



June 2021

Why do 5G spectrum auctions take so long to complete?

Introduction

When auctioning off spectrum licenses, the Federal Communications Commission (FCC) typically uses a multiple-round auction format, and multiple-round auctions often take a while to complete while providing price discovery and other benefits. For example, the FCC used the clock auction design for the first phase of Auction 107. The FCC's Auction 107, which offered 5,684 licenses, started on December 8, 2020 and concluded on February 17, 2021 after 97 rounds were spent in the clock phase which was then followed by an assignment phase.

A multiple-round auction can require several months to complete, which imposes a significant cost on bidders. The participating bidders need to monitor the auction consistently, which is a demanding resource commitment.

There are a number of reasons why multiple-round spectrum auctions can take a while. After all, a sale of spectrum licenses worth billions of dollars to many different buyers cannot and should not be done hastily. But in this *Insights* we explore how strategic bidder behavior can prolong a multiple-round spectrum auction.

Example: FCC's Auction 107 Clock Phase

Auction 107 offered 280 megahertz of mid-band spectrum in the 3.7-3.98 GHz band (the "3.7 GHz Service") for flexible use (including 5G) on an unpaired basis in three blocks divided into 20-megahertz sub-blocks by partial economic area (PEA) in the contiguous states and the District of Columbia. There were two phases in the auction. Phase I, the Clock Phase, lasted for 97 rounds and took over a month to complete. In this paper, we are using Phase I of Auction 107 as an example of a multiple-round auction. There were 5,684 licenses offered and all of them were sold. There were 57 qualified bidders and 21 winning bidders. Gross proceeds from the auction totaled more than \$81 billion.

Each license for sale in a spectrum auction has a specified geographical area of coverage, and the licenses in the most densely populated areas generally are valued the most by bidders and therefore face the most contested bidding. As noted above, the spectrum licenses in Auction 107 were defined over PEAs. The most populated PEAs in the FCC's spectrum auctions tend to have

the highest prices per MHz-Pop¹. True to form, in Auction 107 the largest 10 PEAs (out of 406 PEAs) accounted for over 45% of auction proceeds.

One of the key statistics that auction experts look at when evaluating the auction process is *demand to supply ratios*: the number of bids compared to how many licenses are available in each license category or spectrum block in a geographical area. The higher the demand/supply ratio, the more the price likely will need to increase before reaching its final price. The final price is reached when the demand/supply ratio for that license reaches one and does not go up again in subsequent rounds.

Table 1 shows the demand/supply ratio for each license in the largest 10 PEAs by license category for selected rounds in Auction 107. The shaded entries indicate the rounds in which the license achieved and remained at its final price.

Table 1: Largest 10 PEAs by Population in Auction 107 – Demand/Supply by Round in Clock Phase²

				Round																							
Market Number	Market Name	Category	Population	1	5	10	15	20	25	30	35	40	41	42	43	44	45	46	47	48	97						
PEA001	New York, NY	A	25,237,061	4.4	4.4	4.4	4.2	3.2	2.8	1.4	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA001	New York, NY	BC	25,237,061	3.7	3.7	3.6	3.4	3.0	2.6	1.9	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA002	Los Angeles, CA	A	19,410,169	4.0	4.0	4.0	4.0	3.2	2.8	1.4	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0						
PEA002	Los Angeles, CA	BC	19,410,169	2.9	2.9	2.8	2.4	2.7	2.4	2.6	1.4	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0						
PEA003	Chicago, IL	A	9,366,713	3.8	3.8	3.8	3.8	3.4	3.0	1.6	1.6	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA003	Chicago, IL	BC	9,366,713	3.3	3.3	3.3	2.7	2.4	1.9	1.4	1.0	1.3	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA004	San Francisco, CA	A	9,027,937	3.8	3.8	3.8	3.8	3.2	2.8	1.4	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0						
PEA004	San Francisco, CA	BC	9,027,937	2.9	2.9	2.9	2.6	2.3	2.1	2.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0						
PEA005	Baltimore, MD- Washington, DC	ABC	7,842,134	2.9	2.9	2.9	2.6	2.6	2.1	1.9	1.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA006	Philadelphia, PA	A	7,587,252	3.8	3.8	3.8	3.8	3.2	1.8	1.4	1.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA006	Philadelphia, PA	BC	7,587,252	2.0	2.0	2.0	1.8	2.0	1.0	1.7	1.4	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA007	Boston, MA	A	6,776,035	3.8	3.8	3.8	3.8	3.2	1.8	1.4	1.8	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA007	Boston, MA	BC	6,776,035	2.0	2.0	2.0	1.9	2.1	1.0	1.0	1.8	1.3	1.3	1.3	1.1	1.0	1.0	1.0	1.0	1.0	1.0						
PEA008	Dallas, TX	A	6,452,472	3.8	3.8	3.8	3.8	3.4	3.0	1.6	1.8	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0						
PEA008	Dallas, TX	BC	6,452,472	2.0	2.0	2.0	1.9	2.0	1.0	1.7	1.2	1.1	1.0	1.2	1.2	1.2	1.2	1.1	1.0	1.0	1.0						
PEA009	Miami, FL	A	6,291,880	3.8	3.8	3.8	3.8	3.4	2.0	1.6	1.8	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.0						
PEA009	Miami, FL	BC	6,291,880	2.0	2.0	2.0	1.9	2.0	1.0	1.6	1.4	1.3	1.3	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0						
PEA010	Houston, TX	A	5,891,999	3.8	3.8	3.8	3.8	3.4	2.0	1.6	1.6	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0						
PEA010	Houston, TX	BC	5,891,999	2.0	2.0	2.0	1.9	2.0	1.0	1.3	1.0	1.1	1.0	1.0	1.0	1.2	1.2	1.2	1.0	1.0	1.0						

Table 1 shows that although the clock phase in Auction 107 went on for 97 rounds, all the 10 largest PEAs settled by round 48. For example, PEA001, Category A, settled in round 40, meaning supply and demand achieved equilibrium in round 40, and the demand/supply ratio did not change after that round.

Thus, it was not the largest, most expensive PEAs that kept the clock phase of Auction 107 going for 97 rounds. So what were the licenses that kept the auction open?

Table 2 lists the eight PEAs that settled last in the clock phase and shows the supply/demand ratios by round for these licenses.

¹ MHz-Pops means the number of megahertz of spectrum multiplied by the population within a specified service area.

² For category definitions see <https://www.fcc.gov/auction/107/factsheet>.

Table 2: 8 PEAs that Settled Last in Auction 107 – Demand/Supply by Round in Clock Phase

Market Number	Market Name	Category	Population	Round																							
				1	10	15	25	35	45	55	65	75	85	89	90	91	92	93	94	95	96	97					
PEA330	Olney, IL	ABC	102,976	1.00	1.00	2.00	2.00	1.79	1.00	1.00	1.00	1.00	1.00	1.00	1.29	1.29	1.29	1.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA332	Bennettsville, SC	ABC	102,615	0.93	0.93	0.93	0.93	1.00	1.36	1.21	1.00	1.29	1.00	1.00	1.00	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA346	Franklin, NC	ABC	80,814	0.93	1.00	1.00	1.07	1.00	1.00	1.00	1.00	1.14	2.36	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.43	1.00	1.00	1.00
PEA347	New Roads, LA	ABC	79,775	0.93	0.93	0.93	0.93	1.00	1.07	1.00	1.00	1.29	1.43	1.43	1.43	1.43	1.43	1.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA373	Walla Walla, WA	ABC	62,859	0.93	1.00	2.00	2.14	2.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.14	1.00	1.00	1.00	1.00
PEA377	Demopolis, AL	ABC	57,694	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.29	1.36	1.36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA378	Waynesboro, GA	ABC	57,502	1.00	1.00	1.00	1.00	1.07	1.00	1.00	1.00	1.36	1.36	1.36	1.36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PEA397	Aliceville, AL	ABC	34,310	1.00	1.00	1.00	1.00	1.07	1.00	1.00	1.00	1.29	1.36	1.36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The two PEAs that settled last were Franklin, NC and Walla Walla, WA — two relatively small PEAs with populations of less than 100,000. Note that for both licenses the supply/demand ratio in round 1 was less than one, that is, these licenses initially were under-subscribed. This also means that the prices for these licenses did not start increasing until later rounds.

Table 3 illustrates the point further. It shows how many licenses (PEA/categories) settled in earlier versus later rounds. Table 3 shows the average PEA populations for the licenses settled in a given range of rounds as well as the average price in \$/MHz-Pop in round 97.

Table 3: Licenses (PEA/Categories) Settled by Round

Round Settled	Number of PEA/Categories Settled	Average PEA Population	Average Round 97 Clock Price \$/MHz-Pop
32-40	19	3,844,259	0.954
41-50	156	2,006,061	0.799
51-60	139	483,584	0.521
61-70	80	253,571	0.494
71-80	33	180,280	0.363
81-90	19	205,188	0.319
91-97	6	81,090	0.117

The PEAs with higher populations tended to settle first and with prices higher than for smaller PEAs. This pattern is not uncommon in spectrum auctions.

There are a number of reasons why this happens. First, the largest 10 PEAs are highly desirable, and require many eligibility points to bid on.³ The eligibility constraint in the auction rules tends to force bidders to choose which PEAs to bid on first, and many bidders try to win the largest PEAs. Then, as the largest PEAs become increasingly expensive over the rounds, bidders switch to less expensive PEAs. This switching causes the demand/supply ratios of the largest PEAs to fall, while bidding activity does not decrease as much on the smaller, less expensive PEAs or can even increase on those PEAs.

Strategic bidding behavior also can explain the pattern described above. Some bidders, even knowing that they will not be able to win the largest PEAs, still bid on them in the initial rounds — a strategy referred to as “parking eligibility.” A bidder can preserve or “park” their eligibility on the largest PEAs in the earlier rounds. The purpose is to avoid bidding on the licenses they actually want to win, to maintain the demand/supply ratio, and therefore the price increments low on those licenses. This strategy postpones bidding for the smaller PEAs until “parking” in large PEAs becomes riskier (i.e., the risk that the bidder may win a license they do not actually want to win), which increases the length of the auction.

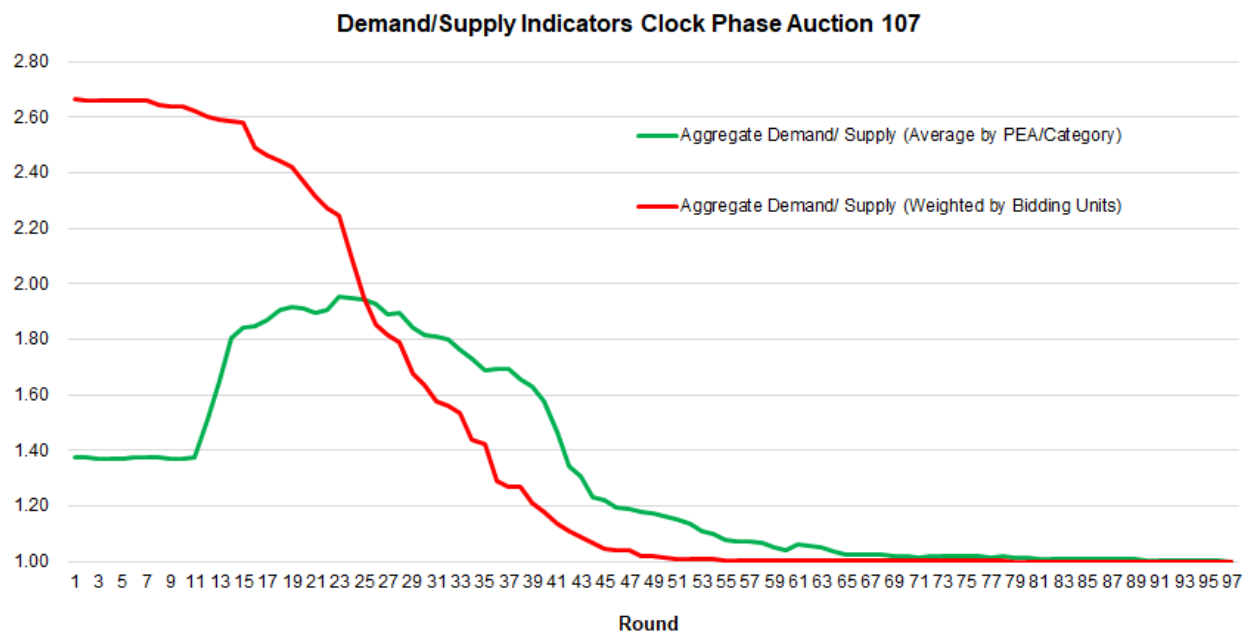
³ Depending on their pre-bid security deposit, each bidder is assigned initial eligibility points. Each license requires a fixed number of eligibility points to be bid on. For example, if a bidder has 100 eligibility points, and licenses A, B, and C require 50 eligibility points each, the bidder can bid on at most two of the licenses.

Figure 1 compares two supply/demand indicators. The green line is the aggregate demand/supply ratio (simple average across licenses). That is, the total number of licenses bid on divided by the total number of licenses available, which for this auction totaled 5,684. This measure does not differentiate between large and small PEAs: one license in the largest PEA and one license in a small PEA have equal weights. The green line remains relatively low and steady in the first rounds, reflective of the bidding on the largest PEAs that take up a lot of eligibility. But soon the green line goes up as the bidders switch from the largest PEAs to smaller, less expensive PEAs that require significantly less eligibility.

In contrast, the red line, which is the second supply/demand indicator, takes into account the number of bidding units required to bid on a license. For this demand/supply indicator, each license is multiplied by (i.e., is weighted by) the number of bidding units assigned to the license, and then that total across all licenses is divided by the aggregate supply (total number of licenses). Note the difference between the red line and the green line. The red line shows that the aggregate total eligibility (i.e., demand/supply ratios) in the auction slowly declines for initial rounds, then falls more quickly, and then declines more slowly for the latter part of the auction, just as we expect it to.

Figure 1 also shows that most of the active bidding and most of the eligibility settles long before the auction is concluded.

Figure 1: Demand/Supply Indicators



Lessons Learned

First, bidders in spectrum auctions need to plan and prepare resources, as the bidding may take a while.

Second, analyzing prior spectrum auctions may provide insight during future auctions as to how close an auction is to ending and how quickly prices may increase on different licenses at different times in the auction.

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