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Revitalizing the Public Airwaves: Opportunistic Unlicensed Reuse of Government Spectrum

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While many policy analysts have focused on the fate of the 700 MHz auctions, the digital TV transition, and the promise of white space devices, a more vast and underutilized resource has gone largely unnoticed: government spectrum. The best available data suggests that the majority of federal spectrum capacity is left unused. Strategic reuse of this spectrum could help obviate the need for significant additional reallocation while enabling a wide range of creative new uses and social benefits. Based on what little information is publicly available, it is reasonable to assume that the repurposing of government spectrum would go far in addressing a number of access-related communication problems. Repurposing currently unused U.S. government-controlled spectrum for opportunistic unlicensed use would benefit society by dramatically expanding access to high-speed broadband and increasing the pace of wireless technology innovation. This approach to spectrum policy presents a "third option" for reform, drawing from both the commons and property rights models of spectrum management.

Introduction

The time has arrived for the unrealized potentials of federal white spaces to receive some well-deserved attention. While many policy analysts have focused on the fate of the 700 megahertz (MHz) auctions, the digital TV transition, and the promise of television white space devices, the best available data suggests that the majority of federal spectrum capacity is left unused (McHenry, 2003; McHenry, 2004) – a situation that has gone largely unexamined. Strategic reuse of government spectrum could help obviate the need for significant additional frequency reallocations while enabling a wide range of creative new uses and social benefits. Based on what little information is publicly available, it is clear that the

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repurposing of government spectrum would go far in addressing a number of access-related communication problems. Repurposing currently unused or underutilized U.S. government-controlled spectrum for opportunistic unlicensed use could dramatically expand access to high-speed, affordable broadband and increase the pace of wireless technological innovation. This approach to spectrum policy presents a “third option” for reform, drawing from both the commons and property rights models of spectrum management.

A growing consensus among engineers, analysts, and key decision-makers holds that recent and imminent technological improvements in the realm of cognitive radio technologies make it possible to strategically “borrow” unutilized spectrum in real time.[1] By using a resource that would otherwise go to waste, intelligent wireless devices can provide a means for building new wireless networks and complement existing telecommunications infrastructure. If employed on a wide scale, policies that open up government spectrum for opportunistic unlicensed reuse have the potential to essentially eliminate the artificial scarcity that too often hinders efforts to develop next generation wireless communications systems. This shift in spectrum regulation would help remedy America’s falling international ranking in broadband penetration by dramatically lowering the costs of communications, fostering a new wave of geolocational and social networking services and applications, as well as driving implementation projects throughout the United States.

In this paper we address the following questions: What is the reported utility of the federal spectrum? What data on current usage rates are publicly available? How can we protect existing uses while allowing unlicensed access? What technologies are needed for opportunistic unlicensed spectrum reuse? Based on open-ended, off-the-record discussions with government officials and an analysis of policy documents, this paper sketches competing normative assumptions underlying possible regulatory policies and examines spectrum use vis-à-vis its unmet potentials for maximizing social benefits. After examining key debates regarding spectrum management models, we propose a “third option” that opportunistic reuse of government spectrum, especially on an open and unlicensed basis, affords the greatest value to the general public. We explain how the government’s tendency to auction off spectrum to raise revenue on a one-time basis is not ideal for ensuring the advancement of new technologies and expanded broadband access for underserved areas.[2] The paper concludes with a series of policy recommendations for implementing opportunistic reuse of government spectrum. By exploring models for spectrum management that take advantage of technological innovations, our analysis aims to help initiate

[1] Ongoing recent talks with staffers at the National Telecommunications and Information Administration, the Federal Communications Commission, and the White House have focused on addressing the issue of underutilized spectrum and how to transition these bands to more productive use. Several proposals based on a working draft of this paper are pending as policy recommendations at the time of this writing.

[2] It is not the auction mechanism, per se, that is not ideal to ensure the advancement of new technologies, but rather the auctioning off of exclusive licenses in an environment where the rules are prone to powerful incumbents warehousing the spectrum or otherwise manipulating the allocation. We note below that in some cases micro-auctioning could be an effective enabler of opportunistic secondary use.

a policy debate on spectrum reforms that may hold profound implications for the future of U.S. communications.

Spectrum Management Regimes

There are few communication policy issues that strike at the heart of political economic and public policy concerns like questions of spectrum management. These questions include the following: Who receives access to the spectrum and for what purpose? Whose interests are being served? What public interest obligations are attached to a licensee's use of the public airwaves? And what path dependencies are created though the allocation and assignment of spectrum for specific purposes and users? When debating how spectrum is controlled, we are really discussing issues of power. These issues are complicated by what Nuechterlein & Weiser call the "twin peculiarities" for air transmissions using spectrum; more specifically, a lack of obvious property rights in frequency assignments and a constant threat of interference between one service or user and others (Nuechterlein & Weiser, 2005, p. 229). These peculiarities have engendered a long and colorful history of regulatory dilemmas and power struggles over spectrum management.

In theory and in law, the airwaves belong to the public. However, decisions regarding who gets to use the airwaves, for what purpose, and subject to what conditions, are contentious, inviting close governmental regulation predicated on a rationale of spectrum scarcity. Traditionally, the Federal Communications Commission (FCC) has allotted spectrum for the exclusive use of designated private parties. Despite the fact that the airwaves belong to the entire American polity, the historical record suggests that spectrum in the United States has been largely monopolized by commercial interests with little concern for the public interest (McChesney, 1993; Pickard, 2008). However, this state of affairs is not inevitable. With the right policy interventions and combined with new technological capacities, the potential for changing course to dramatically increase spectrum access remains an achievable goal. Any path to reforming the spectrum management regime leads through two regulatory bodies, the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA).

Regulating Access to the Airwaves

The question of access is a critical element in determining whether a communications system is being operated in an open and participatory manner. Communication bottlenecks undermine the types of services offered, create artificial scarcity, and lead to increased pricing. Such vulnerabilities are exemplified by U.S. spectrum policy surrounding the licensure of the public airwaves, which dates back to the 1927 Radio Act, the 1934 Communications Act, and the founding of the Federal Communications Commission (FCC). The FCC, which holds jurisdiction over all non-Federal spectrum uses, including state and local public safety, makes frequency assignment decisions based primarily on the model of exclusive licenses. Although not all spectrum is divvied up in this manner, more than 95% of the public airwaves (under 30 GHz) are either reserved for governmental use or licensed to private parties (Kobb, 2001; NTIA "Redbook," 2008).[3]

Although tiny slivers of so-called "unlicensed" frequencies have generated enormous economic activity and innovation (everything from Wi-Fi devices to baby monitors and cordless phones co-exist within these frequencies), they are an exception to a regulatory norm that systematically fails to take advantage of the potential efficiencies of advanced communications technologies (New America Foundation, 2005). Wi-Fi use at 2.4 GHz and 5.8 GHz may be the poster child for the success of unlicensed spectrum, but the model has not yet been replicated widely in other spectrum areas despite its proven benefits.[4] In 2002, a "Spectrum Policy Task Force" was established to help the FCC identify needed reforms to better utilize radio spectrum. The task force released several promising reports that helped spur discussion on opening vacant channels in the television spectrum for unlicensed use, but it was disbanded in 2005 (FCC, 2002). Unlike spectrum access for private, state and local governments' use authorized by the FCC, any federal government use of spectrum falls under the jurisdiction of another regulatory body — one that controls as much, if not more, spectrum, but receives considerably less attention from interest groups and the press: the National Telecommunications and Information Administration.[5] Given our focus on federal spectrum, the remainder of the paper primarily deals with spectrum policy issues that fall under the NTIA's purview.

The NTIA and Federal Access to the Airwaves

The NTIA was formed as a sub-agency of the Commerce Department in 1978 to serve as the President's principal adviser on telecommunications and information policy, and to manage federal government's use of spectrum, including military use. Headed by the Assistant Secretary for Communications and Information, NTIA relies on the assistance of one of the oldest federal agencies, the Interdepartmental Radio Advisory Committee (IRAC), which NTIA chairs. IRAC, which helps coordinate federal use of spectrum, is composed of representatives from 20 federal agencies that rely on spectrum in carrying out their various responsibilities.[6] In addition to the main IRAC members, over four dozen

[3] In cases like the citizens' band (CB), spectrum is set aside for amateur use, or according to "Part 15" rules which allow some public wireless devices such as garage door openers and microwave ovens to operate in unlicensed spectrum.

[4] Another recent significant spectrum reform measure was the relocation of incumbent UHF broadcasters from the 700 MHz band in advance of the transition to DTV. It is important to note that these broadcasters received in return extensive government subsidies to help pay for system upgrades, customer premises equipment (i.e., the DTV converter box coupon program), and a de facto expansion of their broadcast license to allow for up to six broadcast channels for every one they held previously.

[5] We thank J.H. Snider for emphasizing this point.

[6] For a GAO overview of IRAC, see GAO-0401028. IRAC Representatives Effectively Coordinate Federal Spectrum but Lack Seniority to Advise on Contentious Policy Issues. September 2004.

additional governmental organizations use spectrum and must coordinate their needs via NTIA.[7] Like the FCC, NTIA allocates spectrum on the basis of an exclusive use by a licensee.[8]

Reallocations of government spectrum are difficult for a number of reasons. They involve coordination between the FCC and the State Department to develop a joint position that is then presented before the United Nation's International Telecommunications Union (ITU). Ideally, this process could be partially circumvented via spectrum sharing (discussed below), which is not a reallocation, but rather a repurposing that does not necessitate a dramatic shift in spectrum assignments. Nevertheless, government spectrum holders have little incentive to abdicate unneeded or underutilized spectrum since they pay only a nominal fee for access. A presidential task force was formed in 2003 to develop recommendations for federal agencies to utilize spectrum more efficiently. Two promising reports came out making recommendations for ascertaining underused federal spectrum.[9] The task force also helped create the Commerce Spectrum Management Advisory Committee (CSMAC).[10] The NTIA report that came out in March 2008 proposed several recommendations (discussed below), but thus far the issue has gained little attention (Nuechterlein & Weiser, p. 234; NTIA, 2003). The lack of movement can be at least partially attributed to institutional factors. The NTIA is more shielded from public pressures to disclose

[7] Currently, 69 federal agencies and departments utilize federal radio spectrum for communications, navigation, broadcasting, and other uses.

[8] There are some exceptions where government agencies share frequencies and networks. For example, NTIA literature notes that the USDA runs a National Interagency Fire Center where emergency replies can be utilized during emergencies and the Treasury Department operates a "Federal Commons" as an interoperable frequency assignment to be shared among all Federal agencies for law enforcement and coordination with state and local police during emergencies. See Federal Strategic Spectrum Plan, p. 3.

[9] For example, recommendation #7 called for "spot compliance checks and signal measurement surveys to verify the accuracy of the records of the Government Master File (GMF), identify congestion and instances of duplicative operations that could be combined, and evaluate the utility of underutilized spectrum. NTIA should use the results of these reviews in the development of new and improved spectrum management policies, and the Federal Strategic Spectrum Plan." See http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm and see also http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report2_06242004.htm

[10] The CSMAC

> advises the Assistant Secretary of Commerce for Communications and Information at NTIA on a broad range of issues regarding spectrum policy and on needed reforms to domestic spectrum policies and management to enable timely implementation of evolving spectrum-dependent technologies and services to benefit the public. The members are spectrum policy experts, appointed as 'Special Government Employees' from the private sector and balanced in terms of their points of view. Committee members offer expertise and perspective on reforms to enable new technologies and services, including reforms that expedite the American public's access to broadband services, public safety, digital television, and long-range spectrum planning. (http://www.ntia.doc.gov/advisory/spectrum/)

The CSMAC held its first meeting in 2006.

information and is less transparent compared to the FCC. J.H. Snider notes that often, specific federal agencies — not the NTIA — make key decisions regarding federal government spectrum use. Another significant distinction is that, unlike the FCC, the NTIA is not subject to the Administrative Procedure Act, and is therefore far less accountable to the public. Information such as spectrum assignments is not currently made public and even non-classified information held by the NTIA must be obtained via Freedom of Information Act (FOIA) requests (Snider, 2006). Snider spent more than a year attempting to acquire information from the various government agencies via FOIA requests but faced ongoing and substantial barriers to attaining access to this information. In addition, the NTIA keeps all of the information regarding federal allocations in an inaccessible and relatively secretive database known as the Government Master File. During our discussions, an often voiced concern among federal employees was that even governmental agencies themselves have a difficult time finding information on federal spectrum. Finally, since the NTIA also lacks the FCC's resources, reallocation costs pose a significant disincentive.

Government Spectrum Allocations and Uses

Government spectrum allocations range from weather surveillance and fire fighting by the U.S. Forest Service to ship monitoring and national security measures by the military. Available data suggest that a significant amount of this spectrum is under-utilized, and could at least be shared if not reallocated outright (McHenry, 2003; McHenry, 2004). There are several challenging aspects in dealing with government spectrum assignment that complicate reallocation efforts. First, it is difficult to identify where specific uses are located. Understandably, spectrum set aside for military use is often kept classified, but information showing how various agencies are using particular swaths of spectrum is also unnecessarily opaque.[11] Moreover, the relatively scarce information available online is often outdated.[12] Second, the use of particular bands may change with the season or geographic region. For example, some bands might be designated for communications during fire season in the Western states, but otherwise remain unused. Because of the general lack of publicly available data on precise federal spectrum location and uses, this paper provides a preliminary investigation rather than an in-depth analysis, which would be possible if more information (and additional spectrum use measurements) were made available. Nevertheless, there is increasing evidence suggesting that the application of spectrum-sharing technologies in federal spectrum would substantially alleviate the problem of broadband scarcity and greatly enhance wireless technological innovation. While these arguments have been employed in cases involving white spaces[13] and other underutilized pieces of spectrum, little attention has been given to government-monopolized spectrum.

It is estimated that the federal government wholly controls over 13% of all allocated spectrum bands and shares around 56% of all other bands, which translates to 270,000 frequency assignments to

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[11] An example of some of the most detailed information made available by NTIA can be seen in a nearly decade-old Office of Spectrum Management report, "Federal Long-Range Spectrum Plan," http://www.ntia.doc.gov/osmhome/LRSP/Final-LRSP.pdf

[12] As of October 2009, the NTIA's spectrum chart was dated October 2003 and does not include numerous changes to spectrum allocations that have happened during ensuing years.

[13] See FCC Docket #04-186.

federal agencies (Nuechterlein & Weiser, 233-4)[14]. Although it is rather imprecise about exactly which agencies control what spectrum, one NTIA chart estimates that 82% of the spectrum between 3MHz and 30MHz is allocated for use by the Federal Government.[15] Research by J.H. Snider calculates that federal government and shared spectrum account for 64% of all allocations under 3.1 GHz (2003). One of the biggest blocks is found at 225-400 MHz, which, according to Ben Kobb's *Spectrum Finder*, "is devoted to military aircraft, tactical and training communications, satellite links for ground, air, surface and subsurface users, rocket test and telemetry, position location networks and Presidential communications." There is reason to believe that not all of this spectrum is being well utilized since, as Kobb notes, "The FCC called on the government to offer some of this spectrum to the private sector," but the Department of Defense (DOD) "takes a dim view of such assertions. It regards the 225-400 MHz band as the single most critical spectrum resource of the military tactical forces" (p. 91). In addition, there are large sections of government spectrum between 902 and 1850 MHz and smaller swathes at 108-174 and 400-450 MHz.

Although general allocation data are available, current usage rates are difficult to ascertain given both the datedness and scarcity of data made available by authorities such as the NTIA and IRAC. Based on a variety of sources, however, we can make empirically-backed estimates as to how federal spectrum is being used. It is generally assumed that the DOD is the leading user of government spectrum.[16] Other agencies' spectrum usages are listed in the NTIA's Federal Strategic Spectrum Plan. For example, the report lists the Department of Agriculture's Forest Service use of conventional land mobile radio systems as concentrated in three bands: 162-174 MHz, 406.1-420 MHz, and 1710-1850 MHz (Spectrum Plan, B-160). Similar information is listed under each agency in terms of current use and future needs. However, it is difficult to know for certain how much of this spectrum is actually being used at any given time.

While few studies on actual spectrum use have been conducted, frequency use data were collected in six locations along the East Coast in 2004 and documented an average total spectrum use of less than 10% (3.4% in Great Falls, Virginia, 6.9% in Vienna, Virginia, 11.4% in Arlington, Virginia, 13.1% in New York City, New York, 1% in Green Back, West Virginia, and 11.7 % in Vienna, Virginia. What is clear from these data is that even in the midst of New York City during a national convention (when a far higher-than-average use of law enforcement and federal agency spectrum would be expected), the vast majority of the public airwaves still remains unused (McHenry, 2004). Another compelling study based in

[14] According to the fiscal year 2004 Adjusted Agency Prorated Reimbursement Report FOIAed by J.H. Snider at the New America Foundation, there were 265,900 frequency assignments as of October 3, 2003.

[15] For an overview, see the new CED chart: www.cedmagazine.com/WorkArea/downloadasset.aspx?id=157960

[16] This assertion is borne out by figures from the FY 2004 Adjusted Agency Prorated Reimbursement Report which shows that the Air Force holding 10.6% of federal spectrum allocations, the Army holding 13.0%, the Coast Guard holding 6.4%, Department of Homeland Security holding 1.3%, and the Navy holding 13.6%. Under the DOD's spectrum requirements, it describes its strategy as a "Network Centric Architecture Vision" that consists of "autonomous, self-healing, ad hoc networks, producing a shared information environment." Elsewhere it notes that "SDRs programmed with rules will dominate the future battlefield." See Spectrum Plan, B-174.

Washington D.C. indicated that government spectrum was grossly underutilized in a major metropolitan center (McHenry, 2003).

Other data further raise questions about how federal agencies are using spectrum. Material retrieved through the Freedom of Information Act and kept in the New America Foundation's archives contain a list of government agencies and the number of spectrum assignments from 2004. Some of the organizations that have spectrum are somewhat counter-intuitive. For example, the Supreme Court has been given 13 "assignments" of spectrum; the Library of Congress — 9; the National Archives and Records Administration — 6; the National Gallery of Art — 12; the Smithsonian — 73. The precise measurement of "number of spectrum" is still unclear, and pales in comparison to the Department of Energy's 9,312 and the Air Force's 28,227. Nonetheless, despite its ambiguity, this data raises vexing questions about how government spectrum is being utilized and why further information is being kept out of the public record.

The Federal Spectrum Strategic Plan

In 2003, President Bush announced the "Spectrum Policy Initiative," establishing a:

> U.S. spectrum policy for the 21st Century that will foster economic growth; ensure our national and homeland security; maintain U.S. global leadership in communications technology and services; and satisfy other vital U.S. needs in areas such as public safety, scientific research, Federal transportation infrastructure, and law enforcement. (Whitehouse, 2003)

In 2004, as part of this initiative, the President directed Federal agencies to formulate, within one year, agency specific strategic spectrum plans that include spectrum requirements for future technologies or services, planned uses, and suggested spectrum efficient approaches to meeting these requirements (Whitehouse, 2004).

Finally released in March, 2008 after several years' delay, the Federal Spectrum Strategic Plan is a mere 13 pages of analysis, but is followed by 200-plus pages of appendices that describe in some detail the uses of spectrum by several federal agencies.[17] Instead of pointing out places where spectrum is underutilized, most of the agencies make the case for needing more spectrum. One exception is where the Department of Transportation explicitly identifies seven frequency bands that "are no longer needed to support its mission requirements: 9 - 14 kHz; 90 - 110 kHz; 4400 - 4500 MHz; 16.2 - 17.7 GHz; 24.250 - 24.650 MHz; 25.250 - 27.5 GHz; and 36 - 38.6 GHz." The Department of Agriculture's Forest Service's use of conventional land mobile radio systems, which is concentrated in three bands: 162 - 174 MHz, 406.1 - 420 MHz, and 1710 - 1850 MHz, recently vacated the 1710 - 1755 MHz band that was auctioned for advanced wireless services. The Department of Energy and Tennessee Valley Authority also vacated

[17] The report includes spectrum information from the following groups: Broadcasting Board of Governors, Department of Agriculture, Commerce, Defense, Energy, Homeland Security, Interior, Justice, State, Transportation, Treasury, Veterans Affairs, National Aeronautics and Space Administration, National Science Foundation, Tennessee Valley Authority, U.S. Coast Guard, and U.S. Postal Service.

from this band, suggesting at least the possibility that these agencies might be sitting on more under-utilized spectrum (Spectrum Plan, pp. B-160, 179, 212). Given that at least three agencies had to vacate the same spectrum bands suggest that these are very general parameters.

The Spectrum Plan's policy prescriptions are remarkably vague, although it makes references to a "new spectrum management model" that aims for "dynamic spectrum access" based on time, location, and frequency. While making allowances for expanding military needs, the report also articulates the need for expanded spectrum access for "private sector growth and innovation," as well as to "more efficiently utilize the spectrum resource through economic and non-economic incentives." It further mentions "incentive mechanisms," including "secondary markets, property rights, sharing and fees" (Spectrum Plan, p. 10). The concluding recommendations section avows to continue incrementally improving upon spectrum management, but does not go into specifics. However, there are some noteworthy statements earlier in the report. For example, the Spectrum Plan states, "Many agencies plan to implement smart technologies such as SDR." It further notes that the

> NTIA is monitoring the development of such spectrally efficient approaches and encourages additional technology developments, particularly in the area of dynamic spectrum access. The NTIA will look to both the government and private sector for assistance and support in devising the necessary plans and strategies that will allow evolution of the spectrum management system . . . (Spectrum Plan, p. 9)

The report lists a number of improvement measures such as "narrowbanding land mobile channels" and increasing "management flexibility with land mobile service national frequency allotment plans" (Spectrum Plan, B-6, B-7). According to the report, the largest Federal users of the land mobile service are the DHS, Army, Air Force, Navy, DOI, and DOJ (p. B-10).

In summary, the Spectrum Plan advocates new policies and incentives for sharing underutilized federal spectrum with non-federal entities. Of significant note, the NTIA report concludes — very similarly to our own assessment — that "Currently, regulatory hurdles prevent federal and non-federal spectrum users from efficiently sharing spectrum . . ." (Spectrum Plan, pp. 9-10). Elsewhere, the report notes, "Several agencies had called for rule changes and policy reforms to improve interoperability and sharing in emergencies." It also notes that the "NTIA, with the advice of [IRAC], recently took steps to address the need for non-Federal entities to use public safety spectrum in appropriate situations" (Spectrum Plan, p. 10). Based on lessons learned from Hurricane Katrina, the need to share spectrum during emergencies is abundantly clear.[18] The NTIA seems amenable to this and other sharing imperatives. However, while appearing to be advocating for sharing federal spectrum with non-federal users via smart technologies, the NTIA report is vague about implementation and timelines for sharing use. Moreover, shared use requires data on actual use, including both the allocated use and the claimed use by licensees. Thus, a

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[18] See, for example, the following reports submitted to the FCC: http://www.nella.org/jra/dr/katrina/jeff-allen-talk.pdf. The full report is located at the following: http://www.nella.org/jra/dr/katrina/katrina-final-report.html. See also the following comments supporting ad hoc networking:http://www.mediaaccess.org/file_download/164

logical first step given the conclusions of the Federal Spectrum Strategic Plan, would be a spectrum audit documenting allocated, assigned, and actual uses of all federal and commercial frequency bands.[19] Although the existence of this data is presumed given the frequent references to "underutilized" spectrum (and a single mention of the Government Master File), more precise information is needed (p. 3). Indeed, the overall lack of information and the unmet potentials of more efficient utilization are problems for public policy. [20]

A Need for Spectrum Reform

The FCC and NTIA have continued to privilege a model for licensure that allows only a single entity to broadcast on a given frequency, often at a specific power level and geographic location. This "command and control" mentality of spectrum management — by which the FCC and NTIA allocate spectrum into bands, assign and prescribe how these bands will be used, and oversee the method of giving exclusive rights to specific licensees — is woefully outdated given current technologies and spectrum needs. While digital technologies have radically transformed almost every facet of current society, the U.S. licensure regime is predicated on use of the public airwaves as if we were still utilizing pre-computer (analog) technologies dating back to the World War I era. Tim Wu wrote an op-ed piece in *The New York Times* likening U.S. spectrum policies to "Soviet Style Rules . . . [governing] . . . a command and control system dating from the 1920s." Wu estimates that "At any given moment, more than 90% of the nation's airwaves are empty" (2008). Other analysts referred to current spectrum management policy as a "paradigm for economic inefficiency" (Weiser & Hatfield, 2005). Whether one looks at the debate over low-power FM radio licensure, interference temperature, or unlicensed devices in unused television broadcast bands, the story is invariably the same: incumbent interests already invested in licensed frequencies seek to prevent competition by maintaining the antiquated regulatory status quo. In this way, incumbents dramatically slow down change or stop it altogether. "Among neutral observers," Nuechterlein & Weiser note, "there is little dispute that . . . the current spectrum regime requires a comprehensive overhaul" (p. 239). With such an overhaul in mind, an in-depth reassessment of federal spectrum usage and policies is a necessity.

Models of Spectrum Reform

Generally speaking, in recent years, two conflicting models have repeatedly faced off in discussions on spectrum management policy reform: the property rights and the commons approach. The

[19] As of this writing, Senator Kerry's office has proposed legislation to conduct this assessment; however, the bill only covers frequencies under 3.5 GHz. In the House, a similar bill has been proposed to conduct a spectrum audit for all frequencies under 10 GHz. While both bills have been introduced, thus far they have failed to move forward through the legislative process.

[20] As of Fall 2009, internal discussions amongst White House staff have already begun looking at the question of how best to identify current spectrum use amongst federal agencies and how to implement reforms to maximize shared use while minimizing disruption and harmful interference for current users. One possible outcome from these discussions would be a presidential directive to implement the assessments called for in this paper.

former is most often associated with Ronald Coase (1959) and the latter is given clearest expression by Yochai Benkler (2006). Fierce debates have raged between these two camps over the past several years. We do not wish to merely rehash what is, by now, a fairly familiar argument. However, a brief overview of this debate is necessary for us to provide the foundation upon which we argue for a third option for spectrum reform that supports unlicensed use (a major component of the "commons model") but protects primary license holders (a major component of the "property rights model").

The "commons model" views spectrum as a public resource to be shared. In this sense, the government treats the spectrum like a public park. The "property rights model," on the other hand, sees the spectrum as something to be owned and managed exclusively by private parties. According to this model, the FCC treats the spectrum as it would treat private land (Nuechterlein & Weiser, pp. 239-240). Each model contains different assumptions about how the spectrum should be controlled and operated to reach its highest potential and what interests should be advanced by these uses.[21] As with all media systems, the structural attributes of spectrum management are bound up within larger political economic relationships. In this case, spectrum policy has shifted toward privatizing the public airwaves, reflecting broader shifts in the economic and political landscapes over the last several decades to market-based approaches and deregulation. This shift in the reigning regulatory paradigm has combined with the fact that, increasingly, spectrum is being used less for traditional broadcast media, and more for data communications services like cell phones and Internet access.[22]

In turning to the private property model, it is instructive to recall that the 1927 Radio Act allowed for "the use of such [radio] channels, but not the ownership thereof." This "nonownership" clause was seamlessly transferred into the 1934 Communications Act, establishing the foundation for licensure of the public airwaves. However, Ronald Coase, in his seminal 1959 article, "The Federal Communications Commission," characterized the 1927 Radio Act as a missed opportunity for asserting a property rights regime of spectrum management in which market operations would dictate allocations and assignments (Hazlett, 1990).[23] This article, which helped launch an intellectual movement in support of spectrum

[21] It should be noted that hybrid models and other alternatives are also emerging as well. The Spectrum Policy Task Force reached a conclusion that a mix of flexibly-licensed spectrum and unlicensed spectrum is superior. For an economic case for unlicensed use of white spaces, see Pierre de Vries, "Populating the Vacant Channels," New America Foundation Working Paper, 2006. http://www.newamerica.net/publications/policy/populating_the_vacant_channels and the forthcoming New America Foundation Whitepaper, "Seven Key Options for Spectrum Allocation and Assignment" by Sascha D. Meinrath and Benjamin Lennett (in press).

[22] During the Fall 2009, public hearings held by the FCC regarding the National Broadband Policy, numerous commercial wireless incumbents stated their need for additional spectrum to meet expected data demand over the next half-decade (see: http://www.fcc.gov/workshop for transcripts and video recordings of these panels).

[23] Proponents of Coase tend to be more focused on the private market with respect to assignments primarily – the equivalent of real property lots – and less so on allocations – the equivalent of zoning (which is pre-assignment). Though Thomas Hazlett suggests that Congress did not approve of property rights in spectrum, the de facto establishment of a property rights regime is largely what transpired.

privatization, lamented the fact that these early laws codified the public interest doctrine and established the spectrum as public property, albeit under federal oversight of select users with exclusive licenses. According to the "Coase Theorem," spectrum policy based on public interest grounds was fundamentally flawed. Instead, Coase believed that a clear assignment of exclusive and permanent property rights in frequencies would allow the free market to allocate resources to their most efficient use — assuming that transaction costs are kept low. Coase argued, "Since it is generally agreed that the use of private property and the pricing system is in the public interest in other fields, why should it not also be in broadcasting?"[24] Building on this analysis, telecommunications firms and their lobbyists, industry-funded non-profit organizations, as well as many independent research institutes and academics, have fought for decades to shift spectrum licensure toward a more Coase-like private property model.

Another market-based approach, though falling short of treating the spectrum as private property, replaces the comparative hearings model by allocating spectrum to the highest bidder via auctions (Weiser & Hatfield, 2008; Hazlett, 2008). This practice became increasingly standard in the 1990s under the Clinton administration.[25] The private property approach to spectrum management generally views the market as a neutral if not benevolent arbiter of a crucial resource. Given its inherent biases toward the monetization of "public interests" (and externalization of benefits that cannot be commoditized), many critics see this approach as disproportionately benefiting powerful economic interests and privileging profit-making uses, especially given the prohibitive costs for purchasing exclusive rights to spectrum. In light of this bias, policy historians Moss and Fein (2003) provide a useful corrective

[24] This is, of course, a highly debatable assertion. It is noteworthy that two of the major figures Coase set out to challenge in his article were Charles Siepmann and Dallas Smythe, both of whom were involved in the FCC's 1946 "Blue Book" initiative, which aimed to codify broadcasters' public service responsibilities. The key for Coase vis-à-vis efficiency is that the initial assignment of rights is unambiguous, which is why "property" in the electromagnetic properties of the atmosphere – which is very technology dependent – is more problematic than Thomas Hazlett concedes, especially when they are fluctuating based on the parameters that make a frequency variously "white."

[25] Other market-oriented reforms dictated that personal communication services and secondary markets were operated in ways that treated spectrum as private property. The past few years have witnessed a renewed call for further privatization of spectrum. Although Hazlett differs with Weiser and Hatfield regarding potential drawbacks, these leading spectrum researchers have supported in their writings the basic principle that in many, if not most cases, spectrum is best utilized within a private property rights regime. Weiser & Hatfield have explained how the core Coaseian presumption of clearly defined and stable property rights is not typically true with spectrum (as it is with real estate). See also, Michael Calabrese, NAF Working Paper "Principles of Spectrum Reform," 2001. Calabrese makes the important point that the electromagnetic properties of the atmosphere are not anything like real property. Cementing the banding (zoning) plan developed for analog technologies into permanent property boundaries could be the equivalent, in a digital world, of requiring that residential lots be sold only in round plots.

to Coase's assumption that the driving concern behind the 1927 Radio Act was primarily technical and economic.[26]

Another alternative to Coase's model is posited by Benkler in his discussion of a "commons-based peer-production" model, which advocates collaboration and sharing over privatization of resources:

> Removing property and contract as the organizing principles of collaboration substantially reduces transaction costs involved in allowing . . . potential contributors to review and select which resources to work on, for which projects, and with which collaborators. This results in allocation gains, that increase more than proportionately with the increase in the number of individuals and resources that are part of the system. (Benkler, 2002)

Benkler (2002) argues that these models use a "variety of technological and social strategies to overcome the collective action problems usually solved in managerial and market-based systems by property and contract." Moreover, the economic core of Benkler's critique holds that exclusive licensing is the economics of centralized infrastructure investment, and control by a network operator; it can do better at ensuring quality of service for its defined function, but is slow to evolve or innovate. In contrast, unlicensed spectrum-sharing is the economic model of the Internet, with most control and investment decentralized to the edges of the network, which promotes more consumer choice and rapid innovation (Snider, 2006b; Zittrain, 2008). Such critiques have proliferated even as the property rights model has increased in prominence in recent years. Indeed, there are accumulating signs that commons-inclusive models are beginning to gain favor as the inefficiencies of single-use licensure become increasingly clear.[27]

Contrary to the general economic and political trends outlined above, a somewhat neglected scholarly tradition addressing the normative concerns as well as the practical benefits of sharing resources also exists. Frequently referred to as a commons-based approach to the management of communications systems, Benkler's model emphasizes cooperation and innovation as opposed to privatization and enclosure (Comstock & Butler, 2000; Hamelink, 2000; Lessig, 2001; Benkler, 2004; Benkler & Nissenbaum, 2006). For example, noting how many of the efficiencies associated with a property rights regime often constrain action, Benkler's *Wealth of Networks* lays out the benefits afforded by a commons-based policy orientation:

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[26] Moss and Fein demonstrate that, in fact, officials were less concerned about devising an economically efficient means of allocating scarce spectrum and much more concerned about preventing monopoly markets and the concentration of political power. By privileging democratic principles over economic concerns, at least some government officials involved in the policy debates aimed to create a diversity of voices on the airwaves. Nevertheless, such normative concerns have been largely stripped from the property rights model of spectrum management.

[27] For example, real time micro-auctioning/micro-payments is a potential hybrid approach – allowing both for primary licensure and the opportunistic reuse of underutilized spectrum by third parties. See Meinrath and Lennett (in press).

> Commons are another core institutional component of freedom of action in free societies, but they are structured to enable action that is not based on exclusive control over the resources necessary for action . . . Now that material conditions have enabled the emergence of greater scope for nonmarket action, the scope and existence of a core common infrastructure that includes the basic resources to produce and exchange information will shape the degree to which individuals will be able to act in all the ways that [are] central to the emergence of a networked information economy . . . (Benkler, 2006, p. 24)

Although Benkler discusses the “socioeconomic system” of the commons mostly in relation to Web-based peer production, many of its principles are contained in notions of dynamic spectrum utilization. These principles are typified by two key characteristics: decentralization and “the use of social cues and motivations, rather than prices or commands, to motivate and coordinate the action of participating agents” (Benkler & Nissenbaum, 2006, pp. 400-403). Other proponents of the feasibility of the commons approach include Mark Cooper, who demonstrates that unlicensed spectrum-sharing is ideal for optimal efficiency and collaborative production, though he also allows for a flexible, quasi-property licensed approach (Cooper, 2006).

Given that all technologies are inscribed with social values that foreclose certain possibilities while encouraging others, a growing number of scholars emphasize how the emergence of new radio technologies lend themselves to a commons model via “spectrum sharing.”[28] The advent of computers, innovations in transceiver technologies and digital communications have combined to produce new platforms for dynamic spectrum sharing that are more efficient and cost-effective than anything available to prior generations of spectrum users.[29]

[28] For an online resource that provides ample materials promoting “open spectrum” see http://openspectrum.info/

[29] The October 2009 Berkman Center report prepared for the FCC, “Next Generation Connectivity: A review of broadband Internet transitions and policy from around the world” extends shared use into the wireline world. The study, headed by Yochai Benkler, provides a comparative analysis documenting that shared (open access) policies have proven more successful than single-user/private networking regulations. The reports findings for wireline data communications directly parallel many of our recommendations for the wireless realm with similar shared use and open access implications. As the Berkman report underscores, their

> most surprising and significant finding is that 'open access' policies—unbundling, bitstream access, collocation requirements, wholesaling, and/or functional separation—are almost universally understood as having played a core role in the first generation transition to broadband in most of the high performing countries; that they now play a core role in planning for the next generation transition; and that the positive impact of such policies is strongly supported by the evidence of the first generation broadband transition. (p. 12)

Report available online:
http://www.fcc.gov/stage/pdf/Berkman_Center_Broadband_Study_13Oct09.pdf

The Promise of Smart Radios and Spectrum-Sharing

With the increasing significance of spectrum for telecommunications (ranging from satellite TV and digital radio to Blackberries and iPhones), both the costs of spectrum licenses as well as the potential social benefits have increased dramatically. [30] Advances in wireless telecommunications technology have driven the demand placed upon radio frequencies as people rely more on cell phones and Wi-Fi, and less on traditional broadcast media like terrestrial television. Changing technologies have also expanded the potential dynamism in spectrum sharing schemes according to time, direction of arrival, frequency, and the physical location based on latitude, longitude and altitude (Matheson, 2005).

The Spectrum Policy Task Force's (SPTF) "Unlicensed Devices and Experimental Licenses Working Group" proposed another method of introducing commons to exclusive-use bands by introducing "underlay" rights, thereby allowing unlicensed users to access the exclusive use bands in such a way that prevents interference with the license holder. Advances in smart or cognitive radio (CR) and software defined radio (SDR) technologies have fundamentally expanded options for spectrum use in ways that have yet to be acted upon by regulatory agencies. Traditionally, the artificial scarcity of government licenses to utilize spectrum has led to quandaries in finding frequencies to support wireless broadband Internet. However, these new developments have created opportunities for dynamic spectrum sharing, thus potentially ending the persistent problem of artificial spectrum scarcity by shifting the spectrum paradigm from static to dynamic (Werbach, 2002). This especially holds true for utilizing unused spectrum, referred to as "white spaces."

These emerging "smart" wireless technologies seem to naturally encourage a commons-based model. "Smart" and cognitive radios, for example, rapidly scan and process spectrum use in real time and identify underutilized frequencies. In essence, these systems are aware of their radio frequency (RF) environment and can adapt to changes in this electromagnetic space. Thus, within a given band, two transceivers can send data between each other while "frequency hopping" among available open frequencies. By opportunistically occupying unused frequencies these devices are far more efficient than

[30] For example, consumers have a preference for variety as well as quality in their media consumption habits. In spectrum environments that are not inherently noisy/prone to interference, and when consumers have a preference for variety, the commons has the potential to create more consumer surplus. See E. Bayrak "Welfare Effects of Spectrum Management Regimes," *in Proc. of the 3rd IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks*, October 2008. Also see Bayrak, Ergin, 2008 "Valuing Time Intensive Goods: An Application to the Wireless and Wired Internet," *mimeo*, Department of Economics, University of Southern California, where the author found consumer surplus that accrues to consumers who connect to the internet through Wi-Fi home networks is at least $824 per household per year more than the consumer surplus of wired network users. As a result, Wi-Fi home networking alone (among many other users of unlicensed spectrum) creates considerable consumer surplus, and can be a lower bound on the consumer surplus of unlicensed spectrum. Assuming roughly 30 million Wi-Fi home network users, the total consumer surplus is nearly $25 billion.

traditional "dumb" technologies, which often broadcast on a single frequency, particularly in bands where many users are sharing the same frequencies.

White space devices (WSDs) employ spectrum sensing technologies (so-called, "smart radios") to automatically detect occupied frequencies (Jones & Phillips, 2007). These technologies allow WSDs to identify and utilize the unassigned frequencies between broadcast television channels and outside the coverage areas of licensed broadcasters. They can utilize the unoccupied frequencies in the television bands for digital communications — including broadband networks — forming the foundation for a new communications era that incorporates advances in miniaturization and transceiver technologies to better meet the needs of the general public, government agencies, and commercial interests. WSDs facilitate and improve home, business, city, community, and regional networks, enabling everything from increased rural and municipal broadband access, to enhanced public safety communications, more reliable video conferencing, and the potential for any number of future consumer applications or devices. WSDs facilitate more affordable broadband deployment, particularly in underserved rural areas, as well as stimulate new innovations in consumer products and services. The military has been testing WSD technology for years and has run numerous tests demonstrating its feasibility as a part of the DARPA XG project. In a decisive turning point in the WSD feasibility debate, in October 2008, the FCC Office of Engineering and Technology released its report "Evaluation of Prototype TV-Band White Space Devices – Phase II," which concluded that the "proof of concept" of WSDs had been met, potentially opening a new chapter for broadband deployment and technological innovation (Shared Spectrum, 2006; FCC, 2008).

These technological developments underscore the fact that our contemporary moment marks a critical juncture in telecommunications history akin to the advent of the telephone, radio, or television. Computers and other digital technologies have enabled an entirely new communications medium – distributed, portable, "device as infrastructure" networks. Within these networks, end-user devices are "smart," capable of adapting to changing environments and maximizing efficient use of available spectrum to deliver broadband connectivity. A coalition of consumer and other public interest groups, along with a number of high-tech companies, have actively supported the widespread adoption of these innovative new technologies.

As is often the case, however, technology has outpaced regulation, and new policies are needed to end the artificial spectrum scarcity. Unfortunately, as Nuechterlein and Weiser observe, "today's spectrum incumbents — including broadcasters and the government itself — use their political clout to stifle competition by keeping a firm chokehold on large swaths of spectrum that could be put to more efficient uses . . ." (p. 226). Now that the scarcity rationale no longer holds, traditional spectrum management strategies are largely obsolete. "Just as the First Amendment bars the government from limiting who can own a printing press," Nuechterlein and Weiser suggest "it might well bar the government from restricting access to the airwaves as a medium of communication in the hypothesized word of super-abundant spectrum" (p. 230). These arguments for expanded public access to the public's airwaves will only continue to proliferate as arguments for shoring up an outdated status quo — to the benefit of incumbent power and the detriment of everyone else — become increasingly less tenable (New America Foundation, 2005).[31]

A Third Option for Spectrum Reform

Our proposed model of spectrum management assumes that protecting important government services must remain a priority. Fortunately, smart technology-enabled spectrum-sharing will be able to simultaneously open unused spectrum while protecting legacy uses. John Stine provides a brief synopsis of one potential solution to the problem of protecting primary (government) spectrum users, Synchronous Collision Resolution:

> The Synchronous Collision Resolution (SCR) MAC protocol enables a strict arbitration of spectrum access based on spectrum rights thus enabling a hierarchy of networks in the same spectrum that always guarantees the primary rights holder precedence. Second, it autonomously manages the use of an arbitrary number of channels in the same network all of which support the network achieving a higher capacity. The third and most exciting idea is a new Fast Command and Control model for spectrum management. (Stine, 2005)

In less technical terms, technologies like SCR . . .

> arbitrate the primary and secondary use of both the channel and the network...On one extreme, the primary and secondary users may have completely isolated networks and on the other extreme primary and secondary users fully cooperate to form a single network where access rights transfer with packets. (Stine, 2005)

Furthermore, since the spectrum management scenarios can be built into the software of cognitive radio devices, they can be dynamically shifted (for example, to opportunistically reuse existing networking infrastructure during a natural disaster).

SCR is only one option out of many for ensuring that primary spectrum users maintain precedence over specific bands while allowing additional users to opportunistically reuse what would otherwise go to waste. Unlike most commons, spectrum bands are returned to 100% usability millisecond by millisecond and any underutilized capacity is lost forever. Thus, a tragedy of the anti-commons (i.e., massive inefficiencies and waste of exclusive licensure) exists throughout the RF space. Shared use helps prevent this tragedy. In much the same way that the Unlicensed National Information Infrastructure devices (U-NII) in the 5GHz radio band are shared by military radar and unlicensed 802.11a Wi-Fi devices, additional government bands can be shared using new technologies. Within the U-NII band, the FCC found that "the existing operations include Government radiolocation systems; mobile satellite feeder links;

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[31] The share of the DTV band (channels 2-to-51) that will be vacant after the February 2009 end to analog transmission ranges from 30% in the most congested, coastal markets (e.g., Trenton, N.J.) to 80% or more in small town and rural markets (e.g., Fargo, N.D.).

amateur operations; industrial, scientific, and medical operations; other unlicensed Part 15 operations; and proposed ITS [intelligent transportation systems]," and yet still agreed that sharing primary and secondary use was both feasible and desirable. The FCC also determined that it would "allow U-NII devices in this band to operate on a technology-neutral basis," stating that "We believe this will provide manufacturers flexibility in designing U-NII products and thus will provide consumers with greater choices" (FCC, 199, Paragraph 72).

It should be noted that there are well-founded concerns about interference and other potential drawbacks with spectrum-sharing schemes. As Weiser and Hatfield sum up,

> the FCC should continue moving ahead to implement different proactive and reactive measures that will provide users of commons access spectrum with important assurances that new services and products will not be compromised either by bad actors or poor coordination. (p. 132)

Today, there are new technologies in development to further increase spectral efficiency and protections for primary users. Additionally, there are ample regulatory precedents for sharing spectrum among primary government and private users and secondary unlicensed users. The most efficient spectrum-sharing regimes will make use of networks of cognitive (smart) radios to maximize spectral density and minimize interference. According to Weiser and Hatfield, "Two notable examples of such [spectrally efficient] technologies are 'spread spectrum' and 'cognitive radios,' both of which can be used to avoid creating large 'white spaces' (i.e., unused or underused bands) in the spectrum" (p. 109). Similarly, Cooper describes the technological foundations for spectrum-sharing hardware:

> An agile radio is a software-defined radio, one that can change its use of frequencies, power, and modulation without changing its hardware. In this sense, it is agile – as it can move around the spectrum. Frequency agile radios are a subset of the broader category, which can be agile in other dimensions (power and perhaps wave form). An agile, software defined radio is the basic building block of the new communications network. Adding sensors and a reasoning system to an agile radio gives us a cognitive, intelligent, or smart radio. Cognitive radios are aware. They sense the network and store the rules of the road. Embedded logical systems allow them to decide when to transmit without breaking the law. Cognitive radios can be combined into systems. The cognitive system adds a layer of intelligence to the communications network by looking at the overall topography of the network. (2006, p. 20)

Research into multi-tier networks has been a growing field of inquiry in recent years. Chandrasekhar and Andrews (2008) posit that "a decentralized spectrum allocation strategy as an alternative to centralized/coordinated frequency assignment in a two-tier network" can dramatically increase area spectral efficiency and network capacity. Another group of researchers conducted an in-depth analysis of opportunistic spectrum access and found that "*The Open Spectrum* approach to spectrum access can achieve near-optimal utilization by allowing devices to sense and utilize available spectrum opportunistically." Through their analyses, proofs, and simulations, they demonstrate that a distributed system "provides benefits comparable to the centralized approach while drastically reducing computation complexity." Though only an initial foray into this new realm of opportunistic spectrum reuse, they reached the same conclusion as Cooper: that opportunistic reuse of spectrum is itself optimized through the use of non-centralized (ad-hoc) networking systems (Peng, Zheng, & Zhao, 2006). And with the advent of an increasing number of potential ad hoc devices (e.g., iPhones and Android phones, X-boxes and portable media players) within the consumer market, the benefits that would accrue to spectrum users will increase exponentially over the ensuing decade.

Grokop and Tse (2008) address the issue of sharing spectrum among different wireless networks and discover that there is a natural, game theory-based rational for cooperating among many wireless networks. Accordingly, they demonstrated that the Nash Equilibrium was often attainable, even among rival networks and "that contrary to ones intuition, there can be a natural incentive for devices to cooperate to the extent that each occupies only a fraction of the available bandwidth. Such results are optimistic and encouraging. We suspect it may be possible to extend them to more complex operating protocols such as those that employ carrier-sensing to determine when the medium is free."[32] In addition to technical feasibility, previous research suggests that the economic model for unlicensed sharing affords compelling advantages: low barriers to entry, low transaction costs, and flexible, decentralized investment at the edges of the network.

Altogether, whether one looks at the game theory, technological underpinnings, RF environment simulations, or mathematical proofs, as Cooper summarizes, "the predominant opinion is that information sharing and cooperation will greatly improve the management of the spectrum commons" (2006, p. 24). Since the spectrum commons provides far better spectral efficiency than command and control infrastructures, spectrum regulators must ensure that the necessary transitions are made as new technologies become available to achieve these efficiencies. Given that government agencies have already taken the lead in this area, and given the precedent they already set to encourage spectrum-sharing, opportunistic spectrum reuse of federal bands is a natural place to greatly increase shared access to the public airwaves.

Implications & Policy Recommendations

The roll-out of new spectrum-sharing technologies holds profound implications for the future of telecommunications networks. Based on the data available, there is an abundance of underutilized spectrum that could be shared with a wide range of important services. Indeed, the NTIA's Spectrum Plan

[32] A Nash Equilibrium is where every actor believes they have made the best decision taking into account others' decisions. This is not always the ideal situation when looking at externalities, as in the case of business cartels, but does hold profound implications given the benefits that would accrue to all spectrum users were Nash equilibrium achieved for many spectrum uses. Thus, for example, rather than a half-dozen government agencies holding exclusive licensure over a 50 MHz band (yet requiring 75 MHz of space on rare occasion). By cooperatively sharing spectrum (i.e., allowing opportunistic reuse of unutilized frequencies), all six agencies would have access to the spectrum they need, even on the rare occasions when they need 75 MHz.

report states that sharing is both feasible and desirable, even if implementation plans are vague. Increasingly, policy makers are entertaining a model of spectrum-sharing.[33] Therefore, it is time to begin discussing what this sharing scheme should look like. In the following, we offer a set of recommendations for developing a sharing plan based on opportunistic unlicensed use (i.e., one that may be partially but is not fully monetized), and is based on publicly available data on current usage:

Recommendation 1: Share Spectrum Instead of Leaving it Underutilized

By most measurements, current spectrum use is nowhere near full capacity. As noted above, during the 2004 RNC convention in New York City — when one would expect the local frequencies to be at peak usage — only 13.1% of spectrum was in use (McHenry, 2004). Currently there is an incentive for incumbents to squat on vacant spectrum instead of sharing it. Since the marginal costs of simply adding new users are nearly non-existent, the main barriers to moving forward with implementation are the education of decision-makers and the political will and leadership to push federal agencies to share their spectrum with the general public on a secondary basis.

Recommendation 2: Share Spectrum Before Auctioning

Revenues of spectrum auctions have not meaningfully benefited the general public. J.H. Snider, for example, estimates that while the U. S. has nominally established a spectrum auction system, this system has distributed public assets for only 10% of its value (Snider, 2007).[34] Instead of auctioning spectrum, a more ideal solution would have individual federal agencies incentivized to share their spectrum. The fact that the military agreed to share its radar band without monetary compensation provides us with a powerful precedent. In particular, we do not advocate for metering or other schemes for monetizing underutilized spectrum since doing so would create additional barriers to entry as well as transaction costs, and thus fail to usher in a new and diverse set of spectrum users.

Recommendation 3: In the Near-Term, Share Spectrum Instead of Reallocating

New technologies like smart radios adapt to dynamic scenarios where multiple users can share the same spectrum and hop frequencies as necessary. Moreover, multiple sharing strategies are possible, based on time division, angles of antennae, and geolocations of transceivers. Sharing is much easier than having incumbents, such as federal agencies, migrate to other bands — a process that is both time-consuming and costly. By this measure, dynamically sharing instead of reallocating spectrum better ensures the timely realization of more efficient spectrum management paradigms.

Recommendation 4: Share with Secondary Users While Protecting Federal Primary Use

Government agencies may have regular, intermittent, or extraordinary need for their allocated spectrum. Therefore, we are proposing a "third option" for spectrum use, one that neither relies entirely on commons-based sharing nor on market operations. This could take the form of a general regulation,

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[33] In earlier meetings the authors held with NTIA and FCC officials during the Bush administration, White House support for the implementation of spectrum sharing appeared to be lacking. However, based on more recent meetings with senior FCC, NTIA, and White House staff, there are early signs of a growing political consensus that the time has come to implement shared spectrum access reforms. .

[34] There are exceptions for certain categories, like public safety and terrestrial broadcasting.

legislation, or presidential directive supporting shared use of government bands and should maintain primary use for the agency to which the specific frequencies are allocated. Accordingly, opportunistic unlicensed use would be secondary to agency needs. Numerous technological solutions exist to ensure the primacy of government use while supporting unlicensed reuse of available frequencies. Therefore, implementation should be technologically neutral and certification of devices should focus on ensuring that primary uses are protected (e.g., by geolocational database or RF sensing). Because different manufacturers may choose to implement different solutions for opportunistic spectrum reuse, information on spectrum use (e.g., modulations, frequencies, reception sensitivities of equipment to out-of-band emissions, etc.) must be provided by government agencies so that proper equipment certification criteria can be drawn up for each band. Bands should be viewed as modular elements so that consumer equipment manufacturers may choose to support the use of specific frequencies depending upon the technical specifications and certification criteria provided. Government prioritization would be integrated into contention protocols in devices utilizing shared spectrum.

Recommendation 5: Reserve Repurposed Spectrum for Unlicensed Use

Shared federal spectrum should be reserved for unlicensed use since unlicensed optimizes flexibility for critical ad hoc operations (e.g., emergency response and natural disasters) and supports the creative deployments of new technologies. While traditional licensure creates a significant barrier to entry and facilitates massive inefficiencies in spectrum use, smart technologies render such licensure unnecessary. Moreover, unlicensed access eliminates the transaction costs of utilizing available frequencies. As noted earlier, a number of sophisticated arguments emerged in the recent DTV white-space debate that helps substantiate the need for unlicensed use, while refuting arguments against such an approach.[35]

Recommendation 6: Make Federal Spectrum Data Publicly Available Online

The U.S. should follow the lead of other countries and make information on federal allocations more widely accessible. Making allowances so that certain security-related information should remain classified, it is imperative that all other spectrum information become accessible in order that agencies as well as non-federal entities can base key decisions on the best available data regarding where sharing spectrum is feasible. Presently, according to the Spectrum Plan, this information is recorded in the Government Master File (Spectrum Plan, p. 3). External pressures brought to bear on the NTIA would likely bolster internal efforts to free up this crucial information. Moreover, the new Obama administration has welcomed this greater transparency. The Democratic Party made this goal explicit in their 2008 platform, vowing to "create a new 'open source' government, using technology to make government more transparent, accountable and inclusive," requiring that "agencies conduct significant business in public and release all relevant information unless an agency reasonably foresees harm to a protected interest." They also promise to

> make government data available online [via] an online video archive of significant agency meetings" to "enhance the flow of information between citizens and government

[35] See, for example, Sascha D. Meinrath and Michael Calabrese, "Unlicensed 'White Space Device' Operations on the TV Band and the Myth of Harmful Interference," New America Foundation, March 2008.

> . . . by involving the public in the work of government agencies. (Democratic Platform Committee)

Assuming these officially stated goals are more than election year rhetoric, such gestures are positive steps toward engaging the public, whose participation is necessary for reforming U.S. spectrum policy. Passing the recent Radio Spectrum Inventory Act sponsored by Senators Kerry, Snowe, Nelson and Wicker is a first step in the right direction.[36]

Conclusions and Future Inquiry

This study is contributing to a broader discussion focused on the gross underutilization of federal spectrum resources. Policy decisions that open up government spectrum for opportunistic unlicensed reuse have the potential to essentially eliminate spectrum scarcity in the United States. Among many other social benefits, such as creating jobs and providing for public safety, this revitalization of the public airwaves would help to not only establish a desperately needed communications infrastructure, but also to bring affordable Internet services to underserved areas, and to reverse America's sub-optimal state of broadband penetration (Peha, 2008; Weiser, 2008). The technologies that can enable commons-based spectrum management have arrived. All that prevents these much-needed spectrum management reforms is a lack of political impetus. Whereas sufficient political will among policymakers is presently lacking, the recent rise of a public interest bloc pushing for unlicensed use of television white spaces gives hope that a similar focus could arise around federal white spaces. Indeed, we argue that the recent DTV white space debate is merely the tip of the iceberg, and that our analysis and policy recommendations can serve as a small step toward kick-starting a much-needed discussion about the future of U.S. federal spectrum policy.

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[36] For a good analysis of this bill, see Harold Feld, "Kerry-Snowe Spectrum Inventory Bill: A Good Starting Point for Licensed and Unlicensed Supporter," March 26, 2009. http://www.publicknowledge.org/node/2056

References

Bayrak, E. (2008, October). "Welfare Effects of Spectrum Management Regimes," *in Proc. of the 3rd IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks*, 1-11.

Benkler, Y. (2006). *The Wealth of Networks: How Social Production Transforms Markets and Freedom.* New Haven, CT: Yale University Press.

Benkler, Y., & Nissenbaum, H. (2006). "Commons-based peer production and virtue," The *Journal of Political Philosophy, vol. 14*, no. 4, 394-419.

Benkler, Y. (2004). Sharing nicely: On sharable goods and the emergence of sharing as a modality of economic production," *Yale Law Review, 114*, 273-358.

Benkler, Y. (2002). "Coase's penguin, or Linux and the Nature of the Firm," *Yale Law Review, 112,* 369-446.

Chandrasekhar, V., & Andrews, J. (2008). "Spectrum allocation in two-tier networks." Available online at: http://arxiv.org/abs/0805.1226v1

Coase, R. (1959). "The Federal Communications Commission," *Journal of Law and Economics, 2.*

Comstock, E. W., & Butler, J.W. (2000). Access denied: The FCC's failure to implement open access as required by the communication act. *Journal of Communications Law and Policy,* Winter.

Cooper, M. (2003). Open communication platforms: Cornerstone of innovation and democratic discourse in the Internet age. *Journal of Telecommunications and High Technology Law, 1.*

Cooper, M. (2006). "Governing the spectrum commons: A framework for rules based on principles of common-pool resource management." last retrieved November 20, 2009, from http://cyberlaw.stanford.edu/attachments/GOVERNING%20THE%20SPECTRUM%20COMMONS.pdf

Democratic Party's National Platform (2008, August). "Renewing America's Promise," suggested for adoption its meeting in Pittsburgh in early. Retrieved from, http://benton.org/node/16054

de Vries, P. (2006). Populating the vacant channels: The case for allocating unused spectrum in the digital TV bands to unlicensed use for broadband and wireless innovation (New America Foundation), Working Paper No. 14, 2006. last retrieved November 20, 2009, from http://www.newamerica.net/files/WorkingPaper14.DTVWhiteSpace.deVries.pdf

Federal Communications Commission. (2008). Copy of Report of Successful White Space Devices, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-08-2243A3.pdf

Federal Communications Commission. (1997, January 9). FCC Report and Order, "Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range." Available online at: http://www.fcc.gov/Bureaus/Engineering_Technology/Orders/1997/fcc97005.txt

Federal Communications Commission. (2002, November), Spectrum Policy Task Force Report, ET Docket No. 02-135, www.fcc.gov/sptf/reports.html

Federal Strategic Spectrum Plan (2008). "Spectrum management for the 21st Century: The President's Spectrum Policy Initiative." Last retrieved November 20, 2009, from http://www.ntia.doc.gov/reports/2008/FederalStrategicSpectrumPlan2008.pdf

Grokop, L., & Tse, D. (2008, April 13-18). Spectrum sharing between wireless networks. The 27th Conference on Computer Communications, 201 – 205.

Hamelink, C. (2000). *The ethics of cyberspace*. London: Sage.

Hazlett, T. W. (2008). A law & economics approach to spectrum property rights: A response to professors Weiser & Hatfield, *George Mason Law Review, Vol. 15,* No. 4.

Hazlett, T. W. (1990), The rationality of U.S. regulation of broadcast spectrum, 33, *The Journal of Law & Economics*, 133.

Jones, S. K., & Phillips, T. W. (2007). Federal Communications Commission, Office of Engineering & Technology., OET Report FCC/OET 07-TR-1006, Initial Evaluation of the Performance of Prototype TV-Band White Spaces Devices viii, 14, http://fjallfoss.fcc.gov/edocs_public/attachmatch/DOC-275666A1.pdf

Kobb, B. Z. (2001). Wireless *Spectrum Finder: Telecommunications, Government, and Scientific Radio Frequency Allocations in the U.S. 30 MHz-300 GHz.* New York: McCraw-Hill.

Lessig, L. (2001). *The future of ideas: The fate of the commons in a connected world.* New York: Random House.

Matheson, R. (2005). "Flexible spectrum use rights." Retrieved from, http://www.its.bldrdoc.gov/pub/ntia-rpt/05-418/05-418_matheson.pdf

McChesney, R. (1993). *Telecommunications, mass media, & democracy*. Oxford: Oxford University Press.

McHenry, M. (2003). Dupont circle spectrum utilization during peak hours, a collaborative effort of the New America Foundation and The Shared Spectrum Company. Retrieved from http://www.newamerica.net/files/archive/Doc_File_183_1.pdf

McHenry, M. (2004). "Spectrum occupancy measurements" (six reports). Last retrieved November 20, 2009, from http://www.sharedspectrum.com/measurements/

Meinrath, S., & Lennett, B. (in press). "Seven key options for spectrum allocation and assignment." Washington, DC. New America Foundation.

Meinrath, S., & Calabrese, M. (2008, March). "Unlicensed 'White Space Device' Operations on the TV Band and the Myth of Harmful Interference," New America Foundation. Last retrieved November 20, 2009, from http://www.newamerica.net/files/WSDBackgrounder.pdf

Moss, D., & Fein, M. (2003). "Radio regulation revisited: Coase, the FCC, and the public interest." *Journal of Policy History 15*.

National Telecommunications and Information Administration. (2008). "Red book," or "Manual of regulations and procedures for federal radio frequency management." http://www.ntia.doc.gov/osmhome/redbook/redbook.html

National Telecommunications and Information Administration. (2003, May 29). "Presidential memorandum on spectrum policy for the 21st century." Retrieved from http://www.ntia.doc.gov/ntiahome/frnotices/2004/PresMemoonSpectrumPolicy.htm

National Telecommunications and Information Administration. (2004, February 23). Document titled "FY 2004 adjusted agency prorated reimbursement."

New America Foundation. (2005). "Measuring TV white space." http://www.newamerica.net/publications/policy/measuring_tv_white_space_available_for_unlicensed_wireless_broadband

Nuechterlein, J.E., & Weiser, P. J. (2005). *Digital crossroads: American telecommunications policy in the Internet age,* The MIT Press: Cambridge, MA.

Peha, J. M. (2008). "Bringing broadband to unserved communities." Brookings Institute Report, www.brookings.edu/papers/2008/07_broadband_peha.aspx

Peng, C., Zheng, H., & Zhao, B. (2006). Utilization and fairness in spectrum assignment for opportunistic spectrum access. *Mobile Networks and Applications*, *Vol. 11*(4), pp. 555 – 576. Available online at: http://www.cs.ucsb.edu/~ravenben/publications/abstracts/CA-monet06.html

Pickard, V. (2008). Media democracy deferred: The postwar settlement for U.S. communications, 1945-49. PhD Dissertation, University of Illinois.

Snider, J.H., & Holmes, N. (2003). “The citizen's guide to the airwaves: A graphic depiction of the uses – and misuses – of the radio frequency spectrum.” Washington, DC. New America Foundation.

Snider, J.H. (2006a, May 10). “Public needs to know how government runs its airwaves,” *San Francisco Daily Journal.*

Snider, J.H.. (2006b). NAF Working Paper on “Economic case for unlicensed use of the white space.” Retrieved from http://www.newamerica.net/publications/policy/the_economic_case_for_re_allocating_the_unused_spectrum_white_space_between_tv_channels_2_and_51_to_unlicens

Snider, J.H. (2007). “America's $480 billion spectrum giveaway: How it happened, and how to prevent it from recurring.” New America Foundation.

Shared Spectrum. (2006). Press Release for “Successful demo of next generation wireless.” http://www.sharedspectrum.com/inc/content/press/XG_Demo_News_Release_060918.pdf

Stine, J. (2005). Spectrum management: The killer application of ad hoc and mesh networking. Mitre Corporation. Case #05-1166.

Weiser, P. (2008). “The untapped potential of wireless spectrum.” Brookings Institute Report, http://www.brookings.edu/papers/2008/07_wireless_weiser.aspx

Weiser, P., & Hatfield, D. (2005). “Policing the spectrum commons.” *Fordham Law Review*, Vol. 74.

Weiser, P., & Hatfield, D. (2008). “Spectrum policy reform and the next generation of property rights.” *George Mason Law Review, Vol. 15.*

White House. (2003). Memorandum for the Heads of Executive Departments and Agencies, Spectrum Policy for the 21st Century, 69 Fed. Reg. 1569 (Jan. 9, 2004), 39 Weekly Comp. Pres. Doc. 726, 727 (May 29, 2003), online at http://www.whitehouse.gov/news/releases/2003/06/20030605-4.html

White House. (2004). Presidential determination: Memorandum for the heads of executive departments and agencies, improving spectrum management for the 21st Century, 40 Weekly Comp. Pres. Doc. 2875 (Nov. 30, 2004), available online at http://www.whitehouse.gov/news/releases/2004/11/20041130-8.html

Werbach, K. (2002). “Radio revolution: The coming age of unlicensed wireless.” New America Foundation. Last retrieved November 20, 2009, from http://www.newamerica.net/publications/policy/radio_revolution

Wu, T. (2008. July 30). “OPEC 2.0,” *The New York Times.* Last retrieved November 20, 2009, from http://www.nytimes.com/2008/07/30/opinion/30wu.html

Zittrain, J. (2008). *The Future of the Internet*. New Haven: Yale University Press.