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In the Matter of)
)
Amendment of the Commission's Rules with) GN Docket No. 12-354
Regard to Commercial Operations in the)
3550-3650 MHz Band)

Reply Comments of

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PALs as Options to Exclude GAA

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1. Introduction and Summary

I, William H. Lehr,¹ respectfully submit these reply comments in response to the Further Notice of Proposed Rulemaking in Regard to Commercial Operations in the 3550-3650 MHz Band ("*FNPRM*").²

¹ Economist and Research Scientist, Computer Science and Artificial Intelligence Lab (CSAIL), Massachusetts Institute of Technology; Contributor to the PCAST (2012) report on spectrum policy. See Attachment 1 for further biographical details. All opinions expressed herein are the author's alone.

² See Further Notice of Proposed Rulemaking, In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, Before the Federal Communications Commission, GN Docket No. 12-354, Released April 23, 2014, available at:

First, I agree with many of the other commenters in this proceeding in applauding the Federal Communication Commission's (FCC's) efforts to expand commercial access to radio frequency spectrum by crafting rules for the Citizens Broadband Radio Service (CBRS) in the 3550-3650 MHz (3.5GHz) band,³ and in moving forward to implement the recommendations of the *PCAST Report*.⁴ As a spectrum policy analyst and economist, and as a contributor to the *PCAST Report*, I support the FCC's efforts to implement the three-tiered model for sharing spectrum to be managed by a dynamic Spectrum Access System (SAS) that was advanced in the *PCAST Report*.⁵ This is an important step toward expanding spectrum sharing opportunities and enhancing economic incentives to use spectrum efficiently over time.

The FNPRM's three-tiered framework envisions adding two new tiers of commercial users to the Incumbent Access tier: Priority Access License (PAL) users; and Generalized Authorized Access (GAA) users. PAL users would bid for licenses that would grant them an assured degree of interference protection;⁶ whereas GAA users would access spectrum on a license-by-rule basis, but without additional interference protection rights.⁷ A key question that arises is how PAL and GAA users might coexist and share spectrum.

http://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db0425/FCC-14-49A1.pdf, hereafter "3.5GHz FNPRM"). The opinions expressed herein are those of the author alone.

³ Many commenters approve the FCC's efforts to expand commercial access to spectrum in the 3.5GHz band for shared use by multiple tiers of users, with sharing to be managed by a Spectrum Access System; however, there is significant heterogeneity in the commenters views regarding the PAL license terms, the extent to which GAA or PAL access should be preferred, the design of the SAS, and other issues. For example, see the comments filed by AT&T, Google, Microsoft, Nokia Solutions and Networks, Pierre de Vries, T-Mobile, Verizon, Wireless Innovation Forum, and others. (These comments were filed as "Comments of X," on July 14, 2014, in response to the 3.5GHz FNPRM, note 2 *supra*. Hereafter, these will be referenced solely as "Comments of X filed in the 3.5GHz FNPRM on July 14, 2014" unless another docket is being referred to.)

⁴ See PCAST (2012), "Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth," President's Council of Advisors on Science and Technology (PCAST), July 2012, available at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

⁵ I also support the many commenters who agree that the initial specification of exclusion zones designed to protect Federal incumbent users are too large, having been derived based on modeling scenarios that are inconsistent with current thinking of how the CBRS will be used (e.g., with more realistic modeling of radio system performance); and that power levels limits should be relaxed to allow more scope for commercial deployment.

⁶ The FNPRM proposes allocating PALs in 10MHz chunks on a Census Tract basis, for one-year licenses. Some commenters argue in favor of much more granular assignments (e.g., see Google Comments to 3.5GHz FNPRM, filed July 14, 2014); while others argue in favor of larger license areas and longer license lives (e.g., see T-Mobile or Nokia Solutions and Networks Comments, separately filed to 3.5GHz FNPRM, July 14, 2014).

⁷ GAA users would not have a claim of interference protection from other authorized users, and would be required to avoid interfering with PAL or incumbent users. However, all users of the spectrum may

Although many commenters support the FCC's overall approach in this proceeding, they disagree with respect to how PAL and GAA access to spectrum might best be managed.⁸ Some parties have emphasized the importance of the PAL tier,⁹ while others have focused on the importance of the GAA tier.¹⁰ Some parties have called for greater reliance on a dynamic SAS to manage interference on the basis of more realistic models of the actual interference environment,¹¹ while others argue in favor of more static licensing terms (with larger territories and longer lived licenses than proposed in the *3.5GHz FNPRM*).¹²

Whether a spectrum user needs and is willing to pay for the interference protection afforded by a PAL, or whether GAA rights are sufficient for the user will depend on the usage context. The usage context will be a function of an individual user's wireless technology, business model, and market conditions (including the associated interference environment) that will evolve over time.¹³ In this sort of complex decision-making situation, rife with asymmetric, uncertain, and private information, it is desirable to allow market forces greater scope for managing when and where PAL and GAA users may co-exist.

In these reply comments, I focus narrowly on how this may be accomplished by modifying the payment rules for PALs. This will help expand opportunities and improve economic incentives for both PAL and GAA users to invest in and make use of the CBRS. In *FNPRM* paragraph 127, the FCC seeks comments regarding how the payment rules for PAL bidders might be modified to

expect to be protected from illegal uses of the spectrum, which presumably would include non-compliant GAA, PAL, or incumbent devices.

⁸ For example Google, the Wireless Innovation Forum, and Pierre de Vries argue in favor of managing spectrum access on the basis of interference threshold requirements, rather than geographic license territories, which would enable greater scope for GAA co-existence with PAL users. In contrast, AT&T, Verizon, T-Mobile argue in favor of expanded PAL protection rights and against GAA operation in active PAL territories (see separate comments to *3.5GHz FNPRM*, filed July 14, 2014).

⁹ See Comments Nokia Solutions and Networks to *3.5GHz FNPRM*, filed July 14, 2014.

¹⁰ See Comments of Microsoft to *3.5GHz FNPRM*, filed July 14, 2014.

¹¹ See Comments of Google to *3.5GHz FNPRM*, filed July 14, 2014.

¹² See Comments of T-Mobile to *3.5GHz FNPRM*, filed July 14, 2014. The *3.5GHz FNPRM* proposes that PALs should grant access to 10MHz of spectrum and be awarded for 1 year and on the basis of Census Tracts (see paragraph 6, 49).

¹³ For example users with interference-sensitive applications (e.g., hospitals) or seeking to deploy multiple cells over a larger serving area (e.g., LTE mobile network operator) may feel they need PAL interference protection for their usage case, whereas users of interference-tolerant applications (e.g., latency/noise tolerant data services or devices) or mass market consumers deploying cells for home networks may find GAA spectrum preferable. Also, the value of interference protection is likely to be higher in congested markets (urban rather than rural markets) and may be expected to change over time (either becoming more valuable as aggregate commercial usage increases over time or less valuable as technologies enabling more intensive sharing continue to improve and other spectrum becomes available).

provide additional incentives "for the productive use of spectrum" by allowing winning bidders to delay final payments until "initiation of service" in a specific PAL.¹⁴

A simple way to do this, within the context of the existing SAS and licensing framework, is to view the PAL as an *option to exclude GAA usage*. PAL licensees would acquire the right to exclude GAA access, owing P1 when the PAL is awarded, and then owing P2 when the licensee elects to exercise the option at some later time before the license expires. Until such time as the PAL option is exercised, GAA usage would be permitted in the PAL license territory.

In Section 2, I further elaborate how this might work in practice; and in Section 3 discuss the benefits such an approach offers. Section 4 addresses some of the concerns I anticipate might be raised; and Section 5 concludes.

2. PALs as *Options to exclude GAA*

As noted above, a principal difference between a PAL and GAA is that PAL users pay for a right to interference protection. Whether such protection requires exclusion of GAA users depends on the particular usage context. Viewing the PAL as an option to exclude GAA users from some point onward during the life of the license allows adjustment to the particular usage context.

In its simplest implementation, the licensee would *owe* P1 when the PAL is acquired (following the auction) and P2 when the "option to exclude" is exercised, for a total payment of P1+P2.¹⁵ Two extreme cases may occur. First, the licensee may elect to exercise the option immediately, owing P1+P2. Were all licensees to do this, it would preclude any GAA operation in PAL spectrum. Second, the licensee may elect never to exercise the option. In that case, GAA devices would be permitted to operate in the spectrum for the entire duration of the license. Were all licensees to do this, GAA devices would be permitted to operate in all commercially accessible 3.5GHz spectrum.¹⁶ Enabling the PAL option expands market opportunities for GAA access in a way that is responsive to the needs of individual PAL users that may vary by market and over time.¹⁷

For example, the most obvious case is that of a PAL user that does not expect to be operational in a license territory immediately upon receipt of the license, but anticipates requiring excluding GAA users once the PAL user goes operational. In that situation, both the PAL and GAA users

¹⁴ See FNPRM, paragraph 127.

¹⁵ The licensee owes the payment when the obligation for the payments takes place. The actual payments may be further split in time between down payments and final payments, if desired. This will impact valuations, but the added complexity of such further refinements is ignored here.

¹⁶ GAA devices also may be permitted to operate in Incumbent Access spectrum. The focus here is on whether GAA devices are allowed to operate in PAL spectrum or only GAA spectrum.

¹⁷ For example, in the same geographic regions or over time, different PAL users may have different tolerances to potential interference and preferences for excluding GAA devices. This means that the share of PAL spectrum open to GAA usage may decline more or less gradually over time.

can benefit: the GAA users gain from having expanded access to spectrum; and the PAL users gain by being able to delay (and thereby reduce¹⁸) their payments for interference protection.

Alternatively, the PAL user may recognize that they do not need to exclude GAA access over the entire territory, and may expect that the need to exclude GAA access may never arise unless the density of GAA usage exceeds some congestion threshold. Such a licensee may find the option to exclude valuable even if the licensee believes it is relatively unlikely that the option will be executed, and taking advantage of the option reduces spectrum access payments while still providing contingent interference protection.¹⁹ Furthermore, it is worth noting that interpreting the PALs as options does not reduce the obligation of GAA to avoid interfering with PAL users, nor the effectiveness of other enforcement mechanisms that may be required to ensure this occurs.²⁰ Indeed, the option to exclude GAA is a complementary interference management tool, available to PAL licensees (who may individually choose to invoke the option) and the FCC (which may modify the attractiveness of exercising the exclusion option by the design of the PAL licenses and auction/pricing/payment mechanisms used to award PALs).

Finally, a user who never expects to invoke the exclusion option (and thus incurring P2) and does find the interference protection afforded by just paying P1 sufficiently valuable might simply elect to use GAA spectrum.²¹

The basic schema is simple to implement and involves just two modifications. First, the payment needs to be split between P1 and P2; and second, there needs to be a process for implementing the option in the SAS and connecting that with the FCC mechanism for collecting payments.

With respect to how to split the payment, there are multiple options, but as a start, the simplest approach might be to split the total PAL auction bid into two equal-sized payments. A winning bidder (with a bid of P for a PAL) would expect to owe $\frac{1}{2} P$ when the license is awarded and $\frac{1}{2} P$ when the licensee elects to exercise the option to exclude. The opportunity to delay payment would provide winning bidders with an economic incentive to avoid excluding GAA users unless the benefits of such exclusion outweigh the costs of exercising.

¹⁸ Taking into account the time value of money, and the contingency of potentially not needing to invoke the exclusion provision should interference protection requirements be met while still allowing GAA sharing in the band.

¹⁹ The option provides a measure of insurance that is valuable against contingent harms, the expected value of which may vary by user or market environment.

²⁰ For example, interference claim thresholds for receivers, third party monitoring (including spectrum sensing), software/firmware requirements for PAL/GAA devices that may be adopted to ensure compliance with the SAS, or other interference management strategies may also be incorporated as part of the overall spectrum management framework. The adoption of "PALs as options" is compatible with other approaches for managing interference, and should ease adoption of these since it makes exclusion policies more flexible.

²¹ It is possible that in the future, the growth of aggregate GAA usage might necessitate some mechanism for rationing GAA access. This might induce interest in purchasing PALs to ensure access even if the interference protection afforded by a PAL is not desired. Note, these comments are agnostic as to the amount of spectrum that may be reserved for GAA access and how aggregate GAA access is managed.

Integrating this into the SAS/FCC payment collection framework would be relatively easy. The licensee would register its intent to exercise the option to exclude GAA users with the SAS and the FCC as of a certain date (exercise date). The SAS would be updated to reflect that the affected PAL spectrum was no longer available for GAA use; and the FCC would know that P2 is due and initiate collection subject to its payment/collection rules. This minor adjustment to the SAS represents a minimalist approach to making the SAS more dynamic (a goal of spectrum policy!) and the allocation of spectrum between exclusive PAL and GAA use more responsive to market forces (economic efficiency in spectrum management!), while keeping the practical elements that need to be adjusted as simple as possible (minimal implementation costs!).

Obviously, the above schema could be made more complicated to better match the splitting of payments to the value of the option (P1) and the value of its exercise (P2).²² The apportionment factor (z , set above at 50%) could be adjusted either up or down to front or back-load payments and might even be split into more than two payments. The split in payments might be adjusted based on market data or some other basis that may better inform the relative apportionment of value.

Discussing such refinements is beyond the scope of these reply comments, but the basic idea for this approach originates in the law & economics literature discussing the relative merits of different legal regimes for protecting against harmful externalities arising from the exercise of property rights.²³ Spectrum access rights are a form of property right,²⁴ and getting the

²² These are Real Options, which are closely related to Financial Options, which are a subclass of Derivative Securities. There is a wealth of theory and practical experience in how these may be designed to carefully tailor the payments to shape incentives. For a discussion of these, see for example, Dixit, A. and R. Pindyck (1994), *Investment under Uncertainty*, Princeton: Princeton University Press, 1994; Trigeorgis, L. (1996), *Real Options*, Cambridge: MIT Press, 1996; or, Wilmot, P. (1998), *Derivatives: the Theory and Practice of Financial Engineering*, New York: John Wiley & Sons. The benefits of this theory and experience may prove useful in informing industry stakeholders' valuations of the PALs, however, taking account of the many options afforded for the design of the PALs is not necessary in order to implement the basic and simple idea. Keeping things simple may be preferable, at least initially.

²³ For example, see Calabresi, G., & Melamed, A. D. (1972), "Property rules, liability rules, and inalienability: one view of the cathedral," *Harvard Law Review*, 1089-1128; Coase, R. H. (1960), "The Problem of Social Cost," *Journal of Law and Economics*, vol. 3 (October) 1; Kaplow, L., & Shavell, S. (1996), "Property Rules versus Liability Rules: An Economic Analysis," *Harvard Law Review*, 109(4), 713-790; Ayres, I., & Talley, E. (1995), "Distinguishing between Consensual and Nonconsensual Advantages of Liability Rules," *The Yale Law Journal*, 105(1), 235-253; or Smith, H. E. (2004), "Exclusion and Property Rules in the Law of Nuisance," *Virginia Law Review*, 90(4), 965-1049.

²⁴ Earlier folks tended to associate property rights with exclusively licensed spectrum and contrasted that with unlicensed spectrum that was modeled as a common. 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 are a continuum of potential sharing (rights) models. For further discussion, see for example, CFP (2014), "Toward More Efficient Spectrum Management," MIT Communications Futures Program (CFP) Spectrum Working Group White Paper, March 7, 2014, Notice of Ex Parte submission to GN Docket 12-354, available at <http://apps.fcc.gov/ecfs/comment/view;jsessionid=y1ppTXCR9CN27jGyTHkGh9bwb6b0CHPLwJn25YJvLsWWvQ2xNI2S!-448120223!-58662085?z=dyszsz&id=6017604194>.

assignment of such rights correct in order to induce appropriate incentives for allocating and using spectrum efficiently has long been recognized by economists and scholars interested in spectrum management reform.²⁵ A valuable insight from Professor Ayers is that options theory can augment property rights and liability rules to render them closer substitutes for enforcing efficient allocation of usage rights, especially in decision-making contexts with imperfect information (asymmetric, private, uncertain).²⁶ Managing interference in today's complex world of wireless offers just such a situation where the optimal assignment of radio resources depends on a mix of factors that may be unknown to regulators and may change over time with market conditions.

3. Benefits of Modified Payment Terms

Regarding PALs as real options (guaranteed access to PAL spectrum with interference protection, plus right to exercise right to exclude GAA operations in the PAL spectrum as of option exercise date) offers multiple benefits, including:

- More efficient spectrum usage and expanded access for commercial users;
- Encourages participation of PAL and GAA commercial users by enabling better matching of PAL costs with network investment requirements and by expanding access for GAA;
- Simple to implement so low implementation costs;
- Reduces potential risk of spectrum hoarding by PAL; and,
- Flexibility and consistency with dynamic shared spectrum future

Each of these benefits is discussed further in the following sub-sections.

3.1. More efficient spectrum usage and expanded access to commercial users

The key motivation for this proposal is to enhance incentives and prospects for efficient use of our radio frequency spectrum. By allowing flexibility in whether GAA use is allowed in the PAL spectrum, the PAL Option approach expands the economically viable spectrum accessible to both GAA and PAL users.

This is the overall goal of the PCAST report's recommendations and the FCC's efforts to define rules for the new CBRS in 3.5GHz. If successful, the benefits of this approach may be extended to other bands.

This approach affords greater scope for economic market forces to help direct the efficient use of spectrum resources, and thus helps reduce the need for more detailed technical rules and

²⁵ For example, see Coase, R. H. (1959), "The Federal Communications Commission," *Journal of Law and Economics*, 2 (October) 1-40; Hazlett, T. W. (1998), "The Law and Economics of Property Rights to Radio Spectrum: Introduction," *Journal of Law and Economics*, 41(S2), 521-522; Werbach, Kevin (2004), "SUPERCOMMONS: Toward a Unified Theory of Wireless Communication," *Texas Law Review*, 82 (March 2004) 863-973; or Goodman, E. (2004), "Spectrum Rights in the Telecosm to Come," *San Diego Law Review*, 41, 269-404.

²⁶ See Ayres, I. (2010) *Optional law: the structure of legal entitlements*, University of Chicago Press, 2010.

specifications that the FCC policy process and the requirements of dynamic wireless markets are ill-equipped to frame appropriately. As such, this approach is more consistent with the policy goals of service and technical neutrality, and the desire to minimize regulatory-induced distortions.²⁷ The CBRS rules should facilitate the commercialization of both PAL and GAA business models, and leave it to market forces to the extent possible, to determine the appropriate balance between these two models in the marketplace. Both spectrum usage models are important to different groups of commercial actors, and denying adequate spectrum resources to either type of user will make the CBRS less attractive to that class of actors. As explained further below, the PAL Option approach can improve incentives for both PAL and GAA users to participate.

3.2. Encourage participation of PAL and GAA commercial users

3.2.1. Better matching of PAL costs with network investment requirements

The PAL Option approach enables PAL users to better match their spectrum acquisition costs to their network investment and operational requirements. After securing their spectrum rights, it will take time for PAL users to build out their networks and their operational requirements for interference protection may evolve over time.

This is likely to be especially relevant for PAL users like mobile network operators that anticipate using the spectrum as part of a wide-area service (i.e., larger than a single PAL), which may have different requirements in different parts of their serving areas.²⁸ The PAL Option approach allows PAL users to lower their payments, thereby reducing the cost of acquiring spectrum. In effect, the option allows more granular management of the spectrum resources and is complementary to and akin to the benefits of smaller license territories.²⁹ By lowering the cost of acquiring spectrum for efficient PAL operators, the option approach should encourage greater commercial participation.³⁰

²⁷ While regulatory interventions in markets may be necessary, they are often a second-best solution since regulators typically have less good information than market participants and their tools have limited flexibility. A goal of service/technical neutrality in regulatory design is to minimize the potential adverse impact of regulatory distortions and allow greater scope for market forces to select appropriate business models and technologies. While we may aspire for commercial neutrality in spectrum policy, this goal is not fully achievable and technical rules are an unavoidable and necessary component of any real world spectrum management regime. However, introducing market-based tools such as envisioned in the PAL option approach may help ameliorate the potential rigidities and problems associated with such technical rules.

²⁸ Spectrum and interference protection requirements will vary market-by-market based on customer density (rural/urban) and the spectrum assets that the mobile operator already has. The next generation of mobile systems based on 4G LTE are designed to flexibly manage and integrate diverse spectrum resources.

²⁹ See Lehr, W. and J. A. Musey (2013), "Right-sizing Spectrum Auction Licenses: the case for smaller geographic license areas in the TV Broadcast Incentive Auction," white paper, available at <http://apps.fcc.gov/ecfs/document/view?id=7520959686>.

³⁰ The presumption is that the value of the option to exclude GAA is based on the operational requirements of the PAL operator, and not on some other strategic motivation (e.g., to foreclose GAA

3.2.2. Expanded access for GAA

A key feature of the PAL Option approach is that it expands access for GAA spectrum beyond what would otherwise be available. A number of commenters have noted that GAA operation could occur in many parts of a PAL without causing any harmful interference³¹ to the PAL user, either because the PAL user is not yet operating, is operating in a small portion of the PAL, or because the PAL user can tolerate co-existence with GAA in the same spectrum.³²

The option to share PAL spectrum is separable from any efforts to reserve some minimum amount of 3.5GHz spectrum for GAA access as proposed in the *FNPRM*, but this expanded access may make it easier to tailor a solution for ensuring adequate spectrum access for both GAA and PAL users.

3.3. Simple implementation

As noted above, very little is needed to implement this approach. Fundamentally, it may be accomplished by a slight modification in the payment terms for implementing the PALs and readily incorporated via functionality already anticipated in all but the most conservative and least-dynamic visions of the SAS. At a minimum, the SAS is expected to be able to provide guidance to CBRS band users (incumbent, PAL, and GAA) on which frequencies are available in which license areas for use, and this database information needs to be updatable on a relatively coarse (not necessarily real or near-real-time basis) that is fully consistent with reasonable parameters for the timing of option exercise notification.³³

Would-be PAL bidders may take advantage of the full wealth of option theory to craft their valuation and bidding strategies, but little additional complexity is required to implement the basic form of this idea as proposed here. However, this does not preclude more complex refinements, if desired. Ample ideas for some of the ways this idea might be expanded exist in the Options literature.

3.4. Reduced risk of under-utilized 3.5GHz spectrum

A concern is that PALs might be acquired that are subsequently under-utilized. This may be because the bidders have not yet deployed active systems, because they have acquired excess resources for future growth and peak traffic needs, or because they value having the spectrum be

competition by limiting GAA access to spectrum). As discussed further below, the PAL Option approach also offers benefits to the extent that such other strategic motivations might be a concern.

³¹ For example, see Google Comments to *3.5GHz FNPRM* filed July 14, 2014.

³² For example, the expected GAA usage may not pose a sufficiently significant risk of harmful interference for the PAL user or the PAL user's usage may be localized in time, geo-space, or direction.

³³ For example, it is certainly reasonable to require that exercising of the Exclusion Option have a required lead time for notification before becoming effective (unless invoked immediately) in which to accommodate the orderly closure and exclusion of GAA usage in the PAL. This lead-time may be measured in days, weeks, or longer; but need not be expected to take effect in very short time periods.

free of radio signals. This last reason may be because they are interested in the PAL spectrum for guard bands, or potentially, because they have a strategic desire to deny spectrum resources to potential competitors.³⁴ In each of these cases, different industry stakeholders may have conflicting notions of what constitutes under-utilized spectrum.

Indeed, if no one elects to build, deploy, and use PAL/GAA compliant devices, the spectrum will remain under utilized and the FCC's efforts to create a viable CBRS will be considered a failure. However, it remains uncertain how utilization of the CBRS spectrum will proceed.³⁵

The PAL option approach provides an economic incentive to the licensee not to preclude GAA utilization of the spectrum unless there is a real economic value to doing so (although that value may be a private value to the licensee). By opening additional spectrum for GAA users, the PAL option approach helps promote GAA usage.

Additionally, the PAL option approach is superior to other approaches that might be considered for ensuring spectrum is utilized. First, it is important to point out that the technical utilization of spectrum is often not the best metric of whether the level of spectrum utilization is economically or socially optimal. For example, radio telescopes that are trying to extract weak signals from space prefer spectrum with very low noise from other transmitters. This is true for other radio services and system designs as well. Prospective customers and investors for wide-area systems may demand that sufficient excess spectrum resources be available in advance of need and in anticipation of peak traffic demands (i.e., appear under-utilized from the perspective of real-time measurements of spectrum occupancy) to justify investing in or subscribing to the commercial services that are expected or already operating in the spectrum. Regulatory rules that embed build-out requirements, technical utilization (spectrum occupancy) standards, or otherwise seek to manage spectrum utilization directly are likely to be hard to implement effectively.³⁶

The PAL option allows PAL and GAA users more scope to design their systems and services, and to differentiate their business models to compete more aggressively in wireless markets.³⁷ Some wireless system operators may choose to invest more in small cells and more capable radio systems that enable higher spectral efficiency, while other operators may use more spectrum

³⁴ Whether it is even economically rationale to hoard spectrum resources as suggested in Note 30 *supra* is debatable, however, this is a concern that has been voiced by participants in spectrum reform discussions.

³⁵ At this stage, there remains significant uncertainty regarding which uses/business models/technologies will be most successful; how fast traffic will grow; how much co-existence between the three tiers of users will be economically viable; etcetera.

³⁶ Build-out or technical occupancy rules with too much detail and specificity are likely to over-constrain PAL user flexibility in choosing technologies, wireless architectures, or business models; and rules that are too loose may be ineffective.

³⁷ This is analogous to the differentiated offers for broadband service from DSL resellers. They may differentiate their services based on their offered quality-of-service (jitter, latency) and its variability. A service that is under-provisioned in the sense that it is more vulnerable to congestion (dropped packets, increased latency during peak periods) may be less expensive. Which is the more attractive broadband service (taking into account price and service quality) may depend on who the customer is (e.g., and their willingness to pay for higher quality service).

resources to economize on efficiencies elsewhere in the overall system. Ultimately, the goal of efficient spectrum usage is to maximize the value of the wireless services that make use of the spectrum, not to maximize the energy in any particular band.

By helping to expand access to economically viable (lower cost, additional) commercial spectrum for PAL and GAA users, the PAL option approach helps promote competition that is not biased in favor of a particular business model. *Ceteris Paribus*, this offers the most effective mechanism for deterring spectrum hoarding strategies that might be designed to limit competition.

3.5. Flexibility and consistency with dynamic spectrum access

As recognized in the *PCAST Report*, enabling continued growth in wireless services of all kinds requires expanding commercial access to spectrum resources. It is neither feasible nor economically desirable to meet all of this demand with new allocations of dedicated spectrum. Fortunately, the design of modern wireless systems makes it unnecessary to rely on dedicated spectrum resources. The future of wireless is to share spectrum much more intensively, and there are many technologies, business models, and regulatory regimes that make this possible.³⁸ For example, a key feature of the 4G LTE technology that mobile network operators are currently in the process of adopting around the world is its ability to provide fine-grained, dynamic control of spectrum frequency resources.

Advances in smart networking and radio systems, including in such technologies as cognitive and software defined radios, signal processing, and advanced Internet architectures³⁹ are enabling a more capable wireless future. These advances will help support new services (for public safety, for Internet of things, for smart grids, for mobile cloud computing, etc.) and will help accommodate the exponential growth in wireless traffic that is expected.

Realizing this future depends on designing systems that are more flexible. A key goal of spectrum management is to decouple radio services and higher level user services from the underlying spectrum resources to make such services more robust, flexible, and capable. It is already the case that wireless telephony is no longer bound to specific frequencies. This unbundling of spectrum resources, long-lived spectrum infrastructure (like towers and even base station hardware radios), and wireless services enables more scalable investment, expanded options for mix-and-match ways to provision and differentiate services, and increased opportunities for competition.

The PAL option approach is consistent with this trend toward a more dynamic, flexible, and shared spectrum management regime. In the future, it is not inconceivable that spectrum

³⁸ Exclusive licensed, unlicensed, and the new three-tiered regime planned for the 3.5GHz CBRS band are all spectrum sharing regimes that allow spectrum resources to be dynamically allocated to different users/uses on a granular basis (in time, power, space, code, etcetera). See CFP (2014), note 24 *supra*.

³⁹ For example, the author is part of the research team involved in the NSF-funded MobilityFirst Future Internet Architecture project that is focused on expanding mobility support in the Internet (see <http://mobilityfirst.winlab.rutgers.edu/>).

resources might give rise to a rich selection of financial securities for managing risk and allocating value across investors, system operators, and end-users. This might be analogous to the range of financial securities associated with other of the raw commodity resources on which our economy depends (e.g., oil, electric power, grains, etc.). This securitization and commoditization of basic resources is a key component of our global trade and economic production systems.⁴⁰

The PAL option approach is a simple first step toward building a more robust SAS ecosystem that is consistent with such an evolutionary path, and helps "future-proof" the regulatory process (without committing anyone to the bolder vision such a trajectory implies).

4. Potential Challenges and Issues to Resolve

The purpose of this reply comment is to suggest a simple change to the interpretation of PALs that I believe would offer a range of important benefits, however it is likely that others may be able to suggest additional enhancements or refinements to this concept that are worth addressing. And, there are likely to be a range of challenges to adopting the PAL Option approach and questions that would need to be addressed before moving forward. In this section, I briefly touch on a few obvious issues that might be of concern.

4.1. Feasibility of Enforcing GAA Exclusion Option

A key concern for all users of the CBRS spectrum is the efficacy of the SAS in protecting compliant access. Incumbent and PAL users with explicit interference protection rights are justified in being concerned that those rights are honored. Similarly, investors and users of GAA devices also have a vested interest in ensuring that whatever framework is eventually adopted provides the spectrum access they can reasonably expect.⁴¹ In Chapin & Lehr (2007), we explained how important it is for the commercial success of dynamic spectrum access for stakeholders to trust the sharing regime.⁴²

The PAL Option approach is consistent with the most conservative and easiest to implement version of the SAS-managed 3-tiered scheme being proposed for the CBRS band. If it proves infeasible to effectively switch PAL spectrum from allowing GAA operations to excluding GAA operations, then it seems implausible that any sort of GAA exclusion or shared operation would be possible. Consequently, these comments assume (and the author believes that is a reasonable

⁴⁰ The securitization of raw commodities allows businesses to manage supply and demand risk, trading off forward and spot purchases/sales to best accommodate their special needs. Options are a well-understood tool.

⁴¹ Because users of GAA spectrum will not have a legal right for interference protection from other legal users of the CBRS spectrum and will have an obligation to avoid causing interference to Incumbent or PAL users with protected access rights, the GAA spectrum users access will be uncertain. An effective SAS regime will help reduce the uncertainty and its attendant investment costs.

⁴² See Chapin, J. and W. Lehr (2007), "The path to market success for dynamic spectrum access technologies," *IEEE Communications Magazine*, May 2007.

assumption) that the enforcement of the PAL exclusion option would be practically and technically feasible as described here.

4.2. Impact on Commercial Access Licensing Revenues

The current proposal is to auction PALs. Because these are anticipated to be for one year and based on Census Tracts (or potentially smaller geographic units), this will entail auctioning many more spectrum licenses, each of which will be less valuable (per license), than has been tried previously.

Some may be concerned that allowing PAL bids to be split into two payments, P1 and P2, will result in lower total license (auction) proceeds being collected. This is certainly a possible outcome. However, it is also possible that implementing the PAL option may increase license proceeds. This might occur if the PAL option encourages participation from PAL and GAA users that results in more confidence (higher future expectations of growth) and self-fulfilling faster growth of a rich commercial ecosystem of CBRS users (devices, applications, and services). Anticipation of such a larger market could induce higher valuations in PALs today.

Whether this is true or not, however, seems like the wrong question. The goal should be to promote efficient spectrum usage, not raise spectrum proceeds. Even without this proposal, it is conceivable that demand for PALs will be limited and the price per PAL and number of PALs purchased will be small. This would leave more spectrum available for GAA users. Alternatively, it is conceivable that demand for the spectrum will be strong and that concerns over acquiring adequate interference protection sufficiently intense that PALs will be scarce and prices may be relatively high (although presumably significantly less expensive on a MHz-POP basis than what is expected in the broadcast spectrum incentive auctions). Uncertainty over the value of PALs and concerns over the relative scarcity of PAL and GAA spectrum may deter ex ante investment in developing business models and technologies to invest in using the spectrum. The PAL option approach provides a market-based way to help manage this scarcity better.

4.3. Threat of Option Allowing Inexpensive Mechanism for Restricting GAA Access

Another potential concern might be if PAL prices are sufficiently low that it is inexpensive for bidders to warehouse spectrum with initial P1 payments, and the mere threat of later invoking the GAA exclusion option proves a sufficient deterrent to investment in GAA devices that the GAA ecosystem of devices and services fails to succeed. Under this scenario, enabling the PAL Option might enable a lower cost way for potential bidders to foreclose GAA access and usage.

On further reflection, this scenario does not seem overly concerning. First, future radio technologies will need to tune to all of the frequencies in the band, with the SAS indicating which frequencies are available in which license areas. Second, the FCC has committed to ensuring at least a minimum level of spectrum access for GAA devices (even if GAA access to PAL spectrum is fully excluded, which could be the case without the PAL option or with the PAL option if all licensees choose to exercise immediately). Thus, if the GAA model works anywhere, it should only be more viable and work better if the PAL Option enables additional GAA spectrum resources.

At this point, it is unclear what the appropriate price for a PAL should be, although the hope is that because aggregate spectrum scarcity should be reduced, the restrictions on PAL usage rights, the short license terms, and small geographic areas, that PAL prices will be low and easily affordable for both large mobile network operators and small users like hospitals.

4.4. Mispricing of Payments

Closely related to the above concern is the concern that the mechanism for splitting the payment between the initial option purchase price, P1, and the exclusion exercise price, P2, will fail to appropriately mimic the economic value of the two rights.

The proposal to split the payment in half is obviously ad hoc but has the advantage of being simple and relatively neutral in its assumptions. More complex mechanisms might be suggested and future adjustments using market or modeling data could be utilized.

At a minimum, this approach implies a non-trivial benefit for postponing exercising the exclusion option until it proves sufficiently important to the PAL licensee. Whether it provides too great or too little an incentive to invoke exclusion will depend on both the mechanism used to allocate payments and the aggregate expected payments.

4.5. Nits and Details

In addition to the above questions/challenges, I can imagine a host of other nits and details that will need to be addressed. To suggest the range of possible questions, but not to try and identify all such questions, here are a few:

4.5.1. Exclusion on subsequent license terms and Reversibility

How does exercise of the exclusion option in a year impact the option to exclude in future year licenses? For example, if the licensee purchases a PAL for year 1, 2, and 3 and executes the exclusion option in year 1, does that mean that the exclusion option for year 2 and 3 are assumed executed at the commencement of the new term? Is it possible to re-introduce GAA sharing in PAL spectrum once the exclusion has been invoked? The choice of how to treat sequential licenses will impact initial valuations regardless of whether the PAL option approach is adopted or not, and the PAL option just provides a more nuanced way to think about this problem which needs to be addressed in any case.⁴³

Some might argue that the types of PAL systems that are most likely to choose to invoke the GAA exclusion option are likely to be long-lived and the need for exclusion would be

⁴³ For example, assuming that the exercise price is fixed at $\frac{1}{2}P$ (as proposed earlier), then the value of exclusion might be decreasing as the license approaches termination (assuming that the value of exclusion is constant per unit of time) or increasing (e.g., if congestion is increasing sufficiently rapidly), which may make it more or less likely that an option would ever be exercised after some proportion of the license were past. The treatment of exclusion rights on subsequent licenses to the same spectrum would impact this calculus, but similar sorts of concerns apply to bidding on multi-year licenses and are not unique to the PAL option approach.

monotonically increasing in the level of traffic, and hence the desire to reverse the exclusion in subsequent periods would be a rare occurrence.

On the oft chance that that is not the case, Professor Ayers "option law" framework posits creating both call and put options to allow for more dynamic flexibility in how resources are allocated.⁴⁴

4.5.2. Separate trading of Option and Spectrum access rights

Some might wonder about whether it should be possible to separately acquire or trade the PAL access option and exclusion options. Potentially something along the lines of a carbon trading scheme might be possible, that would allow users to trade or acquire exclusion rights to create resources for GAA access.

Certainly in real world markets, such repackaging of rights is both feasible and generally regarded as contributing to overall efficiency. Figuring out how this might work and impact the management of sharing in the CBRS is beyond the scope of this comment, but at least initially, this might add to implementation cost.

4.5.3. Other stuff

There are likely to many more nits and details that will occur to folks, some of which may be easily answered and others that may require more thought and further adjustments.⁴⁵ Fundamentally, the PAL Option approach is intended to be a simple first step to inject a helpful and scalable tool for introducing economic incentives into the CBRS management framework.

Its adoption will impact the need and efficacy of other aspects of the CBRS framework (e.g., how much spectrum to reserve for GAA? whether GAA operation in PALs should be permitted at all? What technical rules or build-out requirements are needed to promote efficient spectrum utilization? Etc.). While the intent is to propose a modification that either complements or offers a better substitute for alternatives under discussion, its full evaluation will depend on a more complete articulation of the CBRS rules framework (length of licenses, territory size, power limits, etc.).

It is precisely in this context of a partial and evolving set of rules that introducing economic incentive mechanisms may prove most valuable.

⁴⁴ See Ayres (2010), note 26, *supra*.

⁴⁵ For example, as presented, PAL licensees may invoke their exclusion option individually. What are the interaction effects across PAL spectrum on the SAS and on PAL and GAA users in adjacent spectrum? Answering this question may depend on the granularity of the licenses and SAS management capabilities.

5. Concluding remarks

These reply comments offer the suggestion that the FCC modify its payment rules such that PALs are viewed as a real option, such that the payment is split into two parts: P1 for the right to use PAL spectrum and the interference protection it affords, which is owed upon the award of the license; and P2 to exercise the option to exclude GAA use of the spectrum from the time the option is exercised for the remaining duration of the license. Until the PAL option to exclude is exercised, GAA is permitted in the PAL spectrum.

This PAL Option approach provides a simple way to introduce economic incentives and market forces into the CBRS framework for managing shared commercial access in the 3.5GHz band. This will enhance economic incentives of both PAL and GAA users to participate in the band and use spectrum efficiently, will promote competition, and is consistent with the long-term trajectory for the evolution of wireless services and spectrum usage.

6. Attachment 1: About the author

Dr. William Lehr is a telecommunications/Internet industry economist and policy analyst with over twenty years of experience in academic research and industry consulting.⁴⁶ He is currently a research scientist in the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology (MIT). Dr. Lehr's research focuses on the economic and policy implications of broadband Internet access, next generation Internet architecture, and the evolution of wireless technology. Dr. Lehr has written extensively on spectrum policy matters and advised policymakers in the U.S. and abroad on wireless and spectrum management issues. Dr. Lehr was an invited expert participant in the PCAST report.

Dr. Lehr holds a PhD in Economics from Stanford, an MBA in Finance from the Wharton School, and MSE, BA, and BS degrees from the University of Pennsylvania.

⁴⁶ For more information, please visit <http://people.csail.mit.edu/wlehr>.