SPECTRUM LICENSE DESIGN, SHARING, AND EXCLUSION RIGHTS

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Abstract

The FCC is in the midst of a rulemaking to create a novel tripartite sharing regime in the 3.5GHz band. This has the potential to be a watershed event in the decades long transition toward more flexible and dynamic, market-based management of the radio frequency spectrum. As part of this proceeding, Lehr (2014(b)) proposed interpreting commercial licenses to protected access as options contracts that explicitly separated the interference protection and exclusion rights as a way to endogenize market-based incentives to share spectrum. This paper builds on Lehr (2014(b)) by setting forth the larger vision implicit in the earlier proposal and expanding on the case for separating exclusion and interference protection rights. This separation will enable a licensing regime that will support more dynamic and granular assignment of access rights; is more consistent with the future of radio networks and spectrum utilization; and will expand the economic tools available to regulators for incentivizing efficient spectrum usage, which necessarily includes sharing spectrum more intensively.

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I. INTRODUCTION

The transition of radio frequency spectrum management from Command and Control (C&C) toward market-oriented regulation has been a decades long process.[1] Under C&C style regulation, the regulator specifies important technical and business characteristics regarding how the spectrum is to be used, including the choice of technology, the services to be offered, and the operator to whom the rights are to be assigned.[2] Although the FCC has taken significant steps to reform regulatory rules and expand access to spectrum on more liberal, market-oriented terms, much remains to be done to complete the transition.

The FCC's effort to define a new *Consumer Broadband Radio Service* (CBRS) in the 3.5GHz band represents an important, and potentially watershed, event in implementing the desired paradigm shift in how spectrum resources are managed.[3] The plan is to enable a novel sharing and management regime that will allow multiple classes of rights holders (more than two) with differential interference protection and usage rights to share spectrum on a more flexible and dynamic basis than has heretofore been feasible.[4] The planned CBRS will allow two classes of commercial users (licensed and unlicensed) to share spectrum with incumbent federal users (principally, radar systems).[5] The expectation is that the commercial users will use the spectrum to support the deployment of small (low power) cells. A so-called *Spectrum Access System* (SAS), with a database engine at its center, is expected to play a key role in managing access to the spectrum on a fine-grained basis, by time and location.[6]

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1. RF is the radio frequency portion of the electromagnetic spectrum from approximately 3 kHz to 300 GHz that is used for wireless services such as mobile and fixed electronic communications, over-the-air broadcasting, and remote sensing.

2. U.S. GEN. ACCOUNTING OFF., GAO-04-666, SPECTRUM MANAGEMENT: BETTER KNOWLEDGE NEEDED TO TAKE ADVANTAGE OF TECHNOLOGIES THAT MAY IMPROVE SPECTRUM EFFICIENCY, REPORT TO CONGRESSIONAL REQUESTERS (May 2004).

3. *See* FCC, GN Doc. No. 12-354, IN THE MATTER OF AMENDMENT OF THE COMMISSION'S RULES WITH REGARD TO COMMERCIAL OPERATIONS IN THE 3550–3650 MHZ BAND 15–47 (Apr. 21, 2015) [hereinafter 3.5GHz R&O] (explaining the technical considerations for proposed regulatory amendments).

4. *Id.* at 128.

5. *Id.* at 46.

6. Martin Weiss et al., *Socio-Technical Considerations for Spectrum Access System Design*, IEEE INT'L SYMP. ON DYNAMIC SPECTRUM ACCESS NETWORKS, Sept. 2015. The SAS is a resource governance system in the sense of Ostrom. It is comprised of more than just the collection of database systems and associated spectrum sensing infrastructure described in 3.5GHz R&O *supra* note 3, at 90–111. Understanding

In Section two, I provide a brief review of the progress of spectrum policy reform and explain how I see the 3.5GHz sharing model fitting into the overall spectrum policy reform agenda, and why it has the potential to be transformative in facilitating the ongoing paradigm shift from command-and-control toward market-based spectrum management. Motivated by that vision, I submitted comments to the FCC in 2014 in which I proposed interpreting commercial licenses to protected access as options contracts that explicitly separated the interference protection and exclusion rights as a way to endogenize market-based incentives to share spectrum.[7] In its April 2015 order, the FCC requested comments on my proposal as a possible way to address the challenge of managing sharing between protected licensed and unlicensed commercial radios.[8]

In Section three, I review the comments that have been received, none of which addressed my earlier proposal substantively, but almost all of which opposed its further consideration as part of the 3.5GHz rules framework. I reprise what I perceive to be the benefits of my earlier proposal and the broader context in which I believe it should be considered. Regardless whether some version of my proposed modification to the licensing framework is adopted as part of the 3.5GHz framework, the core idea (separating interference protection and exclusion rights) remains important for the future success of the SAS and our collective evolution to a better future for spectrum management. I explain the basis for this conclusion in Section four.

II. Setting the Stage: Spectrum Management Reform and 3.5GHz Proceeding

In the following subsections, I review the long-term progression of spectrum policy reform that has been driven by a mix of advances in radio technologies, the growth of wireless markets and usage, and changing thoughts about regulatory policy. This sets the stage for the current debate over the framework that will govern spectrum sharing in the 3500-3650MHz ("3.5GHz") band.

A. From Dedicated to Shared Spectrum

We continue to be in the midst of a decades long paradigm shift in spectrum management going back to the 1980s. Although we are far from done, we may be nearing the end of the beginning. The transition is from a model based on *dedicated* spectrum to one based on *shared* spectrum, where dedicated refers to spectrum dedicated to specific uses and technologies, and

the SAS as a "resource governance system" necessitates consideration of the institutional/market/regulatory frameworks of rules, rights, and shared experiences that will determine how the SAS operates and is managed in the real world. Munawwar Sohul et al., *Spectrum Access System for the Citizen Broadband Radio Service*, IEEE COMM. MAG., July 2015.

7. FCC GN Docket No. 12-354, IN THE MATTER OF AMENDMENT OF THE COMMISSION'S RULES WITH REGARD TO COMMERCIAL OPERATIONS IN THE 3550-3650 MHZ BAND (Aug. 2014).

8. *See* 3.5GHz R&O, *supra* note 3, at 123–27 (defining "use" of PAL frequencies).

where shared refers to spectrum that is managed on a much more dynamic and flexible basis.[9]

Historically, the dominant model of spectrum management was "command & control" under which spectrum was allocated by government regulators for specific services that were segregated by band and technology.[10] The license framework design was closely predicated on the nature of the service,[11] the requirements of then-current technologies,[12] and assumptions about the appropriate industry/market structure.[13] In addition to putting too much decision-making control and responsibility on ill-informed government regulators, C&C regulation was inflexible and difficult to adapt as technologies and markets evolved.

For example, in the 1940s, before the advent of mobile telephony or the rise of cable-based TV, over-the-air television broadcasters were allocated licenses for exclusive use to dedicated frequency channels in the broadcasters' coverage areas.[14] The limitations of then-available analog television broadcast

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9. *Dynamic* here refers to management that supports spectrum sharing that varies along any dimension (time, space, context), where context may refer to what and how spectrum is being shared and with whom. In this paper, my use of Dynamic Spectrum Access (DSA) is intended in the broadest possible sense to encompass the many narrower and partially overlapping uses of the term by wireless experts in the standards, research, and trade press communities. For example, some limit DSA to refer to secondary spectrum sharing via cognitive radios. While cognitive radios offer one way to share spectrum, there are many others based on legacy and new technologies and service models. For example, in my usage, Wi-Fi and 4G LTE are also forms of DSA. Qing Zhao & Brian Sadler, *A Survey of Dynamic Spectrum Access*, IEEE SIGNAL PROCESSING MAG., May 2007.

10. In the U.S. and most other countries, RF spectrum is designated as a national resource that is managed on behalf of the citizenry by the national government. The Radio Act of 1912 in the U.S. mandated that the federal government license radio transmissions and for seagoing vessels to monitor distress signals. In the wake of the Titanic disaster, it was recognized that regulatory oversight of radio transmissions was needed to ensure non-interfering operations. The earlier act was superseded by the Radio Act of 1927 that created the Federal Radio Commission (FRC), the government body responsible for regulating spectrum until it was superseded by the Communications Act of 1934. That Act created the Federal Communications Commission (FCC) as an independent regulatory authority with broad responsibilities to regulate the nation's telecommunications infrastructures, including responsibility for administering non-federal uses of spectrum. Federal uses of spectrum are administered separately by the National Telecommunications Information Agency (NTIA), within the Department of Commerce, in the executive branch of government.

11. For example, over-the-air TV, mobile telephone, radar, radio astronomy, etc. call for very different service, usage, and radio network architectures. Many of these aspects are intrinsic to the nature of the service.

12. The spectrum allocations were predicated on the technical requirements of the available technologies. This determined how much spectrum was needed to offer the intended service with an appropriate network architecture and radio technology.

13. For example, regulators would determine how many network-based operators should be enabled and what the dominant business model would be for deploying radio networks for the service. For example, TV stations were allocated on the basis of 6MHz channels based on the requirements for NTSC analog transmission as of 1941, and sufficient channel capacity was allocated to offer a growing number of local VHF and UHF stations in each market. In contrast, the FCC initially allocated spectrum to enable two cellular operators to compete in each market. In 1983, the FCC assigned 20MHz (later expanded to 25MHz) of paired spectrum in the 800MHz band to each of two cellular operators, based on the requirements for deploying 1G AMPS systems. The frequencies for the A and B licenses in each market were the same across markets to facilitate the deployment of radio base station equipment and handsets that were tied to specific frequencies. By way of contrast, the ISM bands were opened for unlicensed use under Part 15 rules because the presumed mode of deployment would be via isolated and local (low-power) base stations deployed by end users. In each case, the spectrum allocations and licensing frameworks were coupled tightly to the technologies, service, and business models used by the radio network operators and their users.

14. KPMG LLP ECONOMIC CONSULTING SERVICES, HISTORY OF THE BROADCAST LICENSE APPLICATION PROCESS, REPORT PREPARED FOR FCC (Nov. 2000), https://transition.fcc.gov/opportunity/

and receiver technologies helped determine the size of the exclusive license territories and limited the ability to reuse frequencies in adjacent territories lest the signals from different TV channels interfere with each other.[15] In spite of significant advances in technologies and market changes, much of the spectrum below 1GHz is still allocated to exclusive use by over-the-air TV broadcasters.[16]

Over the years, the FCC has undertaken numerous steps to reform spectrum management practices. For example, the introduction of spectrum auctions in the 1990s substituted a market-based bidding process for administrative beauty contests as the principal mechanism for assigning new commercial licenses.[17] Additionally, the license terms were liberalized to allow bidders greater flexibility in choosing the wireless technology to use.[18] The liberalization of the Part 15 rules governing the use of unlicensed, low power radios in the 1980s and 1990s similarly granted greater flexibility and scope to determine the technical and business characteristics for how spectrum resources would be used by unlicensed radios.[19] However, in spite of these advances, after 2000, pressure to enable market-based spectrum reforms increased with the framing of national policy agendas to promote spectrum management reform.[20] In 2002, the FCC's Spectrum Policy Task Force (SPTF) concluded that "advances in technology create the potential for systems to use spectrum more intensively and to be much more tolerant of interference than in the past" and "to increase opportunities for technologically innovative and economically efficient spectrum use, spectrum policy must evolve towards more flexible and market-oriented regulatory models."[21]

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meb_study/broadcast_lic_study_pt1.pdf.

15. *Id.*

16. *Commission Adopts Incentive Auction: Second Order On Reconstruction*, Doc. No. 12-FCC-268 (June 17, 2015). Already for several decades, it has been the case that most television viewers receive their programming via wired cable or telephone networks or direct broadcast satellite, and do not watch over-the-air broadcast channels. Moreover, wireless and digital technologies and markets have advanced and spawned the rapid growth of important new services such as mobile broadband that are demanding expanded access to spectrum resources. With the Broadcast Incentive Auction, which is scheduled to be completed in 2016, much of this spectrum will finally be reallocated for new uses (see *FCC Incentive Auction R&O, 2014).*

17. Peter C. Cramton, *Money Out of Thin Air: The Nationwide Narrowband PCS Auction*, 4 J. ECON. & MGMT. STRATEGY, 267 (1995). Cellular telephony services were enabled in the U.S. with the allocation of two cellular licenses in each market in the 1980s in an attempt to promote facilities-based competition from the outset. In an effort to further expand competition and provide capacity for the growth in mobile telephony services, the FCC conducted the first spectrum auction of PCS spectrum in 1994. Moreover, to further expand the scope for market forces to dictate how the spectrum was used, the new PCS auction licenses left it to the winning licensees to choose the wireless technology to be used. For further discussion of this first PCS Auction see Cramton (1995).

18. MARTIN SPICER, FCC WIRELESS TELECOMM. BUREAU, INT'L SURVEY OF SPECTRUM ASSIGNMENT FOR CELLULAR AND PCS (1996).

19. 47 C.F.R. § 15 (2016) (the FCC rules and regulations that govern the operation of low power, unlicensed radio devices); REP. OF THE SPECTRUM EFFICIENCY WORKING GROUP, F.C.C. SPECTRUM POL'Y TASK FORCE (2002). In 1985, the FCC first authorized the operation of non-licensed spread spectrum radios that operated across multiple frequency bands; and in 1989, the FCC liberalized the emission limit permissions, which expanded options for deploying unlicensed radios. These and subsequent actions paved the way for the emergence of wireless local area networking and the rise of the Wi-Fi technologies that have become ubiquitous today. For further discussion, see Marcus *et al.* (2002).

20. *Id.*

21. MICHAEL MARCUS, FCC SPECTRUM POL'Y TASK FORCE, FINDINGS AND RECOMMENDATIONS 3

Moreover, growing awareness of the importance of the broadband Internet as basic infrastructure and the growth of mobile broadband as a key element focused attention on the need to expand commercial access to spectrum,[22] and forced recognition of the infeasibility of meeting future demand solely from new allocations of dedicated spectrum.[23]

The future must embrace shared spectrum, but spectrum may be shared in many ways. For example, cellular operators manage their exclusively licensed spectrum so as to share the spectrum among their mobile customers, and via roaming agreements, with the subscribers of other mobile service providers.[24] In contrast, Wi-Fi users share the spectrum non-cooperatively.[25] Which approach works better depends on the usage and business models of the radio operators. New radio architectures and technologies like smaller cells, cognitive and software radios, smart antennas, and better modulation and signal processing make it feasible to share and manage spectrum on a much more dynamic and granular basis.[26]

Opportunities to technically share spectrum among multiple users or uses are limited by the available radio technologies. Legacy techniques for managing spectrum interference relied overly on static frequency assignments[27] and geographic license territories,[28] and worst-case modeling to

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(2002). Similar conclusions were reached by policymakers in the United Kingdom around the same time. The reports highlighted two models: the flexible, exclusive-licensed model which was appropriate for cellular-like service providers seeking to deploy wide-area coverage networks; and the unlicensed "commons" model which was appropriate for deploying isolated wireless LANs.

22. Memorandum from the President of U.S. on Unleashing the Wireless Broadband Revolution to the Heads of Executive Departments and Agencies (June 28, 2010) (on file with The White House). In 2010, the National Broadband Plan (*see* FCC, 2010) and a presidential memorandum called for making available an additional 500MHz of spectrum for commercial broadband services.

23. PRESIDENT'S COUNCIL OF ADVISORS ON SCI. AND TECH, EXEC. OFF. OF THE PRESIDENT, REPORT TO THE PRESIDENT: REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM TO SPUR ECONOMIC GROWTH (2012). According to PCAST (2012), which examined options for expanding commercial access to Federal spectrum, the "essential element of this new Federal spectrum architecture is that the norm for spectrum use should be sharing, not exclusivity."

24. Philip Goldstein, *AT&T, Verizon, T-Mobile Forge Pact To Explore Spectrum Sharing With Government*, FIERCE WIRELESS (Jan. 31, 2013), http://www.fiercewireless.com/story/att-verizon-t-mobile-forge-pact-explore-spectrum-sharing-government/2013-01-31. Similarly, over-the-air TV broadcasters managed their spectrum to share it with TV viewers over their broadcast coverage area. While many no longer regard over-the-air TV as an efficient use of scarce spectrum and there are certainly more efficient technologies available today for over-the-air delivery of broadcast-like video services, this does not mean that legacy TV broadcasting was not a model for sharing spectrum resources.

25. Krishna Jagannathan et al., *Non-Cooperative Spectrum Access: The Dedicated vs. Free Spectrum Choice*, 30 INST. ELEC. & ELEC. ENG'R. J. ON SELECTED AREAS COMM. 1 (2012).

26. William Lehr & Miquel Oliver, *Smaller Cells and the Mobile Broadband Ecosystem*, INT'L TELECOMM. SOC., CONFERENCE (2014), http://hdl.handle.net/10419/101406 (stating that smaller cells allow spatial reuse of spectrum and are a key strategy for sharing spectrum more intensively); John Chapin & William Lehr, *Mobile Broadband Growth, Spectrum Scarcity and Sustainable Competition*, (39th Research Conference on Communication, Information, and Internet Policy, Conference Paper), http://ssrn.com/abstract=1992423 (stating other radio technologies enhance spectral efficiency and make it feasible to support services across a wider array of frequencies). In effect, the propagation characteristics of spectrum in different frequencies becomes less important as a component in the overall radio system, enabling the spectrum to become closer substitutes. *Id.*

27. *Paired Spectrum*, TELECOM ABC, http://www.telecomabc.com/p/paired-spectrum.html (last visited Feb. 22, 2016) (describing traditional cellular systems which rely on paired spectrum channels for different operators, one for upstream and the other for downstream communications, separated by guard bands to limit out-of-band interference).

protect radio systems from interfering with each other. Advances in wireless and digital technologies (radios, antennas, and other network components) are making it increasingly feasible to share spectrum in non-interfering ways by separating signals on the basis of any or all of the dimensions of electrospace (frequency, time, geo-location, direction-of-arrival at receiver, etc.).[29]

Enhancements to 4G LTE cellular technologies enable mobile network operators (MNOs) to aggregate spectrum resources on a much finer-grained and dynamic basis to support services with diverse quality-of-service requirements (e.g., mobile telephony and streaming video).[30] At the same time, expansion of the family of 802.11 standards has expanded the capabilities, range of operating frequencies, and management capabilities of "Wi-Fi"-like unlicensed radio networks.[31] MNOs, providers of complementary services (*e.g.*, mobile content and applications, software), and device manufacturers (like Apple and Google) are exploiting opportunities to integrate licensed and unlicensed spectrum resources to support a growing array of more capable mobile services.[32] At the same time, researchers are developing new internet architectures to take advantage of heterogeneous spectrum and network resources to support expanded and flexible options for mobility that include mobility of end-users, services, and networks in time, space, and context.[33]

Finally, it is worth noting that while the focus thus far has been on meeting the growth in demand for spectrum resources from commercial

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28. Jeremy Fox & Patrick Bajari, *Measuring the Efficiency of an FCC Spectrum Auction*, 5(1) AM. ECON. J.: MICROECON. 100 (2012) (describing how static geographic license territories are designed to limit in-band and out-of-band interference from signals in adjacent territories).

29. Arthur S. De Vany et al., *A Property System for Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study*, 21 STAN. L. REV. 1499 (1969) (stating that interference occurs at the receiver, when a receiver cannot disentangle its intended signal from other background energy arriving at the receiver's antenna); Robert Matheson & Adele Morris, *The Technical Basis for Spectrum Rights: Policies to Enhance Market Efficiency*, 36 TECH. POL. 783 (2012) (proposing sharing spectrum in terms of resource bundles based on the technical dimensions of electrospace). Interference occurs at the receiver, when a receiver cannot disentangle its intended signal from other background energy arriving at the receiver's antenna. De Vany et al. (1969), Matheson (2006), and Matheson and Morris (2012) proposed sharing spectrum in terms of resource bundles based on the technical dimensions of electrospace.

30. Ian F. Akyildiz et al., *The Evolution of 4G Cellular Systems: LTE Advanced*, 3 PHYSICAL COMM. 217 (2010) (stating that data traffic is more likely to be asymmetric and asynchronous, short and long data packets, often calling for unpaired, asymmetric spectrum). The evolving 4G LTE standards are intended to enable much more granular allocation of contiguous and non-contiguous frequency channels on a finer-grained basis in terms of location, time, and other waveform characteristics. *Id.*

31. William Lehr & Miquel Oliver, *Smaller Cells and the Mobile Broadband Ecosystem*, INT'L COMM. SOC., CONFERENCE (2014), http://hdl.handle.net/10419/101406.

32. In the Matter of Current Trends in LTE-U and LAA Technology, ET Doc. No. 15-105 (2015) (stating that 66% of mobile traffic data will be offloaded to Wi-Fi networks by 2019). A significant proportion of mobile data traffic is off-loaded to unlicensed spectrum used by Wi-Fi networks.

33. *See* MOBILITYFIRST, http://mobilityfirst.winlab.rutgers.edu/ (last visited Feb. 22, 2016) (discussing MobilityFirst's status as an NSF-funded Future Internet Architecture (FIA) that was started in 2010 and is developing the protocols and prototype components needed to support mobility as basic Internet functionality). Whereas the legacy architecture of the Internet was premised on moving packets between static host end-points, the MobilityFirst architecture will support mobility as the norm for dynamic host and network mobility at scale. *Id.* Context-aware mobility will make it feasible to condition mobility support not just in time and space, but also in terms of the intended purpose of the communication and local network conditions (e.g., a user may move from a "work" identity context to a "home" identity context, resulting in differential support for routing, service authorization, etc.). *Id.*

communication-oriented services, demand is also growing from government and non-communication-oriented spectrum users.[34] These last include sensing applications such as radio telescopes.[35] Integrating these other types of spectrum users raises significant additional technical, market, and policy challenges. Foremost among these include the fact that most of these other users are not commercial, for-profit entities, and hence are governed to a significant extent by non-market-based forces.[36] For example, government users are mission-driven and subject to administrative and budgetary constraints that limit their incentives and ability to respond to market forces. Indeed, many of the activities that we rely on government to undertake are activities that we believe are unlikely to be adequately provisioned by private sector markets. Public safety is an obvious example, and is doubly noteworthy since its usage requirements are distinct from commercial usage in many ways. For example, public safety needs for spectrum access are contingently everywhere, whereas commercial are strongest where commercially viable services are in greatest demand.[37] Moreover, society is generally supportive of the notion that public safety should get priority access to resources when they need it.[38] Finally, public safety needs are often greatest precisely when commercial needs are less (e.g., during an emergency which disrupts commercial operations).[39]

In summary, therefore, technological trends and market requirements are moving us toward a future in which spectrum can and needs to be managed on a much more flexible and dynamic basis. Different radio networks, services, and users require access to spectrum in different ways that vary by location, time, technology, and need. Many of these models are shared, but the sharing is managed in different ways. Sometimes the sharing is managed by a network operator with access to exclusive spectrum licenses, and sometimes the spectrum is shared in an uncoordinated way by unlicensed devices.[40] The spectrum may be shared over different time-scales and traded in (near-)real-

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34. *See* U.S. DEP'T OF DEF., ELECTROMAGNETIC SPECTRUM STRATEGY: A CALL TO ACTION (2013), http://www.defense.gov/news/dodspectrumstrategy.pdf (last visited Feb. 22, 2016) (describing projected growth in spectrum requirements for the Department of Defense).

35. *See* ANTTI V. RÄISÄNEN & ARTO LEHTO, RADIO ENGINEERING FOR WIRELESS COMMUNICATION AND SENSOR APPLICATIONS 346 (2003) (describing recent uses for radio telescopes).

36. *See* WILLIAM E. KENNARD, CONNECTING THE GLOBE: A REGULATOR'S GUIDE TO BUILDING A GLOBAL INFORMATION COMMUNITY ii (1999), https://transition.fcc.gov/connectglobe/regguide.pdf. ("However, there are clearly some remote and high cost areas where market forces alone will not result in the satisfactory deployment of services.").

37. For example, first responders need the capability to respond anywhere, whereas for-profit businesses provide services only where it is profitable to do so. FIRSTNET.GOV, http://www.firstnet.gov/about/why (last visited Feb. 22, 2016).

38. For example, lights and sirens tell drivers to get out of the way of first responders on the roads. Accommodating such diverse needs is a commonplace requirement when you have diverse classes of users sharing the resource. *Id.*

39. As a consequence of this uncorrelated demand, there are significant scale and scope economies if commercial and public safety users can share radio infrastructure and spectrum resources. *Id.*

40. *See generally* KENNETH WALLSTEDT & MIKAEL PRYTZ, *The Spectrum Crunch–Busting the Solutions Myth*, ERICSSON, http://www.ericsson.com/openarticle/the-spectrum-crunch_1473414408_c (last visited Feb 22, 2016) (explaining various spectrum allocation methods, including management by licensed operators and uncoordinated access by unlicensed devices).

time markets or as a consequence of leasing deals or merger and acquisition activity.[41] The spectrum may be bundled with network infrastructure or be shared separately.[42] I do not believe it is appropriate for our spectrum management regime to pre-ordain any particular wireless service, business, or market model, or radio technology for sharing spectrum. A sound market-based regulatory regime should facilitate sharing among whatever efficient models emerge, while protecting opportunities for further innovation and the emergence of new and potentially better models for sharing spectrum. Moreover, because we are always living with legacy models, the management regime should facilitate an orderly transition.

B. Benefits of the 3.5Ghz Proceedings Spectrum Access System (SAS)

As noted earlier, the National Broadband Plan (2010) identified the need to significantly expand spectrum access for commercial mobile broadband in light of the importance of such services as national communications infrastructure, and later that year, the President issued an Executive Order directing the heads of agencies and executive departments to "collaborate with the Federal Communications Commission (FCC) to make available a total of 500MHz of Federal and nonfederal spectrum over the next 10 years, suitable for both mobile and fixed wireless broadband use."[43]

Following up on this, the NTIA reviewed federal spectrum uses to identify spectrum that could be fast-tracked to expand options for commercial spectrum access.[44] The 3.5GHz band was identified as one of the bands that could potentially be shared with commercial users.[45] Then, in July 2012, the

41. *See* Harold Furchtgott-Roth, *The Changing Market for Spectrum*, FORBES (Dec. 1, 2014, 11:28 PM), http://www.forbes.com/sites/haroldfurchtgottroth/2014/12/01/the-changing-market-for-spectrum/#6da2b2d9425f (discussing current trends in real-time spectrum market sales); Jasmin Melvin, *FCC Head Says Mergers Can't Solve Spectrum Crunch*, REUTERS (Apr. 13, 2011, 6:21 AM), http://www.reuters.com/article/us-fcc-spectrum-merger-idUSTRE73B7D020110413 (detailing spectrum reallocation between merging corporations); RANDALL BERRY ET AL., MARKET STRUCTURES FOR WIRELESS SERVICES WITH SHARED SPECTRUM 2 (2013), http://web.ics.purdue.edu/~nguye161/allerton13.pdf (highlighting variations in time-scale across spectrum).

42. *See* LIU CUI, DIMENSIONS OF COOPERATIVE SPECTRUM SHARING: RIGHTS AND ENFORCEMENT 7 (2014), http://d-scholarship.pitt.edu/20584/1/Cui_Gomez_Weiss_2014.pdf (describing the nature of infrastructure sharing between spectrum users).

43. Memorandum on Unleashing the Wireless Broadband Revolution, 2010 DAILY COMP. PRES. DOC. 201000556 (June 28, 2010), https://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

44. U.S. DEP'T OF COM., AN ASSESSMENT OF THE NEAR-TERM VIABILITY OF ACCOMMODATING WIRELESS BROADBAND SYSTEMS IN THE 1675–1710 MHZ, 1755–1780 MHZ, 3500–3650 MHZ AND 4200–4220 MHZ, 4380–4400 MHZ BANDS (2010) (discussing the NTIA's Fast Track report identifying 150MHz of spectrum in the band 3500-3650MHz (3.5GHz) as potential spectrum that could be shared with commercial users). The NTIA Fast Track report identified 150MHz of spectrum in the band 3500–3650MHz (3.5GHz) as potential spectrum that could be shared with commercial users as part of the goal of meeting the president's order to identify 500MHz of additional spectrum for commercial broadband. *Id.* The principal current occupants of the band are Department of Defense radar systems that are too expensive to relocate, making it infeasible to clear the band of federal users to allow it to be reallocated for dedicated commercial use). *Id.*

45. In some cases, it was deemed feasible to clear federal users out of certain frequency bands, relocating their uses to other bands. Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550–3650 Mhz Band, 27 FCC Rcd. 15594, 15595 (2012) ("The 3.5 GHz Band was identified by the National Telecommunications and Information Administration (NTIA) for shared federal and

President's Council of Advisors on Science and Technology (PCAST) concluded that a new system for managing federal spectrum was called for, and the "essential element of this new federal spectrum architecture is that the norm for spectrum use should be sharing, not exclusivity."[46] It was in the context of these changes that the FCC launched a proceeding to develop a plan for sharing spectrum in the 3.5GHz band in 2012.[47]

The FCC proposed to establish a new Citizens Band Radio Service (CBRS) in the band that would enable sharing with two classes of commercial users. Building on earlier experience with crafting rules for enabling database-managed unlicensed shared access with TV broadcasters, the FCC moved forward with its proposal for a tripartite sharing model that would include Incumbents (federal users, principally DoD radar), Protected Access License (PALs), and General Authorized Access (GAA) users.[48] In the event that there was contention for PALs, licenses would be auctioned.[49]

The PAL users would be granted a guarantee of interference protection, while also being obligated to avoid interfering with Incumbent users.[50] GAA users are obligated to avoid interfering with Incumbent and PAL users, and are expressly denied claims for interference protection from other legal users of the band.[51]

The plan is for these three tiers of users to share the 3.5GHz band with the assistance of a Spectrum Access System (SAS).[52] The SAS framework is anticipated to be a system of multiple dynamic databases, augmented with sensing technology, that is intended to facilitate non-interfering co-existence

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non-federal use . . . .").

46. PRESIDENT'S COUNCIL OF ADVISORS ON SCI. AND TECH., EXEC. OFFICE OF THE PRESIDENT, REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM SPUR ECONOMIC GROWTH iv (2012). https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

47. *See* Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550–3650 Mhz Band, 27 FCC Rcd. 15594, 15595 (2012). (showing the government's efforts to expand access to the 3.5 GHz spectrum). The PCAST (2012) report identified the need to expand commercial access to government spectrum as a national priority).

48. *See generally* In the Matter of Unlicensed Operation in the TV Broad. Bands, ET Doc. No. 04-186, *Third Memorandum Opinion and Order*, 27 FCC Rcd. 3692, 3696 (2012) (illustrating the government's effort to move to a tripartite spectrum sharing model).

49. *See* Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550–3650 Mhz Band, 30 FCC Rcd. 3959 (2015) (discussing the PALs auction process in the event of high competition).

50. *Id.* at 47. There is debate as to whether Incumbent users have an obligation to avoid interfering with PALs. The presumption is that the framework will be implemented so as to protect Incumbent users in the band from interference from the commercial entrants. But it is reasonable to expect that commercial users once active in the band will have an expectation that their usage under the status quo will be protected, limiting Incumbents from arbitrarily modifying their usage in ways that would interfere with the commercial users. Thus, I conclude that Incumbents will have an implicit or explicit obligation to not interfere that makes the protection reciprocal. How to enable all parties flexibility to modify their behavior and avoid locking in any ex ante status quo that would preclude future innovation is a challenge that will need to be addressed.

51. *Id.* This does not mean they lack any interference protection since they can still assert a claim against illegal users of the band. Presumably, Incumbents, PAL users, or other GAA users who cause interference through illegal radio operations are subject to enforcement actions.

52. *See generally*, FCC, GN DOCKET NO. 12-354, REPORT AND ORDER AND SECOND FURTHER NOTICE OF PROPOSED RULEMAKING (2015) (explaining the changes to the FCC rule regarding the use of 3.5GHz band for three levels of use).

among the multiple classes of spectrum users in the band.[53] The core of the SAS is a database that could be queried to see what spectrum may be available for use in each location.[54] Spectrum availability information could be updated to reflect changes in regulatory rules, rights assignments, local spectrum conditions, or other information. Moreover, the SAS could provide context-dependent responses regarding spectrum availability for different classes of users sharing the spectrum.

The SAS approach offers a number of important advances. First, the SAS provides capabilities that can enable finer-grained spectrum sharing. An appropriate SAS with knowledge of authorized transmitters in the band can allocate spectrum to additional users when sharing by such users would not interfere with current protected users, or can signal to current users with reduced priority access when they have to cease operations so that higher priority users may have non-interfering access.[55] The SAS framework holds forth the promise for partial automation of spectrum management,[56] which may render it feasible to implement more real-time adaptability to local conditions (in time, geo- and network-space).

Second, the SAS creates a regulatory framework that holds the promise of facilitating more flexible and timely updates to spectrum policies. When new interference models or rights permissions are established, the database and related SAS infrastructure may be updated more easily and with reduced scope for cumbersome bureaucratic hearings.[57] The SAS provides a unified framework for considering multiple classes of users in multiple locations over time, and if extended to additional bands as seems desirable in the future, over multiple spectrum bands. This may help standardize and simplify spectrum management practices, reducing the transaction costs of modifying and communicating spectrum rules.

Third, the SAS framework provides greater scope for flexible enforcement options.[58] For example, the SAS may be used to enforce time-limited leases that may be used to grant time-sensitive permissions. Radios that operate under such permissions may be required to obtain updated (by time and location) certificates in order to continue operating in the band.[59]

Fourth, the SAS may collect and provide information to spectrum stakeholders that would be useful for managing radio networks, planning investments, and contracting over spectrum rights. This role may be important over multiple timescales, up to and including helping to support real-time spectrum markets. For example, by its nature, the SAS helps match available

53. *Id.* ¶¶ 301–78.

54. *Id.* ¶ 307.

55. *Id.* ¶ 75.

56. *Id.* ¶ 313.

57. *Id.* ¶¶ 235–37.

58. *See* LIU CUI ET AL., DIMENSIONS OF COOPERATIVE SPECTRUM SHARING: RIGHTS AND ENFORCEMENT (2014) (explaining the need for a variety of enforcement mechanisms); *see also* MARTIN B.H. WEISS ET AL., ENFORCEMENT IN DYNAMIC SPECTRUM ACCESS SYSTEMS (2012) (describing possible enforcement of spectrum usage rights).

59. *See* JOHN M. CHAPIN & WILLIAM H. LEHR, TIME-LIMITED LEASES FOR INNOVATIVE RADIOS (2007) (explaining the use of certificates in the granting of leases).

spectrum resources to spectrum users and uses. This is akin to the market matching function of an exchange. The SAS may also aggregate spectrum utilization data over space and time, enabling learning and better modeling and management of non-interfering shared usage and spectrum availability over time. This may assist in the planning of radio network designs and investments.[60]

Taken together, the promise of the SAS framework to substantially improve the informativeness, flexibility, and efficiency of spectrum management is significant.[61] However, realizing these benefits is far from an accomplished goal. While progress has been made on multiple fronts to design and implement SAS databases, there are still numerous technical, regulatory, and business details that need to be worked out.[62] For example, stakeholders are still not agreed on precisely what data will be included in the SAS, how the data will be managed, who will have access to the SAS, and what role the SAS will play in active enforcement.[63] DoD representatives have opposed providing detailed information to the SAS on the performance of military radar systems on the grounds of national security concerns.[64] Cellular operators who have expressed interest in PALs have raised concerns about ceding control of their spectrum access to third-party SAS operators.[65] SAS operators like Google and proponents of GAA unlicensed sharing have voiced concerns that a SAS lacking strong dynamic authority to manage interference protections may hobble unlicensed access in the CBRS.[66]

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60. Knowledge of real-world wireless performance can assist in network provisioning and planning. Radio users' networks can learn where spectrum is readily available and where it may be more scarce and modify operations accordingly.

61. By way of contrast, the chart of frequency allocations may be understood as a version of today's "SAS" that is not informative, flexible, or efficient. It is often used to illustrate the confusion and complexity of spectrum management challenges. *See* U.S. Dep't of Commerce, *United States Freequency Allocations: The Radio Spectrum*, (2003), http://www.ntia.doc.gov/files/ntia/publications/2003-allochrt.pdf (charting the allocation usage breakdown of the radio spectrum in the U.S.).

62. Weiss, *supra* note 6.

63. F.C.C. 12-354, *supra* note 52.

64. The NTIA, as an agency that is part of the executive branch of government, regulates federal spectrum that is used by the DoD and other government agencies, while the FCC, as an independent regulatory authority, regulates commercial spectrum use. As a consequence, the DoD has not filed public comments in the 3.5GHz proceeding, but staff in DoD, NTIA, and the FCC have met separately to address the concerns of government agencies in crafting the CBRS sharing framework. On behalf of federal users, the NTIA has filed a single set of comments addressing concerns that SAS not connect directly with sensitive federal databases or systems. *See* Letter from Paige Atkins, Assoc. Adm'r, Office of Spectrum Management, Nat'l Telecomm Info. Agency, to Julius Knapp, Chief, Office of Eng'g & Tech., FCC (Mar. 24, 2015), http://apps.fcc.gov/ecfs/document/view?id=60001041337 (describing the NTIA's stance on several issues of the rule and its implementation).

65. *E.g.*, FCC, GN Docket No. 12-354, VERIZON COMMENTS ON FURTHER NOTICE OF PROPOSED RULEMAKING (2015), http://apps.fcc.gov/ecfs/document/view?id=60001115774; FCC, GN DOCKET NO. 12-354, COMMENTS OF CTIA – THE WIRELESS ASSOCIATION (2015), http://apps.fcc.gov/ecfs/document/view?id=60001115782; FED. COMMC'N COMM'N, GN DOCKET NO. 12-354, COMMENTS OF AT&T (2015), http://apps.fcc.gov/ecfs/document/view?id=60001115745.

66. *E.g.*, FED. COMMC'N COMM'N, GN Docket No. 12-354, COMMENTS OF GOOGLE, INC. (2015), http://apps.fcc.gov/ecfs/document/view?id=60001115575; FED. COMMC'N COMM'N, GN Docket No. 12-354, COMMENTS OF MICROSOFT CORPORATION (2015), http://apps.fcc.gov/ecfs/document/view?id=60001115762; FCC, GN Docket No. 12-354, COMMENTS OF WIRELESS INNOVATION FORUM (2015), http://apps.fcc.gov/ecfs/document/view?id=60001117259.

C. Shared Unlicensed GAA Access to PAL Territories

One issue of central concern relates to the potential for GAA unlicensed devices sharing with PALs. Following on the tried-and-true model that cellular operators have relied on for licensing spectrum, cellular operators have argued in favor of excluding GAA operations from PALs that are *in use*;[67] whereas advocates of expanded GAA use have argued that GAA operations should be restricted only when required to avoid interfering with actual PAL operations.[68]

In the most recent 3.5GHz order released in April 2015, the FCC determined that GAA use should be permitted in PALs that were not *in use*, and issued a Second Notice of Proposed Rulemaking in which the FCC sought comments on how "*in use*" should be determined.[69] The FCC asked whether the determination of *in use* should be based on (a) an engineering definition, (b) an economic definition, or (c) a hybrid.[70] As a proposal for the economic definition, they pointed to my earlier proposal "PALs as Options to Exclude GAA Access," in which I proposed interpreting PALs as financial options.[71]

Since then, a number of commenters have responded, with the majority supporting an engineering-based definition.[72] The responses received tended to align with well-established industry positions. On one side are the cellular providers like AT&T and Verizon that are strong advocates of exclusively licensed spectrum with its strong interference protection guarantees.[73] On the other side are the advocates for unlicensed access which includes both those

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67. *See* comments *supra* note 65. Traditionally, MNOs have acquired spectrum licenses for exclusive access to specific frequencies in the bands in their serving areas. In most cases, these licenses have been acquired at auction or via market transactions (e.g., M&A activity). The license provisions allow the MNOs to seek injunctive relief to exclude most other radios sharing the spectrum, although certain types of easements have been granted. For example, low power Ultra-wideband (UWB) radios that operate in the noise floor have been granted rights to operate because it was determined that the transaction costs of negotiating for shared access would be too costly for UWB technologies.

68. *See* comments *supra* note 66. The proponents generally advocate relying on an engineering definition as implemented by the SAS to determine when PALs are *in use*, but differ as to how that should be accomplished.

69. *See* 3.5GHz R&O *supra* note 3, ¶¶ 418–30:

> "The Report and Order above, we determined that allowing opportunistic access to unused Priority Access channels would serve the public interest by maximizing the flexibility and utility of the 3.5 GHz Band for the widest range of potential users. When Priority Access rights have not been issued (e.g., due to lack of demand) or the spectrum is not actually in use by a Priority Access licensee, the SAS will automatically make that spectrum available for GAA use on a local and granular basis. While there is substantial support in the record for an opportunistic use approach generally, we see wide divergence in the record to-date regarding specific implementation of our "use-it-or-share-it" rule. We therefore seek focused comment on specific options, rooted in the record, for defining "use" by Priority Access licensees."

70. *Id.* ¶¶ 420–30.

71. Commission Seeks Comment on Shared Commercial Operations in the 3550-3700 MHz Band, 80 Fed. Reg. 34119 (June 15, 2015).

72. *See Comments of Key Bridge*, FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view (describing the unique commentary of Key Bridge, one of the authorized TVWS database providers, which provided a partial endorsement of the Lehr proposal, recommending that the FCC adopt a hybrid approach).

73. *Comments of AT&T*, FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view; *Comments of Verizon*, FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view.

who directly involved in supporting wireless services that use unlicensed spectrum (e.g., the vendors of unlicensed equipment for Wi-Fi), as well as providers of equipment, content, and applications that depend on end-users having wireless access to the Internet but who are concerned about the potential abuse of market power if mobile network operators provide the only path to the Internet.[74] This last group includes companies like Google and Microsoft, as well as consumer advocates like Public Knowledge.[75]

Pro-GAA commenters like Google, Microsoft, and Public Knowledge are strongly opposed to any economic definition of use that might allow PAL licensees to exclude GAA access on any grounds other than as required by technical interference protection needs, as enforced by the SAS.[76] Their principal concerns were twofold: (1) that PAL licensees might warehouse spectrum for the purposes of foreclosing GAA access; and (2) GAA use should be promoted in the widest range of potential uses to maximize commercial access to available spectrum resources.[77]

In contrast, cellular provider proponents argue in favor of a more static role for the SAS with respect to PALs. For example, AT&T has proposed that GAA devices be excluded from operating in any PAL Census Tract territory for the duration of the license once the PAL licensee begins offering service;[78] while Verizon has proposed that specification of the PAL exclusion contours be defined and input to the SAS by the PAL licensee, with GAA use permitted only in the remaining PAL territory outside those self-specified contours.[79]

On one side, cellular providers claim to fear interference from GAA devices will reduce the economic value of PAL spectrum rights.[80] To the extent that fear is justified, it might deter cellular operators investment in using the spectrum. Indeed, some might argue that supporters of GAA access just want to get a free ride by acquiring rights to spectrum that cellular operators

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74. *Comments of Google*, *supra* note 66; *Comments of Microsoft*, *supra* note 67; *Comments of Open Technology Institute and Public Knowledge*, FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view.

75. *Id.*

76. Comments of Google, *supra* note 66; Comments of Microsoft, *supra* note 67; *Comments of Dynamic Spectrum Alliance*, FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view; *Comments of the Wireless Internet Service Providers Association* FCC ELECTRONIC COMMENT FILING SYSTEM (GN Docket No. 12-354) (July 15, 2015), http://apps.fcc.gov/ecfs/document/view.

77. *See Comments of Open Technology Institute and Public* Knowledge, *supra* note 74:

> The proposal by MIT economist William Lehr, summarized in the Second FNPRM, amounts to a blank check for warehousing spectrum, contrary to the Commission's stated goal of facilitating intensive use by 'the widest range of potential users.' It is also completely unnecessary, since the proposed rules establish out-of-band emission limits sufficient to protect neighboring PALs.

See also Comments of Wireless Internet Service Providers Association, *supra* note 76:

> The economic definition proposed by William Lehr also should be rejected. It is nothing more than a ruse to foreclose opportunistic use when there are engineering bases that can easily allow opportunistic use. Lehr's options approach would vest in licensees the ability to hoard and warehouse spectrum.

78. *Comments of AT&T*, *supra* note 65.

79. *Comments of Verizon*, *supra* note 65.

80. *See, e.g.*, *Comments of AT&T*, *supra* note 65; *Comments of Verizon*, *supra* note 65 (commenting on the potentially negative economic impacts of interference from GAA devices).

are prepared to pay for (in part, by pushing for rules that will make the spectrum less attractive to cellular operators and hence more likely to be available for unlicensed use).

On the other side, proponents of unlicensed access argue that the SAS is adequate to protect against any legitimate threats of GAA interference.[81] Many view the cellular operators' expressed concerns regarding future interference and calls for stronger limits on GAA access as disingenuous attempts to foreclose GAA-based competition. On both sides there is a noted lack of trust and consensus on what is needed to limit harmful interference and what spectrum rights different classes of users ought to have.

Regulators are caught in the middle by their relative lack of knowledge about the true plans and operating requirements and capabilities of the different stakeholders,[82] by the complexity of the proposed sharing regime,[83] and by the lack of actual real-world empirical data and experience on which to make evidence-based decisions.

The Lehr (2014(b)) proposal was intended to address this challenge on multiple levels. It was intended (1) to help moderate the debate, (2) as a practical response to a difficult question, and (3) as a bit of mechanism to give regulators greater scope for a more nuanced management of license design.[84] In the next section, I explain how each of these roles was intended.

III. LICENSES AS OPTIONS TO EXCLUDE: A PROPOSAL IN NEED OF UNDERSTANDING

In the following sub-sections, I first describe a simplified roadmap for spectrum reform that is useful in understanding the multiple roles that I intended my proposal in Lehr (2014(b)) to play. After that, I reprise briefly why I think the proposal should be more seriously considered as a way to determine whether PAL spectrum is "in use."

A. Spectrum Policy: Today, Tomorrow, and the Future

Figure 1 offers a stylized roadmap for the challenge confronting spectrum

81. *See, e.g.*, *Comments of Open Technology Institute and Public Knowledge*, *supra* note 74.

82. Asymmetric information is a key justification for transitioning from command and control to market-based regulation in telecommunications and other regulatory domains. For example, the transition from Rate of Return to Price Cap regulation was motivated, in part, to address information asymmetries and provide regulated entities greater scope for making incentive-compatible investments in achieving cost efficiencies. *See* David E.M. Sappington & Dennis L. Weisman, *Price Cap Regulation: What Have We Learned from 25 Years of Experience in the Telecommunications Industry?*, 38 J. REG. ECON. 227 (2010)(discussing regulatory policy in the telecommunications industry).

83. The 3.5GHz framework has many moving parts and negotiations are occurring concurrently with negotiations over reforms in other bands that matter to the stakeholders (e.g., 600MHz broadcast spectrum, 5.8GHz, above 24GHz, etc.). Many of the stakeholders do not consider these bands in isolation but as part of a long-term spectrum management strategies. This makes it difficult for stakeholders to contract over multiple bands, which might otherwise assist in the realization of Coasian efficient bargaining were that possible. William Lehr, *Spectrum License Design, Sharing, and Exclusion Rights* (43rd Res. Conf. on Comm., Info., and Internet Pol'y, Oct. 15, 2015), https://www.researchgate.net/publication/282858949_Spectrum_License_Design_Sharing_and_Exclusion_Rights.

84. WILLIAM LEHR, PALS AS OPTIONS TO EXCLUDE GAA 6 (2014).

policymakers in the 3.5GHz proceeding and more generally.[85]

Now	**Launch new sharing regime** -- N-tiered (more than 2) -- Government + Commercial -- Approved rules to enable launch Commercial Operations
Future	**Manage Spectrum Sharing** -- Active sharing at scale. Interference management -- Extend to new bands, accommodate growth -- New services, technology, business models
Horizon	**Dynamic Spectrum access** -- Cognitive/software radio, smart antennas, etc. -- Electrospace model : sharing in any dimension (t, geo, freq, etc.) -- Secondary markets -- Financial securities to manage availability risk

Figure 1: Spectrum Policy Roadmap

Today, we are in the process of defining a new regime that is novel in so far as it defines multiple tiers of protected users whose spectrum access will be managed, in part, via a SAS.[86] Although the current 3.5 GHz proceeding identifies only three tiers of users, the framework could readily be extended to additional tiers for even finer-grained rights assignments (hence "N-tiered" in Figure 1).[87]

Today, stakeholders are tussling over the rules and sundry details needed to launch this new sharing regime, and their arguments are appropriately framed in terms of expectations about what will be required to operate at scale under this sharing regime once it is in operation.[88] In this (hopefully, relatively near) future, there will be investment in new radios, services, and business models as market activity based on this new sharing regime expands (see the second row of Figure 1).[89] The tussle over rules is based on divergent visions as to how commercialization of the 3.5Ghz band will or should proceed.[90] The present challenge is to implement a set of rules so that we can move forward

85. I say "more generally" because the 3.5GHz proceeding represents in microcosm the overall transition from dedicated to shared spectrum.

86. *See* 3.5GHz R&O, *supra* note 3, ¶ 301.

87. *Id.*

88. *Id.* at 91.

89. Of course, if this does not happen and commercialization fails (no investment in radios, services, or business models using the newly available spectrum) then folks will debate whether the failure was because the concept was doomed from the start (e.g., because some believe commercial/government sharing is a bad idea) or failed because the wrong rules framework was adopted.

90. Some of the divergence is due to differences in forecasting, and some of those differences reflect differences in strategic goals for the band.

with actual commercialization and embark on realization of the hoped-for future. Because all forecasts are imperfect and the current rules leave many details unspecified, the future will require adaptation and further refinement as market experience (and trust) with sharing evolves.[91]

The horizon goal for the more distant future is to evolve toward a spectrum management system that can support flexible Dynamic Spectrum Access, under which spectrum may be shared on a much finer-grained basis by making use of a panoply of smart radio technologies (Row 3 in Figure 1).[92] In an ideal version of this future, spectrum resources would be increasingly commoditized and fungible. With liquid secondary trading markets, spectrum resources would be *economically mobile* (i.e., able to be directed to their highest value uses with minimal transaction costs). In such a world, it is reasonable to expect that there might be derivative financial securities to allow for better management of the spectrum "commodity" risk, potentially like the financial options associated with other commodities like oil, grains, or insurance.

If successful, the 3.5Ghz model of SAS-based spectrum management has the potential to be extended to other spectrum bands, providing a template and framework for this idealized future for dynamic spectrum access management. Indeed, the path to realization of the 3.5GHz model is another brick—albeit a pivotal one— in the ongoing paradigm shift toward market-based spectrum management.

Lehr (2014(b)) was intended to address all three rows of Figure 1. In its most obvious role, my proposal should be seen as an attempt to address the challenge of how to manage sharing between PAL and GAA users once the sharing markets are operating.[93] In terms of Figure 1, that corresponds to Row 2. Below, I reprise the key benefits of such an approach.

A second intended role (corresponding to Row 1 of Figure 1) was to improve the quality of the discussion by provoking focused attention on the economic justification for exclusion and its relationship to other features in the framework's design (e.g., technical details for interference protection, duration and geographic scope of licenses, requirements for vacating spectrum, etc.). The hope was that a more thoughtful consideration of the economic incentives to share spectrum would contribute to our collective understanding and would help accelerate the movement toward consensus on the rules framework. With respect to that second role, my effort has thus far failed to gain traction. Unfortunately, the comments submitted so far do not seriously engage the proposal in Lehr (2014(b)), and may be regarded as doing little other than restating positions already established before the FCC issued its most recent order. This is perhaps not surprising, in light of the complexity of the

91. The FCC 3.5GHz R&O leaves many details to be worked out by market participants, including by one or more multi-stakeholder groups that the FCC suggests may be formed (¶¶ 413–17). *See* Chapin and Lehr (2007(b)) for discussion of importance in building trust through market experience.

92. The horizon goal is what we sail toward, but never get to.

93. If demand for PAL or GAA usage is sparse, then the question of how PAL and GAA should share becomes a moot point.

challenge involved in implementing the 3.5GHz sharing model proposed by the FCC, the many issues that still divide stakeholders,[94] and the multiple issues that the Lehr (2014(b)) proposal identified but left unresolved.[95] It is possible that more serious debate of the Lehr (2014(b)) proposal may follow in time. In Section 4, I will address the core idea of the proposal regarding the need to separate exclusion (property ownership rights) and interference protection in future licensing frameworks.

Finally, with respect to the third role (corresponding to row 3 in Figure 1), it is an interesting and important research question as to what sorts of derivative financial securities might be appropriate in the context of managing our collective spectrum resources. Treating spectrum licenses as options contracts offers one obvious way this might occur. Certainly, research is needed to examine the emergence of spectrum-based financial securities further if we are to consider seriously enabling real-time markets in spectrum. Derivative securities in financial markets have played an important role in risk creation and management for all sorts of commodities, and hence it is only logical to expect that they may have a useful role with respect to spectrum if we are successful in commoditizing spectrum more fully.[96]

In the next sub-section, I reprise the Lehr (2014(b)) proposal to highlight the advantages that such an approach might have for determining when PAL spectrum is *in use*.

B. Hybrid Definition for in Use is Necessary

As noted earlier, in its Second Notice of Proposed Rulemaking the FCC asked whether an engineering, economic or hybrid determination should be used to determine when PAL spectrum was *in use*, and hence when unlicensed GAA users should be excluded from operating in the spectrum.[97] Regardless of how this question is answered by others, I conclude that the determination will necessarily be a hybrid, whether explicitly recognized as such in the final rules (my recommendation) or not (as most of the commenters have thus far argued in favor of).

First, I do not think it reasonable or practical to believe that Lehr (2014(b)) could be implemented solely on the basis of economic rules, and so an engineering component is unavoidable. The engineering component is

94. These issues are large and small. For example, stakeholders still disagree about such things as admissible transmission power levels for commercial radios in the band; the timing for commercial radios to detect incumbent operations and clear the spectrum; the accuracy and methods for geolocating radios; the SAS access security provisions; how multiple SAS will interoperate; etcetera.

95. For example, Lehr (2014(b)) proposed an ad hoc mechanism for establishing the exercise price for the option (*i.e.*, split the PAL auction price into two equal payments with the second half representing the exercise price). Lehr (2014(b)) also noted the challenge of how to integrate the options into successive licenses and the potential for secondary trading of the option and access exclusion rights.

96. Futures, options, and portfolio assets are all forms of derivatives that have been used effectively for risk management in many commodity markets. However, derivatives must be regulated. I view the lack of adequate financial regulation that enabled the unrestricted explosion in derivative securities prior to the 2008 financial meltdown as not about managing risk but about creating new sources of risk that could be traded.

97. JOHN M. CHAPIN & WILLIAM H. LEHR, *supra* note 60, at 8.

inextricably bound to the notion of what constitutes adequate interference protection (e.g., what propagation models or spectrum metrics and data are used to determine if interference is occurring by the SAS, specification of allowed operating behaviors such as power limits, etc.) and hence is intrinsic to the proposal in Lehr (2014(b)). Given that an engineering perspective is central to the determination, the real question is whether an economic perspective is also fundamentally intrinsic (and hence a hybrid mechanism the only option), and whether explicitly incorporating one is advisable (as my original proposal recommended).

Second, in answering the first part of the preceding question, I believe it is also unreasonable to believe that a purely engineering determination of what constitutes *in use* is feasible. Purely as a matter of what the written rules are, it is obviously feasible to recommend and encode rules that specify a purely engineering determination.[98] However, the efficacy of these rules and their impact on incentives to invest and comply will depend on the larger institutional and industry context.[99] Economic considerations have informed stakeholder positions to date and will continue to inform those positions as they tussle over resolution of further aspects of the rules.[100] For example, we might anticipate that stakeholders with divergent views on the exclusion debate to be more (less) willing to contemplate updates to SAS-based propagation models with more (less) scope for enabling sharing.[101] The specification of an engineering determination will only shift the way in which the economics of *in use* are fought over in the marketplace and in policy forums.

I will postpone until the next section a discussion of why I believe it is desirable to explicitly include an economic perspective in the rules framework for determining when PAL spectrum is *in use*.

C. Benefits of Treating PALs as Options

In this sub-section, I briefly reprise my proposal and discuss what I believe are some of the benefits (Some of the benefits of Lehr, 2015(b)). The essence of the proposal was to modify the payment terms to enable PALs as a bundle of rights that granted the licensee the right to interference-protected spectrum and an option to exclude GAA users from the license territory upon payment of a subsequent exercise price. This modification separates the property right for interference protection and exclusive access.[102] Figure 2

98. Lehr, *supra* note 84, at 14.

99. *Id.* at 17.

100. *Id.* at 13.

101. As discussed further below, worst-case models tend to result in larger de facto exclusion zones. If exclusion rights are explicitly granted and separate from the interference protection that they provide a means for enforcing, then the rights holders may be more willing to accept dynamic adjustment to exclusion zone protections (if not to the licensed territories themselves).

102. Related ideas have been addressed in research by Weiss & Cui and Cave & Webb who discussed defining property rights in terms of interference rights (analogous to the right to pollute). *See generally* Martin B. Weiss & Liu Cui, *Tradeable Spectrum Interference Rights* TPRC, 1 (2011) (discussing the definition of property rights in terms of interference rights); Martin Cave & William Webb, *License to Interfere*, IEE COMM'N ENG'R 42 (Dec. 2003) (elaborating on property rights through the lens of interference rights).

summarizes the benefits that I believe would flow from adopting a version of this proposal.[103]

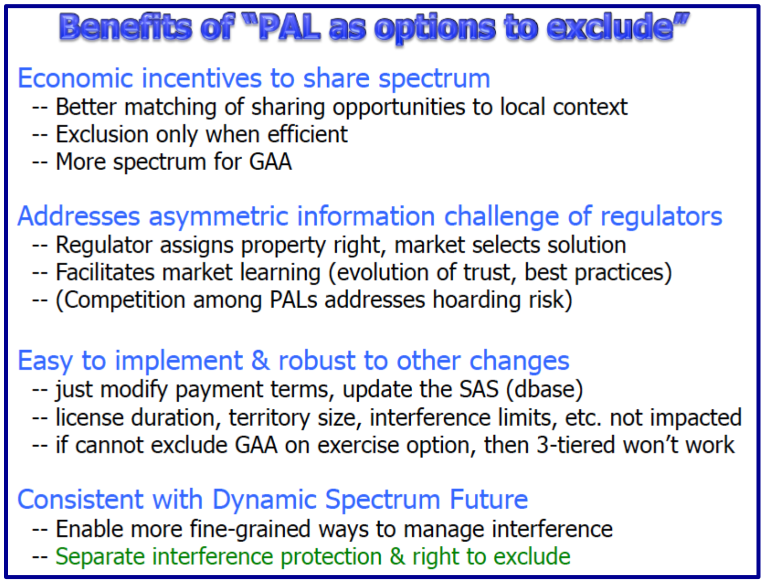

Figure 2: Benefits of PALs as Options to Exclude

It is worthwhile briefly reviewing these benefits again here. First, the proposal explicitly adds an economic incentive-based mechanism for endogenizing the choice of whether PAL spectrum is shared with GAA users. PAL licensees pay less if spectrum is shared, and GAA users can potentially access more spectrum than when the exclusion option is exercised.[104] Lehr (2014(b)) proposed an ad hoc and simple way to set the option and exercise price; more complex ways that ought to be discussed were this proposal to be seriously considered could implement anything from "always exclude" (exercise price equals zero) to "never exclude" (exercise price equals some large number).[105]

Second, the option approach is intended to address the asymmetric information challenge confronted by regulators and is part of the goal to move toward market-based regulation.[106] Introducing an economic tool to the license design (as will be explained further below) provides a way to manage learning from diverse behaviors. It is presumed that not all PALs will be

103. *See* In the Matter of the Commission's Rules with Regard to Commercial Operations in the 3550–3650 MHz Band, Reply Comments of William Lehr, GN Docket No. 12-354 (2014) (discussing these benefits in somewhat different form).

104. *Id.* Of course, for those who oppose any exclusion right, GAA access is maximized, holding the modeling of interference protection zones constant (but as argued above, that is not a realistic assumption since those are yet to be determined).

105. *Id.* This latter outcome is the one advocated by GAA proponents, but as a purely engineering determined result.

106. *Id.*

purchased/controlled by the largest cellular providers. If that were to happen then I do not believe that the 3.5GHz experiment would be viewed as a success and other regulatory interventions may become necessary (e.g,. application of alternative models for spectrum holding constraints). Eliminating the option to exclude in this proceeding does not eliminate the threat that may be posed by large cellular operators to alternative spectrum usage models, nor does its inclusion necessarily render it easier for cellular operators to foreclose GAA competition. As with the pricing of the option, were the exclusion option to be considered more seriously, it would be important to address the hoarding question more seriously as well. I do not perceive that to be a significant credible risk, but to the extent it is, I believe it could be addressed with other aspects of the rules framework.

Third, the proposal was expressly designed to be easy to implement, requiring only simple changes to the payment terms and being implementable in even the simplest SAS. If the SAS could not handle the registration of when exclusion options had been exercised and adequately enforce interference protection under those circumstances, then the entire sharing framework would be called into question. The simple change could be made without requiring changes to the license durations, territory sizes, interference protection limits or other features, although adoption of the proposal would likely influence stakeholders' positions on these other issues that remain topics of dispute.

Fourth, and as will be discussed more fully in the next section, the proposal positions licensing so as to be more consistent with a Dynamic Spectrum Access (DSA) future.[107]

IV. LICENSE DESIGN: SEPARATING EXCLUSION AND INTERFERENCE PROTECTION RIGHTS

In the following sub-sections, I briefly review the law and economics literature discussing the importance of exclusion rights as one of the most important rights for property rights regimes, and explain how this relates to spectrum management policy.

The purposes for spectrum policy are several, and folks may disagree on what are appropriate roles. Although everyone seems to agree that *the* central justification for spectrum policy is the need for rules and enforcement mechanisms to manage the incidence of *harmful* interference.[108] However,

107. *See* supra note 9.

108. A.C. Morris, *Spectrum Auctions: Distortionary Input Tax or Efficient Revenue Instrument?*, 29 TELECOMM. POL'Y 687–709 (2005) (Other roles that are potentially more contentious, but nevertheless play a big role in spectrum policy debates are the use of spectrum policy to raise auction funds as a source of general government revenues; in the service of promoting broadband internet access; or in order to promote increased competition. As a funding source, auction proceeds are politically attractive because they provide an alternative to taxation, and some economists believe that auctions are less distortionary. *Id.* With respect to national industrial policy, the National Broadband Plan expressly notes the importance of making additional spectrum available for commercial operators to expand mobile broadband services. FCC, NATIONAL BROADBAND PLAN (2010). In my view, the conflation of broadband and spectrum policy, while politically understandable, is unfortunate since it fails to adequately recognize the ways in which these policy domains need to be addressed as distinct challenges. And, competition considerations have played a large role in

even though all stakeholders recognize the need for regulation to protect against *harmful* interference, there is no general agreement on what constitutes harmful interference.[109]

Incumbents might argue that the presence of energy from any non-affiliated radios operating in incumbent spectrum constitutes *harmful interference* since the energy from such radios might add to the noise floor and hence interfere with other actual or potential uses of the spectrum by the Incumbent.[110] For example, if the incumbent use is for an application that requires detecting low power signals that may be close to the ambient noise floor (e.g., like radio astronomy or interacting with sensors in some contexts), then any additional noise *might* be deemed to be too much noise.

Alternatively, it may be feasible for technology to allow new radios into the spectrum without disrupting incumbent applications in the spectrum (although this may not preserve the Incumbents ability to change or scale its usage in the future without incurring interference related costs). For example, the FCC has enabled sharing easements via the rules permitting unlicensed devices to share TV broadcast spectrum and the rules permitting ultra-wideband devices to spread their signals across the noise floor of existing licensed spectrum users.[111] The ITU and other standards bodies specify standards that establish the limits for what constitutes harmful interference in specific contexts.[112]

Furthermore, with potential modifications to the spectrum usage models or radio technology and infrastructure,[113] expanded sharing options that have

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spectrum policy from the start as noted earlier. The design of rules for the 600MHz incentive broadcast auction include provisions that are intended to limit the amount of spectrum that might be acquired by the largest MNOs in order to help ensure the sustainability of viable competition among facilities-based MNOs.

109. Thomas W. Hazlett & Sarah Oh, *Exactitude in Defining Rights: Radio Spectrum and the "Harmful Interference" Conundrum*, 28 BERKELEY TECH. L.J. 227, 227 (2013):

> Spectrum use rights generate more robust market development when they feature technically fuzzy borders but are awarded in economically efficient bundles. The key ingredients are (a) exclusive, flexible rights; (b) frequency borders set via standardized edge emission limits; (c) large bundles of complementary rights that limit fragmentation; and (d) fluid secondary trading that allows mergers to end border disputes by eliminating borders. Regulators should focus less on delineating precise interference contours, and instead expeditiously distribute standard bandwidth rights to economically responsible agents, taking care to avoid undue fragmentation (and tragedy of the anti-commons).

Michael J. Marcus, *Harmful Interference and Its Role in Spectrum Policy*, 102 PROCEEDINGS OF THE IEEE 265 (2014).

> Since the formalization of radio regulations over a century ago, a major goal of spectrum policy has been to control interference. Some level of interference in radio systems is inevitable due to the limitations of achievable performance in transmitters, receivers, and antennas as well as propagation uncertainties in the real world.

110. *See generally* Mitchell Lazarus, *Finding the Harm in "Harmful Interferencei,"* CommLawBlog (Jan. 26, 2016, 3:57 PM), http://www.commlawblog.com/2009/01/articles/broadcast/finding-the-harm-in-harmful-interference/ (elaborating on harmful interference arguments).

111. Unlicensed Operation of TV Broad. Bands, 27 FCC Rcd. 3692 (2012); In the Matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 17 FCC Rcd, 7435 (2002).

112. *See* Marcus, *supra* note 109.

113. There is a plethora of potential technical and non-technical means available to enable expanded co-existence among multiple radio users. For example, re-configuring or upgrading transmission and receiver equipment with cognitive or software radio capabilities, smart antennas, enhanced tolerance for interference, adopting new modulation or different air interface standards are among the technical changes that are available

the potential to be Pareto improving for all users are often possible. However, such modifications are likely to require adjustment costs and result in an increased incidence of interference events as shared utilization increases.[114] Apportioning the sharing of costs and benefits associated with the change to a new regime poses an unavoidable challenge.[115] Nevertheless, to an economist, the idea that the goal of policy should be to minimize technical interference rather than to maximize the economic benefit of using scarce spectrum resources is fundamentally wrong-headed. As Ronald Coase famously remarked:

> It is sometimes implied that the aim of regulation in the radio industry should be to minimize interference. But this would be wrong. The aim should be to maximize output. All property rights interfere with the ability of people to use resources. What has to be insured is that the gain from interference more than offsets the harm it produces. There is no reason to suppose that the optimum situation is one in which there is no interference.[116]

In summary, therefore, spectrum policy confronts two fundamental challenges: (1) the need to protect spectrum users from the negative externalities arising from interference; and (2) how to apportion the costs and benefits of adjustments associated with addressing the first challenge.

In the context of spectrum licensing, especially with respect to so-called "exclusive use" licenses such as those granted to over-the-air broadcasters and cellular MNOs, it is unclear precisely what rights those licenses should or actually confer.[117] For example, it is unclear whether the spectrum licenses that grant the licensee protection from harmful interference imply that the licensee has the right to exclude all other radios from sharing the spectrum, or only other radios that cause *harmful* interference.

Disputes over whether licenses do or should grant a clear right to exclude other radios, or whether exclusion is necessary to provide adequate interference protection pose a challenge for spectrum management reform. On the one hand, exclusion of shared usage that would not cause harmful interference forecloses potentially socially efficient sharing opportunities.[118] If licensees were granted a clear exclusion right, some fear they might use it to inefficiently hoard spectrum or foreclose potential competitors.[119] On the other

to expand capacity for shared usage. There are also non-technical options such as negotiating insurance or other business arrangements that would immunize parties against economic harms suffered as a consequence of what is agreed to be harmful interference. For example, a landowner may be rendered indifferent to trespassing hikers on his land if the hikers pay a fee.

114. *Promoting Economic Efficiency in Spectrum Use: The Economic and Policy Research Agenda 15*, NITRD WIRELESS SPECTRUM R&D SENIOR STEERING GROUP (Apr. 23, 2013), https://www.nitrd.gov/nitrdgroups/images/2/2e/WSRD_Workshop_IV_Report.pdf.

115. *Id.*

116. Ronald Coase, *The Federal Communications Commission*, J. L. & ECON. 1, 27 (1959).

117. When the license rights were acquired via auction rather than via an administrative proceeding (that did not require payment for the rights), the presumption that the licensee has an economic right to exclude other users is stronger. Thomas W. Hazlett & Evan T. Leo, *The Case for Liberal Spectrum Licenses: A Technical and Economic Perspective*, 26 BERKELEY TECH. L.J. 1037, 1038 (2011).

118. *Id.* at 1053–58.

119. Yochai Benkler, *Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption*, 26 HARV.

hand, figuring out what sharing is possible without causing harmful interference and adjudicating interference disputes is costly.[120] Some have argued that licensing spectrum with clear exclusion rights (and flexible use and transferability rights) will provide licensees with strong incentives to use the spectrum efficiently.[121]

A. Why Exclusion Right Is Important

Spectrum access rights are a form of property right,[122] and getting the assignment of such rights correct in order to induce appropriate incentives for allocating and using spectrum efficiently has long been recognized as important by economists and scholars interested in spectrum management reform.[123]

In discussing various models of property rights, the right to exclude other users from enjoyment of the resource is a central right for both private property and common pool resource rights models.[124] An exclusion right can serve several functions in property law. First, it protects a rights holder against negative externalities due to the actions of others that would infringe upon the ability of the rights holder to enjoy the benefits of usage or ownership rights to the resource.[125] There is an extensive law and economics literature discussing

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J. OF L. & TECH. 69, 127 (2012); INTERNET POLICY AND ECONOMICS: CHALLENGES AND PERSPECTIVES 169 (William H. Lehr and Lorenzo Maria Pupillo eds., 2nd ed. 2009).

120. Thomas W. Hazlett & Evan T. Leo, *The Case for Liberal Spectrum Licenses: A Technical and Economic Perspective*, No. 10-19 GEO. MASON UNIV. SCH. OF LAW 1 (2010).

121. *Id.* at 11.

122. Thomas W. Hazlett, *Assigning Property Right to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*, 41 J.L. & ECON 529, 530 (1998). Earlier folks tended to associate property rights with exclusively licensed spectrum and contrasted that with unlicensed spectrum that was modeled as a common resources. Dorothy Robyn, *Making Waves: Alternative Paths to Flexible Use Spectrum*, THE ASPEN INST. (2015), http://csreports.aspeninstitute.org/documents/Spectrum_Making_Waves.pdf . In truth, both are property rights regimes with different definitions of what constitute the relevant property rights, and between exclusively-licensed spectrum and unlicensed there is a continuum of potential sharing (rights) models. *See Toward More Efficient Spectrum Management: New Models for Protected Shared Access*, MIT COMMUNICATIONS FUTURES PROGRAM (2014), http://cfp.mit.edu/publications/CFP_Papers/CFP%20Spectrum%20Sharing%20Paper%202014.pdf ("The purpose of this white paper is to help illuminate active current discussions about important new models for managing shared access to radio frequency spectrum that are on-going in the research community, industry, and regulatory forums around the world."). *See also* Gerald R. Faulhaber & David Farber, *Spectrum Management: Property Rights, Markets, and the Commons* 2 (AEI-Brookings Joint Center for Regulatory Studies, Working Paper No. 02-12, 2002), www.ictregulationtoolkit.org/Documents/Document/Document/ 3629 ("[P]ropose[s] a legal regime rooted in property rights that can simultaneously support both private markets and a commons that can accommodate the rapid diffusion of the new radio technologies, leading to a far more efficient allocation of this important and limited national resource.").

123. *See, e.g.*, Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON 1, 44 (1959) (indicating efficient spectrum use has been the focus of many academic writings by economists and legal scholars).

124. *See* Shyamkrishna Balganesh, *Demystifying the Right to Exclude: Of Property, Inviolability, and Automatic Injunctions*, 31 HARV. J.L. & PUB. POL'Y 593, 596 (2008) ("The idea of exclusion, in one form or the other, tends to inform almost *any* understanding of property, whether private, public, or community. The only variation tends to be the person or group in whom it is vested."); *see also* Thomas W. Merrill, *Property and the Right to Exclude*, 77 NEB. L. REV. 730, 733 (1998) ("[T]he concept of property is not limited to private property, but includes also what may be called common property and public property.").

125. Balganesh, *supra* note 124, at 616. Spectrum is regarded as a national resource in the U.S. and law precludes private ownership. STUART MINOR BENJAMIN & JAMES B. SPETA, TELECOMM. LAW AND POLICY, 15 (4th ed. 2015). The government is authorized to license usage rights to the resource in the public interest. *Id*. at

the relative merits of different legal regimes for protecting against harmful externalities arising from the exercise of property rights.[126]

Second, an exclusion right can prove useful in protecting investment incentives and facilitating recovery of sunk, shared, or common costs.[127] Indeed, this is a principal motivation for intellectual property law (patents, copyright) and a potential solution to public goods problems.[128] The ability of the exclusion rights holder to deny consumers the right to enjoy the resource can render it feasible to contract for payment for enjoyment of the resource, and thereby ensure a reasonable expectation that investment costs associated with efficiency enhancing innovations and sustaining the resource will be recoverable.[129] Without such reasonable expectations, investment would not be incentive compatible.

Of course, direct regulatory interventions (e.g., administrative control) offer an alternative mechanism for resolving this challenge. An attraction of relying on an exclusion-rights-based approach is that it allows this investment and cost recovery problem to be decentralized to the market.

A potential problem with the exclusion-rights-based approach is that it may be inefficient if markets are imperfect (as in the real-world they always are, at least to some extent). For example, patent protection affords an innovator the opportunity to potentially earn monopoly rents and monopoly pricing is often inefficient.[130] Potentially more worrisome, the exclusion right might be used to raise rivals' costs or to foreclose competition and so disrupt markets and innovation.[131] Concerns over this risk have played a big role in motivating interest in ensuring adequate access to unlicensed spectrum because of concerns that novel business models and technologies may lack the resources to compete with well-funded or established incumbents in acquiring more expensive licensed spectrum access rights.[132]

Moreover, in the context of spectrum, a significant challenge confronting policymakers is the fact that markets for spectrum resources are incomplete.[133] While theory suggests that auctions may be efficient in assigning resources to their highest value uses in the first instance, secondary markets are needed to ensure the assignment remains efficient over time.[134] Secondary markets for spectrum are nascent and lack liquidity on both sides.[135] Indeed, the 3.5GHz

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126. *See, e.g.*, Ronald, H. Coase, *The Problem of Social Cost*,,3 J.L. & ECON. 1, 1 (1960) (discussing legal regimes protecting against harmful interference of property rights).

127. *See* Joseph E. Siglitz, *Economic Foundations of Intellectual Property Rights*, 57 DUKE L.J. 1693, 1696 (2008) (explaining how exclusive intellectual property rights enable cost recovery and incentivize innovation).

128. *Id.*

129. *Id.*

130. *Id.* at 1710.

131. *Id.*

132. Mark R. Kiesel, *Emphasize Barriers to Entry*, PIMCO (Sept. 2014), https://www.pimco.com/insights/investment-strategies/global-credit-perspectives/emphasize-barriers-to-entry.

133. Yochai Benkler, *Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption*, 26 HARV. J.L. & TECH. 71, 126–32 (2012).

134. *Id.*

135. *Id.*

sharing initiative is an effort to help expand market options for spectrum users.[136]

Thus, in spite of the claims of some analysts, the debate remains unresolved as to whether exclusion-based approaches or some other approach for addressing the dual challenges of spectrum policy is to be preferred.[137] Moreover, since neither pure approach (market v. administrative) is even feasible,[138] it is unclear how best to facilitate a market-based approach, which continues to be the preferred trajectory for spectrum reform.

In light of this uncertainty, it is desirable to separate exclusion rights and rights to interference protection in spectrum licensing frameworks in order to provide evolving market and policy frameworks/mechanisms adequate scope to adapt and work out appropriate solutions. While the need for an exclusion right is strongly supported in the institutional design literature for enabling market-based resource management, it remains debatable as to how this applies in the context of spectrum management.[139] On the other hand, as earlier noted, interference protection rights are a central requirement of spectrum management policy.[140] Conflating the two forces the optimization of each to rise or fall together. This is unnecessary and inappropriate.

We should remember that the path-breaking work on introducing market-based concepts to spectrum management by Ronald Coase (1959) was originally greeted with derision because it was so out-of-step with then current thinking about what was required to manage spectrum interference.[141] Today, many in the wireless world have business models based on licensing regimes that grant them a legal right to injunctive relief to exclude other operators from sharing the spectrum.[142] In an earlier age, it seemed natural to regard spectrum frequencies, radio infrastructure (towers, back-haul facilities, base station and handset radios, etc.) as co-specialized assets.[143] In the past, technical capabilities dictated that mobile technologies and networks were closely

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136. Lawrence E. Strickling, *Innovation, Collaboration and Sharing*, NTIA Blog (Apr. 17, 2015), https://www.ntia.doc.gov/blog/2015/innovation-collaboration-and-sharing-35-ghz-band.

137. Yochai Benkler, *Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption*, 26 HARV. J.L. & TECH. 69, 83 (2012).

138. That is, because spectrum markets are incomplete and cannot be rendered complete overnight, allocating exclusion rights and relying on efficient Coasian bargaining to result in efficient contracts is not feasible.

139. THE ECONOMICS OF SPECTRUM MANAGEMENT: A REVIEW 7 (Commissioned by Australian Communication and Media Authority (2007).

140. *See supra* Part IV. LIU CUI, MARCELA M. GOMEZ, & MARTIN B. H. WEISS. DIMENSIONS OF COOPERATIVE SPECTRUM SHARING: RIGHTS AND ENFORCEMENT (IEEE DySPAN, McLean, Virginia, April 1-4, 2014), http://d-scholarship.pitt.edu/20584/.

141. CYBER POLICY AND ECONOMICS IN AN INTERNET AGE 201 (William H. Lehr & Lorenzo Pupillo eds., Springer Science + Business Media Dordrecht 2002). Thomas W. Hazlett et. al., *Radio Spectrum and the Disruptive Clarity of Ronald Coase*, 54 J.L. & ECON. S125, S125 (2011).

142. THE ECONOMICS OF SPECTRUM MANAGEMENT: A REVIEW, *supra* note 141 at 11. Sarah R. Wasserman Rajec, *Tailoring Remedies to Spur Innovation*, 61 AM. U.L. REV. 733, 744 (2012).

143. WILLIAM LEHR, ECONOMIC CASE FOR DEDICATED UNLICENSED SPECTRUM BELOW 3GHZ 35 (New America Foundation 2004). JOHN M. CHAPIN & WILLIAM H. LEHR, MOBILE BROADBAND GROWTH, SPECTRUM SCARCITY, AND SUSTAINABLE COMPETITION 7 (Paper for 3rd Research Conference on Communication, Information and Internet Policy, Arlington, VA, September 23-25, 2011), http://ssrn.com/abstract=1992423.

coupled to particular operating frequencies.[144] The operators sought to control those frequencies over their coverage footprint so that they could meet their customers' expectations of (near-) ubiquitous coverage.[145] In that world, long-term exclusive licensing of spectrum allowed MNOs to coordinate usage of these assets and internalize the externalities that might otherwise have arisen if spectrum resources, radio infrastructure, and services were unbundled and management (ownership control) were decentralized.[146] That model has helped propel several decades of many billions of dollars worth of investment and innovation in creating the mobile broadband services we have today.[147]

Spectrum use based on the unlicensed model, as exemplified perhaps most dramatically by Wi-Fi use in the ISM 2.4 and 5GHz bands has also contributed significantly to the growth of wireless and mobile services. Many billions of dollars in investment and innovation are also associated with this model. Under current unlicensed rules frameworks (e.g., Part 15), no user has an exclusive right to use the spectrum, and hence no user has the right to exclude other users.

Too often the question has been whether the preferred model for spectrum management ought to mirror the legacy model of exclusively-licensed spectrum or of non-exclusive (open access) unlicensed spectrum. A better question is how best to realize a world in which both models and potentially others that reflect further refinements might co-exist harmoniously to maximize the economic benefits to be realized from shared spectrum utilization. Locking in legacy regulatory models—whether for licensed or unlicensed use—appears as ill-conceived as locking in legacy technologies; and potentially more damaging since regulatory reform generally proceeds at a slower clock speed than technologies or markets.

B. How May Exclusion and Interference Protection Be Separated

Today, in a world of software radios and agile infrastructure, it is possible to imagine different configurations for how radio and network infrastructure and spectrum assets might be unbundled or bundled. Just as we would like to enable technical and business model flexibility to allow markets to choose what works best in each context, we need economic and institutional flexibility to balance how spectrum regulation can adjust the terms of sharing arrangements.

The SAS proposed for the 3.5GHz band represents an important step toward creating the necessary institutional and regulatory infrastructure to

144. KONSTANTINO CHATZIKOKOLAKIS ET. AL, SPECTRUM SHARING: A COORDINATION FRAMEWORK ENABLED BY FUZZY LOGIC (International Conference on Computer, Information and Telecommunication Systems, July 2015) http://ieeexplore.ieee.org/xpls/abs_all.jsp.

145. *Id.*

146. Thomas W. Hazlett & Sarah Oh, *Exactitude in Defining Rights: Radio Spectrum and the "Harmful Interference" Conundrum,* 28 BERKELEY TECH. L.J., 227, 234–35 (2013).

147. CHAPIN, *supra* note 145. Jonathan Spalter, Chairman, Mobile Future, Comments Before the Federal Communications Commission 14 (July 15, 2014), http://mobilefuture.org/wp-content/uploads/2014/07/MFOpenInternetCommentsJuly2014.pdf.

support this flexibility.[148] The current design of the SAS is heavily reliant on a database engine.[149] Much of the debate has been over how dynamic and granular (in terms of frequency assignments, time, geography, radio performance characteristics, etc.) the SAS should be and how interactive and responsive to feedback from the environment (e.g., data on the local or wide-area wireless environment including spectrum utilization, terrain characteristics, network congestion, etc.).[150] For users to trust the system, they have to believe that the capabilities are commensurate with the challenges. For example, can the SAS effect notification and relocation of lower-priority devices with sufficient accuracy and speed to provide adequate interference protection for higher-priority users (whether those be incumbent government or PAL users). And, on the other side, is the SAS so conservative in its enforcement of guard bands (in time, frequency, location, power, etc.) or burdensome for lower priority users as to significantly reduce commercial interest in sharing the spectrum (whether by PAL or GAA users).[151]

Moreover, the details for precisely how this will work remain theoretical since we have no operational experience of how all of this will work at scale. We are, perforce, basing our decisions on theory, simulations, and pilot studies.[152] And, there are many promising research directions to explore how we might manage interference more dynamically and interactively, including adjusting exclusion zones more dynamically and along multiple dimensions (not just in terms of geospatial, frequency, or time separation).[153] With suitably capable radio system designs, it is possible to disambiguate the signals from signals that do not occupy (or, equivalently, are excluded from) exactly the same space in the multidimensional electrospace.[154] As these ideas are worked out further, the various SAS will need to be updated.[155] Consequently,

148. Federal Communications Commission, Comment Letter on Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band (April 23, 2014).

149. MARTIN B.H. WEISS, WILLIAM H. LEHR, AMELIA ACKER & MARCELA M. GOMEZ. SOCIO-TECHNICAL CONSIDERATIONS FOR SPECTRUM ACCESS SYSTEM (SAS) DESIGN (IEEE International Symposium on Dynamic Spectrum Access Networks (DYSPAN), Stockholm, September 2015).

150. *Id.*

151. PAL users oppose excessive exclusion zones to protect Incumbent users, while remaining concerned that GAA users might interfere with PAL usage. GAA users oppose excessive exclusion zones associated with protecting both Incumbent and PAL users. Exclusion zone may be designed with multiple dimensions including restrictions on admissible locations or times where transmissions may occur, power limits on such transmissions, etcetera. Rules that require PAL or GAA users to vacate spectrum more quickly may require more expensive sensing capabilities or more frequent communication with the SAS, which may increase the costs of network or end-user device equipment and operations.

152. Additionally, the pilot studies and testing has been focused on validating the technology, which is not always indicative of how the technology will operate or be used in the real-world with real users. More research and testing is needed to explore the non-technical aspects of deploying novel radio technologies.

153. *See e.g*., Mohammed Altamimi et al., Enforcement and Spectrum Sharing: Case Studies of Federal-Commercial Sharing (Mar. 29, 2013) (The 41st Research Conference on Communication, Information and Internet Policy), http://papers.ssrn.com/sol3/papers.cfm; Jung-Min (Jerry) Park et al., Security and Enforcement in Spectrum Sharing (2014), (BRADLEY DEPT. OF ELEC. AND COMPUT. ENG'G), https://wireless.vt.edu/pdfs/securityandenforcement.pdf: Abid Ullah et al., Multi-Tier Exclusion Zones for Dynamic Spectrum Sharing (2015) (unpublished manuscript), http://www.arias.ece.vt.edu/pdfs/multitierexclusions.pdf (providing examples of ideas for how to dynamically adjust exclusion zones and enable more real-time spectrum sharing in the context of 3.5GHz spectrum or elsewhere).

154. *See* Matheson and Morris, *supra* note 29 and accompanying text surrounding; *supra* note 15.

155. *Id.* at 150.

we may anticipate that the SAS and stakeholders behavior will evolve as real-world experience regarding technical options for managing interference accumulates and research ideas mature toward commercialization at scale.[156]

C. License Design, Economic Methods, and Flexible Spectrum Management

As explained in the preceding two sections, there are many perspectives on whether and how exclusion as an economic property right and interference protection might be implemented. We will need time to work these out. With respect to interference protection, legacy static exclusion zones based on large geographic spatial or frequency separation foreclose extensive opportunities to share spectrum more efficiently.[157]

Additionally, it is reasonable to expect that we may wish to have additional or different tiers or classes of users with different rights to spectrum access and interference protection in 3.5GHz, and in other bands, as markets and technologies evolve.

The SAS framework as discussed earlier provides a model for how both sorts of changes might be accommodated.[158] Changes in the interference management techniques and other aspects of license design (duration of licenses, size of license territories, etc.) will impact the value of exclusion rights as one of the property rights conveyed by the licensing framework (and vice versa).[159]

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156. Martin B.H. Weiss et al., Socio-Technical Considerations for Spectrum Access System (SAS) Design (2015) (unpublished manuscript) (http://d-scholarship.pitt.edu/25828/).

157. *See supra*, note 155.

158. *See supra* text note 52 and accompanying text.

159. *See e.g.*, Thomas W. Hazlett and Evan T. Leo, *The Case for Liberal Spectrum Licenses: a Technical and Economic Perspective* (Mar. 23, 2010) (discussing the efficiency of liberal licenses) (unpublished manuscript), http://papers.ssrn.com/sol3/papers.cfm.

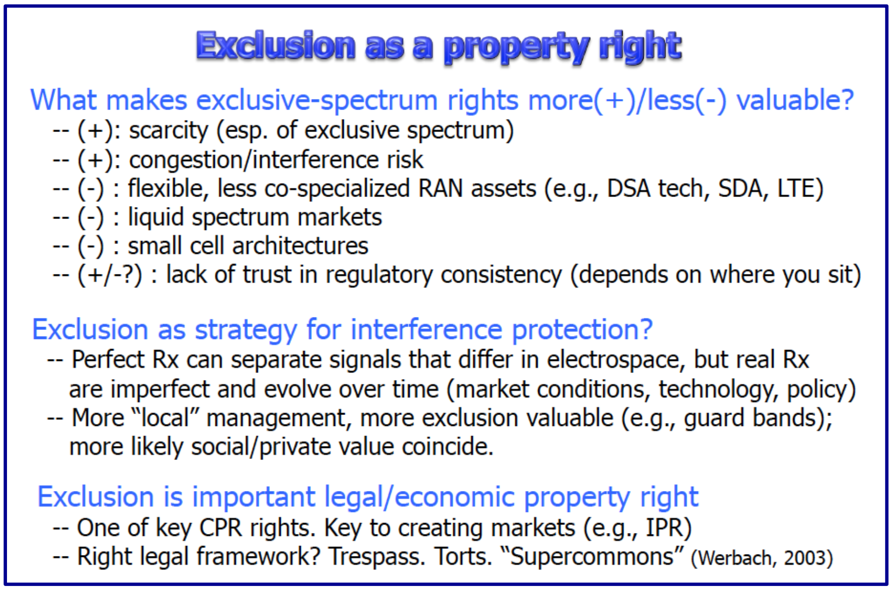

Figure 3: Value of Exclusion Property Right

Figure 3 offers some speculations for how changes to other aspects of the licensing framework and spectrum environment may impact the value and interest in exclusion rights.

First, to the extent spectrum remains scarce—either because of regulatory or market impediments that prevent efficient utilization of under-utilized spectrum or because demand is sufficiently high in particular bands or locations—exclusive spectrum rights should be more valuable. This appears almost as a tautology; but on careful reflection it is reasonable to imagine that spectrum values will differ by context (band, location, regulatory regime) and scarcity will impact spectrum values differentially and the relative value of exclusive or shared spectrum may be inverted.

Second, for stakeholders that perceive a high cost and risk from congestion or interference, the value of exclusive rights will be higher.[160] It is important to note that some radios or applications may be robust to interference or may operate in environments where the likelihood of interference is limited, reducing their valuation for exclusive access rights.[161] Other radio designs or applications might be less tolerant of interference but may also be able to accommodate more selective exclusive interference rights. For example, consider an application like radio-astronomy that would like to exclude other users to minimize background noise, but only needs that when the telescope is actively sensing, an activity that could be scheduled.

Third, users with more agile radio technology that is better able to adapt

160. *See* KIMBERLY M. RANDOLPH, STOUT RISIUS ROSS, SPECTRUM LICENSES: VALUATION INTRICACIES (2011) (explaining the added value of restricting spectral traffic).

161. *Id.*

to other frequencies or make use of spectrum with less assured availability or quality (interference protection) should value exclusive spectrum less. To the extent that becomes more prevalent in the marketplace, the premium for exclusive access rights should be less. In the 3.5GHz band, the rules call for commercial radios to be capable of tuning to frequencies across the entire band to allow them to be dynamically assigned to specific frequencies and relocated as necessary.[162]

Fourth, and complementary to the preceding, increased liquidity for spectrum access rights ought to make other rights more valuable and hence may reduce the value of exclusive use spectrum in any particular band, the value of exclusivity overall. Of course, just as the prevalence of other media channels has reduced the value of radio advertising time on average; certain radio advertising slots (e.g., drive-time in major metro areas) has become more valuable.[163] In a portfolio with diverse assets, prices for particular assets may move in unpredictable ways.

Fifth, as wireless architectures transition to smaller cells, spectrum in different frequencies will become closer substitutes. Additionally, the rights to exclude spectrum become less valuable as the spectral space over which other use is excluded shrinks.[164] The 3.5Ghz framework is proposing PAL territories be relatively small, comprised of a single Census Block; and be of relatively short duration.[165] In such small territories and short-duration licenses, the value of an option to exclude is relatively less.[166] However, as suggested in Lehr (2014(b)), it may be feasible for the PAL interference protection rights and option-to-exclude to trade separately.[167] This might make it feasible for a SAS administrator to aggregate exclusion options and then use targeted exercise as another tool with which to manage access to the spectrum controlled by the SAS.[168] The flexibility to pursue such business models might help foster the sort of inter-SAS administrator competition that the FCC believes is important for the success of the model and for the "race to the top" competition that will help SAS practices evolve successfully.[169]

Sixth, increased trust in regulatory consistency may render exclusive rights either more or less valuable depending on where one sits in the policy

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162. *See supra* note 9. For example, under the currently proposed rules, PALs will provide licensees with access to 10MHz of 3.5GHz spectrum, but not to specific frequency assignments. The analogy is to "seats in a movie theater" as opposed to a specific seat assignment as at a concert.

163. CHARLES W. LAMB, JR. ET AL.,MARKETING 569 (11th ed. 2010); ANDREW SWEETING, DEPARTMENT OF ECONOMICS, NORTHWESTERN UNIVERSITY, COORDINATION, DIFFERENTIATION AND THE TIMING OF RADIO COMMERCIALS, http://public.econ.duke.edu/~atsweet/ASweeting_RFTimingAccepted.pdf.

164. Lehr, W. and M. Oliver, *Small Cells and the Mobile Broadband Ecosystem* (June 2014) (unpublished manuscript) (http://www.econstor.eu/handle/10419/101406).

165. Commission Seeks Comment on Shared Commercial Operations in the 3550−3650 MHz Band, 79 Fed. Reg. 31247 (proposed June 2, 2014) (to be codified at 41 C.F.R. pt. 1).

166. Lehr, *supra* note 72.

167. *Id.*

168. A SAS administrator in a position to make higher value economic use of the exclusion-options should be able to acquire them from the PAL licensees. Of course, there is a risk that aggregation of exclusion-options might also be used as a strategy to foreclose competition. This need to protect against foreclosure strategies remains, however, whether there are exclusion options or not and so needs to be addressed.

169. FED. COMM. COMMISSION *supra* note 4.

debates and what one thinks the likely outcome will be.[170]

Separating exclusion and interference management rights in the licensing framework by the mechanism proposed in Lehr (2014(b)) or some other approach is desirable to allow markets, policymakers, and industry stakeholders to adapt interference management and exclusion practices as experience accumulates and markets evolve.

Explicitly including an economic component in license design that separates the exclusion and interference protection rights facilitates regulatory flexibility and transparency. As argued earlier, a purely engineering based approach is, at best, a legal fiction since economics and incentives will creep in in any case.[171]

V. CONCLUDING REMARKS

This paper makes the argument that the future of spectrum usage is shared spectrum in its many forms. This means being friendly to the commercialization of lots of new radio technologies that make it possible for the scope, capabilities, and spectrum usage for all kinds of wireless services to continue to improve and grow. All sorts of applications and radio networks with legacy and new technologies that are deployed and managed by commercial enterprises, government agencies, and end-users will need to share limited spectrum resources. Meeting that goal will require supporting flexible business/market models and regulatory frameworks.

The tripartite sharing model and the attendant Spectrum Access System (SAS) framework being developed to enable commercial-government sharing in the 3.5GHz band represents an important watershed event.[172] If successful, the SAS framework provides an important step toward enabling more flexible and dynamic spectrum management to support the sorts of flexible and adaptable technical, business, and rules frameworks that will be needed to evolve as wireless technologies and markets continue to evolve. This model enables much finer-grained allocation of spectrum resources which supports more intensive sharing of spectrum in multiple dimensions.

While most of the focus on design of the SAS has addressed the engineering capabilities of the SAS, it is also important to include economic functionality into the SAS and the licensing framework it enables. In Lehr (2014b), I proposed one way to do this by explicitly separating interference protection rights from exclusion rights.[173] This was to be accomplished by reinterpreting PALs as options contract, granting licensees the option to exclude other radios from operating in the PAL territories.[174] The option could

170. MOHAMMED ALTAMINI ET AL., *ENFORCEMENT AND SPECTRUM SHARING: CASE STUDIES OF FEDERAL COMMERCIAL SHARING*, http://d-scholarship.pitt.edu/1966/1/TPRC_2013_Final.pdf.

171. *Supra* note 100.

172. Lawrence E. Strickling, *Innovation, Collaboration and Sharing in the 3.5 GHz Band*, National Telecommunications & Information Administration (Apr. 17, 2015), http://www.nita.doc.gov/blog/2015/innovation-collaboration-and-sharing-35-ghz-band.

173. Lehr, *supra* note 84, at 16.

174. *Id.*

be exercised by an additional payment of the exercise price during the life of the contract. Although the proposal left many details to be determined and although commenters to date have largely dismissed the idea from further consideration,[175] this paper explains why further consideration of this core concept is important.

Exclusion rights play an important role in property rights models for incentivizing efficient resource usage, which is a key goal of spectrum management policy. They have played a key role in the management of spectrum access for TV broadcasting and cellular services.[176] The model of exclusive-use licensed spectrum is likely to remain important, although perhaps less so, in the future.[177] Today and in the future, we expect to need a multiplicity of spectrum regulatory models (licensed, unlicensed, and others) to support the requirements of diverse technologies, business models, and wireless applications.[178]

Meanwhile, technical and non-technical options for managing and mitigating harms arising from interference have exploded.[179] In light of these advances, continued reliance on legacy static models of exclusion zones derived from worst-case modeling of interference that lock in excessively large geospatial and/or frequency separation of radio networks are an inefficient and unnecessarily coarse mechanism for managing interference.[180] Consequently, the time has come to explicitly separate exclusion-rights and interference protection rights in our licensing frameworks. An approach like that proposed in Lehr (2014(b)) would allow us to endogenize the choice of whether to use exercise of the exclusion-right as a complement or substitute for other interference protection mechanisms that may exist.[181] Endogenizing this decision in this way and creating the capability for spectrum usage models to adjust to changing market contexts is in keeping with the desire to transition from dedicated spectrum to market-based shared spectrum management.

175. *Id.*

176. Daniel A. Farber, *Access and Exclusion Rights in Electronic Media: Complex Rules for a Complex World*, 33 N. Ky. L. Rev. 459, 473 (2006).

177. WILLIAM LEHR ET AL., MANAGING SHARED ACCESS TO A SPECTRUM COMMONS, (Nov. 11, 2005) http://cfp.mit.edu/ docs/lehr-crowcroft-sept2005.pdf.

178. *Id.*

179. *Id.*

180. *Id.*

181. Lehr, *supra* note 84.