"5G AND BEYOND: EXPLORING THE NEXT WIRELESS FRONTIER"

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Testimony of
Mary L. Brown
Senior Director
Cisco Systems, Inc.

Thank you, Chairman Doyle, Chairman Pallone, Ranking Member Latta, and Ranking Member McMorris-Rodgers, and members of the subcommittee. My name is Mary L. Brown and I am here to provide you with views from a leading technology vendor, Cisco Systems, Inc., on the future of wireless and the key spectrum policies and government decisions that Cisco believes will continue to advance our economy and access to universal broadband. Thank you for the invitation to testify here today.

Cisco Systems, Inc. is a global provider of IP-based networking equipment, solutions and services based in San Jose, California. As a Fortune 100 company with revenues of $49 billion, our customer base spans enterprise customers of all sizes and types, governments, and service providers. In wireless, Cisco offers Wi-Fi and Private 5G solutions. Our service provider engineering teams build core 5G networking and transport solutions used by operators around the world. Spectrum is vital to all of our customers, and they want the technologies and services to enable them to put spectrum to work.

Summary

This testimony covers three broad areas of interest to this subcommittee. First, I discuss the importance of US leadership in spectrum policy globally, including advanced technologies such as Wi-Fi 6E and 5G, and how that benefits US interests at home and abroad. Second, I want to share with you some thoughts on spectrum coordination across government agencies and suggest ways to improve those discussions in the future. Finally, you are faced with the task of

reauthorizing spectrum auction authority that will expire at the end of the fiscal year. I hope to provide you with arguments about why this important tool must be reauthorized.

Importance of global leadership in spectrum policy

Radio systems are incredibly diverse. There are thousands of types of radio systems in use and more being invented almost every day. It is hard to think of a natural resource that can be exploited to solve so many different challenges, or one where rapid technology advancements continue to support an ever-expanding set of use cases. For commercial radio systems, two radio systems stand out as the most important to the country's economic and broadband policy goals – the unlicensed technology known as Wi-Fi and the licensed mobile technology known as 5G.

Thanks to the leadership from Congress, the United States finds itself in the enviable position of being a technology leader in both unlicensed and licensed technology. Not only does this mean that US consumers get the best and get it first, but companies domestic and foreign see the US as the place where advanced technologies are developed and deployed.

Wi-Fi is a prime example. Federal Communications Commission (FCC) decisions, beginning in the mid-1980s, created the opportunity for a new form of unlicensed radio, known as "spread spectrum," that was increasingly being demanded by American businesses to transmit data. As the market continued to develop in the 1990s, market participants saw the value of open standards and interoperability of these systems – leading to the first Wi-Fi standard in 1997, and to the creation of Wi-Fi Alliance in 1999. And while market participants today are global – about 800 companies are members of the Wi-Fi Alliance – the industry skews to the United States in that many of the most significant players, including Cisco, are US companies.

Wi-Fi has been by any measure an enormous success. The Consumer Technology Association recently estimated that US sales of unlicensed devices (many of which are Wi-Fi) totals $95.8 billion annually.[1] Comcast, in a 2021 report, noted that on its network alone its customers are connecting nearly 1 billion devices, and that 77% of its customers report they will be adding more smart devices this year.[2] Indeed, Deloitte recently noted that sales of Wi-Fi 6 devices will

[1] CTA, Unlicensed Spectrum and the US Economy (2022), available at: https://shop.cta.tech/collections/research/products/unlicensed-spectrum-and-the-us-economy-quantifying-the-market-size-and-diversity-of-unlicensed-devices

[2] Comcast, 2021 Wi-Fi Trends Report, available at: https://corporate.comcast.com/press/releases/comcast-report-xfinity-households-1-billion-devices-wifi-2021.

significantly outpace 5G devices in 2022,[3] with the Wi-Fi Alliance projecting 4.4 billion Wi-Fi devices to be shipped this year.[4] All told, the Wi-Fi Alliance estimates the economic value of Wi-Fi in the United States to be $1.6 trillion by 2025 and globally as high as $4.9 trillion by 2025.[5] It has remained a truism for more than a decade that more than half of the world's Internet traffic begins or ends on Wi-Fi.

Congress' delegated to the FCC the impetus to build on Wi-Fi's runaway success story, when in the 2018 Mobile NOW Act it declared, as matter of federal policy, that for unlicensed spectrum the FCC must

> "…maximize the benefit to the people of the United States of the [unlicensed] spectrum resources of the United States; … advance innovation and investment in wireless broadband services; and … promote spectrum policy that makes available on an unlicensed basis radio frequency bands sufficient to meet consumer demand for unlicensed wireless broadband operations."[6]

When efforts to make unlicensed 5 GHz spectrum contiguous largely came up dry, the FCC in 2018 opened a Notice of Proposed Rulemaking on 6 GHz, culminating in a ground-breaking decision to open the band in 2020. Opening 1200 MHz of spectrum in the 6 GHz band alleviates the congestion increasingly becoming an issue for a technology that had not had any new spectrum since the mid-2000s, over 15 years ago, and before the introduction of the first smartphone. The 6 GHz band enables an entirely new generation of advanced Wi-Fi technologies – today, Wi-Fi 6E and tomorrow, Wi-Fi 7. It is essential for Wi-Fi to stay abreast of evolving broadband capabilities whether that broadband connection is 5G (fixed or mobile), cable, fiber or satellite. Wi-Fi 6E represents a 3-4X improvement in data speeds over Wi-Fi limited to the 2.4 and 5 GHz bands, and equipment now being certified is being advertised with peak data rates of as much as 10 or more gigabits per second. As the broadband connections to which Wi-Fi is attached speed up, as devices themselves consume and use more data, Wi-Fi networks must keep

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[3] Deloitte, TMT Predictions, 2022 at 57, available at: https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions.html

[4] Wi-Fi Alliance, 2022 Wi-Fi Trends, available at: https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-2022-wi-fi-trends.

[5] Wi-Fi Alliance, Global Economic Value of Wi-Fi (2021-2025), available at: https://www.wi-fi.org/download.php?file=/sites/default/files/private/Global_Economic_Value_of_Wi-Fi_2021-2025_202109.pdf

[6] Mobile NOW Act, Section 17 (2018) adopted as part of the Consolidated Appropriations Act of 2018.

up if Wi-Fi is to continue to play its important role in delivering broadband to American consumers. US innovation – such as innovation in virtual and augmented reality devices – depends upon it.

Enterprises, too, reap the benefit. Wi-Fi is the most widely deployed spectrum technology in American business. It is important to understand that for many companies, the bulk of enterprise data traffic may be inside the enterprise only, and may never see the Internet. Nevertheless, that data is critical to enabling American industry to deeply digitize its operations using wireless, providing platforms for business innovation and competitiveness. 5G will soon become part of the enterprise story, and at Cisco, we are looking forward to enabling a convergence of Wi-Fi and 5G for our enterprise customers within their networks.[7]

To add to the innovation curve, the FCC's 2020 decision is enabling for the first time ever, automated spectrum sharing through a mechanism known as Automated Frequency Control (AFC). These database services, informed by the FCC's licensing records, will steer Wi-Fi operations away from frequencies in use by nearby microwave links, and in the process enable Wi-Fi signals to match the strength of Wi-Fi transmitters in the 5 GHz band without causing harmful interference. It is a measure of the enthusiasm for the future of Wi-Fi that 14 applicants filed to become AFC system administrators. Industry is very much looking forward to the FCC moving these applications through a review process this year, so that we can show the world the practical value of spectrum sharing.

Finally, the FCC was the first to open the door to Wi-Fi 6E, but its decision has now been magnified many times over, with regulators around the world moving to open 6 GHz to Wi-Fi and similar radio systems. That is a huge benefit to the US-based Wi-Fi manufacturing sector, and we hope to obtain universal availability of the 6 GHz band.

For 5G, while we are right to be concerned about falling behind, our 5G infrastructure is strong and growing. Key to this endeavor has been the FCC, the National Telecommunications and Information Administration (NTIA) and Department of Defense collective (DoD) willingness to do the hard work of making mid-band spectrum available. Mid-band spectrum is composed of frequencies in the 3 GHz and the 2.5 GHz bands, and is proving to be an essential ingredient for 5G. In fact, the most widely deployed spectrum for 5G in the world is in the 3 GHz band. This enables global economies of scale for the devices that use 3 GHz. As we have seen last year's record-breaking $81 billion auction of 3.7 GHz spectrum, "mid-band" spectrum is highly desirable for 5G networks, and some of the mid-band "have-nots" used that auction to flesh out their spectrum portfolios. In our country, competition for 5G offerings will be robust.

[7] Cisco recently launched a Private 5G solution that can be used by mobile operators to meet the needs of their enterprise customers or by enterprises themselves, using spectrum available to them such as in the Citizens Band Radio Service (CBRS).

With mid-band spectrum, operators can immediately use it to supplement capacity for downlink traffic. Traffic that was carried on low-band frequencies to customers' devices can now be placed on mid-band spectrum if the customer's device is within range. The early deployment pattern is straightforward. To utilize the spectrum for supplemental downlink, 3 GHz transmitters are mounted on existing towers. While the 3 GHz radio waves do not travel as far as radio waves in low band spectrum, they can carry a significant amount of downlink traffic to nearby devices. The more difficult 3 GHz deployment path is network densification – namely, mounting network radios much more closely together. Naturally, this may require many more towers. Network densification does enable more ubiquitous mid-band coverage, at least in dense urban areas. To date, what has been observed among US carriers are different approaches and priorities to network densification.

The question of how much mid-band spectrum is required is an interesting one. The global mobile community called on regulators to provide one gigahertz of mid-band spectrum in 2019. The Global Mobile Operators Association has divided mid-band into "lower" and "upper" segments, with lower segments extending to 1.5 GHz. In the US, the FCC has delivered, or is on track to deliver, about 750 MHz of mid-band spectrum, while discussions continue about possible commercial use in the 3.1 – 3.45 GHz range. We should remind ourselves that as an advanced economy, most of this mid-band spectrum was already in use, and it has been through the substantial and dedicated efforts of those at the FCC, NTIA, and DoD that the US has been able to vault into a global leadership position in mid-band spectrum availability.

Even as the unlicensed community, led by US companies, works to bring Wi-Fi 7 to market in the 2024 timeframe, so too are US interests focused on 6G. The Alliance for Telecommunications Industry Solutions (ATIS), a North American standards organization, has launched the Next G Alliance to focus on 6G. Cisco participates in the Alliance. While 6G will be the product of the global standards community, it is extremely important that the United States develop a consensus vision of what it hopes 6G will uniquely accomplish that is different from 5G. In 2021, the Alliance defined six broad goals for 6G technology, which is the very first and necessary step toward deciding what to standardize. Those goals are (1) trust, security and resilience (2) cost efficiency (3) enhanced digital capabilities for multi-sensory experiences, including human to machine interaction (4) use of artificial intelligence in the network fabric (5) advancements in cloud and network virtualization, and (6) design that addresses energy efficiency.[8] Various working groups operating under the Next G initiative are now discussing the next level of detail in technology, spectrum, applications and more.

[8] NextG Alliance, "Roadmap to 6G," is available here: https://nextgalliance.org/white_papers/roadmap-to-6g/

Cisco has also called upon Congress to support OpenRAN initiatives that would enable 5G (and future "G") operators to pick and choose from among vendors. Cisco is a strong proponent of open standards, and we believe that the mobile industry would benefit from an OpenRAN approach. Technology improves in environments where there is competitive supply. We also believe that opportunities created by OpenRAN could contribute to building US domestic 5G technology supply.

Issues in Spectrum Coordination Across Government Agencies

There is one unfortunate issue upon which we can all agree – we have not found that happy place in spectrum policy decision-making where collaboration reigns over confrontation. The issues cut across several FCC dockets, but I will focus on two. The first involves repurposing federal spectrum to commercial use or sharing federal use with commercial use. The second involves Executive Branch agency constituents, using commercial spectrum, who are unhappy with FCC proposed or decided policies that introduce new sharing requirements or adjacencies.

Trying to make sense of these complex debates is fraught with peril. Government's attention should first be placed on two fundamental truths. One, advanced spectrum sharing technologies and layering different systems into the same spectrum bands are going to be increasingly used tools going forward as demand for spectrum continues to build. Two, regulators will continue to be faced with the prospect of packing more radio systems more tightly together, creating new adjacencies that require careful evaluation of impacts to adjacent incumbent systems, especially receivers. There is no place any longer for wide guard bands between radio systems where spectrum lies fallow.

Fostering a climate of collaboration instead of contention will require some new approaches.

Most fundamentally, Congress should make clear to NTIA and to the Executive Branch generally, that it wants NTIA to be the lead agency on spectrum matters. That includes NTIA being responsive to its sister agencies, and includes those agencies working through NTIA to advance their concerns during the time when the FCC is building its record.

Second, the recently revised FCC/NTIA Memorandum of Understanding (MOU) is an important development that we all should celebrate. The agencies' commitments to following through on regular dialogue and problem solving can be an important mechanism that can help bring certainty to spectrum policy decisions. As part of the NTIA's Commercial Spectrum Management Advisory Committee in its last term, I co-chaired the committee that initially made the proposal for the MOU to be dusted off and modernized. I am delighted that the agencies have now done so.

Government's work should not stop there. One observation from these recent debates, particularly where the dispute involves agency constituents, is that these constituencies are mainly user communities. In other words, they operate systems, and they know a lot about the systems they operate. But they are not researchers or developers, or, for the most part, PhDs in electrical engineering. In the disputes involving user communities, the common refrain is that they do not perceive there is an authoritative neutral voice evaluating the engineering of whatever is being proposed from their perspective. And while they may not be deeply schooled in radio theory, or advanced sharing technology, the absence of a champion within the decision-making process tends to cause these communities to strike a more confrontational pose, and sometimes we see agencies doing so on their behalf.

One policy innovation for Congress to consider is to create that neutral and authoritative voice to enable collaboration. Our country is fortunate to have the NTIA Boulder lab. That is the place that shouldered the work of reviewing advanced sharing technology for the Citizens Band Radio Service. Due to that work, once CBRS finally launched, the Department of Defense did not seek to overturn the FCC rules, and in fact was more in the mode of a collaborator with industry. When tapped to do what it does best, the Boulder lab is one place we can go for ground truth and building engineering consensus. However, Congress must be mindful that the lab needs to be funded to do whatever it is asked to do, and its evaluations should not be used for delay. Many in industry have pointed to the lengthy evaluation of sharing technology in CBRS that contributed to years-long delays in opening that band to commercial service.

Another policy innovation this body could consider is to fund the FCC to hire third party consulting research in the engineering field. The FCC today resolves issues in a quasi-adjudicative mode. Parties bring evidence to them, and the FCC's expert staff work to understand and evaluate that evidence, ultimately providing a recommendation to the Commission on the best resolution for rulemaking or licensing. What the FCC does not do – but other regulators in other countries do – is fund independent engineering research to more fully and impartially develop a record for decision-making. In the US, we have never funded the FCC to do this. In the UK, Ofcom maintains a broad research program in support of its regulatory agenda. This is yet another option to create a more collaborative approach to spectrum problem-solving, as it avoids the FCC having to choose between evidence brought forward by competing and often contentious camps. One pathway toward this idea is simply to ask the FCC what engineering research it would undertake if funded to do so, and why it believes that research would be important.

Some additional, but more technical, matters might benefit from a Congressional nudge, but could potentially decrease contention and enable our country to use spectrum more efficiently. Propagation models predict how radio waves lose energy as they travel through the air, buildings or terrain. The state of our propagation modeling today is an informed best guess usually

derived from International Telecommunications Union group decision-making, with all the attendant compromises that you can imagine would happen in such a setting.[9] This is an area where government could really help industry advance our understanding of when radio wave transmissions will create issues and when they will not. Better modeling will mean government can make better spectrum decisions both for questions around sharing but also around adjacencies. It is not a problem that private sector members can resolve by themselves. Expertise exists at NTIA, the National Institute of Standards and Technology (NIST) and the FCC. Congress should ask these experts what problems should be solved first, and give them the means to move forward.

Finally, there are important sharing scenarios that simply cannot be solved without use of Monte Carlo analysis and modeling. Opening the 6 GHz band to unlicensed use was the most recent example. In that case, Monte Carlo analysis hypothesized "new" transmitters operating in geographic proximity to existing radio systems, and asked if harmful interference from the new transmitters to the old receivers would result. That analysis then informed the creation of mitigation techniques (conditions on operations such as power levels) for the "new" transmitters – enabling more use of spectrum than would otherwise be possible. The FCC needs to build confidence in the use of Monte Carlo analysis – for spectrum stakeholders and for its own decision-making. The Europeans have built a public Monte Carlo tool, and while it may not be perfect, they are refining it. In the US, when Monte Carlo analysis is used, it is based on proprietary models. Naturally, the builders of those models do not warm to the idea of sharing their intellectual property with the world. But these tools – while not necessarily decisional in any particular case – are ones that should be available to the FCC and to the broader community to help inform their understanding and build confidence in decision-making.

Auction authority

In 1993, Congress took a leap of faith, providing for five years of FCC auction authority in the Budget Reconciliation Act of 1993. At the time, the problems of choosing between competing applicants for spectrum licenses had demonstrated that beauty contests and lotteries yielded arbitrary results and resulted in lengthy delays as the private market then reconstructed a semblance of a rationalized spectrum footprint that made economic sense. At the time, no one thought that the FCC's auctions would amount to much – the goal was simply to put spectrum in the hands of those who wanted it most with the hope that networks could be deployed quickly.[10]

[9] The ITU-Radio sector is composed of nearly 200 governments (one country, one vote), and has been estimated to have another 800-900 representatives from the private sector and academia participating in its work programs.

[10] Peter Crampton, "Money Out of Thin Air; the Nationwide Narrowband PCS Auction" Journal of Economics and Management Strategy (1995).

Heads turned when the first auction – for 10 nationwide paging licenses – cleared $617 million. In the nearly 30 years since, Congress has maintained FCC auction authority and has itself been a source of policy innovation. In 2012, for example, Congress authorized the first "incentive" auction – a groundbreaking new form of auction that enabled broadcasters, on a voluntary basis, to be paid to exit needed 700 MHz spectrum, enabled mobile licenses to be created for first-in-the-world 4G networks, and provided an significant down payment on an interoperable new 4G network for First Responders, now known as "FirstNet."[11] This was the first time auctions had been used to incent the exit of incumbents, and provided a much-needed tool to the FCC as it began the tremendously important work of transitioning spectrum allocations from 20th Century technologies to 21st Century technologies. Since then, incentive auctions have successfully been used for millimeter wave spectrum (Auction 103) and most recently, for C-band downlink spectrum at 3.7 – 3.9 GHz (Auction 107). It has been said by others, but is worth repeating – by authorizing incentive auctions, Congress creates a market where none existed before, and where market dynamics can better align spectrum use to meet our national needs.

Many continue to think of auctions as simply a budget reconciliation tool. It is true that over the decades, auctions have amassed over $175 billion, enabling spending on a variety of important public interest programs. However, thinking about auctions narrowly, as the vehicle that puts the cash into the federal budget ATM, misses the mark. Far more important is the economic value and innovation created by the networks that have been built as a result of auctions. Economic value includes not just mobile operator capital investment and job creation – although that amounts to hundreds of billions of dollars and millions of new jobs – but also the spillover effects to GDP growth measuring in the hundreds of billions of dollars.[12] To governments at all levels, that means revenue that over time swamps the dollar amounts received for the sale of the spectrum. Moreover, US innovation is also fueled by efficient spectrum allocation from auctions. Spectrum availability acts like a magnet for network research and development, and translates into a strong hand for US intellectual property.

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[11] In Auction 101, the forward auction generated about $20 billion and the reverse auction paid out $10 billion.

[12] Analysis Group, "The Economic Impact of Allocating Mid-Band Spectrum to 5G in the United States," available at: https://www.analysisgroup.com/globalassets/uploadedfiles/content/news_and_events/news/sosa-rafert-economic-impacts-of-reallocating-mid-band-spectrum-to-5g-1.pdf (400 MHz of 3 GHz mid-band spectrum will yield $154b in capex, $274 billion in additional GDP and 1.3 million new jobs).

Recognizing these links, the FCC on a bipartisan basis and pursuant to Congress' direction has been working fast and furiously on making sure there is spectrum available for 5G networks – allowing carriers to repurpose spectrum holdings for new generations of technology, securing critical 3 GHz "mid-band" spectrum, and opening up "high band" millimeter wave spectrum for innovative new services. These efforts would not have been as swift or as successful without auction authority. The effort continues even today as the FCC works to get a 2.5 GHz auction over the finish line,[13] and in its consideration of other bands such as 3.1-3.45 and 12 GHz.

Moreover, the FCC's auction authority has been put to work to solve other critical problems. While smaller in dollar value, auctions are heavily relied upon to administer broadcaster licenses and provide an efficient mechanism to resolve competing interests. In fact, smaller auctions have been used to distribute license awards in a variety of radio services, from VHF Public Coast stations to Multichannel Video Distribution & Data Services licenses. More significantly, reverse auctions for rural high-cost support mean that the discipline of the auction reveals the least amount of subsidies the FCC needs to dedicate to achieve its universal services objectives. That expertise and capability would not exist but for the auction authority Congress grants to the FCC.

At the level of international leadership, the FCC auctions program has spread around the world as other countries recognized the compelling benefits of assigning spectrum resources via auction. This recognition has sped assignment of spectrum to carriers globally, enabling faster deployments. As a result, not only are the countries of the world and their populations far more connected than at any time in human history, but availability of these technologies globally means US businesses of all types can conduct business at a global scale, whether selling into foreign markets or managing supply chains.

Finally, this topic would not be complete without mentioning that the auction activity Congress enabled provided the trajectory for US economists Paul Milgrom and Robert Wilson to win the Nobel Prize in Economics in 2020 on the strength of their work in spectrum auctions.

And some thought you were simply balancing the federal budget.

The evidence is clear - auction authority has become a key tool in how the FCC conducts it work in a variety of contexts, and pays dividends many times over. Auction authority renewal deserves your consideration this year to provide a predictable path forward for its use.

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[13] Auction of Flexible-Use Licenses in the 2.5 GHz Band for Next-Generation Wireless Services, Further Notice of Proposed Rulemaking, AU Docket No. 20-249 (released February 9, 2022). As of today's hearing date, the FCC is considering comments received on February 23, 2022 on its proposed revised bidding rules.

Conclusion

As we look toward the future, some wonder if the auction "engine" that has served the country so well over the last 30 years will lose its efficacy as fewer spectrum bands become available or as technology changes. These are good questions, and here are a few answers.

First, the 5G and 6G technologies being deployed or that are under development continue to work best in exclusive use spectrum, where one licensee can manage its own network using its own licensed spectrum frequencies. The hunt for spectrum supporting exclusive use is not over, and therefore auctions remain relevant, even if to some degree, spectrum must be shared in some cases.

Second, incentive auctions are a tool to transition from decisions of the past to the needs of the future. Incentive auctions will remain an important tool for some time as older uses wane and new ones are introduced.

Finally, over the 7+ decades left in this century, it might be that wireless technology could evolve to diminish the need for spectrum licenses as we know them today. Future networks might be supplied with spectrum from an intelligent sharing mechanism, eliminating the need for individual licensees to be assigned specific frequencies. At a practical level back here in 2022, what we can say about that future is that if this happens, technology barriers are likely to be less of an issue, while business and economic barriers are going to be more significant. None of it will be easy or quick. It is nevertheless an enticing thought, as such a future state could well represent the pinnacle of efficient spectrum use with attendant benefits that we cannot clearly see today.

For now, continuing governmental policy focus on developing and learning about spectrum sharing technologies, continuing our efforts to better understand issues around band adjacencies, emphasizing collaboration over confrontation, and advancing both unlicensed and licensed radio technology to meet the needs of consumers are the most practical steps we can take toward the future.