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THE C-BAND SPECTRUM AUCTION: RETROSPECTIVE AND PROSPECTIVE OBSERVATIONS

MITRE authors: Carolyn Kahn, Susan Hanson, Stephen Giles, Connor Freeberg, and Dr. Leila Ribeiro

RETROSPECTIVE AND PROSPECTIVE OBSERVATIONS

“Going once, going twice, sold!”
 The C-band auction set a record as the highest grossing auction of electromagnetic spectrum ever. It may have also been the highest revenue-generating auction of any kind ever.¹

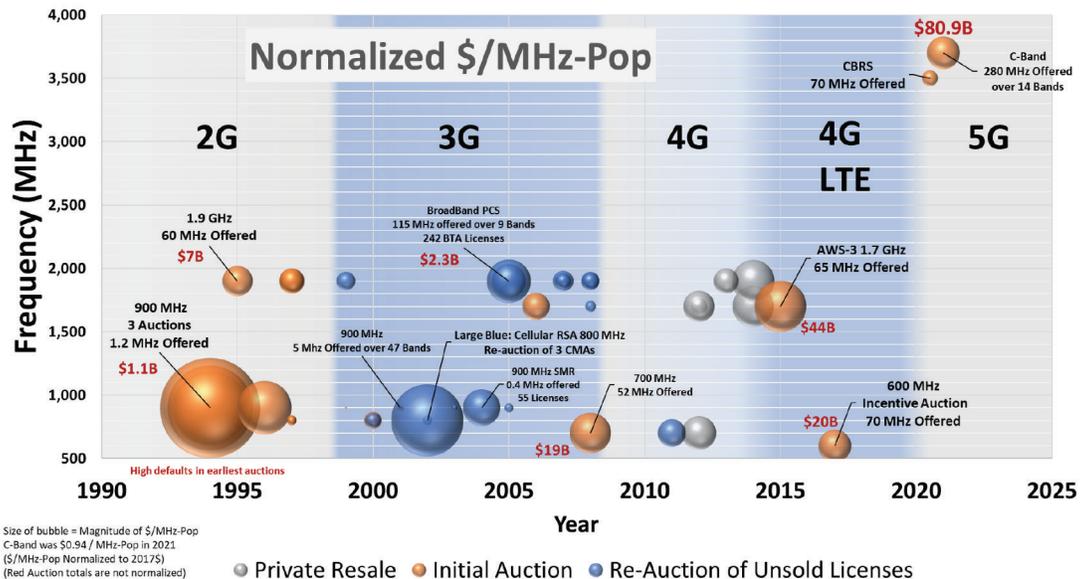
The Federal Communication Commission (FCC) conducted Auction 107 for 280 megahertz (MHz) of electromagnetic spectrum in the C-band, specifically 3.7–3.98 gigahertz (GHz). The initial clock auction results of the C-band auction exceeded all expectations, reaching \$80.9 billion, which was about 170% higher than prevailing *a priori* industry projections. On top of this result, bidders will pay an additional \$9.7 billion in accelerated clearing payments, \$3.3 billion in relocation costs, and \$0.3 billion in premiums resulting from the assignment phase of the auction. These results indicate that spectrum supporting mobile networks will continue to hold value.

The C-band auction concluded on February 17, 2021, with highest bids from the three major U.S. mobile network operators (MNOs) – Verizon (\$45.4 billion for 3,511 licenses), AT&T (\$23.4 billion for 1,621 licenses), and T-Mobile (\$9.3 billion for 142 licenses).

In the six months prior to the auction, multiple auction estimates were published in the \$30 billion range, including those by Morgan Stanley, Raymond James, Sasha Javid, and MITRE. More optimistic estimates included the Besen Group’s estimate of \$40 billion, the New Street estimate of \$52 billion, and the January 2020 C-Band Alliance estimate from NERA and Evercore of \$43 to \$77 billion.

THE INITIAL CLOCK AUCTION RESULTS OF THE C-BAND AUCTION EXCEEDED ALL EXPECTATIONS, REACHING \$80.9 BILLION, WHICH WAS ABOUT 170% HIGHER THAN PREVAILING *A PRIORI* INDUSTRY PROJECTIONS.

MITRE conducted a retrospective analysis of the C-band auction to highlight key observations and factors contributing to higher-than-expected results. The graphic below shows the C-band auction results on a normalized dollar per MHz per number of people covered (\$/MHz-Pop) basis and provides a context to compare other spectrum auctions by year and wireless technology generation.



Time to market of a new generation of wireless technology

Both the C-band auction and the Advanced Wireless Services (AWS)-3 auction from 2015 (see chart) represent the first major dedicated spectrum offerings for their respective generations of wireless technology, 5G and 4G LTE, when demand for these services was seen as very promising. In both auctions, revenue surpassed historic auction result-based projections – taking into consideration key parameters such as frequency band, bandwidth, and geographical area. In these cases, the antenna and chipset technologies were already available so the spectrum could be utilized almost immediately, forgoing an otherwise two-year wait time for research and development efforts to develop the technologies. Further, the perceived relatively low risk and early entry opportunities for the transition likely increased value.

Changes in market demand

It appears there is a trend that new generations of mobile wireless technologies follow an alternating pattern in terms of bringing significant transformation to their consumer base and MNO business opportunities. A transformational shift came with the transition from 2G to 3G, supporting new data applications as packet switching became the norm, resulting in increased profitability. Conversely, the transition from 3G to 4G offered mostly improved performance over similar types of applications and similar consumer populations, which did not have an analogous impact on profitability.

The expectation by MNOs that 5G opens the opportunity for new vertical markets, industries, capabilities, and users adds a new dimension to its promise and potential value. New vertical markets include, but are not limited to, supporting mission-critical requirements in the healthcare, transportation, and manufacturing industries. Innovative technical capabilities introduced by 5G standards (e.g., edge computing, the ability to support private networks,

network slicing, low latency) enable greater transformation of higher value markets. New types of users will be supported, beyond the human-centric consumer basis, such as machine or device-centric (Internet of Things) network users. These new opportunities increase the value of licenses by extending user density from major metropolitan areas to suburban and rural locations (further influencing the successes of the AWS-3 auction and to lesser degrees the 700 MHz and 600 MHz auctions).

At the same time, the COVID-19 global pandemic is changing market dynamics. It is creating new demand for wireless services across reliable and resilient networks. The pandemic has also influenced the location of demand, as remote work, education, and socialization have become more common, which also may have contributed to increased spectrum value in suburban and rural areas.

Existing MNO holdings and business strategy

Existing MNO holdings and their business strategies likely contributed to increased auction values for several reasons. First, the C-band auction of 280 MHz of contiguous blocks of spectrum nationwide is the FCC's largest auction of mid-band spectrum to-date and enables continuous coverage and capacity at the scale of a national network. A “sweet spot” of electromagnetic spectrum, mid-band provides

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RETROSPECTIVE AND PROSPECTIVE OBSERVATIONS

a balance of the coverage benefits of low-band spectrum and capability benefits of high-band, or millimeter wave, spectrum. The C-band spectrum is relatively unencumbered, and the opportunity for MNOs to gain exclusive versus shared access increases the value of this spectrum.

At the start of the C-band auction, T-Mobile, with its purchase of Sprint, had access to a large swath of mid-band spectrum that was not available to other MNOs. The slow rollout of high-band millimeter wave spectrum may have incentivized Verizon and AT&T to acquire more mid-band spectrum to mitigate their perceived disadvantages compared to T-Mobile while, at the same time, motivated T-Mobile to further secure its mid-band holdings.

Also, many countries are making C-band spectrum available for 5G, and global harmonization enables increased economies of scale and shorter time to market. Growing pressure on U.S. government leaders in recent years over the lack of mid-band spectrum availability for 5G, which has fallen behind countries like China and South Korea, may have also influenced MNO auction decisions.

Additionally, with the evolution of Multiple-Input Multiple-Output (MIMO) and other technologies, the premium for explicitly paired spectrum has fallen. Smaller license areas can realize higher auction values, since winners are able to tailor their bids to their buildout requirements and the area's population density; however, the ability to leverage existing network infrastructure can counteract this hedging. These combined effects may have triggered increased auction value in the C-band.

Increased economic and policy uncertainty

The pandemic, along with the U.S. election, increased economic and policy uncertainty. The resignation of FCC Chairman Ajit Pai, who was intensely focused on identifying spectrum for repurposing to support the rollout of 5G services, called into question the next set of priorities for the FCC. Thus, bidders may

have perceived a higher level of uncertainty regarding the stability (including quantities, properties, and timeliness) of the "spectrum pipeline," resulting in pressure to bid more intensively on available licenses.

Speculative bidding

As spectrum values rise over time, spectrum is increasingly seen as an opportunity for speculative bidding for resale and secondary markets. This is particularly true as network buildout continues to expand from urban to rural areas. Speculative bidding, in turn, may be further driving up auction prices. Like the stock market bubble of the 1990s when the stock market may have been overvalued, unfounded optimism may have spurred the higher-than-expected results of the C-band auction.

The relative impact of these contributing factors on the approximately \$50 billion delta between estimated and actual auction results is estimated qualitatively below.

Contributing Factor	Estimated Relative Impact
Time to market of a new generation of wireless technology	Moderate to High
Changes in market demand	Moderate to High
Existing MNO holdings and business strategy	Moderate to High
Increased economic and policy uncertainty	Low to Moderate
Speculative bidding	Low to Moderate

As a result of the record-breaking bids in the C-band auction, MNOs must raise additional capital to complete their auction purchases as well as fund subsequent infrastructure and network buildout requirements to utilize their newly acquired spectrum. It remains to be seen if higher-than-expected auction prices will cause the MNOs any significant issues with their ability to maintain the cash flow necessary to meet buildout requirements.

Effects of the C-band auction will likely permeate future auctions. Big C-band auction spenders like Verizon are unlikely to dominate the next spectrum auction as they focus on building out their current spectrum holdings. Furthermore, immediate availability of the spectrum might not be as much of a factor for Verizon, AT&T, and T-Mobile – as indicated by the difference in premium between the A and BC blocks of spectrum in the C-band auction. The clock auction format has been shown to perform well in terms of generating high auction prices; additional rules could be considered for future auctions to foster participation by a larger number of bidders. Proven technical solutions are needed to increase the value of shared spectrum and manage spectrum use with band incumbents.

Policymakers could leverage spectrum auction proceeds to a greater extent by enabling reinvestment opportunities that generate higher value to the U.S. wireless ecosystem, although statutory changes might be required. For example, a portion of the auction proceeds could be allocated not only toward reducing the deficit, but also toward national requirements to meet U.S. telecommunications goals, such as closing the digital divide, modernizing and automating infrastructure for spectrum management, and monetizing federal spectrum management. Also, expanding the Spectrum Relocation Fund to reimburse federal agencies for additional costs, beyond those covered in current legislation, could make increased spectrum available for repurposing. There are unique challenges with each spectrum band and auction, which provide the opportunity to develop novel solutions and lessons learned to benefit future spectrum decisions.

POLICYMAKERS COULD LEVERAGE SPECTRUM AUCTION PROCEEDS TO A GREATER EXTENT BY ENABLING REINVESTMENT OPPORTUNITIES THAT GENERATE HIGHER VALUE TO THE U.S. WIRELESS ECOSYSTEM.

Endnotes

1. The next largest spectrum auction worldwide is the German 3G/UMTS auction in 2000, which generated DM98.8 billion, or about \$70.11 billion. As a reference for comparison, the most expensive artwork sold at auction was Da Vinci's "Salvator Mundi," which sold for over \$450 million in 2017; this item was previously sold in 1958 for \$60 because it was dismissed as a copy at the time. Another reference point is Christie's auction house, which earned over \$5 billion in revenue in 2019. Lawrence M. Ausubel, "C-Band Auction: Market Reactions and Next Steps for Deployment," FCBA Wireless Telecommunications Committee," April 6, 2021. <https://www.cnn.com/style/article/leonardo-da-vinci-salvator-mundi-louvre-abu-dhabi/index.html>. <https://www.statista.com/statistics/273256/revenue-of-christies-international/>
2. <https://www.reuters.com/article/us-fcc-wireless/fcc-says-verizon-att-t-mobile-won-78-billion-in-c-band-spectrum-auction-idUSKBN2A02SI>
3. <https://www.fiercewireless.com/regulatory/analysts-beef-up-c-band-auction-forecast-to-26b-35-2b-range>
4. <https://www.lightreading.com/iot/the-full-list-here-are-actual-bidders-in-c-band-auction/d/d-id/764793> and <https://www.lightreading.com/5g/here-are-new-c-band-auction-estimates/d/d-id/766333>
5. <https://www.fiercewireless.com/regulatory/c-band-clock-phase-auction-tops-charts-80-9b>
6. <https://www.rcrwireless.com/20201208/spectrum/c-band-auction-is-underway-in-a-shift-that-will-shape-5g>
7. https://www.prweb.com/releases/the_besen_group_releases_c_band_spectrum_evaluation_tool/prweb17256773.htm
8. <https://www.fiercewireless.com/wireless/cbrs-auction-inches-toward-600-million-after-round-8>
9. <https://ecfsapi.fcc.gov/file/1012753329068/CBA%20-%20NERA%20and%20Evercore%20Valuation%20Cover%20Letter%20and%20Attachments.pdf>

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