Analysis of Proposed Modifications to CBRS PAL Framework

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1. Executive Summary

The Citizens Broadband Radio Service ("CBRS") framework[2] reformed U.S. spectrum management by making it more market-based and consistent with the tide of technical and market innovations that have been transforming the architecture and design of wireless networks, technology, and services.

The FCC has now asked for public comment on modifying key aspects of the *2015 CBRS Rules* framework in a recent *2017 Proposal for CBRS Rule Changes*.[3] The contemplated changes focus on modifications to the licensing framework for Priority Access Licenses ("PALs"), which are the commercial access licenses that offer interference protection. The contemplated changes include: (a) enlarging the license areas for PALs; (b) extending the duration of PAL licenses; and (c) making PAL licenses renewable (see Table 1).[4]

Table 1: Proposed Revisions to CBRS PAL Licensing Framework

	2015 CBRS Rules	*2017 Proposal*
Geographic License Area	Census Tract (POP~4,000)	PEAs (POP~298,000)
License Terms	3 years (3+3 consecutive)	10 years
Renewal Presumption	No	Yes

1 In preparing this paper, the author would like to acknowledge the support of WISPA, GE, Google, and Ruckus Wireless. All views expressed herein are the author's own.

2 *See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,* Report and Order and Second Further Notice of Proposed Rulemaking, FCC 15-47, 30 FCC Rcd. 3959 (2015) http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db0421/FCC-15-47A1.pdf ("*2015 CBRS Rules*").

3 *See Promoting Investment in the 3550-3700 MHz Band*, Notice of Proposed Rulemaking and Order Terminating Petitions, FCC 17-134, 32 FCC Rcd. 8071 (2017) https://ecfsapi.fcc.gov/file/1024196454861/FCC-17-134A1.pdf ("*2017 Proposal for CBRS Rule Changes*").

4 These are not the only changes being proposed, but are the most important ones and the focus of this paper.

Adopting these outlined changes would significantly diminish prospects for CBRS to promote economic growth, technical innovation, and the use of wireless technologies by new industry segments. The stated justification for adopting these changes is to foster a favorable investment environment for the band; however, the changes would result in exactly the opposite effect as a cost-benefit analysis of the contemplated changes will demonstrate. They would be unlikely to significantly improve investment incentives for national cellular providers—the sole beneficiaries of the changes—while significantly harming other potential users of the CBRS band, and would put significant benefits in terms of economic growth and innovation that might otherwise result at risk.

The *2015 CBRS Rules* were intended to expand commercial access to an additional 100 MHz of 3.5 GHz spectrum for a diverse range of wireless infrastructure investors with heterogeneous and varying usage requirements, business models, wireless technologies and network architectures. The rule changes under consideration in the *2017 Proposal for CBRS Rule Changes* would effectively foreclose economically viable access to the spectrum for large classes of commercial users, denying consumers the benefits of increased competition and innovative new services, including expanded, cost-effective access to rural broadband services. Reduced access to the spectrum implies reduced spectrum efficiency, and reduced competition in wireless services implies reduced choice and higher prices for consumers.

The proposed rule changes would render the PALs uniquely more attractive to the largest cellular service providers with national footprints, i.e., Verizon, AT&T, Sprint, and T-Mobile—precisely the same firms that control the lion's share of spectrum resources allocated for mobile broadband and dominate the highly concentrated market for cellular services. In contrast, potential CBRS users with geographically localized spectrum needs, new entrants, and/or entrants seeking to deploy novel or purpose-built wireless network applications are likely to find their ability to access the CBRS spectrum significantly diminished.

The CBRS users that would be harmed by the changes include many providers of fixed broadband access services in rural areas that rely on wireless networks to cost-effectively reach their customers; businesses and other enterprise-scale customers (including local governments and non-profits) seeking to deploy private LTE networks in support of novel wireless applications, including Internet of Things ("IoT") applications, in hospitals, manufacturing and distribution facilities, hotels, entertainment venues, or municipal services; and various new types of wireless infrastructure providers such as those interested in providing carrier-neutral small-cell support for mobile broadband and other wireless access models.

A cost-benefit analysis of the proposed changes demonstrates that the benefits to national cellular providers, the sole beneficiaries of the proposed changes, would be negligible in terms of reducing the costs for them to access CBRS spectrum, and would mostly result from the adverse implications the rule changes would have for competition.

Diminished access to the band by a large class of potential infrastructure investors could easily result in a $20 billion per year or more reduction in consumer welfare associated with higher pricing for broadband services and, more importantly, resulting from decelerated access to spectrum for fixed wireless broadband deployment in rural areas and delayed or denied realization of the benefits of localized wireless networks for IoT-driven innovations that are potentially worth hundreds of billions of dollars to the U.S. economy. The risk of incurring these losses is a cost of the proposed changes for which the FCC has not properly accounted.

2. CBRS and its Importance for Spectrum Management

The CBRS framework adopted in 2015 significantly expands the supply of spectrum available to commercial users by creating a framework for commercial users to share 150 MHz of spectrum in the 3.5 GHz band with incumbent users who cannot be relocated at this time.[5] This spectrum is well-suited for shared use by many types of mobile and fixed wireless applications and services that may be deployed and managed by a wide variety of spectrum users, service providers and network operators. A large number of users are anticipated to utilize the spectrum in small cell configurations operating at low power. However many of these users may also use the spectrum for backhaul to connect the small cells. CBRS spectrum will also operate at higher powers to support access to individual customers at greater distances, as in the case of wireless broadband access providers, or in localized private LTE networks for Industrial IoT ("IIoT"). Because the spectrum is close to spectrum currently in use for such applications, users will benefit from lower equipment costs from multiple competitive manufacturers.

Importantly, the CBRS framework represents an important step toward enabling more efficient, market-based management of our scarce national spectrum resources, compared to FCC approaches in other bands. The CBRS band was designed to make this spectrum accessible to all types of commercial users, and thereby maximize its ability to expand wireless license availability to new industries and business modes, providing access for innovative wireless uses that heretofore have lacked economically viable licensed spectrum options. The three-tiered CBRS model is intended to enable flexible shared access between users with diverse usage requirements, business models, wireless technologies and network architectures. For example, the CBRS framework was designed to make the commercial spectrum usable by both large and small wireless system users, with diverse spectrum needs. While a significant portion of the CBRS spectrum is reserved for non-exclusive shared use (General Authorized Access or GAA), provisions were also included for PALs that accommodate spectrum users with a need for additional guarantees of interference protection and the predictable availability of exclusive-use spectrum.[6]

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5 The principal incumbents include Federal radar (e.g., Naval shipborne radar) and fixed satellite earth station users, as well as some legacy fixed wireless users. Both PAL and GAA commercial users must avoid interfering with incumbent users, which means that CBRS spectrum is not available in certain locations and at certain times, both of which may change dynamically as incumbent usage changes. For example, Naval ship radar is an important incumbent user and the availability of CBRS spectrum varies depending on the joint locations of the naval ships and the CBRS users.

6 PAL licensees have exclusive use rights to their spectrum, whereas GAA users have no rights to exclude other GAA users and hence face the risk of potential interference if the spectrum becomes congested.

2.1. CBRS as the next step in evolution of market-driven spectrum management

Historically, the government engaged in industrial policy by allocating spectrum in exclusive fixed frequency bands for specific uses and users, using tightly regulated wireless technologies, under a regime broadly referred to as "Command and Control" ("C&C") spectrum management. More recently, the trend has been toward enabling more market-based spectrum access.[7] Two market-based models for spectrum access are dominant: exclusively-licensed and unlicensed. Cellular providers and over-the-air broadcasters rely principally on exclusively-licensed spectrum, with the former having acquired most of their spectrum via auctions. Enterprises and consumers have principally relied on unlicensed spectrum in the form of Wi-Fi for wireless local area networking.

Licensed spectrum in low- and mid-frequency bands has the advantage that the licensee has exclusive-use rights which allow the licensee to manage spectrum congestion. Unlicensed spectrum is free to access, but users must tolerate congestion caused by other users of the band. Both spectrum management regimes are valuable, and which is most appropriate in a given situation depends on the usage context (the application, technology, business model, etc.). Historically, most spectrum was exclusively assigned because earlier generations of wireless technology did not co-exist easily.[8]

The FCC designed auction regimes to favor providers of wide-area network services by lowering the riskiness (cost) of investments by these companies through geographic areas and license terms that matched their business plans. In other bands, it created non-auctioned licenses or registration systems for businesses operating point-to-point radios and for specialized radio uses such as Intelligent Transportation Systems. Finally, the FCC opened a few bands for unlicensed use for companies and individuals requiring access to spectrum but not the certainty or preclusive rights of a license.

Over time, access to spectrum has become increasingly important to a far wider number and variety of companies, business plans, and technologies than in the past when the FCC established the assignment regimes for existing frequency bands. Importantly, these non-carrier companies need not only unlicensed spectrum, but also licensed spectrum. Today, ever more bandwidth-hungry wireless applications (e.g., fast-response interactivity and multimedia, real-time, video-assisted remote management, streaming video) are core to the operations of companies that are not nationwide cellular providers.

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7 The FCC's 2002 Spectrum Policy Task Force ("SPTF") report provided specific recommendations to the FCC on ways "to evolve the current 'command and control' approach to spectrum policy into a more integrated, market-oriented approach." The SPTF concluded that "to increase opportunities for technologically innovative and economically efficient spectrum use, spectrum policy must evolve towards more flexible and market-oriented regulatory models" that should include balancing access to both "exclusive spectrum" and "open access spectrum" (*see Spectrum Policy Task Force Seek Public Comment on Issues Related to Commission's Spectrum Policies*, Public Notice, FCC 02-322, 17 FCC Rcd. 24,316 (2002) https://apps.fcc.gov/edocs_public/attachmatch/FCC-02-322A1.pdf).

8 For example, the sizes of legacy broadcast licenses were set so that a customer relatively far from the broadcast station's tower would not suffer interference from other stations broadcasting in adjacent territories in the same band or adjacent bands. Modern digital TV broadcasting technologies allow many more signals to co-exist in the same spectrum.

To accommodate the growth in demand for spectrum resources from existing and new users of all kinds, wireless network operators have been adopting a range of strategies to address the challenges posed by spectrum scarcity. This includes shrinking the cell sizes of licensed access points and moving toward heterogeneous networks that combine larger and small cells. Smaller cells require less power and line-of-sight issues are less important, which means that lower and higher frequency spectrum are closer substitutes. Additionally, for nomadic uses, different technologies are becoming closer substitutes (e.g., LTE vs. Wi-Fi), and, increasingly, licensed and unlicensed spectrum resources may be used in a complementary fashion by network operators.

In addition to supporting frequency agility in service provisioning, developments in (i) software and cognitive radios, (ii) advanced coding systems, (iii) smart antenna designs, and (iv) wireless and networking research make it feasible to manage spectrum on a much more granular and dynamic basis with respect to frequency, space, or time. For example, the shift to smaller cells allows more fine-grained spectrum management in space, so that the same frequency can be used for different applications and by different users or networks in different small cells that may be closer in physical space than would be possible with larger sized cells. The capabilities of the Spectrum Access System ("SAS") which is being developed for the CBRS band and other improvements in wireless network management capabilities make it feasible to allocate spectrum on a closer-to-real-time basis. For example, LTE supports dynamic frequency aggregation, which allows a cellular network provider to dynamically configure the amount of frequency (bandwidth) assigned to a customer to accommodate higher-bandwidth services (for example, to download a large file more quickly or support better quality video streaming). Although national cellular providers are increasingly adept at more fine-grained spectrum management, such capabilities are neither needed nor enabled by many smaller wireless network operators.

The CBRS framework was designed to account for these important changes in the wireless marketplace. This framework recognizes that, unlike in the past, today's wireless marketplace includes a far more diverse set of companies that require access to licensed and unlicensed spectrum to support a far larger number of business operations. These businesses need licensing rules that permit economically feasible license acquisition by this larger set of potential bidders, rather than rules designed solely to accommodate the interests of large national carriers. The FCC's current CBRS rules were designed to accommodate the need for spectrum resources for all of these diverse users, while also providing additional spectrum access opportunities for the national cellular providers.

2.2. Details of the CBRS Framework

The FCC finalized the essential features of the CBRS framework in April 2015.[9] This included establishing PAL licenses for 10 MHz exclusive-use spectrum in a Census Tract, under a three-

[9] See *2015 CBRS Rules*, Note 2 *supra*. Work on enabling spectrum sharing, including expanding commercial access to government spectrum had been ongoing for many years. The 3-tiered sharing framework was originally proposed by a Presidential expert advisory group in 2012 (*see Report to the President Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*, Executive Office of the President, President's Council of Advisors on Science and Technology

year non-renewable license, with the potential for bidding for two consecutive license terms (3+3). In each Census Tract, up to seven PAL licenses could be allocated (for a total of 70 MHz), with GAA operation allowed in all of the 150 MHz spectrum not allocated to PALs.[10] To dynamically manage the three tiers of spectrum users (incumbents, PAL, and GAA) on a granular basis with respect to time, geolocation, and type of wireless user, an SAS framework is under development by industry in collaboration with government and academia. The FCC has already tentatively approved seven SAS administrators from industry.[11]

The license terms were crafted to enable maximally efficient shared access to the CBRS spectrum on a fine-grained basis (with respect to location, time and frequency) so as to enable flexible sharing among multiple classes of users. This is in keeping with trends in wireless technology, network architectures, and markets noted earlier.

Many of the potential users of the CBRS will be smaller, local or regional companies that require access to spectrum in discrete geographic areas, unlike national cellular providers. Because of this, it is not economically viable for them to invest in licensed spectrum resources or incur the added costs of implementing spectrum use over large areas. But even though their spectrum requirements may be limited in geographic scope and in the range of frequencies they can utilize, they need access to licensed spectrum because many have spectrum needs that require the added interference protection and congestion management benefits offered by exclusive PAL licenses. The FCC's record shows that these potential PAL bidders include hospital, campus, and factory-automation users with business needs that might require the added security of PAL license protection to justify the user's willingness to invest in a network capable of using CBRS spectrum. These are precisely the sorts of users associated with the many bold new applications anticipated to drive IoT investments associated with adding digital smarts to our power grids, factories, supply-chains, healthcare, and government services. The expansion of IoT applications by commercial end-users across all sectors of the economy has the potential to deliver significant economic benefits in the form of lower costs, increased productivity and expanded consumer choice.

(PCAST) (July 2012), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf). The final rules were established in May 2016 by *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Order on Reconsideration and Second Report and Order, FCC 16-55, 31 FCC Rcd. 5011 (2016) https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-55A1_Rcd.pdf.

10 A user may acquire multiple PAL licenses in a Census Tract (up to 4), and may simultaneously operate in GAA spectrum. The ability to access more than 10 MHz of spectrum and to mix exclusive-use and general access spectrum resources is consistent with the goal to make spectrum more dynamically sharable (in space and time), and is in keeping with changing traffic patterns and markets for wireless services.

11 As of December 2016, the FCC announced that it had "conditionally approved seven entities: Amdocs, Inc.; Comsearch; CTIA-The Wireless Association ("CTIA"); Federated Wireless; Google, Inc.; Key Bridge; and Sony Electronics, Inc. ("Sony"), as SAS Administrators in the 3550-3700 MHz band (3.5 GHz Band)" (*see 3.5 GHz SAS and ESC Applications*, Public Notice, DA 16-1426, 31 FCC Rcd. 13,355 (2016) https://apps.fcc.gov/edocs_public/attachmatch/DA-16-1426A1_Rcd.pdf). CTIA later withdrew from consideration.

Consequently, the current CBRS framework was intended to accommodate the diverse requirements of all potential users—from national cellular providers to rural broadband access to the single-location network operator (a stadium, hospital, university laboratory, or manufacturing facility). The CBRS band was designed with enough flexibility to let the users' choices of applications, business models, and wireless network technology determine the mix of PAL and GAA spectrum resources they use. The FCC did not engage in industrial policymaking by seeking to pre-determine which types of applications and which users would be able to make use of the spectrum. Rather, the CBRS framework was designed in order to accommodate and promote competition and innovation within the band, and thereby, across the entire spectrum of wireless services. A goal of the CBRS is to promote increased dynamic sharing of spectrum and to demonstrate the viability of a model for spectrum management that, if successful, can help point the way to more efficient, market-based spectrum management, unlocking artificial spectrum scarcity across all spectrum bands. By designing a level playing field open to participation by all types of potential CBRS users and by not seeking to pre-determine which types of business models and uses should be favored in the licensing framework, the original CBRS design makes spectrum management more responsive and dynamically flexible to adapt to changing technology and market conditions.

2.3. National cellular operators are frequency agile

In the following, I explain why the value of CBRS spectrum is different for the national cellular providers than for many of the other potential users of the band. For the national cellular providers, the CBRS band is just another frequency band that expands their existing portfolio of spectrum assets. The principal value of the CBRS spectrum for the national cellular providers is to add capacity in local areas (small cells) where they may find themselves capacity constrained. The need for and ability to be frequency agile and capable of fine-grained spectrum management is a direct result of the business model and network technology used by the national cellular providers. Consequently, the national cellular providers' businesses and networks are not dependent on having contiguous geographic coverage in the CBRS or any other band. Indeed, having such coverage would likely result in the spectrum being under-utilized in many less-densely populated areas where the national cellular operators do not confront capacity constraints. The same is not true of many of the other potential users of the CBRS that are interested in deploying wireless networks for specialized purposes and with local or regional coverage requirements, and for which the CBRS offers a unique mix of spectrum capabilities not otherwise available.

Although many spectrum users are only able to operate in a single band and do not need to have networks capable of fine-grained spectrum management, frequency agility and the capability to support fine grained spectrum management are necessary and efficient capabilities for the national cellular providers. The design of 4G LTE technology is intended to support such flexibility and all of the national operators make use of spectrum assets across multiple bands with differing levels of availability in different geographic markets.

Frequency agility is necessary for the national cellular providers because their value proposition depends on providing seamless mobility ubiquitously on a national basis, at least for their most essential services—telephony and messaging. Delivering this capability requires the national providers to make use of diverse spectrum resources because they have grown through mergers and acquisitions, resulting in cellular providers having a patchwork of spectrum resources. No single licensed band has sufficient national capacity and coverage to allow them to meet their customers' demand for services in all locations. To meet growing demand for mobile broadband and other future services, national cellular providers remain hungry for commercial access rights across the entire radio spectrum, and they are willing and able to make use of spectrum available under a range of regulatory and business arrangements (i.e., licensed, leased, or unlicensed and under varying time horizons).[12]

Ensuring that national cellular networks are designed to be frequency-agile is also efficient because it reduces their risk exposure to spectrum scarcity since they are not dependent on access to any single band. Moreover, being able to choose the lowest cost spectrum to deliver services in a particular location and time helps cellular operators lower their costs. Were it not for the ability to offload the majority of cellular broadband traffic onto Wi-Fi, the growth of mobile broadband would have been significantly retarded by the lack of mobile network capacity.[13] Offloading the traffic onto Wi-Fi also reduced cellular providers' costs by reducing their need for expensive licensed spectrum.[14]

Finally, it is worth noting that the national cellular providers already have national coverage footprints and their principal *valid* justification for needing to acquire additional spectrum is to expand capacity, and the need for expanded capacity is greatest in locations where the providers face the greatest traffic loads. This is in high-usage, dense urban environments. Moreover, their greatest demand and need for PALs is in these same high-usage, congested locations where GAA spectrum is a much less attractive substitute. In rural markets, where the spectrum is inherently less congested and cellular providers are more likely to have access to exclusively-licensed spectrum resources already in their spectrum portfolio, the cellular providers should find GAA spectrum a closer substitute for more expensive PAL spectrum, if they require additional spectrum at all. In any case, because it is expensive for cellular providers to deploy small cells and the value of the underlying spectrum is less in rural markets, it is reasonable to expect cellular providers to focus their small cell investments where they face the greatest demand pressure which is in their

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12 Mobile providers are continuously investing to upgrade and expand their networks. Upgrading often requires the redesign of access networks (including cell site densification to expand capacity and take advantage of new spectrum resources) and replacement of legacy equipment. To avoid disruptions to their consumers and facilitate the roll-out of new services, cellular providers have become adept at adapting to dynamic changes in the underlying spectrum environment in ways that are largely transparent to end-users: users with newer handsets that include chipsets that are able to take advantage of increased wireless network agility see improved performance, but those with legacy handsets do not suddenly find their radios no longer capable of connecting.

13 If cellular providers had not been able to take advantage of customer or hotspot provider Wi-Fi access points (or small cells), they would have been incentivized to densify their existing networks even more rapidly, shrinking the geographic coverage of large cell sites to facilitate spatial reuse of their available licensed spectrum. For a discussion of how unlicensed has contributed to the value of wireless, including cellular, see, Paul R. Milgrom, Jonathan Levin, & Assaf Eilat, *The Case for Unlicensed Spectrum* (Oct. 23, 2011), https://ssrn.com/abstract=1948257; or Richard Thanki., *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum* (2009), http://apps.fcc.gov/ecfs/document/view?id=7020039036.

14 Smartphone users regularly switch between LTE and Wi-Fi service, often to reduce cellular data charges, avoid usage caps, or improve performance.

urban markets. Thus, it seems implausible to suppose that re-designing the PAL framework in order to favor national cellular providers would have any significant impact on their investment plans to deploy the smaller cell network architectures that will characterize future 5G networking.

A second reason for why cellular providers might seek to acquire additional spectrum is to foreclose competition in their existing markets or markets they may wish to enter at a later time.

If not foreclosed, CBRS spectrum should be attractive to a diverse range of users with business models that would allow them to provision wireless services rather than having no other choice but to purchase from cellular carriers or rely on unprotected spectrum. Whereas in high-density areas PALs may be most useful for adding capacity to relieve congestion, in rural and underserved non-rural areas PALs may be more useful for extending wireless coverage. Many of the potential users of the CBRS would be deploying new networks, and would find the PALs useful for both expanding coverage and adding capacity.

Although the national cellular operators would not need the PALs for expanding coverage (since they already have national coverage), they have an incentive to deny access to the spectrum from other potential CBRS users because such usage threatens the national cellular operators' businesses in multiple ways. First, enterprise customers may use the CBRS spectrum to self-provision wireless capabilities that might otherwise have provided a source of customer revenue for national cellular networks. This would reduce potential demand for cellular-provided services. Second, fixed wireless broadband or other wired broadband providers (including regional service providers) may use the CBRS spectrum to offer fixed or mobile broadband services that would compete directly in the end-user markets with the services offered by national cellular providers in any markets where they overlapped. Third, new types of wireless infrastructure providers such as the providers of neutral host networks (i.e., small cell networks deployed in a single venue or regional market that provide services for multiple wireless networks) may lower the costs for additional entry into the deployment of 4G or 5G networks. Making such wholesale wireless network platforms available could enable expanded competition from Mobile Virtual Network Operators (“MVNOs”). Any or all of these sources of potential competition pose a threat to the market power of national cellular networks if enabled to compete by an appropriately designed CBRS. Facilitating such foreclosure is not a *valid* reason to facilitate the acquisition of additional spectrum by national cellular providers, but does help explain why cellular providers favor the proposed changes to the CBRS framework.

As I explain further below, the contemplated changes to the CBRS framework would foreclose access to protected spectrum and competition from potential competitors, even if the cellular providers choose not to utilize the CBRS spectrum; and if the cellular providers acquire exclusive rights more cheaply than is economically efficient, then spectrum policy would be artificially reducing the incentive for cellular providers to be spectrally efficient.[15]

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[15] The best spur to efficiency is competition. If poor design of the CBRS band allows cellular providers to avoid confronting the true economic opportunity cost of the spectrum (e.g., by excluding otherwise efficient competing users or bidders), then that weakens cellular providers incentives to use spectrum efficiently.

2.4. Why smaller CBRS license areas will produce more overall utility

A key feature of the *2015 CBRS Rules* framework was the focus on establishing small license areas to facilitate the efficient mapping of spectrum resources to heterogeneous spectrum needs, while expanding access to the widest range of potential users. Small license areas allow both users with geographically-localized, specially-contoured usage profiles and users with wide-area access needs to efficiently match acquired spectrum to their particular needs. The former may be interested in only a small amount of spectrum in one or a few areas, while the latter can acquire multiple licenses in multiple areas. Larger license areas effectively preclude a large number of companies from participating in the auction or using the spectrum. This is likely to reduce efficiency and the overall value produced by the band.

Smaller PAL areas allow better matching between potential user needs and the assets that are licensed for their use, and enhances efficiency in multiple ways. First, users do not need to purchase or be allocated access to spectrum in areas other than where they actually need it. If the spectrum is for PALs, then the costs of acquiring unnecessary PAL spectrum are avoided. Second, if excess spectrum is acquired via PALs, then other potentially efficient uses of the spectrum by other users is excluded (whether by other GAA users or other PAL users that may have been accommodated were PALs allocated and configured on the basis of smaller license territories). Third, if there are more users in contention for the spectrum than can be supported, then that will push up the value of PALs. Allowing potential bidders for PALs to better match spectrum to their actual needs helps ensure the widest participation by potential bidders. In this way, the willingness-to-pay for protected PAL spectrum is better matched to the available spectrum resources, making it more likely that there will be an efficient allocation if there are multiple users contending for access. Moreover, with PALs sized to allow more efficient mapping of licenses to spectrum needs, all users of CBRS will be better able to balance the use of PAL and GAA spectrum.[16]

Census Tract PALs represent a compromise license area that is already significantly larger than what may be required by many potential users interested in operating CBRS applications at a single location that may be campus-sized or smaller (a mall, a manufacturing facility, a hospital complex, or a stadium). Census Tracts are designed to represent statistical sub-divisions of counties and are sized to capture a population of around 4,000, but they vary in size and population coverage depending on population density and natural contours.

The suggested change to expand PAL license territories to the size of Partial Economic Areas ("PEAs") would effectively foreclose a large number of potential users of CBRS spectrum that might otherwise be interested in taking advantage of the CBRS spectrum to deploy wireless networks that support coverage (for services such as rural broadband) and localized private LTE networks for quality of service (for services such as IIoT). PEAs are simply too few and too large: whereas there are over 74,000 Census Tracts, there are only 416 PEAs, with a median population

[16] For example, a local, regional, or even national provider can acquire PALs in markets where it looks as if the risk of congested GAA is higher, while avoiding those costs in markets where congestion is unlikely, and use GAA instead. Users may even choose to operate with both PAL and GAA spectrum in the same license area.

size close to 300,000 people.[17] For every one PEA there are 178 Census Tracts. If other bidders for PEA-sized PALs are foreclosed, as seems likely, then the national cellular providers may be able to acquire the PAL spectrum inefficiently cheaply and realize the added benefit of being able to foreclose would-be competitors. Alternatively, with Census Tract PALs, it is reasonable to anticipate a wide diversity in valuations. In markets where spectrum to expand capacity is at a premium, PALs should be in high demand and the prices may be high even if the winning bidders end up being the national cellular providers. However, in many rural markets, the high-bidders and winners of scarce PALs may be the wireless network operators with localized spectrum needs for coverage. With Census Tract-sized licenses, there would be plenty of PAL spectrum and an opportunity for lots of different CBRS users to participate.

Advocates of large license areas argue that any excess spectrum acquired could be reallocated via a secondary spectrum market. This is not a valid reason to favor large license territories since the availability of *efficient* secondary spectrum markets could also serve to allow those seeking to acquire larger spectrum territories to acquire spectrum if the license territories are small. More importantly, at this stage, the performance of CBRS secondary markets is purely hypothetical. Secondary markets for CBRS spectrum do not yet exist and it is unclear whether such markets will actually exist and be efficient. The FCC's record also suggests that secondary markets in other bands are inefficient and do not in practice provide companies with geographically smaller spectrum needs with the access they require. Furthermore, if secondary markets *are efficient*, then small territories ought to trade well also. Favoring large territories by auctioning only PEA-sized PALs would impose asymmetric transaction costs on the small users who would need to induce those with excess spectrum to partition it and make it available for secondary market leasing. Those with excess spectrum may prefer not to partition their spectrum either to foreclose the competition or simply to avoid incurring the transaction costs.[18] Moreover, if those with excess spectrum are small users, then they have to incur spectrum leasing costs that are likely to be higher for them than for a large national operator who is likely already to have an in-house team to manage spectrum transactions.[19]

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[17] There are 74,002 Census Tracts in the United States (including Puerto Rico and the Islands) (see https://www.census.gov/geo/maps-data/data/tallies/tabgeo2k.html); and only 416 PEAs with a median population size of 298,749 and 80% have a population over 100,000 (*see Expanding the Economic and innovation Opportunities of Spectrum through Incentive Auctions*, Public Notice, DA 14-759, 29 FCC Rcd. 6491, Appendix A (2014) https://apps.fcc.gov/edocs_public/attachmatch/DA-14-759A2.pdf.)

[18] A (false) counter-argument for why small license parcels might asymmetrically disadvantage large network operators who would need to acquire multiple small parcels to match their coverage needs is that they may be subject to strategic hold-up from small parcel holders who had PALs in spectrum territories where they knew a large operator was seeking coverage. This is implausible for several reasons. First, there are likely to be multiple small PAL providers so no one PAL holder could preclude access by a large carrier in any area; and second, large providers do not require contiguous PAL spectrum for their networks (even if that may be desired). In any case, if the markets are efficient, such strategic hold-up would not be feasible; and if the markets are not efficient, then policymakers have a problem in either case.

[19] For example, the small user with excess spectrum would need to incur both the fixed or sunk costs of setting up a capability to participate in leasing spectrum and would not be able to spread recovery of

Excessively large license areas also exacerbate the risk that national cellular providers will engage in spectrum hoarding in order to foreclose competition. The larger the license territory, the more potential competition may be foreclosed and the greater the risk that hoarded spectrum may be denied to other potential users. A common regulatory response to such situations is to impose build-out requirements that confront licensees with a "use it or lose it" constraint. However, imposing such regulations constrains network operator investment decisions, and uniform rules are likely to poorly accommodate the heterogeneity in investment circumstances confronted in the real world. The larger the license territory, the longer it may take to deploy infrastructure to make use of the spectrum, and the more difficult it is to match build-out requirements to efficient investment plans or limit the adverse impact of hoarding. Thus, larger license territories may increase the costs of spectrum regulation and of investment in infrastructure to make use of the CBRS spectrum.

Finally, as noted earlier, the direction of spectrum management reform is to facilitate the transition to more market-based, dynamic spectrum sharing. Larger license areas artificially limit the range of diverse users that may simultaneously co-exist and operate in the CBRS spectrum, thereby defeating a key goal of spectrum policy.

2.5. Longer license terms and renewability are inappropriate

The current CBRS PAL licenses have non-renewable three-year terms (optionally doubled to six years for the initial term). This ensures that the spectrum can be dynamically reallocated to new users or uses on a relatively frequent time scale to allow more efficient use of the band. This is consistent with the goal of transitioning toward more efficient, market-based spectrum management and facilitating more dynamic spectrum sharing. With shorter licenses, spectrum users need to confront market forces more frequently and allows for more frequent resetting of spectrum acquisition costs to reflect market realities.

The inability to repurpose spectrum resources that were originally allocated with long, effectively perpetual, licenses has been one of the major reasons that spectrum has been under-utilized and used inefficiently in so many bands for so long. As examples, consider the television broadcast spectrum in the 600 and 700 MHz bands, where it has taken decades to repurpose or open this spectrum to shared use; or the Federal spectrum in many other bands (including the 3.5 GHz band).

In principle, this problem could be addressed by efficient secondary markets; however, in practice such markets have not yet emerged either because of regulatory or market impediments. The emergence of efficient secondary markets depends on the resolution of a number of chicken-egg problems. The existence of sufficient supply is contingent on the existence of sufficient demand (and vice versa) to justify the costs of setting up and participating in a market. If one side or the other has strategic reasons to delay or oppose the emergence of such a market, that further complicates the problem.

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those costs over multiple spectrum bands and markets. Large national operators are continuously engaged in spectrum transactions and so have more experience and transactions over which to spread the recovery of leasing operation costs.

In the absence of efficient secondary markets, the longer the license term, the lower the opportunity cost of spectrum to an incumbent licensee, and hence the lower the incentive for the licensee to use the spectrum efficiently.[20] Increasing the prospect of renewability further exacerbates the problem.

Moreover, having longer license terms and an enhanced prospect for renewability amplifies and mirrors the problems that arise with larger license territories, as discussed above. When license terms are longer, the licensee may be forced to acquire excess spectrum—meaning spectrum for longer than the licensee can efficiently use it. With shorter, non-renewable licenses, a licensee who wants more spectrum over a longer duration than a single license can participate in subsequent license auctions. With shorter license terms, both those seeking spectrum for long durations and short durations can participate on closer to equal terms. For example, with perpetual licenses or assured renewability, there is no possibility for a new entrant to acquire the spectrum (unless the incumbent decides to lease it using a questionable secondary market). With no prospect of renewability, an incumbent and entrant face the same chances of acquiring the spectrum for the next license term, and the shorter the license, the more often that competition occurs.

While longer license terms will not improve efficiency, they will increase the chance for foreclosure. Longer license terms and the prospect for renewability will serve to foreclose many enterprise users with more localized or specialized spectrum requirements. These are precisely the same users who hold the greatest potential for deploying innovative new wireless applications and promoting increased competition in wireless services. By contrast, lengthening the license terms and allowing license renewability favors the large national carriers that can readily absorb any excess spectrum commitments as part of their already extensive portfolios. Foreclosing competition for the spectrum reduces the prices that these operators may be expected to pay for the licensed spectrum if they bid. Even if they do not acquire the spectrum, this approach reduces the likelihood that they will face viable competition from other CBRS users in the future.

There are two principal justifications which are typically cited in support of longer term, renewable licenses. The first is that transacting for the spectrum is costly and if the same user is the efficient user of the spectrum across multiple terms, then requiring additional transactions incurs costs without any compensating benefit with respect to spectrum assignment and spectrum efficiency. This fails to account for the likely substantially higher cost overall of precluding efficient users that are not the initial auction winner. And with an expectation of renewal, the initial license winner would have to be the efficient user in perpetuity for this justification to have weight, which is very unlikely. Furthermore, encouraging dynamic sharing and transitioning to a more flexible spectrum management framework as intended for the CBRS will enable more flexible and lower (total) costs for dynamically reassigning spectrum. The SAS infrastructure is designed to efficiently sustain

[20] Once a licensee acquires spectrum at auction, the auction payment is a sunk cost. If there are efficient secondary markets, then the opportunity cost for the licensee to continue using the spectrum is set by the price that the licensee could earn if the spectrum were sold on the secondary market to another (potentially higher-value) user.

and manage the transaction costs of more dynamic reallocation of spectrum rights associated with the original CBRS framework based on Census Tracts and three-year licenses.

The second justification for longer term licenses is to provide a closer matching between the spectrum license term and the life of the network investments associated with using the spectrum.[21] The mobile wireless industry argues that without access to longer licenses, potential CBRS users will not want to invest in network resources that are dependent on using the spectrum. This is most likely to be true if the investments in the networking technology and infrastructure are closely coupled to the use of spectrum in a particular frequency band (or are co-specialized investments).

The investment costs of using CBRS spectrum depend on the goals of the CBRS user making the investment. If the user is a national cellular provider, then the user does not have to invest in creating a brand image since the national provider already has one. The principal long-term investment is associated with building out the small cell infrastructure where such infrastructure does not already exist. Most of the costs of those investments are associated with physical site costs and are not frequency dependent. As noted earlier, the national cellular providers do have an incentive to deploy small cells, but in deploying those cells most of their costs will not be strongly frequency dependent. And because the CBRS band is likely to be used by national carriers to address capacity constraints in areas where they already have nearby infrastructure and where they almost certainly have backhaul at desired sites, these costs are even less dependent on access to these particular frequencies. Adapting the infrastructure to use other frequencies, to contend with and manage congestion (e.g., if operating in GAA spectrum without the benefits of PAL exclusivity), and add other improvements is something that modern radio technologies are designed to accommodate through software upgrades (which is a major benefit of software radio technology[22]). All of the national cellular operators have or are adopting wireless technologies to enable them to share spectrum more dynamically on a finer-grained basis. The effect of these investments is to render their network investments less co-specialized and less in need of long-term license protection to induce them to invest.

By way of contrast, consider the investment calculus for an enterprise user of CBRS spectrum. For such users, acquiring customers is not an issue if the purpose of the network is to support their own use. Similarly, the equipment costs of the radios are likely to be a significant infrastructure-related investment of their deployment. The economic depreciation life of most computing or electronic equipment (including the radios) is likely to be on the order of a few years, and certainly less than the decades-long terms that are the real-world result of ten-year terms with an expectation of renewal.

Furthermore, many of the users of CBRS spectrum for novel or innovative uses are likely to be confronting significant uncertainty regarding the costs and benefits of the proposed spectrum. Shorter license terms allow them greater scope to make future adjustments sooner.

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21 The investments include the investments in network infrastructure, which may involve technology that is frequency-specific; and investments in acquiring customers (e.g., in creating a brand image).

22 National cellular operators have software-controlled networking capabilities that allow them to balance traffic loads among their multiple cell-sites and frequencies on a dynamic basis.

The FCC has recently asked for comment on whether it should extend the license terms to ten years and make them renewable. If adopted, these rule changes would amplify the inefficiencies associated with making the license territories too large, effectively foreclosing or significantly diminishing the attractiveness of using CBRS spectrum for many industrial, rural, and other users. The contemplated changes would tailor the PAL licenses for the needs of the largest cellular providers and foreclose participation from those that have different business models.

Finally, lengthening the licenses would significantly constrain the ability of policymakers to adjust the framework in light of changing technology and market experiences. The CBRS framework is an appropriate innovation in spectrum management necessitated by changes in the wireless marketplace, the presence of potential new bidders for licenses, and the characteristics of the 3.5 GHz band. The whole concept of developing an SAS to manage sharing between multiple classes of users, and the potential that that may be extended to additional classes of users or to additional spectrum bands makes it important to preserve design flexibility. Given the pace of innovation in wireless technology, ten-year licenses would severely limit this needed flexibility.

3. Benefits of Contemplated Changes Non-existent, Costs Significant

The costs of increasing the geographic size of PALs and extending their license terms are larger than the benefits. As discussed below, the benefits of these changes are negligible. But the costs are significant, precluding use of the band by entities that are likely to produce large benefits for the economy.

3.1. Contemplated CBRS changes promise negligible benefits

The national cellular providers are the only class of PAL users that stand to benefit from the proposed changes in the CBRS framework. As discussed above, the potential *valid* (i.e., pro-competitive, efficient) benefits to cellular providers from the contemplated changes are likely to be minimal. The ability of national cellular providers to invest in 5G small cells neither depends on nor would be significantly enhanced by re-designing the CBRS license framework to uniquely favor them.

While national cellular providers profess a need to expand their capacity and make substantial investments in small cells and elsewhere to deliver next-generation 5G services, these operators' incentives to invest are unlikely to be significantly encouraged by receiving preferential access to CBRS spectrum.[23] They need to invest in re-architecting their networks for small cells, but those small cells will operate on multiple frequency bands and so will need to be frequency agile. Consequently, their investment in transitioning to small cells will include investments in site leases, arranging for backhaul and other network-related costs and will not depend on their having access to 3.5 GHz spectrum. Nevertheless, it is understandable why the national cellular providers would like to have preferential access and why the adverse impact of this approach on potential competitors is beneficial to their private interests. That, however, is a potential cost, not a *valid* benefit of the proposed changes.

[23] National cellular providers already need to invest in expanding capacity for existing 4G LTE networks.

Even if the purported benefit of the changes is to advance 5G services, the Commission must recognize that 5G involves a far larger set of entities than the nationwide cellular companies. 5G is not merely an incremental evolutionary improvement over historic cellular services, which customers can expect to see as a by-product of "business-as-usual" continuous network improvements which have characterized competition among cellular providers since the 1980s. These types of improvements are likely to happen whether cellular providers have access to the CBRS spectrum or not, and re-engineering the CBRS solely to advance such incremental goals would be a waste of an important opportunity to jumpstart investment in true next-generation wireless. The development of 5G is more likely to occur if many companies, not the limited set of the national mobile carriers, with diverse use cases are not foreclosed and are allowed to compete for PALs to help drive their business models.

5G networks are different from earlier generations of wireless services because they depend on a far larger set of companies with diverse capabilities to produce new wireless structures that can deliver order of magnitude improvements in wireless performance along multiple dimensions, such as 1 millisecond latency services, 10 Gbps data rates, and the ability to support 100-fold or more connected devices simultaneously (i.e., IoT).[24] Achieving that sort of performance improvement will require small cells served by much more capable base stations, a lot of in-network intelligence (including computing and storage capabilities close to the network edge), and investments and innovation in end-to-end networks by not only the handful of nationwide carriers, but also by many new players. Traditional cellular operators are not the only service providers expected to participate in the realization of the 5G vision, and FCC spectrum decisions that favor these carriers over other companies will undermine, rather than advance, 5G.

Consequently, the proposed changes to the CBRS framework would not accelerate, but would hamper investment in the more rapid delivery of competitive, next generation wireless services. Customers of the national cellular providers would not benefit, because of the suppression in choice, competition, and innovation that would result if the potential changes to the CBRS license regime were adopted. If PAL rules are changed as contemplated, national cellular providers would have reduced incentives to invest in improving their services or enhancing the spectral efficiency of their networks due to the reduction in competitive supply and demand challenges.

Finally, representatives of the large wireless carriers have previously made claims regarding the likely impact of 5G technology on U.S. economic growth and output.[25] These projections relate to economic growth from 5G generally, however, and do not focus on growth related specifically to 5G services provided using CBRS spectrum, or to licensed 5G services which are a subgroup of all 5G services. Without such additional detail, the FCC cannot rely on the asserted impact being produced by the changes these carriers seek in the 3.5 GHz band. In fact, the changes the large

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[24] *See* Ian Poole, *5G Requirements for the next generation Mobile Wireless System*, Radio-Electronic.com (last visited Dec. 27, 2017), http://www.radio-electronics.com/info/cellulartelecomms/5g-mobile-cellular/wireless-system-requirements.php/.

[25] *See* Petition for Rulemaking of CTIA at 5, WT Docket No. 12-354 (filed June 17, 2017) https://ecfsapi.fcc.gov/file/10616144416997/170616%20-%20FILED%20CTIA%203.5%20GHz%20Petition%20for%20Rulemaking.pdf.

carriers seek may well reduce the economic impact they cite by undermining 5G overall, as discussed elsewhere in this paper.

Thus, the potential benefits of the proposed reforms are likely to be negligible or even negative. On the other hand, the potential costs of adopting the proposed changes could be quite significant. In the following sections, I consider the substantial risk to economic growth and innovation that the CBRS reforms raise. Incurring these risks is an unnecessary cost. Thus, the Commission's cost-benefit analysis of the effects of adopting the proposed revisions to the CBRS framework should conclude that the potential costs significantly exceed the potential benefits, as discussed below.

3.2. Contemplated rule changes threaten progress toward closing the rural broadband access divide and would increase costs by tens of billions of dollars

The FCC has stated that ensuring universal access to broadband services is an important policy goal because such access is appropriately perceived to be essential infrastructure to participate in today's Digital Economy.

The rural broadband gap is a direct result of the economics of serving less-dense rural markets because the costs of deploying fixed broadband services rise steeply for wired infrastructure when homes are farther apart.[26] For example, the costs of deploying fiber are estimated to be in the range of $3,500 to $5,500 when population densities are on the order of 100 to 1,000 inhabitants per square kilometer, but rise to $9,000 to $13,000 when population densities are 10 to 100 inhabitants per square kilometer.[27]

In such situations, fixed wireless technologies are important tools. Whereas fiber and other wired infrastructure typically follows roads and the costs rise with the number of route-miles of plant that must be installed to reach all the homes in the serving area, fixed wireless can use point-to-point and point-to-multipoint radio connections to deliver broadband directly to homes within range of its tower(s) for the relatively small incremental costs of adding an antenna and radio at each customer's location.[28]

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26 A study of the costs of actual rural fiber-to-the-home deployments found that the average cost per household in rural areas was more than twice the cost of deployment in rural towns, a regression based on the data found that the "Cost per location = $4,430 + $12,911 * (route miles/locations)" (*see* Masha Zager, *Modelling the Cost of Rural Fiber Deployment*, Broadband Properties (Mar./Apr. 2011), http://bbpmag.com/2011mags/marchapril11/BBP_MarApr_CostOfFiber.pdf).

27 *See* Patrick Forth, Wolfgang Bock & Michael Hitz, *Connecting Rural Markets: How Fixed Wireless Is Unlocking Digital—Everywhere*, BCG.Perspectives (Oct. 20, 2014), https://www.bcgperspectives.com/content/articles/telecommunications_digital_economy_connecting_rural_markets_fixed_wireless_unlocking_digital_everywhere/#chapter1 ("Forth et al.").

28 According to Forth et al., Note 278 *supra*, the cost of fixed wireless receivers is on the order of $200-$300 dollars and the costs of towers and active receiver equipment range from $50k to $300k. Although the costs may vary quite a bit depending on the technology and quality of broadband service offered and the number of customers to be served, the ability to avoid the costs of installing wired local distribution network afforded by wireless deployments results in a significant reduction in the costs of deployment.

Taking advantage of these favorable economics, there is a vibrant community of more than 2,000 fixed broadband service providers across the country providing broadband services to nearly four million subscribers, a majority of which are in rural markets that are under-served.[29] The typical Broadband Wireless Access ("BWA") provider is small, with only around 1,200 customers, and provides service in one or only a few local communities.[30]

The CBRS spectrum would significantly increase the ability of existing and prospective BWA providers to expand the coverage and capacity of their services to rural customers in unserved and under-served markets;[31] and in markets where other providers exist or may exist in the future, their continued presence or expansion will help ensure rural customers have competitive choices for their broadband service providers.

Many BWA providers desire to expand coverage to unserved and underserved areas and/or improve the quality of their services (e.g., increase coverage, capacity and peak data rates) to keep pace with consumer demand and the continuing improvements in broadband data rates being delivered to subscribers in better served urban markets. The opportunity to use PALs would allow BWA providers to serve more customers with better service in markets where they already have service and would improve the economics for new infrastructure build-out in adjacent communities where they currently do not have infrastructure. The ability to improve the quality of existing infrastructure that may be currently operating in 2.4, 2.5, 3.65, 5 GHz or other bands, by augmenting it with 3.5 GHz spectrum, can help BWA providers sustain the value of their existing investment, and avoid stranding their investments. In particular, those BWA providers that use 3.65 GHz today can easily and economically migrate to the 3.5 GHz band without the need to acquire additional hardware.

Unfortunately, the contribution that BWA providers have made toward solving the rural broadband deficit and to adding to the competitive landscape for broadband services is put at risk by the proposed changes to the licensing framework. The proposed revisions to the PAL framework would essentially foreclose the ability of potentially all BWA providers from acquiring PAL spectrum. A typical BWA provider would find the coverage of a PEA more than an order of magnitude larger than the BWA's addressable market.[32] If the PAL comes with build-out

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29 *See* Jimmy Schaeffler, *Ready for Takeoff: Broadband Wireless Access Industry Report*, Carmel Group (Sept. 2017), http://www.wispa.org/Portals/37/Docs/Press%20Releases/2017/TCG's_2017_BWA_FINAL_REPORT.pdf ("Schaeffler").

30 *See* Schaeffler, Note 290 *supra*.

31 BWA providers may expand their coverage footprint in existing markets or enter adjacent markets where their expansion or entry costs are likely to be lower.

32 The average BWA has 1,200 subscribers, and assuming an adoption rate of 30%, suggests a typical addressable market of 4,000 potential subscribers; whereas the population of the typical PEA is well in excess of 100,000 and the median size is 299,749. Those estimates suggest that the coverage of a PEA is 25 to 75 times larger than the typical BWA provider's market. *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion,*

requirements, then the BWA would have to radically change its business model to comply should it succeed in acquiring a PAL at auction. BWA providers have confirmed on the record that addressing its need for PAL spectrum via hypothetical secondary market transactions does not offer a viable solution for BWA providers.

While it is true that many BWA providers use unlicensed spectrum, that has become increasingly problematic as unlicensed usage has increased and the available spectrum has become congested from increasing consumer demand. Moreover, as the quality of broadband services that consumers expect to receive continues to increase, the ability to operate solely in unlicensed spectrum while ensuring acceptable service quality is becoming more difficult. PAL spectrum would provide BWA providers with additional interference protection and congestion management capabilities. I would expect that BWA users may elect to use a mix of PAL and GAA spectrum to serve their customers, and the PAL licensing framework should be designed to make this feasible. If not, the unnecessary risk of foreclosing BWA competition and use of the CBRS spectrum is a definite possibility.

The potential magnitude of the cost of foreclosing BWA provider competition may be estimated in several ways. First, Microsoft (with help from the Boston Consulting Group) has estimated that solving the rural broadband challenge with wireless will cost around $10 billion.[33] By way of comparison, another analyst has estimated that it might cost as much as $40 billion if the challenge were to be met by deploying fiber or cable to the premises;[34] and another study estimated that the costs of deploying Fiber to the Premises ("FTTP") is seven times more expensive than using fixed wireless technology to provide broadband service to the home.[35] These numbers suggest that using

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and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act, 2016 Broadband Progress Report, 31 FCC Rcd 699, Table 10 (2016) (reporting broadband adoption rates); *Wireless Telecommunications Bureau Provides Details About Partial Economic Areas*, Public Notice, 29 FCC Rcd. 6491, at Appendix A (2014) (listing PEA populations).

[33] Microsoft proposes using TV white space ("TVWS") in the 600 MHz band and other spectrum to help address this challenge. *See* A Rural Broadband Strategy: Connecting Rural America to New Opportunities, Microsoft (July 10, 2017), https://msblob.blob.core.windows.net/ncmedia/2017/07/Rural-Broadband-Strategy-Microsoft-Whitepaper-FINAL-7-10-17.pdf. Their analysis concludes that the optimal mix of technologies would cost between $8 to $10 billion, whereas FTTP would cost $45 to $65 billion.

[34] Paul de Sa explained that FCC analysis concluded that in 2015, approximately 14% of residential and small-to-medium businesses lacked access to FTTP and/or cable service capable of delivering 25/3 Mbps (down/up) service and that delivering service to all of those premises would cost about $80 billion, but that service could be delivered to 98% of those premises for about $40 billion. The remaining 2% would likely be remote rural premises for which the costs of deploying wired infrastructure are significantly higher. Consequently, this analysis suggests a ballpark estimate for the costs of deploying wired cable or FTTP for the under-served communities would be around $40 billion (*See* Paul de Sa, *Improving the Nation's Digital Infrastructure*, FCC Office of Strategic Planning and Policy Analysis (Jan. 2017), http://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0119/DOC-343135A1.pdf).

[35] *See* Schaeffler at Figure 6, Note 290 *supra*.

fixed wireless instead of wired broadband to solve our rural broadband problem could save the U.S. economy upwards of $30 billion to $60 billion in investment.

Moreover, another recent study has sought to estimate what the benefits to the U.S. economy might be from expanding access to next generation networks—which is a challenge that BWA providers could contribute to if not foreclosed by bad spectrum policy. Singer, Naef, and King (2017) estimate that regulatory reforms that would help lower the costs of deploying next generation infrastructure such as FTTP or 5G could result in incremental investment of $69.2 billion in wired and wireless infrastructure, which they estimate could sustain an additional 498 thousand jobs and add $42.09 billion to annual GDP over the next five years.[36]

The Singer et al. estimates suggest that expanding broadband access has the potential to add over $1,000 to annual GDP for each new home that can be served, which suggests that a future without BWA providers may result in annual GDP being lower by *more than $4 billion*.[37]

Because CBRS spectrum is the only "new" spectrum available in the near term, a significant portion of these savings and contributions to GDP can come from deployment in the band. Foreclosing participation by those current BWA providers that can efficiently commercialize the band for fixed wireless deployment will undercut these efforts and delay, if not stop, billions of dollars of consumer benefits from occurring.

3.3. Contemplated rule changes threaten investment and deployment of Industrial IoT technologies

The IIoT supports intelligent industrial operations through digital connectivity between machines, computers, and people. IIoT enables the monitoring, collection, and analysis of industrial data, and

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[36] *See* Hal Singer, Ed Naef & Alex King, *Assessing the Impact of Removing Regulatory Barriers on Next Generation Wireless and Wireline Broadband Infrastructure Investment*, Economists Incorporated & CMA Strategy Consulting (June 2017), http://ei.com/wp-content/uploads/2017/06/SingerAssessingImpact6.17.pdf ("Singer et al."). Their analysis relies on a business model that compares a base case scenario to a scenario in which the FCC adopts a number of rule changes that reduce the costs of deploying advanced broadband infrastructure (e.g., new pole attachment rules, etc.). Their analysis concludes that if the investment-favorable policies are adopted that up to 26.7 million additional premises may be served by advanced broadband services based on FTTP (driving $45.3 billion in incremental investment and expanding GDP by $28.35 billion) and 14.9 million additional premises based on 5G (driving $23.9 billion in incremental investment and expanding GDP by $13.74), for a total of 41.6 million additional premises served, total incremental investment of $69.2 billion, and total additional GDP growth of $42.09. In both cases, much of this investment will be in less dense areas (52% rural).

[37] Singer et al. (Note 367 *supra*) forecasts that removing regulatory barriers to the deployment of broadband infrastructure will result in an additional 41.6 million premises being served by FTTP or 5G, adding $42.09 billion to GDP, which implies each additional premise served adds $1,012 to GDP. The BWA industry currently provides access to 4 million subscribers, most of whom would be without broadband if it were not for the BWA providers, and if allowed to compete in the CBRS spectrum, the number of previously-unserved subscribers that BWA providers will serve is likely to increase.

it is enhancing efficiency, security, and productivity across a variety of industries in the United States. IIoT is expected to play a huge role in driving growth in the U.S. and global economy. For example, McKinsey estimates that IIoT's contribution to the global economy to be $11.1 trillion per year by 2025 in nine areas, including factories ($3.7 trillion), healthcare ($1.6 trillion), and smart cities ($1.7 trillion).[38] Accenture forecasted that IIoT could add $7.1 trillion to the U.S. economy and $14.2 trillion to the global economy by 2030.[39] Although these forecasts may be optimistic and subject to a great deal of uncertainty, with their realization depending on success in a range of inter-dependent domains, they nevertheless highlight how fundamental and important IIoT could be to our future.[40]

While GAA spectrum may suffice for various end-user use cases instead of PALs, there are likely to be situations where the interference protection of PALs is mandatory. Adopting the contemplated changes to CBRS renders it economically infeasible, however, for small, local end-user customers (e.g., enterprises, anchor institutions, municipalities) to acquire PALs to support their own geographically targeted wireless network deployments. It will not be economically rational for such single-network operators in localized areas to bid on geographically extensive PEA licenses. Denying such an opportunity to such users may deter or delay their investment in adopting innovative IIoT applications. This adverse outcome would significantly diminish the value of the CBRS as a platform for the development and deployment of innovative wireless services.

Several examples of IIoT-related deployment scenarios that may make use of PALs in CBRS spectrum are discussed below.

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38 See The Internet of Things: Mapping the Value Beyond the Hype, McKinsey (June, 2015), https://www.mckinsey.de/files/unlocking_the_potential_of_the_internet_of_things_full_report.pdf.

39 See Paul Daugherty & Bruno Berthon, *Winning with the Industrial Internet of Things*, Accenture (2015), https://www.accenture.com/t00010101T000000Z__w__/at-de/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_11/Accenture-Industrial-Internet-of-Things-Positioning-Paper-Report-2015.ashx.

40 The adoption of IIoT solutions is likely to have profound implications for how work is organized within firms, and hence is likely to require substantial experimentation and collective learning to identify best practices and to support firms adopting IIoT. Creating a spectrum environment that supports such experimentation by making flexible and appropriate spectrum resources available to potential adopters is likely to be important. Consider how much growth has already occurred associated with innovative applications by users of Wi-Fi spectrum.

3.3.1. IIoT in Hospitals

IIoT has great potential to deliver significant benefits across the entire healthcare sector. One study estimated that IIoT in healthcare could be a $110 billion market globally by 2020.[41] Another study found that 87% of healthcare organizations are expected to have adopted IIoT applications by 2019 and 76% believe that IIoT will transform the industry. There are many opportunities for using IIoT to improve patient care while lowering healthcare costs.

Hospitals can benefit significantly from the deployment of IIoT innovative solutions. For example, hospital buildings can be made "smarter" with information technology. Controlling the temperature, lighting, air quality and other aspects of the ambient environment can have a direct impact on healthcare outcomes and the quality of the patient's experience. IIoT sensor-enabled control systems can also help hospitals lower energy costs while enabling better real-time control of the in-hospital environment. In addition, hospitals are device-intensive institutions that rely on expensive, portable equipment (monitors, imaging equipment, wheel chairs, respirators, etc.). Wireless connectivity will make it easier to connect devices, integrate the input and output of those devices with Big Data analytics and Artificial Intelligence applications in the Cloud, and implement better inventory control. Hospital staff need secure mobile communications to facilitate real-time alerts, location tracking of patients and medical staff, and allow secure patient information exchange of rich-media data (e.g., MRIs, X-rays).

Secure, connected IIoT devices facilitate real-time, portable patient monitoring and even aid in the delivery of drugs and other treatments, in response to patient or doctor provided real-time data.[42] Studies have shown that real-time monitoring can significantly increase healthcare outcomes by allowing problems to be identified sooner and appropriate responses delivered faster.[43] The monitoring of patients with adjustable devices that can be unobtrusively embedded in the

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[41] *See* TJ McCue, *$117 Billion Market for Internet of Things in Healthcare by 2020*, Forbes (Apr. 22, 2015), https://www.forbes.com/sites/tjmccue/2015/04/22/117-billion-market-for-internet-of-things-in-healthcare-by-2020/#1e8a409169d9.

[42] For example, sensors can be embedded in smart-chairs or beds; embedded in wearable vests; or even be implanted to allow tracking of vital functions such as heart rate, core body temperature, and oxygen levels. Insulin pumps or smart-drugs can be automated with IIoT technology to support real-time monitoring and drug dosage control. For other examples of some of the many ways IoT may revolutionize healthcare, *see 6 Applications of IoT in the Healthcare Industry*, Cabot (Feb. 10, 2016), https://www.cabotsolutions.com/2016/02/applications-iot-healthcare-industry/; Yash Mehta, *Connected Healthcare: Internet of Things Examples in Health Care*, DZone (July 13, 2016), https://dzone.com/articles/connected-healthcare-internet-of-things-examples-I; or, Ilnagko Balasingham, *IoT in eHealth: Challenges-Opportunities*, Univ of Oslo (Apr. 2014), http://www.internet-of-things.no/Presentasjoner_02_april_2014/I_Balasingham_OUH_Conference_IoT_Oslo_02_April_2014_Final.pdf.

[43] For example, a monitored hospital patient has a 48% chance of surviving cardiac arrest compared to 6% for an unmonitored patient. See Felipe Fernandez & George C. Pallis, *Opportunities and challenges of the Internet of Things for healthcare: Systems engineering perspective*, MobiHealth (Nov. 2014), http://ieeexplore.ieee.org/document/7015961/?reload=true.

environment or comfortably attached to the patient can help reduce hospital costs and improve the patient's experience. Real-time monitoring of healthcare professionals can also provide significant benefits. For example, IIoT devices can monitor when a clinician approaches a patient's bed without washing his or her hands, providing an alert and logging the incident for future review.[44] Ensuring hospital staff wash their hands can stop the spread of Hospital Acquired Infections ("HAI"), which are estimated to account for 90 thousand deaths per year and *cost $3 to $4 billion*.[45]

With all of these wireless devices needing reliable and consistent access to radio-frequency spectrum, hospitals will benefit greatly from the deployment of a private wireless network using CBRS. With control over their own private LTE network (rather than relying solely on Wi-Fi), hospital administrators can proactively address dead spots, manage congestion and RF interference, and ensure secure and predictable quality-of-service for many types of essential and opportunistic communications. In such specialized environments with a wide range of wireless communications simultaneously sharing network resources, the interference protection of PALs is critical.

In the United States, there are 5,500 hospitals with an average size of 75 to 100 thousand square feet, including outside areas.[46] While these hospitals are especially attractive environments for IIoT deployments, their spectrum needs are sufficiently localized that hospitals would be effectively foreclosed from obtaining PALs if the FCC adopted PEA-based licensing.

3.3.2. IIoT in Manufacturing

Enabling smart manufacturing is another obvious area where IIoT innovation has the potential to deliver substantial economic benefits. For example, one study reported that manufacturers that were utilizing IoT solutions realized a 28.5% average increase in revenues from 2013 to 2014, and forecasted that global investment in IoT solutions by manufacturers would grow from $29 billion in 2015 to $70 billion by 2020.[47] Another study estimated that employing smart manufacturing practices in the U.S. has the potential to *save manufacturers $57.4 billion annually* by allowing them to implement more efficient real-time data analysis and decision-making processes.[48]

Using IIoT to enable machine-to-machine communications at factories and within the warehouse can help drive more efficient on-demand resource management. IIoT systems will reduce the need to hold excess inventory, minimize waste (e.g., from defective products), and increase up-time. IIoT also improves predictive maintenance of machinery, which requires bandwidth-hungry edge analytics. Monitoring of individual machines' energy usage and operations and implementing

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44 See Cabot (2017), Note 423 *supra*.

45 See Mehta (2016), Note 423 *supra*.

46 See *CBRS & Hospitals*, GE Ventures (Dec. 4, 2017).

47 See John Greenough, *How the Internet of Things is revolutionizing manufacturing*, Business Insider (Oct. 12, 2016), http://www.businessinsider.com/internet-of-things-in-manufacturing-2016-10.

48 *See* Gary Anderson, *The Economic Impact of Technology Infrastructure for Smart Manufacturing*, NIST Economic Analysis Briefs 4 (Oct. 2016), http://nvlpubs.nist.gov/nistpubs/eab/NIST.EAB.4.pdf.

plant-wide scheduling can improve maintenance (reducing outage-related costs and delays in production) and energy efficiency.[49]

Thus, modern manufacturing facilities typically have complex and intensive communication needs, including the need for wireless connectivity. For many manufacturers, such connectivity for their operations will require the improved quality of service ("QoS") and predictable wireless signal quality made possible by licensed spectrum. Certainly, for machine-to-machine control of smart manufacturing production chains, it is reasonable to expect managers to require communication services with predictable service quality. Many enterprises may wish to deploy private networks using CBRS PAL spectrum for the added interference protection and for establishing service level agreements ("SLAs") on network performance in support of critical, smart manufacturing processes that rely on controlled, predictable network signal quality.

In addition, the use of a private LTE network operating on CBRS spectrum would enable manufacturers to control their connectivity costs. This approach would allow manufacturers to avoid the growing mobile and wireless data service costs associated with outsourcing their connectivity to established wireless carriers. In fact, with manufacturers' equipment and operations increasingly relying on wireless connectivity, self-provisioning this connectivity through their own private CBRS LTE networks will often be a more cost-effective approach.

If the FCC adopted PEA-based licensing in the CBRS band, however, it would be economically impractical for manufacturing facilities to acquire PALs. Manufacturing facilities are typically significantly smaller than even a census tract, and it would not be economically rational for them to bid on PEA licenses that cover large amounts of geographic territory. Without access to CBRS the manufacturer is left with two unacceptable choices: (1) incur inefficiently high cellular carrier fees; or (2) accept the limitations of a connectivity solution that relies on unlicensed spectrum alone. Thus, if the contemplated changes to the PAL license framework are adopted, use of the CBRS to support IIoT innovations such as factory and business automation would be impaired.

3.3.3. Smart Cities, Community Broadband, Neutral Hosts and Connected Venues

Another key market opportunity for IoT innovation is in making urban environments "smarter." For example, a study by Accenture forecasted that 5G (broadly defined) could help drive $275 billion in telecommunications investment in making cities smarter, and that the investment could contribute to creating 3 million jobs and add $500 billion to GDP.[50] The study focuses on three areas where the deployment of IoT in order to make cities "smarter" could deliver significant

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[49] Manufacturing in the U.S. accounts for almost 1/3rd of national energy consumption and greenhouse gas emissions, and better management of factory energy efficiency can have a large impact on manufacturing costs and industrial impacts on climate change. For example, one vendor of IoT solutions claims to be able to reduce manufacturing clients' lighting bills by over 60% and air conditioning bills by over 20%. *See What are the cost savings from Industrial IoT?*, TechNative (Aug. 21, 2017), https://www.technative.io/what-are-the-cost-savings-from-industrial-iot/.

[50] *See* Majed Al Amine, Kenneth Mathias & Thomas Dyer, *Smart Cities: How 5G can help municipalities become vibrant smart cities*, Accenture (2017), https://www.ctia.org/docs/default-source/default-document-library/how-5g-can-help-municipalities-become-vibrant-smart-cities-accenture.pdf.

benefits. For example, adding IoT capabilities to buildings and the energy/power grids can significantly reduce energy consumption, with national savings in terms of reduced lighting bills alone amounting to $1 billion. IoT traffic management can help cities address congestion which today costs the average medium-sized city $100 million annually, and smart parking meters can help towns add significantly to revenues. IoT can also help improve public safety. For example, sensors can detect the sound of gunshots, aiding police and first-responders to better focus and respond to crime. The Accenture analysis notes that these and many other benefits are realizable by cities of all sizes and cites numerous examples. Thus, deploying smart city IoT is not just for large metropolitan areas, but is applicable to smaller cities and towns, including those in rural areas which remain less well served by the national cellular providers (for obvious reasons).

While it is certainly true that the national cellular providers have an important role to play in helping to deliver the wireless connectivity that will be needed to realize the 5G vision, especially for delivering wide-area connectivity, a central presupposition of 5G is that companies other than carriers will use small cells to improve capacity in discrete locations. Today, cellular providers mostly lease tower space for their macro-cells on towers owned by other infrastructure companies (e.g., Crown Castle or American Tower Company, etc.), and many of those towers are shared by multiple cellular providers. The same is likely to be the case in the small cell future, and it is reasonable to believe that many local small cell networks might be connected via privately-administrated wireless networks. Malls, office parks, entertainment venues, municipal governments, and neighborhood community groups may wish to deploy wireless networks to support managed connectivity across multiple small cell APs.

The potential to develop infrastructure solutions and services to allow these local wireless networking needs to be met with shared infrastructure is giving rise to the "neutral host" business model. The model for deploying shared access is especially attractive for addressing in-building capacity and dead spot problems. Cellular signals do not propagate well through walls and congestion problems often arise in high-traffic areas (e.g., near elevators, in lobbies). While a range of solutions have been adopted to address these problems and enable cellular providers to better offer seamless connectivity and support higher bandwidth applications within congested locations, the cost and complexity of these solutions has limited their applicability to only the largest of public and commercial properties.[51] Another approach is for small cells to be deployed and shared by multiple wireless networks, thereby serving as neutral hosts.[52] When coupled with the open accessibility of the CBRS spectrum, this approach greatly increases the affordability of the solutions and makes them applicable to a vastly broader range of properties.

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[51] These solutions include Distributed Antenna Systems ("DAS") that may be deployed by the building owner and may be shared by multiple cellular providers to provide improved in-building connectivity.

[52] *See* Berge Ayvazian, Randall Schwartz & Haig Sarkissian, *The Business Case for Neutral Host Networks: a Win-Win for MNOs and Venue Owners*, Wireless2020 (Jan. 2016), http://www.wireless2020.com/media/white-papers/NeutralHostWhitePaper01192016.pdf or SCF & 5G Americas, *Multi-operator and neutral host small cells: Drivers, architectures, planning and regulation* (Dec. 2016) http://www.5gamericas.org/files/4914/8193/1104/SCF191_Multi-operator_neutral_host_small_cells.pdf.

In addition to deploying such small cell "neutral host" networks within buildings, such networks could also be deployed to provide campus-sized managed connectivity for a retail mall, an office park, or a small town as part of a municipal network. Small cells could be connected wirelessly or via wired infrastructure. If deployed by the municipality, a small-cell network could be shared with anchor institutions such as schools and libraries, and could deliver needed access to next generation wireless capabilities. When such infrastructure is deployed, in most cases it will make sense to share it with cellular providers, but that does not preclude co-existence on the infrastructure with other providers—including new providers of wireless services. Communities that have deployed fiber infrastructures already[53] or other providers of wired infrastructure such as cable companies may seek to partner with small-cell neutral host providers to offer mobile broadband services that would compete directly with the national cellular providers.

3.3.4. Preserve incentives for local investment in wireless infrastructure

Using cost-effective spectrum to help reach more unconnected rural consumers and delivering on the IIoT future will require substantial participation and investment by all stakeholders, as well as significant investment in local wireless network infrastructure. Much of this investment will be in deploying assets for which wireless connectivity is necessary. The ability of end-users to deploy their own wireless network solutions expands the business-model choice space and allows end-users to avoid being dependent on the investment whims and business practices of cellular providers. Hospitals, manufacturing facilities, and building owners in towns and cities are just a few examples of the sorts of end-users that might want to move faster or do something different than what national cellular providers might choose to do. Ensuring that such end-users' self-deployment options are not foreclosed by limiting access to PAL spectrum to national cellular providers helps preserve the option for end-users to self-deploy wireless networks. Whether that is the best solution or not will depend on who the end-user is and their local context. In markets that are well-served by cellular providers, the choice to self-provision and operate a private LTE or neutral host network will confront a higher hurdle; in markets that are less well-served, self-provisioning may be the only option available if end-users want to unlock the benefits of IoT where they live and work.

Moreover, to the extent a vibrant market for end-user deployed private networks and small cell infrastructure emerges, this will stimulate investment in further innovation by equipment and application solution providers and will expand market demand for shared small cell ("neutral host") local network infrastructure (within venues and in local communities) that can provide a platform to promote competition across the wireless value chain.

Raising barriers to investment flexibility for investors interested in deploying such applications risks denying, or at least delaying, the realization of the multi-billion and even multi-trillion dollar growth opportunities cited in the forecasts above. Incurring that risk is a cost of the FCC's contemplated changes.

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53 For example, my town of Concord, MA has a municipal electric utility that deployed fiber optic infrastructure as part of its investment toward making its local distribution grid smart (e.g., to enable advanced SCADA functionality), and with the fiber in place, the Municipal Light plant offers broadband service in competition with other wired providers, Comcast and Verizon. I consider myself lucky to have two high-quality wired broadband providers competing for my business in Concord.

3.4. Contemplated rule changes will harm consumers and innovation by reducing competition

It is generally accepted by economists that competition, when feasible, delivers substantial benefits in promoting efficiency, economic growth, lower costs and prices, and expanded consumer choice.[54] Competition induces firms to innovate and invest in adopting best practices to remain competitive over time. What is true for other goods and services is also true for wireless.

As explained above, the proposed reform of the CBRS framework threatens existing and potential competition in wireless services. Therefore, a potential cost of adopting the contemplated changes are the benefits that would be foregone because of the adverse impact on wireless competition.

There are numerous studies of the price impact of competition on telecommunication services going back decades.[55] These include studies of cable, fixed telephone, and mobile telephone pricing, including numerous examples of studies that estimate that competition lowers prices by 10-20%. A more recent study by Mahoney and Rafert (2016) analyzing the impact of competition on broadband pricing found effects consistent with the earlier results. Not surprisingly, that study found that the price effects varied depending on the number of competitors in the market and the quality of the competitor's service. For example, the biggest price drops resulted when a monopoly market for Gbps service became a duopoly market, resulting in 34% to 37% price declines.[56]

It is not possible to characterize the precise nature of the competition that may be foreclosed if BWA providers, neutral host and other small infrastructure providers, and end-users are blocked from accessing the CBRS by the contemplated rule changes; however, the prior literature suggests that additional competition would reduce broadband wireless pricing by at least 10%.

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[54] Competition promotes allocative (resources are directed to their most valuable uses), productive (costs are minimized), and dynamic (investment is optimal over time) efficiency.

[55] For a summary of this literature, see William Lehr, *Benefits of Competition in Mobile Services*, at pages 21-26, attached to Letter from Rebecca Murphy Thompson, General Counsel, Competitive Carriers Association, to Marlene F. Dortch, Secretary, Federal Communications Commission, WT 13-135 (Mar. 24, 2014 http://apps.fcc.gov/ecfs/document/view?id=7521094963.

[56] *See* Dan Mahoney and Greg Rafert, *Broadband Competition Helps to Drive Lower Prices and Faster Download Speeds for U.S. Residential Consumers*, Analysis Group (Nov. 2016) http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/broadband_competition_report_november_2016.pdf. Their analysis demonstrates that the price effect on competition is greatest when the competitor offers higher quality services, but is evident even when there are multiple competitors in the market.

Given that total industry revenues in 2016 were approximately $247.2 billion,[57] and following Singer et al. (2017) in assuming a price elasticity of -2.1,[58] this would indicate that the total impact on consumer surplus of 10% lower prices would be approximately *$20 billion per year*.[59]

3.5. The impact of the contemplated rule changes on PAL auction revenues is ambiguous

A final factor to consider is the potential impact of the contemplated PAL rule changes on the auction revenues that may be raised from the sale of PAL licenses. While the goal of the CBRS framework is to enable the efficient allocation of spectrum resources to their highest value uses for the economy, if the PALs are deemed scarce then the auction for those licenses will raise government revenue receipts.

The auction of AWS-3 spectrum in 2015 raised an astounding $41.3 Billion and repurposed 65 MHz of paired spectrum in the 1.6/2.1 GHz bands, implying an average price of $2.72/MHz-POP.[60] However, those prices represent an exceptional outlier. For example, the recent 600 MHz auction of broadcast spectrum which was thought to be particularly valuable, especially to address rural coverage issues, raised $19.3 billion for 84 MHz of spectrum. This result implied a price of $0.93/MHz-POP, still making it the second most successful spectrum auction in

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57 This estimate of 2016 revenue aggregates Fixed Broadband Access revenues ($56.4B), reported by Statista (https://www.statista.com/statistics/280435/fixed-broadband-access-revenues-in-the-united-states/), Mobile Industry revenues ($188.5 billion), reported in the FCC's 20th Wireless Competition Report (*Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, et al.*, Twentieth Report, FCC 17-126, 32 FCC Rcd. 8968 (2017) https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-126A1.pdf), and Broadband Wireless Access provider revenues ($2.3B), reported in Carmel (2017), Note 29 *supra*.

58 See Singer et al. (2017), Note 36 *supra*.

59 This estimate follows the method used in Lehr (2014), Note 55 *supra*. It is based on a commonly used approach for estimating the impact on consumer surplus originally proposed by Hicks (1940) and then applied to telecommunications services by Hausman (1977,1999), and other scholars since. The method is useful because it allows estimates to be derived with limited market information. *See* J.R. Hicks, The *Valuation of the Social Income*, 7 Economica 105 (1940); Jerry A. Hausman, *Valuing the Effect of Regulation on New Services in Telecommunications*, 28 Microeconomics 1 (1997); and Jerry A. Hausman, *Cellular Telephone, New Products, and the CPI*, 17 Journal of Business and Economic Statistics 188 (1997).

60 A common metric for comparing spectrum transactions is the "$/MHz-POP," which computed by taking the price paid for the spectrum assets and dividing it by the product of the amount of frequency (MHz) times the population in the territory covered by the spectrum license (POP). The unpaired AWS-3 spectrum sold for substantially less, $0.52/MHz-POP. The paired spectrum is especially valuable (and scarcer) for cellular providers because it enables separate uplink and downlink channels with good frequency separation, consistent with the way cellular networks are designed. *See* Peter Cramton & Pacharasut Sujarittanonta, *Bidding and Prices in the AWS-3 Auction* (May 2015), ftp://www.cramton.umd.edu/papers2015-2019/cramton-aws-3-auction-prices.pdf.

history.[61] The value of 3.5 GHz PAL spectrum is likely to be well below $1/MHz-POP on average because (a) it is shared spectrum with incumbents that have superior access rights even with respect to PAL licensees, and (b) it is higher frequency and competes with a range of other spectrum assets (including to some extent unlicensed in the 2.4 GHz and 5 GHz bands). One analysis suggests that the average value for PAL spectrum may be well below $0.40 or even $0.20/MHz-POP.[62] Of course, the variance in spectrum values across markets is quite substantial. Spectrum in dense urban areas is typically much more expensive than spectrum in rural areas, where spectrum is relatively uncongested. Thus, even if 3.5 GHz spectrum is valued high at more than $1/MHz-POP in dense urban markets (where the cellular providers are most likely to be capacity constrained), the prices in rural markets may be closer to $0.10/MHz-POP or even less.

Assuming the 70 MHz of PAL spectrum were valued between $0.10-$0.50/MHz-POP, that would suggest a total auction value of $2.3 to $11.3 billion.[63] However, that is much more than should be expected to be raised in an auction of PAL licenses because, as noted, the spectrum is shared with incumbents. I would not be surprised if even the lower bound estimate is significantly higher than what we might expect PAL licenses to sell for, if, as the FCC has proposed, they are essentially converted to perpetual licenses.

This might suggest to some that an important benefit of the contemplated FCC changes is the prospect of earning auction revenues which may very well be in the range of hundreds of millions or even a few billion dollars. Even assuming this were true, it would not offset the costs of assuming the risks of derailing the growth opportunities discussed earlier. However, such an assumption is unreasonable on several counts.

First, foreclosing a large number of bidders from participating in the auction may exclude high bidders and, to the extent the principal motivation of cellular providers is to foreclose competition, result in lower overall pricing. With small license territories, a local user may be willing to bid a much higher $/MHz-POP for the spectrum desired than if the territory encompasses a market an order of magnitude larger (as is the case when one goes from Census Tracts to PEA-sized license areas). BWA providers, factory facilities, and small towns are located all over the country, and many are in rural areas that are poorly served by cellular providers. With smaller territories it is very possible that the local bidders may have a significantly higher willingness-to-pay. That may also be true in some urban markets, but in those markets we may expect cellular providers to win a larger share of the licenses.

Second, extending the license term will increase the price of a license relative to a single license, but need not translate into larger license revenues overall. Depending on what happens with

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61 *See* Jonathan V. Cohen & Jennifer Oberhausen, *2017 Spectrum Developments*, Wilkinson Barker Knauer, LLP (May 16, 2017), http://nsma.org/wp-content/uploads/2017/05/2017-05-nsma-2017-spectrum-developments.pdf.

62 See *Short: Globalstar, Inc. (GSAT),* Kerrisdale Capital Management, LLC (Oct. 2014), https://www.kerrisdalecap.com/wp-content/uploads/2014/10/Globalstar-GSAT-presentation.pdf, which reports transactions for 2.6 GHz spectrum with valuations in the $0.2 to $0.4 range, demonstrating a steep decline in the value per MHz-POP as the frequency increases.

63 The U.S. population is 323 million.

demand and future spectrum scarcity, a one-time spectrum auction (for perpetual licenses, which is what you get with assured renewability) or a series of longer-term licenses (without renewability) need not yield higher total PAL license proceeds than a sequence of shorter licenses that are auctioned more frequently.

For these reasons, it is not possible to say that adopting the contemplated PAL rule changes will actually result in larger total auction proceeds. It is conceivable that auction proceeds may be reduced.

4. Summing up: Costs of contemplated rule changes outweigh the benefits

A cost-benefit analysis of the proposed changes to the CBRS framework demonstrates that the costs of the contemplated changes outweigh the benefits, mainly because the changes would replace a licensing framework that opens the band to a wide group of bidders and investors with one that restricts it to a small group of similar companies. The nature of the contemplated changes makes it easy not only to determine overall costs and benefits, but also easy to identify who the net beneficiaries and net losers would be.

The sole beneficiaries of the contemplated changes would be the national cellular providers who would benefit by lower cost access to spectrum, but potentially even more importantly by the reduction in the threat they would otherwise face from increased competition in wireless services. The willingness of national cellular operators to integrate unlicensed spectrum into their spectrum plans, their extensive use of and portfolios of spectrum across many bands, and their need to expand capacity of their networks and invest in small cells, *whether they get 3.5 GHz PAL spectrum or not* supports the conclusion that even the national cellular providers would derive little valid benefit from the proposed change.

On the other hand, the large numbers of smaller local end-users (such as hospitals, entertainment venues and the hospitality industry), rural broadband providers, industrial broadband users, and local small cell infrastructure providers would be harmed by the contemplated changes. These changes would effectively foreclose these parties from acquiring PAL spectrum and would raise entry barriers and decrease their incentives to invest in wireless networks making use of the CBRS band. Because many of these potential users are key players in solving our rural broadband gap, in the adoption of IIoT applications and technology, and in providing alternative infrastructure platforms to support expanded competition and choices in wireless networking, these changes risk substantially diminishing future growth opportunities. The growth opportunities put at risk may be approximated conservatively as including:

- Reversing progress on closing the rural broadband divide, and potentially reducing U.S. annual GDP by $4 billion.
- Threatening potentially trillions of dollars of benefits to the U.S. economy associated with growth of IIoT applications. For example, postponing the realization of a $100 billion worth of benefits by a year costs $10 billion (at an interest rate of 10%). Many of the estimates noted above are much larger and the potential delay could be significantly longer.

- Diminished competition could plausibly result in reductions in consumer surplus of $20 billion per year.

With little to gain and billions of dollars to lose, a cost-benefit analysis of the proposed changes concludes that the changes should be rejected.