Before the
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION
DEPARTMENT OF COMMERCE

In the Matter of	)	
Development of a National Spectrum Strategy	)	Docket No. NTIA-2023-0003

COMMENTS OF BROADCOM INC.

April 17, 2023

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I. INTRODUCTION AND SUMMARY

Radiofrequency spectrum is an essential national resource, and government spectrum policies have a direct impact on the country's security, economic, and societal goals. As the National Telecommunications and Information Administration ("NTIA") recognizes in its Request for Comment, commercial spectrum access "advance[s] U.S. innovation, connectivity, and competition, create[s] high-paying and highly skilled jobs, and produce[s] improvements to the overall quality of life." It is also critical for the United States to "continue to lead the world in advanced technology."[1] Given the current array of wireless technology demands and the rich diversity of technological development expected in the coming years, making 1,500 megahertz of additional spectrum available is an important first step to meet the United States' economic and governmental needs. More will be required, but Broadcom strongly supports NTIA's proactive efforts to build a foundation in a National Spectrum Strategy.

As an American company and a global leader in semiconductor and infrastructure software solutions, Broadcom is deeply invested in the Nation's spectrum strategy. We have a history of innovation in the semiconductor industry, with roots in the technical heritage of AT&T/Bell Labs, Lucent, and Hewlett-Packard/Agilent. We offer thousands of products that are used in enterprise and data-center networking, home connectivity, set-top boxes, broadband access, telecommunications equipment, smartphones and base stations, factory automation, power generation and alternative energy systems, electronic displays, and more. Broadcom's products materially contribute to a wide range of industries and applications, including broadband, cellular (3G, 4G, 5G, and in the future, 6G), networking, wireless connectivity, storage, and industrial use cases (such as automation, renewables, and automotive electronics).

[1] *Development of a National Spectrum Strategy*, Request for Comments, Docket No. NTIA-2023-0003, 88 Fed. Reg. 16244, 16245 (Mar. 16, 2023) ("RFC").

Indeed, Broadcom's products are so ubiquitous that it is estimated 99.9% of all internet traffic crosses a Broadcom chip.[2] Broadcom's presence in these diverse markets provides us a unique understanding of the overall communications ecosystem.

Broadcom strongly endorses a planning process for the National Spectrum Strategy that ensures that the United States continues to be at the forefront of wireless technologies, services, applications, and devices. As the lengthy list of wireless uses in the Request for Comments reflects, the drive toward digitization of every economic function in society is also placing substantial new demands on spectrum. Broadcom and others are working hard to develop innovative technologies to meet those needs. But those technological solutions are subject to government constraints: spectrum allocations, technical rules, and important government spectrum uses, to name only a few. The federal government has a critical role to play in ensuring that the United States is using the available spectrum wisely and well.

Broadcom agrees wholeheartedly with NTIA that developing an effective National Spectrum Strategy will require substantial and ongoing collaboration between federal and non-federal stakeholders,[3] and urges NTIA to employ an "all of government" approach in partnership with the private sector to tackle these critical, complex issues. Moreover, while NTIA can and must plan for the long term, it should design and implement a spectrum strategy that is focused on regular and ongoing dialogue between federal and non-federal stakeholders, as opposed to a one-time implementation with future reviews. Spectrum demands and technologies change over time: the United States no longer uses Advanced Mobile Phone System, over-the-air television signals are digital, rather than analog, and ultrawideband services use spectrum in a way few

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2 *Broadcom Broadband Teach-In with Morgan Stanley*, Broadcom, 6 (Apr. 12, 2021), https://investors.broadcom.com/static-files/dc859b84-1f7d-4d61-a8d6-337a138d1274.

3 *See* RFC at 16245.

would have anticipated decades ago. The United States must be nimble and adaptive in its approach to spectrum management and allocation for continued technological leadership and success. To that end, NTIA would also benefit from regular engagement with, and participation in, standards-setting bodies, and should consider employing consulting experts that can apprise NTIA—and by proxy, other federal agencies—of developments in demand, technical capabilities, and associated spectrum requirements.

Of course, simply *deciding* to repurpose or share spectrum is not enough. The federal government should make spectrum available purposefully and thoughtfully, considering the needs of different use cases and the business realities related to deployments, to determine whether a particular band or frequency range is well suited for sharing or repurposing. To that end, Broadcom suggests that NTIA explore several spectrum ranges as potential areas for repurposing or sharing. For International Mobile Telecommunications ("IMT")/licensed use, much will depend on the outcome of the Partnering to Advance Trusted and Holistic Spectrum Solutions ("PATHSS") report, but Broadcom believes that the combination of global harmonization, capacity, and propagation supports making as much 3 GHz spectrum as possible available for IMT/licensed use. Furthermore, given the need for mid-band spectrum, NTIA should look to the 12.7-13.2 GHz range for IMT/licensed use, which is already under consideration by the Federal Communications Commission ("FCC"). For unlicensed use, the immediate focus should be on completing the 6 GHz band by allowing unlicensed operations up to 7250 MHz, which would provide a fourth 320-megahertz channel. The 802.11bn project (Wi-Fi 8) has extended the Wi-Fi channel plan to include the 7125-7250 MHz range.[4] 6 GHz radios

[4] *Draft Amendment to IEEE Standard 802.11-2020*, IEEE Standards Association (Mar. 16, 2023), https://mentor.ieee.org/802.11/dcn/23/11-23-0480-00-0uhr-uhr-proposed-par.pdf ("*Draft Amendment to IEEE Standard 802.11-2020*").

can easily be extended to cover this range, providing significant economic value for American consumers and enterprises. Completing the 6 GHz band would be valuable not just for future applications using Wi-Fi 8, but also for Wi-Fi 6E and forthcoming Wi-Fi 7 devices that are already capable of covering up to 7250 MHz. Longer term, services using unlicensed spectrum would benefit from additional 320, 160, and 80 MHz channels (up to 7625 MHz).

Increasing available spectrum for both IMT and unlicensed use will allow the United States to continue to meet its spectrum goals, to the benefit of the Nation's people, economy, and national security. A comprehensive approach also reflects growing needs among both IMT and unlicensed use cases, and the fact that Americans rely daily on services provided under many different spectrum access models. Broadcom looks forward to engaging with NTIA and others in this critical and worthwhile endeavor.

II. PILLAR #1 – A SPECTRUM PIPELINE TO ENSURE U.S. LEADERSHIP IN SPECTRUM-BASED TECHNOLOGIES

1: What are next-generation services' short, medium, and long-term spectrum requirements?

For commercial orthogonal frequency-division multiplex access technologies like 5G, Wi-Fi 6E, and Wi-Fi 7, spectrum needs include not only more available frequencies, but also frequencies that facilitate wider channels. Wider channelization will have benefits beyond just increased capacity. It will also support improved energy efficiency, reliability, latency, and location capability. Advances in these basic characteristics will support myriad applications, some of which are not yet commercially available, and others of which are in early stages of development.

In addition, advanced communications services, such ultra-high-definition video, smart city, contextual internet, augmented, virtual, and mixed reality, and unified communications,

require high reliability and extremely low latency. These needs can only be met through indoor and outdoor network densification. Given that the vast majority of data is consumed indoors, the most urgent demand is to enable dense networking indoors at the end of fiber and DOCSIS networks.

IMT/Licensed: In the short term, Broadcom supports making as much spectrum as possible in the 3 GHz band available for IMT/licensed use. The 3 GHz band enjoys global harmonization, and the band's characteristics—capacity combined with sufficient propagation for outdoor networking—make it a key band for current and future use cases. How much spectrum to make available, as well as the resolution of technical questions regarding the appropriate power levels and steps necessary to protect government operations, will depend on the incumbents in the band, and Broadcom looks forward to reviewing the upcoming PATHSS report on each of these issues.

In the medium- and long-term, Broadcom supports making available 500 megahertz of spectrum available for IMT/licensed use in the 10-15 GHz range of the mid-band. The FCC's current proceeding on 12.7-13.2 GHz[5] could meet this need for increased capacity in dense network deployment scenarios (such as in urban areas) as IMT moves to multi-gigabit capacity capabilities.

Unlicensed: For unlicensed operations, there is an immediate and urgent need for another 320-megahertz channel for indoor operations. The best and most spectrally efficient way to accomplish this is to complete the incomplete 320-megahertz channel stranded at the top of the 6 GHz band by extending indoor low-power unlicensed use up to 7250 MHz under terms similar

[5] *See Wireless and Telecommunications Bureau and Office of Engineering and Technology Establish GN Docket No. 22-352*, Public Notice, DA No. 22-1069, GN Docket No. 22-352 (rel. Oct. 6, 2022).

to those governing the top of the current 6 GHz band. This approach would provide a fourth 320-megahertz channel in a spectrally efficient manner because it requires only an additional 125 megahertz. Providing this channel elsewhere would require a full new 320-megahertz designation, likely a more complex undertaking. This channel is needed for channel diversity in dense networking environments, such as multi-dwelling buildings. This approach would also provide for an additional 160-megahertz channel and two more 80-megahertz channels for high-throughput, high-density enterprise and municipal applications such as transportation hubs, sports and entertainment venues, and high-density retail outlets. The same frequencies may also be capable of use for Standard Power operations based on Automated Frequency Coordination ("AFC") control, as in the 6 GHz band, depending on incumbent operations.

6 GHz Wi-Fi radios can be configured via software modifications to operate up to 7250 MHz *now*, meaning that vendors can deliver products that work at those frequencies quickly and economically—if and when they are made available for unlicensed use. IEEE 802.11 is already working on a technology (802.11bn) that will become Wi-Fi 8, and it is already channelized up to 7250 MHz through a recent IEEE Project Authorization Request,[6] and this channelization could easily be extended to cover 802.11ax (Wi-Fi 6E) and 802.11be (Wi-Fi 7) products. Longer-term, unlicensed technologies would benefit from accessing frequencies up to 7625 MHz, so that a fifth 320-megahertz channel could be provided to support industrial, medical, and Internet of Things networks. A single radio could be extended to cover the 6 GHz band up to 7625 MHz, thus reducing the costs for connectivity in end-user devices and networking equipment.

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[6] *Draft Amendment to IEEE Standard 802.11-2020.*

2: Why is currently available spectrum insufficient?

Demand is rising rapidly for wireless services, and meeting this demand requires additional spectrum resources. Further, spectrum applications increasingly require higher capacity and reduced latency, which wireless technologies will provide through wider channels than are generally available today. For instance, the United States has already begun the wired broadband transition from 1 gigabit per second ("Gbps") or "multi" Gbps broadband service to 10 Gbps and beyond. The vendor community is already discussing 50 Gbps passive optical network technology for the long term, and applications and devices will quickly evolve to exploit this new capability. Leaving last-generation wireless connectivity at the edge of such powerful fixed networks would prevent consumers and enterprise users from effectively utilizing the capacity, reliability, and latency advancements that are enabled by this jump in bandwidth. Furthermore, significantly more bandwidth will be required to enable emerging services such as cloud and edge-rendered extended reality to multiple simultaneous users (for instance, in classroom settings). For many in the United States, these innovative applications will be accessed through Wi-Fi, and Wi-Fi 8 will provide the bandwidth and capabilities necessary to do so. Providing the spectrum necessary for future Wi-Fi deployment will allow a wider range of consumers to access these innovative applications.

Growing demand for Wi-Fi also means that there is a current and urgent need to create another 320-megahertz indoor low-power channel by completing a stranded channel at the top of the 6 GHz band and permitting unlicensed operations up to 7250 MHz. That spectrum could also be used for standard-power devices subject to database coordination to avoid harmful interference to incumbent services. Finally, as noted above, Broadcom also recommends making available a fifth 320-megahertz channel above 7250 MHz, if possible. As in the case of the 5 GHz and 6 GHz bands, such spectrum could be shared with incumbents, enabling more

intensive and efficient use of available spectrum relative to current deployments. Such an approach would not require repurposing of spectrum from current users.

The exceptional rate of adoption seen in the 6 GHz band for Wi-Fi demonstrates the demand for additional spectrum. In just three years, over 1,200 different products have been launched with Wi-Fi 6E.[7] According to International Data Corporation forecasts, 350 million Wi-Fi 6E products were shipped in 2022.[8] Nearly every major U.S. operator has 6 GHz Wi-Fi on their roadmap.[9] Broadcom notes that since the FCC made the decision to open the 6 GHz band for unlicensed use in April 2020, the number of fixed links has grown by 8%, and the Commission has not found any cases of harmful interference involving devices operating under the 6 GHz rules, demonstrating the efficacy of the Commission's rules.

3: What spectrum bands should be studied for potential repurposing?

For IMT/licensed use, Broadcom looks forward to studying the forthcoming PATHSS report, which will discuss how much spectrum is available in the 3 GHz band, as well as the licensing and technical rules that DOD suggests for the band. Overall, Broadcom supports the study of an additional 500 megahertz of new spectrum for IMT use, with a focus on the 10-15 GHz range of the mid-band. As noted above, the FCC is already exploring the 12.7-13.2 GHz band, which would meet this need. For unlicensed use, NTIA should make available 500 megahertz of spectrum from 7125-7625 MHz. Given that radios for Wi-Fi 6E and 7 can operate

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7 *See Intel Says Wi-Fi 6E Device Count Surpasses 1200*, World of Wi-Fi Roundup (Feb. 9, 2023), https://wifi.substack.com/p/world-of-wi-fi-roundup-intel-says.

8 *See Wi-Fi® Momentum in 2022*, Wi-Fi Alliance & The Beacon (Mar. 15, 2022).

9 *See Nearly Every Major Operator Has 6 GHz on Its Roadmap, Says Broadcom*, RCR Wireless News (Nov. 21, 2022), https://www.rcrwireless.com/20221121/network-infrastructure/wi-fi/nearly-every-major-operator-has-6-ghz-on-its-roadmap-says-Broadcom.

up to 7250 MHz with software modifications, policymakers should place a special focus on immediately freeing up the 7125-7250 MHz range for unlicensed use under terms consistent with the FCC's approach to the current 6 GHz band. Any study of spectrum repurposing or unlicensed access higher in the band should also consider the many available methods of protecting incumbents, including different power levels, device capabilities, and spectrum access mechanisms.

4: What factors should be considered in identifying spectrum for the pipeline?

Identifying spectrum for the pipeline must involve analysis focused on physics and economics. Making spectrum available must be purposeful, and policymakers must evaluate and understand the number and size of channels necessary for different use cases to determine whether enough spectrum can be made available in the right frequencies to have a meaningful impact. For unlicensed use, for example, making additional contiguous spectrum available would be especially valuable and helpful from a technical perspective because wide contiguous channels are needed to distribute data wirelessly at the end of multi-gigabit fiber networks. To be successful, any strategy must also take account of the economics of deployment. Simply making spectrum available for particular use cases may not have an equal impact in all locations. For example, low-latency, high-reliability wireless for indoor operations cannot be provisioned through outdoor macro-cell cellular networks. It requires densification and will mostly be provisioned over Wi-Fi. In outdoor networks, and some indoor deployments, cellular densification is required. Evaluating whether spectrum should be made available in particular bands, and for particular use cases, must therefore account for the economic realities of deployments and the physical realities of both applications and particular band characteristics.

5: How can the Federal Government better meet U.S. goals through spectrum management?

Technological developments impacting spectrum management cut across multiple industries and areas of expertise. Core technologies are constantly undergoing change and development. Broadcom urges NTIA to collaborate and engage in open dialogue with industry experts to remain current on key developments in core technologies, including spectrum-sharing technologies, and advances in interference-analysis tools, such as the use of large-scale probability analyses rather than limited link-budget analyses. NTIA could also benefit from engaging consulting experts who can help keep the federal spectrum management community apprised of developments as they happen. Aiding the government in remaining current and knowledgeable in this manner would be a valuable contribution from NTIA to the federal community.

6: How should spectrum sharing be defined, and what technologies are available to facilitate spectrum sharing?

Broadcom agrees with and endorses NTIA's proposed definition of spectrum sharing as "optimized utilization of a band of spectrum by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic."[10] In terms of currently available spectrum-sharing technologies and processes, the unlicensed community is eager to see the commercial deployment of AFC in the coming months to enable standard-power 6 GHz Wi-Fi, and is excited about the expansion of spectrum sharing that AFC will make possible. Scaling up AFC will be necessary for the maturation of Wi-Fi 6E and the development

[10] RFC at 16246.

of Wi-Fi 7. Broadcom believes that Open AFC[11]—an open-source tool that AFC system operators can use to carry out AFC functions to protect radio astronomy and fixed microwave links—could be modified to operate in other frequencies, be used to protect other incumbents, and could even be used to analyze sharing capabilities.

7: What are the benefits and drawbacks of exclusive-use licensing, pre-defined sharing, and dynamic sharing, and what methods can be used to protect against harmful interference?

The primary benefit of licensed-exclusive use is exclusivity itself. Exclusive use means that technological decisions about how to manage spectrum are easier, because all the spectrum is available for a particular use. However, the exclusive-use approach comes with a real economic cost, because it creates significant delays in accessing the spectrum, precludes other uses of the spectrum, and the spectrum can often be underutilized or inefficiently utilized in some areas.

The licensed-shared approach has the benefit of enabling current users of the band to continue using the band, and it could be implemented far more rapidly than if users must be migrated to a new frequency. Static, pre-defined sharing has the benefit of more reliable access for secondary users, but overly cautious rules can leave significant unused spectrum on the table. Dynamic sharing enables more dense use, allowing the broadest range of operations to coexist in the same spectrum, which can increase the efficiency of spectrum use considerably. However, dynamic sharing may limit the number of users to address aggregate interference, or dynamically remove frequencies in order to protect a new license, which can lead to reduction in service levels for a given event or in a specific location. The United States has been the leader in

[11] *See Open AFC*, Telecom Infra Project, https://telecominfraproject.com/open-afc/ (last accessed Apr. 4, 2023).

innovative dynamic sharing approaches and technologies, and we now have a powerful set of tools at our disposal to implement dynamic sharing. This began with Dynamic Frequency Selection ("DFS"), which allows sensing of incumbent radar operations to avoid Wi-Fi interference into such receivers operating in the same frequencies. Dynamic sharing has evolved to include cloud-based systems such as the tiered framework in the Citizens Broadband Radio Service ("CBRS"), and AFC systems that will enable standard-power unlicensed operations in the 6 GHz band.

However, static and dynamic sharing approaches can become outdated because they often rely on reference points, including assumptions on receiver performance and incumbent technologies, that become inappropriate over time. Sharing criteria, if not modernized, may also inhibit incumbent technologies from evolving and improving, either because rules preclude change to the incumbent devices, or because incumbents are not required to make changes under the established rules (even when outdated incumbent technology might severely limit sharing).

Spectrum policies and spectrum management approaches that support coexistence should not be treated as "set-it-and-forget-it" decisions that ignore future technological advances. Rather, policies should create the expectation for all band users that if it is possible to make coexistence function better over time, government has an obligation to act. As a corollary, as improvements are made, there has to be a clear-eyed assessment of whether changes will materially improve coexistence, and to what extent the decisions will strand investment.

To protect users in adjacent bands against harmful interference, regulators should consider several factors. On the transmitter side, rules setting appropriate power levels and requiring appropriate filtering are important. But the receiver side is important as well, and the National Spectrum Strategy should set an expectation that spectrum users should improve

receiver performance over time, and create incentives for doing so by basing interference analyses on current receiver capabilities rather than allowing out-of-date receivers to undermine national spectrum goals. Stronger receiver performance—whether through filters, error correction, signal processing, or other measures—can mitigate and render harmless received energy that might otherwise cause harmful interference. This is especially true where incumbent receivers are dated. The FCC's proposed policy statement regarding how it will approach these receiver-performance issues is a good start, and Broadcom encourages NTIA to incorporate these policies into the National Spectrum Strategy.[12]

9: How should the National Spectrum Strategy account for international harmonization?

The United States has historically played a central role in leading international discussions on spectrum harmonization. The United States needs to demonstrate a continued willingness and ability to take on that role and to encourage other nations to work collaboratively to maximize the potential of global spectrum. The 6 GHz band is one example: countries accounting for nearly 70% of the world's GDP have opened all or part of that band to unlicensed use. The United States should continue to impress upon other nations the importance of opening the 6 GHz band to unlicensed use, as well as the benefits of broader international harmonization. Importantly, the National Spectrum Strategy should also include a commitment to pursue spectrum harmonization both inside and outside of multilateral settings such as the International Telecommunication Union. Most important spectrum decisions are made by individual countries, and the U.S. government should increase bi-lateral outreach to other countries on spectrum

[12] *See Principles for Promoting Efficient Use of Spectrum and Opportunities for New Services*, Draft Policy Statement, FCC-CIRC2304-01 (rel. Mar. 30, 2023), https://www.fcc.gov/document/promoting-efficient-use-spectrum-opportunities-new-services.

matters, including by strengthening spectrum policy knowledge among U.S. embassy staff in key countries.

III. PILLAR #2 – LONG-TERM SPECTRUM PLANNING

1: How can a long-term spectrum planning process be carried out inclusively and transparently?

Given the nationwide impact of spectrum decisions, a wide range of stakeholders will be affected by or interested in the development of a National Spectrum Strategy. These stakeholders range from the federal community, to industry (including equipment manufacturers and vendors), to consumers, to interest groups and academics. It is important to have a wide range of well-informed views represented in the planning process. NTIA can pursue a transparent and inclusive planning process by establishing a plan for regular communication, and by proactively engaging in discussions with stakeholders that have important technical knowledge and relevant experience. This might include, for example, a process or framework for regular engagements with the vendor community and relevant academic institutions, as well as participation in long-term planning carried out by relevant standards-setting organizations.

2: What should a long-term planning process look like, and what information is needed for planning purposes?

Broadcom commends NTIA for thinking beyond immediate and short-term goals and considering long-term spectrum planning. However, rather than adopting a long-term approach based on periodic reviews and updates, Broadcom suggests that NTIA consider a more frequent, iterative planning and improvement process. Such a process, based upon collaboration within the federal community and between federal and non-federal entities, will allow for a nimbler spectrum strategy that reflects and accounts for current national and global issues, federal mission goals, industry advancements, and the latest in technological developments. The data

that will support long-term planning include improved propagation models, spectrum-sharing tools, and noise-floor measurements. The government can take a leading role in developing tools to collect and assess these kinds of data, which would aid all stakeholders in realizing more intensive use of spectrum.

3: How can federal and non-federal stakeholders engage in productive ongoing dialogue?

Improving federal and non-federal spectrum coordination will require frequent and ongoing discussions among federal stakeholders, and between federal and non-federal stakeholders. Ensuring that dialogue is productive and effective will require a shift in paradigm, however. To support those ongoing discussions, the executive branch should make clear that the President has entrusted and empowered NTIA to make critical decisions regarding federal spectrum policy, albeit with regular and consistent input from other federal stakeholders. With this authority, NTIA should occupy a leadership role, including education, persuasion, and decision-making regarding federal spectrum.

4: What technical and policy-focused activities can the U.S. Government implement that will foster trust among spectrum stakeholders?

Please see response to Pillar 2, Question 2.

5: What additional spectrum-focused engagements would improve trust, transparency, and communication among federal and non-federal stakeholders?

Please see response to Pillar 2, Question 1.

6: Are there any specific spectrum bands or ranges to be looked at that have high potential for expanding and optimizing access? What, if any, metrics are ideal for measuring the intensity of spectrum utilization by incumbents in candidate bands?

For the reasons noted in response to Pillar 1, Questions 1 and 2, Broadcom believes that NTIA should examine:

- making available the largest possible range of spectrum in the 3 GHz band for IMT/licensed operations, consistent with the outcome of the PATHSS process;
- opening 500 megahertz of mid-band spectrum in the 10-15 GHz range (e.g., 12.7-13.2 GHz), for IMT/licensed;
- completing the stranded 320-megahertz channel at the top of the 6 GHz band by permitting unlicensed operations to 7250 MHz; and
- to the extent possible, and on a longer-term basis, facilitating unlicensed use up to 7625 MHz, creating a fifth 320-megahertz channel.

NTIA also requested comment on the ideal metrics for "measuring the intensity of spectrum utilization by incumbents in candidate bands."[13] Broadcom's view, however, is that measuring the intensity of spectrum utilization is not the most effective way to develop the requisite understanding of a candidate band. The focus instead should be on understanding a band's interference environment, including the number of systems, antenna characteristics and directionality, receiver performance, and height above average terrain. These metrics will give NTIA and others a clearer picture of the band in question and will inform the feasibility of reorganizing or repurposing a band. Furthermore, this information may allow NTIA to find a way to preserve incumbent operations regardless of their intensity and also allow sharing to improve the total utility the band produces—the country no longer has the luxury of limiting our inquiry to under-utilized bands. It is also useful to analyze, for a particular band, to what extent a roadmap for deploying wireless technologies in the band exists or is under development.

7: How can the spectrum workforce be strengthened and diversified?

Broadcom is committed to creating a welcoming and inclusive workplace, and understands that a talented, engaged, and diverse workforce is critical to business success.[14] To

[13] RFC at 16247.

[14] *See Workforce*, Broadcom (last accessed Apr. 4, 2023), https://www.broadcom.com/company/citizenship/workforce; *see also* Greg Lotko,

that end, Broadcom supports all efforts to increase diversity in the workforce pipeline. Broadcom encourages the government to invest in and pursue early and consistent educational initiatives focused on the introduction of core engineering concepts. These might include programs focused on early-age introduction to STEM and STEM-related careers, such as those promoted by the Broadcom Foundation,[15] along with concerted efforts to keep students interested in these careers through secondary education and beyond.

IV. PILLAR #3 – UNPRECEDENTED SPECTRUM ACCESS AND MANAGEMENT THROUGH TECHNOLOGY DEVELOPMENT

1: What innovative capabilities for spectrum management are being explored today?

Broadcom, along with Cisco Systems and Meta Platforms, leads the Telecom Infra Project's Open AFC Software group. That group has focused on designing and developing a modular and customizable software, called Open AFC, for use by AFC operators to enable standard power Wi-Fi access in the 6 GHz unlicensed band. Open AFC will allow AFC operators to import data from national databases (like the FCC's Universal Licensing System database and Equipment Authorization system); acquire, maintain, and validate information provided by standard power APs to ensure they are permitted to operate in the 6 GHz band; calculate and provide maximum allowable power levels and permitted operation frequencies to APs; and retain information for recordkeeping purposes.[16] Open AFC will improve spectrum access by

Mainframe, Broadcom (Nov. 18, 2021), https://mainframe.broadcom.com/blog/diversity-paving-way-mainframes-future (Broadcom supports diversity not just for diversity's sake, but "because we recognize it brings real business value, helping to attract more talent with fresh ideas that have the power to take a growing industry to its next chapter").

[15] *See A Message from Our Board*, Broadcom Foundation, https://broadcomfoundation.org/ (last visited Apr. 11, 2023).

[16] *See Open AFC Software Architecture,* Telecom Infra Project, 9 (Nov. 2021), https://cdn.brandfolder.io/D8DI15S7/at/kj985vm9p375wxtft2kjc58/TIP_Open_AFC_Open_

simplifying, streamlining, and standardizing the process of operating an AFC, allowing more devices to access and take advantage of the 6 GHz band. As discussed above, Broadcom believes that Open AFC could be expanded to allow federal government users to coordinate use in other frequencies and assist in sharing with other licensed users in those frequencies. Broadcom would welcome the opportunity to demonstrate the capabilities of the Open AFC software to NTIA and federal spectrum users and discuss its implications for future spectrum sharing.

2: What policies would enable development of new and innovative uses of spectrum?

The rules that apply to some wireless devices risk undermining innovation and technological advancement. Some rules require equipment manufacturers to lock in many technical details of a device. Manufacturers must then pursue a time-consuming, expensive, and uncertain formal change before they can implement superior device parameters that become available after they seek certification. While some device requirements are necessary to ensure compliance with interference protections or other policy decisions, regulators should work to adopt rules that set forth specific technical outcomes rather than prescribing specific technical means of achieving those outcomes. For the same reason, Broadcom encourages regulators to make iterating device classes and models easier and faster to allow companies to bring the best and most up-to-date technologies to consumers, rather than taking an unnecessarily rigid approach. Manufacturers should be encouraged to design devices not only for current rules, but also for anticipated advances, and the government should encourage those developments by facilitating changes in device class as rules and capabilities evolve.

AFC_Software_%20Architecture_v10_FINAL_November_2021_GREEN_-_Public_Access.pdf.

3: What role should the government play in promoting research and development in spectrum management and technologies? What technologies exist to appropriately prevent out-of-band interference?

The federal government has a long history of funding and producing original research and development relevant to wireless technologies. But another important way for NTIA to advance national spectrum policies is to give the federal government access to the exceptional research and development being conducted by industry and by research institutions. This role should be a part of the National Spectrum Strategy. In this role, as noted above, the government (through NTIA) should pursue regular and consistent communications with industry and other stakeholders who are involved in the development of spectrum technologies and standards. Doing so will allow for more-informed policy development, evolution of the National Spectrum Strategy over time, and a federal community that stays current on changes that are relevant to federal spectrum users.

Broadcom recommends three specific areas where NTIA could make important contributions by bringing industry advances to the federal community: interference mitigation technology, spectrum-sharing tools, and the use of large-scale probability analysis. First, the state of the art in interference mitigation is advancing rapidly, through both improvements in filtering technologies and other means of addressing unwanted in-band energy, such as error correction and signal processing. NTIA should ensure that it has staff with deep knowledge of these key technologies, stays abreast of improvements, and has regular and reliable mechanisms for transferring this knowledge to federal spectrum users. Ensuring that incumbent devices are, to the extent possible, taking advantage of the best technologies and approaches would significantly reduce the risk of harmful interference. Second, the United States is the world leader in spectrum-sharing technologies, driven by innovative policies that have incentivized the private and public sectors to develop new and effective sharing approaches. NTIA has played a key role

here in its work in the CBRS band and should now ensure that it takes full advantage of the advances in the 6 GHz band, such as the Open AFC software described above. Third, NTIA has important knowledge about the application of Monte Carlo and other probability studies to interference analysis, especially through its work at the International Telecommunication Union and with its European colleagues, where governments have more comprehensively harnessed the power of these analytic tools. NTIA can play an important role in dispersing that knowledge among federal agencies and ensuring the use of these tools to produce more reliable studies than the previous generation's small-scale, worst-case approach can offer.

Regarding out-of-band interference, innovations in radio design and filtering technology continue to improve. Such innovations allow for a steeper energy roll-off outside of the intended channel, reducing adjacent channel interference and allowing for greater compatibility of systems operating in adjacent bands. Radio modernizations such as reducing the energy at the band edge can also shape the emissions away from adjacent bands. Another modernization is the ability to puncture a sub-channel near a band edge and thus reduce out-of-band interference.

4: How should NTIA develop a scalable mechanism for managing shared spectrum access using the Incumbent Informing Capability (IIC), and what challenges do non-federal users foresee?

Broadcom believes that the government is best positioned to develop IIC, because it involves interaction with non-public systems. Creating a successful system that encourages sharing and increases efficiency will require maximizing clarity and predictability, even where specifics are unavailable due to the non-public nature of government spectrum use. That is because the challenges related to spectrum sharing with federal users have less to do with the mechanism for sharing, and more to do with the nature of spectrum availability that the mechanism produces. For example, an IIC that reveals a relatively static spectrum availability of

a broad swath of spectrum, for certain uses such as indoor-only, or over a geographic area provides a good basis for sharing and would support use cases that require limited downtime. But where there are narrow bands of spectrum availability that are frequently or unpredictably unavailable due to federal activity, such spectrum may have limited use, and even then, may be dependent on providing sufficient notice to commercial users to transfer activity to an available band. Some of these concerns can be resolved through careful planning and identification of appropriate bands and geographies for sharing, considering the type of federal use in the band (and any relevant geographic areas), the size of the band, and the frequency and predictability of federal activity in the band.

V. IMPLEMENTATION PLAN

NTIA seeks comment on implementation of the National Spectrum Strategy, including which spectrum bands or ranges should be prioritized for in-depth study. Taking a comprehensive approach that includes licensed (including shared-licensed) and unlicensed spectrum will allow for development of the critical technologies and services that the different spectrum access models support.

Broadcom suggests the following initial steps for unlicensed operations. First, NTIA should recommend completing the stranded 320-megahertz channel at the top of 6 GHz band immediately by working with the FCC to open the 7125-7250 MHz range for unlicensed low-power indoor use. Second, NTIA should explore unlicensed use above 7250 MHz, which would be critical for quickly approaching Wi-Fi 8 needs, and the increasingly demanding consumer and enterprise use cases that those new standards will support.

Broadcom suggests the following initial steps for IMT/licensed operations. First, NTIA should recommend that the 12.7-13.2 GHz range would serve to provide a much-needed 500

megahertz of mid-band spectrum to support developing multi-gigabit IMT capabilities. Second, upon publication of the PATHSS report, NTIA should take action on the lower 3 GHz band as soon as possible, providing up to another 350 megahertz for IMT/licensed operations.

VI. CONCLUSION

Broadcom supports a comprehensive National Spectrum Strategy that will open the door to critical improvements in unlicensed, licensed-exclusive, and licensed-shared operations. Supporting completion of the stranded 320-megahertz channel in the 6 GHz band for unlicensed operations, examining unlicensed use from 7250-7625 MHz, recommending action on the 12.7-13.2 GHz band for multi-gigabit IMT use, and taking action in 3 GHz following the PATHSS process will all support the national economy and security, as well as continued U.S. leadership in spectrum technologies. In the longer term, Broadcom encourages NTIA to implement a strategy focused on ongoing communication and collaboration between federal and non-federal stakeholders and looks forward to participating in this process.

Respectfully submitted,

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