverse and forward auction. For example, if the costs of acquiring and/or repacking a given increment of bandwidth from OTA broadcasting in a specific DMA outweigh the revenue gained from the sale of flexible-use licenses, then that spectrum will remain allocated to the TV Band. However, where the opposite is true, the reallocation will occur. By comparing the supply and demand for spectrum in each area, all reallocations from TV licenses to flexible-use licenses will increase spectrum efficiency. Figure 3 charts the process of the variable approach.

[23] Although it is possible to conduct both auctions simultaneously. See Ishikida, Takashi, John O. Ledyard, Mark Olson & David Porter, *Experimental Testbedding of a Pollution Trading System: Southern California's RECLAIM Emissions Market*, 8 RESEARCH IN EXPERIMENTAL ECONOMICS (2001): 185-220; and Evan Kwerel & John Williams, *A Proposal for a Rapid Transition to Market Allocation of Spectrum*, Federal Communications Commission OPP Working Paper No. 38 (Nov. 2002).

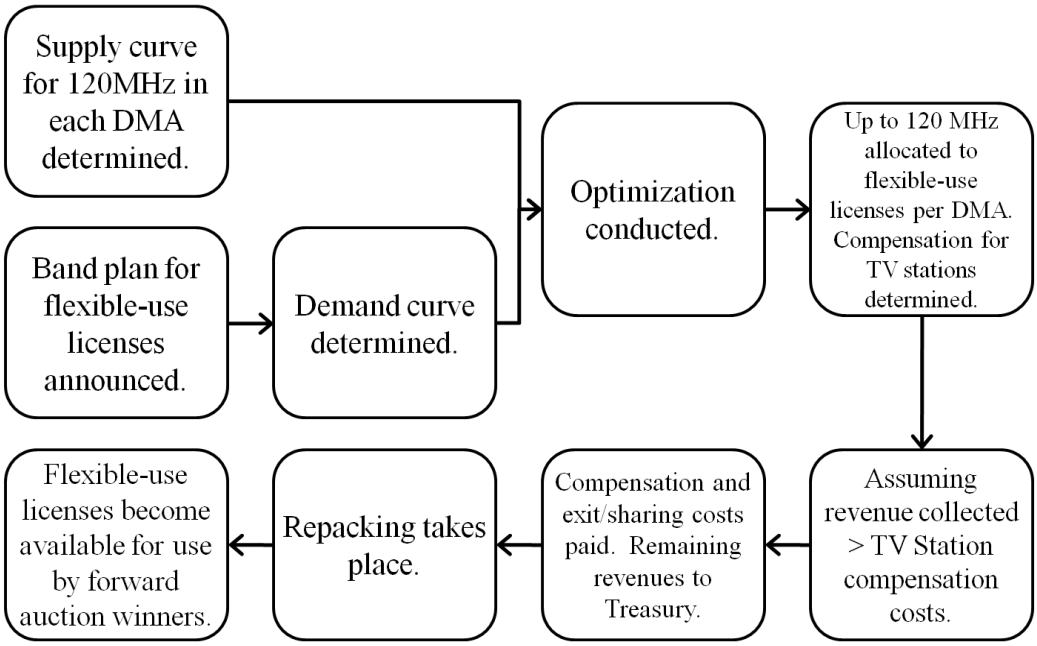


Figure 3: Sequence of Events for Complete Optimization. (Start upper left; finish lower left.) First, the reverse auction collects data to determine the supply curve across all TV markets. Either after that or at the same time, the FCC determines the band plan for flexible-use licenses and holds the forward auction. Then an optimization is conducted by the FCC using the information gleaned. Efficient reallocations are scheduled. TV markets are repacked. Relocated and exiting stations are compensated. Finally, bandwidth – in the form of flexible-use licenses – becomes available for license winners in the forward auction.

However, such a proposal does have drawbacks. First, it would require a very complex set of FCC calculations to ensure maximum efficiency (Section II highlights the different types of bids which must be examined in the reverse auction). Secondly, the amount of spectrum that can be efficiently reallocated must be determined for each DMA. This would most likely limit the forward auction band plan to be designated in DMAs; using traditional mobile markets (CMAs, BTAs, MTAs, EAs, and REAGs) would potentially create serious difficulties in area overlaps. For example, since an EA would span multiple DMAs, and would likely cover only parts of some DMAs, determining the optimal amount of spectrum to be reallocated becomes quite complicated. Finally, a variable approach would require auctions to reveal the entire supply (reverse auction) or demand (forward auction) curve. While this is not as serious a drawback as the other two, it does limit the choices of the FCC.

As an alternative to the variable approach, the harmonized approach calls for the FCC to target a nationally uniform spectrum reallocation. From the FCC's perspective, this simplifies the process. In addition, the flexible-use license band plan can employ any franchise area map. However, if the FCC chooses to take this approach, they will be vulnerable to the possibility of the forward auction payments failing to cover total exit (and repacking costs) from the reverse auction. In this case, the reallocation would be canceled, and the TV Band would remain locked into the broadcasting allocation. This prospect of

failure may yield individual television stations a greater incentive to become hold-ups. While competition within each DMA should limit this abuse, the reliance on every television market clearing does increase the profitability of such a harmful strategy.[24] Furthermore, since there is an overall revenue target, there is a public good aspect in that every bid contributes to meeting the target. Thus, participants in the forward auction might have to raise their own winning bids to help reach the target. Allowing for nationwide licenses can reduce this public good aspect if such licenses are the most valuable. Should the FCC maintain the flexibility to exempt a small number of "high cost" markets[25] from a (virtually) "all or nothing" transition, the hold-up problem would be further mitigated.[26] That is, if broadcasters do not know the amount of spectrum that will be auctioned in the forward market the potential for a hold-up problem will be lessened. The sequence of events in an all-or nothing approach is shown in Figure 4.

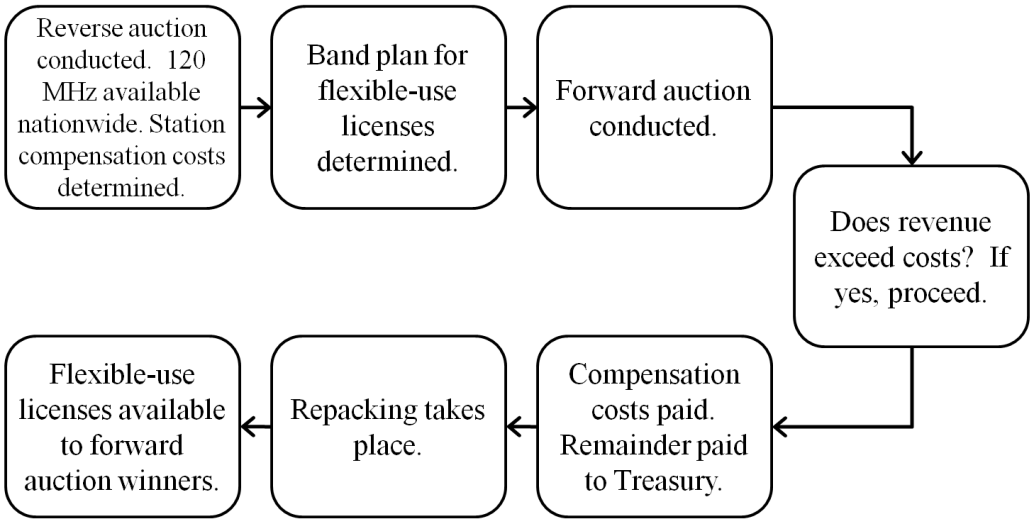


Figure 4: Sequence of Events with harmonized approach and 120 MHz reallocated nationwide. First, the reverse auction is held and the cost for freeing 120 MHz nationwide is found. Then, the band plan is determined and the forward auction is held. If the forward auction revenue does not exceed the TV station compensations, then the reallocation is canceled. Otherwise, the 120 MHz is cleared, and the stations are compensated. The spectrum then becomes available to the winners of the forward auction.

Recap of Spectrum Reallocation Optimization

- A band plan is created for the target level of TV Band spectrum to be reallocated.
- The FCC will use either a variable or a harmonized approach.
- The variable approach uses the supply and demand curve to determine the most efficient allocation, but is very complicated. It can limit the FCC's choice of map to be used in reallocating spectrum to flexible-use licenses.

[24] For example, see Scot D. Kominers & E. Glen Weyl, *Holdout in the Assembly of Complements: A Problem for Market Design*, AMERICAN ECONOMIC REVIEW (forthcoming, 2012).

[25] Namely, markets where it turns out to be very costly to reallocate the entire target spectrum block.

[26] This, of course, has implications for the band plan chosen for the flexible-use licenses, as some of the spectrum targeted for reallocation would remain in the TV Band.

- The harmonized approach clears a fixed amount of bandwidth nationwide rather than allowing a differing amount for each DMA. This simplifies the optimization and allows for the forward auction to use any franchise map. However, it can result in a less efficient allocation and possibly lead to the entire reallocation process being blocked.

Using the Standard FCC Auction Format

Given a band plan, the FCC could conduct its standard Simultaneous Multi-Round (SMR) Auction. In this auction, a set of prices for each area in the band plan will be found. For example, if the auctions averaged a price of $1.50 per MHz-POP, total revenue for the forward auction would reach $38.9 billion with 120 MHz offered. If the minimum revenue target to pay for OTA repacking ($1.75 billion) and exit costs were $3.1 billion, then $35.8 billion would go to the US Treasury and to public safety radio network development as defined in the Incentive Auction legislation.

A concern with the SMR relates to the political temptation to reserve (not allocate) some licenses when the high bids they attract fall below the associated station exit and repacking costs. However, this approach (imposing a price/cost test to each license) exposes bidders to significantly higher aggregation risks. For example, if a bidder wants to have licenses in several geographical regions for coverage, dropping one would cause a significant reduction in value that is not represented by the bids for the single licenses. Picking and choosing which geographical regions to drop based on the SMR bids is therefore inappropriate. If SMR is to be used, it is essential that the FCC proceeds with a harmonized plan.

Using a Combinatorial Auction

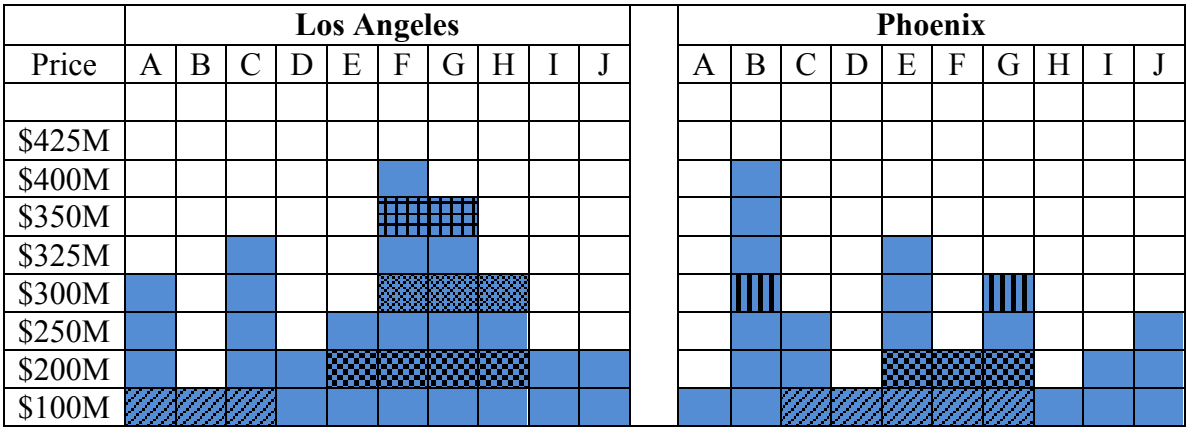
The FCC used a simple combinatorial auction for the 700 MHz auction. In this auction, overlapping license areas were – mostly – aligned so that smaller license bids could be added together to compete with larger predefined packages in determining the highest bids. This would be a better format than the SMR auction if the variable process is used. Peter Cramton suggests using a combinatorial clock auction to conduct the forward auction.[27] The auction, as modeled, allows bidders to package licenses as they see fit based on the current clock prices for each license offered. Combinatorial auctions have the advantage of reducing aggregation risks that are present in the SMR. For example, at the current clock prices, a bidder could link their offers to purchase Los Angeles, San Diego, Phoenix and San Francisco licenses. This means that the bidders are willing to pay the sum of the clock prices for all four licenses if those prices are accepted. The combinatorial process would continue until demand meets the target level of MHz. If the total revenue raised exceeds costs, the reallocations are made.

[27] Peter Cramton, *Incentive Auctions*, presentation at Northwestern University (June 3, 2011).

When bidders are faced with aggregation risks, as they are in mobile markets, combinatorial auctions are the allocation mechanism of choice. The bid information from a combinatorial forward auction can be directly used as the demand schedule to determine the optimal reallocation in the variable approach.

Suppose we were allocating spectrum just in LA and Phoenix. Table 2 lists a hypothetical set of descriptive bids from a combinatorial auction. We see that if all 120 MHz are allotted to flexible-use licenses in each area, a total of $2B in revenue would be raised. However, if only 60 MHz are made available in each area, then $2.75B in revenue would be raised.[28] Additionally, bidders might have a preference for a specific group of DMAs, these package bids are shown with different geometric shading in Table 2. This example was constructed to conform to the standard FCC mobile band plan structure. However, the FCC might alternatively create a generic 12 MHz paired license. Bidders would only have to report how much bandwidth, in 12 MHz increments, they desire in each license area. This would simplify the process for the FCC. However, all available frequency spaces may not be valued equally. For example, some carriers have licenses procured in the 700 MHz auction so that the adjacent J Block license in our example might be more valuable to them.

Table 2: Descriptive Bids from a Combinatorial Clock Auction (12 MHz/license)



At a clock price of $100M per MHz for a 12 MHz license, there are exactly 120 MHz demanded in either packages or individual licenses bid. Different desired packages are shown using geometric shading and individual license bids contain no geometric shading. As the clock price moves up to $200M for each license, demand falls so that 108 MHz is demanded in LA and 84 MHz in Phoenix. The clock price continues to increase until it reaches $425M when there are no further bids.

Using this table of defined demands, the FCC could find the level of MHz in each market that maximizes the total surplus using the offers from the incentive auction. An important point to note is that if a complete optimization were utilized, then different levels of MHz in each geographic area could occur, without the constraint of minimum compensation costs for a national reallocation effort. It might also mean that there are areas in which

[28] This outcome mimics a real possibility, that putting more spectrum into the market will lower auction revenues. The socially efficient path is not to maximize the auction revenue, but to deploy spectrum in the most productive manner. *See* Thomas W. Hazlett, Roberto E. Muñoz & Diego B. Avanzini, *What Really Matters in Spectrum Allocation Design*, 10 NORTHWESTERN Journal of TECHNOLOGY & INTELLECTUAL PROPERTY 93 (2012).

some stations will not need to be repacked because the FCC has found that repacking costs outweigh the value of the bids for licenses allocated the underlying spectrum.[29]

The process described above would select new spectrum configurations without the possibility of a potential failed reallocation from a harmonized revenue target to cover compensation costs. It also provides additional competitive pressure on TV stations since their offers need not be selected in order for other reallocations to occur. It results in more revenue to the Treasury, and is economically efficient. Its biggest drawback is its high level of computational complexity for the FCC.

Recap of Forward Auction Design

- The forward auction format will be SMR or a combinatorial auction.
- The SMR is more familiar and thoroughly studied. However, it limits the FCC to using the harmonized allocation optimization and will likely result in lower revenues.

IV. ANCILLARY ISSUES

A. Auxiliary Reverse Auction Rules

In addition to the choice of auction formats described in Sections II and III, there are other practices that can hinder or enhance participation in reverse auctions. One common practice is to impose a *reserve price*. In this context, the reserve would set a price cap, the *maximum* amount that would be paid to a station for exiting a particular TV market.

Reserve prices can be public or private. Public reserve prices usually come in the form of a listed maximum bid amount that would be accepted. The reason for a reserve price is if the buyer (US Government) has an alternative opportunity for the resource. That is, at prices above the reserve price, the spectrum is most productively left in its current employment. Here, the whole point of the "incentive auction" exercise is to discover (and unlock) the value of new spectrum uses. The 5-step process is designed to reallocate TV Band spectrum only if the bids for flexible-use licenses are sufficient to compensate those interests (broadcasters) which are negatively impacted. There is no reason to impose reserve prices in the reverse auction when the process is structured to, in essence, supply the appropriate valuation cross-check via the winning bids received in the forward auction.

Alternatively, private reserve prices are used when the buyer believes that there will be little seller competition and wants to insert itself as a potential seller to create additional competition. However, in the context of an incentive auction, this could be very risky for the Government to do. If the reserve is too low, too little spectrum will become available. Moreover, the FCC has the discretion, given the structure of the process, to effectively reject offer prices, limiting the spectrum repurposing in a given market to less than 120

[29] This process is akin to the two-sided auction described in Kwerel & Williams (2002).

MHz. Furthermore, by not disclosing the amount of spectrum being contemplated in the forward auction, the FCC can reduce the rationale for reserve prices in the reverse auction.

In order to have a competitive incentive auction, participation from as many stations as possible in the auction is important. There should be no restrictions on which stations can participate in the auction, similar to how the current legislation prevents arbitrary participation restrictions in the forward auction. One of the main elements that regulate bids in an SBRA is the number of participants. Bidders must weigh the premium they may receive by raising their bid verses the possibility of being underbid by another participant. Full participation causes bidders to bid closer to their true value. Along these same lines, it has been found in experiments[30] that not providing information on the number of bidders participating in an auction causes bids to more closely reflect opportunity cost. Not providing information on competitors' actions in an auction also seems to temper bids towards participants' true opportunity costs.

The *transparency* of the process, in terms of how a TV station's bid will be used and how the winners will be paid, is important here. Raising the cost of bid preparation and participation has a negative effect on station participation. Any uncertainty as to how stations will be compensated for winning bids will also tend to reduce participation. Relying on an outside appraisal process to estimate, say, the enterprise value of participating stations and then using these estimates to compensate stations that agree to exit or share – in effect, adjusting offer bids ex-post via an uncertain formula – will predictably reduce participation.

Finally, a more difficult issue is whether the FCC should make any promises regarding future reverse auctions. In some discussions it is asserted that this process will be repeated again in the future – which would require additional congressional authorization (the 2012 legislation limits the FCC to one "incentive auction") – in order to clear out additional spectrum. Anticipating this, some stations may opt out of this round of reverse auctions in order to reap higher exit compensation in this potential future auction. The FCC could announce a regulatory commitment that there will be no future auction for at least some specified number of years. If credible, this would likely increase participation in the reverse auction and lower exit bids. However, such a policy is unenforceable. Moreover, to the extent it could have some binding impact on future FCC actions, it would be socially expensive, as it would rigidify existing under-employment of spectrum resources. These high social costs would likely more than offset any short-term gains such a policy would achieve.[31]

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[30] Joy Buchanan, *Information Effects in Multi-Unit Dutch Auctions*, Economic System Design Master's Thesis, Chapman University (2011); Aleksander S. Pekec & Ilia Tsetlin, *Revenue Ranking of Discriminatory and Uniform Auctions with an Unknown Number of Bidders*, 54 MANAGEMENT SCIENCE (2008): 1610–1623.

[31] Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, 40 RAND JOURNAL OF ECONOMICS (2009): 424-54.

B. Timetable

For forward auction participants, one of the primary dangers is that once their bids have been placed, flexible-use licenses will yet fail to be assigned for many months or years. Widening the interval of uncertainty will result in reduced participation rates and lower auction prices. Therefore, one action the FCC should take is to develop a timetable for the release and use of the spectrum to winners in the forward auction, as well as rules governing what recourse is offered bidders when FCC deadlines are unmet. One possibility is to give participants the right to opt out of their bid if the timetable is violated. This would reduce the risk of bidding. But, if the option to opt out is implemented and deadlines are not met, it is possible for the entire auction to collapse as bidders withdraw from the process. This catastrophic outcome is powerful testimony to the importance of FCC rules and processes that move forward with dispatch and result in expeditious spectrum reallocation.

Recap of Ancillary Issues

- There should be no (maximum) reserve prices in the reverse auction.
- All full-power U.S. TV stations should be invited to participate in the reverse auction.
- Bidders should be given as little information as possible while participating in the auction.
- Promises restricting future reverse auctions could help participation, but would require tying regulators' hands in ways that could more than offset short-term gains.
- Allowing winning bidders to opt out if timelines are unmet can increase participation but may eventually damage the spectrum reallocation process.

V. CONCLUSIONS

The FCC has many options as it reallocates TV Band spectrum to flexible-use licenses. Determining the best approach is crucial for the process to be successful. A table is provided at the end of this paper detailing choices and trade-offs.

The FCC can attempt to find the most efficient allocation of the repurposed spectrum using a variable approach that uses the information about the supply curve provided from the reverse auction and the demand curve obtained from the forward auction. This complex optimization process requires soliciting bids to cover the complete demand and supply space. The end result could be less than 120 MHz being cleared in some (of 210) TV markets, since some are more crowded than others and will be more costly to clear. To limit potential administrative confusion, the FCC can instead use a "harmonized" approach to spectrum clearing. This way, the FCC commits to freeing a specified amount of MHz for flexible use licenses nationwide. This opens the risk of having to cancel the reallocation if insufficient revenue is raised from the forward auction to compensate exiting and relocating broadcasters.

Since each television market must be cleared separately, a reverse auction must be held in each market with “excess” television stations. However, the types of possible bid formats are complicated by the specific features of the television market. In particular, television stations may be able to channel-share so that two TV licensees can occupy just 6 MHz of frequency space instead of 12 MHz, continuing to transmit one digital television signal that delivers two (or more) channels of programming via ATSC multiplexing.

Allowing a broadcaster to offer multiple bids, say, one to channel-share and one to exit, would allow for a greater flexibility for bidders and reduce costs. In addition to channel-sharing, many companies own multiple television stations and may want to either surrender all of their stations or none of them. A traditional auction does not allow for companies to place a bid contingent on multiple stations being accepted (called a combinatorial bid). Instead, they must submit piecemeal bids, which could expose them to the risk of obtaining some, but not all, of the transactions they desire. Additionally, some stations broadcast in multiple television markets, so the outcomes from one market's auction are tied to the outcomes in neighboring markets. Accommodating combinatorial and channel-sharing bids is essential for efficiency, increasing reverse auction participation and lowering the costs of band clearing. Unfortunately, the added complexity to the auction and optimization process might limit the FCCs ability to allow such bids.

An efficient reverse auction selects those stations with the lowest costs for exit. There are three auction properties necessary for this outcome:

- The auction must be simple enough for broadcasters to place informed bids.
- The auction must encourage broadcasters to reveal their true exit costs.
- The auction must allow all reasonable bid configurations (combinatorial bidding).

In addition to auction efficiency, keeping total compensation for station exits as low as possible is also an important goal. Unfortunately, no known auction format has all of these properties, but many come close. We propose three possible approaches.

A sealed bid reverse auction with *as bid* pricing has broadcasters place sealed bids. Once all offers are collected, they are accepted from lowest to highest until all necessary bandwidth is cleared in the given market. Broadcasters with accepted offers receive compensation equal to their placed bid and either exit the market or channel-share, depending on their accepted bid. This format is very simple for bidders to understand. But, because compensation is equal to whatever was offered, broadcasters must think strategically when bidding. Broadcasters are encouraged to place offers higher than their true costs in order to receive higher compensation. This can lead to inefficient outcomes if those broadcasters place offers too high in an attempt to game the system.

A sealed bid reverse auction with Vickrey pricing operates in much the same way. However, rather than compensation equaling the broadcasters' offers, each exiting broadcaster receives compensation equal to the value of the offer they displaced by having their (lower) offer accepted. This is complicated for bidders to understand, and can therefore lead to inefficient bidding. In addition, this can result in what publicly appears to be an overpaying of broadcasters, because if a particularly low offer displaces a much higher offer, the broadcaster receives compensation equal to that high offer. However, this approach encourages broadcasters to place offers equal to their true valuation of market exit.

A descending clock auction has many of the same end results as a sealed bid reverse auction with Vickrey pricing, but is much easier for bidders to understand. This format begins by posting a high price, called the clock price, for all auction participants to see. Given this exit price, each broadcaster indicates whether it is willing to give up its TV license. If more licenses are offered than required to obtain the desired amount of spectrum in the market, the price ticks down, and participants indicate if they are still willing to exit at this new price or not. Bidding is simple and straightforward: all broadcasters need to do is say "yes" or "share" or "no" at the current price.

As the price falls, some broadcasters will drop out of the bidding. The clock price continues to fall until the number of broadcasting licenses being offered to sell is just equal to the amount needed to obtain the target amount of spectrum for reallocation. Winning bidders thereby commit to relinquishing their rights (by either exiting the market or channel-sharing) and will receive the final clock price in compensation. Thus, these exiting broadcasters will receive a *uniform price* that is equal to or higher than what they might have accepted. This provides incentives for truthful revelation of value and the auction thus determines which stations are most efficient to select for exit. However, this can have the same problem as with the Vickrey pricing, where it appears some participants receive "windfalls." This is especially true if the variable approach is being used to determine the reallocation nationwide, as the clock must continuing ticking until all participants drop out (thus obtaining the supply curve), which reveals all levels of payment participants would have accepted.

In terms of the forward auction design, the FCC is familiar with how to organize such auctions. However, the Commission – assuming it does not switch to national licenses in its band plan, as most other nations utilize – needs to improve competitive bidding procedures by allowing for packaged bids such that regional or national aggregations can be most efficiently pursued. Progress on combinatorial clock auctions makes it feasible for the FCC to pursue this expanded format. The sophistication of the bidders that will likely be involved in the forward auction further supports this transition.

A general guideline for auction design is to maximize participation and to minimize the amount of unnecessary information participants are given. Therefore, the FCC should not impose restrictions on which television stations can participate. Additionally, participants should not be provided either the number of participants in the auction or the number of participants still remaining in the auction as the clock ticks on. These rules will maximize the competitiveness of the auction process and are likely to produce the best outcomes.

Developing a flexible and transparent auction process is critical if the FCC is to quickly and smoothly reallocate spectrum from broadcast television to mobile broadband services. Releasing the proposed details of the process, while allowing public comment and discussion as required by administrative law, is an important first step to ensuring that the process progresses in an expeditious manner.

Issue	Approach Option	Pros	Cons
Reverse Auction Format	Sealed Bid Reverse Auction: As Bid Pricing	• Easiest for bidders to understand • Can use bids for variable auction	• Encourages strategic bidding • Depending on supply elasticity, may cost more than other options • May lead to inefficient outcomes
	Sealed Bid Reverse Auction: Vickrey Pricing	• Achieves most efficient outcome possible • Incentivizes bidders to reveal their true exit cost • Can use bids for variable auction	• Confusing to bidders • Political difficulties due to “windfalls”
	Descending Clock Auction	• Easy for bidders to understand • Easy to place bids • Strong incentives for truthful bidding	• Political difficulties due to “windfalls” • Must make special accommodation for variable approach

Forward Auction Format	Simultaneous Multi-Round Auction	• FCC and bidders are familiar with the process	• Requires harmonized allocation optimization
	Combinatorial Auction	• Added flexibility for bidders • Leads to higher revenue • Allows for variable allocation optimization	• Adds new elements into the standard bidding process

Reverse Auction Rules	Combinatorial Bids	• Increases allocation efficiency • Will likely lower costs	• Increases complexity of optimization • May be unnecessary
	Promise of No Future Auctions	• Greater Participation • Lowers costs in upcoming auction	• Limits future auctions • Locks in inefficient spectrum allocations
	Reserve Price		• Increases risk of auction failure
	Providing Bidder Information	• Is standard in FCC auctions	• Allows for strategic bidding • Raises cost of auction • Increases risk of collusion
	Timetable with Opt-out Bids	• Lowers costs of auction	• Raises probability of spectrum reallocation failure

Forward Auction Rules	Combinatorial Bids	• Increases allocation efficiency • Will likely raise auction revenue	• Increases complexity of optimization • Adds new elements into the standard bidding process
	Providing Bidder Information	• Is standard in FCC auctions	• Allows strategic bidding • Lowers auction revenue • Increases risk of collusion
	Timetable with Opt-out Bids	• Raises auction revenue	• Raises probability of spectrum reallocation failure

Allocation Optimization Routine	Variable	• Allows for greatest possible efficiency • All efficient reallocations will occur • No inefficient reallocations will occur	• Very complicated to implement • Limits band plan areas in forward auction
	Harmonized	• Ensures contiguous spectrum nationwide • Band plan areas can be divided in most convenient manner	• Hold-ups can block large gains • Raises possibility of spectrum reallocation failure