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Hearing on

Our Wireless Future: Building A Comprehensive Approach to Spectrum Policy

JULY 16, 2019

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Chairman Doyle, Ranking Member Latta and Members of the Committee:

Thank you for holding this hearing on building a comprehensive approach to spectrum policy. In our increasingly wireless world, using radio frequencies productively is more important than ever.

My name is Joe Kane, and I am a Fellow in Technology and Innovation Policy at the R Street Institute. R Street is a nonprofit, nonpartisan, public policy research organization. Our mission is to engage in policy research and outreach to promote free markets and limited, effective government in many areas, including spectrum policy. I have engaged in significant research on some of the most pressing spectrum issues before the federal government today, including the role of spectrum markets generally and ways to improve secondary markets for spectrum licenses. I have also focused on proceedings regarding particular bands, including the 2.5, 3.5, 3.7–4.2, 5.9, 6 and 24 GHz bands.

My findings from this research are united by one theme: that allowing markets to determine how spectrum is used leads to efficient outcomes that benefit both consumers as well as the entire wireless ecosystem. On the other hand, allowing political favoritism and government mandates to rule in spectrum policy leads to inefficient use of radio frequencies, to the detriment of everyone who relies on wireless services.

The attached appendices contain some of my recent work on spectrum policy that may be useful to the Subcommittee as it seeks to build a comprehensive approach to spectrum policy.

Appendix A provides an overview of the role of markets and spectrum policy, and highlights the ways in which mistaken government policies of the past have led to suboptimal spectrum allocation in the present. Continuing the modern shift to market mechanisms — as opposed to command-and-control regulation — is the best way to remedy these failures.

Appendix B discusses the crucial role of secondary markets for spectrum. Secondary markets allow current licensees to transfer all or part of their license rights to other parties. As in markets for other scarce resources, open exchanges for spectrum operating rights are essential to ensuring that spectrum allocation can keep up with changing economic and technological realities. The piece also suggests specific ways to reduce transaction costs that act as barriers to the proper functioning of secondary markets.

Appendix C discusses the 3.7-4.2 GHz band, which represents the best opportunity to create a large, contiguous swath of midband spectrum for 5G. The critical questions that any policymaker should ask regarding policy governing this band is how much spectrum can be repurposed from satellite downlink to mobile broadband use, and how long it will take to repurpose it. The paper shows why a market-based approach — in which the private holders of licenses to this band are allowed to simply sell their rights to other private parties — fits the bill for these purposes. It also argues that such an approach can be combined with policies that curtail some satellite usage rights and permit more extensive fixed-wireless use of the band.

Appendix D discusses the 24 GHz band, in which unfounded claims of interference with weather satellites in a nearby band threaten to delay 5G deployment. The Committee should ensure that the political machinations of the Executive branch do not impede private development without good cause.

Appendix E discusses the 5.9 GHz band, which has been set aside for automotive safety for 20 years. The piece argues that the lack of deployment of connected-vehicle technologies, combined with developments in unlicensed technologies like Wi-Fi, suggest that automotive-safety should seek to mature in other spectrum bands, and that the 5.9 GHz band should be allocated for unlicensed use.

These documents provide firm grounding for a comprehensive, market-based approach to spectrum policy that will keep up with the changing wireless marketplace, allowing consumers to get the services they need today and entrepreneurs to create the innovations of tomorrow. I thank the Subcommittee for its attention to these issues. If I can be of any assistance to Members of the Subcommittee, please feel free to contact me or my colleagues at the R Street Institute.

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THE ROLE OF MARKETS IN SPECTRUM POLICY

Joe Kane

CONTENTS

INTRODUCTION

Today, almost everyone depends on, or at least uses, a wireless device every day. We use our smartphones to stream videos and text friends, we fly on airplanes that navigate with radar and we look at weather maps constructed by satellites. The future of wireless devices is even more exciting and will include the expansion of the Internet of things, improved telemedicine and increasingly connected cars. But in order to reach the best possible wireless future, we must grapple with the technically difficult, legally complicated and politically contested medium of the electromagnetic spectrum.

Electromagnetic radiation has long been harnessed to engage in communications. Over time, we have increased the efficiency with which we use the spectrum of electromagnetic frequencies and the parts of the spectrum that are usable. The techniques and innovations that make wireless devices work both shape and depend on spectrum policy.

That policy has endured a checkered history—one characterized by invasive government control that is justified by mistaken economic reasoning. As a result, the role for markets has been minimized and this has held spectrum back from its maximum productivity. While the roots of these mistakes have been effectively refuted, their effects still persist in statutes and regulations.

By implementing further market-based reforms, the federal government can greatly increase the productive use of spectrum to the benefit of American consumers and entrepreneurs. To this end, improving the terms of spectrum licenses to incentivize innovation and efficiency, thinking critically about the role for both licensed and unlicensed spectrum and removing government regulation of speech over broadcast spectrum should be priorities for policymakers in every branch of government.

Accordingly, this paper discusses how wireless communication using spectrum works. It then recounts the history of spectrum regulation in the United States and the policy shortcomings that it created. Finally, it suggests a market-based lens through which to view future spectrum reforms and then applies that lens to several current policy issues.

USING SPECTRUM TO COMMUNICATE

The term "spectrum" applies to a range of frequencies of electromagnetic radiation. We interact with the spectrum all the time in the form of visible light, as the different colors our eyes perceive are the result of electromagnetic waves that vibrate at different frequencies and have different wavelengths. We can communicate through visible light, for example, by transmitting different frequencies of light to indicate meaning, as a colored flag would do, or modulating the amplitude or brightness of the light, as when the lights dim in a theater.

Wireless communications apply a similar principle, using waves too long for our eyes to perceive. These "radio waves" are generated and transmitted by sending an electric current through an antenna. These waves can then be received by an antenna at the other end of the transmission. Information is encoded into the wave usually in a pattern that slightly varies its frequency or amplitude.

These wireless signals are sent and received as particular wavelengths, and each wavelength has unique characteristics for how signals travel and propagate. Longer wavelengths, for example, tend to travel farther and are better able to penetrate physical obstacles like walls or trees. Shorter wavelengths reach less far and are often limited by their physical surroundings, but they also have the ability to carry larger quantities of information more quickly than lower bands.

To account for these tradeoffs and other factors, constructing wireless networks requires clever engineering. For example, low band spectrum is necessary for over-the-air television signals that need to get through the walls of your home. But for a Wi-Fi network within your home, higher frequencies that do not propagate as far are necessary in order to limit interference with neighbors' signals. A combination of both low and high band spectrum can provide the coverage and capacity needed to construct a nationwide 5G network.[1]

While the number of electromagnetic frequencies is vast, the amount available for communication cannot, in practice, be divided infinitely because signals that are carried by waves too close together will interfere with one another. This results in messages not getting to their intended destinations. Harmful interference can be mitigated by various methods including technical protocols for how and when different users transmit signals and legal rules governing who can operate radio equipment in a particular way. Technological innovations can allow for more efficient use of spectrum and essentially can create "more" of it by allowing more information to be squeezed into narrower bands.

HISTORY OF SPECTRUM LICENSING

Not long after Marconi and Tesla started experimenting with "wireless telegraphy" in the late 1800s, the United States government took an interest in regulating spectrum use. A review of the history of the government's involvement in spectrum policy reveals a general shift in views, from treating spectrum as a scarce resource that merited substantial intervention in earlier years to a more economically oriented willingness to let markets play a greater role in allocating it.

Major regulatory efforts in the United States began in 1910 when the Department of the Navy alleged that spectrum use was characterized by rampant interference with almost no management over spectrum users or frequencies. At that time, the Navy issued a dire warning to the Senate Commerce Committee with respect to spectrum use: "There exists in many places a state of chaos [...] It is not putting the case too strongly to state that the situation is intolerable, and is continually growing worse."[2]

Congress attempted to remedy this "state of chaos" via the Radio Act of 1912.[3] Though the original impetus of the law was linked to the sinking of the *HMS Titanic*, it is most notable for its requirement that everyone using a radio apparatus do so under the terms of a license acquired from the Department of Commerce.[4] This began the policy of spectrum licensing in the United States that continues to this day.

Several years later, the Radio Act of 1927 moved the licensing authority from the Commerce Department to a newly created Federal Radio Commission (FRC) and provided more detailed rules.[5] The Commission's purpose was:

> to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license.[6]

The FRC was also charged with applying a "public interest" standard to spectrum use:

> If upon examination of any application for a station license [...] the licensing authority shall determine that public interest, convenience, or necessity would be served by the granting thereof, it shall authorize the issuance, renewal, or modification thereof.[7]

Rather than allowing markets to determine its most productive use, this broad government discretion over spectrum was the bedrock of future regulation and legislation until much more recently.

In 1934, President Franklin Roosevelt signed the Communications Act, which replaced the FRC with the Federal Communications Commission (FCC).[8] The Communications

1. Peter Rysavy, "Low Versus High Radio Spectrum," *High Tech Forum*, March 5, 2012. http://hightechforum.org/low-versus-high-radio-spectrum.

2. George von Lengerke Meyer, "House of Representative Report No. 924: Letter to Committee on the Merchant Marine and Fisheries," *Radio Communication*, March 30, 1910, p. 4. https://books.google.com/books?id=RmA3AQAAIAAJ&pg=RA1-PA168&lpg=RA1-PA168&dq#v=onepage&q&f=false.

3. S. 6412, An Act To regulate radio communication, 63rd Congress, 1912. http://legisworks.org/sal/37/stats/STATUTE-37-Pg302b.pdf.

4. Ibid. p. 303.

5. H.R. 9971, An Act For the regulation of radio communications, and for other purposes, 69th Congress, 1927. http://www.legisworks.org/congress/69/publaw-632.pdf.

6. Ibid. p. 1162.

7. Ibid., p. 1167.

8. 47 U.S.C. § 151. https://www.law.cornell.edu/uscode/text/47/151.

Act has been amended several times since then, but it still forms the basic foundation of U.S. communications policy. The FCC continued to perform licensing functions for the use of spectrum in comparative hearings, which became known as the "beauty contests."[9] Would-be licensees submitted applications for the use of certain frequencies, and the Commission would decide who got to use what frequencies and how the awardees could employ their allocations, based on the Commission's determination of whether the applicant would serve the "public interest, convenience, and necessity."[10] The FCC's role, therefore, went far beyond its original intention[11] merely to manage interference, instead literally determining if radio stations could play rock or classical music.[12]

Throughout this period, the rationale for such invasive government involvement was the same as it was in 1910: spectrum is a scarce resource, therefore, the government must control it and ensure that it is used in the "public interest."[13] And, the government leaned on its own discretion rather than on markets to decide how spectrum ought to be used.[14] Accordingly, the winners of "beauty contests" got the right to broadcast without paying for it. The absence of a price system to compare the relative opportunity costs of alternative uses necessarily resulted in spectrum being underutilized and less productive than it otherwise could have been.[15]

Enter Ronald Coase

A landmark shift in the old way of thinking began in 1959 when economist Ronald Coase, who would later win the Nobel Prize in economics, published a paper entitled simply "The Federal Communications Commission."[16] Coase challenged the very foundation of U.S. spectrum policy throughout its history. Spectrum is indeed scarce, he said, but that quality in itself is wholly irrelevant to whether government needs to control it.[17] After all, Coase explained, the whole point of market exchange is to rationally allocate scarce resources.[18] Therefore, as with other economic goods like land and paper, the most efficient way of allocating spectrum was, in Coase's view, to create a market for it rather than to give it away for free at the whims of the FCC.

At the time, Coase's proposal was far outside of mainstream communications policy and the scarcity rationale for government control of spectrum continued to dominate policy for decades. When the FCC had a chance to comment on the possibility of a market for spectrum in 1978, commissioners said that the odds of competitive bidding being implemented or improving upon beauty contests were tantamount to "those on the Easter Bunny in the Preakness."[19] Even if the FCC had been willing to consider a market for spectrum at the time, enabling legislation would be needed, yet Congress gave the idea of auctions an equally icy response. Indeed, some members fought to legislate against any possibility of spectrum markets throughout the 1980s.[20] The reluctance to adopt Coase's argument was doubtlessly fueled by the fact that policymakers (and incumbent licensees) preferred a regime that gave them more discretion over the outcomes. The command-and-control regime was never merely a necessary evil in response to spectrum's scarcity; it was a tool of social policy used to control the content of the airwaves.[21]

Eventually, however, the logic of Coase's argument carried the day. In 1993, Congress passed a law allowing the FCC to distribute licenses through competitive bidding.[22] The agency began conducting spectrum auctions in 1994 and has

9. Jonathan E. Nuechterlein and Philip J. Weiser, *Digital Crossroads: Telecommunications Law and Policy in the Internet Age* (MIT Press, 2013), p. 93. https://books.google.com/books?id=2aN5AAAAQBAJ&.

10. 47 U.S.C. § 309. https://www.law.cornell.edu/uscode/text/47/309.

11. At the outset of the FCC, individual commissioners may not have been intent on adjudicating the content of broadcasts but the lack of a price mechanism made that outcome inevitable as the Commission searched for a non-price rule to evaluate the "public interest." See, e.g., Louis G. Caldwell, "Freedom of Speech and Radio Broadcasting," *The Annals of the American Academy of Political and Social Science* 177 (Jan. 1935), pp. 197-202. https://www.jstor.org/stable/1019983?seq=1#page_scan_tab_contents.

12. *Citizens Comm. to Keep Progressive Rock v. FCC*, 478 F.2d 926, 930 (D.C. Cir. 1973). https://scholar.google.com/scholar_case?case=12200776955555767706&hl=en&as_sdt=6&as_vis=1&oi=scholar.

13. 47 U.S.C. § 303. https://www.law.cornell.edu/uscode/text/47/303.

14. The courts explained that the FCC's authority under the Communications Act is rooted in the scarcity rationale in *NBC v. United States*, 319 U.S. 190 (1943), pp. 216-17. https://scholar.google.com/scholar_case?case=11254761392460211230.

15. For example, the FCC recently proposed to liberalize spectrum that it set aside for educational television in 1963 but that went largely unused: "Two decades later, nearly half of all states had zero ITFS licensees, even though we were essentially giving away licenses for free." *See, Statement of Commissioner Brendan Carr*, In the Matter of Transforming the 2.5 GHz Band, WT Docket No. 18-120, May 10, 2017. https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0510/FCC-18-59A4.pdf. Frequencies in the Ultra High Frequency (UHF) band have also been known to be underutilized for some time. See, e.g., Philip J. Weiser and Dale N. Hatfield, "Policing the Spectrum Commons," *Fordham Law Review* 74:2 (2005), p. 669. https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=4111&context=flr.

16. Ronald H. Coase, "The Federal Communications Commission," *Journal of Law and Economics* 2 (October 1959). https://www-journals-uchicago-edu.mutex.gmu.edu/doi/pdfplus/10.1086/674871.

17. Idid. p. 891.

18. Ibid. p. 894.

19. Glen O. Robinson, "The Federal Communications Commission: An Essay on Regulatory Watchdogs," *Virginia Law Review* 64:2 (March 1978) p. 243. https://www-jstor-org.mutex.gmu.edu/stable/1072617?origin=crossref&seq=1#page_scan_tab_contents.

20. Thomas W. Hazlett et al., "Radio Spectrum and the Disruptive Clarity of Ronald Coase," *Markets, Firms, and Property Rights: A Celebration of the Research of Ronald Coase Conference* (Dec. 2009), pp. 10-11. https://www.chapman.edu/ESI/wp/Porter-Smith-Hazlett-RadioSpectrum.pdf.

21. Brent Skorup and Joseph Kane, "The FCC and Quasi-Common Carriage," *Minnesota Journal of Law, Science & Technology* 18:2 (June 2017), p. 637. https://scholarship.law.umn.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1429&context=mjlst.

22. H.R. 2264, "Omnibus Budget Reconciliation Act of 1993" 103rd Congress. 47 U.S.C 309(j). https://www.law.cornell.edu/uscode/text/47/309.

completed around 100 since then.[23] Policy debates continue about the structure of FCC auctions, but spectrum's scarcity is now generally understood to make it ideal for market allocation rather than making such allocation impossible.[24]

THE USE OF MARKETS IN SPECTRUM POLICY

For decades, legislation and regulation had been based on the scarcity rationale, and that rationale has now been shown to be mistaken. It is true that there were interference problems in the early days of radio communication, but that state of affairs was the result not of private spectrum markets but of their absence. It is easy to see that, without property rights, competing uses for other resources, like land, would result in "interference" that reduces overall productivity. For example, if one person wants to use a piece of land for farming but another wants to use it for an office building, the two aims are obviously incompatible. Yet, they can be kept from "interfering" by defining tradable rights to the land in question.

For these reasons, the government should continue the process of reversing its mistaken rejection of tradable rights in spectrum and view new legal rules governing its use as analogous to those governing the use of land. Whether spectrum is, in fact, analogous to land is a matter of some debate[25] but as a matter of economic incentives, there is much to be said in favor of the comparison. For example, the owner of a piece of land can (among other things), divide it up, transfer it, use it in diverse ways and exclude others from using it. When property rights are assigned to land, the resulting opportunities for profit incentivize the owner to use the land productively. Likewise with spectrum: flexible, durable rights to operate in the spectrum promote productive use.[26]

While there may be divergent value judgements over the best social outcome from spectrum policy, many of them could be better realized through a free market. Insofar as free markets are desirable generally, the overall goal of spectrum policy should be to maximize its productive use. Importantly, this implies that, while mitigating interference is important, the goal is *not* to minimize interference at all costs.[27] Maximizing productivity may mean tolerating some interference or creating rules that are flexible enough to allow creative engineering to resolve problems. The FCC has made significant strides toward a more market-based approach to spectrum, but substantial policy issues remain before the above framework can be fully realized.

POLICY ISSUES

With wireless technologies becoming ubiquitous in more parts of people's everyday lives, spectrum policy has a growing impact on the public and the nation. Accordingly, several key questions that have come to the forefront of recent spectrum policy are outlined below. Each of these requires careful thought and consideration.

Flexible Use

As with any scarce resource with alternative uses, with spectrum, a flexible ability to change how it is used is essential to making it as productive as possible. Given the rapidly changing nature of technology and the economy, the FCC should not be expected to anticipate the best use of a given spectrum band for all time.

The FCC has been moving in the direction of flexible-use licensing, with clear benefits along the way. For example, commercial mobile radio services (CMRS), which include things like cell phones, utilize flexible-use spectrum. While quantifying the benefits of such spectrum is difficult, economist Tom Hazlett has estimated that the consumer surplus[28] from CMRS spectrum was over $81 billion in 2003.[29] Since that estimate predates most of the wireless devices in use today and future demands from ever-expanding connectivity will continue to grow, flexible-use spectrum certainly generates far greater amounts of consumer surplus today. This fact invites the important note that, while FCC spectrum auctions often raise large sums for the U.S. Treasury,[30] the main benefits of getting spectrum into the marketplace come from the uses to which it is put. These gains swamp the sums collected in initial auctions.

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23. "Auctions Summary," Federal Communications Commission. http://wireless.fcc.gov/auctions/default.htm?job=auctions_all.

24. See, e.g., Gregory L. Rosston and Jeffrey S. Steinberg, "Using Market-Based Spectrum Policy to Promote the Public Interest," *Federal Communications Law Journal* 50:1 (1997), p. 92-99. https://www.repository.law.indiana.edu/cgi/viewcontent.cgi?referer=https://scholar.google.com.au/&httpsredir=1&article=1147&context=fclj.

25. See generally Coase, pp. 891, 908-10. https://www-journals-uchicago-edu.mutex.gmu.edu/doi/pdfplus/10.1086/674871; Philip J. Weiser and Dale N. Hadfield, "Spectrum Policy Reform and the Next Frontier of Property Rights," *Colorado Law Legal Studies Research Paper Series* 8:8 (March 19, 2008). https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/6262/spectrum.pdf?sequence=1; Thomas W. Hazlett, "A law and economics approach to spectrum property rights: a response to Weiser and Hatfield [sic]," *George Mason Law Review* 15:4 (2008). https://goo.gl/MNwF1H; Thomas W. Merrill and Henry E. Smith, "Making Coasean Property More Coasean," *Journal of Law and Economics* 54:4 (November 2011). https://goo.gl/hqDFGc; J. Pierre de Vries and Jeffrey Westling, "Not a Scarce Natural Resource: Alternative to Spectrum-Think," Telecommunications Policy Research Conference, Oct. 2, 2017. https://goo.gl/mAgzkj.

26. Coase, pp. 897-98. https://www-journals-uchicago-edu.mutex.gmu.edu/doi/pdfplus/10.1086/674871; Thomas W. Hazlett and Evan T. Leo, "The Case for Liberal Spectrum Licenses: A Technical and Economic Perspective," *George Mason University Law and Economics Research Paper Series* (March 23, 2010), pp. 11-12. https://www.law.gmu.edu/assets/files/publications/working_papers/1019CaseforLiberalSpectrumLicenses20100412.pdf.

27. Coase, pp. 903-04. https://www-journals-uchicago-edu.mutex.gmu.edu/doi/pdfplus/10.1086/674871.

28. I.e. the difference between what consumers would be willing to pay and what they actually pay.

29. Thomas W. Hazlett, "Spectrum Tragedies," *Yale Journal on Regulation* 22:2 (2005), p. 251. https://www.manhattan-institute.org/pdf/cde5-17-04_hazlett.pdf.

30. For example, the 2014 AWS-3 Auction yielded over $44 billion in gross bids. "Auction 97: Advanced Wireless Services," Federal Communications Commission. http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97.

Flexible-use licenses also allow market transactions to assemble contiguous blocks of spectrum for the same use. Such aggregation confers technical advantages, as contiguous channels allow for greater throughput than spreading transmissions over multiple channels. Having to work around bands that are restrictively licensed for different uses or attempting to reshuffle predefined uses through a bureaucratic process is more costly and time consuming than necessary.[31]

One potential shortcoming of this approach is the possibility of holdouts: precisely because contiguous frequencies are known to be complements, one or a few users situated in the middle of a band of frequencies could demand extraordinarily high rates to allow that band to be unified. This could result in a fragmentation that decreases the overall productivity in what is known as the "tragedy of the anticommons."[32] While this is a serious concern for private spectrum markets, two points should be borne in mind. First, one must consider the relevant alternative: The costs from holdouts may still be lower than the deadweight loss caused by the FCC defining the use of contiguous blocks of spectrum by regulation. That is, it is not obvious that the cost of buying out a holdout is higher than that which results from bureaucratic reallocation processes at the FCC.[33] A holdout that can be persuaded to move with enough cash is preferable to one that is unable to move because of regulatory rigidity. Second, the fact that the price of any spectrum license is high does not necessarily indicate a failure of the market. A so-called holdout's willingness to forgo buyout offers is itself an indication of that holdout's high valuation of the spectrum. It is unclear that the government ought to override the licensee's subjective valuation.

License flexibility is now an essential consideration whenever the FCC reevaluates the rules for spectrum bands. Many bands, however, still suffer from underutilization because of restrictions on the services that may be offered within them. Current proceedings on the 2.5,[34] 4.9[35] and 5.9 GHz[36] bands illustrate this fact. The FCC set aside these bands for particular uses that have not come to fruition, leaving the spectrum fallow. For this reason, the FCC has the opportunity to dramatically increase the productivity of those bands by designating them for flexible use. Flexible use is more important than ever in today's rapidly evolving technological landscape. The most productive use of particular frequencies may change rapidly and restrictive regulatory frameworks should not stand in the way of this dynamism.

License Size and Duration

Besides flexible use, other attributes of spectrum licenses can enhance the productive use of radio frequencies. The geographic area covered by a license has significant effects on how spectrum is utilized. Historically, the FCC has carved up the United States in a variety of different ways, including areas as large as the entire country and as small as census blocks. As with assembling contiguous frequencies, the ability of market transactions to efficiently aggregate or disaggregate licenses for particular areas is essential.

While interested parties will insist on their preferred geographic size, these preferences are not always economic necessities. Smaller companies, for example, sometimes fear they will be unable to gain access to larger licenses either in full (from the initial auction) or in part (on the secondary market). But spectrum policy should not bias outcomes in response to the preferences of companies, regardless of size. The goal is productivity and efficiency; and, when a secondary market is in place, the original size of license becomes, in itself, less relevant to that objective.

The real question becomes one of transaction costs. The relative transaction costs of the FCC facilitating more auctions for smaller license areas—compared to those for private companies conducting secondary-market transactions with larger licenses—is not evident *a priori* and will depend upon the economic factors present in the specific case.[37] For example, if a certain frequency is licensed using one size of geographic area, there may be efficiencies to preserve those same geographic areas for adjacent bands. Factors such as

31. See, e.g., the repack following the recent Incentive Auction, in which television spectrum was reallocated to alternative uses in Colin Gibbs, "FCC's repacking effort may far exceed 39 months: Guggenheim," *FierceWireless*, Aug. 25, 2017. https://www.fiercewireless.com/wireless/fcc-s-repacking-plan-may-far-exceed-39-months-guggenheim; and John Eggerton, "FCC Frees Up $742 Million More for Post-Incentive Auction Repack," *Broadcasting & Cable*, April 16, 2018. https://www.broadcastingcable.com/news/fcc-frees-up-742-million-more-for-post-incentive-auction-repack.

32. Michael A. Heller, "The Tragedy of the Anticommons: Property in the Transition from Marx to Markets," *University of Michigan Law School Scholarship Repository* (1998). https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1608&context=articles.

33. See, e.g., analysis of alternative methods considered by the FCC for reallocating the television band in Thomas W. Hazlett, "Reallocation with Hold-ups and Without Nirvana," *George Mason University Law and Economics Research Paper Series* 14:16 (2014). https://goo.gl/TZDEmm.

34. "In the Matter of Transforming the 2.5 GHz Band Notice of Proposed Rulemaking," Federal Communications Commission, WT Docket No. 18-120, April 19, 2018. https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0419/DOC-350331A1.pdf.

35. "In the Matter of Amendment to Part 90 of the Commission's Rules," Federal Communication Commission, WP Docket No. 07-100, March 1, 2018. https://apps.fcc.gov/edocs_public/attachmatch/DOC-349524A1.pdf.

36. Joe Kane, "For connected cars, let the best technology win," *R Street Blog*, Oct. 2, 2017. https://www.rstreet.org/2017/10/02/for-connected-cars-let-the-best-technology-win.

37. See, e.g., Tom Struble and Joe Kane, "Reply Comment of R Street Institute In the Matter of Promoting Investment in the 3550-3700 MHz Band," GN Docket No. 17-258, Jan. 29, 2018, pp. 11-13. https://ecfsapi.fcc.gov/file/10129084413708/3.5%20GHz%20Reply%20Comments.pdf.

population density in a given area will also contribute to whether aggregation or disaggregation are cheaper overall. It may make sense, for example, to ensure that an entire metropolitan area can be covered by a single license at the outset rather than incurring the transaction costs of assembling a contiguous license from small pieces. On the other hand, dense urban areas may provide sufficiently high revenue to overcome these transaction costs. Likewise in rural areas, smaller licenses may be preferable where use cases are more localized, but they also could be susceptible to anticommons tragedies that result from the difficulty in assembling a critical mass of customers in a sparsely populated area. The tradeoffs in each scenario must be evaluated on a case-by-case basis, however, as there is no universally superior license size.

Even more important than license area is license term length. In order for a robust market to efficiently allocate spectrum to productive uses, spectrum licenses must be characterized by terms long enough to justify long-term investments. In this respect, spectrum is, again, akin to land. The degree to which landowners will invest in improving land—and the types of improvements they build—will be skewed if the land were taken and auctioned by the government after only a few years. The reason people invest in long term projects that increase the value and productivity of land is that they expect to benefit from those investments for years to come.

There is good reason, therefore, to think that spectrum licenses ought to be perpetual. Auctions should be used once to get spectrum to market, but after it is in private hands, it is counterproductive for the government to repeat the process. As discussed above, the justification for limited-term licenses in the first place was based on the mistaken scarcity rationale. Licenses of limited duration now only artificially reduce the value of spectrum and distort its uses.

In this respect, the FCC has made less progress. Licenses are still granted for limited terms (albeit with renewal expectancy) and some recent proceedings have seen attempts to create terms as short as three years in order to make the licenses more affordable for smaller bidders.[38] However, this position seeks to substitute the continual FCC auctions—and the transaction costs they entail—for a robust secondary market in perpetual licenses, which could be leased for any period of time. Congress should harness the efficiencies of such markets by enacting legislation that directs the FCC to move toward perpetual licenses. Indeed, it is possible that the FCC will not be needed at all to manage spectrum. Economic history is replete with instances of resource allocation that might conventionally be thought to devolve into chaos but in which private rules and enforcement mechanisms emerge.[39] If applied properly, similar arrangements could prevail. Such creative, long-term solutions for spectrum policy are therefore worth serious consideration.

Government Spectrum

Another barrier to spectrum access is the extensive control of high-quality spectrum by government agencies. For example, more than half of so-called "beachfront"[40] spectrum is allocated to federal use.[41] This spectrum has simply been given to government users without a market mechanism.[42] While government users often perform important functions with their spectrum, the lack of market prices means there is little incentive for the government to economize on its use and no way to calculate whether it could be put to better use by the private sector.

Many government actions have recognized and sought to ameliorate the need for additional spectrum by addressing federal holdings. The Spectrum Pipeline Act of 2015,[43] for example, directed both the FCC and National Telecommunications and Information Administration to identify spectrum that could be cleared and auctioned for commercial use. Another option would be for the FCC to auction overlay licenses that facilitate the ability of private users to buyout government ones.[44]

Government agencies may have legitimate concerns that critical services could suffer if they are deprived of access to spectrum, and, in some cases, sharing with the private sector may be preferable to removing government users. Innovative sharing arrangements, like the pending Citizens' Broadband Radio Service in the 3.5 GHz band,[45] can allow for private use of underused federal bands. More work is needed, however, to implement such efforts and develop new solutions to

38. "In the Matter of Promoting Investment in the 3550-3700 MHz Band," Federal Communications Commission, Notice of Proposed Rulemaking, GN Docket No. 17-258, Oct. 24, 2017, p. 5. https://ecfsapi.fcc.gov/file/1024196454861/FCC-17-134A1.pdf.

39. See, e.g., Edward Peter Stringham, *Private Governance: Creating Order in Economic and Social Life* (Oxford University Press, 2016); Terry L. Anderson and Peter J. Hill, *The Not So Wild, Wild West: Property Rights on the Frontier* (Stanford Economics & Finance, 2004).

40. This is generally considered to be roughly between 200 MHz and 3,7000 MHz.

41. Brent Skorup, "The Importance of Spectrum Access to the Future of Innovation," *Mercatus Center*, December 2016, p. 2. https://www.mercatus.org/system/files/skorup-spectrum-access-future-innovation-mop-v2.pdf.

42. Agencies pay only a small fee that falls far short of the market value of their spectrum. See, e.g., "Spectrum Management: Incentives Opportunities, and Testing Needed to Enhance Spectrum Sharing," Government Accountability Office, November 2012, p. 11. https://www.gao.gov/assets/660/650019.pdf.

43. H.R. 1314 "Bipartisan Budget Act of 2015, Title IX," 114th Congress. https://www.congress.gov/bill/114th-congress/house-bill/1314.

44. See, e.g., Brent Skorup, "Sweeten the Deal: Transfer of Federal Spectrum through Overlay Licenses," *Mercatus Center*, August 2015. https://www.mercatus.org/system/files/Skorup-Spectrum-Overlay-Licenses.pdf.

45. "In the Matter of Promoting Investment in the 3550-3700 MHz Band," Federal Communications Commission, Notice of Proposed Rulemaking, GN Docket No. 17-258, Oct. 24, 2017. https://ecfsapi.fcc.gov/file/1024196454861/FCC-17-134A1.pdf.

ensure that government spectrum is used just as efficiently as spectrum in private hands.

At any rate, getting spectrum into the marketplace is more pressing now than ever. Developments such as the Internet of things and 5G wireless standards will greatly increase the possible applications of wireless technologies, but spectrum availability could be a bottleneck for innovation. So while government uses of spectrum are often important, that importance should be communicated through market prices that reflect its actual scarcity. Policymakers should ensure that outdated rules and free-riding by government are not the source of an artificial shortage.

Licensed vs. Unlicensed

Although it has been heavily influenced by its ambiguous economic and legal history, licensing is the method of management for much of the spectrum. But licensing is not the only way to manage spectrum use. Unlicensed spectrum has been and continues to be used to great effect. The most familiar unlicensed bands are those at 2.4 and 5 GHz, which are used for applications like Wi-Fi and Bluetooth. Operations in these bands have solved the tragedy of the anticommons by using relatively-low power levels and relatively-high frequencies, such that signals are limited in their range. Interference, therefore, is mitigated by the characteristics of the spectrum and the standards in use rather than by granting licenses. But even with these measures, unlicensed spectrum has sometimes become congested in areas where the number and density of users overwhelms even sophisticated traffic management tools.[46]

Additionally, unlicensed users have sometimes tried to have it both ways: seeking the benefits of licensed spectrum without having to pay for them.[47] Such actions are problematic for two reasons. First, the essence of the unlicensed spectrum bargain is that anyone is allowed to access it but they must also accept interference. Unlicensed spectrum should, therefore, be treated as what it is, and those seeking access to more valuable, exclusive rights should expect to pay for them. Second, asking for licensed-like privileges in unlicensed spectrum compromises efficient allocation. When assigning exclusive rights and absent a market mechanism in which competing uses bid against each other, there is no way of knowing whether a given band is more valuable when used for Wi-Fi than for, say, mobile data. However, some unlicensed spectrum can still be compatible within an overall policy of otherwise exclusive rights, just as public parks complement our largely private-property regime for land.

While the lack of a market mechanism in unlicensed spectrum is a significant concern, many believe that new sharing policies combined with innovative technology—such as dynamic frequency sharing through automated databases[48]—can allow unlicensed spectrum to play an increasingly significant role in our wireless future. Moreover, the existence of unlicensed spectrum could incentivize development of more innovative methods of dealing with interference on shared frequencies that could increase the productivity of unlicensed spectrum and also be applied elsewhere. Making unlicensed spectrum an avenue of consistent productivity rather than a giveaway to interest groups is an ongoing challenge. Policymakers should seek to balance the positive incentives created by exclusive licensing with the benefits of unlicensed spectrum, which can complement it.

Free Speech and Content Regulation

One of the most troubling legacies of the federal government's mistaken twentieth-century spectrum policy is the legal ability of the FCC to regulate the content of communications over the electromagnetic spectrum. While this power seems obviously opposed to constitutional protections of free speech and a free press, courts gave it their blessing for reasons firmly rooted in the scarcity rationale.

In the 1943 case of *NBC v. United States*, for example, the Supreme Court recognized that Congress had given the FCC the right to regulate the content of the airwaves and said that such a delegation was permissible because "[t]he facilities of radio are not large enough to accommodate all who wish to use them."[49]

Similarly, in the 1969 case of *Red Lion Broadcasting v. FCC*, the Court found that: "Because of the scarcity of radio frequencies, the Government is permitted to put restraints on licensees in favor of others whose views should be expressed on this unique medium."[50] On this basis, the Court held that the FCC could regulate political speech of broadcasts, despite the fact that the scarcity rationale was shown to be vacuous in 1959.

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46. Terry Ngo, "Why Wi-Fi Stinks—and How to Fix It," IEEE Spectrum, June 28, 2016. https://spectrum.ieee.org/telecom/wireless/why-wifi-stinksand-how-to-fix-it.

47. This happened, for example, when proponents of Wi-Fi fought the introduction of LTE-U, which sought to use unlicensed spectrum to facilitate mobile traffic. Wi-Fi advocates alleged (likely incorrectly) that LTE-U would create interference that would harm Wi-Fi even though unlicensed users are not entitled to interference protection. See Brent Skorup, "Spectrum NIMBYs and the Return of FCC Beauty Contests," *Technology Liberation Front*, July 23, 2015. https://techliberation.com/2015/07/23/spectrum-nimbys-and-the-return-of-fcc-beauty-contests.

48. As in the pending 3.5 GHz proceeding. See "In the Matter of Promoting Investment in the 3550-3700 MHz Band," Federal Communications Commission, Notice of Proposed Rulemaking, GN Docket No. 17-258, Oct. 24, 2017. https://ecfsapi.fcc.gov/file/1024196454861/FCC-17-134A1.pdf.

49. *NBC v. United States*, 319 U.S. 190 (1943), pp. 216-17. https://scholar.google.com/scholar_case?case=11254761392460211230.

50. *Red Lion Broadcasting v. FCC*, 395 U.S. 367 (1969). p. 390. https://scholar.google.com/scholar_case?case=7640733876913500692.

Since these cases were decided, Justices from across the ideological spectrum have questioned their legitimacy.[51] Nevertheless, both sides of the aisle have recently renewed calls for the FCC to exercise its power to censor content.[52] It is time for Congress or the Court to reverse mistaken, outdated precedents and make clear that the First Amendment applies equally to all media.

CONCLUSION

Despite living in an increasingly wireless world, it is easy to forget that the devices and connections we take for granted are limited by spectrum. Getting spectrum policy right is essential to provide the tools for technological innovation throughout the 21st century. Policy mistakes in the past have limited the productivity of spectrum, but it is not too late to reverse them and continue advancing on the path to rational, market-based allocation rather than expansive regulation. The federal government should now seek to foster the market for spectrum. Wireless technological advances in telemedicine, 5G and the Internet of things are on the horizon. Accordingly, we must ensure that spectrum policy is not the limiting factor to this future.

ABOUT THE AUTHOR

Joe Kane is a technology policy fellow with the R Street Institute, where he works primarily on Internet, telecommunications, antitrust and intellectual property issues, arguing for regulatory frameworks that will promote long-term innovation. He previously was a graduate research fellow at Mercatus Center, where he worked with the tech policy team on issues like telecommunications, intellectual property and space policy. Joe has a bachelor's degree in political science from Grove City College and a master's degree in economics from George Mason University.

51. In his concurrence to *FCC v. Fox Television Stations*, Justice Thomas, for example, has argued that even if the scarcity rationale were true, it would not make discriminatory treatment of different media constitutional. He then goes on to say that the scarcity rationale is, in fact, flawed. 129 S.Ct. 1800 (2009), pp. 1820-21. https://scholar.google.com/scholar_case?case=6114044271141802936. Justice Ginsburg expressed a similar opinion regarding the related case of *FCC v. Pacifica* in her concurrence to a second *FCC v. Fox Television Stations* decision. 132 S.Ct. 2307 (2012), p. 2321. https://scholar.google.com/scholar_case?case=9187101700166207966.

52. Joe Kane, "'News Distortion' Is Not Grounds for Violating the First Amendment," Morning Consult, April 19, 2018. https://morningconsult.com/opinions/news-distortion-is-not-grounds-for-violating-the-first-amendment; John Eggerton, "Sen. Manchin Bemoans Demise of Fairness Doctrine," *Broadcasting & Cable*, May 18, 2018. https://www.broadcastingcable.com/news/sen-manchin-bemoans-demise-of-fairness-doctrine.

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HOW TO REDUCE TRANSACTION COSTS IN SPECTRUM MARKETS

By Joe Kane

CONTENTS

INTRODUCTION

All wireless devices rely on access to radio frequencies over which they send and receive data. In the United States, private access to the radio spectrum is controlled by the Federal Communications Commission (FCC), which licenses spectrum users. The FCC is currently moving toward allocating mid- and high-band spectrum that has not yet been a major component of commercial wireless services. As the wireless market grows, the FCC will need to consider how the regulatory regime that governs spectrum licenses may help or hinder the connectivity of tomorrow. And as private companies move into new bands, the FCC must ensure that conditions are ripe for an innovative and dynamic marketplace

One of the most significant barriers to this robust spectrum marketplace of the future is the existence of transaction costs that inhibit the ability of frequencies to be used productively. Accordingly, this paper seeks to evaluate alternative allocation schemes in light of the transaction costs they elicit and suggests concrete policy reforms that would reduce these costs, thereby enhancing the efficiency of markets for the benefit of everyone who uses wireless services.

SECONDARY SPECTRUM MARKETS AND TRANSACTION COSTS

In recent decades, the FCC has rightly begun to shift away from command-and-control regulation and toward facilitating markets for spectrum.[1] This means that the agency often auctions off relatively flexible spectrum licenses. The rights granted by those licenses can sometimes be sold in secondary markets—that is, outside parties can purchase them from the original licensees. Secondary market transactions take place through FCC-mediated auctions[2] and private acquisitions.[3] The second of these two types of secondary markets is the focus of this paper.

To help the FCC facilitate the creation of more efficient secondary markets, this paper examines two potential sources of transaction costs and ways to mitigate them. First, it looks at how the FCC selects the initial sizes and shapes of license areas before they even reach the marketplace, a decision that can have a significant effect on the transaction costs that parties to market transactions encounter downstream. Second, it discusses ways to improve the operational efficiency of the spectrum market once it has been created.

As with any scarce resource, markets are key to allocating spectrum licenses in a way that produces efficient outcomes. But market transactions do not automatically produce such outcomes; rather, efficiency often depends heavily on the

1. See, e.g., Joe Kane, "The Role of Markets in Spectrum Policy," *R Street Policy Study* No. 146, June 2018. https://2o9ub0417chl2lg6m43em6psi2i-wpengine.netdna-ssl.com/wpcontent/uploads/2018/06/Final-No.-146-for-posting.pdf.

2. "Broadcast Incentive Auction and Post-Auction Transition," Federal Communications Commission, May 9, 2017. https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions.

3. See, e.g., Colin Gibbs, "Verizon to acquire Straight Path for $3.1B, ending bidding war with AT&T," FierceWireless, May 11, 2017. https://www.fiercewireless.com/wireless/verizon-to-acquire-straight-path-for-3-1b-ending-bidding-war-at-t.

initial conditions of the market.[4] Since the institutional constraints on these conditions are often synonymous with FCC policy, the agency should approximate initial conditions that will create flexibility and lower transaction costs so that productive outcomes can prevail in the long run.

DEFINING LICENSE AREAS

Currently, each reallocation proceeding at the FCC considers anew how to design license areas for a particular band, resulting in areas of varied sizes and shapes.[5] In the absence of transaction costs, the initial license size and shape would be irrelevant to the outcome; there would be no difference between disaggregating a large license area into smaller ones or aggregating several smaller areas to make the ideal license size and shape for any given application. But transaction costs—in the form of the time, energy and money required to identify a beneficial exchange, negotiate an agreeable price with all the involved parties and reshuffle the rights so that the exchanged resources can be used—are ubiquitous in the real world, meaning that the design of the initial license areas will affect the secondary markets. Therefore, determining the optimal initial allocation of spectrum license areas is vital to long-run productivity.

The size and shape of the geographic areas covered by these licenses is inevitably the subject of much debate. Some, like the five "regional PCS areas,"[6] are gargantuan and few in number, while others, like the individual areas defined by the over 3,000 separate counties, are smaller and more numerous. License areas also come in many shapes, ranging from geometric forms like rectangles to more irregular forms based on geography and population centers. Understandably, various parties try to push the FCC toward selecting the geographic size and shape most suited to their preferred application. The recent Citizens Broadband Radio Service (CBRS) proceeding in the 3.5 GHz band, for example, largely ignited a debate about whether license areas should be defined based on partial economic areas or census tracts.[7] In the end, the FCC went with the compromise of license areas based on counties.

The initial choice of license size and shape presents many tradeoffs, some of which are foreshadowed in literature concerning the initial conditions in markets for land. Today, the government does not generally assign size and shape to plots of land; instead, market transactions allow it to be divided or combined into customized plots for any number of uses. However, the initial conditions governing plots of land can still have lasting effects on the marketplace.

The Case of Georgia

We can get a sense of the manner in which initial conditions of land plots affect outcomes through Hoyt Bleakley's and Joseph Ferrie's analysis of a natural experiment that took place in the U.S. state of Georgia during the early 19th century.[8] At that time, Georgia sought to implement a method of allocating land that limited the ability of individuals to game the system in their favor. The state decided to divide a large area of land into relatively small rectangular plots and distribute these plots via lottery. The land in the lottery zone was, in that way, different from the land just outside of the zone, which consisted of much larger, irregularly shaped plots.

Bleakley and Ferrie examined the outcome of this lottery and the differences that developed between the plots in the lottery zone and those in the neighboring area over time. Ultimately, they concluded that the way this allocation system was implemented was suboptimal because it caused coordination and holdout problems. Since many plot owners would seek to increase the size of their plots, they would look to buy portions of neighboring plots. But the owners of those neighboring plots also wanted to increase their plot sizes. Making one plot larger moved it closer to the optimal size, but it also made neighboring plots smaller in relative terms and thus further from optimal. Therefore, the initial lottery allocation of small, rectangular plots made it unlikely that bilateral deals would take place. Multilateral deals, in which plot owners who surrounded a central plot attempted to divide it up so that all of their plots ended up closer to the optimal size, were even more complicated because of the transaction costs that result from the possibility of holdouts (discussed in more detail below). Overall, then, the small, rectangular nature of the original plots cut against efficient market operation after the lottery. Bleakley and Ferrie observe that land in the lottery area still exhibited the distortions from this initial allocation 150 years later.

Georgia's system did involve some positive elements that contributed to market efficiency. The most useful one for our purposes was the publication of a list of lottery winners to facilitate market transactions by connecting potential buyers with current plot owners. While the list became outdated quickly, it did increase the rate of turnover for the assigned lots. The lessons learned from this aspect of the Georgia land lottery are especially applicable to spectrum markets.

4. Ronald H. Coase, "The Problem of Social Cost," *The Journal of Law and Economics* 3 (October 1960). https://econ.ucsb.edu/~tedb/Courses/UCSBpf/readings/coase.pdf.

5. "Auction Maps," Federal Communications Commission. https://www.fcc.gov/economics-analytics/auctions-division/auctions/auction-maps.

6. "Regional PCS Areas (RPC)," Federal Communications Commission. https://www.fcc.gov/sites/default/files/wireless/auctions/data/maps/rnpcs.pdf.

7. "In the Matter of Promoting Investment in the 3550-3700 MHz Band," Federal Communications Commission, Oct. 23, 2018, ¶¶ 9–41. https://ecfsapi.fcc.gov/file/10242030623468/FCC-18-149A1.pdf.

8. Hoyt Bleakley and Joseph Ferrie, "Land Openings on the Georgia Frontier and the Coase Theorem in the Short- and Long-Run," Working Paper, March 27, 2015. https://economics.sas.upenn.edu/sites/default/files/filevault/event_papers/draft_v2.3.pdf.

Of course, initial allocations of land or spectrum will never be perfect, and the optimal size and shape will change over time. The goal of any allocation policy, therefore, should be to develop initial conditions—i.e., sizes and shapes of the plots of land or license areas—that minimize the transaction costs of future rights-trading so that these rights can be adapted to new economic and technological circumstances.

License Shape

An important consideration in determining license areas is the shape in which to draw the boundaries. Policymakers setting the initial boundaries for plots of land often face this question. As Gary Libecap and Dean Lueck note, there is a tradeoff between setting land boundaries that are easy to draw on paper and those that are most useful in practice.[9] It may be easy for the government to divide land on a map into rectangles, for instance, but in practice, natural topology may lend itself to more irregular shapes. A straight line on a map may end up dividing land on both sides of a winding river or mountain range, whereas a line following the natural features of the land would appear irregular on paper but make more sense on the ground.[10]

Applying this logic to spectrum in our contemporary context leads to a similar conclusion. Moreover, modern surveying methods have reduced the cost of discerning natural landmarks, and the Census Bureau has created well-known and well-defined boundaries based on a combination of natural and political subdivisions (e.g., census tracts, counties, economic areas, etc.). Since these boundaries often correspond to the way population centers have developed, and providing service to areas with customers in them is more important than providing it to all geographic areas, boundaries based on political subdivisions—though irregular on paper—are useful to licensees seeking to provide wireless services to consumers in a given area. Defining license sizes along these boundaries is also a useful way to avoid conflict between overlapping licenses and to minimize the dead space that a licensee does not need. All of these aspects of geographic and politically defined boundaries reduce transaction costs and thus allow secondary markets to work more efficiently.

What's more, all of this is not merely theoretical; the FCC is currently facing the question of license shape in ongoing proceedings, such as the rationalization of the 2.5 GHz band.[11] In this band, the license areas are defined as circles with a 35-mile radius centered on a transmission station. This makes a certain sense because radio frequencies propagate in all directions, forming circular license areas. But these areas sometimes overlap, creating interference disputes. This has resulted in FCC proceedings that "split the football"—that is, they divide two licenses along a line drawn between the two points at which the conflicting licenses intersect.[12] This blunt policymaking instrument detracts from licensees' flexibility to determine areas to serve based on where the customers are and to make deals to decide how much interference each party will accept in a given area.

License Size

Economic literature commonly finds that, in the context of land, the relationship between plot size and plot price increases at a decreasing rate.[13] In other words, large plots of land are generally more valuable than smaller ones, but only to a point. Intuitively, this is clear from the fact that it is not profitable for one person to buy all the land in the world. The economic reasons for this again come down to transaction costs, which make it difficult to assemble various plots of land, as well as the prevalence of substitutable plots and the fact that the quality of the marginal unit of land decreases over time.

Michael Heller observed problems with rights being too numerous or fragmented in post-Soviet real estate markets.[14] Those conditions are analogous to the problems presented by very small spectrum licenses. In both cases, the costs associated with making a deal with a large number of interested parties can become prohibitive. And even if almost all rights-holders agree to sell their rights, the ability of one or a few parties to hold out for extraordinarily high prices is a serious concern.

The holdout problem can be seen in a simple example. Suppose an entrepreneur has a business plan that requires assembling 100 separately owned spectrum licenses in a certain area to make a profit of $1,000. The entrepreneur will pay up to $1,000 to get those licenses. Suppose that

9. Gary D. Libecap and Dean Lueck, "The Demarcation of Land and the Role of Coordinating Property Institutions," *Journal of Political Economy* 119:3 (June 2011). https://economics.yale.edu/sites/default/files/files/Workshops-Seminars/Economic-History/libecap-120416_2.pdf.

10. Libecap and Lueck, however, found that land allocation in the 18th-century United States was better served by the certainty of geometrically defined plots that could be objectively marked on maps. While topographically defined plots offer greater flexibility, they argue that this benefit was offset by the difficulty of permanently defining rights based on terrain. Ibid., pp. 455–61. https://economics.yale.edu/sites/default/files/files/Workshops-Seminars/Economic-History/libecap-120416_2.pdf.

11. "In the Matter of Transforming the 2.5 GHz Band," Federal Communications Commission, May 10, 2018, pp. 11–19. https://ecfsapi.fcc.gov/file/0510125420096/FCC-18-59A1.pdf.

12. Ibid., p. 3

13. See, e.g., Peter F. Colwell and C.F. Sirmans, "A Comment on Zoning, Returns to Scale, and the Value of Undeveloped Land," *The Review of Economics and Statistics* 75:4 (November 1993). https://www.jstor.org/stable/2110041?seq=1#page_scan_tab_contents; and Tzu-Chin Lin and Alan W. Evans, "The Relationship between the Price of Land and Size of Plot When Plots Are Small," *Land Economics* 76:3 (August 2000). https://www.jstor.org/stable/3147036?seq=1#page_scan_tab_contents.

14. Michael A. Heller, "The Tragedy of the Anticommons: Property in the Transition from Marx to Markets," *Harvard Law Review* 111:3 (1998). https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1608&context=articles.

the incumbent licensees only value their own licenses at $5 each. If the entrepreneur offers each of them $6, everyone wins. But if all but one incumbent accepts the $6, and the entrepreneur spends $594 to acquire those licenses, the last incumbent could demand up to $406 and the entrepreneur's project would still be profitable. While it would be in the entrepreneur's interest to pay the $406, that last incumbent could always demand more. It only takes a few incumbents demanding more than the marginal value of their licenses before the project is no longer profitable. And, in that case, the reallocation never happens; the project never takes place.

In short, licenses that start out too small can result in too many owners of exclusive rights and lead to an anticommons tragedy in which gridlock keeps the market from functioning.[15] In these cases, the transaction costs of negotiating with every rights-holder are simply too high for the deal to be worthwhile to anyone.

Compared to land, spectrum presents an even greater concern. Radio waves cannot be forced to respect imaginary lines on a map, so there will necessarily be either interference or diminished signal strength near the boundaries of license areas. Smaller, more numerous licenses mean more boundaries between license areas. Therefore, not only do small license areas raise transaction costs, they also degrade the overall productive potential of spectrum.

Nevertheless, small spectrum licenses have been proposed in various circumstances, often with the justification that they would allow the market to run its course more easily. Australia, for instance, proposed creating tiny "postage stamp" license areas.[16] And in a CBRS proceeding in the United States, several parties sought to designate the license sizes as census tracts, close the smallest geographic area available.[17] Such plans would have been deleterious to a productive outcome by creating hundreds of thousands of boundaries on which the aforementioned downsides would occur.[18] They would also fail to generate the benefits of personalized licenses in individual venues, like hotels or factories, touted by supporters of census-tract licenses, because the license areas would still be too big to cover a single business. In contrast, larger licenses that can be disaggregated easily would allow a venue to purchase a license that is exactly the size and shape it needs.

15. Ibid, p. 624

16. Lawrence M. Ausubel and Paul R. Milgrom, "Ascending Auctions with Package Bidding," *Frontiers of Theoretical Economics* 1:1 (2002), p.4. https://cowles.yale.edu/sites/default/files/files/koopmans/milgrom1.pdf.

17. "In the Matter of Promoting Investment in the 3550-3700 MHz Band," ¶ 11. https://ecfsapi.fcc.gov/file/10242030623468/FCC-18-149A1.pdf.

18. "Reply Comments of R Street Institute to the Federal Communications Commission," GN Docket No. 17-258, Jan. 29, 2018. https://2o9ub0417chl2lg6m43em6psi2i-wpengine.netdna-ssl.com/wp-content/uploads/2018/04/3.5-GHz-Reply-Comments-1.pdf.

While both of these plans were later abandoned, they illustrate that misunderstandings of the problem of anticommons tragedies is still prevalent in the spectrum policymaking world.

POLICY RECOMMENDATIONS

Draw Large Licenses that Track Preexisting Boundaries

Applying the insights from land markets to spectrum yields some promising policy recommendations for the initial allocation of license areas. As the Georgia land lottery and post-Soviet real estate examples illustrate, a good starting point for the FCC in designing license size and shape would be to draw boundaries based on partial economic areas. These licenses would cover relatively large areas with boundaries that conform to pre-existing political and population-based subdivisions. The FCC should also try to follow naturally occurring boundaries—including those of population centers and topography—rather than arbitrary geometry when designing license areas. In fact, the FCC has already proposed switching from circular license areas to those based on ready-made boundaries grounded in geography and population, like collections of census tracts or counties.[19] This arrangement would better fit the conditions on the ground and enhance the productivity of the bands.

Once these boundaries have been designated, the spectrum market would benefit from the FCC taking a hands-off approach and allowing market actors to freely customize license shapes and sizes. As is the case with the government vis-à-vis land sales, the FCC should have little influence over the geographic area covered by a license purchased on the secondary market or the contracts dividing or combining licenses to create efficiently sized areas. Since working through the complicated FCC database raises the cost of participating in secondary market transactions, the FCC should also take note of the relative success of the Georgia land lottery's publication of winners and seek to make matching potential buyers and sellers as easy as possible.

Common Ownership Self-Assessed Tax

Specifying the right geographic sizes and shapes for initial spectrum licenses is only the start of improving the functioning of the spectrum market; the real benefits come from a robust, ongoing secondary market. Just as it would be wasteful for the government to continuously seize and re-auction land after its initial allocation, rights to use radio frequencies should be bought and sold on the market without FCC interference. This means that FCC auctions should be one-time

19. Ibid., p. 7.

affairs that get bands into the marketplace, and the licenses at auction should be flexible and perpetual in duration.

Perpetual licenses do not necessarily mean that the current license-holders will dominate the market forever. Rather, they mean that licensees will be able to divide up and sell all or some of their rights over time as different use cases become more or less productive. Licensees will also bear the opportunity cost of not engaging in such transactions.

But, as we have seen, market transactions are subject to costs and, as with license shape and size, the institutional structure of secondary spectrum markets will affect the outcome. The FCC's current spectrum regime is often characterized by inflexible licenses that require cumbersome administrative procedures to repurpose. Even when licenses are flexible enough for secondary markets to work, bureaucratic barriers can make matching willing buyers and sellers difficult.

Some ways to lower transaction costs, and thus increase the viability and efficiency of spectrum markets, include lowering the barriers to locating a willing seller, determining a mutually agreeable price and closing the transaction with the FCC's blessing. Economists Paul Milgrom, Glen Weyl and Lee Zhang have proposed a novel approach to doing so: They suggest that every licensee should be granted a perpetual right over his spectrum and given a great deal of flexibility and discretion over exactly how his rights are defined.[20] However they choose to define those rights, licensees must then publicly assign them a dollar valuation. The licensee is then compelled to sell the rights to anyone who offers that amount.

Licensees may of course seek to deter potential buyers by setting a very high price on their licenses, but under this proposal, they are disciplined by a small tax on the self-assessed valuation. So if a licensee sets the price too high to avoid a sale, he ends up paying more in taxes than he would like. If he sets it too low to avoid the tax, he risks a buyer snapping up the spectrum at the cheap price. The dominant strategy, therefore, is for the licensee to accurately report his valuation of the spectrum. In later work with Eric Posner, Weyl has dubbed this system "common ownership, self-assessed tax (COST)."[21]

While gaining insight into how much spectrum users value their rights is helpful, the main benefit of this system would be to enable secondary markets to operate with much lower transaction costs than they presently do. Currently, it is quite difficult to identify which spectrum bands might be good candidates for reallocation to different uses. Often, a months- or years-long FCC proceeding is needed to legally permit spectrum licenses to change hands. Even when secondary-market transactions are allowed, it is cumbersome to work out the details of a contract and conduct rounds of negotiations. All of these transaction costs add up, ultimately reducing the number of exchanges that can be profitably carried out within spectrum markets. The result is that spectrum gets stuck in unproductive configurations, to the detriment of all parties.

The COST proposal would import and improve on the publication of the winners of the Georgia land lottery by making clear offers for spectrum rights sales publically available at all times, thus dramatically reducing transaction costs associated with locating and negotiating with incumbents. Rather than having to hire lawyers, contact the licensee and file with the FCC, someone who wants to buy spectrum in a particular area or frequency band could simply look up the price for rights to that spectrum, decide if they are willing to pay that price and then acquire the rights by paying the price.

Some may object to this plan by claiming that it creates too much uncertainty for incumbent licensees, but the self-tax mechanism actually navigates this problem quite well. Incumbents can always insulate themselves from losing their current rights by reporting a higher value for it. Though by doing so, they will incur a higher tax burden, if the existing use is in fact the most valuable, then paying an additional fee is worthwhile. And, if an incumbent cannot profitably sustain the higher valuation of his spectrum without it being bought and repurposed, then allowing spectrum to remain in that unproductive use imposes a cost to the market as a whole. If another company is willing to pay more (including the sale price and the fee paid on the later valuation) for a given band, then allowing that company to control that band enhances the overall efficiency of spectrum. After all, the aim of spectrum policy ought not to be protecting the private interests of any one party; it should be to facilitate a market in which parties can compete.

One could also conceive of the COST mechanism being used in other applications within spectrum policy. For example, licensees could be made to publish the amount of out-of-band interference their operations can handle and pay a tax on the inverse of this amount (i.e., accepting more interference would mean a lower tax burden). Such a system would incentivize innovation in filtering technology, which would create more fault-tolerant systems and allow more intensive use of each band.

There may be some concern about more ambitious proposals to extend the COST system to the whole economy in a way that would undermine property rights as we know them. But regardless of the merits of that claim, the case of spectrum

20. Paul Milgrom et al., "Redesigning Spectrum Licenses," *Regulation*, Fall 2017. https://object.cato.org/sites/cato.org/files/serials/files/regulation/2017/9/regulation-v40n3-3.pdf.

21. E. Glen Weyl and Eric Posner, *Radical Markets* (Princeton University Press, 2018), p. 61.

does not seem susceptible to it. Spectrum is not a traditional good over which traditional property rights exist. This is partly because of twentieth-century overregulation, but it is also inherent in the nature of spectrum itself. There is considerable debate over whether spectrum is a "thing" that one can own, and the balance of the evidence suggests that it is not.[22] Rather, no one really owns spectrum per se; instead, a licensee simply owns the right to operate radio equipment in certain areas in certain ways. Compared to historical allocation of spectrum and given the nature of spectrum itself, it would not be excessively radical to apply a COST system to it.

Potential Drawbacks

Since this system has never been implemented in practice, there could be unintended consequences. We would largely have to wait and see how players in the market react to a changed incentive structure. For example, investment could be skewed toward improvements to a band that are less visible to outside observers, thus increasing the private value of the spectrum without commensurately increasing its public value or, in turn, its tax burden.

The implementation of the COST mechanism should therefore be evaluated in comparison to other potential reforms to secondary markets. Making all licenses maximally flexible; creating an updated, easy-to-use computer system for use by buyers and sellers; and allowing private sales without FCC interference are all other potential reforms that Congress and the FCC could implement. These reforms would provide many of the same benefits as the COST mechanism.

We must also consider that the reason the above reforms have not been implemented is largely the result of the political machinations of the FCC operating within the agency's current statutory framework. Changes to the status quo will be shaped by the legal requirements and rent-seeking efforts of private interests, meaning that the ideal version of any reform is unlikely to be obtained. We must therefore evaluate reform efforts by what they would be likely to achieve rather than what we would like them to achieve.[23]

The COST system would certainly be a departure from the types of spectrum regulation the FCC has undertaken in the past, but in any event, experimentation to facilitate a more efficient and dynamic secondary market should be a priority for the agency.

CONCLUSION

The current market for rights to radio frequencies is far from ideal. There are numerous sources of transaction costs that reduce the ability of buyers and sellers to conclude deals that will benefit consumers of wireless services. Given its role as a spectrum regulator, the FCC has the power to set initial conditions of spectrum licenses that it auctions. Markets for these licenses would work more efficiently if their starting size is relatively large and their borders track preexisting natural and population-based boundaries. The FCC and Congress should also work together to experiment with innovative market designs, such as the COST mechanism, that have the potential to dramatically reduce transaction costs.

Wireless applications are becoming increasingly prevalent in the world economy, and the United States needs a spectrum market that can adapt nimbly and provide the dynamism the wireless future requires. Accordingly, the FCC should use its regulating authority to foster this kind of market.

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22. Kane, p.4. https://2o9ub0417chl2lg6m43em6psi2i-wpengine.netdna-ssl.com/wpcontent/uploads/2018/06/Final-No.-146-for-posting.pdf.

23. See, e.g., Harold Demsetz, "Information and Efficiency: Another Viewpoint," *Journal of Law and Economics* 12:1 (April 1969). https://www.journals.uchicago.edu/doi/10.1086/466657.

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THE FCC'S 3.7–4.2 GHZ SPECTRUM BAND PROCEEDING: KEY FACTS AND ANALYSIS

Joe Kane

CONTENTS

INTRODUCTION

The Federal Communications Commission is considering proposals to expand flexible use of the 3.7–4.2 GHz spectrum band,[1] initiating debate about how this band should be used. Accordingly, the present study seeks to explain why the band is important, discuss why its allocation has become a matter of debate and evaluate proposals for its better allocation.

Briefly, the 3.7–4.2 GHz, a subset of the "C" band, is an excellent range of spectrum for a variety of communications services, such as cell phones or fixed-wireless broadband Internet access. Currently, however, it cannot be used for those services because it is mostly allocated to satellite operations, such as carrying television content. Despite the fact that not every frequency is being received in every area all the time, the band is allocated to satellite operators in such a way as it cannot be subdivided. More extensive use of the band should be possible, but allowing others to use it could result in harmful interference with existing satellite operators. To solve such problems of competing interests, various proposals have been suggested to allow for sharing or reallocation of the band.

As explained in a prior study on spectrum policy, economic analysis is especially effective for understanding spectrum allocation because spectrum rights behave similarly to property rights.[2] Accordingly, this paper applies an economic framework to proposals for sharing of the C-band to identify the benefits and drawbacks of each.

BACKGROUND

The portion of the spectrum in question is the 3.7–4.2 GHz band, which is attractive for a variety of uses and for a number of reasons. First, at 500 MHz wide, it is one of the largest contiguous blocks of spectrum in the country. Contiguous frequencies are beneficial because they allow for the operation of bandwidth-intensive services that are increasingly prevalent in the wireless economy. Second, the frequency range is well suited to modern communications uses. Lower frequencies were traditionally considered "beachfront" in the past because they could travel farther and better penetrate walls, but higher-frequency spectrum is necessary for future dense networks that will send larger amounts of data over shorter distances. 3.7-4.2 GHz is mid-band spectrum

1. "In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band," Federal Communications Commission, GN Docket No. 18-122, July 12, 2018. https://ecfsapi.fcc.gov/file/07131575002139/FCC-18-91A1.pdf.

2. Joe Kane, "The Role of Markets in Spectrum Policy," *R Street Policy Study* No. 146, June 2018. https://2o9ub0417chl2lg6m43em6psi2i-wpengine.netdna-ssl.com/wp-content/uploads/2018/06/Final-No.-146-for-posting.pdf.

and has some properties of both high and low frequencies. As such, it is attractive to companies like mobile carriers and fixed-wireless broadband providers who would like to have wide channels of mid-band spectrum to provide consumers with fast, reliable service and to upgrade to 5G networks.

Current Allocation

In order to get access to the spectrum, potential new users must deal with incumbents who are already using it. The current users of the 3.7–4.2 GHz band are mostly satellite downlink providers, that is, they send content—generally TV and radio signals—from space to earth. These signals arrive at satellites from places such as a distant studio or a live sporting event. The content is then received back on Earth by cable television "head-ends" or central locations where it is gathered before being sent out to customers.[3]

Changes in the wireless ecosystem, however, make it likely that this spectrum is not currently allocated productively and at least some portion of it would be better used for increased fixed-wireless broadband or mobile service. This is because traditional modes of television viewership are being replaced with over-the-top distribution channels or consumers are switching away from traditional TV altogether. Either way, that video market is converging to IP-based distribution is increasingly the reality in the video market and this likely impacts the optimal allocation of spectrum rights.

Normally, markets for flexible rights in this band could remedy any misallocation relatively easily. For example, businesses that want to use the band for something new could approach the current users and offer to buy access. Such deals would be beneficial to both parties and would likely increase the productivity of the frequencies in question: If the incumbent accepts the offer, this would indicate that the new user expects to make greater profit than the old user. This entails offering consumers services they prefer at lower prices.

However, this band is currently managed in a manner that makes reallocation to efficient uses particularly difficult. Ranges of frequencies are not assigned to individual licensees with only one party holding the right to operate in each one. Rather, the band in governed by a "full-band, full-arc" policy, which means that satellites have the right to transmit over the entire 500 MHz of the band and earth stations can point their dishes at any satellite along the geostationary arc.[4] Thus, at any point, there are many signals from many satellites transmitting over the entire band all over the country.

The result of this arrangement is an "anticommons tragedy," which is defined as an inefficient outcome that results because control over a resource is fragmented or spread out over too many people. As a result, negotiations and mutually beneficial deals cannot be reached because the transaction costs are too high to make them worthwhile.[5] In this case, efficient use of the band is hampered by the fact that property rights are numerous but not clearly delineated. As a result, no entity is able to easily trade away its rights to someone else who wants to use them differently, even if both parties would benefit. For example, if a mobile carrier wanted to purchase the right to transmit on a frequency in this band, it would have to negotiate with every satellite provider, not just one. This causes significant frictions in the bargaining process that preclude the deal from being completed. Solving this problem presents complex economic and technical issues that require serious discussion.

Risks of Interference

The main challenge in repurposing an already-used band is harmful interference with incumbent services. This problem is similar to multiple people having a conversation in the same space:

> If someone is speaking too loudly, information will not reach its intended audience. Likewise, radio signals can overpower each other resulting in service interruptions. In this band, that may look like television or radio station signals dropping out as they encounter interference when they get to a receiver on Earth.[6]

Interference concerns are especially acute in this band because the satellites are in geostationary orbit. This means they do not move relative to the surface of the earth. This

3. "In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band," p. 6. https://ecfsapi.fcc.gov/file/07131575002139/FCC-18-91A1.pdf. This band is not used for direct-to-consumer satellite television. It sends content to a distributor, which then sends it to the end consumer via cable, fiber or terrestrial over-the-air signals.

4. As viewed from the ground on earth, the orbit of geostationary satellites forms an arc across the sky and geostationary satellites are located every two degrees along this arc. Satellite dishes are oriented at a satellite by a specified elevation, pitch around a horizontal axis and azimuth or the direction they point around a vertical axis. The full-arc policy allows satellite users to utilize any elevation and azimuth rather than single, pre-registered ones. What frequencies are actually in use is managed from the perspective of earth stations, which focus their antenna such that they receive a particular satellite's transmission and then tune-in to the particular channels in that transmission that carry the earth-station operator's content. So, while the satellite is likely sending content on all 500 MHz over the entire country, any given earth station does not "listen to" all satellites at once.

5. Michael A. Heller, "The Tragedy of the Anticommons: Property in the Transition from Marx to Markets," University of Michigan Law School Scholarship Repository (1998). https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1608&context=articles.

6. NCTA – The Internet & Television Association, "Comments In the Matter of Expanding Flexible Use of the 3.7–4.2 GHz Band," GN Docket No. 18-122, May 31, 2018, p. 2 and 11. https://ecfsapi.fcc.gov/file/10531818122999/053118%2018-122%20Comments.pdf.

is advantageous for consistent contact between space and Earth, but it also means that, as a matter of physics, the satellites must be about 22,200 miles away. As such, the signals are relatively faint by the time they get to the ground and they are consequently very sensitive to nearby terrestrial signals of much greater power.[7]

While mitigating harmful interference is an important challenge in this case, minimizing interference at all costs is not and should not be the final goal.[8] No party actually wants to incur the costs that would be necessary to be completely interference free all the time. Instead, the level of interference should be balanced with productivity by means of market transactions. For example, satellite providers may be willing to tolerate more interference if mobile carriers pay them enough to cover or mitigate the costs that result. If this band is actually more valuable for mobile or fixed-wireless broadband than it is for its current use, then new users will eventually buy enough access to provide those services. If the incumbent users turn down such offers, this would indicate that they value it more highly than the newcomers do. In this case, creating the conditions for such a market should be the primary goal of the FCC.

POTENTIAL NEW USES

There are two main uses for the 3.7–4.2 GHz band that would likely be more valuable, on the margin, than the status quo:[9] fixed wireless and mobile. This section describes those uses and the particular problems they face with respect to interference with existing satellite operators.

Fixed-Wireless Broadband

Fixed-wireless service involves providing broadband via towers that send data between stationary points. The word "fixed" refers to the fact that the transmitters and receivers are usually stationary, akin to a television or radio antenna affixed to a roof.

Fixed service already has a limited presence in this band and the challenges presented by its coexistence with satellite users are not extreme. Since both fixed-wireless transceivers and satellite earth stations are generally in static, known positions, fixed services can usually aim their signals to keep out of the way of signals coming from space.

7. Satellite Industry Association, "Comments In the Matter of Expanding Flexible Use of the 3.7–4.2 GHz Band," GN Docket No. 17-183, Oct. 2, 2017, p. 36. https://ecfsapi.fcc.gov/file/10022703505533/SIA%20Comments%20on%20Mid-Band%20NOI%202%20Oct%202017.pdf.

8. Ronald H. Coase, "The Federal Communications Commission," *Journal of Law and Economics* 2 (October 1959), p. 27. https://www.jstor.org/stable/724927?seq=1#page_scan_tab_contents.

9. I.e. the next units allocated to fixed wireless or mobile are more valuable than the first units of satellite spectrum that would be cleared.

The word "generally," however, conceals a lot. The situation is complicated by the fact that not all earth stations are registered and thus their locations are not always known. A proliferation of fixed services in this band has the potential to interfere with earth stations simply because the fixed providers are unaware of them.

Incumbent satellite users also stress that not all earth stations are immobile.[10] Some move from place to place between, for example, sports stadia.[11] These characteristics further emphasize the need for timely registration and also provide a potential use-case for a database that can be updated with near-real-time location data to allow for more intensive use of frequencies in all geographic areas without interfering with incumbent users. This system would be similar to those proposed for the 3.5 GHz band[12] and TV white spaces in the 600 MHz band.[13]

Mobile Broadband

A more difficult challenge is posed by mobile services in the 3.7–4.2 GHz band. As the name implies, mobile devices move frequently, so the path between them and a radio antenna cannot help but cross through—and likely interfere with—a space-to-earth satellite transmission. For this reason, using the band for mobile services will likely require clearing satellite users out of at least a portion of it so that it can then be dedicated to mobile or similar services.

Here, however, the anticommons tragedy once again applies. Coordinating such a clearance with multiple rights owners presents high transaction costs and the risk of holdups.[14] Even if almost all satellite users can agree on a price to clear a portion of spectrum, one or a handful can hold up the deal by demanding exorbitant prices for themselves. Accordingly, any solution designed to facilitate mobile services in the 3.7–4.2 GHz band must confront this possibility.

10. Satellite Industry Association, p. 31. http://www.intelsat.com/wp-content/uploads/2017/10/SIA-Comments-on-Mid-Band-NOI-2-Oct-2017.pdf.

11. Since this band is used for downlink, however, the main, outgoing video feed from a sporting event does not use it. That feed is being sent up to space from the venue using a different portion of the C-band. The 3.7–4.2 GHz band would be used, for example, by an earth station at the site of the event to monitor the feed that was already sent up and to make sure there are no problems with it. But since this function could be performed by other means (e.g. at a central studio elsewhere), one may question whether such rights should be allowed to persist without payment if they preclude other uses of the band.

12. Federal Communications Commission, "Notice of Proposed Rulemaking in the Matter of Promoting Investment in the 3550-3700 MHz Band," GN Docket No. 17-258, Oct. 24, 2017, p. 3. https://ecfsapi.fcc.gov/file/1024196454861/FCC-17-134A1.pdf.

13. Federal Communications Commission, "White Space Database Administration," 2018. https://www.fcc.gov/general/white-space-database-administration.

14. Peter Cramton and Evan Kwerel, "Efficient Relocation of Spectrum Incumbents," *The Journal of Law and Economics* 41:52, (October 1998), pp. 649 and 655. https://www.jstor.org/stable/10.1086/467407?seq=1#page_scan_tab_contents.

EVALUATION OF PROPOSALS FOR REALLOCATION

For the aforementioned reasons, balancing the interests of satellite providers and potential new users requires creative solutions. In light of this, the present section reviews some of those proposals from an economic perspective.

Requiring Registration of Satellite Earth Stations

Knowing the location of operational earth stations is a prerequisite for any revitalization proposal in the 3.7–4.2 GHz band. Registration of receiving earth stations is not currently mandatory under FCC rules, and to do so involves a nine-page form that smaller users may have difficulty understanding and completing.[15] Therefore, the FCC should streamline the registration process to require only the bare minimum of information necessary to identify the location of active earth stations and to adequately protect them. Alternatively, the agency could solicit the help of satellite providers themselves to identify the positions of earth stations. This approach has the advantage of dealing with fewer parties who are likely more sophisticated than the average, unregistered earth-station operator. Either way, registration should be mandatory and after a sufficient grace period, unregistered stations should not receive interference protection.

Creating a Satellite Industry Negotiating Consortium

A classic analysis of tradable rights indicates that when there are significant transaction costs, the initial allocation is important to the ultimate outcome of bargaining.[16] And, in this case, transaction costs are quite significant. But, since scrapping the current allocation framework by regulatory fiat is likely untenable for political and legal reasons, the FCC should aim to reduce transaction costs for rights to operate in the 3.7–4.2 GHz band. This would allow bargaining to clear a portion for mobile service.

A potential solution to the hold-up and anticommons problems has been proposed by members of the satellite industry who suggest that the FCC should empower a consortium of current users to act on behalf of all of them and negotiate deals to clear spectrum for mobile use.[17] This proposal would replace the disparate owners with a single body that is easily identifiable to potential buyers or lessees, thus reducing transaction costs and, hopefully, enabling mutually beneficial trades.

The consortium proposal does have potential shortcomings, however. As a government-granted monopoly over the band, it would have a tendency to bring to market a smaller portion of the band at a higher price than that which would prevail in a competitive market. Moving directly to a competitive market in this band is likely not a viable option at this point, however. Such a move would trigger delays from technical and legal problems that would likely bog down the transition for so long that they could outweigh the inefficiencies of alternative proposals. All stakeholders should therefore avoid rejecting a viable alternative simply because it is imperfect. There are no perfect solutions, only tradeoffs.

The consortium proposal estimates that it could clear 100 MHz for new users with an additional 50 MHz "guard band" necessary to adequately separate mobile users from incumbents to avoid interference.[18] Many interested parties have suggested that this number is too low and argue that up to 400 MHz could be cleared.[19] This issue would be solved by markets in a competitive setting: The seller would supply all the spectrum for which buyers were willing to pay a mutually agreeable price. But since the monopoly consortium will tend to undersupply cleared spectrum, it may be advantageous for the FCC to grant the consortium control over clearing the band, but require it to clear only a minimum range of frequencies—perhaps 300 MHz.

Other Factors That Determine Optimal Clearing

Innovations in incumbent services are another important consideration in determining the optimal amount of spectrum to clear. New compression technologies are gradually being implemented in this band.[20] Such development means that the same content can be transmitted with less spectrum, leaving more available to repurpose for mobile. But compression also improves the quality of current uses of the band. In turn, since they can now receive higher resolution content more cheaply, this could increase the quantity of those services, like video, that downstream users demand. In short, compression technologies have an ambiguous effect on the future use of this band, so market transactions are necessary to reveal the most productive alternatives.

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15. Federal Communications Commission, "Sample Application for License of New Earth Station (C-Band Transmit/Receive using U.S. licensed satellites)." https://transition.fcc.gov/ib/sd/se/s312tr.pdf.

16. See Ronald H. Coase, "The Problem of Social Cost," *The Journal of Law and Economics* 3 (October 1960). https://www.law.uchicago.edu/files/file/coase-problem.pdf.

17. Intelsat License LLC and Intel Corp., "Joint Comments In the Matter of Expanding Flexible Use in the Mid-Band Spectrum Between 3.7 and 24 GHz," GN Docket No. 17-183, Oct. 2, 2017, pp. 6-9. https://ecfsapi.fcc.gov/file/1002726526846/Joint%20Comments%20of%20Intelsat%20License%20LLC%20and%20Intel%20Corporation.pdf.

18. Caleb Henry, "SES, Intelsat plead for an extension for C-band dish registration," *SpaceNews*, June 19, 2018. https://spacenews.com/ses-intelsat-plead-for-an-extension-for-c-band-dish-registration.

19. "Statement of Commissioner Michael O' Rielly Re: Expanding Flexible Use of the 3.7 to 4.2 GHz Band," GN Docket No. 18-122, July 13, 2018, p. 2. https://ecfsapi.fcc.gov/file/07131575002139/FCC-18-91A3.pdf; Verizon "Ex Parte Re: Expanding Flexible Use of the 3.7 to 4.2 GHz Band," May 16, 2018, p. 1. https://ecfsapi.fcc.gov/file/10516106415285/2018%2005%2016%20Verizon%205G%20ex%20parte.pdf.

20. "Is There a Better Way to Maximize the Throughput of my Satellite Capacity?", Intelsat, 2018. http://www.intelsat.com/tools-resources/library/satellite-101/digital-compression.

There is also not necessarily a linear progression to the cost of clearing more frequencies. Satellite companies are limited by the characteristics of their hardware and beyond a certain point, they may have to, for example, launch new satellites. This process would result in a sharp jump in the cost of clearing spectrum, and even if that cost is willingly paid by carriers, it could significantly increase the time that clearing takes.

As a practical matter, therefore, there may be good reason to think that a smaller portion of the band will be cleared first with more coming to market as technology and network hardware evolve. In any case, both the FCC and interested private parties should seek to foster an ongoing market in this band rather than treating the current proceeding as a one-time affair.

Reforming the Full-band, Full-arc Policy

It is likely that the current full-band, full-arc arrangement is not conducive to maximally productive use in this band. Since satellite dishes are often only tuning in to a limited range of frequencies from one satellite at a time, the remaining frequencies and positions along the geostationary arc could be put to other uses without meaningfully disrupting current operations.

Incumbents claim that they need these expansive rights in order to have greater flexibility in their provision of service.[21] For example, they may wish to point their receiver at a different satellite or tune in to different frequencies in the future. However, these are rights that are not frequently used by the parties.[22] Most earth stations will persistently receive from only one satellite and use a consistent fraction of the 500 MHz in the band. It would, therefore, be advantageous to make these current uses explicit rather than to pretend that the entire width of the band is being used at every earth station that could point at a different satellite at any moment. Being clear about how this band is actually being used will allow for the utilization of unused frequencies in particular areas.

21. American Cable Association, National Association of Broadcasters, National Public Radio Inc., NCTA - The Internet & Television Association, "Ex Parte Re: Expanding Flexible Use of the 3.7 to 4.2 GHz Band," GN Docket No. 18-122, June 15, 2018, pp. 4-5. https://ecfsapi.fcc.gov/file/10615344709012/061518%2017-183%2018-122%20ACA%20NAB%20NCTA%20NPR%20ex%20parte.pdf; Satellite Industry Association, "Comments In the Matter of Expanding Flexible Use in Mid-Band Spectrum Between 3.7-24 GHz," GN Docket No. 17-183, Oct. 2, 2017, pp. 25-31. https://ecfsapi.fcc.gov/file/10022703505533/SIA%20Comments%20on%20Mid-Band%20NOI%202%20Oct%202017.pdf.

22. Google LLC, "Comments in the Matter of Report on the Feasibility of Allowing Commercial Wireless Services, Licensed or Unlicensed, to Use or Share Use of the Frequencies Between 3.7-4.2 GHz," GN Docket No. 18-122, May 31, 2018, pp. 7-8. https://ecfsapi.fcc.gov/file/105312950814240/2018-05-31%20Google%20Comments%20(GN%2018-122).pdf; Broadband Access Coalition, "Comments in the Matter of Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz," GN Docket No. 17-183, Oct. 2, 2017, pp. 6-7. https://ecfsapi.fcc.gov/file/1002768614835/Mid-Band%20NOI%20--%20BAC%20Comments%20--%20FINAL2%20with%20Attachment%20--%2010.02.17.pdf.

How to move away from the inefficiencies of full-band, full-arc coordination is, however, a delicate matter. It would be most efficient for the FCC to simply codify the existing frequency and directional uses of the band and open unused portions to the rest of the market. This route, however, may present political and legal obstacles that make it untenable. Incumbent users are not eager to have their expansive rights curtailed and they would likely resist such a change, perhaps as a regulatory taking. Whether or not such a case would have merit, the delays presented by prolonged litigation may end up being more costly to timely broadband deployment than attempting to reform the full-band, full-arc policy by an alternative means.

Such an alternative could take the form of simply increasing the flexibility of incumbents to sell unused capacity in the secondary market. If it is true that full-band, full-arc results in satellite incumbents maintaining rights to spectrum that goes persistently unused, then the incumbents ought to be willing to sell or lease that capacity. Satellite users could keep all their rights, but they would face opportunity costs for doing so. For example, the choice to maintain access to the full band and the full arc would mean turning down the revenue from offers to lease unused frequencies. If they do turn down such offers, that fact would demonstrate that maintaining access to the flexibility afforded by full-band, full-arc is more valuable than the alternative use.

This reform would accomplish a similar result as revoking the full-band, full-arc rights but without the delays and costs associated with litigation. This route would, of course, present its own delays and transaction costs associated with setting up and operating the secondary market. Evaluating the tradeoffs of each alternative will take serious study by the FCC.

Holding an Incentive Auction

Another way of repurposing the 3.7–4.2 GHz band would be to hold an incentive auction. This process was used in 2016 to clear parts of the 600 MHz TV band.[23] In an incentive auction, the FCC solicits bids from incumbents on how much money it would take for them to willingly clear a certain amount of spectrum. A second auction then solicits bids for the potentially cleared spectrum until a mutually agreeable price and quantity is reached. It is not clear, however, that this process would be superior to merely enhancing the flexibility of existing licenses and allowing private parties, including the proposed consortium, to make deals on their own.

23. Federal Communications Commission, "Broadcast Incentive Auction and Post-Auction Transition," May 9, 2017. https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions.

The choice between these approaches ought to be merely a matter of comparative transaction costs: the market mechanism that can maximize the ease of voluntary transactions will result in the most efficient outcome. Imposing the FCC as a middleman may delay the process more than a situation in which profit-driven parties deal with each other directly.

Auctioning Overlay Licenses

Another alternative is for the FCC to auction overlay licenses. These essentially give their buyers the right to use frequencies in a way that does not interfere with incumbents. The practical result would be that the overlay licensee negotiates with the incumbent to clear some or all of the licensed frequencies.

The full-band, full-arc characteristics of this band, however, make this option no better than a market for the whole band through something like a consortium model. Because current users can access the entire band, the overlay licensee would need to negotiate with all of them to be sure the desired frequency is actually cleared. The anticommons tragedy will befall such attempts to bargain for individual sections of the band. A solution to this problem, for example, through the consortium model, must be implemented before more efficient deals can be negotiated.

Effect on Downstream Services

Some parties have expressed concern about potential disruptions to downstream services that could result from repurposing portions of the band but those concerns can be incorporated into the economic models discussed above.[24] The current satellite incumbents are a content delivery service and they should be able to sell off some of their assets as dictated by market conditions. Certainly their consumers may prefer to maintain access to satellite service in this band, but the proper result in such a case would be for them to pay more for the delivery service, thereby changing the market conditions and signaling the relative value of satellite service compared to alternative uses.

Additionally, reconsideration of the 3.7–4.2 GHz band's allocation is an opportunity for downstream companies to weigh alternatives, such as fiber or other wireless service on other frequencies. These may be more expensive but again, the fact that certain factors of production become more expensive to certain companies is not, in itself, grounds for government intervention.

The opportunity for reconsidering services is important because there are consumers on both sides of the coin here. It is true that losing some satellite transmission capacity could increase prices or disrupt service for downstream consumers of TV or radio. But the new uses for mobile or fixed-wireless broadband will provide other, or perhaps the same, consumers with better broadband service. Given trends in consumption of media and communications services, it is likely that the overall effect will be a net positive. Changes in price driven by changes in supply and demand are signs of a healthy market, not problems in need of regulatory solutions.

CONCLUSION

We all want our TVs and radios to work, but we also want faster, more reliable Internet that works at home and on the move. The 3.7–4.2 GHz band is an ideal candidate to provide all these services but tradeoffs are omnipresent. The question before the FCC, then, is how to balance the changing demands for satellite downlink and wireless broadband. While past policy frameworks have complicated rights in this band, the agency should seek to rearrange rights in a way that minimizes transaction costs and allows markets to direct spectrum to productive uses.

ABOUT THE AUTHOR

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24. NCTA – The Internet & Television Association, pp. 2 and 11. https://ecfsapi.fcc.gov/file/10531818122999/053118%2018-122%20Comments.pdf; American Cable Association, "Comments in the Matter of Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz. GN Docket No. 17-183, pp. 4-16. https://ecfsapi.fcc.gov/file/10032114823976/ACA%20Mid-Band%20NOI%20Comments%20171002.pdf.

Weather Forecasting or 5G? Why Not Both?

Joe Kane

In 2019, a lot of us check the weather on our smartphones. But some in the federal government think this simple act constitutes having our cake and eating it too. The National Oceanic and Atmospheric Administration (NOAA) is trying to halt the rollout of next-generation wireless services, or 5G, in the 24 GHz band by claiming that it would interfere with weather satellites. But these claims are unsubstantiated. The 5G rollout should be allowed continue so it can eventually enable faster, more reliable connectivity for everything from weather reports to WhatsApp.

Whenever the FCC seeks to allow private use of frequencies in or around bands used by government agencies, it takes precautions to ensure that critical government missions are not harmed. For the 24 GHz band, this process was completed in November of 2017 when the FCC adopted an order based on an open process in which any interested party had an opportunity to comment. Last August, the procedures for auctioning the band were finalized.

However, in March of this year, on the eve of the auction, complaints began to surface in Congress suggesting a change of tune from the NOAA and the National Telecommunications and Information Administration (NTIA), the Commerce Department agency responsible for managing spectrum used by government agencies. The NOAA and NTIA insisted that allowing 5G in the 24 GHz band would interfere with data collection carried out by weather satellites in the neighboring 23.6 GHz band. These objections reached fever pitch when NOAA testimony suggested hurricane forecasts would become wildly inaccurate if terrestrial wireless services were deployed in the 24 GHz band according to the FCC's parameters.

The concerns are based on the potential for 5G services that use 24 GHz on the ground to create harmful interference for weather satellites that sense moisture in the atmosphere using the 23.6 GHz band. Harmful interference would mean that 5G signals in the 24 GHz band are so powerful that they spill over into the neighboring band and make weather data less accurate. But this kind of interference is mitigated by setting out-of-band emission limits.

There is good cause to think that weather satellites would not experience harmful interference from 5G operations in the 24 GHz band under the current FCC limits. Terrestrial services are already operating just below the 23.6 GHz band used by weather satellites. Those services operate under the same noise limit, -20 dBW/200 MHz, that the FCC has provided for 5G operations in the 24 GHz band.

In other words, this noise limit has a track record of successfully protecting weather satellites. FCC Chairman Ajit Pai testified last week, "Before we made our decision there were some 40,000 microwave links in the band immediately adjacent to the 23.6 GHz band that's in question. There's never been a reported case of interference." Moreover, 5G services in the 24 GHz band would be separated from weather satellite operations by a 250 MHz "guard band." Since this feature is not present in the band immediately below the one used by weather satellites, there is even more reason to think the weather satellites will be safe from interference from the 24 GHz band.

Of course, this reasoning is rebuttable by scientists and engineers at the NOAA, NASA and the NTIA. But the objections raised so far have not been accompanied by such a rebuttal. It is no wonder, therefore, that Chairman Pai spoke of his own frustration with demands that the noise limit be at least twice as strict: "Over the last two and a half years we've patiently waited for a validated study to suggest that our proposed limit is inappropriate. We've never gotten such a validated study."

One study analyzed the effect of the FCC noise limit on a sensor that is not in use. There have been rumors of another study addressing an in-use sensor, but it is reportedly only in draft form and was recently removed from NASA's website. And NOAA's simulations may not account for technical characteristics of 5G that make it less likely to interfere with its neighbors.

The process through which the executive agencies raised their objections also warrants skepticism. Not only have their claims been unamenable to evaluation by private stakeholders or the FCC, they also threaten the diplomatic position of the United States in international negotiations on spectrum policy. It is important that United States can speak with one voice during international meetings on the wireless ecosystem such as the International Telecommunication Union's fast-approaching World Radiocommunication Conference. The uncertainty created by the agencies' unsubstantiated doomsday predictions about the 24 GHz band threatens to undermine U.S. interests in international spectrum coordination.

Overall, observers are left in confusion that stems from the apparently tumultuous current state of the NTIA, as reports suggest that the sudden departure of Administrator David Redl may reflect deeper rifts within the Commerce Department about the future of U.S. spectrum policy. In his testimony, Chairman Pai characterized the situation saying, "Some folks in the federal government believe, wrongly, that the development of 5G in this and other bands shouldn't happen….The Department of Commerce has been blocking our efforts at every single turn." Clearly, the 24 GHz band could become part of a larger fight.

It is a major problem if government interests are allowed to halt private wireless deployment with tenuous prophecies of disaster. The FCC is right to stand against calls to prioritize government agencies over consumer access to next generation wireless services that will enhance the wireless applications of today and enable the yet-unknown innovations of tomorrow. Congress too should join the side of consumers with appropriate oversight and legislation to prevent bureaucracy from eroding the benefits of 5G for all Americans.

Are nonexistent connected cars slowing our WiFi?

The FCC can easily fix the problem

Joe Kane in The Benchmark Follow
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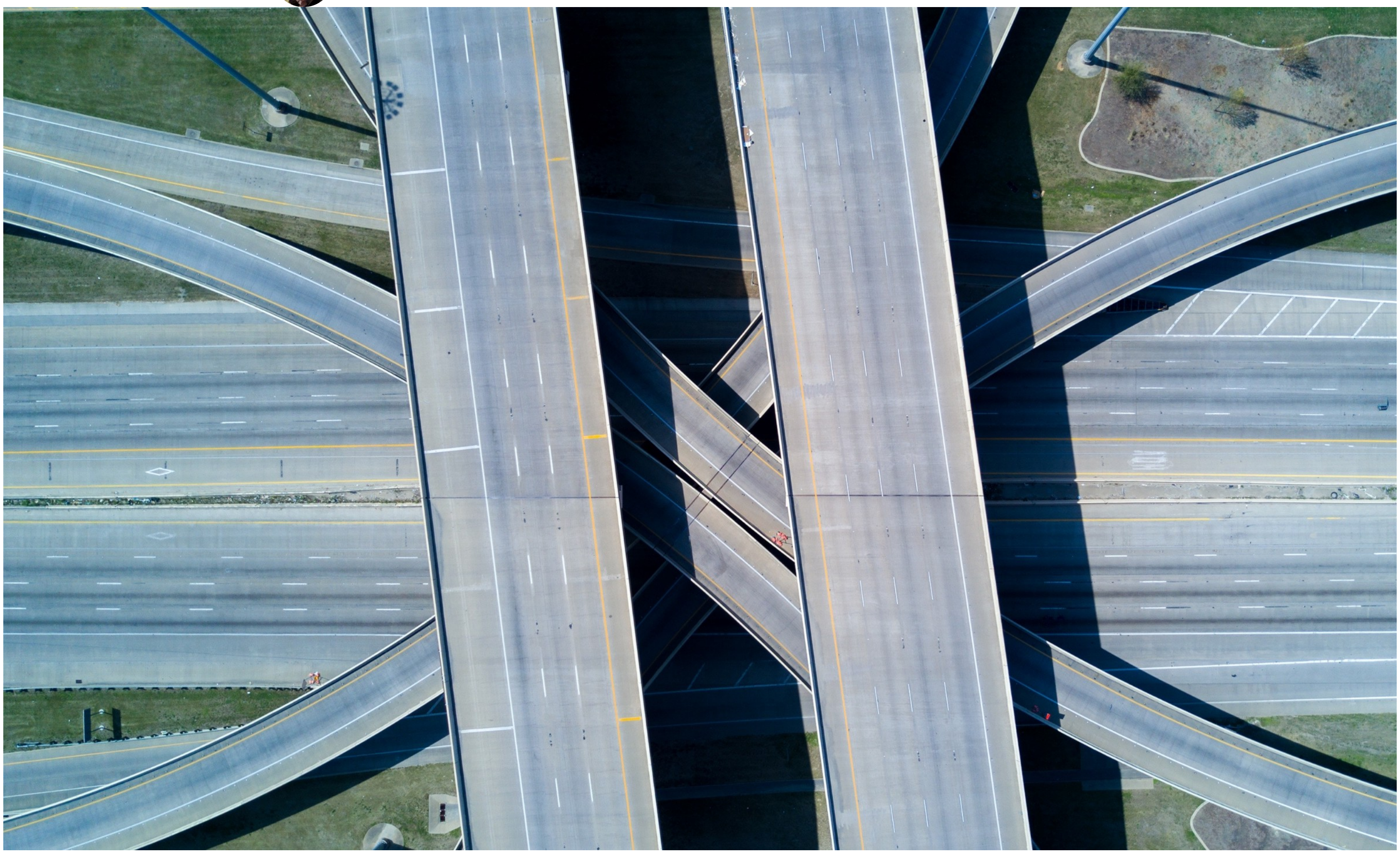


Photo by Omer Rana on Unsplash

Getting connected to Wi-Fi can be a frustrating experience. Even if you can find a signal, your connection may be slow or unreliable. Sometimes the culprit may be many other devices trying to use the same radio frequencies at the same time. The FCC should now help alleviate this problem by creating a large, contiguous swath of high-capacity, unlicensed spectrum — the kind used for Wi-Fi.

The spectrum in question is the 5.9 GHz band. Two decades ago, the FCC allocated this band exclusively for vehicle safety technologies and connected cars. But the failure of those technologies to materialize, combined with the radical growth of unlicensed technologies like Wi-Fi and Bluetooth, suggests that reallocating the band for unlicensed use would be a more productive approach.

The Need for Unlicensed Spectrum

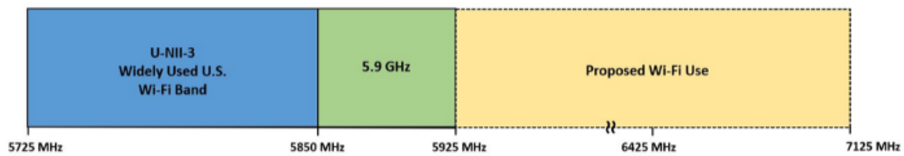
Unlicensed spectrum is best understood in contrast to the majority of the radio spectrum, which is subject to FCC licenses. Licenses to operate in certain spectrum bands are akin to titles to other resources: They afford the licensee a legal right to operate without interference in a certain characteristics that keep signals relatively confined within small areas or buildings. The downside of this is that you may have trouble connecting to your home's network from the other side of the house. The upside is that no one has to pay to use the spectrum.

But as with any unpriced resource, unlicensed spectrum tends to get used quite heavily. The technical rules work to a point, but unlicensed bands are now getting congested, especially in densely populated areas. This fact alone should make policymakers cautious about designating spectrum as unlicensed too readily. But the success of technologies like Wi-Fi and Bluetooth warrants some additional unlicensed allocations.

The Trouble with 5.9 GHz

The FCC is well on its way to augmenting unlicensed allocations by permitting unlicensed use of the 6 GHz band. But in between the unlicensed 5 GHz band and the soon-to-be unlicensed 6 GHz band sits the 5.9 GHz band, which has a more checkered history. The FCC set aside the 5.9 GHz band for vehicle-to-vehicle communications technology in 1999. This move in itself was a mistaken act of central planning. The government is ill-equipped to decide how particular radio frequencies ought to be used, and the attempt to do so has resulted in inefficient and politically precarious policy decisions in the past.

While these practices have largely been replaced by more market-driven allocation, the fallout of the old model is starkly visible in the case of the 5.9 GHz band. Twenty years after it was first gifted to the auto industry, the government's chosen technology, known as dedicated short-range radio communication (DSRC), still has not seen wide deployment. But as productive unlicensed uses have grown dramatically in adjacent bands, the bespoke set-aside for DSRC is now a fly in the ointment of wide channels for unlicensed wireless technologies like Wi-Fi and Bluetooth.



Note: From NCTA.

By designating the 5.9 GHz band for unlicensed use the FCC would create a swath of unlicensed spectrum that connects the 5 GHz and 6 GHz bands. This change would enable expansion of the number of large Wi-Fi channels, 160 MHz wide. Wider channels mean more throughput, which in turn means consumers could expect multigigabit speeds from their Wi-Fi connections — many times faster than today's average speeds. Connecting otherwise fragmented segments of unlicensed spectrum would enable economies of scale, as wide channels can stretch across the whole set of frequencies without having to reduce the productivity of both bands as they approach frequencies protected for DSRC.

Vehicle safety is a serious concern, and cars that can talk to each other could be a lifesaving part of the future of transportation. But we need not choose between safe cars and Wi-Fi. We should just look to technologies and spectrum bands beyond DSRC and 5.9 GHz.

Other Options for Connected Cars

Indeed, automakers have been pursuing alternative vehicle communications standards such as cellular vehicle-to-everything (CV2X) technology. This technology has the support of car makers like Ford and BMW. But the virtue of connected cars is that they can talk to each other and surrounding infrastructure. If the auto industry is split between competing, non-interoperable standards, then the overall value proposition for connected vehicle technology is diminished. In short, a world of widespread connected cars is not ready yet. But the newest Wi-Fi standard, Wi-Fi 6, is already being deployed and is ready to use the 5.9 GHz and 6 GHz bands. Since this spectrum is needed for unlicensed use now, it makes sense to allow connected vehicle technologies to continue to mature using other frequencies.

Car companies should participate in market processes to acquire exactly what they need for whichever technology they choose. While it is true that this would cost them more than relying on a government handout, automakers realize that safety is worth it. As vehicle-to-everything (V2X)

would be a reasonable step.
Moreover, autonomous vehicle manufacturers are making great strides in improving automobile safety without relying on two-way radio technologies at all. Companies like Waymo, General Motors and Tesla are deploying automated systems that use lidar, radar, cameras, and detailed mapping to navigate safely. Perhaps these vehicles will eventually incorporate connected-car technologies as well, but until there is wider agreement among the automotive industry on wide deployment of some interoperable standard, it is not credible to insist that access to any particular band is a necessary prerequisite to improving road safety.

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While all technological developments take time, the rest of the wireless world hasn't stood still waiting for DSRC. Even if DSRC was the best use of the 5.9 GHz band in the 1990s, the wireless ecosystem has changed. Unlicensed technologies and devices have advanced and proliferated, and the spectrum bands dedicated to them are filling up. As the FCC takes the logical next steps to extend unlicensed allocations up through the 6 GHz band, it should not let vestiges of spectrum central planning stand in the way.

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