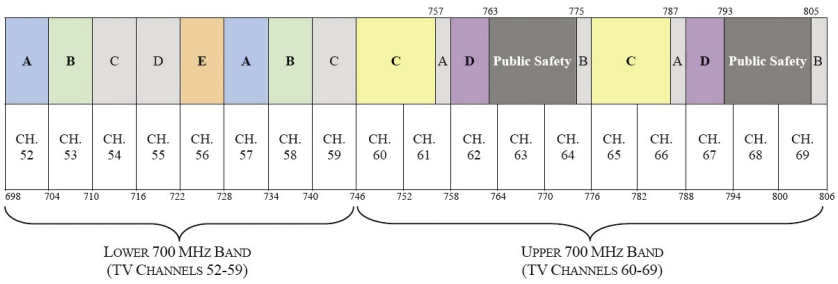
Auctioning off the FCC's Crown Jewels

By Elisabeth Nadin



Block	Frequencies (MHz)	Bandwidth	Pairing	Area Type	Licenses
A	698-704, 728-734	12 MHz	2 x 6 MHz	EA	176
B	704-710, 734-740	12 MHz	2 x 6 MHz	CMA	734
C	710-716, 740-746	12 MHz	2 x 6 MHz	CMA	734
D	716-722	6 MHz	unpaired	EAG	6
E	722-728	6 MHz	unpaired	EA	176
C	746-757, 776-787	22 MHz	2 x 11 MHz	REAG	12
A	757-758, 787-788	2 MHz	2 x 1 MHz	MEA	52
D	758-763, 788-793	10 MHz	2 x 5 MHz	Nationwide	1 *
B	775-776, 805-806	2 MHz	2 x 1 MHz	MEA	52

The 700 MHz spectrum consists of several blocks dispersed across abandoned analog television channels. Hierarchical Package Bidding (HPB) was tested on the C block, which offered a total of 22 MHz in 12 Regional Economic Area Groupings (REAGs) that together would span the nation. (Blocks in gray were auctioned before Auction 73; the D block was set aside for public safety announcements but failed to meet the FCC minimum reserve price.)

It's been called beachfront property . . . the last big slice of the spectrum pie . . . the crown jewels of the Federal Communications Commission (FCC). It is the 700 megahertz (MHz) frequency band, which actually runs from 698–806 MHz and until now has been the exclusive domain of broadcast television. On January 24, as a step on the road toward ubiquitous digital television, the FCC began auctioning off licenses for other uses of swaths of this band in what was called the most significant airwave auction in U.S. history.

The 700 MHz band is a hot commodity, especially for wireless companies, because the signal penetrates walls. Each tower broadcasting in this range can cover at least four times as many square miles as conventional cell-phone towers, which means fewer towers and therefore less expense to the winning bidders. To cell-phone users, it may also mean goodbye to roaming charges. Auction 73, as the 700 MHz auction is officially known, was the first chance for newbies like Google and Cox Cable, who each fronted the money the FCC required to enter the auction, to break into the wireless scene. They would bid alongside entrenched giants like Verizon and AT&T.

Caltech professor of economics Jacob Goeree monitored the auction closely, focusing particularly on one segment of the spectrum called the C block. The auction action was centered here because the C block—two bands totaling 22 MHz of the spectrum—would be sold under a new scheme: companies could bid either for any of 12 large-region licenses or for a package deal to win coast-to-coast coverage. By the end of the auction, which dragged on for 261 rounds spanning 38 weekdays as bidders haggled over tiny portions of the 700 MHz offerings, the C block had generated about a quarter of the $19.6 billion total that the FCC reaped in Auction 73—the most money the federal treasury has ever earned in a single auction. All the bids had been placed anonymously, but before the FCC finally announced the winners on March 20, those who had followed the daily action speculated that Verizon and AT&T were locked in a bidding war with

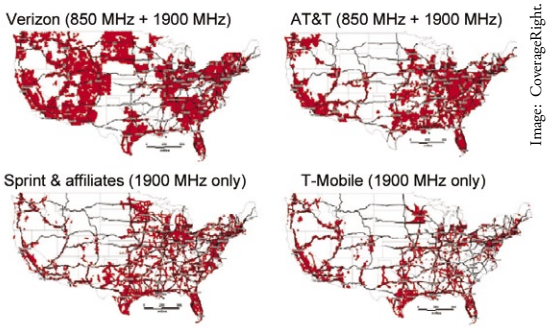
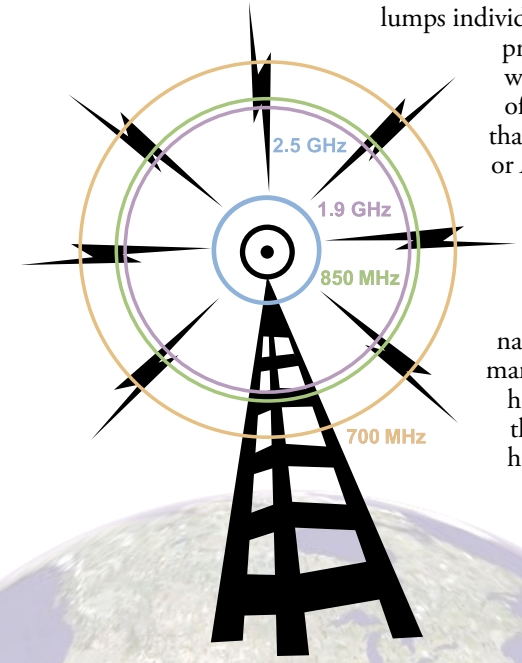


Image: CoverageRight.

Above: Current coverage at the 850 MHz and 1900 MHz frequencies—the primary mobile communications bands in North America—leaves much of the country with no signal. Below: The 700 MHz signal propagates much further, necessitating fewer cell-phone towers.



Google for nationwide coverage, driving prices up. All that had been known for sure was that someone was casting bids that topped $2 billion for the nationwide package as early as the fifth round.

Goeree was personally invested in the action around the C block, as he had designed the bidding mechanism that was used. Called Hierarchical Package Bidding (HPB), it's a relatively straightforward system that lumps individual pieces into larger units that might prove more attractive to someone who would rather buy a whole pie instead of a few slices. In Auction 73, it meant that either some companies—Verizon or AT&T—could win one or more of the 12 regional licenses and fill in their coverage gaps, or another company—Google—could make a big splash by winning the 12-license package to cover the whole nation. "The HPB auction rules let the market discover the best allocation, and how things get packaged, which takes the heat off public officials who would have to respond to lobbying pressures on these issues," Goeree says. HPB was deemed by the FCC to offer the best chance for new entrants or new business models to penetrate the wireless grid.

Crunching Numbers

During the two years preceding that FCC auction, you would find students sitting at computers in the Social Science Experimental Laboratory (SSEL), in Baxter Hall's basement, weighing their options, placing their bids, and waiting for the next round. SSEL director Goeree would stride around the room watching the students in action, or bend his tall Dutch frame over his own computer screen, tracking each bidder's move. He had outlined the stakes—how much money each student stood to make if their bid won—and exhorted them to keep their profit margins as high as possible. Goeree wanted to know, could the bidder who stood to profit most actually win the auction? Time and again the answer was yes.

Goeree had no problem attracting students to run his experiments. "I heard about it from other students," says physics major Justin Chen, who earned enough in the FCC experiments to buy his longboard, on which he's often spotted rolling through the campus. (Chen is no stranger to strategic decision-making: he and a friend at Harvard concocted an equation to help them decide whether it's better to just wait for a bus or to start walking. Their answer, which made worldwide news, showed it's almost always better to wait.)

"It's generally straightforward," remarks Chen. "The experiments are designed assuming that all the players want to make as much money as they can." Before each round, each student bidder read from their screen what licenses they were interested in and how much winning them would be worth: Their earnings from the auction were proportional to the difference between those values and their bids, if their bids won. The better the bidder, the more he won, and in this manner Chen scored his greatest win of $140. A friend once made $303. Not bad for two hours.

Even though the students didn't actually know what they were supposedly buying, they com-

peted with each other so realistically, says Goeree, that their bidding mimicked professional auction behavior. Their motivation, after all, was the same. "You start thinking about your strategies in the game—how you're going to bid to make more money," Chen says. He discovered that the main problem with auctions is that "you can't really lose money, but you can pay too much for something." Auctions are supposed to run such that the winning bid goes to the person who values the prize most. But in an ordinary auction format, the FCC would have no way of making sure that happened, even though they are charged with awarding licenses in an efficient manner that serves the public interest.

Auctioning the Airwaves

Back in 1927, the Federal Radio Commission faced a straightforward task in granting airwave access—the demand was low enough that every applicant got a license. By the time the FCC took over seven years later, television was on its way. Several parties competed for each license, and the FCC had to weigh which one had the public's interest best in mind. The winner often sold its license for a profit, and losers appealed and won, and the FCC found itself mired in lawsuits. It took a lot of time and tax dollars to grant a license. License fees were fixed at a low rate, and the FCC sure wasn't pulling in any money for all its work.

"The experiments are designed assuming that all the players want to make as much money as they can."—student volunteer Justin Chen

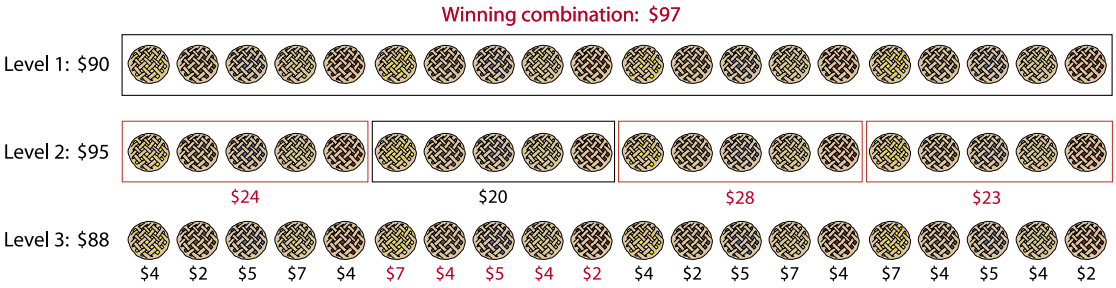
Imagine what happened as the telecommunications industry grew. The FCC now regulates interstate and international communications by radio, television, wire, satellite, and cable. In 1982, the agency switched to a semiregulated but arbitrary license-granting system: a lottery, allowing the FCC to award one applicant and avoid litigation from the losers. But then came a flood that would have made Noah blanch: applicants filed under multiple names to increase their chances, and opportunists realized they stood to make a killing if they happened to win—they could sell the license at a vastly inflated price to someone else who really wanted it. This was especially true for cellular communications, and wireless lottery schemes were called "the number one investor fraud in the country." The FCC seemed like the biggest loser under the lottery system.

A little over a decade later, the FCC switched to a competitive bidding system. The system makes sense to economists, says Goeree, because it gets licenses into the hands of those who value them most. And the FCC came out ahead, too—it no longer had to figure out which applicants qualified; each could bid as high as they decided a license was worth to them, and the FCC would reap the profits. These auctions employed simultaneous multiple bidding for individual licenses—all the companies interested in a license would bid on every license they were interested in, and then stay in the bidding as long as they had the money.

The first FCC auction back in 1994 was considered a great success—the *New York Times* termed it the "Greatest Auction Ever"—and even then Caltech researchers played a pivotal role. Caltech's Johnson Professor of Business Economics and Management, Preston McAfee, helped design the auction together with Stanford University professors Paul Milgrom and Robert Wilson. Another Caltech scientist, Charles Plott, the Harkness Professor of Economics and Political Science, had been testing the FCC's system and discovered that the bidding software was flawed shortly before the auction was supposed to start. Plott impressed the FCC, and the industry, by providing the FCC with a manual backup system he created with Antonio Rangel (BS '93), then an undergraduate student and now an economics professor at Caltech.

Another snafu the FCC faced in the auctions was bidding collusion. Companies weren't allowed to communicate directly but they could signal through the bidding process how to divide the market. With bids that reached over $100 million, bidders could use the many zeros in the bid amounts to signal information that might help in an attempt to keep prices down. The FCC tried to fix this by imposing predetermined bid increments, but the suspicion of bidder collusion continued to overshadow later auctions. The problem was finally resolved in Auction 73, when the FCC decided to use an anonymous bidding procedure. Until the close of the auction, no one but the bidder knew who had placed the highest bid in a round.

The FCC's simultaneous bidding mechanism, used for over a decade and copied around the world, is generally considered a great success. But even prior to that first auction in 1994, some economists saw room for improvement. They worried that companies interested in winning certain combinations of licenses, like a package that might serve the entire East Coast or establish nationwide coverage, might be hurt in the license-by-license competition the FCC was organizing. Several Caltech professors, including John Ledyard, the Davis Professor of Economics and Social Sciences, pioneered a different approach, one in which bidders could place bids on individual licenses as well as combinations of licenses. Their research had convincingly shown that efficiencies and revenues of the FCC auctions were reduced because bidders hesitated to incorporate synergistic values into their bids for fear they would end up being in a bad spot financially when competing fiercely for a desired



In this HPB scheme involving pies, bidders competed on three levels. The winning bids, in red, maximized profits by combining winners in levels two and three. The level-one bidder, who stood to take home 20 pies, couldn't outcompete bidders on level two, who wanted packages of five pies. Likewise, the level-two bidder for the second "block" of five pies lost to those on level three, who bid on the individual pies of that package.

package but winning only part of it. Their findings formed the impetus for the FCC to build a new system that incorporated combinatorial bids.

Building a Better Airplane

When the FCC approached Goeree and his colleague Charles Holt at the University of Virginia in 2004, it asked them to test the combinatorial auction the FCC had already built. Goeree recalls, "It was as if they were saying, 'Before we bring people on board, please fly our plane around.'" Like testing a scale model of an airplane in a wind tunnel, experimental auctions allow economists to control all the variables. "We know everything because we induce it ourselves," Goeree remarks.

The FCC wanted a method in which all buyers could compete equally and the commission would make the most money in the process. It turned out the combinatorial auction the FCC had devised for the 700 MHz auction was too complex. "In computer science it's known as the knapsack problem," says Goeree. "When you have a knapsack of finite volume and you can choose among objects of different sizes and values, how do you pack it to maximize its value?" Or, in mathematical parlance, the problem was "NP-hard"—it exploded exponentially because there were far too many potential combinations on which to bid, in this case too many bandwidth licenses spread over too many geographic regions. "We tested the plane the FCC built and it didn't fly that well," says Goeree. It didn't maximize profits for the FCC or potential wins for the bidders. Most of all, it alienated bidders with its intricacies.

Goeree and Holt tested related auction designs, but these didn't fly well either and were still too complex. Goeree recalls thinking that after having discussed the possibility of combinatorial auctions for over a decade, the FCC might opt out altogether. So he decided to create a new method. "We had a very simple idea for how to do it," he says. "First, imagine you construct a hierarchy of packages by dividing a large nationwide package into two pieces, dividing each of those into two pieces, and on and on, all the way down to the smallest geographic regions that could not be divided further." Unlike previous combinatorial auctions that were considered NP-hard, such a hierarchy makes it trivial to find the best allocation: simply compare the revenues that result from selling in one hierarchy level to the next, starting at the bottom and recursively solving to the top. The challenge Goeree and Holt faced was determining appropriate prices given that package bids would be placed on many different levels. After they solved how to "trickle down" the excess amount of a winning package bid at a higher level by imposing "taxes" on lower-level licenses, Goeree decided to call the FCC and present HPB as a viable alternative.

In his initial tests of the HPB auction, Goeree grouped the available licenses into packages in a three-tiered hierarchy, as shown at the top of this page. Say the HPB is auctioning off pies. On the top level, level one, you stand to win all 20 assorted pies in one fell swoop. On level two, there are four packages, each consisting of five different flavors. On level three, you can bid on the 20 pies separately. Now say you're throwing a party for 200 people—well, you might as well go for the gusto on level one. But if you merely want one pie to take home for dessert, your choice is equally clear: bid on level three. There could be 19 more people like you who also want only one pie, and all your bids together might just win out over the level-one bidder. The intermediate level, level two, may appeal if you own a small diner and want to serve a few different options. And if you wanted a package of five from level two and one more apple pie from level three, well, you could even bid on both levels.

As the bids roll in, the party-throwing bidder on level one might find he can't afford to outbid the personal pie eaters on level three. He might revise

Caltech students compete in earnest in HPB trials.

his strategy and start bidding on three packages on level two and two more pies on level one. The HPB format not only allows bidders to decide what sort of bid suits their needs, it provides flexibility as the auction progresses.

In the view of student volunteer Chen, "HPB is better because you can win two licenses combined as a package for less than what you might bid on the two individually." So if you want an apple pie and you're clearly winning it, and you also want a pecan pie for which there's a lot of competition that you can't afford to outbid, you could lump your resources together for a stronger bid on a package that includes both.

REAGs for the C block split the country into 12 regions. In the two-level HPB format that the FCC chose, bidders could win all 12 regions in one fell swoop or bid on them individually.

Although the FCC ultimately chose to use a two-tiered system, Goeree says his testing showed that even this was more efficient than the previous format. At the bottom level, 12 individual licenses corresponds to 12 geographic regions that the FCC designated—Region 1 is the Northeast, for example; Region 4 is the Mississippi Valley; Region 12 is the Gulf of Mexico. The top level, level one, was forged into a three-package deal: a 50-state grouping of eight of the 12 licenses, another package of two covering Pacific island territories, and a two-license Atlantic package combining the U.S. Virgin Islands, the Gulf of Mexico, and Puerto Rico.

The bidding kicked off on January 24, with one round per day. (On day 10, the FCC accelerated the bidding to five rounds per day to speed up results.) At the close of every round, Goeree's software totaled up the money bid at each level. In a two-level system, let's say the bids at level two totaled $0.8 billion after day one, and at level one the top bid was $1.2 billion. The software then advised bidders on what their next move should be if they wanted to stay in the game. Thus, if there were 12 bidders on level two, they would each be alerted to increase their bid by a little over $33 million to make up the $0.4 billion difference, and the bidders on level one would be told they could sit tight until the next round. There is no need to do your own calculations; the bidders just check if they can afford the suggested bid. "It solves the complexity for them," says Goeree. It also meant that if each bidder at level two followed the advice in unison, they would all move on to the next round. Of course, whoever couldn't fork over the dough would get shut out.

Although the opportunity to win it all in one fell swoop is a strong appeal of Goeree's packages, the FCC saw HPB as an opportunity for smaller players to merge forces at a lower level and overtake one giant bidder at the top. In an October 2007 public notice, the FCC declared, "The HPB auction format was chosen in part because it mitigates issues inherent in some other package bidding formats that give bidders interested in large packages an advantage over bidders interested in individual licenses."

The FCC also liked Goeree's calculation tool and the way the software seemed to prohibit collusion. "In fact, we will use HPB in part because the mechanism for calculating [prices] is significantly simpler than other package bidding pricing mechanisms," it stated. "In addition, we find that . . . HPB procedures in general strike a careful balance between permitting bidders adequate bidding flexibility and discouraging insincere and anticompetitive bidding behavior."

HPB in Action

It became immediately clear that the option to buy the C block in its entirety was extremely valuable. In July 2007, Google chairman and CEO Eric Schmidt had written an open letter to the FCC chairman offering a deal: the promise of a minimum $4.6 billion bid on the national package in exchange for open access to the wireless network that would be set up on the C block, regardless of who won it. Open access means any wireless customer can download any software and use it on the device of their choice, and the service provider would have to abide. This doesn't just mean ring tones, it applies to anything you might use your cell phone for: image-processing software for camera phones, e-mail software for Blackberries, maybe an iTunes knockoff for your Kyocera phone. In the recent past, a closed market meant that AT&T could connive with Apple for exclusive rights to providing iPhone service, and Apple could void the phone's guarantee if users hacked their gadget by installing non-Apple software.

It was also well known that Google was developing its first cell phone. If Verizon Wireless ended up a big winner in Auction 73, Google's open-access bid assured that Verizon would have to provide service to anyone who wanted its plan on a Google phone. Indeed, Google's demand

prompted Verizon, months before the start of the auction, to grudgingly commit to open its network to wireless devices, software, and applications that the company did not offer. This would happen even if Verizon did not win the national package —because of the way the auction is structured, as long as C-block bids topped $4.6 billion, the winner(s) would be obliged to allow their customers to use any mobile phone they wanted and allow outside applications to run on their network.

On day six of the auction, electronics bloggers across the world celebrated. "There was a brief, tense pause in the bidding this morning, but some anonymous giant telecom company (Google, perhaps?) has just pushed the price of the 700 MHz C block over the FCC's reserve price of $4.6B—and the rest of us straight into the promised land of open access," one wrote. "Yep, January 31, 2008, Round 17 will be the day to remember."

The technorati were abuzz, issuing daily progress reports on Auction 73. As it turned out, bidding on the C block at level one ceased shortly after the open-access benchmark was passed. The bids on level two rose to nearly $5 billion as bidders ended up duking it out over licenses for the 12 individual regions.

The auction as a whole drew to a close on March 19, and the FCC waited one day to announce the winners. The leading bid for the C block had shifted back and forth only twice between the cumulative prices for the individual licenses and bids for the national package, demonstrating, according to Goeree, that the market was determining how the spectrum would be most valued. As Goeree's colleague Holt put it, "The lead switched about the same number of times as in the final quarter of the Super Bowl."

As it turned out, Verizon and AT&T spent the lion's share—$16 billion—of the FCC's total earnings. Verizon won C-block coverage of the continental U.S. and Hawaii, while AT&T swept up most of the 12 MHz sold as the B block. It seems likely that Google never really wanted to run a national cellular network, and was happy to call it quits as soon as it secured what it had entered the game to get. And apparently no one else wanted or needed nationwide coverage once open access was guaranteed. But even though HPB did not bring a new entrant to the wireless market, Goeree says, "this auction is a winner because of the open access. It never would have been possible without the 50-state package."

Goeree sees room for improvement, however. The auction was implemented with a mix of hierarchical package bidding for the C block and the FCC simultaneous single-license bidding for other blocks, which were offered in a wide dispersion of license sizes. This dispersion, together with FCC "activity rules," made it difficult for firms to reenter the bidding on the C block after they had started bidding on other licenses, which may have created some inefficiencies.

Overall, the auction is evaluated to be a success. The main outcomes of the 700 MHz auction, entry and open access, would have been virtually impossible in the license-by-license competitions the FCC has organized so far. "Competing for open access by pushing prices over a $4.6-billion hurdle is simply too risky when bidding on individual licenses," Goeree says. "You may end up paying high prices for a subset of licenses that can't guarantee a profitable business plan."

The current chairman of the FCC, Kevin Martin, called the auction the FCC's "transformative auction." When asked about his legacy at the FCC after the Bush administration leaves, Martin responded, "I certainly think that the success of this auction, the success of raising more money than the commission ever raised before in any auction, the success of moving forward with a more open platform that will transform the entire wireless industry, is going to be a significant accomplishment." □

Goeree, pictured here, hopes that the HPB design will transform wireless markets in other countries as well. He recently visited Taipei, where he presented the details of the mechanism to a group of scholars involved with designing Taiwan's own 700 MHz auction.

PICTURE CREDITS: 22, 26 — FCC; 25 — Jacob Goeree; 23, 25 — Doug Cummings