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Via Electronic Filing

National Telecommunications and Information Administration
1401 Constitution Ave., NW
Washington, DC 20230
http://www.regulations.gov/

Re: NTIA Development of a National Spectrum Strategy, Request for Comment; Docket No. NTIA-2023-0003

Dear Madam/Sir:

Qualcomm Incorporated is pleased to respond to NTIA's Request for Comment ("RFC") on the development and implementation of a National Spectrum Strategy for the U.S. As NTIA explains, ensuring sufficient access to spectrum is vitally important to "national security, critical infrastructure, transportation, emergency response, public safety, scientific discovery, economic growth, competitive next-generation communications, and diversity, equity, and inclusion."[1] To fully support each of these key areas, the U.S. must ensure its wireless communications infrastructure can support the increasing demand, continued growth and technological advancement of wireless technologies. Additional spectrum will continue to be needed for mobile, fixed, and satellite operations to support each of the uses and applications detailed in the RFC in transportation on land, sea, air, and in space, manufacturing, healthcare, utilities, agriculture, smart cities, IoT, national defense, national security, climate, and more.[2]

As an American company founded and headquartered in San Diego, California, Qualcomm applauds NTIA's strategic efforts to ensure the U.S. makes additional spectrum available to support the exponentially increasing and expanding user demands on today's mobile networks and wireless infrastructure writ large. NTIA's work to enable more intensive spectrum use is essential to ensuring the U.S. continues to lead the world in advanced communications technologies to further national and economic security.

Qualcomm is a leading wireless technology developer and provider of chipsets used in billions of consumer devices (smartphones, tablets, laptops, and other wireless devices), as well as small cells, Wi-Fi access points, automobiles, even space equipment. Our technological advances are driving the wireless revolution. Qualcomm is behind the rapid proliferation of 5G in the United States and worldwide, and we are working now to open new spectrum bands for the next generation of wireless technology ("6G"). Every day, Qualcomm engineers work tirelessly to squeeze more capacity out of existing spectrum allocations by enabling more intensive

[1] RFC at 3.

[2] *See id*. at 4.

spectrum reuse and improved performance in terms of overall capacity and lower latency through more intensively sharing limited spectrum resources among more users and diverse uses.

To support the industry's technological advances, additional spectrum is needed for licensed mobile operations (5G and 6G) and for unlicensed operations like Wi-Fi. Maintaining a spectrum pipeline is crucial for the roll-out of new wireless technologies. America's mobile technology leadership has been built on a regulatory approach that has favored spectrum clearing, exclusive-use spectrum licenses with flexible use rights, private sector investment, and competition. Fully cleared, exclusively licensed spectrum remains the top priority for the wireless industry to support the continued rapid roll-out of 5G and 6G across the U.S. At the same time, unlicensed spectrum plays an important role for Wi-Fi operations in millions of homes and businesses.

Qualcomm recognizes that there is no greenfield spectrum, and all spectrum bands have incumbents, including federal users, which may not be able to be completely cleared on a nationwide basis to enable mobile and fixed terrestrial operations coast-to-coast. Clearing federal incumbents is increasingly difficult as all users' spectrum needs are growing, forcing all spectrum users to sharply focus on spectrum sharing solutions. Future spectrum access will increasingly rely upon spectrum sharing, and the appropriate spectrum sharing approach is band-specific and tied to present incumbent users' operational needs and locations.

Qualcomm has played a key role in developing innovative sharing solutions for many bands opened for commercial purposes in recent years, including the 3.5 GHz licensed band and the 6 GHz unlicensed band. As discussed below, Qualcomm also has an innovative sharing proposal for the Lower 37 GHz shared licensed band that would allow federal and commercial licensees to share the same spectrum band at the same time and place without harmful interference. This technology-neutral, equipment-based approach would effectively provide each shared licensee with access to the entire 600-MHz-wide Lower 37 GHz band to satisfy ever increasing mobile data demands.

Spectrum sharing between federal users and commercial users can be a win-win. By opening to sharing a frequency band exclusively held by the federal government, federal government users can take advantage of the most advanced wireless technologies, chipsets, and equipment that industry develops for commercial operations in the band, thereby improving federal operations and making more intensive use of the shared spectrum bands. Encouraging all spectrum stakeholders to work collaboratively on spectrum sharing is a successful way forward.

Qualcomm looks forward to partnering with the U.S. government to support increased spectrum access and expanded commercial and government spectrum uses. Qualcomm's standing as a leader in wireless ecosystem innovations is driven by applications and needs of the commercial mobile industry's consumers, enabled by standards organizations and commercial deployments. This uniquely positions Qualcomm as a partner to all U.S. government agencies with spectrum needs. Qualcomm applauds NTIA's efforts to revisit current spectrum uses in all bands to explore opportunities to increase spectrum utilization across the board. We stand ready to help NTIA forecast spectrum access requirements for future applications to take advantage of the extensive innovation that is occurring in the mobile ecosystem.

Responses to NTIA's Questions

Pillar #1 – Spectrum Pipeline to Ensure U.S. Leadership in Spectrum-Based Technologies

1. *What are projected future spectrum requirements of the services or missions of concern to you in the short (less than 3 years), medium (3-6 years) and long (7-10 years) term? What are the spectrum requirements for next-generation networks and emerging technologies and standards under development (e.g., 5G Advanced, 6G, Wi-Fi 8)? Are there additional or different requirements you can identify as needed to support future government capabilities? What are the use cases and anticipated high-level technical specifications (e.g., power, target data rates) that drive these requirements? How much, if at all, should our strategy by informed by work being performed within recognized standards-setting bodies (e.g., 3GPP, IEEE), international agencies (e.g., ITU), and non-U.S. regulators or policymakers (e.g., the European Union)? What relationship (if any) should our strategy have to the work of these entities? Are there spectrum bands supporting legacy technology (e.g., 3G, GSM, CDMA, etc.) that can be repurposed to support newer technologies for federal or non-federal use?*

Because of the never-ending growth in wireless data demand,[3] federal government users will need reliable spectrum access, and mobile network operators, fixed wireless service providers and satellite service providers all will need additional spectrum to support America's continuous appetite for mobile data.

5G Advanced and 6G technologies will require substantial amounts of additional spectrum. The technical requirements and anticipated use cases, like ultra-HD video communications from drones and Augmented Reality and Virtual Reality ("AR/VR") devices supporting immersive experiences in education, healthcare, travel, manufacturing, public safety, national security, and many other fields, require larger bandwidths, higher speeds, and lower latency. AR/VR, in particular, requires high-quality video and audio as well as ultra-low latency connections, which translates into substantial data capacity.

Even though the technical requirements for the next generation of wireless technology are still being developed, given the expected growth rate in mobile data, the operational throughput may approach 1 Tbps by the end of the next decade. To support this, 6G network architecture will need to support scaling to wider bandwidths and higher-order MIMO. At these data rates, metrics like power efficiency and area capacity efficiency will become increasingly important, along with traditional metrics like spectral efficiency, gap to capacity, and peak data rate.[4]

For this reason, the National Spectrum Strategy should be informed by the work that has been done and is currently underway within 3GPP, IEEE, other recognized standards bodies, and Federal Advisory Committees. Standards bodies create the foundation of a transparent competitive ecosystem and provide a continuous technology evolutionary roadmap. The Strategy also should consider the outcomes of work done within the ITU and in countries outside the U.S. While these work efforts may inform NTIA and FCC decision-making, they should not limit

[3] *See, e.g.*, Ericsson Press Release, Ericsson Mobility Report Business Review edition: 5G drives revenue growth (Feb. 7, 2023) *last accessed* Apr. 17, 2023.

[4] *See* Qualcomm-Whitepaper-Vision-market-drivers-and-research-directions-on-the-path-to-6G.pdf

U.S. efforts to open new wireless bands or implement new solutions to increase spectrum access and spectrum utilization.

Spectrum bands currently supporting legacy technologies can be repurposed for newer technologies for federal or non-federal uses, and there is a need to open up bands that permit wider bandwidth operations for 6G and other new technologies. Where 5G supports channel sizes of 100 MHz, and 6G is being designed to support channel sizes of 500 MHz and greater, which means new, wider spectrum bands are needed for 5G and 6G deployments to reach their full potential. For this reason, Qualcomm and others in the wireless industry support identifying spectrum bands for 6G mobile terrestrial uses in the 7.1 to 15.3 GHz frequency range.

2. *Describe why the amount of spectrum now available will be insufficient to deliver current or future services or capabilities of concern to stakeholders. We are particularly interested in any information on the utilization of existing spectrum resources (including in historically underserved or disconnected communities such as rural areas and Tribal lands) or technical specifications for minimum bandwidths for future services or capabilities. As discussed in greater detail in Pillar #3, are there options available for increasing spectrum access in addition to or instead of repurposing spectrum (i.e., improving the technological capabilities of deployed systems, increasing or improving infrastructure build outs)?*

All measures of wireless data demands show extreme growth over the past several decades, and there is no indication this trend will let up. Because there are practical limits to network deployments and there are limits to the capacity of a communications channel in a given band, there is no question additional spectrum bands to support mobile data will be needed well into the future.

There are at least three approaches to increase the data capacity of wireless networks, each of which the wireless industry has been using for many years. *First*, network operators can densify their networks to enable more intensive frequency reuse by adding base stations or access points and by implementing advanced antenna systems. *Second*, operators can deploy a new technology generation, *e.g.*, 4G to 5G or Wi-Fi 6 to Wi-Fi 7, which increases the amount of data that can be carried over the same swath of spectrum. *Third*, they can add new spectrum bands to their network equipment and user devices, which is akin to laying a brand-new data roadway.

While all three of these approaches to increasing the data capacity of wireless networks will continue to be used, data demands still are outstripping the capabilities of existing spectrum bands. Because of this, additional spectrum for commercial wireless services will be needed to satisfy future uses, applications, and services that will be deployed. Every new generation of wireless technology needs new spectrum, and availability of new spectrum will allow the development of the new 6G design. Even though the exact requirements for 6G have not yet been agreed upon, there are indications of what to expect. To achieve those key performance indicates, especially the data rates, large bandwidths (min 500 MHz) will be needed. Such bandwidths are also necessary for high accuracy positioning for sensing applications, another set of applications that will be characteristic of the next generation of wireless technology.

3. *What spectrum bands should be studied for potential repurposing for the services or missions of interest or concern to you over the short, medium, and long term? Why should opening or expanding access to those bands be a national priority. For each band identified, what are some*

anticipated concerns? Are there spectrum access models (e.g., low-power unlicensed, dynamic sharing) that would either expedite the timeline or streamline the process for repurposing the band?

To ensure the U.S. maintains its global leadership in mobile technology, the U.S. should make it a national priority to identify spectrum bands in the 7.125-15.3 GHz frequency range (also referred to as the "upper mid-band") for the next generation of wireless technology: 6G. The next generation of wireless technology is not only a crucial component of connectivity but also of strategic security and economic leadership. The upper mid-band can be the home of new innovative technological solutions (implementing next generation Giga-MIMO technology) that will provide wider coverage using the same network deployment architecture akin to that available in the lower mid-band. As a result, network deployments will be more cost-efficient, allowing for more universal connectivity at affordable prices.

Identifying the upper mid-band spectrum range for 6G is the result of extensive research. It is the natural extension of the lower mid-band allowing for a better future expansion of mobile networks. Its propagation characteristics can be greatly improved with the new advanced antenna technologies currently under development. However, this spectrum range has a diverse set of incumbents with operational parameters that need to be studied for co-existence and compatibility. For this reason, Qualcomm is advancing through the U.S. process a proposal for Agenda Item 10 in WRC-23.

Qualcomm also has a proposal to enable licensed shared operations in the Lower 37 GHz band (37.0-37.6 GHz), as explained in detail below in the response to Question 7. Given that FCC rules require equipment that operates in any portion of the 37.0 to 40.0 MHz UMFUS band to support the Lower 37 GHz band, deployments would quickly follow once the FCC adopts enabling rules.

As an initial step to opening the Lower 37 GHz band for licensed sharing among commercial and federal operations, NTIA and the FCC should work together to enable indoor operations in the Lower 37 GHz band on a licensed-by-rule basis as soon as possible. Such operations can be enabled under the existing UMFUS rules and subject to protection of future shared licensed operations outdoors. Thus, Qualcomm respectfully requests the FCC adopt an NPRM focused on the Lower 37 GHz band proposing to allow indoor operations there as soon as possible and requesting comment on enabling outdoor operations under Qualcomm's shared licensing proposal along with the other proposals for the band in FCC GN Docket No. 14-177.

Finally, last year, the Aspen Institute convened a roundtable on spectrum policy with government and private sector stakeholders to develop an all-of-government national spectrum strategy and a framework for a spectrum action plan. The output of that effort was documented in a report entitled Toward a National Spectrum Strategy, released September 15, 2022, includes a list of spectrum bands to be considered as a spectrum pipeline for expanded terrestrial applications and a list of bands for consideration for expanded satellite uses. Qualcomm stresses the need for additional lower mid-band spectrum for mobile terrestrial service to complement other spectrum holdings for improved provision of services.

4. *What factors should be considered in identifying spectrum for the pipeline? Should the Strategy promote diverse spectrum access opportunities including widespread, intensive, and*

low-cost access to spectrum-based services for consumers? Should the Strategy promote next-generation products and services in historically underserved or disconnected communities such as rural areas and Tribal lands? Should the Strategy prioritize for repurposing spectrum bands that are internationally harmonized and that can lead to economies of scale in network equipment and devices? How should the Strategy balance these goals with factors such as potential transition costs for a given band or the availability of alternative spectrum resources for incumbent users? How should the Strategy balance these goals against critical government missions? How should the Strategy assess efficient spectrum use and the potential for sharing? What is an ideal timeline framework suitable for identifying and repurposing spectrum in order to be responsive to rapid changes in technology, from introduction of a pipeline to actual deployment of systems?

Each of the factors NTIA identifies above in Question 4 should be taken into account when identifying spectrum for the pipeline. At the same time, these factors should not constrain the federal government from enabling innovative spectrum access mechanisms. As NTIA aptly notes, federal government spectrum users and commercial spectrum users will need increased access to spectrum to support "national security, critical infrastructure, transportation, emergency response, public safety, scientific discovery, economic growth, competitive next-generation communications, and diversity, equity, and inclusion."[5]

Each and every spectrum band should be assessed for more intensive spectrum uses. Current incumbent operations should be studied and characterized along these lines: Will the incumbent operations continue to need access to that particular spectrum band? Can they operate in less spectrum (or in a different spectrum band) than what is presently allocated to those operations? Can they be separated from new entrants to the band by geography, space, or time? To the extent the band can support additional operations, what level of protection should be afforded to the incumbents and to the new entrants? Can the new entrants support the same type of operations the incumbent uses in the band or in a different band?

Opening spectrum bands to new users can be a win-win, particularly where the incumbent operations can be improved through sharing spectrum with new entrants who allow the incumbents to take advantage of the newer technologies new entrants will be deploying in the band. This can allow technology advancements to be deployed in existing bands if the incumbent users and new entrants share a common vision of improving spectrum access and spectrum utilization.

5. *Spectrum access underpins cutting-edge technology that serves important national purposes and government missions. Are there changes the government should make to its current spectrum management processes to better promote important national goals in the short, medium, and long term without jeopardizing current government missions?*

It is imperative that the government makes its spectrum management processes more flexible and transparent. As FCC Chairwoman Rosenworcel's Chief Counsel, Umair Javed, noted in his

[5] RFC at 3.

remarks at the March 30, 2023, listening session, "Old solutions cannot solve new problems."[6] Agreeing with that statement, NTIA Administrator Alan Davidson explained: "We must find ways to allow for more intensive use of this finite resource. Technology can also provide better answers: by accessing bands we've never used before; by making more efficient use of current spectrum bands; and by developing exciting new sharing technologies.[7]

Today, there are many technical tools (*e.g.*, synchronized spectrum access, sensing of active receivers, and calculation of interference protection parameters to protect incumbent operations) that can be implemented to protect and expand existing uses and ensure more intensive spectrum utilization by new entrants.

Evaluating spectrum needs and access to spectrum should be done in a coordinated fashion and consider the existing uses and future needs of relevant stakeholders. Government needs to evaluate the existing operations, against potential future uses and ensure improved spectrum access for both existing users and new entrants to the extent that it is possible. And consideration of the national priorities should be front and center.

6. *For purposes of the Strategy, we propose to define "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. To implement the most effective sharing arrangement, in some situations incumbent users may need to vacate, compress or repack some portion of their systems or current use to enable optimum utilization while ensuring no harmful interference is caused among the spectrum users. Is this how spectrum sharing would be defined? If not, please provide a definition or principles that define spectrum sharing. What technologies, innovations or processes are currently available to facilitate spectrum sharing as it should be defined? What additional research and development may be required to advance potential new spectrum sharing models or regimes, who should conduct such research and development, and how should it be funded?*

Qualcomm supports defining "spectrum sharing" as the optimized use of a spectrum band by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic. Further, Qualcomm agrees that to achieve effective sharing arrangements, all potential options should be considered including incumbent users vacating spectrum, compressing, or repacking a portion of their systems to optimize utilization. All these scenarios should be evaluated to ensure that no harmful interference is experienced among the spectrum users.

A foundational element to spectrum sharing is understanding and implementing an appropriate definition of harmful interference applicable to the respective service at issue. For example, the Commission in 6 GHz Report & Order, where unlicensed operations were authorized in spectrum licensed primarily for fixed point-to-point links, specified an interference protection criterion for incumbent fixed links. Yet at the same time, the Commission noted it was "not

[6] *See* Transcript *available at* https://ntia.gov/issues/national-spectrum-strategy/listening-session/march-30.

[7] *See id*.

making a determination that any signal received" at a level in excess of the criterion constitutes harmful interference.[8]

The FCC held that a harmful interference determination is more complex than simply determining whether a given interference protection criterion may be exceeded in certain, often worst-case and sometime rarely occurring, scenarios. While such an approach does offer some estimation of whether harmful interference may occur, other statistical factors need to be considered that may effectively lead to a much lower risk of harmful interference. This includes accounting for the likelihood of co-channel operation on which a victim transceiver is receiving a low-level signal and an interfering transmitter is simultaneously operating nearby and at a sufficient power level to cause harmful interference. Similar real-world interference assessments should be used by NTIA and the FCC as they work together to open up additional spectrum bands for new services and more intensive use.

7. *What are the use cases, benefits, and hinderances of each of the following spectrum access approaches: exclusive-use licensing; predefined sharing (static or predefined sharing of locations, frequency, time); and dynamic sharing (real-time or near real-time access, often with secondary use rights)? Are these approaches mutually exclusive (i.e., under what circumstances could a non-federal, exclusive-use licensee in a band share with government users, from a non-federal user point of view)? Have previous efforts to facilitate sharing, whether statically or dynamically, proven successful in promoting more intensive spectrum use while protecting incumbents? Please provide ideas or techniques for how to identify the potential for and protect against interference that incumbents in adjacent bands may experience when repurposing spectrum.*

Spectrum sharing concepts are best understood and evaluated within the particular details of a given scenario, including the propagation characteristics of the frequency band in question, the technical characteristics of the incumbent services, the intensity of the incumbent operations, and the technical characteristics and operations of the new entrant. Beyond the tried sharing techniques (either static or dynamic) that have been implemented through the years, there are some new technical or regulatory methods that allow for more effective spectrum sharing that should be considered.

For example, through implementing a simple spectrum access rule governing channel occupancy time, it is possible to use time-synchronized access to improve spectrum utilization in unlicensed spectrum bands. Time synchronization enables Coordinated Multi-Point ("CoMP") techniques and other advanced spectrum access techniques to support demanding Industrial IoT applications requiring ultra-low latency, and more reliable connectivity than what can currently be supported in unlicensed bands. *See, e.g.,* Qualcomm March 18, 2020 Ex Parte Letter and March 25, 2020 Ex Parte Letter in FCC ET Docket No. 18-295.

Qualcomm also has been focused on federal/non-federal sharing opportunities in the 37.0-37.6 GHz (the "Lower 37 GHz") millimeter wave ("mmWave") band. Qualcomm has presented to the FCC, NTIA, and DoD a proposal to allocate 100 MHz "primary" licenses to six entities and allow each licensee to access the other 500 MHz on a "secondary" basis.

[8] *See* FCC 20-51 at ¶¶ 130-31.

The proposal relies on: (1) the highly directional nature of mmWave communications, which allows multiple simultaneous overlapping operations in the same geographic area; and (2) uses synchronized silent periods to allow secondary users to listen for and avoid active primary receivers. Extensive simulations in a crowded airport terminal demonstrate secondary access to spectrum beyond the primary licensee's allocations is available most of the time, except when there are two overlapping users where secondary operations will cause harmful interference to the primary licensee.

The diagram below shows how this equipment-based sharing approach works. Where the downlink beams from different operators serving different users overlap, the potential for interference is detected by equipment seeking to operate in another priority licensee's licensed spectrum on a secondary basis. In this case, the secondary operator suspends its use of the secondary channel. When secondary spectrum access is unavailable, the devices continue to operate on their priority licensed channels without interference and with guaranteed quality of service. When the devices move apart so their beams no longer cause harmful interference, operators may resume using the secondary channel to enable increased network throughput through more intensive spatial reuse.

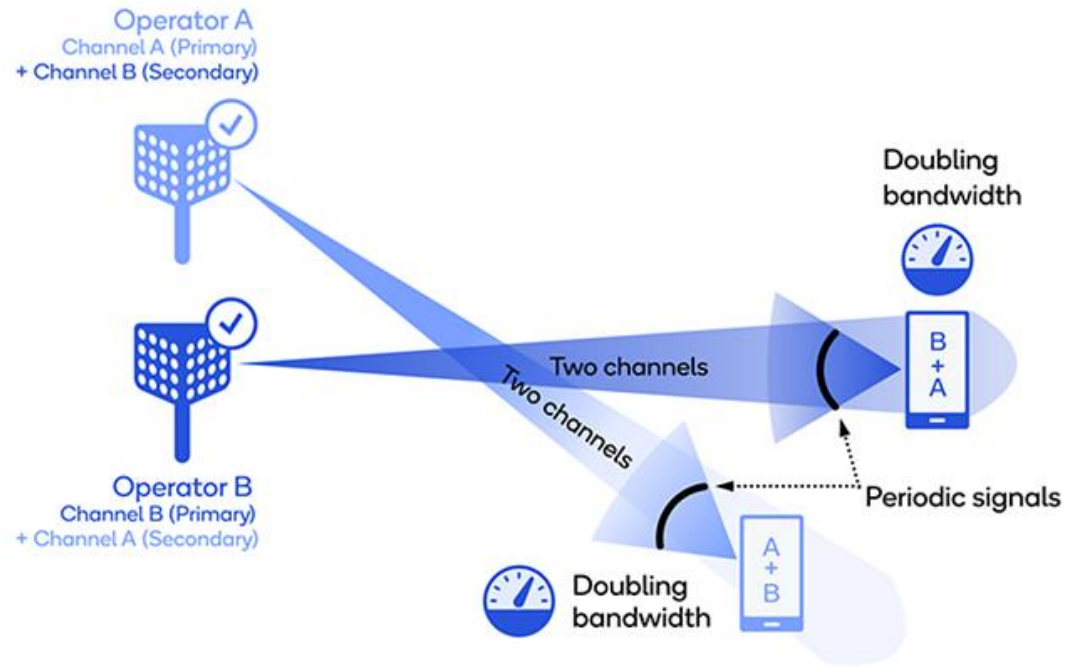


Figure 1. Equipment-based Spectrum Sharing (without any database)

This approach can support a broad range of applications with ultra-high throughput and high reliability that mmWave spectrum bands licensed on an exclusive basis enable today, such as fixed point-to-point and point-to-multipoint links, mobile operations, private networks, device-to-device (peer-to-peer) connections, and mobile hotspots.

This sharing approach can be used by multiple, diverse licensees to provide ultra-high-speed and low latency connectivity for sporting and concert venues, transportation hubs, shopping malls, and urban cores. This approach also can be implemented by municipalities (*e.g.*, for private

networks, public safety communications, and Ultra-HD video and 360-degree security cameras), schools (*e.g.*, for immersive AR/VR/XR learning experiences), businesses (*e.g.*, industrial / manufacturing / warehouse operations), and utility companies (*e.g.*, infrastructure monitoring).

For more information about this spectrum sharing approach, *see* Qualcomm's filing with the FCC, as well as a Qualcomm blog post (both embedded as hyperlinks). NTIA should consider this spectrum sharing approach, for it enables enhanced levels of spectrum utilization and a guaranteed quality of service while minimizing spectrum management overhead and administrative burdens. Importantly, this approach will continue to perform well as spectrum utilization increases over time.

8. *What incentives or policies may encourage or facilitate the pursuit of more robust federal and non-federal spectrum sharing arrangements, including in mid-band and other high priority/demand spectrum? For example, does the current process for reimbursement of relocation or sharing costs adequately incentivize the study or analysis of spectrum frequencies for potential repurposing? Are there market-based, system-performance based or other approaches that would make it easier for federal agencies to share or make spectrum available while maintaining federal missions? At the same time, what mechanisms should be considered to meet some of the current and future federal mission requirements by enabling new spectrum access opportunities in non-federal bands, including on an "as needed" or opportunistic basis?*

The ability to reimburse affected incumbent operations for relocation should remain in the toolkit as it has been successfully used many times in the past. Reimbursing incumbent operations for other costs should be considered as well. For example, incumbent users may be incentivized to relocate or operate using less spectrum if they receive payments beyond their baseline costs for new equipment that operates more efficiently and/or with greater capabilities. Win-win opportunities should be explored as new spectrum technologies and spectrum access tools offer the potential for improved spectrum utilization for all users.

9. *How do allocations and varying spectrum access and governance models in the U.S. compare with actions in other nations, especially those vying to lead in terrestrial and space-based communications and technologies? How should the U.S. think about international harmonization and allocation disparities in developing the National Spectrum Strategy?*

It is preferable to have international spectrum harmonization. Spectrum harmonization allows for economies of scale that in turn translate in lower costs for deployments and for consumer devices using that spectrum. Lower costs directly translate to more consistent adoption of the latest technologies and allow for bridging the digital divide and more ubiquitous connectivity.

However, it is increasingly difficult to achieve full global harmonization. Countries and regions have their own priorities and considerations (like national security, economic policies, etc.) and may diverge. For this reason, in certain circumstances, the U.S. should not be constrained in its work to improve spectrum utilization by the need to achieve harmonization with other countries. U.S. is already a leader in wireless technologies and should continue to open the path for other countries and regions. To the extent the U.S. can lead the way and allow for harmonization, it will allow American companies to continue to innovate and implement wireless technologies globally.

Pillar #2 –Long-Term Spectrum Planning

1. *Who are the groups or categories of affected stakeholders with interests in the development of the National Spectrum Strategy and participating in a long-term spectrum-planning process? How do we best ensure that all stakeholders can participate in a long-term spectrum planning process in order to facilitate transparency to the greatest extent possible, ensure efficient and effective use of the nation's spectrum resources?*

Federal Advisory Committees that work on spectrum issues, such as the FCC's Technical Advisory Council ("TAC") and NTIA's Commerce Spectrum Management Advisory Committee ("CSMAC"), are comprised of representatives from the federal, state, and local governments, commercial entities, and academia with interests in ensuring the efficient and effective use of America's spectrum resources. NTIA can interface with and collect useful information from these representatives via these Committees. In addition, comments provided via this RFC process will provide NTIA with inputs from an even broader cross-section of spectrum stakeholders.

2. *What type of timeline would be defined as a "long-term" process? What are key factors to consider and what are the key inputs to a long-term planning process? What data are required for planning purposes? Do we need data on spectrum utilization by incumbent users, including adjacent band users, and, if so, how should we collect such data and what metrics should we use in assessing utilization? Do we need information from standards-setting bodies and, if so, what information would be helpful and how should we obtain such information? What is the appropriate time horizon for long-term spectrum planning and how often should we revisit or reassess our prior findings and determinations? How do we balance periodic review and reassessment of our spectrum priorities with providing regulatory certainty to protect investment-backed expectations of existing spectrum users? How can federal and non-federal stakeholders best work together?*

Qualcomm firmly believes the National Spectrum Strategy should be a living document that is updated every several years to account for the ever-changing spectrum needs for all spectrum stakeholders. Because of the incessant growth in wireless data demand, mobile network operators will continue to need more spectrum, federal government users will need reliable access to spectrum, and fixed wireless service providers and satellite service providers will need additional spectrum. Maintaining up to date information on spectrum use by all spectrum users will help inform the planning process, which should include near-term, medium-term, and long-term timeframes, and should be adjusted every several years.

Qualcomm recommends that spectrum utilization data on incumbent uses, *i.e.*, the time and location, be collected as it is critically important to assessing the opportunity for more intensive spectrum use. It also is important to determine if new, more spectrally efficient technologies can be deployed to make more intensive use of the spectrum and open up entire bands or portions of them for flexible use services.

3. *How can federal and non-federal stakeholders best engage in productive and ongoing dialogue regarding spectrum allocation and authorization, repurposing, sharing, and coordination? Learning from prior experiences, what can be done to improve federal/non-federal spectrum coordination, compatibility, and interference protection assessments to avoid unnecessary delays resulting from non-consensus?*

To have a productive and ongoing dialogue regarding spectrum allocation and authorization, repurposing, sharing and coordination between federal and non-federal stakeholders, it is essential that there is a common understanding of the spectrum policy priorities. The National Spectrum Strategy can be the vehicle that communicates to all stakeholders those spectrum priorities. When the stakeholders have a common platform from which to discuss their needs and expectations, the discussions can be more fruitful, improving federal/non-federal spectrum coordination, compatibility, and interference protection assessments and avoiding unnecessary delays resulting from non-consensus that inhibit deployments of the latest technologies and impact the economic wellbeing of the country.

In addition, NTIA and the FCC should encourage federal and non-federal stakeholders to engage in deep-dive technical discussions with decision-making personnel inside government agencies and the commercial sector to assess the opportunities relating to spectrum repurposing, sharing, and coordination. U.S. government agency spectrum stakeholders should be given appropriate funding to hire additional spectrum access and radio technology experts and to conduct these open discussions.

4. *What technical and policy-focused activities can the U.S. Government implement that will foster trust among spectrum stakeholders and help drive consensus among all parties regarding spectrum allocation decisions?*

Spectrum stakeholders should have an honest and open discussion and assessment of whether current spectrum users can: (1) operate more efficiently and/or using less spectrum, (2) allow other users to access the spectrum bands in which incumbent operations are occurring without causing harmful interference, and (3) accept a defined level of unwanted signal noise and still operate successfully.

5. *Are additional spectrum-focused engagements beyond those already established today (e.g., FCC's Technical Advisory Committee (TAC),2 NTIA's Commerce Spectrum Management Advisory Committee (CSMAC),3 and NTIA's annual Spectrum Policy Symposium) needed to improve trust, transparency, and communication among the federal government, industry, and other stakeholders (including Tribal Nations) and why? What would be the scope of such engagements, how would they be structured, and why would establishing new engagements be preferable to expanding the use of existing models? If existing models are sufficient, how (if needed) should FCC and NTIA maximize their usefulness or leverage their contributions to enhance and improve coordination?*

The identified federal advisory committees can be supplemented and staffed with appropriate government technical experts to improve coordination and engender trust among the various stakeholders to meaningfully engage in technical discussions that enable more intensive spectrum utilization.

6. *In considering spectrum authorization broadly (i.e., to include both licensed and unlicensed models as well as federal frequency assignments), what approaches (e.g., rationalization of spectrum bands or so-called "neighborhoods") may optimize the effectiveness of U.S. spectrum allocations? Are there any specific spectrum bands or ranges to be looked at that have high potential for expanding and optimizing access? Which, if any, of these spectrum bands or ranges should be prioritized for study and potential repurposing? Conversely, are there any bands or*

ranges that would not be appropriate for access expansion? What, if any, metrics are ideal for measuring the intensity of spectrum utilization by incumbents in candidate bands?

NTIA should closely consider the proposal to open up the Lower 37 GHz band to shared licensed operations between government and private sector spectrum users. This proposal would allow multiple diverse users to access the same spectrum band at the same time and place while ensuring a baseline level of service with a defined Quality of Service ("QoS").

It is not necessary to study the flexible use bands that are allocated on an exclusive basis to the mobile carriers because their networks are being overloaded by mobile data demands and they require additional spectrum now, particularly in bands below 6 GHz, until 6G mobile terrestrial services are deployed in the 7.125 to 15.3 GHz later this decade.

7. *What is needed to develop, strengthen, and diversify the spectrum workforce to ensure an enduring, capable and inclusive workforce to carry out the long-term plans (including specifically in rural and Tribal communities)?*

More funding should be allocated to the FCC and NTIA to attract and hire experienced wireless communications engineers trained in the latest wireless technologies and associated simulation and modeling tools, and who understand how RF interference may occur and be prevented. Each of these wireless communications knowledge areas are essential to assessing the viability of allowing new entrants into existing bands with incumbent federal and non-federal operations.

Pillar #3 – Unprecedented Spectrum Access and Management thru Technology Development

1. *What innovations and next-generation capabilities for spectrum management models (including both licensed and unlicensed) are being explored today and are expected in the future to expand and improve spectrum access (and what are the anticipated timelines for delivery)?*

Qualcomm is one of the leading wireless innovators in spectrum sharing. We have developed many technologies to share spectrum among a variety of wireless systems, and we are continuing to improve spectrum sharing through use of time synchronization, CoMP, and advanced antenna systems that take advantage of the inherent properties of radio propagation in low-, mid-, and high-band spectrum. Some examples of these techniques are described above in our response to Question 7 under Pillar #1.

In addition, 5G Advanced systems will implement dynamic sensing techniques that can sense across large bandwidths, particularly in mmWave spectrum. These techniques can leverage the same hardware for federal purposes to enable sensing across bandwidths on the order of 100's of MHz. Along with integrated AI/ML and advanced high data rate processing, commercial solutions can detect and address concerns with higher accuracy, greater fidelity, and lower latency.

2. *What policies should the National Spectrum Strategy identify to enable development of new and innovative uses of spectrum?*

We are entering a world where spectrum sharing will become more of the norm than the exception as we look to enable more intensive spectrum utilization. The National Spectrum

Policy should encourage the development and implementation of novel sharing means, including those described in these comments.

3. *What role, if any, should the government play in promoting research into, investment in, and development of technological advancements in spectrum management, spectrum-dependent technologies, and infrastructure? What role, if any, should the government play in participating in standards development, supporting the use of network architectures, and promoting tools such as artificial intelligence and machine learning for spectrum coordination or interference protections? What technologies are available to ensure appropriate interference protection for incumbents in adjacent bands? What spectrum management capabilities/tools would enable advanced modeling and more robust and quicker implementation of spectrum sharing that satisfies the needs of non-federal interests while maintaining the spectrum access necessary to satisfy current and future mission requirements and operations of federal entities? How can data-collection capabilities or other resources, such as testbeds, be leveraged (including those on Tribal lands and with Tribal governments)?*

Qualcomm pioneered spectrum technologies in 4G LTE, from demonstrating successful coexistence with Wi-Fi technologies in unlicensed spectrum bands to aggregating licensed with unlicensed spectrum bands to enable mobile operators around the world to support Gigabit connectivity. 5G is designed to be deployed in all types of spectrum—exclusively licensed, shared, and unlicensed. Moreover, 5G standards already include the specifications for a version of 5G that is optimized for shared and unlicensed spectrum—known as 5G NR-U.

Qualcomm is developing new sharing paradigms that involve support of a flexible framework to provide increasingly reliable service. Qualcomm believes coordination among users of shared spectrum bands by using time synchronization among communications nodes provides the foundation for highly useful and robust communications in shared spectrum bands. Time synchronization is used today in many spectrum bands to reduce interference, and 5G can use this synchronization to develop novel and highly effective sharing tools, including:

- Support of guaranteed resources that provide each user with QoS from a guaranteed bandwidth, like what is available from licensed spectrum.
- Support of a sharing framework to cope with more complicated spectrum situations such as mobile incumbent operations, and new sharing rules and deployment models, including "vertical sharing" between operators at different priority levels; and
- Support of advanced techniques such as spatial division multiplexing and CoMP to improve spectrum utilization and support a consistent user experience during higher traffic loads and at the edges of service coverage.

4. *NTIA is pursuing a time-based spectrum sharing solution called the incumbent informing capability (IIC) to support spectrum sharing between federal and non-federal users. What are some recommendations for developing an enduring, scalable mechanism for managing shared spectrum access using the IIC or other similar mechanism, with the goal of increasing the efficiency of spectrum use? What challenges do non-federal users foresee with potentially having limited access to classified or other sensitive data on federal spectrum uses and operations as part of the IIC or similar capabilities, and what recommendations do users have for ways to*

mitigate these challenges? What are the costs and complexities associated with automating information on spectrum use?

A appropriately implemented IIC could be a very important tool to opening additional spectrum bands for non-federal, e.g., commercial, operations. To be most effective, the IIC would need to fairly assess the interference impacts federal systems can withstand, integrate industry-accepted modeling, appropriate technical parameters, to ensure the IIC does not over-protect federal systems. At the same time, upgrading federal systems to newer technologies needs to be considered, particularly if doing so would allow for more intensive spectrum utilization by new entrants.

Federal operations could make greater use of 5G technology. Given the vast number of band and frequency combinations 5G operations use, both base stations and UEs have highly programmable radio subsystems, which include the RF modem, transceiver, RF front end components, and antenna systems. Various spectrum sensing, detect and resolve methods also have been adopted for commercial systems in 3GPP standards.

Qualcomm's RF communications chipsets simultaneously operate in multiple spectrum bands. Mobile carriers use this capability to balance network loading on different bands. It also allows the same chipset to be used to support multiple carrier networks.

From the federal government's perspective, the ability to support multiple bands provides more reliable connectivity and can counter signal jamming. Having devices that can detect and dynamically operate in open spectrum is important to, for example, supporting military training and missions at home and abroad. Multimode radios enable communications that can move to open bands as needed in the foreign locale.

In terms of spectrum sharing paradigms, Qualcomm encourages NTIA to explore simpler spectrum sharing models than the three-tiered model that was applied in the 3.5 GHz CBRS band. Spectrum sharing in the 3.5 GHz band would have resulted in quicker commercial deployments if, instead of two tiers of commercial users, there was a single tier of commercial users who could access to the band so long as priority government operations are protected against harmful interference. Qualcomm supports implementing spectrum sharing approaches that informs commercial users via direct communications – even in band, like the Lower 37 GHz band proposal discussed above – of the time, place, and frequencies used to protect government systems. This approach can be implemented quickly and reliably until more advanced approaches are successfully deployed.

5G Advanced and 6G can drive the convergence of the military's need for cognitive mesh networks and commercial investments in intelligent sensing and communications. Smaller, denser networks of communications and sensor nodes require technologies beyond analog beamforming with integrated Positioning, Navigation, and Timing ("PNT") systems. Multi-hop systems that use sub-6 GHz, mmWave, Terahertz, and other bands, can blend in with encrypted communications in contested environments where no keys are exchanged over-the-air but derived from environmental and channel properties exclusive to the communicating nodes.

5. *What other technologies and methodologies are currently being, or should be, researched and pursued that innovate in real-time dynamic spectrum sharing, particularly technologies that may not rely on databases?*

Please see the above responses.

Implementation Plan

NTIA also seeks comment on the development of an implementation plan for the National Spectrum Strategy, which NTIA plans to release subsequent to publication of the National Spectrum Strategy. Considering all the foregoing, what specific steps should be included in the Implementation Plan that could be taken in the next 12-24 months to ensure the successful execution of the National Spectrum Strategy? Which of the spectrum bands or ranges should be prioritized for in-depth study, for example, and under what timetable should we work toward to repurpose any identified bands? The Implementation Plan will outline specific objectives and the tasks needed to achieve them.

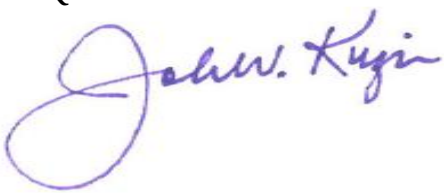
NTIA should develop a framework for implementing the National Spectrum Strategy that allows it to be revised every 2-3 years to account for advances in technology, demonstrated needs to expand spectrum allocations for all types of spectrum users in order to address the most pressing needs for additional spectrum. A major factor to the success of the National Spectrum Strategy is ensuring that the relevant federal agencies with spectrum needs are staffed with technical and engineering expertise to explore and implement new means of spectrum sharing to support the growing spectrum needs for all spectrum stakeholders.

* * *

Qualcomm thanks NTIA for its important work to develop a National Spectrum Strategy. We invite NTIA to contact us if it has any questions regarding the information provided herein or if other questions arise as NTIA develops the critically important National Spectrum Strategy.

Respectfully submitted,

QUALCOMM INCORPORATED



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