THE HAMILTON PROJECT

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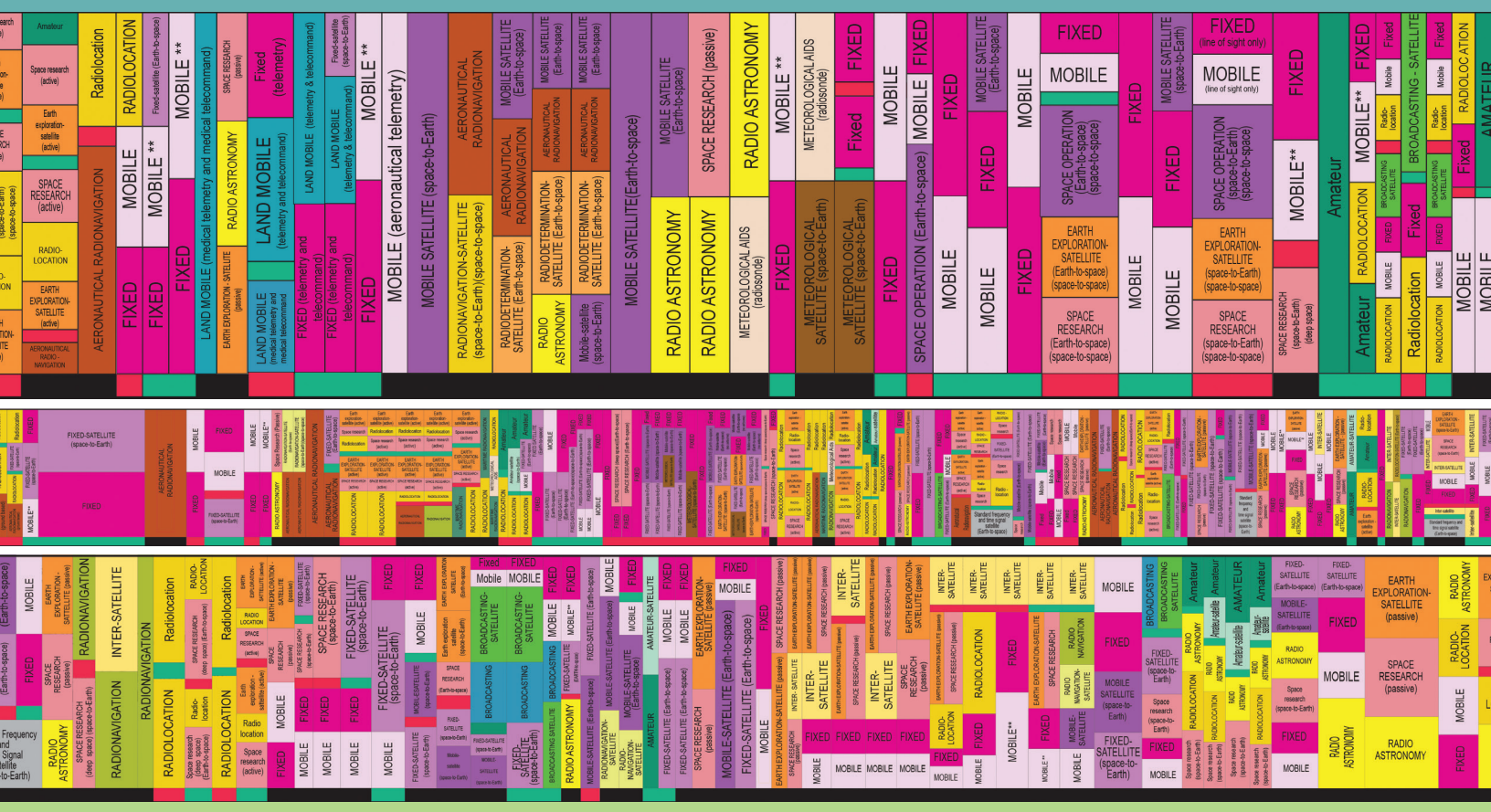
Unlocking Spectrum Value through Improved Allocation, Assignment, and Adjudication of Spectrum Rights

J. Pierre de Vries and Philip J. Weiser



MISSION STATEMENT

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth.

We believe that today's increasingly competitive global economy demands public policy ideas commensurate with the challenges of the 21st Century. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments.

Our strategy calls for combining public investment, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine — to introduce new and effective policy options into the national debate.

The Project is named after Alexander Hamilton, the nation's first Treasury Secretary, who laid the foundation for the modern American economy. Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that "prudent aids and encouragements on the part of government" are necessary to enhance and guide market forces. The guiding principles of the Project remain consistent with these views.

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Cover art adapted from "United States Frequency Allocations: The Radio Spectrum" (National Telecommunications & Information Administration, U.S. Department of Commerce, Washington, DC, 2011). Used with permission.

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NOTE: This discussion paper is a proposal from the authors. As emphasized in The Hamilton Project's original strategy paper, the Project was designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. The authors are invited to express their own ideas in discussion papers, whether or not the Project's staff or advisory council agrees with the specific proposals. This discussion paper is offered in that spirit.

BROOKINGS

Abstract

Technological developments have continued to increase the importance of radio spectrum, with citizens, companies, and government users increasing their use of wireless-enabled services of all kinds, from smartphone apps to satellite navigation. Since technology places limits on the coexistence of multiple radio systems, usage rights must be allocated among various competing uses. Currently, the management of the wireless spectrum in the United States (and in many other countries) is heavily constrained by government regulation. That makes it difficult for spectrum players—whether they are wireless service providers, citizens using unlicensed devices, or government users—to reach mutually agreeable, efficiency-enhancing agreements through direct negotiation with one another.

This Hamilton Project discussion paper describes the importance of moving toward a more economically efficient system for managing the use of wireless spectrum, and proposes concrete policy steps to move us closer to such a system. In particular, it sets forth three pillars of a reformed policy regime: (1) reduce ambiguity about the responsibilities of receivers to tolerate interference by defining harm claim thresholds that state the signal levels that must be exceeded before one operator can claim harmful interference by another, (2) reduce the drawbacks of excessive band fragmentation by introducing band agents that could represent large groups of licensees in negotiating changes in operating rights with neighbors, and (3) move adjudication from the current ad hoc and politically charged process to a more fact-based procedure that can resolve spectrum-related disputes in a timely fashion using judges with expertise in spectrum policy, either in the FCC and/or in a newly created Court of Spectrum Claims.

All three proposals reform the legacy spectrum policy framework by empowering individual spectrum licensees to develop win-win solutions without having to invoke time-consuming regulatory processes. Taken together, these reforms promise to move more spectrum management from a model more closely controlled by regulators to one authorizing end users to make more-flexible, win-win uses of spectrum. Based on our rough estimates, we conclude that these reforms could result in a total of a $10 billion per year in additional consumer surplus.

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Chapter 1: Introduction

The operation of wireless devices has become one of our nation's most valuable forms of economic activity. The wide range of devices using radio frequencies—also commonly referred to as wireless spectrum, or simply "spectrum"—includes cell phones, Wi-Fi networks, GPS devices, terrestrial and satellite TV, air traffic control systems, and even garage door openers. Because there are technological limits on the ability of multiple radio systems to coexist, usage rights must therefore be managed among various uses, industries, and competing interests. At present, the United States' spectrum policy framework largely constrains how wireless devices can be used. This discussion paper addresses the challenge of reforming our legacy policy framework and moving toward a more economically efficient use of wireless spectrum, proposing a set of policy steps to do just that.[1]

The wireless spectrum is separated into frequency bands. A receiving system in one band can tolerate a certain amount of wireless energy transmitted in neighboring bands before the quality of its service is degraded by a neighbor's "interference." The degree of interference that can be tolerated by any given system is also influenced by the characteristics of its own receiving and transmitting equipment. These considerations constantly change as technology and business models evolve. As with any other limited resource, more-efficient use of spectrum rights can lead to economic and social welfare gains.

Technological developments have underlined the importance of spectrum. Between 2009 and 2012, annual investments in U.S. wireless networks rose more than 40 percent—from $21 billion to $30 billion, according to a White House (2013) report—and will likely continue to rise in the future. The U.S. Department of Defense (DoD), moreover, is forecasting exponential growth in its spectrum requirements, with data use forecasted to grow roughly six times between 2000 and 2020 (DoD 2013). Given the importance of all these technologies, maximizing the efficient use of spectrum is a critical policy goal.

Over the past few decades, policymakers have sought to expand wireless services by providing access to frequencies that had previously been controlled by government or private users and could be transitioned relatively easily to more economically efficient uses. But there are few remaining opportunities for easily clearing additional spectrum. Today's great spectrum policy challenge is thus to maximize the value that can be derived from bands already in use. This challenge in turn requires a new framework for the decentralized management of the wireless spectrum.

The Federal Communications Commission (FCC), the independent federal agency responsible for regulating spectrum not used by the federal government, has already started to move away from its legacy command-and-control model of regulation, which greatly restricts how users can operate wireless services. As an alternative model, the FCC has begun to embrace approaches that offer more flexibility by approximating property rights in some cases, and allowing spectrum use by all comers using approved devices (i.e., leaving spectrum as a "commons") in others. There is, however, an important frontier that neither the FCC nor the National Telecommunications & Information Administration (NTIA), the entity managing federal spectrum, has fully explored: how to manage and adjudicate rights in wireless spectrum so that large bands of spectrum are not left underused. As we explain later in this discussion paper, the primary reason for such inefficiencies is a lack of clarity concerning interference prevention between neighboring spectrum users and an inadequate system for allowing trades and resolving disputes between users. The result is that economically efficient spectrum deals are not completed.

The recent case of the company LightSquared serves as an example of the issues that our proposed reforms attempt to address. LightSquared filed for bankruptcy in 2012 following the FCC's ruling that the company would not be allowed to deploy the terrestrial mobile network it had planned in the band adjacent to the one used for GPS operations. If this network had been deployed, its proponents argued, it would have created $120 billion in consumer value (Bazelon 2011). Opponents claimed that it would have cost the aviation community at least $70 billion (Federal Aviation Administration [FAA] 2011). The dispute boiled down to the implications for LightSquared of rules developed almost a decade earlier, and the rights of the myriad GPS users to protection from harmful interference from transmissions in neighboring bands. As the case unfolded, it underscored the challenges LightSquared faced in reaching any accommodation with the many and various

interests in the GPS band. It also underscored the difficulty of overcoming the unpredictability of the U.S. regulatory process for deciding harmful interference claims.

To meet today's spectrum policy challenges (discussed in detail in sections II and III), including dealing with conflicts like that between LightSquared and the GPS industry, this discussion paper outlines three policy reforms that would form the pillars of a new framework for spectrum policy. These reforms would:

1. Reduce the ambiguity about the responsibilities of receivers to tolerate interference by *defining harm claim thresholds*, which would govern what in-band and out-of-band interfering signal levels must be exceeded before a system can claim that it is experiencing harmful interference (subsection IV.A);

2. Overcome the drawbacks of excessive band fragmentation by *introducing band agents*, entities that could represent large groups of licensees in negotiating changes in operating rights with neighbors (subsection IV.B); and

3. *Transform adjudication* from the current ad hoc and politically charged process to a more fact-based procedure that could resolve spectrum-related disputes in a timely fashion using judges with expertise in spectrum policy, either in the FCC and/or in a newly created Court of Spectrum Claims (subsection IV.C).

All three recommended reforms are based on a recognition that today's regulatory regime makes it difficult for spectrum players to reach mutually agreeable, efficiency-enhancing agreements through direct negotiation with one another. Moreover, all three aim to decentralize spectrum management by allowing players to find productive arrangements without government regulators as gatekeepers. Taken together, these reforms promise to move spectrum management from central regulatory control to greater empowerment of end users, enabling more-flexible, win-win uses of spectrum and providing economic benefits of a roughly estimated $10 billion per year in additional consumer surplus (section V).

Chapter 2: Background

As wireless technologies have proliferated over the past several decades, the demand for access to spectrum has increased markedly. During that period, however, regulators have not fundamentally questioned whether there are now more-efficient strategies for overseeing spectrum and managing interference issues. In particular, regulators have often failed to act on the possibility that the benefit from increasing the allowed transmitted signal strength (leading to faster data transfers, for example) is greater than the adverse impact of the increased signal strength on the party experiencing interference.

A. KEY PLAYERS IN THE SPECTRUM LANDSCAPE

Understanding the status quo of spectrum policy requires understanding the key players involved. The FCC and the NTIA in the U.S. Department of Commerce are the government bodies directly involved in the regulation of spectrum. The FCC regulates the use of wireless spectrum by private firms, individuals, and by nonfederal public agencies. The NTIA oversees the multifarious federal government uses, including military radar systems, weather observation, and aviation, to name a few. In many cases, such as satellite services and aviation, oversight is shared between the FCC and the NTIA. Congress oversees the operations of the NTIA and the FCC, and plays an active role in shaping the spectrum rights landscape.

Because there are so many different services that use spectrum, there are many different actors with stakes in how spectrum rights are managed. Large telecommunications companies like AT&T and Verizon are prominent holders of rights to the "licensed" portion of the wireless spectrum. Other notable licensees include broadcasters, satellite network operators, point-to-point microwave services, and amateur radio operators. Players in the "unlicensed" portions of the wireless system, where operation is controlled by equipment regulation rather than by licenses, are more diverse, and include technology companies like Google and Microsoft, manufacturers like Cisco and Qualcomm, wireless internet service providers, and public interest organizations. More recently, the cable industry has become an important stakeholder in unlicensed allocations; Comcast, for example, has deployed nearly 350,000 Wi-Fi access points (Nagel 2013).

Because there are so many different services that use spectrum, there are many different actors with stakes in how spectrum rights are managed.

B. MANAGING INTERFERENCE

The more wireless systems can operate concurrently, the greater the value of spectrum use. Because two radio systems that operate at the same time, place, and frequency—in other words, that "use the same spectrum"—tend to degrade each other's performance, government regulators have long overseen radio operations. Traditionally, they have used command-and-control regulation to closely prescribe how radios could be used.

Since radio systems can degrade each other's performance, "interference" is a critical concept in spectrum policy (see box 1). The amount of service degradation a receiver experiences is a combination of the strength of the unwanted signals delivered by the adjacent service, and the receiver's ability to pick out its desired signal from the surrounding unwanted signals. The responsibility for harmful interference is therefore shared between transmitters and receivers.

BOX 1.

Interference

Interference is defined in the FCC Rules as "the effect of unwanted [radio] energy . . . upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy" (FCC Not dated [b], 47 Code of Federal Regulations [CFR] § 2.1). Such effects are unavoidable; systems are expected to be designed to tolerate interference unless it rises to the level of "harmful interference." For its part, the FCC defines harmful interference as, "interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations" (FCC Not dated [b], 47 CFR § 2.1).

It is important to appreciate that the Communications Act of 1934 sets out the goal of maximizing the value of radio operations—not minimizing interference to any particular spectrum licensee. The impression that the regulatory goal is to minimize mere interference per se may have arisen due to a now-superseded statute of the Radio Act of 1912 that stated that private and commercial stations would be subject to regulations "for the purpose of preventing or minimizing interference with communication between stations in which such apparatus is operated" (Radio Act of 1912, section 4). Under the 1934 Act, the FCC must prevent interference where it deems it necessary, permitting it to "provide flexibility of use [as long as] such use would not result in *harmful* interference among users" (Communications Act of 1934, section 47.303; emphasis added). The statutory imperative is thus not to minimize any interference, but rather to prevent harmful interference. While the definition of harmful interference is broad, it is by definition considerably more stringent than mere interference.

Since the strength of radio signals generally decreases with distance, two wireless systems can operate simultaneously at the same frequencies if they are well separated geographically. This leads to the issuance of licenses based on geographical operating assignments. In practice, these licenses can be organized either by transmitter location or, as they increasingly have been, by designating geographic operating areas. The regulator seeks to limit the effect of one operation on another by imposing operating rules that limit, for example, the transmit power and the amount of signal power that an operator may deliver outside its assigned geographic area and frequencies.

Two wireless systems can operate simultaneously in the same area by using different frequencies. Each transmitter broadcasts on its designated frequencies, and their respective receivers tune to those frequencies, filtering out signals on other frequencies. If the filtering does not reject signals on other frequencies sufficiently well, the device may be unable to operate as designed. Interference can be mitigated by spacing out services in frequency or by using more-frequency-selective, and thus expensive, receivers. Now that spectrum is more crowded and the demand for it is increasing, however, spacing out services is increasingly ineffective. There have been numerous cases where poor receiver performance has precluded or delayed the introduction of valuable new services (NTIA 2003, section IV; FCC TAC Sharing Working Group 2011, appendix C). In many cases today, unlike in the past, the most cost-effective approach is to expect more from receivers by requiring better filters.

Given the reality that filters are imperfect, operation in one frequency band can degrade operations in an adjacent band. In economic terms, radio interference is a negative externality, not unlike pollution. Indeed, unwanted interference can be viewed as a kind of pollution to the licensee of a frequency band who must contend with unwanted interference. Interference inflicts, in other words, a cost on the licensee that it must mitigate or manage (whether by using filters or other methods to manage interference). As Nobel laureate Ronald Coase famously explained, all harm is reciprocal—e.g., one person's harm is another person's benefit, and vice versa (see box 2).

C. SPECTRUM MANAGEMENT PARADIGMS

Since the 1990s the FCC has begun to move away from a command-and-control model of regulation, seeking to provide individual operators with more discretion. Traditionally, regulators have specified not only which stations may operate in a given spectrum range, but also the services that spectrum operators should offer and the technology that they should use. For example, television stations are obligated to broadcast using a particular technology standard. Recently, the FCC has grown increasingly reluctant to specify the service to be offered or the relevant technology to be used.

Two alternative models are beginning to replace the legacy command-and-control model of regulation: (1) exclusive, tradable, and flexible use licenses assigned by auction (e.g., for mobile cellular services); and (2) open access or "unlicensed" regimes that allow unlicensed flexible use (e.g., Wi-Fi, Bluetooth, cordless phones, smart meters, and garage

BOX 2.

Command and Control, Contracts, and Coase

Ronald Coase is known as one of the founders of the Law and Economics movement and is a Nobel laureate, recognized for his work on property rights in "The Problem of Social Cost." This article, published in 1960, built on Coase's earlier work on spectrum policy in "The Federal Communications Commission" (1959). In both articles, Coase explained that, with established property rights and low transaction costs, parties can contract—through what is now called Coasian bargaining—to reach efficient outcomes (that is, win-win solutions that make both parties better off).

door openers). Proponents of each approach have spent considerable energy debating the relative merits of the two approaches despite the fact that they are being implemented side by side, and that both provide viable alternatives to the legacy command-and-control regime.

There are significant opportunities to reform the legacy command-and-control model of regulation. The framework for these opportunities was laid out in a classic article in 1959 on spectrum regulation by Nobel laureate and property rights pioneer Ronald Coase. In that article, Coase called for a move away from command-and-control regulation and toward a system where parties could negotiate between themselves.

Given the well-known frailties of regulatory processes, facilitating such "Coasian bargaining" should be a core policy goal. This transition away from the command-and-control model, however, has only just begun. For instance, only about 20 percent of the highly sought-after 400–3700 megahertz (MHz) band has so far been dedicated to either of these new regimes; the remaining 80 percent is still subject to command-and-control management, leaving plenty of room for more spectrum to be transitioned to either the licensed or unlicensed models of regulation.

Chapter 3: The Failings of Current Spectrum Regulation

The current system of spectrum regulation has three serious shortcomings. First, the FCC and the NTIA fail to define the rights and responsibilities of spectrum access with enough clarity to promote the most efficient coexistence of wireless systems by facilitating bargaining between neighboring spectrum users. Second, the high level of fragmentation among rights holders creates significant transaction costs and an increased likelihood of market failure that can prevent coordination that could enable the more-efficient and more-intensive use of spectrum. Third, the FCC's inability to resolve conflicts through effective adjudication leads to paralysis and lost opportunities. These flaws have a common theme: the current regulatory regime does not give spectrum operators the ability to reach mutually agreeable, efficiency-enhancing agreements through direct negotiation with one another. We will now discuss each concern in turn.

A. INSUFFICIENTLY DEFINED RIGHTS

Claims of harmful interference between systems are at the heart of disputes about whether a user's rights have been violated, or, alternatively, whether a user has lived up to its responsibilities to tolerate reasonable levels of interference.[2] The lack of clarity from the FCC and NTIA about the rights and responsibilities of radio operation constitutes perhaps a basic shortcoming of spectrum regulation today.

A key problem arises when a signal in a particular band interferes with the signal in an adjacent band operating at a similar frequency. Wireless systems in one band that cannot tolerate reasonable signal levels in an adjacent band and are nonetheless protected against interference by limits imposed in the adjacent band are reaping benefits (say, by using cheaper receivers) and imposing costs on operators in adjacent bands (say, through restricted transmit levels). This state of affairs prevents the addition of new wireless services that could foster innovation, improve public safety, and create jobs.

A failing of current spectrum policy is that it focuses on transmitters and fails to address the important role of receivers. Harmful interference has no meaning as a concept, however, outside the context of a specific receiving system. The ability of a radio system to tolerate interference depends not only on the design of the receiver, but also on the relative strength of desired and undesired signal transmissions; the received signal strength, in turn, depends not only on the power of the transmitted signal, but also on the distance between the transmitter and the receiver, and on intervening obstacles. Where the use of filters or other solutions can manage against interference effectively, it is important that policy provides the proper incentives for such solutions.

To return to Coase, consider the famous example from his 1959 article as to how neighbors (in that case, a doctor and a confectioner) can cooperate to manage interference concerns. In that case, the confectioner's loud equipment threatened to constitute a nuisance to the doctor. The critical point raised by Coase is that the relevant harm is reciprocal: avoiding disturbance to the doctor by silencing the confectioner causes harm to the confectioner's business, and allowing the confectioner to make noise disturbs the doctor. Similarly, radio systems with an inadequate ability to tolerate interference can harm the interests of neighboring transmitters—the converse of the conventional assumption that it is always transmitters that harm receivers. As Coase suggested in the case of the doctor and the confectioner, the ideal solution is to define the respective rights of the two parties—whether the doctor has the right to quiet or the confectioner has the right to make noise—so that the parties can find the optimal balance between themselves, allowing for any number of creative solutions (say, the doctor paying the confectioner for noise proofing or delineating operating hours).

To appreciate how spectrum policy can create perverse incentives rather than incentives for creative problem solving, consider its ill-fated initiative to grant new licenses to "low-power" FM stations for local broadcasts in underused parts of the spectrum (FCC 2003). The broadcasters responded to this initiative by suggesting that the relevant standard for judging interference was whether a single listener, owning the lowest-quality receiver on the market, faced *any* interference. The broadcasters' position prevailed, favoring the use of technologically backward equipment at the expense of more-dynamic and more-intensive use of spectrum. Unfortunately, the low-power FM case is not an anomaly and represents a widespread phenomenon of privileging legacy receiver technology over a more-intensive use of spectrum (De Vries 2009; De Vries and Sieh 2011).

The FCC's legacy regime, which ignores the role of receivers, handles interference issues by using the model outlined in the low-power FM case. As in that case, the FCC looks at interference on a case-by-case basis, examining how receivers are affected by signals in an adjacent band and asking what burden the neighbor is creating through its transmissions. Using this approach, the remedy is almost invariably for the neighbor to reduce its transmit power, move its transmitter farther away from the band boundary, or, in a few cases, for the neighbor to purchase additional filters for the receivers affected by its transmission system. Stated differently, the FCC traditionally views all transmitters as the cause of interference and all affected receivers as innocent "victims." Indeed, a 1987 FCC Report and Order stated, "[s]ub-standard receivers do not cause system interference" (FCC 1987, section 7.25).

The FCC's current regulatory regime is vague about the rights and responsibilities of spectrum operators regarding harmful interference. In particular, the relevant definitions (see box 1) are very general and require case-by-case interpretation, a time-consuming process that only well-heeled parties can afford (see Lazarus 2009; Weiser and Hatfield 2008b). In its decisions on spectrum rights, the FCC traditionally issues what might be called rulings "for this day only," declining to adopt any guidance or clarification as to what would constitute harmful interference in other cases. Since spectrum negotiations frequently hinge on responsibilities to mitigate interference, the lack of such guidance about what constitutes harmful interference prevents more-intensive and more-dynamic use of spectrum.

These problems are exacerbated by a lack of user-to-user negotiating authority. At present, there are cases where conflicts between existing neighbors could be agreed upon, but the FCC and NTIA are currently required to mediate and manage those conflicts, creating opportunities for rent-seeking, strategic delay of the relevant approvals, and other potential mischief. As there is no provision for direct negotiation between parties, the government's involvement always looms large. Under current rules, for example, the FCC must approve most changes to the defined set of rights through a notice-and-comment rule-making process, which, at a minimum, adds unnecessary delay to any spectrum-related transaction.[3]

B. FRAGMENTED SPECTRUM RIGHTS

A second challenge for spectrum regulation is to overcome the collective action problem that stems from band fragmentation. Fragmentation refers to the sharing of control of a band among a large number of operators, and sharing a band among multiple uses (known as "services" in spectrum parlance). Such fragmentation is not an accident and arises from decisions made during prior decades, when facilitating the flexible and intensive use of spectrum was not a core policy goal. One reason for the level of fragmentation is that the FCC has traditionally used small geographic area licenses in mobile spectrum license auctions to facilitate participation by smaller, regional operators. Another reason is that the FCC, assuming a world of fixed technologies, has combined a variety of different services in one band because it has deemed that they could coexist successfully. Fragmentation also arises from permitting unlicensed use, where, by definition, operations cannot be controlled by licensees since there are none. Finally, fragmentation can arise from ineffective control of assignments (e.g., the NTIA's weak oversight of the more than 240,000 frequency assignments to federal agencies and government departments, as documented in Government Accountability Office [GAO] 2011).

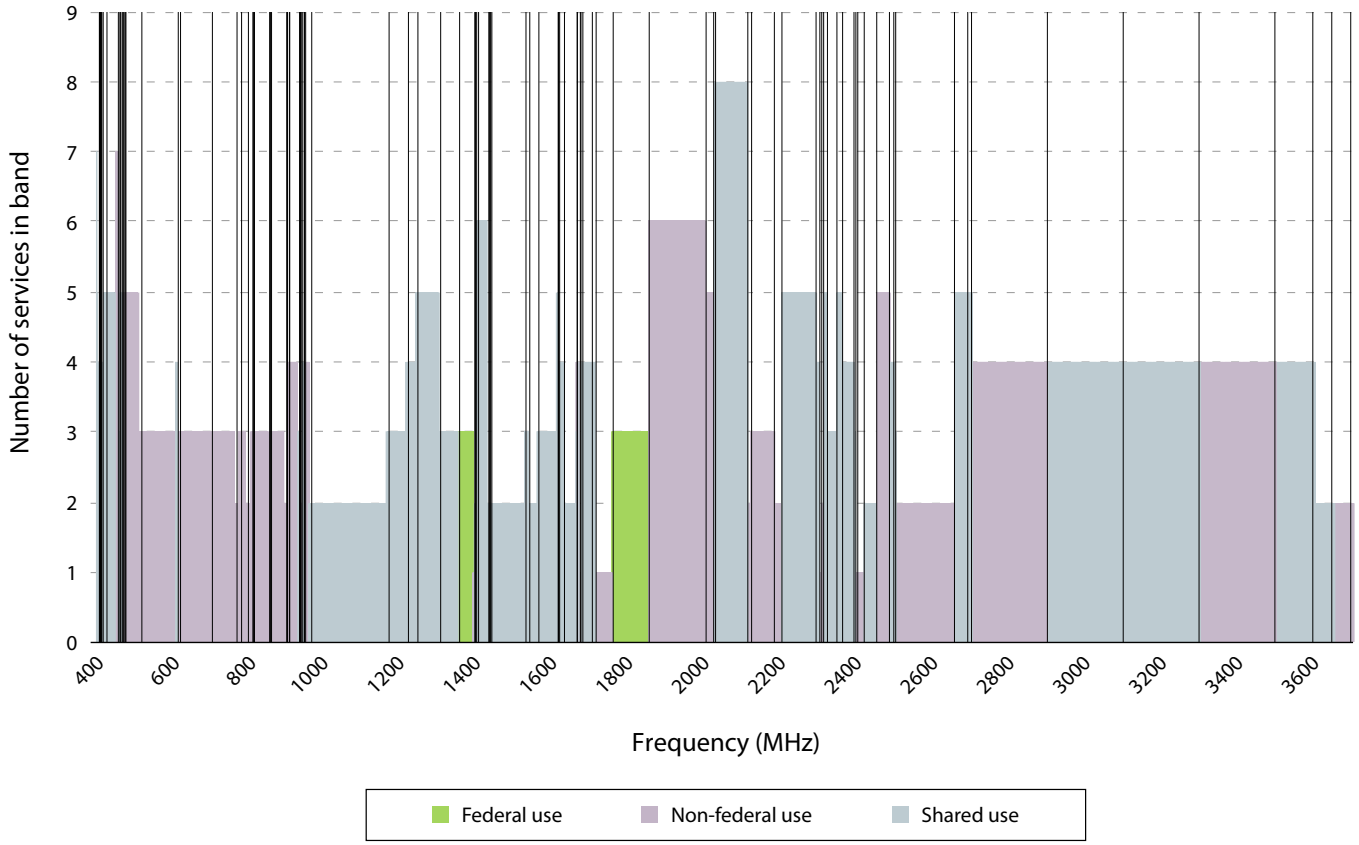
The FCC's current regulatory regime is vague about the rights and responsibilities of spectrum operators regarding harmful interference.

Figure 1 illustrates the degree of fragmentation in the 400–3700 MHz frequency range by plotting the number of service allocations in each band. One can see that most bands are shared by at least two services, and often are shared between federal and nonfederal uses. Many bands are shared among four or more services. Figure 2 charts the number of licenses per band, for bands where that information is available. Note that while there is wide variation in the license count, bands with more than a thousand licenses are quite common.

Fragmentation threatens efficient spectrum allocation because it makes private negotiations more difficult. That is, private

FIGURE 1.

Fragmentation of Bands, Measured by Number of Services



Source: FCC 2014b; authors' calculations.

Note: Vertical black lines represent band boundaries. Where the bands are very narrow, band boundaries pack into thick lines.

negotiations are likely to fail where many parties are involved, particularly if no structure for coordinating among them exists. As Coase makes clear, the opportunity for efficient bargaining outcomes can be frustrated in situations with high transaction costs or where property rights are not well-defined. The transaction costs concern explains why a government must use its eminent domain power to overcome the collective action costs and holdout risk that would ensue were it forced to negotiate with scores (or hundreds) of landowners individually to construct, say, an airport.

To illustrate how fragmented and difficult to manage interests can come into existence, consider the case of Nextel and public safety operators (see De Vries 2009, section 4.1 and references cited therein; FCC 2004). Not only were assignments given to various commercial, governmental, and public safety land mobile radio (LMR) users, but the licensees themselves were quite small, as licenses were assigned to individual municipal police and fire service providers and local commercial operators. Consequently, when interference issues between Nextel's cellular service and individual public safety (narrowband) LMR services arose, the FCC was forced to get involved and develop an extensive process to reallocate spectrum rights in order to manage this conflict. Stated differently, because the rights assigned to individual public safety agencies were so fragmented, the FCC needed to establish a nationwide process to resolve the matter, which was quite challenging, time-consuming, and costly.

The recent case of one prominent auction provides a clear reminder that fragmentation is not simply a function of the total number of licenses, and can be managed effectively if the parties are able to negotiate. In the 2006 Advanced Wireless Services (AWS-1) auction, 104 bidders won 1,087 licenses across the United States in various bands of spectrum. Despite the creation of 922 frequency blocks and six market areas as a result of that auction, ensuing negotiations in this band—used for commercial mobile operations—appear to have addressed any fragmentation concerns. In other words, despite the number of licenses and licensees, the impact of fragmentation in this case was low because there were relatively few boundaries between licenses where problems needed to be resolved. Notably, under

the rules set by the FCC, geographical license areas abutted only a few others, with at most two adjacent frequency blocks; the number of parties to each negotiation was small (unless there was a geographically large license in one block and many small licenses in the adjacent one). Furthermore, each block was controlled by a single licensee, reducing coordination problems. Consequently, even with a large number of distinct licenses, the structure of the bands made negotiation and transactions relatively easy to manage; there have been extensive secondary market transactions leading to better post-auction rationalization of the spectrum holdings, including deals between Verizon and T-Mobile, Verizon and a cable company consortium, and various smaller AT&T and Verizon deals to purchase AWS-1 spectrum licenses. The number of licenses and different uses alone does not determine whether fragmentation issues will arise.

C. INEFFICIENT ADJUDICATION

A third challenge in spectrum regulation concerns the inefficiency of the current adjudication regime. Invariably, conflicts in how spectrum is being used will emerge between neighbors. A system of adjudication is important as a means of resolving such conflicts, and as a means of providing a framework to encourage more-effective conflict settlement.

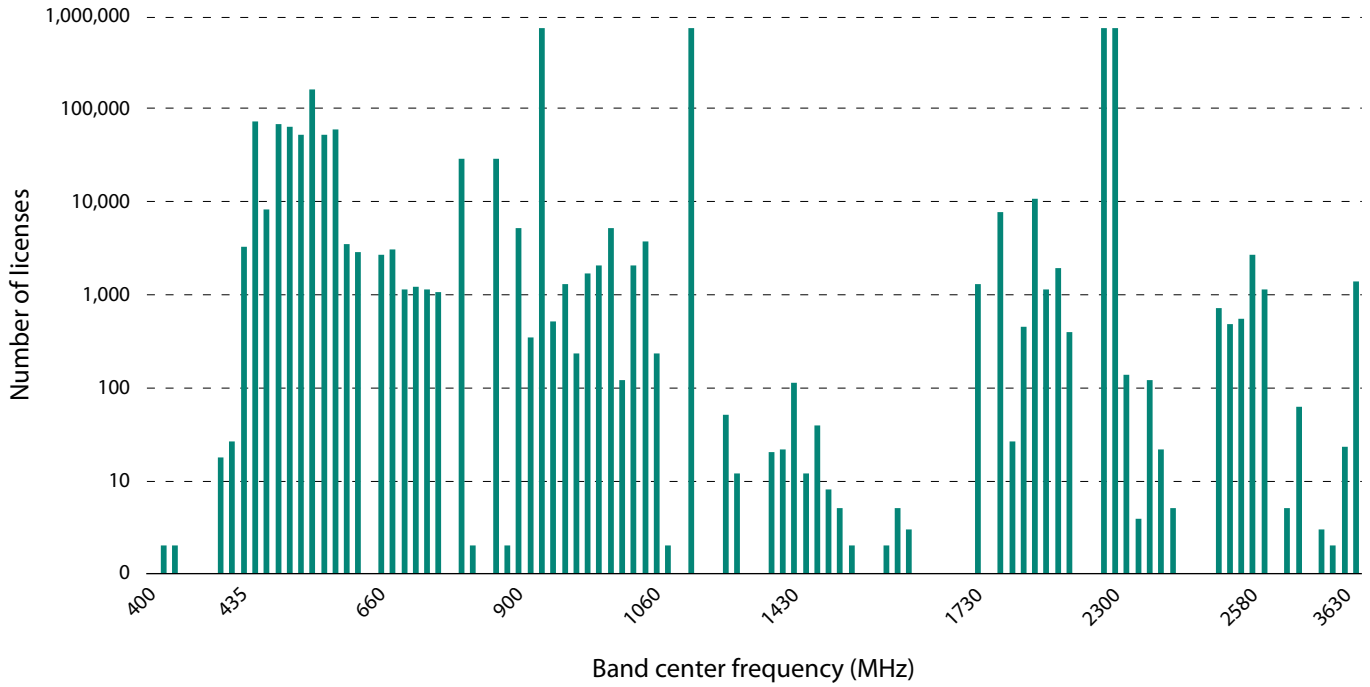
The NTIA, to the extent its processes are visible to the public, does not devote sufficient resources to conflict resolution, preferring to make such generous (and thus inefficient) assignments of exclusive frequencies and geographic areas to its clients that conflicts are precluded. To be sure, federal agencies coordinate among themselves to avoid intersystem interference where many of their services share a band, but since how such spectrum rights are managed is not visible, it is impossible to judge the efficiency of the resulting arrangements.

For its part, the FCC currently has little to no ability to resolve conflicts, as its adjudication process is unpredictable and ad hoc. In most cases, the FCC usually resorts to delay and politics or notice-and-comment rule making when adjudication would have been more appropriate and efficient. In summary, the current state of adjudication in spectrum disputes is at best inefficient.

To take two examples, consider the Comcast network management case and Sirius Satellite Radio and XM's violation of their Special Temporary Authorizations. In both cases, the FCC failed to use an adjudication process to settle high-profile disputes. Rather, as Weiser (2009) explains, the FCC styled the proceeding involving Comcast's network management processes as an adjudication even though it did

FIGURE 2.

Fragmentation of Bands, Measured by Number of Licenses



Source: FCC 2014b; authors' calculations.

Note: Each bar represents a single band, but is not representative of the bandwidth of the band. A bar is not drawn where a license count is not specified in the source data.

not use any judicial process: the actual proceeding mirrored the agency's rule-making processes and did not operate as a true adjudication. The proceeding also evoked the all-too-familiar complaints by dissenting commissioners that they were forced to vote on an Order without the benefit of sufficient time to evaluate its substance.

In the Sirius case, there were longstanding complaints that satellite radio providers were violating the terms of their licenses. Rather than conduct a vigorous enforcement proceeding, the FCC took action and entered into a consent decree with the two companies only once they were on the brink of receiving approval to merge with one another. The FCC's failure to treat seriously the longstanding complaints about Sirius's and XM's behavior is emblematic of the agency's lack of commitment to effective adjudication and enforcement. The agency rarely asks administrative law judges (ALJs), or other independent arbiters, such as independent judges, to find facts. In practice, the vast majority of enforcement decisions are determined by negotiations between the agency and the rule-breaking parties. As FCC Commissioner Tate (2005–2008) put it, Sirius Satellite Radio "failed to comply—knowingly and repeatedly—with the specifications for its FM modulators and the terms of its Special Temporary Authorizations . . . for more than five years" (Sirius Satellite Radio Inc. 2008). This conclusion, unfortunately, was not the result of an enforcement process: it came as a condition of Sirius's approval to merge with XM Radio.

The approach outlined above reflects the FCC's institutional priorities (Weiser 2009). The FCC employs only two ALJs and they rarely are given assignments to handle adjudicative proceedings. Indeed, when ALJs are given assignments, the FCC often maintains a high level of involvement and micromanagement of the proceeding, undermining the ALJs' authority. As for the Enforcement Bureau, its processes are often managed with a level of political oversight and a lack of commitment to neutral determination of complaints. Consequently, it is not empowered to act effectively on complaints and has failed, according to a 2008 GAO report, to either resolve many complaints or explain why no action was taken.

The reality of enforcement at the FCC, in the spectrum context and others, is that the agency rarely uses anything approaching true adjudication. As a formal matter, the FCC charges its Enforcement Bureau with investigating instances where parties are using radio frequencies that they are not authorized to use. But limits of the agency's capabilities, both in terms of personnel and equipment, mean that the agency is rarely successful in redressing such cases. Moreover, even as a formal matter the FCC's authority in this area is limited and its general practice is to confiscate the equipment. In short, the FCC has not developed the capacity to conduct the sort of adjudication handled by courts or even by many administrative agencies. This makes it no surprise that the agency fails to use any such system even for cases where it would seem to be the natural response.

Chapter 4: Toward a Reformed Spectrum Policy Framework

We propose three sets of reforms to address the challenges outlined in section III. We propose that the FCC and NTIA (1) define the rights provided to licensees more effectively (i.e., establish harm claim thresholds) and allow for the modification and transfer of such rights without delays created by regulation; (2) create a mechanism to address collective action problems that follow from overly fragmented spectrum rights (i.e., band agents); and (3) establish an adjudication venue that backstops negotiations and provides a forum for dispute resolution (including cases in which the U.S. government is a party). Implementing any one of these proposed reforms would improve spectrum management, but there is a powerful synergy between them and they reinforce one another in important ways. If implemented, they could unlock considerable social welfare value and, in the case of underused government spectrum, make it easier for it to be shared and/or auctioned at a benefit to the U.S. Treasury.

A. ENHANCING RIGHTS USING HARM CLAIM THRESHOLDS

We propose that the FCC establish harm claim thresholds—in-band and out-of-band interfering signals that must be exceeded before a system can claim that it is experiencing harmful interference—to address the issue of spectrum rights ambiguity, and the related issue of the modifiability of those rights. In defining operating rights in spectrum, the goal of the government is not to develop complete clarity on the nature of the relevant rights. Indeed, as Hazlett and Oh (2013) have argued eloquently, it is not possible or desirable to remove all ambiguity from the relevant rights to use spectrum. Rather, the challenge for policymakers is to capture the necessary complications in defining property rights in spectrum while keeping matters as simple as possible.

Our proposal calls on the FCC and NTIA to adopt a statement in a service's rules that defines the signal levels it needs to tolerate before it can bring a harmful interference claim.[4] This would establish a field strength profile due to neighbors' signals that is defined both inside and outside an assigned service's designated frequencies. Under a system of harm claim thresholds, the relevant threshold must be exceeded at more than a specified, small percentage of locations and times in a measurement area before the affected operator can bring a claim against the neighbor.

Under this model, manufacturers and operators would be allowed to determine for themselves whether and how to build receivers that can tolerate such interference, or even determine that they will choose to ignore these limits and risk adverse results in adjudication (see subsection IV.C). As such, harm claim thresholds do not mandate receiver performance standards.

Implementing any one of these proposed reforms would improve spectrum management, but there is a powerful synergy between them and they reinforce one another in important ways.

The harm claim threshold model is not one-size-fits-all. A frequency assignment's harm claim threshold can be customized to reflect the current and expected performance of systems in its assignment and in those next to it. Thus, different bands will have different harm claim thresholds.

Harm claim thresholds would also apply to interactions between government and private parties. This requires the establishment of a mechanism for reaching an appropriate model for interference limits that could enable other operators to share swaths of spectrum now controlled by the government. In return for agreeing to such sharing, the government would receive funds for agreeing to modified interference limits and authorizing new users of spectrum in blocks previously assigned to the government (President's Council of Advisors on Science and Technology [PCAST] 2012). Both the government agencies and the new users of spectrum would need, as a condition of agreeing to this sharing, the ability to bring an action to enforce those limits and protect their right to operate as agreed upon.

Benefits

Three features of a harm claim thresholds approach shape the benefits that can be derived from it. First, the model does not require that the FCC define the performance levels of individual receivers per se. Instead, it proposes that the FCC should stipulate that receivers must be expected to tolerate a certain degree of interference. Second, our model creates incentives for operators to upgrade their receivers or bargain with their neighbors to avoid the necessity of doing so. Finally, any given user who would like to use its spectrum more intensively and would be willing to purchase the right to create more noise for its neighbors is able to do so. Consequently, this framework enables more-sophisticated and more-efficient means of sharing spectrum use between different parties.

Harm claim thresholds allow markets to dictate the detailed solutions to problems of interference.

Harm claim thresholds allow markets to dictate the detailed solutions to problems of interference. By establishing harm claim thresholds rather than attempting to mandate receiver standards, our proposal delegates decisions about system design, including receiver performance, to manufacturers and operators. For example, they can invest in high-performance receivers that tolerate high levels of adjacent band noise even when their own received signals are weak. Alternatively, manufacturers and operators can deploy more basic receivers, but invest in increasing the level of their own received signals by deploying more transmitters. Finally, they may choose to use a system design that experiences some degradation even when interference is below the threshold; perhaps this degradation will be sufficiently rare as to be tolerable, or their business model is such that fluctuations in performance are acceptable.

In all events, the establishment of harm claim thresholds should facilitate bargaining between neighboring users, allowing wireless system operators to find and adjust the optimum level of mutual interference. In the wake of any such adjustments, the FCC would function as a recorder of spectrum interference levels, putting other parties on notice of the relevant changes rather than serving as a gatekeeper. In cases where a party did not agree to an adjustment and could claim an adverse impact, that party would have the right to bring an action against the purported interfering party.

Though the harm claim threshold approach has yet to be implemented, a recent experience suggests that it would be effective. A resolution that emerged organically from the negotiations that led to the compromise between AT&T and Sirius XM offers a powerful case for the harm claim threshold proposal. As detailed in a 2012 Order on Reconsideration (FCC 2012), the FCC established that operators in one band would be required to work with other operators in another band to address problems where ground power level targets exceeded stated levels (essentially, de facto harm claim thresholds) and harmful interference occurred in receivers. Earlier attempts by the FCC to encourage negotiation failed, seemingly because of a divergence of interests among half a dozen parties. The need for access to additional spectrum led AT&T to broker a deal with Sirius XM, and eventually to buy out license holders who were adversely affected by the compromise. While a compromise interference limit was eventually found, it would appear that resolution was complicated by the absence of an interference baseline, such as a preestablished harm claim threshold.

Implementation

Harm claim thresholds will need to be phased in and refined over time. The harm claim threshold values for an assignment can be chosen by a regulator to reflect the status quo and protect

incumbents. For example, if the receivers in an allocation are very susceptible to interfering signals in frequencies outside their band, the harm claim threshold can be set very low. In such a case, little or no operation will be permissible in the adjacent band without the consent of receivers, and incumbents will not be required to replace existing receivers.

If the regulator believes that better receiver performance is in the public interest but will not be achieved by market negotiation, it can give notice that harm claim thresholds will be increased in the future. The time period for compliance could be chosen to give incumbent operators sufficient time to upgrade their receivers. Conversely, if the status quo is that there is already strong signal operation in the adjacent band, the harm claim threshold for the new assignment could be set high enough that the incumbent in the adjacent band will not be deemed to be causing harm.

There may be cases where the initially assigned harm claim threshold is not economically efficient. For example, there might be net social gain if the threshold were increased, allowing increased transmit power and thus better service in the adjacent band. The FCC should allow parties to adjust the limit by negotiation among affected neighbors. If the FCC deems that there is no prospect of such negotiations being concluded successfully, it could put incumbents on notice that the harm claim threshold level will be increased stepwise over time.

Establishing harm claim thresholds requires additional care where receivers are not controlled by a license holder. This scenario applies to a number of services such as GPS, FM radio, and satellite weather receivers. One possible solution for cases where receivers are not coupled to a transmission license is to require that manufacturers self-certify that a receiver is fit for the purpose in its envisaged use. Such a model could ensure that such receivers operated successfully given the prescribed harm claim thresholds. Such self-certifications could function as an express warranty, and perhaps be enforced under a false advertising remedy. This could be done by individual companies, or collectively through an industry-certified seal of approval. To further enforce such a model, the FCC could also require the manufacturer to submit a testing protocol that allows for validation, as happens now in the European Union (European Parliament and Council 1999).

Unlike the imposition of mandatory receiver performance requirements, where there are doubts about the FCC's statutory authority, we believe that the FCC can add harm claim thresholds to operating rules without additional legislation. Notably, harm claim thresholds do not supersede existing rules and definitions (e.g., FCC Not dated [b], 47 CFR § 2.1; also see box 1) but rather provide additional clarity to them. We also believe that parties could be allowed to modify initial entitlements, with the FCC acting as a recorder of spectrum rights, so to speak, rather than reviewing each such proposal through a rule-making process. In so doing, the FCC would build on its existing rules that allow parties to agree to maxima different from those specified by the FCC.[5]

B. THE FRAGMENTATION CHALLENGE AND THE ROLE OF BAND AGENTS

To address the problem of fragmentation among spectrum rights holders, we propose that the FCC facilitate the establishment of band agents. These agents would operate as entities that can represent and bind large groups of licensees in negotiating changes in operating rights with neighbors. In short, the band agent would be a mechanism to solve the collective action problem associated with large groups, like fragmented spectrum rights holders.[6] Ultimately, band agents allow for a fragmented set of interests to be represented by a single voice.

In the spirit of Schlager and Ostrom's 1992 typology of property rights, one can recognize a variety of radio operating rights in existing regulation, including the right to operate a transmitter ("operation"), the right to determine which transmitters may operate at a given time/place ("management"), the right to determine who will have various rights ("exclusion") and the right to transfer (by assignment, sale or lease) any of the above rights ("alienation"). Our proposal recognizes the right to change operating parameters (e.g., a transmit power ceiling), beyond the initial values determined in FCC rules: the right of "alteration."

Band agents would hold only one type of right—the "alteration" right to negotiate the contours of the operating right to use spectrum in particular bands (and adopt or not adopt protective measures). Using this right, the band agents could bargain efficiently with other parties for changes in operating rights, and these changes—and any side payments that result from the negotiation—would be binding on the licensees they represent.[7] All of the other rights remain vested in their current users. The system would thus operate along the lines of shareholder voting on a proposed merger, whereby a sufficiently large fraction of licensees could authorize an agent to act on behalf of them without requiring individual approval of every single licensee (which would raise holdout cost concerns). Even with a band manager in place, the licensees could still transfer their licenses and determine which transmitters may operate within their license area.

This proposal builds on an established framework for allowing facilitation across various interests in spectrum regulation. The current framework employs both band managers, who are responsible for managing the interference between operators in a band, and frequency coordinators, who facilitate the establishment of operating assignments that minimize in-band interference.[8]

Building on these two models, band agents would possess the ability to negotiate adjustments to operating rules in a given band. They would be able make or accept payments as well as bind the operators in that band. As a point of contrast, while a band manager may, for example, be able to resolve interference between some or all operators in its band, it cannot negotiate changes that are binding on all licensees in its band to reflect an agreement with a neighboring operator.[9]

The most effective way to enable the development of band agents is to establish a framework for voluntary coordination with backstop procedures for when parties cannot agree. In so doing, the FCC would encourage private institutions to spring up to manage this important function. This approach is likely to be superior to detailed upfront implementation mechanisms, because a more-prescriptive and rigid approach risks not taking account of information known only to market participants, let alone risk not being able to change in the face of dynamic conditions.

Public interest concerns and permanent legacy assignments call for the need for "trusted intermediaries" to act on behalf of a range of rights holders. In terms of establishing such intermediaries, our rule of thumb is that every "allotment" of spectrum—in other words, every subdivision of an allocation that refers to a service associated with a specific group of users or providers, such as frequency blocks auctioned separately in a cellular allocation—that has a degree of fragmentation among rights holders should have at least one, or at most a few, band agent(s) so that negotiations can proceed across block boundaries.

Band agents for unlicensed bands would be assigned by a regulator who would designate a small number of band stewards or "stamp holders" who would be able to authorize the use of an unlicensed band.[10] For the stewards to function efficiently as band agents, they would have to have the power not only to agree to changes to the operating rules in their band among themselves and with neighbors, but also to accept (or make) side payments that could be distributed to affected parties (say, to upgrade equipment). Band stewards could also emerge organically in unlicensed bands coordinated by database managers, provided the FCC gave them the power to allow devices controlled by them to operate at higher power levels than the rules permit if the affected neighbors agree to those signal levels. For example, a whitespace database manager could negotiate an agreement with a TV broadcaster whereby devices affiliated with the manager would be allowed increased transmit power if payments are made to the broadcaster.

Benefits

The existence of band agents would facilitate mutually beneficial rearrangements of operating rights among parties within bands and across band boundaries. Such deals often cannot be struck under the status quo because of collective action problems such as a single hold-out blocking an agreement that would be beneficial to the whole, or because negotiations among a large number of parties can be prohibitively expensive and time-consuming.

For example, band agents would allow for more-efficient negotiations among parties within bands where there are multiple licensees in multiple service allocations, such as the 2050–2110 MHz band, where there are 10,800 licenses divided among eight different service types. If these interests were represented by a handful of band agents representing the different services (e.g., TV broadcasting auxiliary service, local TV, cable relay, and Earth exploration satellite), more-efficient rearrangements of rights within the band and with mobile telephony neighbors would be possible.

Band agents would also be useful to consolidate interests in unlicensed bands where changes need to be negotiated within and across allocations, such as the ongoing matter involving Globalstar (Lung 2013). At present, the FCC is forced to address such matters by operating as a de facto band agent for unlicensed operators and by operating as the regulator and adjudicator of spectrum property rights.[11] Band agents could far more effectively negotiate changes in unproductive operating rules that cannot be changed under the current regime because of the opposition of fragmented stakeholders that are unable to reap the financial benefits of change (e.g., U-PCS; see Hazlett 2008, 114; Hazlett and Oh 2013). On the federal side, band agents representing federal wireless operations could provide a mechanism for federal users to be exposed to the costs of their radio use, creating a financial benefit for trading away those rights.

Band agents could also take the FCC out of its frequently conflicted position of acting on behalf of a group of licensees while simultaneously refereeing conflicts between these licensees and others. For example, when interference issues arose between Nextel's cellular service and individual public safety LMR services that were assigned to individual municipal police and fire service providers and local commercial operators, the FCC was forced to get involved and develop an extensive process to reallocate spectrum rights in order to manage this conflict. If a band agent had been available to act on behalf of public safety, the FCC would not have been both advocate and judge. (The recent creation of FirstNet to hold the license of the new 20 MHz broadband public safety band is recognition of the need for such consolidated control.)

Implementation

We recognize that the introduction of band agents into spectrum policy is a notable change and would need to be phased in. As discussed above, the current levels of

fragmentation are an intended consequence of political considerations (e.g., small geographic licenses to serve local constituencies), industry structure (e.g., local control of public safety operations, ancillary services associated with local broadcasting licenses), or regulatory choice (e.g., allowing for unlicensed uses of spectrum). In many cases, policymakers may not wish to undo those decisions. Consequently, and because the band agent model needs to be proven out and refined, we believe that a partial and incremental introduction of band agents is a sensible and important first step.

As we note above, the concept of band agents is not completely foreign to spectrum policy. Rather, band agents can be thought of as band managers or frequency coordinators with additional powers. The concept of band managers is well established in spectrum regulation; such managers are typically responsible for managing the interference between operators in a band. Frequency coordinators, by contrast, facilitate the establishment of operating assignments that minimize in-band interference, playing more of a facilitator role and lacking any formal authority themselves (Williams 1986). In the 800 MHz band, for example, the FCC has certified specific associations to coordinate the choice of frequencies for LMR systems before it will accept license applications.[12] Building on these two models, band agents would possess the ability to negotiate adjustments to operating rules in a given band, meaning that they would be able to make or accept payments as well as bind operators in that band.

The band agent model could be implemented in several possible ways, depending on the existing circumstances in a given band (see box 3 for a summary). Different situations will require different solutions to achieve the single goal of enabling a small number of agents to act on behalf of many principals in search of win-win deals with neighbors.

We propose, as a first option, the appointment of the band agent in the same way that shareholders appoint managers to act on their behalf. Under this model, the FCC would reallocate (e.g., recognize a transfer of) the alteration rights of individual licensees—say, the next time a license was renewed—to the band agent. Under such a model, the FCC would need to determine the voting rights of the affected spectrum licensees, who would become, in effect, band shareholders.

Moving forward, the FCC could include collective action clauses in new licenses; these clauses would be similar to those that allow a supermajority of bondholders to agree to a debt restructuring that is legally binding on all holders of the bond, including those who vote against the restructuring. It could also add overarching conditions to all licenses in a given band that would lead to a consolidation of interests in the same way that oil and gas property rights can be unitized if a supermajority of rights holders agree.

A second option for developing band agents is to build on existing institutions, such as frequency coordinators. The LMR bands, for example, are in dire need of delegated management as the FCC is currently embroiled in deciding minor technical details as a result of the absence of decentralized management.[13] The existing 800/900 MHz frequency coordinators could be provided with additional authority to negotiate operating arrangements.[14] At present, frequency coordinators cannot negotiate effectively since they do not hold licenses, and their rights would need to be augmented to enable them to do so. Although there are more than a handful of coordinators—about ten per band—that is still significantly fewer than the tens of thousands of current licenses.[15]

For federal government spectrum rights, either a single entity or individual departments and agencies could act as band agents. At present, the NTIA is nominally the band manager for spectrum dedicated to the federal government. In practice, however, the NTIA operates at best like a frequency coordinator, because it cannot control federal departments and agencies, especially powerful ones like the DoD and FAA. Moreover, federal agencies are not authorized to negotiate commercial arrangements that enable more-efficient uses of spectrum.

BOX 3.

Ways to Introduce Band Agents

1. Licensees appoint the band agent in the same way that shareholders appoint managers to act on their behalf.

2. The FCC and NTIA build on existing institutions, such as frequency coordinators, band managers, and federal agencies, by extending their powers.

3. The FCC auctions alteration rights. In licensed bands, alteration rights may be separated from, or included with, other spectrum rights. In unlicensed bands, the FCC assigns stamp holder rights, or allows spectrum sharing database operators to act as agents.

A single band agent for federal allocations could be seen as an alternative to, or a variant of, the Government Spectrum Ownership Corporation (GSOC, aka the GSA for Spectrum) proposed by Lenard, White, and Riso (2010). Just like the GSOC, a single federal band agent would be able to negotiate changes in spectrum rights with the private sector. The federal band agent would take on many responsibilities currently borne by the NTIA; the agent may or may not be the NTIA itself.

Given the extent to which spectrum is shared between federal and nonfederal users—a trend that is likely to continue and is being encouraged by the Obama administration—it makes sense to assign band agent powers to a single federal agent or, where appropriate, give the specific departments and agencies that use wireless spectrum the additional powers necessary to negotiate commercial agreements (see, e.g., Strickling 2013).

Third, band agent rights could be assigned by auction. This is, indeed, what happens currently in the case of exclusively assigned flexible use rights, such as commercial mobile spectrum licenses; however, one can envisage a situation where the rights to alter operating parameters are auctioned separately from rights to operate transmitters within those parameters. Such an approach could even work in unlicensed allocations. At one level a band agent in an unlicensed band would seem to be an oxymoron; after all, by definition an unlicensed band allows anyone to operate a compliant device without third-party permission. However, the FCC could use an auction to assign a small number of band stewards or "stamp holders" who would be able to authorize the use of an unlicensed band (De Vries 2011). A system for such stewards could also work for decoupled receivers—in other words, in cases where licensees do not control the design, sale, or operation of receivers used with their system, including TV, GPS, FM radio, and satellite weather receivers—which have many of the same cross-allocation coordination challenges of unlicensed bands.

It will be critical to establish effective incentives for band agents to operate effectively. In general, the fundamental incentive for band agents will be to share in the benefit of gains from trade as rights are transacted among neighbors. The details of how a share of this benefit is paid to the band agent will depend on the implementation; the incentive structure will vary among the options we described above. If the band agent receives benefits at the end of the process based on the creation of new wealth (through win-win transactions), it has a direct incentive to strike the best possible deal. If it were acting on behalf of licensees as a manager would for shareholders, the usual panoply of management incentives could be used, including fixed remuneration and/or a share in the proceeds of a successful negotiation. If the agent acted as a market-maker, bringing together licensees across band boundaries, it might charge a fixed fee or a percentage of the net benefit of striking a deal.

In general, the fundamental incentive for band agents will be to share in the benefit of gains from trade as rights are transacted among neighbors.

We recognize that a band holder regime is vulnerable to a variety of difficulties. For example, there is the well-understood challenge of aligning the interests of an agent with those of its principals, like the interests of a company's managers with the interests of its shareholders. In arranging a trade of spectrum rights, there may well be relative winners and losers within the group represented by a band agent; the agent faces an invidious challenge in dividing up the spoils. Finally, if the gains are very large, the greed of all the parties may preclude them from striking a deal. Our working assumption based on the pervasive use of principal/agent arrangements and market makers is that the benefits will exceed the costs, and that difficulties can be resolved—but this will have to be worked out as this concept is developed.

The FCC has considerable discretion as to how it might catalyze the emergence of band agents. The FCC's support for frequency coordinators provides a precedent for how the agency could support the development of these new entities. In such an approach, the FCC could put in place the mechanisms that band agents would need, such as authorization for licensees to cede some rights, the power for agents to negotiate

changes in operating parameters, and the power for agents to make or accept payments on behalf of licensees.

The creation of band agents for federal operations is inherently more challenging than the creation of band agents for private licensees. Most notably, given the inability of government agencies to accept remuneration from private entities (e.g., as part of a deal to alter spectrum operating rights), there are powerful limits in terms of what can be done to create a win-win solution. Developing strategies to encourage the federal government to use its spectrum assignments more productively is an area for further research and, ultimately, more legislative action. Legislation would be required, for example, to create a GSOC to enable federal agencies to benefit from win-win solutions or allow agencies to act as band agents.

C. REFORMING SPECTRUM ADJUDICATION

We propose the development of an effective adjudication regime that moves adjudication from the current ad hoc, politically charged, and notice-and-comment driven process to a more-fact-based process.[16] This regime will also be afforded the resources to adjudicate spectrum-related disputes in a timely fashion by judges with sufficient expertise in spectrum policy. Our proposal to achieve this goal is two-fold.

First, we propose that the FCC employ either ALJs or administrative judges, as opposed to the traditional ALJs, to develop factual findings in spectrum disputes. The key difference is that such judges are not a formal part of a federal government–wide system for selecting such officials. Indeed, the FCC does not actually have many ALJs on staff and those in place lack the specialized expertise that would enable more-effective adjudication in this area, making the administrative judges model an appealing alternative.

In practice, the resolution of spectrum disputes is very likely to turn on specialized knowledge of how wireless services operate and how to assess violations of a threshold level of tolerable harm. Rather than ask generalist judges to learn such details, Congress could empower specialized adjudication of spectrum disputes. For the FCC, the development of a specialized adjudication function would involve building a capacity it does not currently have. To do so, it would need to hire up and train those who could manage this system (including technical advisers, which could rotate from other parts of the agency).

Second, even with the FCC acting as an expert adjudicator, we propose that Congress establish a Court of Spectrum Claims that could hear cases in this field. Such a body would be housed within the existing Court of Claims, the court that hears cases involving claims against the U.S. government. It would consist of specialized decision makers who could hear cases in the spectrum field.

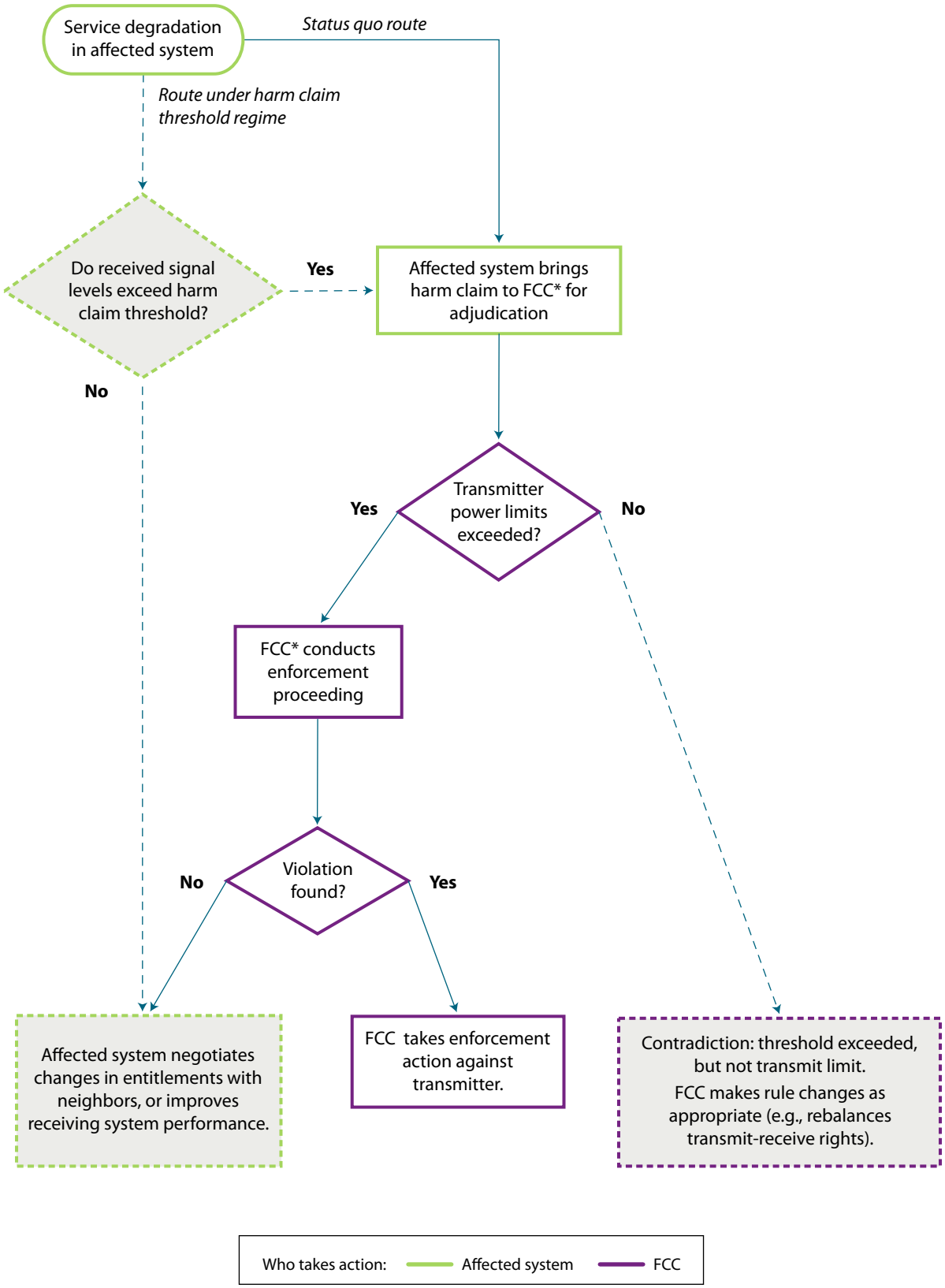
There are two underlying reasons why such a body should be established. First, such a body would provide an alternative and a check against the FCC's possible failure to operate effectively in this area. Second, even if the FCC were operating effectively (and the establishment of such a body would greatly enhance that likelihood), the FCC is not set up to handle disputes involving the federal government as a party. The number of spectrum disputes involving the federal government (and agencies like the DoD) may well increase as the initiative to encourage spectrum sharing between federal and nonfederal users gains traction. The establishment of a specialized court outside of the FCC would enable the U.S. government to sue or be sued when appropriate. We also recommend that a Court of Spectrum Claims be allowed to hear disputes between two private parties, ending the FCC's monopoly on hearing such claims and providing a choice of forum. In all events, appeals from either the FCC or the Court of Spectrum Claims would proceed to the Court of Appeals for the District of Columbia to promote uniformity of decisions in both forums.

Under our proposed framework for reform, the basic path of spectrum rights adjudication would change radically. To set the template for adjudications, the FCC would need to conduct rule-making to establish the set of harm claim thresholds. (The NTIA would need to develop a parallel process for government spectrum shared with private parties.) In the wake of these rules, parties could alter the relevant property rights through contracting and Coasian bargaining that would refine the relevant thresholds. If a dispute later arose (as to where the initial or refined entitlements were breached), the parties could either resolve the matter through an agreement or subject the matter to formal adjudication (either at the FCC or at the Court of Spectrum Claims.). As is often the case in civil litigation, the mere threat of litigation (and opportunity for discovery) could aid the parties in moving to a settlement.

Under our model, adjudication would come into play when a harm claim threshold is exceeded. In such cases, a plaintiff could bring a claim by alleging that a party has exceeded its allowable transmit power. Regardless of whether the adjudicative body is the FCC's Enforcement Bureau (as it would be at present) or another body (such as a Court of Spectrum Claims), there would be three separate questions that would determine the issue of liability for the interference in question: (1) Was the harm claim threshold exceeded in the first place? (2) Did the plaintiff suffer harm by the criteria in 47 CFR § 2.1 (FCC Not dated [b]; also see box 1)? (3) Was the influencing system operating outside its allowed transmitter parameters? If the FCC determined that the first two showings were made, but the influencing system was operating properly, the underlying rules are to blame, and the FCC would need to revise them by adjusting the relevant harm claim threshold and/or guidance on operating parameters. This interactive dynamic is why the

FIGURE 3.

Enforcement Process



Note: A decision tree for making enforcement decisions as described in the text. Grey shading and dashed boxes show the steps added to the current status quo by harm claim thresholds.

* If adjudication were reformed as we recommend, some of the adjudication roles currently played by the FCC under the status quo might be taken over by an independent adjudicator.

establishment of harm claim thresholds both depends on and feeds into the role of a vibrant adjudicative framework.

After liability is established, the next question is what remedy is appropriate for a violation. A showing of actual harm (e.g., service degradation), while not necessary to establish liability, would be relevant in selecting the proper remedy. Similarly, a greater or lesser showing of fault would influence the selection of the remedy. Where an affected system is not yet operating, for example, an immediate injunction would not be necessary or appropriate. Moreover, extraordinary circumstances that explain the violation of the harm claim threshold and attendant operating parameters—say a change in weather—could also militate for a more-lenient remedy. As the Supreme Court has explained in the context of patent law, relevant remedial decisions must result from the exercise of sound discretion and not be issued automatically when any violation is shown.[17]

To see how the process outlined above would work in practice, consider figure 3. This representation underscores that the use of harm claim thresholds makes clear that an affected system bears some responsibility to mitigate the effects of interference, as shown by the unshaded boxes on the left-hand side. Consequently, unlike under the current model (where the presence of interference is prima facie evidence), the harm claim threshold model looks at both sides of the boundary.

As we see it, adopting harm claim thresholds without a reformed system of adjudication will fail to realize the promise of introducing harm claim thresholds. After all, instituting a more-calibrated system of defining the right to use spectrum invites disputes and will only be effective with a regime suited to settling such disputes. As for the case of spectrum shared between the federal government and private licensees, neither side is likely to accept a harm claim threshold as valid unless it knows that claims will be enforced. Moreover, with respect to the band agent proposal, the negotiation of regimes for managing spectrum among a wide variety of players could easily lead to disputes and thus be greatly aided by an effective adjudication framework.

Chapter 5: Cost/Benefit Analysis

The principal benefit of our proposed reforms is to enable the more-dynamic and more-intensive use of spectrum. In so doing, our reforms will give rise to a series of benefits to consumers and producers. These benefits include lower costs, faster innovation, and more-rapid growth of wireless services. The Treasury will benefit considerably from such improvements, but mostly through the downstream impact of increased tax revenue.[18] Finally, by removing the FCC from its current prescriptive and case-by-case oversight role, our proposal will also restrict opportunities for rent seeking and market distortion by reducing the FCC's role in spectrum management.

We attempt to quantify these benefits by estimating the number of megahertz of spectrum—the "amount" of spectrum—that could benefit from these reforms. We then multiply this with a dollar-per-megahertz estimate of additional consumer surplus that would be generated.[19] This is an admittedly imperfect measure, since both the dollar-per-megahertz value estimate and the number of megahertz are subject to many uncertainties. Many of the benefits of our reforms, particularly regarding improved adjudication, cannot be easily tied to per-band valuations. However, we believe this provides a reasonably defensible lower bound on monetary benefits.

Any new regulatory regime also has costs. Though there are unintended consequences of action and change (just as there are unintended consequences of inaction), we estimate the costs of our proposal that can reasonably be anticipated.

A. BANDWIDTH MADE AVAILABLE BY REFORMS (MHZ)

Freeing up guard bands using harm claim thresholds

Using harm claim thresholds will have a variety of benefits, including facilitating the more-intensive use of spectrum, enabling the deployment of new services, and reducing the costs of negotiations. Since these are difficult to quantify, we focus on ways in which the institution of harm claim thresholds would reduce the reliance on wide frequency buffers—known as "guard bands"—that are placed between different kinds of services. We take this approach because there are conventional ways to value the spectrum bandwidth represented by guard bands.

To appreciate the role of implicit guard bands, consider the high-profile LightSquared/GPS case we discussed above. As we explained, LightSquared's planned use of the spectrum was precluded in that case by the interference that such service was projected to cause to GPS devices (Knapp and De La Torre 2012). Notably, GPS receivers were designed on the assumption that the adjacent band would be relatively quiet, allowing some receivers to "listen" to frequency ranges wider than their assigned bands to achieve greater location accuracy. As a result, such receivers could not reject the higher signal levels that terrestrial LightSquared transmitters would have generated in the adjacent band once they began operating. The type of implicit guard band at issue in cases like LightSquared is readily apparent. There are also less obvious cases of implicit guard bands, such as the "duplex gaps" between the base-to-mobile and mobile-to-base parts of certain spectrum allocations, and bands that serve to protect mobile handsets.[20]

We recognize that estimating the number of bands that can benefit from harm claim thresholds and use spectrum more effectively is uncertain. The number will depend at least in part on the degree to which harm claim thresholds incentivize improved receiver performance, which in turn will lead to more services being deployed in a given bandwidth. There are, at the very least, a number of cases where 10–40 MHz in implicit guard bands can be significantly reduced over time. For the purposes of the calculation, we will conservatively assume this number to be 200 MHz, but it could be as high as 600 MHz.

Estimating fragmentations and bandwidth benefits of band agents

As noted previously, fragmentation leads to economic inefficiencies and less-intensive use of spectrum than would be possible if a mechanism such as band agents were in place to overcome coordination issues. To provide a bird's-eye view of the benefits of having a band agent to reduce fragmentation, we analyzed the data in the FCC Spectrum Dashboard and Table of Federal Allocations in the frequency range 400–3700 MHz.[21] We counted the number of distinct services in federal and nonfederal allocations using the taxonomies of the Spectrum Dashboard and the Table of Federal Allocations.

There are a number of different possible measures one could use to capture the extent of license fragmentation. First, if one considers a band that contains four or more services to

be fragmented, then 46 percent (1532 MHz) of this spectrum meets the criterion (see figure 1). (This count does not include bands with many unlicensed devices.) Second, if we focus on the number of licenses per band (see figure 2) rather than on the number of services, we can refine the fragmentation criterion to four or more services as well as seven hundred or more licenses, leaving 19 percent of nonfederal spectrum (277 MHz) bands as fragmented.[22] Finally, if we posit that difficulties are only likely to arise at boundaries between fragmented bands and count bands containing four or more services where either or both adjacent bands are similarly fragmented, 40 percent (1317 MHz) of the 400–3700 MHz frequency range could be considered as fragmented.[23] In summary, approximately 1000 MHz of the 400–3700 MHz frequency range is significantly fragmented.

Building on the above analysis, we have identified half a dozen large contiguous band regions, each more than 20 MHz wide, where four or more services occur on either side of all internal band boundaries (see table 1). Our estimates for the amount of fragmented spectrum in 400–3700 MHz ranged from 277 MHz to 1532 MHz, depending on fragmentation criteria. The rough inventory in table 1 lists six bands, ranging from 45 MHz to 610 MHz, for a total of 1154 MHz. Not all of them will prove amenable to defragmentation in the short to medium term. We assume that only 400 MHz could be governed more effectively. However, the total could in fact be more than 1000 MHz.

B. ESTIMATES OF SOCIAL SURPLUS ($ PER MHZ PER YEAR) AND INCREMENTAL VALUE ($ PER YEAR)

First, we must reiterate the challenges of coming up with a meaningful estimate of the economic benefits that would flow from our proposal. We are not, for example, estimating the value of the sharing of government spectrum that would result from our proposal. We are also not assigning any specific value to the benefit that comes from facilitating the rollout of new services and new technologies, or to the value of the time saved in negotiations among a range of parties. We do not venture such an estimate because it is difficult, if not impossible, to ascribe the lost value in such cases. Caveats aside, we have sought to develop a rough estimate of the spectrum bandwidth in megahertz that would be realized as a result of our proposals.

To estimate dollar per megahertz value, we start with the value of an allocation to commercial cellular service as a baseline, since that is the currently most highly financially valued measurable use of spectrum. The auction value of such licenses is of the order of one dollar per megahertz per capita (see, e.g., Bazelon and McHenry 2012, figure 1), or roughly $300 million

TABLE 1.

Large Band Regions with Four or More Allocations on Either Side of Band Boundaries

Band Region (MHz)	Bandwidth	Allocations
406–460	54 MHz in seven contiguous bands	Amateur, aviation, federal fixed and mobile, general aviation air-ground, industrial/business radio, maritime, low power auxiliary, paging and radiotelephone, personal locator beacons, public safety radio, radiolocation, remote pickup, rural radiotelephone, space research
1215–1300	85 MHz in two contiguous bands	Amateur, federal aeronautical radionavigation, earth exploration-satellite, federal earth exploration-satellite, radiolocation, radionavigation-satellite, space research, space research radiolocation
1850–2110	260 MHz in four contiguous bands	AWS-2, broadband PCS, cable antenna relay, earth exploration satellite, local television transmission, fixed microwave, mobile satellite service, space operation, TV broadcast auxiliary
2200–2300	100 MHz in two contiguous bands	Earth exploration-satellite, fixed, mobile, space operation, federal and non-federal space research
2345–2390	45 MHz in two contiguous bands	Aviation, fixed, mobile, radiolocation, WCS
2690–3300	610 MHz in four contiguous bands	Aviation, federal aeronautical radionavigation, federal and non-federal earth exploration-satellite, federal and non-federal radiolocation, maritime, maritime radionavigation, meteorological aids, radiolocation, radio astronomy, space research

Source: FCC 2013b; FCC 2014b.

Note: AWS = Advanced Wireless Services; PCS = Personal Communications Service; WCS = Wireless Communication Service.

per megahertz for the United States, as the U.S. population is slightly over 300 million. The economic literature suggests that the annual consumer surplus is a multiple of the auction value; we conservatively assume that the multiple is one; in other words, we assume that an auction price of $300 million per megahertz leads to additional consumer surplus of $300 million per megahertz per year.[24] We then posit that the value generated by implementing our reforms is a small fraction of this baseline value.

We estimate that clarifying the interference rights and responsibilities would lead to more-productive use of the implicit guard bands. We estimate that this improvement will be worth at least a few percent of the bands' value if they were to be used for wireless broadband service, our baseline value assumption. For the purpose of calculation we will conservatively assume this percent increase in value to be 2 percent.

The value of fragmented bands in their current state is not known, and it is unlikely that the full value of commercial mobile broadband use will be realized for them if their band agents could negotiate effectively. We will therefore assume that reducing fragmentation would increase consumer surplus by some fraction of the baseline cellular service value. For the purpose of calculations, we will make the conservative assumption of 5 percent. We have not been able to devise a method to quantify the value of improved adjudication on a dollar-per-megahertz basis, so we will ignore adjudication for the purposes of this cost/benefit calculation.

To estimate the incremental value that could be gained by implementing the reforms we propose, we combine the quantities derived above:

- Baseline value for consumer surplus associated with highest value use (cellular): $300 million per megahertz per year
- Harm claim thresholds
  - Incremental consumer surplus obtained by reducing guard bands through the use of harm claim thresholds: 2 percent of baseline value, or $6 million per megahertz per year
  - Guard bands amenable to reform: 600 MHz
  - Incremental consumer surplus due to reform: $3.6 billion per year
- Band agents
  - Incremental consumer surplus obtained by improved ability to find highest use by using band agents in fragmented bands: 5 percent of baseline value, or $15 million per megahertz per year
  - Fragmented bands amenable to reform: 400 MHz
  - Incremental consumer surplus due to reform: $6 billion per year

Adding these estimates yields a potential increment in consumer surplus of $9.6 billion per year.

C. COSTS

The establishment of harm claim threshold levels constitutes a major undertaking. It would entail costs for both stakeholders and the government entities (the FCC and the NTIA, if it followed suit). The harm claim threshold is a new concept that will need to be tested and refined over time. There is the risk, if not the likelihood, that the initial value of a harm claim threshold will not be set to the exact value that maximizes social welfare. Some imprecision in setting the initial value for the harm claim threshold is inevitable, and can be corrected by market transactions among the parties. But we believe that the inefficiencies in the current regime are so great that the benefit will be substantial and outweigh the costs imprecision even if obstacles to Coasian bargains preclude reaching the optimal solution.

There are also costs of retraining staff and adopting new equipment. The implementation of harm claim thresholds will increase the number of field measurements that will have to be made, although measurements will only be necessary when a claim of harm is being made. There are currently about 600–1,200 technicians in the cellular and public safety industries able to make such measurements. If one assumes conservatively that implementing harm claim thresholds will roughly double this population, about one thousand technicians will have to be trained to make such measurements, at a cost of about $5,000 per person.[25] This yields a total cost of around $5 million. More staff will also need more equipment. About 3,000 high-quality spectrum analyzers are sold per year in the United States, at prices up to $15,000 each. Assuming sales double, this cost will approach $45 million per year.

Perhaps the most easily identifiable cost of a band agent regime is the need to create new institutions: the agents represent a new layer of management. Since licensees will cede some of their powers to band agents, there is the potential cost of inefficiency in any principal–agent arrangement: the agents may not always act in the best interests of the licensees. However, we believe that since band agents will be introduced to remedy severe collective action problems in fragmented bands (e.g., hold-outs and free-riders blocking the successful conclusion of socially beneficial negotiations), the net result will be positive. The incremental surplus gain may be reduced from such inefficiencies, but it is highly unlikely that the overall outcome from the reform will be worse than the status quo.

Investing in the appropriate infrastructure to establish a more-effective adjudication process is an ambitious undertaking. For all intents and purposes, the FCC engages in very little to no such adjudication at present. Developing this capability, or building a new institutional structure for such adjudications,

would bring important benefits but also entail significant costs. Like the costs associated with establishing harm claim thresholds, there would be the cost of a need to hire and train personnel. The benefits of the ability to expedite decision making going forward as well as to facilitate agreements of a kind that would not be made in the absence of an effective adjudication backstop could be considerable, even if these benefits are difficult to quantify at present. Such an adjudication system will be critical to enabling protective arrangements for shared spectrum situations that can provide the government with additional revenue and enable the more-efficient and more-intensive use of spectrum—as acknowledged by the Commerce Department Advisory Committee.

Chapter 6: Questions and Concerns

Do these proposals threaten national security by reducing the amount of spectrum available for the military?

No. None of these proposals sets out to reallocate military spectrum assignments to other uses without the federal government supporting such moves. They are intended to increase the value and efficiency of all radio operations, civilian and military.

Could the use of harm claim thresholds have changed the outcome in the LightSquared/GPS case?

Yes. Consider, for example, an alternative course where the FCC had instituted harm claim thresholds in 2003. Those thresholds could have provided that all deployed GPS receivers would enjoy protection and LightSquared would have been precluded from operating in a fashion that would cause harmful interference to them. Alternatively, the thresholds could have stated that the thresholds in the lower part of the Mobile Satellite Service (MSS) band, farthest away from GPS, would be increased ten years later in 2013 to levels that would allow LightSquared to deploy terrestrial transmitters without being deemed to be causing harm (i.e., creating harmful interference) to terrestrial GPS receivers. Yet another possibility would have been to set the harm claim threshold low, and to set an especially low harm claim threshold above a certain altitude and around airports in order to protect aviation applications. Under such a regime, LightSquared would have been obligated to upgrade all aviation equipment to tolerate its signals as part of an agreement to change the relevant harm claim thresholds. Under the latter two cases, moreover, at least the lower 10 MHz of spectrum that LightSquared had access to could be used for terrestrial services, generating an estimated consumer surplus of $300 million per year (assuming auction value of $1 per megahertz per person, a U.S. population of 300 million, and an annual consumer surplus equal to the auction value).

What are some potential challenges with the band agent approach?

We recognize that there are challenges to the successful operation of a band agent regime; we note two major challenges here in order to stimulate discussion. Band agents, by definition, represent the interests of a diverse group of principals. After a successful renegotiation of rights, the principals as a group will necessarily be better off (otherwise the negotiation would not have succeeded). However, there are likely to be winners and losers within the group. The band agent could arrange for transfer payments to compensate the losers, but it is likely that there will still be some scenarios in which some of them will not be satisfied. This may be one reason why it will be useful to have more than one band agent in a given band; dissatisfied principals in one group will have the option to defect to another band agent for subsequent negotiations. A second difficulty occurs when the gain negotiated by the band agent is very large: when the pie to be divided is very large, the risk of strategic behavior rises greatly, with individual licenses positioning for a greater share of the rewards. Finally, there are potential conflicts of interest between the principals as a group and the agent; the agent may, for example, prefer the continuance of a status quo that funds its functions, rather than a change that would be to the benefit of the principals.

How many band agents can there be per band?

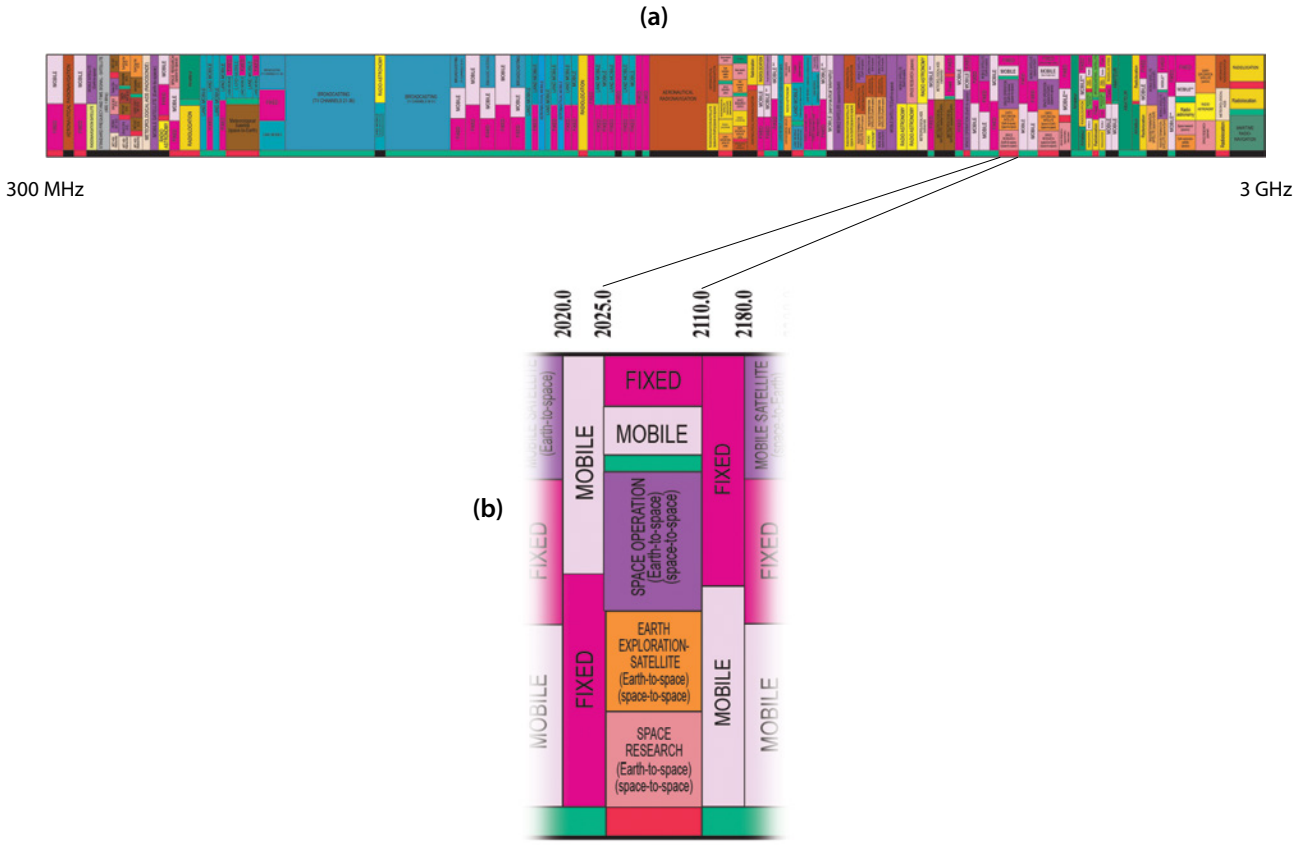
Under our model, there does not need to be just one band agent in a frequency band. For example, each different allocation in a band might be represented by its own agent; in the 2025–2110 MHz band, say, there might be agents representing licensees in the Cable Antenna Relay, Earth Exploration Satellite, Local Television Transmission, Space Operation Service, and the TV Broadcast Auxiliary services, respectively (see Figure 4 (a)). In a single-allocation band with multiple interests, each might be represented by an agent; in the 800 MHz land mobile radio (LMR) bands, for example, there might be agents representing the petroleum, electrical utility, railroad, fire alarm, and forestry industries.

Does the lack of disputes between major wireless carriers suggest that adjudication is unnecessary?

One misleading claim about the current system of spectrum regulation is that the lack of disputes between major wireless providers suggests that adjudication is unnecessary. It might well be true that "interference issues between wireless carriers are always resolved in the field without FCC intervention." To the extent that is the case, it is so because the FCC's processes are not reliable, the relevant parties are relatively few and well known to one another, and the associated technologies are common among those parties. By contrast, in spectrum bands with greater numbers of operators, or where an incumbent

FIGURE 4.

(a) U.S. frequency allocations, 300 MHz–3 GHz (b) 2025–2110 MHz



Source: U.S. Department of Commerce 2011.

operator is sharing access to spectrum with another provider, the likelihood of disputes emerging—and not being resolved easily, as they are between cellular providers—is great. The cellular case is the exception that proves the rule: the often-large license areas and repeated interactions in many settings by nationwide operators create considerable incentives for cooperative behavior (Weiser and Hatfield 2008a, 588–91). In other contexts, where there is no perceived benefit to the incumbent in allowing additional spectrum usage by the adjacent band user, the incentive is to delay or slow the process, or to attempt to use politics to affect the outcome based on safety of life arguments that politicians readily understand for the incumbent licensee.

You seem to be double counting bands as increasing in value, simultaneously, from both the band agent and harm claim threshold proposals. Do you think this is appropriate?

One might argue that this estimate includes double counting since some bands that are currently fragmented are also "quiet" bands that would be counted as candidates for amelioration by using harm claim thresholds. We believe that our marginal value estimates of a few percent are so low that the benefits would be additive, and thus it is plausible to add these estimates. However, even counting only half of the benefit still yields a substantial value estimate.

Chapter 7: Conclusion

When auctions for spectrum licenses and modern unlicensed deployments began in earnest around twenty years ago, there were relatively many accessible opportunities to tap into unused or deeply underused swaths of spectrum. To satisfy future demand by wireless services for more access to spectrum and for more-efficient uses of spectrum over the next twenty years, policymakers will need to look to a new horizon for different kinds of policy reforms.

Policymakers should take on the reforms outlined in this discussion paper if they indeed wish to take a step toward the next great policy frontier and toward ensuring more-effective and more-efficient use of spectrum. After the FCC implements the pending incentive auctions in the TV band, it will not have any obvious opportunities for shifting large swaths of spectrum from less-efficient to more-efficient uses (Weiser 2008). Unless the FCC decides that such an alternative opportunity is available, it should begin pursuing these initiatives.

This discussion paper suggests a set of complementary spectrum policy reforms—to address band fragmentation, the lack of defined interference rights, and the absence of an effective adjudication framework—that will facilitate more-intensive use of spectrum by existing and emerging wireless services. We recognize that these reforms will not be easy to implement, and that it will take time to refine them and phase them in. But we are convinced that they will give rise to considerable benefits over time. We estimate that such reforms can provide economic benefits of nearly $10 billion per year in additional consumer surplus. This is only a rough estimate that does not capture any of the revenue the federal government will gain as a result of the spectrum-sharing initiatives that these reforms will make possible, the many dynamic benefits that will come from a heightened level of flexibility in spectrum use, or the unquantifiable benefits of more-efficient institutions. Consequently, the case for moving ahead with these spectrum policy reforms seems quite compelling.

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Endnotes

1. By "economically efficient," we mean using resources more effectively, which enables society to be better off as a whole.
2. For example, FCC (Not dated [b], 47 CFR § 2.102(f)) requires that "stations of a service shall use frequencies so separated from the limits of a band allocated to that service as not to cause harmful interference to allocated services in immediately adjoining frequency bands." In so doing, the rules recognize the possibility of interference between services in adjoining bands.
3. For cases in point of such resolutions, the cases of Wireless Communication Service (WCS)/SiriusXM and Sprint/DISH in Advanced Wireless Services (AWS)-4 provide notable examples of this very situation. See FCC (2012) regarding the WCS, satellite radio dispute; and FCC (2013d) regarding the AWS-4 dispute. The rules for cellular mobile radio systems allow parties to negotiate changes in field strength limits at their geographical boundaries (FCC Not dated [b], 47 CFR § 27.55). Cellular/Personal Communications Service (PCS) systems would not be able to operate up to the edge of their licensed areas without such agreements. There are mutual benefits and harms that lead to good faith negotiations among the parties.
4. In so doing, we elaborate on earlier work on this topic. See, e.g., De Vries (2013); FCC TAC Receivers and Spectrum Working Group (2013); and President's Council of Advisors on Science and Technology (PCAST; 2012, section 3.2).
5. FCC (Not dated [b], 47 CFR 27.55 (a)) allows the field strength at the geographical border of a license area to exceed the value specified in the rule if adjacent affected service area licensee(s) can agree to a different value.
6. In developing the concept of a band agent, we are not introducing an entirely new idea into the world of spectrum regulation. Congress recognized the limits of fragmented and individualized public safety licensees when it established FirstNet, an independent authority within NTIA that holds the license to the entire 20 MHz of public safety broadband spectrum. FirstNet can in effect negotiate on behalf of, and bind, public safety spectrum users.
7. Cf., FCC (2013a, 7): "The band manager would also be able to bargain with high power licensees for increased rights, e.g., higher power limits, as a market alternative to administrative provisioning, at least for low-power uses that do not spread across a great many licensees. . . . The 'band manager' concept could take different forms, and would appear to fall within the current secondary market rules."
8. In the 800 MHz band, for example, the FCC has certified specific associations to coordinate the choice of frequencies for LMR systems before it will accept license applications.
9. For example, a 700 MHz Guard Band Manager has the authority to manage interference between operators to whom it subleases spectrum; the 800 MHz band Transition Administrator is responsible, among other things, for facilitating issue resolution and administering the alternative dispute resolution process in that band.
10. A system for such stewards could also work for decoupled receivers—i.e., in cases where licensees do not control the design, sale, or operation of receivers used with their system, including TV, GPS, FM radio, and satellite weather receivers; decoupled receivers have many of the same cross-allocation coordination challenges of unlicensed bands.
11. In effect, the FCC is both the representative of the interests in an unlicensed band and the adjudicator between these interests and those of its neighbors, creating a clear conflict of interest and the potential for confusion between the two roles. Whether or not the FCC can manage that conflict effectively (say, by having different internal constituencies represent each role), this situation is clearly suboptimal.
12. See FCC (Not dated [a]) for a list of frequency coordinators.
13. For example, the FCC is forced to decide on waiver rules for train coupler transmitters. See FCC (2013c), 3.
14. See FCC (2014a) for a list of frequency coordinators: nine below 800 MHz, and ten at 800/900 MHz.
15. For example, as of September 2013, the FCC Spectrum Dashboard listed more than 28,000 licenses in the 809–849/854–894 MHz band.
16. Indeed, even when the FCC styles a matter as an adjudication it often uses its traditional notice-and-comment procedure to reach an ultimate judgment. In the XM/Sirius case noted above, for instance, the FCC did not ever actually find facts and reach a judgment.
17. See *eBay Inc. v. MercExchange, L.L.C.* (2006), which holds that a four-factor test must be applied before granting a request for an injunction for a possible violation of the Patent Act.
18. Unlike auctions for using wireless spectrum transitioned from other uses, our proposed reforms do not lend themselves to many immediate and directly quantifiable monetary benefits to the U.S. Treasury. The principal exception to this is that our proposed initiatives would give rise to such revenue opportunities to the extent that the federal government shares spectrum and receives payments from private entities as a result of them. In short, the benefits from such spectrum sharing between the federal government and commercial entities could be substantial, but are difficult to quantify.
19. Consumer surplus is the monetary gain obtained by consumers because they can obtain something for less than the highest price they would be willing to pay; it is a measure of the welfare that is created by a particular market structure.
20. For example, 10 MHz below and 20 MHz above the 1.9 GHz Broadband PCS cellular band used by mobiles, and similarly, the 20 MHz below the 2.1 GHz is mobile cellular receive band.
21. The Spectrum Dashboard covers the range 235–3700 MHz. We based our analysis on data downloaded from FCC (2014b).
22. We exclude bands that contain federal services from this analysis since we do not have data on the number of federal assignees, reducing the total spectrum inventory to 1492 MHz.
23. The upper 33.5 MHz of the 2400–2483.5 MHz band is included in the first count (ignoring boundaries) since it contains five services according to the Spectrum Dashboard inventory; however, since none of its neighbors are fragmented, this sub-band is excluded from the second count.
24. Rosston (2003) compares incremental consumer surplus of $30 billion to $50 billion per year for cellular licenses auctioned for $30 billion, for a multiple of around 1.3x; Hazlett, Muñoz, and Avanzini (2012, table 1) indicates consumer surplus of $170 billion to $210 billion a year for licenses auctioned for $50 billion, for a multiple in the three to four times range.
25. We assume four days of training at $1,250 per day.
26. Strategic behavior is when parties take actions designed to maximize their long-term rewards by not revealing their true interests and, in many cases, by holding out from entering into an otherwise win-win agreement. Such behavior can be seen as a particular form of a transaction cost and, if not managed or overcome, can thwart socially valuable solutions.
27. Weiser and Hatfield (2008b, 588 n. 218), quoting James D. Young, president, U.S. Tower Operations, Crown Castle International.

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Highlights

In a new Hamilton Project discussion paper, Philip J. Weiser of the University of Colorado Law School and Silicon Flatirons Center, and J. Pierre de Vries of the Spectrum Policy Initiative, Silicon Flatirons Center, propose three major reforms to the regulatory structure of the wireless spectrum. While each of these proposals stands on its own, they integrate to form a package of policy proposals that transform the regulation of the wireless spectrum.

The Proposal

Define harm claim thresholds to reduce the ambiguity over responsibilities for interference harm. Authors J. Pierre de Vries and Philip J. Weiser explain how a system of harm claim thresholds could generate default spectrum rules that are clear enough to facilitate more bargaining between rights holders to reach the economically efficient trade-off between the rights of transmitters and receivers.

Introduce band agents to overcome the drawbacks of excessive fragmentation. To address the collective action problems created by fragmentation among spectrum rights holders, the authors propose that the Federal Communications Commission and National Telecommunications and Information Administration facilitate the establishment of band agents that can represent and even bind large groups of fragmented licensees.

Reform spectrum adjudication to improve the reliability and efficacy of dispute resolution. To advance important spectrum policy reforms, it is important to move adjudication from the current ad hoc, politically charged, and notice-and-comment-driven process to a more fact-based process. The authors put forth proposals that would resolve spectrum-related disputes in a timely fashion using judges with expertise in spectrum policy, in the Federal Communications Commission and/or in a newly created Court of Spectrum Claims.

Benefits

Complementary spectrum policy reforms that address the lack of defined interference rights, band fragmentation, and the absence of any adjudication framework would facilitate more intensive use of spectrum by both existing and emerging wireless services. Such reforms could provide economic benefits of nearly $10 billion per year in additional consumer surplus.

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