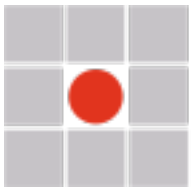

Public Knowledge

Breaking the Logjam:

Creating Sustainable Spectrum Access Through Federal Secondary Markets

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I. INTRODUCTION

It has become trite to observe that the use of wireless services, both fixed and mobile, has grown exponentially in the last two decades. But policies governing access to spectrum have failed to keep pace. The 1990s saw two important changes in spectrum allocation that supported the phenomenal growth of wireless networks of all sizes, ranging from national networks supporting tens of millions of subscribers with mobile handsets to extremely low-power networks permitting those subscribers to use hands-free Bluetooth devices. During that decade, Congress and the FCC embraced a policy of distributing exclusive rights of access through license auctions,[1] while simultaneously permitting low-power "unlicensed" spectrum access for properly certified devices.[2] Over the course of two decades, this combination of spectrum allocation approaches produced the existing environment in which licensed and unlicensed providers offer complimentary – and occasionally competing – products for an increasing variety of services.

Recent developments in technology make possible a third way to allocate spectrum, which combines features of certain kinds of unlicensed spectrum with the higher power and interference protection associated with licensed spectrum distributed by auction. By combining the technical rules developed by the FCC to allow unlicensed access on unused broadcast television channels (the "TV white spaces") with the ability to dynamically reassign spectrum from one user to another as well as the ability to conduct real-time auctions, the federal government can dramatically increase the availability of spectrum access through real-time secondary markets in spectrum. As discussed below, this system would not require existing federal users to migrate or require the development of new service rules for each band of spectrum, vastly shortening the time it takes to make federal spectrum available for non-federal use. At the same time, using real-time auctions as a means to allocate spectrum to prevent congestion, rather than allowing open access on equal terms as is traditional in unlicensed access, would permit higher power levels and greater interference protection than is permissible in unlicensed allocation.

Real-time auctioning would also permit the federal government to directly recoup the value of the use of public assets, while balancing with this the need to make spectrum available for non-revenue generating purposes. One of the attractions of clearing federal spectrum and auctioning exclusive, geographic-based licenses is that such an approach has the potential to raise substantial revenue the federal government. Auctions of desirable spectrum routinely raise billions of dollars. But this advantage of raising revenue comes at a high social cost. The high cost of spectrum licenses forecloses all but the most well capitalized bidders from winning licenses. This has a significant impact both on the structure of the mobile wireless industry and on the use of wireless access for services other than commercial mobile radio service (CMRS) and broadband. Industrial users have complained that it has become impossible to win licenses in recent auctions in markets where CMRS providers anticipate significant future demand for high-

[1] *See* Omnibus Budget Reconciliation Act of 1993, Pub. L. No. 103-66, § 6002; Balanced Budget Act of 1997, Pub. L. No. 105-33, §§ 3002-04.

[2] *See* Kenneth R. Carter, Ahmed Lauhjouji, and Neal McNiel, Unlicensed and Unshackled, OSP Working Paper #39 (2003), available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf.

bandwidth applications.[3] Many CMRS providers and potential new entrants also complain that auctions by their very nature favor the largest providers because these providers have a superior ability to attract capital and to extract revenue from the licenses after the auction. This impedes the development of robust competition. The need to raise substantial amounts of revenue immediately to recoup the cost of licenses also discourages spectrum auction winners from experimenting with new business models.

Dynamic secondary markets for federal spectrum provide a means of addressing needs for spectrum access that the current choices – licensed and unlicensed access – do not meet. The rise of secondary markets in commercial spectrum since the Federal Communications Commission (FCC) reformed the secondary market rules in 2004, the recent announcement by Harbinger Capital Partners that it will invest billions of dollars to create a nationwide 4G LTE network, which will lease capacity to retail providers,[4] and announcements by Verizon and Clearwire indicating their willingness to lease access to their spectrum to rural providers,[5] all demonstrate the demand for leased-based, rather than auction-based, allocation of high-power spectrum with protection from interference. As an additional benefit, the development of tools to manage dynamic federal spectrum secondary markets would likely further stimulate existing commercial secondary markets by facilitating creation of the "private commons" model envisioned by the FCC when it created the existing secondary markets rules in 2004.[6]

We stress that none of this makes federal secondary markets a replacement for either exclusive licensing or for unlicensed access. Rather, we believe that dynamic federal secondary markets would provide an important new means of allocation to address unmet needs. This approach should be used in combination with proposals to increase spectrum access via opportunistic sharing and further auctions of exclusive licenses. Indeed, we anticipate that existing users of exclusive licenses and of unlicensed access will likewise benefit from this new option for spectrum access. AT&T's recent decision to create WiFi hotspots in high-demand markets such as New York to supplement its existing CMRS network[7] provides one example of how even a carrier dependent on licensed spectrum can benefit from the availability of alternate means of spectrum access.

II. THE TRADITIONAL WAYS TO ALLOCATE SPECTRUM ACCESS CANNOT KEEP PACE WITH DEMAND

The two existing systems for allocating spectrum access – auctioning exclusive licenses and open unlicensed spectrum – can no longer keep pace with growing demand. While one may debate whether or not we face a genuine "spectrum crisis," the FCC's massive research effort as

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[3] *See Reply Comments of the American Petroleum Institute, National Broadband Plan Public Notice #6,* Docket No. 09-47, 09-51, 09-137, (filed November 13, 2009).

[4] Peter B. de Selding, "SkyTerra Buyer Commits to Multibillion-Dollar Ground Network," Space News (March 29, 2010). Available at: http://www.spacenews.com/satellite_telecom/100329-skyterra-buyer-commits-multibillion-dollar-ground-network.html.

[5] Maurgeritte Reardon, "Rethinking the Wireless Spectrum Crisis," Cnet.com (May 25, 2010). Available at: http://news.cnet.com/8301-30686_3-20005831-266.html

[6] *Promoting Efficient Use of Spectrum Through The Elimination of Barriers to Secondary Markets*, *Second Report and Order, Order on Reconsideration, and Further Notice of Proposed Rulemaking*, Docket No. 00-230, (2004). Available at: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-167A1.pdf

[7] Maurgeritte Reardon, "AT&T Offers Free WiFi in New York City," CNN.Com, May 25, 2010, available at: http://www.cnn.com/2010/TECH/mobile/05/25/att.free.wifi.nyc.cnet/?hpt=T3

part of the National Broadband Plan generated a clear consensus that demand for wireless capacity – for commercial mobile services, fixed services, and public safety – will rapidly outstrip the current allocations of licensed and unlicensed spectrum capacity. In response, the FCC proposed finding 500 MHz of spectrum for auction while expanding unlicensed spectrum access through completion of the TV "white spaces" proceeding, encouraging the development of new technologies to promote shared use, and allocatiing a band of spectrum for unlicensed use, unencumbered by licensees requiring interference protection.[8]

Each of these proposals, however, faces considerable political, economic and technical objections. Those favoring the creation of more licensed spectrum face the practical problem of identifying where they would find more spectrum for auction – particularly paired spectrum in the frequency ranges prized by cellular providers. Those advocating an emphasis on unlicensed access and other forms of shared spectrum face resistance from federal deficit hawks hoping for billions in auction revenues. More importantly, none of these proposals addresses the underlying problem that the demand for wireless capacity will continue to grow and will, ultimately, exceed the capacity of a short term injection of licensed or unlicensed capacity.

In short, our current system of allocating spectrum access is ***no longer sustainable***. Just as the shift to auctions and unlicensed allocation made possible the phenomenal growth of wireless services over the last 15 years, federal policy must find a new, sustainable system of spectrum allocation to meet growing demand from all sectors of society. Three developments in the last five years point toward a new spectrum allocation mechanism that can supplement existing licensed and unlicensed allocations.

First, several regulatory actions by the FCC permitting licensees to lease their spectrum through approved "secondary market" transactions have created an expanding secondary market in spectrum access. Spectrum Bridge, a major broker of spectrum leases, reported to the FCC that it "has successfully completed tens of millions of dollars of secondary market transactions in 2009 alone."[9] In March, Harbinger Capital Partners announced plans to invest billions in a 4G network that would offer to lease spectrum wholesale.[10]

Second, the FCC's TV white spaces proceeding has demonstrated the viability of a new generation of flexible "smart radios," able to avoid interfering with existing licensees. Under the proposed rules, fixed devices for point-to-point transmission and lower-power mobile devices would operate on empty channels in the existing broadcast bands. These devices communicate their position to a central database containing information on existing licensed services in the geographic area entitled to interference protection. The database then provides operating instructions to the devices, informing the devices on which channels they may operate in, and at what power. Unlike traditional unlicensed allocations, which operate under the same rules and power levels nationally, the TV white space devices transmit on frequencies and at power levels determined by applying FCC rules to the spectrum environment in a given location. This permits

[8] Connecting America: The National Broadband Plan, Chapter 5 (2010). Available at: http://download.broadband.gov/plan/national-broadband-plan-chapter-5-spectrum.pdf

[9] Comments of Spectrum Bridge, Inc., GN Docket Nos. 09-157, 09-51 (filed September 30, 2009).

[10] "Hedge Fund Harbinger Capital Plans 4G Network," (March 30, 2010). Available at: http://www.marketfolly.com/2010/03/hedge-fund-harbinger-capital-plans-4g.html

the unlicensed devices to co-exist with the existing licensed services without causing harmful interference.

Third, the FCC has approved the concept of dynamic frequency assignment as sufficiently reliable to satisfy the needs of public safety. Proposals for public safety use for the 700 MHz band returned by broadcasters as part of the conversion from analog to digital television broadcasting have relied on the ability to dynamically reassign spectrum access from commercial users to public safety users instantly on an as needed basis in the event of an emergency.

Taking these three developments together allows the federal government to create a new approach to spectrum allocation – dynamic federal spectrum secondary markets. Consider a system where the federal government enters all known federal users in a database similar to the white spaces database. As with the existing broadcast band, this "federal band" would have a broadly dispersed "Swiss cheese" distribution of actual transmitters and receivers. Some bands would be entirely off limits on a nationwide basis, but others would be unused in specific geographic areas – although they might be subject to immediate dynamic reallocation back to federal users on an as needed basis.

The devices – and the users of such devices – linked to the database would not need to know the specific frequencies or why some frequencies are available and others are not. Rather, those needing spectrum access would simply inform the database of their overall capacity need, and the database would respond with a specific set of instructions to the device.

While such a system could permit unlicensed access for free, requiring the devices to purchase access through real-time auctions has a number of advantages. First and foremost, it recognizes the political reality that management of federal spectrum includes raising federal revenue. While it is difficult to predict precisely how much revenue the federal government could raise over time through federal spectrum secondary markets, our preliminary economic analysis suggests that, under certain conditions, the federal government could raise more money over time by leasing spectrum than through a one-time auction of the sort used to distribute standard licenses. The revenue generated by the auctions could also be used to maintain the network and database – either directly by the federal government or through a federal contractor. Finally, real-time auctioning also creates a mechanism to resolve potential interference issues between users through the simple expedient of market transactions rather than through contention-based protocols or spectrum etiquettes.

The technology to develop such a federal secondary market system already exists – at least at the proof of concept stage. Indeed, Google investigated the possibility of building such a network when it participated in the 700 MHz auction in 2007. Such a system would not ***displace*** either auction or unlicensed access. To the contrary, any bands of federal spectrum subsequently allocated for auction or for unlicensed use could simply be removed from the federal secondary markets database. This approach allows spectrum desperately needed to address a variety of industrial needs to come to market quickly, without the delay and expense of migrating existing federal users to new spectrum. In particular, it provides spectrum access for non-cellular services such as wireless backhaul, machine-to-machine communication, and industrial users that have reported increasing difficulty competing at auction with mobile carriers. The secondary market model also addresses concerns that the largest cellular carriers will be able to dominate future

spectrum auctions as a result of their superior capitalization and greater ability to extract revenue from licenses post-auction.

Finally, critics of spectrum auctions have raised concerns that incumbent users may bid on spectrum licenses for the purposes of keeping spectrum out of the hands of competitors. These critics point to the failure of some licensees to build out systems despite aggressive bidding as evidence that these incumbents have no genuine interest the licenses. Incumbents and others favoring distribution by auction have disputed that licensees hoard spectrum. They respond that many reasons exist why incumbents might bid on licenses but take years to begin build out. Changes in the technology or business environment might upset previous business plans, for example. Whether by accident or design, however, the problem of licensees failing to build out systems, and thus preventing any use of the spectrum in question, has become sufficiently urgent that the FCC has addressed it in several recent proceedings. Spectrum hoarding concerns have also arisen in commercial secondary markets, as evidenced by the FCC's decision to limit the amount of spectrum made available to SkyTerra.

Without addressing the underlying merits of these concerns, we note that using dynamic real-time auctions of federal spectrum would prevent hoarding and improve competitive access. The proposed federal secondary markets network would lease spectrum in real-time. When a provider was not actively using the spectrum, it would become available. By leasing on the basis of throughput capacity rather than on the basis of frequency bands would make it extremely difficult, if not impossible, to lease "all" of the spectrum solely for anticompetitive purposes. Furthermore, holding the capacity in real-time against all comers with genuine need would prove an expensive competition, as it would require holding the winning bid in multiple repeating auctions.

II. WHAT IS "FEDERAL SPECTRUM?"

Before we can discuss how to implement such a system, we must first explain precisely what we mean by "federal spectrum." By law, the Federal Communications Commission controls all access to the airwaves by non-federal users. The Communications Act assigns authority to manage use by federal users to the President. The President delegated that power to the Assistant Secretary of Commerce for the National Telecommunications Information Administration (NTIA), a delegation subsequently confirmed and modified by statute. Over the years, certain frequency bands have been allocated to the federal government.

As a statutory matter, there is no such thing as "federal spectrum" distinct from "commercial" spectrum. Bands may be allocated "on a primary basis for Federal Government use," 47 U.S.C. § 927(b), but this does not restrict the FCC's ability to authorize additional, non-interfering uses. Under the Communications Act, and as modified in the National Telecommunications and Information Agency Organization Act (NTIA Act), the FCC grants ***licenses*** to non-federal users. 47 U.S.C. §301. By contrast, the Communications Act assigns the power to authorize use of spectrum for "government owned stations" (*i.e.* federal users) to the President. 47 U.S.C. §305(a). In 1992, Congress ratified delegation of this authority to the Assistant Secretary of the NTIA, 47 U.S.C. § 902(b). The Commission may, therefore, authorize

non-interfering use of "federal spectrum" under its own authority, and may even authorize interfering uses subject to certain conditions. *See* 47 U.S.C. § 323, § 903(e).

Congress, however, has expressed a desire for the FCC to coordinate with the NTIA rather than proceed by unilateral action. Indeed, 47 U.S.C. § 922 requires the Chairman of the FCC and the Assistant Secretary to meet "at least biannually" to discuss "actions necessary to promote the efficient use of the spectrum, including spectrum management techniques to promote shared use of the spectrum that does not cause harmful interference as a means of increasing commercial access." § 922(4). Congress further demonstrated a desire to expand the mixed use of frequencies primarily allocated for federal use through coordination between the Department of Commerce and the Commission by authorizing the Secretary of Commerce to, "at any time allow frequencies allocated on a primary basis for Federal Government use to be used by non-Federal licensees on a mixed-use basis for the purpose of facilitating the prompt implementation of new technologies or services or for other purposes." §927(2). Congress explicitly instructed the NTIA to modify its regulations to facilitate the "prompt and impartial consideration of such requests," §903(b)(5), subject to rules and procedures developed by the FCC. §903(e).[11]

A. Role of the NTIA and Other Federal Agencies In Management of Federal Spectrum.

Although the Communications Act centralizes authority for federal assignment in the President, delegated to the Assistant Secretary for the NTIA, management of federal spectrum requires a complex balance between the current needs of federal agencies, and their possible future needs. Further, although the NTIA has a general coordination responsibility, usually exercised by its hosting the Interdepartmental Radio Advisory Committee (IRAC), the NTIA does not have direct authority over the agencies it authorizes to use particular allocated frequencies. To make matters more complicated, agencies are not entirely forthcoming with the NTIA with regard to the nature of their needs. Often, agencies cite an inability to predict future needs with precision, or security considerations, or both. This makes it difficult for the NTIA to provide the public with a complete picture of federal spectrum use or to estimate future federal spectrum need.

This lack of transparency in federal use creates enormous frustration for those trying to expand non-federal access to spectrum allocated on a primary basis to federal users. As a result, non-federal users often cite a culture of obstruction, bureaucratic inertia, and a refusal to adopt

[11] Although Section 903(e) states that an entity must obtain a "license" as a precondition of operating a "radio station utilizing a frequency authorized for the use of government stations," the Commission has previously found that the term "license" is sufficiently broad so as to include operation of properly certified Part 15 "unlicensed" devices pursuant to rules and limitations adopted by the Commission. *See* In re Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, Second Report and Order and Second Memorandum Opinion and Order, 19 F.C.C.R. 24,558 at ¶¶ 75–76. (2004) *See also* 47 U.S.C. § 3(42) (2000) (defining "license"). Likewise, the Administrative Procedures Act defines license as "the whole or a part of an agency permit, certificate, approval, registration, charter, membership, statutory exemption or other form of permission." 5 U.S.C. § 551(8) (2000).

more efficient technologies as evidence that vast swaths of federal spectrum could be cleared and made available for non-federal use.

But the truth is not so simple. Federal agencies are properly security conscious and risk averse in the areas of national security and public safety. As a nation, we want the military defense radar to look like empty, unused space. Creating a regime that too easily allows hostile powers or terrorists to "fill in the lines" and identify national security assets does not serve the national interest.

Nor does it serve the national interest to freeze federal use of spectrum at existing levels. In assessing the need for federal spectrum and the ability of agencies to operate more efficiently, the NTIA and other federal agencies must remain mindful that demand for wireless capacity is increasing among federal agencies for the same reason it is increasing for non-federal users. Requiring the federal government to contract for future spectrum use after clearing and auctioning spectrum would be more expensive and less efficient in the long run. Moreover, it would discourage federal agencies from being genuinely innovative in spectrum use, since any increased reliance on wireless would require that agencies expand their budgets for spectrum access fees.

At the same time, however, spectrum access has grown too important simply to trust that federal agencies accurately report their needs to the NTIA, and that the NTIA, in turn, accurately assesses these needs in coordinating allocations. Even assuming good faith and complete information, shutting non-federal interests out of the decisions on federal spectrum access forecloses the NTIA and federal agencies from the benefit of alternative perspectives. A lack of transparency also fosters an insular and defensive approach to spectrum management, where federal agencies seek to preserve their spectrum from private sector "poaching." This perspective is only reinforced by the current system, where honesty about future spectrum needs and efficiency in existing use is rewarded by clearing and transferring spectrum to the private sector. For these reasons, Congress explicitly instructed the NTIA to take steps to increase transparency in federal decisions on spectrum management. 47 U.S.C. §903(a)-(b). Although the NTIA has complied with the minimum obligations under the statute, it could, and should, do more to enhance transparency in federal spectrum management without compromising national security.

B. How The Law Plays Out To Create The Current Landscape

"Federal spectrum" therefore proves something of an elusive animal, which has consistently served to muddy the debate. On the one hand, we speak of "federal spectrum" as a unitary entity managed by the NTIA. We conceive of the bands assigned to specific agencies in the same way we think of the FCC assigning commercial spectrum by frequency band for specific purposes. Thus, in commercial spectrum, we can speak of "the TV broadcast bands" and understand the needs of that service. Part 74 of the Commission's rules explains what full power and low power television broadcasters do, how the FCC assigns them licenses, the permissible frequencies and power, and so forth. The band may be "Swiss cheese" in terms of geographic locations where the frequencies are not assigned, but – like Swiss cheese – its basic character is understood.

Federal spectrum creates a far more challenging problem in that it is assigned by agency, not service. In theory, agencies apply through the procedures outlined in the NTIA's voluminous "Red Book" and provide specific information on projected use. In practice, agencies with broad duties and national jurisdiction often receive broadly defined national grants of authority for use for a wide variety of purposes. One cannot speak of "FAA spectrum" in the same way that one speaks of "broadcast spectrum." Further, the same spectrum bands might be allocated to different agencies on a geographic basis for very different purposes.

While the NTIA has improved its efforts to provide more specific information in recent years, it remains difficult to determine how agencies actually use the spectrum allocated to them. For example, the most comprehensive analysis of federal spectrum use remains the *Federal Strategic Spectrum Plan*, published in March 2008 as the culmination of President Bush's spectrum planning initiative begun in 2004.[12] While providing a general overview of use by agency, it is virtually impossible to determine the precise characteristics and of any given spectrum band – or even whether a band listed as used by an agency is shared with non-federal users. By contrast, for non-federal users, it is possible to find in the FCC regulations a precise description of each service.

Federal agencies maintain that because of the lack of specific information, any effort to reallocate spectrum to clear and auction bands for commercial use, or to permit shared use on an unlicensed basis, cannot be done. It is simply too messy and too uncertain to try to clear bands because displaced federal users may have no place to go. It is not possible to allow unlicensed access at low power because the various agencies using the same bands nationally use them for very different purposes, making it impossible to authorize useful power levels on a national basis for unlicensed devices.

At the same time, however, the fact that so many different users can operate simultaneously in these bands for so many variable uses suggests that the objections to permitting greater non-federal access on a shared basis can be overcome. After all, all of these federal agencies somehow manage to use the frequency bands in question without interfering with each other. The purported lack of certainty that would make opportunistic sharing impossible for unlicensed spectrum does not seem to prevent federal agencies from accomplishing the same opportunistic sharing for themselves via the mechanism of the IRAC and existing federal allocation. One must conclude either that federal agencies have greater information and coordination than they care to admit, or that barriers to mixed use (or relocation of federal users in already occupied bands to clear spectrum for national auction) can be overcome with somewhat less difficulty than suggested.

Finally, we must recognize that the current stalemate over how to enhance non-federal access to spectrum allocated primarily for federal use results from competing policy goals as much as from uncertainty or intransigence on the part of federal users. Although the Federal Communications Commission is prohibited by law from considering how to maximize federal revenue through spectrum management, the NTIA is required by law to consider precisely this question, although not as the sole determining factor. This creates an unfortunate conflict between maximizing the broadly defined public interest and maximizing auction revenue. This

[12] Available at http://www.ntia.doc.gov/reports/2008/FederalStrategicSpectrumPlan2008.pdf.

conflict is further sharpened by sharp disagreements among industry stakeholders and public interest advocates for financial and ideological reasons. Traditionally, carriers have favored maximizing "clear and auction" policies, supported by advocates who believe that creating property interests in licenses will enhance efficiency and maximize public welfare ("the property school"). On the other hand, the technology sector has favored increasing unlicensed access, supported by advocates who believe that maximizing universal access to spectrum without the need for licensed intermediaries will enhance efficiency and maximize public welfare.

The result of this political and economic conflict of interests, layered on top of a legal structure that makes coherent analysis of federal spectrum difficult to start with, has been utter paralysis in the management of federal spectrum for the last several years. Although both supporters of licensing and supporters of unlicensed generally agree at this point that both allocation systems have value, each camp insists that its needs are paramount and should be met first. More importantly, each camp recognizes the very real likelihood that allocating spectrum to one camp would automatically preclude allocating it to the other – and who knows when any further spectrum would be allocated? As a result, to paraphrase a well worn cliché about the public airwaves in the form of weather, "while everyone talks about the spectrum shortage, nobody does anything about it."

III. DYNAMIC AUCTIONS PROVIDE A WAY FORWARD

In recent years, the problems cited as obstacles to mixed federal and non-federal use – the uncertainty of the spectrum environment, the "Swiss cheese" nature of bands, the inability to offer a sufficiently large contiguous band necessary to support high-bandwidth traffic, the need of federal agencies to access "empty" spectrum immediately, and the need to maintain national security around certain types of spectrum use – have all been solved in other environments. All that remains is to put the pieces together. While this could be done on a dynamic basis for unlicensed spectrum, as proposed by the FCC in the TV White Spaces proceeding, layering real-time dynamic auctions has certain advantages. While charging for spectrum use does, as argued by unlicensed advocates, limit who can use the spectrum, imposes an added layer of complexity on the technology, and requires a centralized architecture at some level to facilitate billing and revenue collection, real-time auctions address the need for federal revenue and provide those willing to pay for it with a level of interference protection unavailable to users of unlicensed spectrum.

A. Designing The Federal Spectrum Secondary Market Network

The design for a secondary market system essentially parallels the design approved by the FCC for unlicensed opportunistic use of the broadcast television white spaces. That design works as follows: a central database contains information on all licensed transmitters. Devices contacting the database are given a set of rules for transmission based on their geographic location and the varying criteria for protection assigned by the Commission. Further, even where a device may operate on a particular 6 MHz channel, the power at which it can operate will depend on whether the open 6 MHz channel is adjacent to an occupied 6 MHz channel.

This provides a basic model for a federal system. First, create a database of federal bands and the uses of these bands by geographic location. Federal agencies using the same spectrum bands for different purposes in different geographic locations can be easily accommodated and avoided. Power levels for available frequency bands can be set based on protecting neighboring services given the specific characteristics of local services. As with the TV White Spaces database, federal users can update the database at any time. Thus, as federal spectrum use changes, the database makes new spectrum available or limits access accordingly.

For federal users that may require immediate access to spectrum, the system would borrow technology similar to that approved in concept by the FCC for the public/private partnership in the D Block, itself based on existing technology for sharing licensed spectrum among licensed users. Under the original D Block proposal, a private entity holds a national 10 MHz license adjacent to the 12 MHz national license held by the Public Safety Spectrum Trust (PSST). The D Block holder would have access to the PSST spectrum, and would lease the spectrum to others. When public safety operators needed access to the spectrum, they would be able to access the spectrum immediately, including the privately held D block spectrum. This would give public safety users access to 22 MHz of spectrum at need, while allowing the D Block holder to lease up to 22 MHz subject to immediate access by public safety users. Although the failure of the D Block auction prevented implementation of the system, the public safety community, the FCC, and private investors proposing the system all agreed that current (for 2007) technology would meet the necessary technical needs.

Those seeking access to federal spectrum between 30 MHz and 3000 GHz would not access the spectrum based on spectrum band, or power. Rather, parties would query the database for throughput capacity, specifying mobile, fixed, point-to-point, or mesh. The database would determine whether the request could or could not be met. Finding a solution, the database would provide instructions to the transmitting devices. As additional, non-federal users seek access, the network would conduct real-time auctions among the competing users.

Such a system would likely satisfy some uses -- such as wireless backhaul, machine-to-machine, low-bandwidth mobile uses, and other uses not readily accommodated by existing architectures – more easily than others. But the secondary market system could permit multiple competing uses and modulation technologies, providing would be users with considerable flexibility. Conflicts between users for incompatible uses within the same geographic location would be resolved by auctioning in real-time rather than by permanent service rules. It would require only that the database have the capacity to recognize not only how a particular modulation technology impacts federal users, but how multiple systems impact each other. Indeed, a sophisticated system – but one still within existing design capabilities – would offer to parties options that minimize interference among competing systems and so reduce the need to out-bid competing users.

This might impose some limits initially, such as limiting would-be users to pre-approved modulation schemes. But the vast number of well-understood modulation schemes already available ensures that limiting users to a pre-approved menu of options should still provide for a wide range of applications made available through the system.

IV. ADDRESSING TRADITIONAL OBJECTIONS TO FEDERAL SECONDARY MARKETS

Objections to secondary markets in federal spectrum generally fall into two distinct categories: technical objections and political and economic objections. The technical objections largely focus on whether or not the system described could be built and whether it could adequately protect federal users. As discussed above, the basic technical problems for each element of the proposed system have already been solved. The more substantive objections that remain are more political/economic in nature. These objections include the problem of compiling a sufficiently comprehensive database of federal spectrum users, inducing federal users to report their use accurately and dynamically, and whether there exists a sufficient market to justify development of the network in the first place. We note that while many of these objections (e.g., difficulty in protecting federal users) are often posed as technical objections, they are more accurately described as political and economic objections since they flow from the need to address federal user behavior rather than from the inability of existing technology to handle a complex spectrum environment in a dynamic manner.

A. The Proposal Requires No New Breakthroughs In Technology

Implementing the proposed network does not require speculative technology. All of the elements of the proposed system either already exist, or have been approved in concept by the FCC for use in commercial spectrum. In 2007, Google sought permission to implement a similar system of real-time auctions for access when it bid on the C Block in the 700 MHz auction.[13] Spectrum Bridge operates a TV White Spaces database for experimental licenses, and nine parties submitted proposals to operate the national TV white spaces database.[14] As part of the National Broadband Plan, the FCC announced that it would require all 700 MHz licensees to provide public safety entities with access to spectrum in an emergency on an as needed basis.[15]

Were this system implemented, it would be necessary to draw up rules to protect services. This would require an honest examination of the likelihood of interference by users with existing federal systems. For example, certain bands are used primarily for naval operations, limiting the need to protect coastal areas (including the Great Lakes). Bands involving transmission of strong signals by federal users may be robust enough to allow sharing by non-federal users using weaker signals. Bands used for weather radar may be usable on the ground without creating undue interference. Further, even where bands are available, the database would need to instruct transmitters on permissible power levels and out-of-band emissions (OOBE) to shield operations (both federal and non-federal) in neighboring bands.

Certainly these problems are complex. But they have all been solved in other spectrum environments. Indeed, the Defense Advanced Research Agency (DARPA), has developed technology to perform this precise function for U.S. military deployment abroad, so that U.S. troops can have adequate access to spectrum in any theater of operation, while coordinating with

[13] Letter of Rick Whitt, Docket No. 06-150 (May 21, 2007) Available at: http://fjallfoss.fcc.gov/ecfs/document/view?id=6519412640

[14] Order, Unlicensed Operation In the TV Bands, Docket No. 04-186 (February 1, 2010). Available at: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-10-215A1.pdf

[15] Connecting America: The National Broadband Plan, Chapter 5 (2010). Available at: http://download.broadband.gov/plan/national-broadband-plan-chapter-5-spectrum.pdf

allied troops or an allied host country. Nothing suggests that the domestic U.S. spectrum environment is so much more complicated that the same technology could not work here.[16]

Creating the proposed secondary market network for federal spectrum, therefore, requires no radical technological breakthroughs. It merely requires combining elements of existing technologies into a single system. While this does, of course, require overcoming challenges that invariably arise in the course of implementation, this is true of any new network. Such a system could be designed today and construction begun. But the fact that such a system is possible as a matter of engineering does not resolve all objections.

B. Problems With Federal Inputs

As noted above, the current regulatory regime creates an unfortunate incentive for federal agencies to resist transparency in federal spectrum use. Indeed, efforts to pass pending bills designed to create a database of the federal spectrum inventory have been met with resistance not from industry or public interest advocates – all of whom favor passage – but from Defense Department officials ostensibly concerned with national security.[17]

How, then, to construct an accurate database so that the operation of federal secondary markets can move forward? First, it is important to address legitimate concerns by federal users with regard to national security and their ability to access needed spectrum. At the same time, it will also be necessary to provide proper incentive for federal users to participate and update the system as needed.

From a national security standpoint, the key lies in the fact that no one without suitable security clearance needs to have access to the contents of the database. The database provides a set of instructions to a transmitter based on stated capacity needs, not based on a request for particular frequencies. The transmitting device (and its user) do not need to know why particular frequencies are unavailable. Indeed, information as to the frequencies on which the user's devices are transmitting can even be hidden from the user. All the user needs to know is that the device is operating in accordance with the user's stated needs. This not only protects bands off limits for security reasons, it prevents parties from "filling in the blanks" and guessing the uses of prohibited spectrum through knowing on what frequencies certain top secret operations must take place.

The next problem is somewhat more difficult. How can agencies be compelled to provide accurate information for the database? Here, it seems that the best approach is to rely on self-interest. A failure to provide information means a channel is considered open and ready for use. Agencies concerned with interference will apply proactively. Agencies that suffer interference can add their information to the database in real-time. As noted above, a critical aspect of the design will include a means by which federal agencies can signal they require immediate access to "open" spectrum. Accordingly, an agency's failure to include information in the database would not preclude it from using assigned frequencies.

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[16] Benjamin Lennett, "Good Enough For the Pentagon: The Feasibility of "Smart Radio" Technology in the TV White Spaces," New America Foundation (2008). Available at: http://www.newamerica.net/files/nafmigration/Good_Enough_for_the_Pentagon.pdf.

[17] Matthew Lasar, "Congress Wants Big NatSec Exemptions for Spectrum Inventory," Ars Technica. Available at: http://arstechnica.com/tech-policy/news/2010/03/congress-wants-big-natsec-exemptions-for-spectrum-inventory.ars

More difficult is the problem of agencies claiming more spectrum than they actually use, or failing to clear discontinued uses. Such "false positives" in the database may happen has a result of honest error or from strategic behavior by agencies that do not trust in the reliability of the secondary markets network. Here, the ability to assign on a dynamic basis may prove particularly useful when combined with sensing technology. The secondary markets network can incorporate the ability to systemically "audit" uses and confirm that a band is actually in active use. Again, we stress that federal users will be able to exclude non-federal users from particular bands and access the bands themselves in real-time. Indeed, the default setting for many bands may be that they are unused and available for leasing, subject to an interrupt signal from the assigned federal user.

It is not hard to imagine tweaks to the system that would allow it to learn with regard to the surrounding spectrum environment, either by improved spectrum sensing or by detecting patterns in demand over time. It is also possible to begin the system with an incomplete inventory and add more "channels" as the rules for additional bands are formulated. Further, we note that similar objections have been raised, and solutions proposed, in the FCC's TV White Spaces proceeding. These solutions should be applicable to federal spectrum.

C. The Economic Value Of Federal Secondary Markets

Assuming that it is possible to implement such a system, would it prove economically worthwhile? This requires weighing the competing aspects of federal spectrum policy discussed in Section II. Would such a system raise revenue? Is there a demand for secondary market spectrum? Would it promote access to spectrum in a manner that helps to alleviate the pending spectrum shortage, or would focusing on designating bands for auction or for unlicensed opportunistic sharing better serve federal policy? We examine each of these in turn.

1. Would the Federal Government Realize Significant Revenue From Secondary Markets?

Any entrepreneur examining whether to bring a product to market must answer the same question: is it worth it? Federal spectrum policy, while not focused solely on maximizing revenue, does take the ability to raise revenue into consideration when considering whether to make federal spectrum available. At any rate, the implementation of the system must at least pay for itself. Accordingly, we examine whether a market for federal spectrum on a dynamic lease basis, or even on a non-dynamic lease basis, exists.

Secondary Markets in Spectrum have expanded tremendously in recent years, and demand continues to grow. There is a common belief in the spectrum policy community that spectrum secondary markets have "failed." This belief is rather at odds with existing evidence. A simple perusal of the FCC's "Daily Digest" shows a steady stream of filings reflecting spectrum leasing activity across numerous bands. Spectrum Bridge reports that it has brokered "tens of millions of dollars" in secondary market transactions in 2009. Industrial users have reported that demand for non-CMRS uses is increasingly unmet by existing allocations, and that they are turning to existing secondary markets to meet the need. As a consequence of these and other comments in the National Broadband Plan proceeding, the FCC has announced that it will commence a proceeding on how to further facilitate the use of secondary markets.

Private sector investment also suggests strong interest in spectrum secondary markets. The hedge fund Harbinger Capital Networks has announced an investment of billions of dollars to develop existing satellite spectrum in which it has rights to create a wholesale leasing network. The proposed network in many ways replicates the proposal by Frontline to create a wholesale network via the 700 MHz D block, indicating that at least some significant investors remain convinced that the failure of Frontline came from other factors – such as the cost of bidding at auction and the uncertainty of working with the Public Safety Spectrum Trust – rather than from a lack of demand for leased spectrum. Indeed, in the short time since Harbinger announced its plans, rumors have surfaced in industry press of a possible deal to lease the spectrum to T-Mobile.[18]

The focus in spectrum policy on CMRS spectrum, we believe, has clouded the perception in policy circles on the existing widespread use of existing secondary markets and the signs of continued growth in this sector. We should therefore observe that even CMRS licensees are finding access to non-CMRS spectrum a useful supplement to their licensed spectrum. Whereas CMRS providers had initially resisted including the capability to access unlicensed spectrum in their phones, they have now wholeheartedly embraced the use of unlicensed as a means of handling increasing demand for data traffic. In perhaps the ultimate culmination of this trend, AT&T has announced it will build a WiFi hotspot in New York City's Times Square expressly for its subscribers to take data traffic off of its overburdened licensed network.

While CMRS providers would obviously prefer more licensed spectrum, they appear increasingly willing to entertain other options to supplement existing systems – including leasing access to spectrum. When combined with the comments of industrial users and wireless ISPs (WISPs) for access to spectrum protected from interference, the case for market demand would seem to be adequately proven.

Federal secondary markets provide adequate spectrum to raise revenue. Would this increasing demand for private spectrum translate into demand for federal spectrum leases, particularly given the fragmented and uncertain nature of federal use? The database system permitting opportunistic use of federal spectrum alleviates many of the concerns that spectrum leasing is impractical, or would fail to attract sufficient interest because of the inability to guarantee access to sufficient spectrum.

The critical aspect of our proposal is that it moves from the current model used in the commercial sector in which individual licensees make spectrum available in specific bands to a model that makes all unused "white space" available all the time. The range of federal spectrum, from 30 MHz to 300 GHz, covers a great deal of spectrum capacity. As spectrum analyzer tests have shown time and again, the vast majority of this capacity remains unused at any given moment. Because the proposed system allows devices to maintain capacity by jumping from band to band as actual federal spectrum use shifts, the system provides adequate reliability for commercial use. While some users will undoubtedly prefer other alternatives, a federal secondary market can prove quite profitable serving only a portion of the market for spectrum access, given its projected exponential growth.

[18] http://www.goinglte.com/t-mobile-exploring-wholesale-deal-with-harbinger-1166/

Proponents of auctions question whether secondary market revenue could match revenue obtainable through direct auctions. But this is a false comparison. Nothing in the proposed system prevents federal policymakers from identifying spectrum for auction and removing auctioned frequencies from the database. Again, because users would purchase capacity across a vast range of frequency bands, the removal of certain channels would not prove disruptive to existing secondary market users. While one would expect that the price paid in federal secondary markets would rise as more spectrum is removed from availability – whether by reallocation by auction, increased federal use, or allocation to free unlicensed service. From the perspective of maximizing federal revenue, such an outcome would be a win-win.

We recognize that both the Office of Management and Budget and the Congressional Budget Office would need to develop methods to estimate potential secondary market revenue, both to offset the cost of implementing the proposal and as part of calculating likely impact on the national debt. To begin this discussion, we have included an economic analysis for a hypothetical auction of spectrum in bands similar to those already auctioned for mobile and fixed wireless broadband use as against ten years of spectrum leasing revenue (see: "Technical Appendix"). Using accepted tools of estimating spectrum auction revenue, we determine that it is possible for the federal government to make ***more*** money over a ten-year period through leasing spectrum than through auctioning spectrum.

In the analysis, we recognize the preliminary nature of these findings. We do not claim that this proves that leasing will *always* be superior for raising revenue than traditional auctions. The study also assumes the standard leasing model rather than the dynamic model proposed here. At the same time, we also note that spectrum leasing, either using traditional models or the dynamic model proposed here, creates certain savings to bidders and federal users not reflected in most budget estimates. For example, no one has calculated the opportunity cost to the federal government from the lack of spectrum for necessary operations in the future, whereas such a cost is entirely avoided through leasing spectrum. Leasing spectrum also avoids the disruption of migrating federal users. This would not only save costs for both licensees and federal users, it would dramatically shorten the time between allocation and productive non-federal use. We anticipate that future studies will more clearly define the advantages of federal spectrum leasing, particularly dynamic leasing as proposed here.

Leasing would promote other federal objectives as well as revenue generation. Revenue generation is not the only federal policy. Even if leasing would generate less revenue than auctioning, the ability of leasing to advance other federal policy goals provides further justification for implementing a system of federal secondary markets. In particular, the ability of the proposed secondary market system to address spectrum demand, encourage innovative new uses of spectrum, advance spectrum technology – particularly the use of cognitive radio – and enhance competition in wireless markets weighs heavily in favor of adopting a secondary market system along the lines proposed here.

As supporters of enhanced access to unlicensed spectrum have observed, the flexibility and availability of unlicensed spectrum allows for innovation and competitive access in a completely different manner from that derived from licensed spectrum. The increasing cost of winning spectrum licenses – particularly in the most desirable markets – ensures that only the best capitalized market participants can hope to win desirable licenses. Even bidding credits for small businesses can only do so much to offset this economic reality. Furthermore, since a

license winner must pay the balance of the winning bid in a lump sum before receiving the license, successful bidders will have a strong incentive to maximize immediate financial return.

While supporters of auctions believe the incentive to maximize profit ensures that bidders will put spectrum to its "highest best use," many industry stakeholders and non-commercial users argue that this dynamic inherently forecloses the development of non-commercial networks, and prevents the development of networks and technology with significant social utility. The development of complementary networks and technologies using unlicensed spectrum supports the view – now embraced by licensed users as well – that ensuring easy access to spectrum by means other than auctions plays an important role in the wireless ecosystem.

At the same time, however, unlicensed access lacks many of the advantages of licensed spectrum. The lower power levels permitted inhibit the ability to create unlicensed networks that cover significant geographic areas. Many commercial stakeholders have complained that the lack of interference protection for unlicensed access makes it unsuitable for certain applications, and unreliable for the provision of commercial services. Some have also expressed concern that the open nature of unlicensed spectrum makes it particularly vulnerable to overcrowding. While the often forecast "tragedy of the commons" has not emerged, it certainly the case that the limitations of unlicensed access limit innovation in the space in the same way that limitations on licensed spectrum limit innovation in the licensed space.

Federal secondary markets would combine many of the advantages of licensed spectrum and unlicensed spectrum. Leased spectrum would enjoy interference protection (accept against federal users) similar to licensed spectrum distributed by auction. At the same time, the availability of significant spectrum capacity in real-time should keep prices affordable for most stakeholders. The widespread availability of spectrum through "smart radios" would also stimulate the development of this technology, a long-standing federal goal.

While it appears at first glance that leased federal spectrum would not provide a basis for competing retail services, this spectrum would play an important role in facilitating competition by providing spectrum-constrained providers with access for backhaul and other purposes. This would allow these providers to use more of their licensed capacity for the direct provision of services, and provide alternatives to leasing spectrum from commercial rivals.

Secondary markets as part of a sustainable spectrum policy. Inclusion of federal secondary markets as a means of addressing spectrum access needs does not displace either exclusive licensing or unlicensed access. Rather, this additional tool provides a way to further federal policy, raise federal revenue, and relieve spectrum constraints on numerous stakeholders – especially those outside the CMRS industry.

V. CONCLUSION

Distributing exclusive licenses by auctioning built the modern cellular mobile industry in the 1990s. Enhanced access to unlicensed spectrum made the "WiFi revolution" possible in the 2000s. Though these allocation systems have proven complimentary in the real world, public policy debates remain gridlocked in an artificial choice between them. Worse, neither can adequately address the skyrocketing demand for wireless capacity from commercial, non-commercial, and government users.

Since 2004, secondary market transactions have emerged as an important way to address rising demand for wireless capacity. Federal policy must move past the traditional models, supported by traditional excuses and perspectives that have left federal spectrum management paralyzed by a false dichotomy between auctions and unlicensed access. The rise of commercial secondary markets and the availability of modern wireless technology could pave the way for another revolution in allocation, with the capacity to create a sustainable spectrum policy for the 21st Century.

TECHNICAL APPENDIX:

Estimation of Potential Revenue Accruing to the Treasury by Leasing of Hypothetically-Cleared Spectrum in the 2025-2110 and 2200-2290 Bands on the Secondary Market

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Introduction

This paper seeks to test whether the federal government would benefit from an ability to lease spectrum via a secondary market system similar to that created by the Federal Communications Commission (FCC) for FCC licensees in 2003.[19] The paper assumes an "ideal case" of 45 MHz cleared on paired bands, proximate enough to bands recently auctioned so as to permit estimation. The 2025-2110 MHz band, located and 2200-2290 MHz. By employing a regression analysis based on auction revenues in comparable bands data available from the approximately five years of secondary market leasing activity since the FCC's *Secondary Markets Order*, the paper concludes that the federal government would realize greater revenue from leasing spectrum access over time rather than auctioning the spectrum in a standard "big bang" auction.

The authors do not suggest that this analysis proves definitively that the federal government would always realize greater revenue from leasing than from auctions. Nor do the authors suggest that the determination of whether use of auctions, secondary markets, or opportunistic sharing with no cost for access better serve the competing goals of the Communications Act should rest on a revenue determination. Rather, the authors intend this paper to serve as a starting point for a serious examination of the role federal spectrum secondary markets could play in enhancing spectrum access. Because federal law,[20] as well as practical political considerations in a time of federal deficits, requires consideration of how management of federal spectrum will enhance federal revenue, the authors constructed this "ideal case" comparison to provide a baseline for consideration along the lines of federal revenue enhancement.

The results of the analysis illustrate that federal secondary market flexibility could provide significant enhancement to federal revenue and could serve as a valuable compliment to secondary market transfers via auctions. The FCC and NTIA should therefore explore whether it would advance the goals of

[19] *See Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, 18 FCC Rcd 20604 (2003).
[20] *See* 47 U.S.C. §922(1).

federal policy to create a regime for leasing federal spectrum capacity similar to that created by the FCC for FCC licensees.

Background

Although Congress has prohibited licensees from "owning" spectrum since the Federal Radio Act of 1927, the FCC has generally allowed licensees to make spectrum available via a narrow class of permissible secondary market mechanisms. Notably, the FCC permitted parties transferring spectrum licenses, subject to FCC approval under Section 310(d), to receive compensation for transfers that clearly included the value of license despite the legal prohibition on "selling" FCC licenses. Over time, the FCC permitted more explicit experiments in secondary market mechanisms by allowing some services to explicitly lease capacity for various purposes.[21] Finally, in 2003, as part of a general effort to increase spectrum access through reliance on market mechanisms, the FCC officially sanctioned secondary market transactions whereby licensees could, subject to their service obligations, lease spectrum.

Under the current regime, licensees enjoy considerable flexibility in the leasing arrangements into which they may enter. Indeed, the Commission decisions permitting secondary market transaction regarded this flexibility as an important element in promoting more efficient spectrum access. Licensees may partition their license areas, choosing to lease capacity for only a portion of the geographic coverage of the license. Licensees may auction access in real-time and create a "private commons," may licenses capacity for a fixed term, or may make other arrangements based upon the commercial needs of the parties. The Commission requires only minimal reporting of these quasi-transfers to comply with statutory requirements, and primarily limits the arrangements of licensees by holding licensees ultimately responsible for complying with all limits and obligations imposed on the license. *i.e.*, A licensee is not

[21] For example, in the 1980s, the FCC permitted broadcasters to lease capacity in the vertical blanking interval (VBI) for datacasting. In the 1990s, the FCC actively encouraged non-commercial users of 2.5 GHz spectrum to lease capacity to commercial users in the hopes of creating a "wireless cable" service, and subsequently to create the commercial Broadband Radio Service.

excused because a license violation was committed by a lessor or because a lessor failed to provide adequate service.

Since 2003, the use of spectrum secondary markets for those leasing spectrum has grown considerably. In recent comments to the FCC, Spectrum Bridge, a broker of secondary market agreements between licensees and those seeking to lease spectrum capacity, reported that it "has successfully completed tens of millions of dollars of secondary market transactions in 2009 alone."[22] Clearly, many entities find it useful to lease spectrum rather than to buy and sell it. Reasons for this on the part of those seeking to lease rather than purchase may include the high cost of winning licenses at auction, a need for access to spectrum for a limited period of time, a need for narrowly tailored geographic access, and a desire to avoid broader service obligations. For those seeking to lease excess capacity, leasing offers a way of generating revenue and meeting service/build out requirements for spectrum acquired and held in reserve against future need. Indeed, as described below, leasing spectrum often permits licensees to earn a premium on the leased portion of the spectrum over what sale of equivalent capacity would earn.

Would Secondary Markets Work For Federal Spectrum?

The success of the FCC's secondary market regime raises the question of whether similar secondary market flexibility would provide a useful mechanism for enhancing access to spectrum currently dedicated to federal use on an exclusive or predominant basis. From an economic perspective, secondary market mechanisms for federal spectrum are equivalent to those that existed for FCC licensees prior to 2003. From time to time, the federal government will clear bands of spectrum for auction by the FCC. Although the Communications Act provides that this auction does not create an ownership interest in the license, the effect of the auction replicates the effect of a private "sale" of an FCC license subject to Section 310(d). Federal users must vacate the spectrum auctioned. Even if the federal government for some reason cancels the license obtained at auction, access to the spectrum does not revert back to the

[22] Comments of Spectrum Bridge, Inc., GN Docket Nos. 09-157, 09-51 (filed September 30, 2009).

previous federal users. From an economic standpoint, for all intents and purposes, the federal government can either "sell" spectrum via auction or hold it for its own use.

What would be the impact of permitting the federal government to lease spectrum capacity with the same flexibility currently enjoyed by FCC licensees? Given the lack of available literature on this question, this paper will begin with the simplest question – would permitting secondary market flexibility enhance federal revenue generation as compared to an auction?

Assumptions Underlying Hypothetical Test Case

The analysis will consider an ideal case of two bands allocated for federal use either on an exclusive basis or mixed basis with non-federal users. According to the federal spectrum report published by the NTIA in 2008, the 2025-2110 band is used by NOAA and NASA for satellite uplinks, and by non-federal users for mobile news gathering services. NOAA has exclusive use of the 2200-2290 MHz band for radar. The analysis will assume that the federal government will clear 45 MHz paired between the two bands. Although this arguably eliminates a significant advantage of leasing over auctions, the ability to avoid expensive relocation of users, it will also eliminate the need to develop complex models that account for variable conditions within the band designed to avoid interference with existing federal users. Further, as explained below, assuming clearance of the band will facilitate direct comparison with the AWS-1 auction, which involved cleared, paired federal spectrum with similar characteristics.

Estimation of Potential Auction Revenues

The first step toward evaluating revenues accruing to trading spectrum on the secondary market is to establish the potential level of revenue accruing to that spectrum from clearance at auction. For purposes of exemplification, we assume that the two bands we have selected -- 2025-2110 and 2200-2290 – can be cleared in such a way that half the bandwidth can be leased to non-NOAA uses by FCC spectrum auction. This would result in 42.5 MHz and 45 MHz, respectively, being available for national licensing and auction. The optimal geographical units in which to license this spectrum is an empirical question

which we shall address shortly. Before that issue can be resolved we must attempt to answer whether this bandwidth share more vital characteristics with the 2.5 GHz BRS spectrum to which it is adjacent or to the potential AWS-2 spectrum to which it is also adjacent, for this will determine the comparanda on which evaluation of auction revenues will depend. It is likely that either the market will evaluate this spectrum in the same way it has evaluated spectrum in Auctions 6 and 86, which have allocated BRS spectrum, or the market will evaluate it in roughly the same way it has evaluated AWS-1 spectrum in Auction 66.[23] It is not, however, necessary to resolve this quandary by postulation. It is possible to create a dataset based on all three auctions – 6, 66, and 86 – which can be used for regression analysis and which will allow estimation of a range of estimates depending on whether the hypothesized revenue will be closer to that obtained in Auctions 6 and 86 or that in Auction 66.

The initial regression equation will take the form of:

$$\ln P_i = a + b_1 \ln POP + b_2 \ln MHz + b_3 \ln POP{*}\ln MHz + b_4\, BRS + b_5\, AUC86 + b_6\, EA +$$

$$b_7\, CMA + b_8\, REAG + e, \qquad (1)$$

where $\ln P_i$ is the natural logarithm of the clearing price of license *i*, ln*POP* is the natural logarithm of the population of the geographic unit of license *i*, ln*MHz* is the natural logarithm of MHz in which license *i* is denominated, ln*POP**ln*MHz* is the interaction effect of the natural logarithms of population and MHz, *BRS* is a dummy variable scored 1 if license *i* was at auction as a BRS license, 0 if an AWS license, *AUC86* is a dummy variable scored 1 if license *i* was auctioned in Auction 86, *EA* is a dummy variable scored 1 if the area in which license *i* was auctioned was an Economic Area,[24] *CMA* is a dummy variable scored 1 if the area in which license *i* was auctioned was a Cellular Market Area, *REAG* is a dummy

[23] Since the AWS-2 auction has not yet occurred, we have only AWS-1 data available. Use of this data will probably result in overestimation of revenues since financial markets were not nearly so constrained in 2006 as they are today.
[24] These are names for geographic coverage area of spectrum licenses set by the FCC. Economic Areas (EA) are somewhat larger than Cellular Market Areas (CMA) and Regional Economic Area Groups (REAG) are significantly larger than either EAs or CMAs. The units in which BRS licenses were auctioned are Basic Trading Areas; no dummy variable for this geographic coverage area was included because it would be collinear with *BRS*.

variable scored 1 if the area in which license *i* was auctioned was Regional Economic Area Grouping, and *e* is the disturbance term.

These independent variables were chosen for a variety of reasons. First, population of the geographic area of the license and MHz in which the license are denominated, as well as their interaction effect, have been established as key predictors of the price at which the license will clear. Second, *BRS* was chosen to test for differences between BRS and AWS prices. Third, *AUC86* was chosen to test whether the slight discount at which BRS licenses in Auction 86 cleared is statistically significant. Finally, *EA*, *CMA*, and *REAG* were included to test for differences in price based on geographic area of coverage of license.

The independent variables were regressed on the dependent variable with the results presented in table 1:[25]

Table 1. Regression Results

Variable	Estimated Coefficient	Standard Error	T-statistic	P-value
Intercept	-29.9355	1.3037	-22.9622	<0.0001
lnPOP	2.9616	0.0865	34.2585	<0.0001
lnMHz	8.4087	0.3687	22.8037	<0.0001
lnPOP * lnMHz	-0.5333	0.02512	-21.2151	<0.0001
BRS	-2.312	0.2843	-8.1325	<0.0001
EA	0.9386	0.1767	5.3126	<0.0001
CMA	0.9733	0.1959	4.9683	<0.0001

Variables *AUC86* and *REAG* were dropped from the equation because their coefficients

[25] Ordinary Least Squares (OLS) regression was used.

failed to meet the threshold for statistical significance. All the remaining coefficients were significant at $p < 0.0001$. The entire model was significant at $p < 0.0001$ (T-statistic = 971.0826) and the R^2 of the model was .8071. These results suggest that the model fits the data well and will be an effective estimator of potential auction revenue.

We first estimated revenues under the assumption that the market will evaluate this spectrum similarly to BRS spectrum. The predicted value of any license to be auctioned for 493 Basic Trading Areas was calculated as:

$$\ln P\hat{}_i = b\hat{}X\hat{}, \qquad (2)$$

where the caret "^" indicates a predicted value and X is a vector of regressors relevant to BRS-like spectrum. We assumed that the spectrum would be auctioned in two blocks in recognition of the two different bandwidths. Hence the predicted value of each block was

$$R_i^n \ln P\hat{}_I \qquad (3)$$

where *n* is 493. The two blocks were then summed for a final estimate of revenues under this assumption. The predicted revenue accruing from auctioning of 42.5 MHz and 45 MHz of 2025-2110 and 2200-2290, respectively, in 493 BTA units was $147,766,005.[26]

We next estimated revenues under the assumption that the market will evaluate this spectrum similarly to AWS-1 spectrum auctioned in EA units. The predicted value of any license to be auctioned for 173 Economic Areas[27] was calculated as:

$$\ln P\hat{}_i = b\hat{}X\hat{}, \qquad (2)$$

[26] This is likely to be an underestimate of revenue, since the BRS spectrum allocated in Auction 6 and 86 was partially encumbered by potential interference from previously allocated P35 BRS and EBS licenses. However those two auction represent the only opportunity for evaluation of the spectrum by a primary market and, thus, the only price comparanda. The P35 licenses were issue before the FCC initiated spectrum auctions.

[27] The EA and CMAs covering the Gulf of Mexico were excluded because there is no census data from which to calculate ln*POP*.

where the caret "^" indicates a predicted value and X is a vector of regressors relevant to AWS-1-like spectrum auctioned in EAs. We assumed that the spectrum would be auctioned in two blocks in recognition of the two different bandwidths. Hence the predicted value of each block was

$$R_i^n \ln P^\wedge_I \qquad (3)$$

where *n* is 173. The two blocks were then summed for a final estimate of revenues under this assumption. The predicted revenue accruing from auctioning of 42.5 MHz and 45 MHz of 2025-2110 and 2200-2290, respectively, in 173 EA units was $4,103,065,159.[28]

We finally estimated revenues under the assumption that the market will evaluate this spectrum similarly to AWS-1 spectrum auctioned in CMA units. The predicted value of any license to be auctioned for 733 Cellular Market Areas was calculated as:

$$\ln P^\wedge_i = b^\wedge X^\wedge, \qquad (2')$$

where the caret "^" indicates a predicted value and X is a vector of regressors relevant to AWS-1-like spectrum auctioned in CMAs. We assumed that the spectrum would be auctioned in two blocks in recognition of the two different bandwidths. Hence the predicted value of each block was

$$R_i^n \ln P^\wedge_I \qquad (3')$$

where *n* is 173. The two blocks were then summed for a final estimate of revenues under this assumption. The predicted revenue accruing from auctioning of 42.5 MHz and 45 MHz of 2025-2110 and 2200-2290, respectively, in 733 CMA units was $4,201,703,372.

[28] Both this and the following calculation are likely to be slight overestimates of actual revenues at auction, since AWS-1 spectrum was not encumbered by rigorous build-out requirements to prevent spectrum warehousing and since the latest 700 MHz auction it is unrealistic to assume that the FCC will not impose build-out conditions. Furthermore, it is unlikely that financial markets will be as robust a support to the capitalization of bidders in future spectrum auctions as they were for Auction 66. Both factors will tend to reduce price somewhat.

We must now examine the ways in which relevant spectrum – the spectrum at auction in Auctions 6 and 86 and in Auction 66 – is cleared in the secondary market at a premium or discount in relationship to its clearing price at auction, since that will help us evaluate the potential revenue from offering the hypothesized spectrum on the secondary market.

Secondary Market Transactions

Secondary market transactions occur in various venues, ranging from private negotiations between in-house or external counsel of the licensee and the leasee[29] to electronic auction-like facilities provided by firms like Spectrum Bridge's SpecEx subsidiary. While the FCC requires notification and approval of all secondary market transaction involving spectrum licenses, the FCC rarely disapproves such transactions. Unfortunately the FCC's rules do not require disclosure of the price at which the license cleared in the secondary market. However, it is frequently possible to ascertain that price through press coverage, press releases of the involved parties, and industry analyst studies.

What is likely the most lucrative secondary market transaction is the acquisition of spectrum in the 700 MHz band by ATT&T from Aloha Partners just prior to Auction 73 for $2.5 billion. Aloha Partners had paid $34,853,070 for rights to the spectrum in Auctions 44, 49, and 60. The price paid by AT&T represents a premium of 7072.97% over Aloha Partners' outlay to obtain the spectrum at auction. Such windfalls, however, are extremely rare and must be treated as anomalous cases.

Secondary markets are particularly efficient as a result of their being able to aggregate and disaggregate partitions of any particular license, making it possible for customers to lease exactly and only the amount of spectrum needed for the specific time period. Railroads have made particular use of this function of secondary markets to gain coverage of narrow bands of spectrum contiguous to railbeds. Large sporting events have also availed themselves of the secondary to obtain additional spectrum for short-duration occasions. Similarly construction companies are able to lease limited amounts of spectrum

[29] The vast majority of secondary market transactions are de facto lease transfers of spectrum licenses.

for the duration of the construction project and no longer. Secondary markets have also been used by major corporations like Clearwire to assemble national footprints in P35 BRS and EBS licenses in the 1.5 GHz band for its WiMax deployment. Secondary markets, thus, provide efficiencies and opportunities to tailor to client which primary markets like auction are simply incapable of realizing under current rules. In particular the revenue stream from secondary markets is dependent on use: clients pay only for what they use and the duration of the lease by which they use it; the warehousing of spectrum becomes a liability rather than an advantage under the rules under which they operate.

Estimation of Potential Secondary Market Revenues

It is necessary to compare the price of spectrum at auction to the price of similar spectrum at offer in a secondary market to determine the premium or discount which offering on a secondary market presents for potential leasors and leasees. The standard method for comparison of spectrum is the dollar/MHz/population standard under which the total net dollar amount fetched by the spectrum is divided by the number of MHz at offer and by the population covered by the spectrum. When there are many licenses at offer in an FCC auction, the most common standard measure is mean dollar/MHz/population and this standard will be used here.

BRS spectrum cleared in Auction 6 with a mean dollar/MHz/population of $0.0183. BRS spectrum cleared in Auction 86 with a mean dollar/MHz/population of $0.0192. Using data from new reports, press release by principals, industry analysts, and data provided by SpectrumBridge, Inc., it was possible to compile a dataset of the prices fetched by 675 BRS licenses which have been traded on secondary markets. The mean dollar/MHz/population obtained by those licenses on secondary markets in 2007-2009 was $0.1617, a premium of 783.61% over the mean dollar/MHz/population obtained in Auction 6 and a premium of 742.19% over the mean dollar/MHz/population obtained in Auction 86. Applying these premiums to projected auction revenues to be obtained from auction of the 2025-2110 and

2200-2290 bands, we arrive at a range of revenues of $1,096,700,818 to $1,157,904,105, depending on which premium most closely models the premium for leasing of the 2025-2110 and 2200-2290 bands.[30]

AWS-1 spectrum cleared Auction 66 at a mean dollar/MHz/population of $0.1852. Trading of AWS-1 spectrum has been far less brisk than BRS spectrum, partly because so much of it remains warehoused by the major bidders as they analyze how to integrate the spectrum into their existing systems. However, a database of 39 licenses which have been leased on secondary markets and the prices which they have fetched has been assembled from new reports, press release by principals, industry analysts, and data provided by SpectrumBridge, Inc. The mean dollar/MHz/population at which this AWS-1 spectrum has cleared on secondary markets is $0.5683. This represents a 206.86% premium over price cleared at auction. Applying these premiums to projected auction revenues to be obtained from auction of the 2025-2110 and 2200-2290 bands, we arrive at a range of revenues of $8,487,600,588 to $8,691,643,595, depending on whether the 2025-2110 and 2200-2290 bands are allocated in EA or CMA units.[31]

Conclusion

It is apparent that the hypothesized leasing of cleared spectrum in the 2025-2110 and 2200-2290 bands would be more lucrative if traded on the secondary market rather than by traditional FCC spectrum auction. Depending on how the market evaluates that spectrum, i.e., whether the market regards the appropriate comparandum of this spectrum as being the BRS 2.5 GHz band or the AWS-1 spectrum, and depending on the geographic aggregations in which the spectrum is offered, projected revenues from leasing of this spectrum on the secondary market range from $1,096,700,818 to $8,691,643,595. These are significantly higher than the projected revenues from FCC auction of the same spectrum, which is in

[30] It is probable that these estimates slightly overestimate revenues since the premiums accruing to BRS spectrum on the secondary during the period in question were somewhat inflated by Clearwire's use of the secondary market to obtain national footprint for its WiMax deployment.

[31] The relatively small n of AWS-1 licenses which have been traded on secondary markets makes these estimates less reliable than the estimates based on the market evaluating the 2025-2110 and 2200-2290 bands as more similar to the BRS spectrum.

the range of $147,766,005 to $4,201,703,372, depending, again on market evaluation and geographic aggregation.