

Visual Directory of Spectrum Licenses

Introduction

The wireless spectrum is by nature a limited resource, similar to land, and is therefore very valuable. The US government created the Federal Communication Commission (FCC) to regulate the wireless industry and license portions of the wireless spectrum to service providers. The mission of the FCC is to promote competition and thereby create incentives for innovation in wireless services, thus generating the maximum value from this limited public resource.

For competition to thrive, new entrants must be able to surmount the high barriers to entry in the wireless industry. Large capital expenses are required to build a network of cellular towers and backhaul wire line networks. But the greatest barrier to entry is acquiring the actual spectrum to operate on. Virtual network providers have failed because incumbent operators have no incentive to lease spectrum to competitors. Furthermore, the incumbent wireless operators often try to block new entrants from competing by gathering as much of the available spectrum for themselves. They accomplish this through mergers (AT&T + Cingular; Sprint + Nextel) or by outbidding new entrants at spectrum auctions. During the Clinton administration, FCC Chairman Reed Hundt put a cap on the amount of spectrum that operators could acquire in a given area to promote competition. But the big operators successfully lobbied under the new administration to repeal that rule. The upshot of that decision was a big win for both Verizon and AT&T in the recent 700 MHz auction.

Project Goals

In order to help promote competition in the wireless industry, I planned to create a visualization tool that could be used by wireless policy analysts who watchdog both the FCC and the large incumbent operators. My visualization would help analysts in their tasks by giving them an easy way to compare license holdings between multiple wireless carriers and determine which companies are strongest and which are at a disadvantage.

The information about licenses can be quite complicated. The licenses are divided into geographical regions using one of three different methods, to be explained in a later section. Additionally, the services an operator may provide are restricted by the type of license granted. For instance, early cellular licenses only allowed voice transmission. Later spectrum allocations, such as PCS (Personal Communication Services) and AWS (Advanced Wireless Services), were intended for data-oriented services, in addition to greater voice coverage. Another element to consider when comparing

license holdings is the frequency. Lower end frequencies in the 700MHz or 800MHz range are much more valuable because they can penetrate walls easily. Furthermore, the higher frequencies (1900MHz) cannot travel as far, so they require a greater number of towers to service a given area, putting the operators using these frequencies at an economic disadvantage. To illustrate that point, note that the top two operators, AT&T and Verizon, operate at 800MHz, while the distant third and fourth largest operators, Sprint and T-Mobile, operate at 1900MHz.

Useful knowledge cannot be gleaned from just perusing the raw data about the licenses. There is simply too much going on, and there are many thousands of licenses, which cannot be understood with a glance at a table. My goal was to present these four fundamentally important variables (total bandwidth, region, services, and range) in a manner that would enable policy analysts to determine the strength of any given operator and to quickly determine the level of competition in any given region.

I do plan to implement this idea, but given several constraints, my goal for this course project was only to create a mock up of this visualization. The complexity of the data and the short amount of time available in the semester were two of the driving factors for that decision. Additionally, I am working alone on this project and my programming skills are rusty. One other significant reason for not implementing this project yet was the difficulty in mapping the borders of the license regions. Fortunately, towards the end of the semester I discovered coordinates for these areas which will make implementation easier later on.

Data

The data source for this project was taken from the downloadable version of the FCC's [Universal Licensing System](#). This database currently only includes information about cellular licenses. However, I thought it was critically important to include license information for the other types of licenses that wireless operators use, including PCS, AWS and the recent 700MHz offerings. These data are not available for download from the FCC's website, but they can be requested using the Freedom of Information Act. Since I knew that I would only create a mock up for this project I decided to include these elements despite not having the real data for them yet.

Related Work

There are three different sources in which to find work related to visualizing spectrum licenses: government agencies, academic researchers, and the operators themselves.

Government Agencies

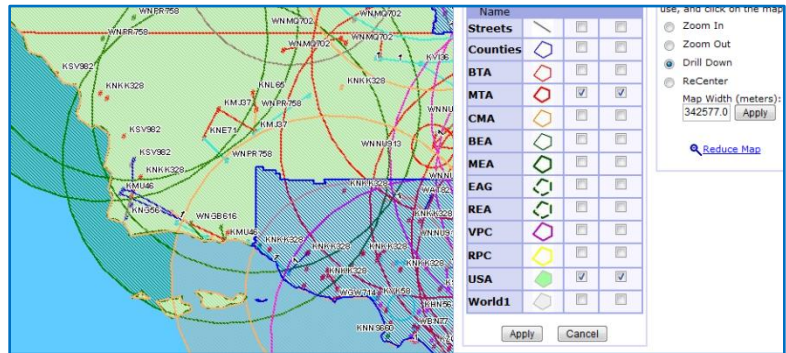
For many years the NTIA (National Telecommunication and Information Administration) has published the United States Allocation Frequency Chart (link to full size image from thumbnail). This chart is notorious among policy analysts and visualization experts alike for its poor quality. The information it presents is not very helpful



for analysts. It only describes what kinds of services are available at each frequency (for instance broadcasting, maritime mobile, military, cellular, etc.). It does not describe who is licensed to operate on those frequencies.

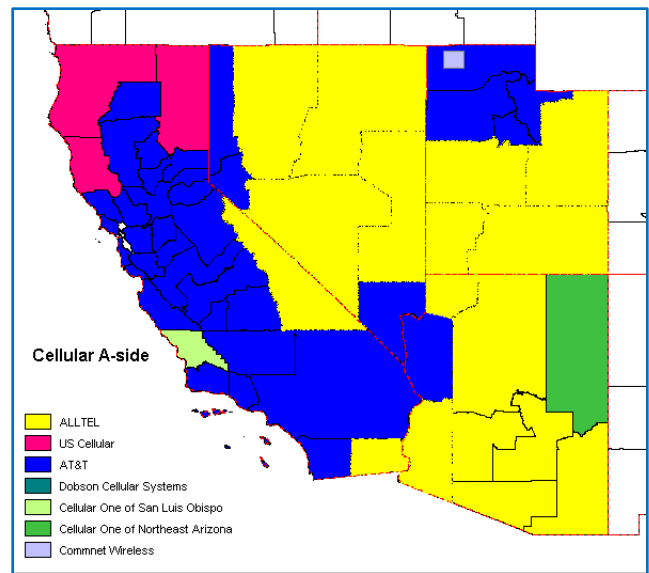
The FCC has a dynamic visualization of the data it makes available through the ULS databases (figure 2). However, this visualization is also very poor. It treats licenses as point values based on actual tower locations, and shows the coverage area using a concentric circle. This approach could be useful to

show a realistic idea of the area an operator can service, but the implementation is very clunky. For instance, it treats each license separately regardless of ownership. Thus, a simple query for a single operator will give a complex and essentially meaningless visualization. A query for multiple vendors would be indecipherable. The options for the different types of markets are also confusing (the polygons with different colors). Additionally, there are several colored pound symbols (#) placed on the map which I have yet to figure out the meaning of. The tool also suffers from very long delays whenever a user enters a new query or adjusts the options of the current display. Overall, this visualization tool is ineffective.



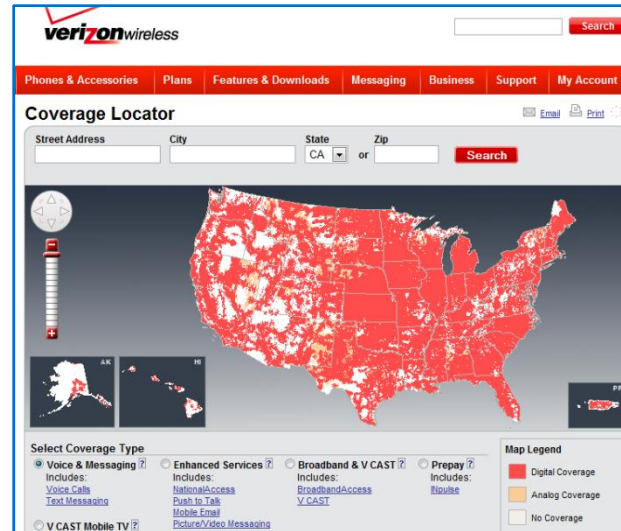
Academic Research

Andrew Shepherd at the University of Kansas has created several maps of cellular and PCS licenses that are much more enlightening than the government resources. Unfortunately, these are broken up by region, so that a user cannot switch between a nationwide and local view. His maps give the user a quick view of which operators have licenses in each area. However, because he has mapped only certain licenses (cellular in figure 3), his data is much simpler. When cellular was first introduced, only two blocks were allocated in each area. Thus, it was possible to easily show all competitors in an area using two maps side by side. With PCS and AWS licenses there are typically five different blocks, each using different kinds of market areas overlapping with each other. Thus, while these maps are useful, they cannot handle showing all levels of services (cellular, PCS, and AWS) and all levels of geographic boundaries.



Operator Coverage Maps

Undoubtedly, the best visualizations have been created by the operators themselves. They need these kinds of visualizations for their own analysis of strengths and weaknesses of their own networks. Unfortunately, most of these visualizations are proprietary and difficult to find. But the operators offer simpler visualizations on their websites for marketing purposes. These are useful because they are based on actual coverage rather than just licensed areas, and they even offer filters for viewing coverage of different types of services in each area. The transition between zooming is smooth and queries run quickly. Unfortunately, the drawback of these systems is that the data from all the operators is not aggregated. Comparison of different operators is not possible.

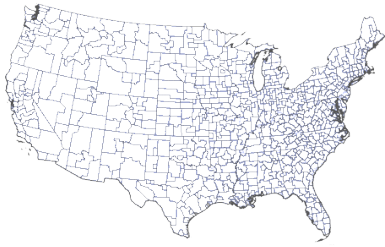


Design Description

The use of maps was obviously a necessary element of any approach I would take for this visualization. The fact that the licenses are tied to geographic regions makes the use of maps obligatory. One shortcoming of the Verizon coverage map shown above is that a user cannot determine how much bandwidth the operator has in any area. To their credit, it does distinguish between analog and digital coverage, but this is not much help. I decided the best way to show bandwidth on a map was to use color, similar to a Data Map or Heat Map. The more bandwidth an operator has in a given area, the darker the color in that section of the map.

One problem that arises when dealing with an operator's full bandwidth capacity is that the licenses for different frequencies may have been allocated using different market boundaries. In the early days of cellular, the FCC granted licenses using Cellular Market Areas (CMAs), which were loosely based on state counties. Two blocks of spectrum, A and B, were given out in each area. When the FCC began auctioning the PCS licenses, they created slightly larger zones, called Economics Areas (EAs). When it became apparent that operators were providing services for large portions of the country the FCC decided to also offer much large regions, Regional Economic Area Groupings (REAGs), which included several states. In the recent 700MHz auction, each of the different types of regions were used, depending on the block. For instance the A block was based on the original Cellular Market Areas, the C block licenses adhered to the large REAGs, and there was even a single, nationwide D block.

CMAAs



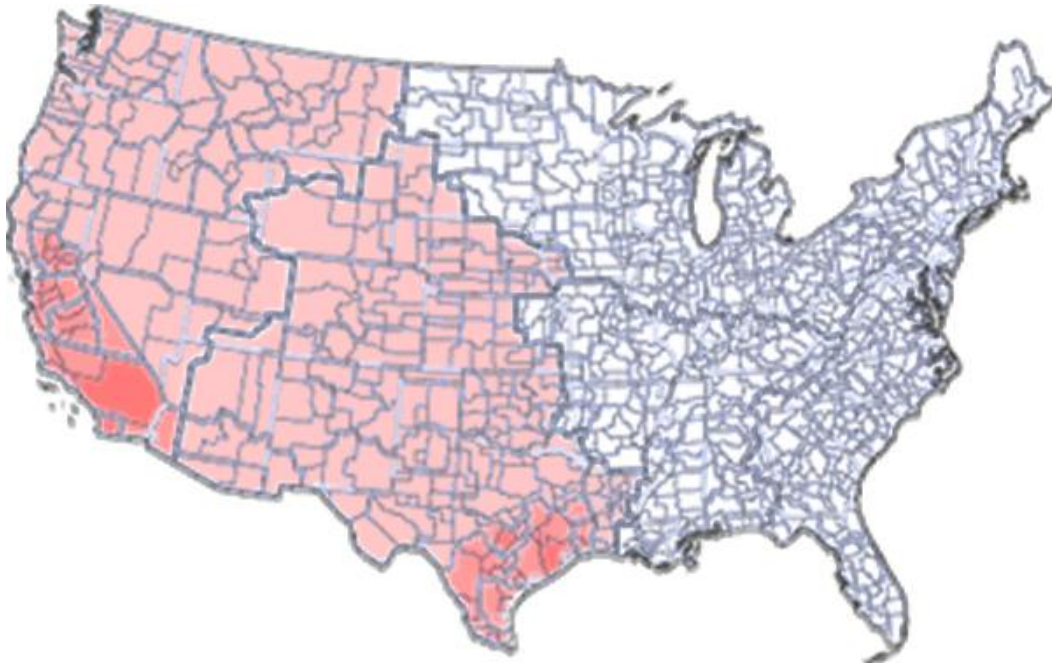
EAs



REAGs

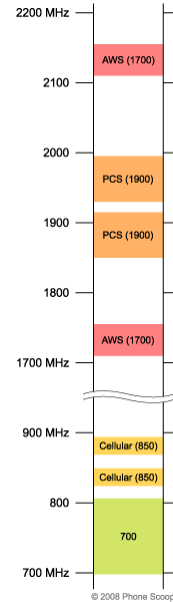


Displaying these different market areas can be very tricky. And implementing the heat map display within them makes it even trickier. To solve this problem, I decided to use a layered technique. Each layer will be transparent, with the exception of the geographic borders. The heat map colors for each layer will use an additive effect, so that when the layers are placed atop each other the visualization will appear darker in areas where an operator has multiple licenses. See below.

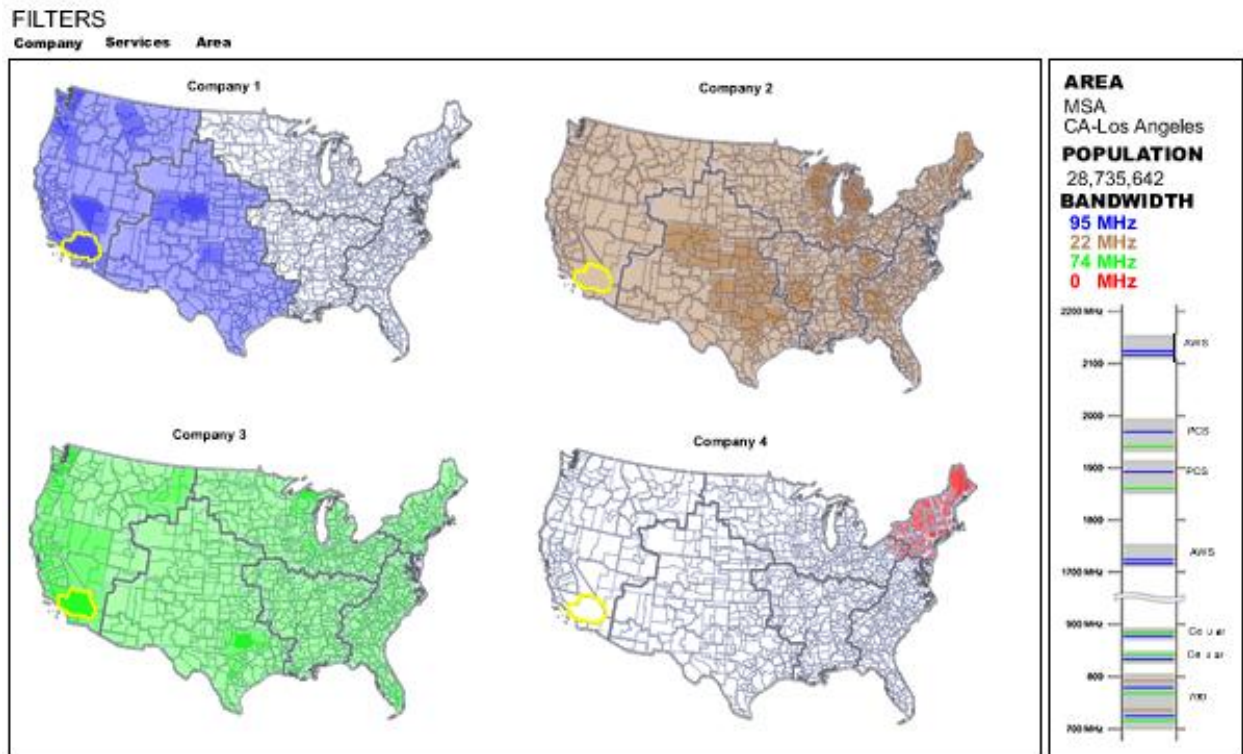


The next problem I had to tackle was a method for displaying the services available (cellular vs PCS, etc) and also for showing the frequency range of the license. While getting feedback one person suggested that I also add a visualization of the full wireless spectrum, and the portion of it that was currently displayed on the map. I did not like this idea at first because the radio spectrum is large, and licenses used by cellular operators are a very tiny slice of it. However, when doing research I came

across a graphic that I thought would be useful to solve all three of these problems. It shows just the important sections of the spectrum and what kinds of services are available in each. I decided to take this graphic and adapt for my visualization. When a user click on a specific region on the map, the operator's information will also be displayed on this detailed graphic, thus informing the user of both the amount of spectrum licensed as well as the type.



Finally, there was the issue of comparing multiple operators at once. To accomplish this requirement I decided to employ the Small Multiples method. At first, I was wary of using this method because I feared detailed data may be lost if several carriers were compared and the windows shrank. However, I eventually realized that the maps give a general idea from the outset. They do not offer fine grained detail unless the user zooms in, at which point the smaller windows do not matter. Furthermore, the detailed spectrum slice can accommodate multiple carriers when viewing selected market areas. Here is the final mock up:



In this mock up the user has selected four operators. Each one is assigned a unique color for the heat map. The user has selected a region on one of the maps, which triggers a parallel selection on the other maps. The detailed data is then made available in the sidebar: total bandwidth along with the type of services the operator can provide in that area. The colored bands in the sidebar are proportional to the amount of bandwidth the operators have in those ranges.

The filters along the top can be used to adjust the visualization. The user may want to only view certain market areas or states. Or they may wish to only look at cellular license and so filter out PCS and AWS using the Services filter. The user can also click an option in the filters to separate the layers of each operator, instead of overlaying them. This will produce more windows in the display. It's possible that too many windows would be generated and the maps become too small to be useful. To prevent this, a limit will be set on the window sizes. When the windows become too small the interface will set up a tabbed pane display.

Future Work

I plan to carry this project forward this summer and during the next school year. Most likely, I will incorporate it as part of my Masters Project next year. I am interested in wireless policy and will probably present a research paper for my project. Thus, I will not only be the creator of this visualization tool, I will also be the first policy analyst to use it for research!

My next step is to take the recently discovered coordinates for the market areas and develop a working prototype of the visualization. I will attempt to develop this as a web application using AJAX technology. This seems like the best approach as it requires a database on the back end that will need frequent updates. While I am developing the prototype I will contact the FCC and request the necessary data for the PCS, AWS, and 700MHz services.

Once the prototype is up and running I will contact a few real policy analysts and ask them for their input. I would like to know which data they believe are important and should be included as well as their opinions on the effectiveness of the visualization methods. There are several policy analysts at the New America Foundation that I will try to contact. I will also ask some of the I School faculty to suggest people who may be interested.

Beyond functionality, this visualization is in dire need of better design aesthetics and usability. I chose to focus this project strictly on the data representation, not the aesthetics or interface design. I plan to take INFO 213 – User Interface Design as well as Professor Ryokai's Interface Aesthetics course next spring. By then I should have a good idea of which features and data are most useful to policy analysts. My final step will be to take those functions and create a better user interface around them.