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Good morning Chairwoman Cantwell and members of the Committee. Thank you for the opportunity to testify today on the extremely timely and important topic of spectrum policy and technologies and their impact on national security.

Introduction

My name is Monisha Ghosh, and I believe that I can offer a broad and balanced perspective on the matters before this Committee, given my years of experience working in the wireless industry, government research and regulatory organizations, and academia.

To summarize my professional background, I am currently a Professor of Electrical Engineering at the University of Notre Dame. I came to academia in 2015 when I joined the University of Chicago after 24 years working in industry on wireless research and development, at Philips Research, Bell Labs and Interdigital, including contributing to the TV White Spaces (TVWS), an early Dynamic Spectrum Sharing (DSS) effort where we demonstrated the first cognitive radio that operated in the TVWS while protecting incumbents. I took two recent leaves of absence from academia to serve in government: 2017 – 2019, as a Program Manager in the Computer and Network Systems (CNS) division of the Computer and Information Science and Engineering (CISE) directorate at the National Science Foundation (NSF), where I helped manage NSF's research programs in spectrum and wireless and started the first program to study the applications of artificial intelligence (AI) and machine learning (ML) in wireless networks, and January 2020 to June 2021 as the Chief Technology Officer (CTO) at the Federal Communications Commission (FCC), where I worked primarily on helping craft the rules for unlicensed access in the 6 GHz band and a pilot project with the US Postal Service (USPS), as directed by Congress, to examine the feasibility of automatically gathering broadband coverage data using apps on smartphones mounted in postal vehicles[1].

I continue to be actively engaged with both industry and government as an academic. I have co-chaired the FCC's Technological Advisory Council's (TAC) working group on Advanced Spectrum Sharing since

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[1] REPORT TO THE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION OF THE SENATE AND THE COMMITTEE ON ENERGY AND COMMERCE OF THE HOUSE OF REPRESENTATIVES https://www.fcc.gov/sites/default/files/report-congress-usps-broadband-data-collection-feasibility-05242021.pdf

2022, where we deliberate on technologies for advanced spectrum sharing. I am also an active member of industry's NextG Alliance, developing standards for 6G and beyond, and participated in the National Spectrum Consortium's (NSC) Partnering to Advance Trusted and Holistic Spectrum Solutions (PATHSS) Task Group which partnered with the Department of Defense (DoD) to explore efficient sharing solutions in 3.1 – 3.45 GHz.

In addition, I am the Policy Outreach Director for SpectrumX[2], NSF's Center for Spectrum Innovation, led by the Wireless Institute[3] in the College of Engineering at the University of Notre Dame. SpectrumX was initiated in September 2021 with a five-year $25M NSF grant that brings together 56 researchers and staff from 30 universities and a number of Minority Serving Institutions (MSIs) with broad expertise spanning radio technologies, wireless terrestrial and satellite networks, scientific uses of spectrum and economic considerations related to spectrum allocations. A Memorandum of Agreement (MOA) is in place among the NSF, FCC, and the National Telecommunications and Information Administration (NTIA) to ensure that the research undertaken in SpectrumX, and the NSF Spectrum Innovation Initiative more broadly, can directly impact spectrum issues of importance to the nation. In addition to research, major focus areas of the Center are broadening participation in spectrum research and developing a workforce that can continue to expand U.S. leadership in spectrum policy and wireless technologies.
Disclaimer: The opinions expressed in this testimony are my own and do not necessarily reflect the positions of the various organizations with which I am affiliated.

<u>Summary of testimony</u>

I will focus my remarks today on the following three areas:

(1) **Spectrum Policy that enhances U.S National Security**. National security is ensured by leadership in spectrum policy and relevant technologies, not only in the commercial wireless sector but also in science (e.g. weather forecasting and radioastronomy) and mission-critical Federal applications. The spectrum needs of **all** these applications are growing, and the U.S should continue to lead by ensuring that policies and technologies that allow spectrum to be sustainably allocated to all uses are explored: exclusive licensing, shared usage and unlicensed, according to current and future spectrum **needs**, not **wants**. The use-cases that will be deployed should be carefully considered

[2]SpectrumX: https://www.spectrumx.org/
[3] Wireless Institute at Notre Dame: https://wireless.nd.edu/

when spectrum is allocated under different licensing regimes: determining the right mix will deliver the appropriate policy that continues to ensure leadership.

(2) **Dynamic Spectrum Sharing (DSS), or Dynamic Spectrum Access (DSA)** refers to two or more different types of users, e.g. television and unlicensed wireless devices or Federal radar and cellular networks operating over the same frequencies at the same time and in the same geographical area. Usually, a primary user, or incumbent, has priority in the band, unlike unlicensed bands where all users are treated as co-equals. DSS may require systems to share information with each other, employ databases or sensing to ensure that the primary user is protected from harmful interference. It is becoming increasingly clear that DSS will be an integral component of all future systems requiring access to spectrum. This is true in the U.S. and internationally: spectrum is getting congested everywhere in the world since the physics of propagation remains the same. The innovative 3-tier sharing adopted by the U.S. in the Citizens Broadband Radio Service (CBRS) has demonstrated conclusively that spectrum can be shared successfully between mission-critical applications such as Navy radar and commercial applications. The CBRS framework, by making easily available spectrum under GAA (General Authorized Access), has also spurred innovative use cases that are not well served by either Wi-Fi or operator-deployed cellular networks. However, we need to develop sharing technology further to be more scalable and truly dynamic to address the protection needs of different types of incumbents. In addition to creating spectrum policy to support DSS, the next generation of cellular technology, 6G, that is already under discussion worldwide, needs to be "sharing native," i.e., "incorporate spectrum sharing mechanisms by design to coexist with incumbent service providers"[4] as stated by the White House.

(3) **Long term spectrum research and development** is essential for the U.S. to continue leading the world in delivering innovative spectrum policies and technologies. The NTIA recently released the National Spectrum Strategy (NSS)[5] and the Implementation Plan[6], thoughtfully written documents laying out a collaborative agenda that includes industry, government and academia for addressing immediate spectrum challenges as well as developing long-term planning, research and development (R&D), and education and workforce development (EWD). Many of the outcomes

[4] White House Joint Statement Endorsing Principle For 6G: Secure, Open and Resilient by Design, https://www.whitehouse.gov/briefing-room/statements-releases/2024/02/26/joint-statement-endorsing-principles-for-6g-secure-open-and-resilient-by-design/

[5] NTIA National Spectrum Strategy, https://www.ntia.gov/sites/default/files/publications/national_spectrum_strategy_final.pdf

[6] NTIA National Spectrum Strategy Implementation Plan, https://www.ntia.gov/sites/default/files/publications/national-spectrum-strategy-implementation-plan.pdf

listed in the plan detail how the NSF through its spectrum initiatives, including SpectrumX, can address the needs of data collection, experimentation and testbeds, and developing educational activities. In order for such R&D efforts to impact policy in the near term and to be transformative in the long term, adequate funding needs to be prioritized for collaborative efforts between industry, academia and government to continue to grow.

Detailed testimony

(1) **Spectrum Policy that Enhances National Security**

The U.S. has long led the world in innovative spectrum policies from allocating spectrum for unlicensed services in the eighties, to developing auction mechanisms in the nineties and now exploring sharing mechanisms in the new century. These innovations have spurred economic vitality not just in the U.S., but worldwide. Although commercial wireless expansion is extremely important, we also need to ensure that services that are critical to our nation's security continue to have priority access to the spectrum that is indispensable to their operations and mission, such as radars (land, sea and airborne) for defense, weather, and aviation; dedicated terrestrial, ground-to-air, and ground-to-space communication links; position, navigation, and timing systems including GPS; environmental remote sensing satellites; and radio telescopes. Furthermore, commercial wireless use cases are growing beyond conventional mobile broadband and Wi-Fi to include verticals such as factory automation, remote oil-field monitoring, precision agriculture, community networks to serve the underserved and to provide improved indoor coverage; these emerging applications are not well served today by either Wi-Fi or cellular and are increasingly moving to the shared spectrum framework available in the CBRS band for affordable deployments[7].

High-power, exclusively licensed spectrum will continue to be the backbone for delivery of wide-area mobile broadband coverage outdoors, while Wi-Fi will continue to utilize the unlicensed bands for indoor use and short-range outdoor use. However, true sharing, where systems occupy the same spectrum in time and space, is extremely challenging when, for example, megawatt airborne radars and high-power outdoor base stations operating at hundreds of kilowatts need to coexist. On the other hand, sharing may be easier with low/medium power systems deployed indoors or at lower

[7] OnGo Alliance Use Cases for CBRS, https://ongoalliance.org/ongo-solutions/

heights. It is widely recognized that 80% of all data either originates or terminates indoors[8], which further accentuates the need to improve indoor connectivity. Leveraging the natural RF isolation provided by buildings, especially newer energy-efficient buildings with low-E glass, can lead to spectrum sharing where the same spectrum that is used by high-power outdoor incumbents can be reused by indoor systems. This is similar to 6 GHz unlicensed usage in the U.S., but the model can be extended to shared licensed use as well. In fact, the neutral-host model deployed using CBRS indoors accomplishes this today[9] and China, too, has allocated the 3.3 – 3.4 GHz band for shared indoor use[10]. However, as detailed in my comments presented at the NTIA's listening session in April 2023, the amount of shared spectrum available today, 150 MHz, is far lower than the total mid-band spectrum allocated for exclusively licensed use (~ 600 MHz) and unlicensed spectrum (~1900 MHz)[11] and may not be enough to fully support the many innovative use-cases that are being developed. Our European allies have recognized the value of low/medium power shared licensing and are expanding usage by 400 MHz in 3.8 – 4.2 MHz[12]. It should be noted though that these allocations do not leverage DSS, which can further improve spectrum utilization by sharing spectrum with primary as well as secondary users.

(2) **Dynamic Spectrum Sharing (DSS)** needs to consider both co- and adjacent-channel interference concerns of incumbents. There is no one-size-fits all solution to these potential interference scenarios. Sound spectrum policy should be based on fundamental technical analyses, measurements and testing which includes all stakeholders, such as the federal agencies (e.g., FCC and NTIA) and spectrum stakeholders (commercial wireless, DoD, scientists). Most of the current spectrum allocations that share between incumbent services and new entrants (e.g., Television White Spaces (TVWS), 6 GHz and CBRS) employ some variants of a spectrum-use database to assign channels so that the incumbent is protected. These methods rely on predicted propagation and

[8] A 5G America's Whitepaper on Energy Efficiency and Sustainability in Mobile Communications Networks, December 2023, https://www.5gamericas.org/wp-content/uploads/2023/12/Energy-Efficiency-and-Sustainability-in-Mobile-Communications-Networks-WP.pdf
[9] 5 Bars Indoor For Everyone – The Power of CBRS and Neutral Hosts in Wireless Networks, https://ongoalliance.org/5-bars-indoor-for-everyonethe-power-of-cbrs-and-neutral-hosts-in-wireless-networks/
[10] China Issues 5G Spectrum Licenses For Indoor Coverage, February 2020, https://www.gsma.com/futurenetworks/5g/china-issues-5g-spectrum-licences-for-indoor-coverage/
[11] Comments of Professor Ghosh at the NTIA Listening, April 17 2023, https://ntia.gov/sites/default/files/publications/ghosh.pdf
[12] Ofcom, Evolution of the Shared Access Licence Framework, Call For Inputs, https://www.ofcom.org.uk/__data/assets/pdf_file/0032/255965/call-for-inputs-evolution-of-shared-access.pdf

interference based on models, and often do not take into account many of the details of the systems that will coexist in the band. Interference protection contours are thus often set to satisfy worst-case interference scenarios which may have a low probability of occurrence resulting in overprotection and spectrum-underutilization. Database-mediated sharing is a proven technique for a number of frequency bands, but may not be suitable for all situations since this method is inherently less dynamic and does not react in a timely fashion to actual propagation and interference conditions. The FCC TAC in 2022 published a whitepaper on lessons learnt from CBRS[13] that summarizes how future centralized spectrum management systems based on databases could be improved and become more dynamic. The Advanced Spectrum Sharing Working group will continue addressing DSS under the new FCC TAC charter[14].

More advanced technical approaches for DSS can be developed that leverage specific characteristics. For example, modern wireless systems, both cellular and Wi-Fi, use smart antenna array systems that tailor the transmitted energy optimally in 3-dimensional space towards intended users. The same systems could also be adapted to steer energy away from incumbent systems. Such approaches require changes in 6G and beyond standards to be “sharing native”, i.e., designed from the very beginning to operate in shared frequency bands with incumbents instead of solely in licensed or unlicensed bands where deployed systems utilize standards that do not account for incumbent use: an exception is Dynamic Frequency Selection (DFS) in Wi-Fi bands with incumbent Federal radars. Sensing is an integral technology that enables DSS, however, the separate sensing network deployed for CBRS cannot protect incumbents that are geographically more distributed than Navy radars: we need to develop distributed sensing approaches that leverage the dense footprint of base-stations and devices to develop cooperative sensing approaches to detect incumbents. Improved receivers and accurate definitions of “harmful interference” can also lead to better spectrum sharing as described in FCC’s recent policy statement[15].

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[13] Recommendations to the FCC Based on Lessons Learned from CBRS, FCC TAC, December 2022, https://www.fcc.gov/sites/default/files/recommendations_to_the_federal_communications_commission_based_on_lessons_learned_from_cbrs.pdf

[14] FCC 2024-2025 Working Groups Charter, https://www.fcc.gov/sites/default/files/2024%20TAC%20WG%20Charters.pdf

[15] Policy Statement, Promoting Efficient Use of Spectrum through Improved Receiver Interference Immunity Performance, https://docs.fcc.gov/public/attachments/FCC-23-27A1.pdf

(3) **Long term spectrum research and development** is essential for sustained development and testing of DSS approaches in real-world environments to prove their robustness in protecting incumbents in various bands. The 7.125 - 8.4 GHz band has a very different mix of incumbent users compared to 3.1 – 3.45 GHz and may require different approaches. The NSS Implementation Plan lays out very concrete steps to address these issues, but the longest-term deliverable is set for November 2027. DSS R&D efforts will most definitely need to continue beyond this. While the 3.1 – 3.45 GHz has been studied for a few years within PATHSS, the 7.125 – 8.4 GHz band requires in-depth analysis into incumbent use, propagation mechanisms and possible use-cases. I urge this Committee to consider ways that this long-term R&D into DSS can be adequately and sustainably funded in industry, academia and government. Furthermore, as demands on spectrum from all users continue to grow, new bands will need to be continually evaluated for sharing and perhaps new sharing modalities developed.

Concluding Remarks

The U.S. leads the world today in innovations in spectrum policy that have delivered wireless applications that impact all aspects of our life, from broadband connectivity to national security and scientific breakthroughs. This leadership must continue to ensure that all options are evaluated to create a sustainable spectrum strategy for every system that requires access to spectrum. Dynamic Spectrum Sharing is a key technological innovation that was conceived of and first implemented in the U.S.; however, we must continue the innovations to ensure that both policies and technologies lead to the development of a truly sharing-native wireless ecosystem that continues to serve all needs.

I thank you for the opportunity to share my thoughts on this very important topic and welcome any questions.