Wireless Visions:

Creating and Contesting Sociotechnical Imaginaries of Electromagnetic Spectrum

Honors Thesis

Presented in Partial Fulfillment of the Honors Requirements in

Science and Technology Studies, College of Arts and Sciences, Cornell University

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April 2014

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INTRODUCTION

In the 21st Century in the United States, wireless technologies have a growing prevalence in people's everyday lives, from television broadcasts to mobile phones, Wi-Fi internet access to health sensors, 4G and LTE access to GPS technologies. Radio spectrum – the electromagnetic waves that carry these wireless signals – has become an integral part of the United States' technical and economic infrastructure. Technical and regulatory decisions about spectrum are caught up in wider visions for the future, claims regarding the potential of technology, and claims about the nature of social progress and the good life. Non-government users of spectrum are regulated by the Federal Communications Commission (FCC), which has certain social and technical motivations and framings for their actions. There are also larger debates regarding what types of regulations should be implemented, which has implications for what devices are used, how technologies may develop, and what access the public has to wireless technologies. These debates involve stakeholders from government, industry, public interest groups, standards setting bodies, local communities, and more – each with their own motivations and framings. Thus spectrum and spectrum management represent a sociotechnical system.

One of the main contemporary debates regarding spectrum is the "spectrum crunch." The spectrum crunch is caused by a large increase in demand by the American public for wireless services and devices, yet there is a finite amount of usable spectrum, and demand for spectrum will outpace the supply. New decisions and regulations are debated by the stakeholders to determine what actions to take next. One of the new ideas is the use of spectrum sharing, allowing multiple users to share the same frequency of spectrum. But what is the nature of this point of intersection in the policy debate? How are spectrum related policy decisions affected by broader and deeper frameworks and orientations toward the world? The concept of sociotechnical imaginaries provides a way to gain insight to these questions.

I begin by describing the concept of sociotechnical imaginaries. I then discuss the history of radio spectrum debates through the lens of sociotechnical imaginaries. Spectrum use and wireless devices are not new, but are in fact over a century old. A historical review of radio spectrum shows us that the debates occurring today are not new, and shows us the lasting repercussions of prior policy and technical decisions. The history spans five eras, the "Pre-Regulation Years" from 1900 to 1912, the "Formative Years" from 1912-1934, "Commercial Broadcasting" from 1934 to the 1960s, "Reform Movements" from the 1960s to 1970s, and "New Changes" from the 1970s to the present. I then discuss the current day problem of the spectrum crunch, providing a brief overview of the solutions that have been discussed. After that, using the concept of sociotechnical imaginaries, I analyze two case studies involving the FCC's Notice of Proposed Rule Making (NPRM) process, when the FCC solicits public comments on proposed rules. Both cases discuss spectrum sharing in different contexts. The NPRM process will help open up stakeholder debates. Finally, I end with some concluding thoughts about spectrum and sociotechnical imaginaries.

SOCIOTECHNICAL IMAGINARIES

I use sociotechnical imaginaries to analyze the historical and current debates surrounding radio spectrum policy. As described by Jasanoff and Kim 2009,[1] sociotechnical imaginaries are "collectively imagined forms of social life and social order reflected in the design and fulfillment

[1] Jasanoff, Sheila, and Sang-Hyun Kim. "Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea." *Minerva* 47.2 (2009): 119-146.

of nation-specific scientific and/or technological projects." These imaginaries represent both feasible futures and visions of futures that ought to be attained, with projections of "what is good, desirable, and worth attaining for a political community."[2] Though policy outcomes are not strictly determined by sociotechnical imaginaries, Jasanoff and Kim argue that they are "powerful cultural resources that help shape social responses to innovation."[3] Jasanoff and Kim use the state as the unit of analysis, analyzing imaginaries at a national level and associating imaginaries with state actions such as national policies, funding allocations, investments, and development priorities. Jasanoff and Kim argue that while prior Science & Technology Studies (S&TS) scholarship looks at the processes involved in the production of science, including the use of imaginaries, there is a lack of work investigating the role of the state in defining the purposes of science and technology, and how science and technology projects encode and reinforce particular conceptions of a nation. There is also a gap between "the relationship of science and technology to political institutions."[4] They develop the concept of sociotechnical imaginaries in part to help understand the role of the state in science and technology.

As a tool, sociotechnical imaginaries build upon work done by social theorists about the role of imagination in states, social classes, and other social structures. Sociotechnical imaginaries also build upon prior work in Science & Technology Studies discussing collective visions and imaginaries among scientists and technologists, or "technoscientific imaginaries." From the field of anthropology, Benedict Anderson offers an influential approach to understanding the nation in *Imagined Communities* (1983). Anderson conceptualizes the nation as an "imagined political community," as he posits that communities, and more broadly

[2] Jasanoff, Kim (2009).
[3] Jasanoff, Sheila, and Sang-Hyun Kim. "Sociotechnical Imaginaries and National Energy Policies." *Science as Culture* 22.2 (2013): 189-196.
[4] Jasanoff, Kim (2009), 120.

nationalism and nation, are distinguished by the style in which they are imagined.[5] In *The Imaginary Institution of Society* (1998), author Cornelius Castoriadis uses the concept of imaginaries to describe social orders that transcend the individual, writing "the institution of society is in each case the institution of a magma of social imaginary significations."[6] Charles Taylor differentiates social imaginaries from social theory in *Modern Social Imaginaries (2004)*, stating that (i) imaginaries focuses on the way people imagine their social surroundings in images, stories, and legends, (ii) unlike a social theory which is held by a few people, social imaginaries are held by large groups, and (iii) social imaginaries are common understandings that make widely shared common practices and legitimacy possible.[7] Taylor argues that social imaginaries are influenced by moral orders, which carry some notion about how we ought to live together in a society. This idea is picked up by Jasanoff and Kim as the normative dimension in sociotechnical imaginaries. Taylor also discusses how social imaginaries can change over time by being influenced by new or modified practices, providing a dynamic quality to social imaginaries which is not clearly suggested by Jasanoff and Kim's use of sociotechnical imaginaries. In my use of sociotechnical imaginaries, I reintegrate this dynamic quality to better understand changes in spectrum policy.

From Science & Technology Studies, the concept of scientists having imaginations has a long history. More specifically, the concept of technoscientific imaginaries is used by George E. Marcus in *Technoscientific Imaginaries: Conversations, Profiles, and Memoirs* (1995), using conversations and dialog to explore the role of imaginaries for scientists facing changes within institutions and in professional practices at the end of the 20th century. He writes that "this is a

[5] Anderson, Benedict. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. London: Verso, 1983. 6
[6] Castoriadis, Cornelius. *The imaginary institution of society*. Mit Press, 1998. 359.
[7] Taylor, Charles. *Modern social imaginaries*. Duke University Press, 2004. 23.

socially and culturally embedded sense of the imaginary that indeed looks to the future and future possibility through technoscientific innovation but is equally constrained by the very present conditions of scientific work."[8] Further work surrounding the use of imaginaries in science and technology has promoted a collective nature of imaginaries, rather than individual, thus allowing scientific practices and communities to be built around them, embedding the promises and visions of those imaginaries.[9] Further work has also investigated how scientific imaginaries can carry some notion of larger public needs, how science can be fashioned to serve the public good.[10] Jasanoff and Kim (2009) build upon this strand, positing that "technoscientific imaginaries are simultaneously also 'social imaginaries,'" merging two lineages of work surrounding imaginaries into the concept of sociotechnical imaginaries.

Sociotechnical imaginaries also relate to the concept of co-production in science and technology. At its core, co-production is "the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it."[11] Scientific and technological knowledge both embed and are embedded in the social – practices, norms, discourses, and institutions.[12] Co-production helps explain how new objects and phenomena emerge and stabilize, how controversies are framed and resolved, how

[8] Marcus, George E., ed. *Technoscientific imaginaries: Conversations, profiles, and memoirs*. Vol. 2. University of Chicago Press, 1995. 4.
[9] Fujimura, John. "Scientists as Sociocultural Entrepreneuers." *Genetic Nature/Culture: Anthropology and Science Beyond the Two-culture Divide*. Ed. Alan H. Goodman, Deborah Heath, and M. Susan Lindee. Berkeley: University of California P, 2003. 192.
[10] Fortun, Kim, and Mike Fortun. "Scientific imaginaries and ethical plateaus in contemporary US toxicology." *American Anthropologist* 107.1 (2005): 43-54.
[11] Jasanoff, Sheila, ed. *States of knowledge: the co-production of science and the social order*. Routledge, 2004. 2.
[12] Jasanoff (2004), 3.

science and technology can be made intelligible and ported across time, place, and culture, and finally, how science and technology are endowed with legitimacy and meaning.[13]

Jasanoff uses the concept of co-production to explain the development of science and the development of governance, policy, and state-making in *States of Knowledge* (2004) and in *Designs on Nature* (2005). In the latter work, she deploys co-production to discuss and compare the development of biotechnology regulation in the United Kingdom, Germany, and the United States. While not using the language of sociotechnical imaginaries, she relates how scientific knowledge and science regulation were co-produced. In particular, she discusses how politics concerning life sciences contribute to projects creating certain imaginaries of nationhood or nation-building.[14] These themes are expanded through Jasanoff's later work developing sociotechnical imaginaries.

Jasanoff and Kim describe sociotechnical imaginaries as collectively imagined, containing implicit understandings about the public good, and reflected in national science or technology projects. Sociotechnical imaginaries affect broad social responses to scientific and technological projects, and may affect policy outcomes. They allow us to view scientific and technological projects and developments within a larger society, and analyze their interaction with social life. In particular, by focusing on nation states as an important unit of analysis, the role of national policies is highlighted within a larger context of national culture. Sociotechnical imaginaries can show "how different imaginations of social life and order are co-produced along with the goals, priorities, benefits, and risks of science and technology."[15] Sociotechnical imaginaries may be particularly salient at moments of co-production, such as emergence,

[13] Jasanoff (2004), 5.
[14] Jasanoff, Sheila. *Designs on nature: science and democracy in Europe and the United States*. Princeton University Press, 2005. 7.
[15] Jasanoff, Kim (2009) 141.

contestation, and stabilization of new objects or phenomena. In their 2009 paper, Jasanoff and Kim deploy sociotechnical imaginaries as a tool to compare the trajectory of nuclear power in the United States and South Korea and investigate how national political cultures contribute to forming visions of the “goods” and “bads” of nuclear power. They also look at what types of promises these imaginaries fulfill. While the U.S. and South Korea have imagined about nuclear power during the same timeframe post-WWII, they had very different outcomes. The United States, an established world power, had a sociotechnical imaginary built around the idea of “containment,” containing a potentially dangerous technology, trying to move from the frightening nuclear technology of the bomb to more benign versions such as nuclear power. Eventually, the focus on “containment” of nuclear hazards, and “containment” of opposition led to the end of nuclear power as a state project. The South Korean sociotechnical imaginary was built around the idea of using atoms for development – a nuclear program would help boost the nation to become a world economic and military power. Dissent to the nuclear program was concerned more about US hegemony than nuclear hazards, but had little effect. They argue that the differences in the ways the two nations imagined nuclear technologies highlights not only the different development of the technologies, but also differences in each nation’s political development, and can be seen as co-production of technological and political orders.

Sociotechnical imaginaries expand the earlier concept of technological style, as expressed by Thomas Hughes. Hughes uses style to explain why technological systems are adapted differently in different environments.[16] Like sociotechnical imaginaries, Hughes posits that style can be used for comparative purposes, providing the example of how the designs of electrical

[16] Hughes, Thomas. 1987. “The Evolution of Large Technological Systems.” in *The Social Construction of Technological Systems.* Ed. Bijker, Weibe, Hughes, Thomas, and Pinch, Trevor. 68.

systems differ between London, Paris, Berlin, and Chicago. [17] Social factors, particularly regional and national historical experiences and values affect the different styles in different places and contexts. Technological style differs from sociotechnical imaginaries by placing emphasis on role of history shaping technological outcomes. Sociotechnical imaginaries expand on the concept of technological style by positing that sociotechnical systems are not construed based on just past experiences and values, but based on future imaginaries as well. While Hughes describes technological systems as socially constructed, his discussion on technological style tends to focus more on artifacts, while sociotechnical imaginaries make greater use of co-production. The focus on future imaginaries and relationship to co-production make it a more useful concept to discuss the ideation and creation of sociotechnical systems, particularly during moments of emergence and contestation.

Jasanoff and Kim's work also expands on expectation studies in the field of S&TS. Expectations are similar to imaginaries but often are seen as products of individual scientists and engineers rather than larger social groups and national cultures. Yet expectations, as described by Borup et al, 2006, have some important qualities. They write that expectations may differ in different groups as "the obduracy of the emerging technology is different for different groups." Expectations enable communication and coordination of different actor communities and groups at different levels or scales of organization (vertical coordination) and among groups at the same level or scale (horizontal coordination). Furthermore, expectations may change over time as new conditions or problems emerge. These qualities about expectations can be applied to sociotechnical imaginaries surrounding radio spectrum in the U.S. Seeing sociotechnical imaginaries as being different for different groups and being used for communication and

[17] Hughes (1987) 69

coordination allows us to investigate how imaginaries with conflicting values or visions come into contact with one another. Viewing sociotechnical imaginaries with a dynamic quality allows us to see how these values and visions, as well as the groups promoting imaginaries, change over time. Imaginaries may change over time due to both cultural change and technological changes, although some imaginaries may have more staying power than others. The values and visions promoted by sociotechnical imaginaries are not only embedded into the policies surrounding spectrum, but also in the technologies that access and use spectrum. As argued by Latour,[18] morals and values are embedded in technologies, or nonhuman actors. Thus we would expect sociotechnical imaginaries to be expressed in both policy and technological outcomes.

Martyn Pickersgill redeployed the concept of sociotechnical imaginaries by analyzing the discourses of individuals and transnational collectives, rather than states, to investigate how the field of neuroscience intersects with law.[19] He finds that anticipatory discourse and debates about neurolaw crosses bioethical, legal and scientific communities, embodying a certain dominant sociotechnical imaginary in regards to the roles of and relationships between law, science, and scientists. Les Levidow and Theo Papaioannou use sociotechnical imaginaries to study bioenergy innovation in the UK. They found that UK policy was centered on three different imaginaries – localism, agri-diversifcation, and oil substitution, each combined with environmental and economic justifications for promoting the public good. They expand on the concept by trying to link sociotechnical imaginaries and technological pathways (such as oil substation via advanced biofuels of localization via anaerobic digestion), and that some

[18] Latour, Bruno. “Where are the Missing Masses? The Sociology of a Few Mundane Artifacts.” *Shaping Technology/building Society: Studies in Sociotechnical Change.* 1992

[19] Pickersgill, Martyn. "Connecting neuroscience and law: Anticipatory discourse and the role of sociotechnical imaginaries." *New Genetics and Society* 30.1 (2011): 27-40.

combinations of sociotechnical imaginaries and technological pathways have greater impact in shaping the actions of state bodies than other combinations.[20]

The use of sociotechnical imaginaries can also be understood in contrast to other concepts and tools that can be used to study policies or common beliefs. Discourse primarily focuses on language – what people say, read, or write, and has been applied to media policy studies.[21] While sociotechnical imaginaries encompass discourse, which is seen as one "reservoir" from which actors build their policy preferences,[22] sociotechnical imaginaries go beyond discourse by including a focus on the materiality of science and technology as artifacts of imaginaries. Similarly, ideology helps think about the nature of power and social structures, but lacks a focus on materiality. Spectrum's properties as a physical phenomenon, as well as the technologies and applications surrounding it are important to think about, and analyzing spectrum as a sociotechnical system better incorporates the physical aspects.

In this thesis, I argue that the sociotechnical imaginaries framework has important contributions to the way we understand, analyze, and practice contemporary questions of spectrum policy and spectrum reform in the United States. Several qualities of spectrum policy make it an appropriate case to use the sociotechnical imaginaries framework. Spectrum policy is contested, and new technical and regulatory possibilities are emerging, such as the ability to share spectrum on a widespread scale. While the U.S. government, particularly the FCC, may promote one imaginary about spectrum usage, this imaginary is generally contested – in terms of policy and regulatory outcomes, technological outcomes, who should be allowed to participate, and along other dimensions – there are alternative imaginaries held by other groups which may

[20] Levidow, Les, and Papaioannou, Theo. 2013. "State imaginaries of the public good: shaping UK innovation priorities for bioenergy." *Environmental Science & Policy* (30). 36-49.
[21] Streeter, Thomas. 2013. "Policy, Politics, and Discourse." *Communication, Culture & Critique.* (6) 488-501
[22] Jasanoff, Kim (2009) 123

conflict with that of the FCC. While one imaginary may become dominant over others for a period of time, what is interesting is to see is why and how different imaginaries conflict, and how these differences are negotiated in and through policy making processes. Because of this, it makes sense to conduct an analysis in units of social groups rather than nation-states. Imaginaries are visions shared in varying degrees by a community, and are not the singular vision of an individual. Spectrum policy debates have many voices and communities, perhaps because of the ubiquity of its applications and relatively low barriers to entry for those who are so inclined. These voices include policymakers, scientists, technologists, and spectrum users ranging from amateur radio communities to corporations to Wi-Fi users to government users. While the state may be the ultimate arbitrator of power in terms of its ability to create rules and regulations, the imaginary or imaginaries in which the state operates are built by state-related and non-state actors, and are often contested. Even though these imaginaries are held by units of social groups, because spectrum policy is decided at a national level, imaginaries relating to radio spectrum envision the future on a national scale.

Sociotechnical imaginaries help us understand the complexities of spectrum debates. Spectrum and its related uses and technologies constitute a sociotechnical system which cannot be examined by just a scientific or technical analysis. Nor can the materiality and artifacts of spectrum be ignored in favor of only examining the social and political aspects of spectrum. Spectrum technologies are closely tied with developments in technology practices, cultures of use, and the regulatory environment. Sociotechnical imaginaries allow us to see contestation of spectrum at a deeper level than individual pieces of regulation or artifacts, but rather at a level where the imaginary of spectrum itself is being contested. They also contain a prescriptive dimension which matches well with imaginaries surrounding spectrum, which are often rooted in some conception of a normative good.

Analyzing spectrum through sociotechnical imaginaries contributes to Science and Technology Studies by showing how technical debates are shaped not only by differences in arguments and framing, but by differences in deep sociotechnical visions about the future and the good life. In particular, sociotechnical imaginaries help us understand the role of states and states' policies in defining the conceptions and purposes of technology, and in turn, how technologies are used to reinforce certain future visions of the nation, society, and the good life. Sociotechnical imaginaries allow us to look at artifacts, discourses and practices simultaneously, and the broader imaginaries in which they sit. Furthermore, sociotechnical imaginaries' relationship to co-production makes it a useful tool to investigate moments of emergence, contestation, and stabilization. Historically, all three of these moments are present in spectrum, and moments of emergence and contestation are occurring now with new spectrum-using devices and applications and new proposals for spectrum regulation. Alternate sociotechnical imaginaries of spectrum compete to become the dominant imaginary within the U.S., which are especially seen during emergence and contestation. Seen in this way, as detailed in the historical section of this thesis, current contestation over spectrum is not a new phenomenon, but a continuation of tensions between alternate imaginaries that have reoccurred historically.

More broadly, sociotechnical imaginaries contribute to policy discussion by providing a framework and vocabulary for thinking about technology not as a neutral tool, but as being co-produced and influenced by broader and deeper visions about the future, by visions of technological development, and by visions of the good life. This can offer new ways to think about power and authority, particularly the role of technical knowledge, practices, and artifacts.

As discussed with spectrum, sociotechnical imaginaries provide a way to look beyond the particularities of one case, to see policy from a deeper view. For instance, while stakeholder analyses may be useful for understanding certain case studies, competing imaginaries may contest the notion of who counts as a stakeholder. At a fundamental level, studying sociotechnical imaginaries, and the tensions involved in shaping them help answers questions about who counts, what is progress, and meanings of nationhood – broadly, normative conceptions of good – upon which technological policies (as well as knowledge, practices, and artifacts) are built and contested. Furthermore, imaginaries are not found in individuals but in larger social groups. This allows sociotechnical imaginaries to look beyond immediate stakeholders in Washington D.C. or other centers of policy, and understand technology and policy co-production within a broader cultural context.

Sociotechnical imaginaries likewise contribute to thinking in Human Computer Interaction by providing a framework and vocabulary for thinking of policy not as an external, separate process from technology design, but as something that is co-produced with new technological designs, artifacts, practices, and knowledge. As computing or computer-infrastructure technologies and policies interact more with each other, technologies and policy have to be understood together. Understanding the processes of policy development and technological design and development through co-production means that the discourse and framing of technology is just as important as the technical aspects. Furthermore, analyzing this relationship through sociotechnical imaginaries highlights broader cultural aspects. The role of cultural values in technological design has been investigated both by people outside[23] and

[23] Latour (1992).

within[24] the HCI community, particularly in "third wave" HCI.[25] Further work should be done concerning what cultural values conform to dominant sociotechnical imaginaries, and if and how they should be considered when designing technologies. Further work should also consider not just what values are embedded within technologies, but what broader imaginaries are embedded within technologies as well. Understanding the dominant sociotechnical imaginary shaping technology policies can provide a bridge between technologists and policy makers, and allow the development of technologies less likely to create conflicts (and public relations tensions) between the affordances of a design and technology policies. Furthermore, by comparing differences in imaginaries at the state level, HCI researchers can leverage sociotechnical imaginaries as a tool for designing technologies for other cultures, or technologies for development in other nations.

Evaluating U.S. spectrum policies through sociotechnical imaginaries reveals several themes and issues that repeatedly emerge over both historical and contemporary spectrum debates. These themes represent important dimensions and qualities of spectrum imaginaries which undergo processes of emergence, contestation, and stabilization over time. The first dimension is defining what range of actors are allowed to participate in spectrum debates, both in terms of what groups' imaginaries are deemed legitimate and in terms of what groups are envisioned as legitimate actors. The second dimension is defining what the "public interest" and "the public good" mean. Spectrum is managed in the public interest, but understanding what the "public interest" means varies and is contested over time. The third dimension is that sociotechnical imaginaries are shaped by the regulations and technologies that are already

[24] Nissenbaum, H. How computer systems embody values. *Computer*, 34, 3 (2001), 120-119.
[25] Fallman, D. The New Good: Exploring the Potential of Philosophy of Technology to Contribute to Human-Computer Interaction. *ACM CHI 2011.* 1051-1060.

enacted and in place. Sociotechnical imaginaries themselves do not emerge from a vacuum but are built upon, mobilize, and are constrained by the historical technological and regulatory legacies of spectrum. The last dimension reveals the direct and real consequences sociotechnical imaginaries have on immediate questions surrounding spectrum management policies and techniques. This is particularly seen through the actions of the Federal Communications Commission and other policy actors, in debates such as whether spectrum should be managed through a property rights or commons like regime.

HISTORICAL SOCIOTECHNICAL IMAGINARIES OF SPECTRUM

I first explore these themes of sociotechnical imaginaries through an analysis of the history of U.S. spectrum policy. I then use two case studies to explore these themes and dimensions in a contemporary setting. I split the history of spectrum into five major parts. First are the pre-regulation years, when radio technology first emerged, circa 1900 to 1912. The second period covers 1912 to 1934, when the first major rules regulating radio were created through multiple Radio Acts and the 1934 Communications Act. The third period discusses the emergence of FM radio and television in the commercial broadcasting system circa 1934 to the 1960s. The fourth section reviews broadcast reform movements in the 1960s and 1970s. The fifth historical section discusses deregulation practices from the 1970s to the present.

PRE-REGULATION YEARS (CA 1900 – 1912): THE *RADIO ACT OF 1912*

Early Radio

There is a wide and rich history surrounding the emergence of radio technology and early radio practices. Much of my analysis builds upon the work done by Susan Douglas in *Inventing*

American Broadcasting.[26] This work discusses radio prior to 1912, when the technology first emerged, and before U.S. regulation of radio. Douglas investigates this period as the social construction of radio, placing the birth of radio within the context of pre-1912 institutions, discourses, and cultural practices. I expand on this analysis by reframing the groups, values, and desires that Douglas writes about within the framework of sociotechnical imaginaries.

Guglielmo Marconi first demonstrated the wireless radio in the United States in 1899, which was met with wonder, representing quite a new spectacle, particularly for the press.[27] In the early years, three main imaginaries around radio began to develop: centered on the press, the Navy, and amateur users. The first imaginary had the press at the center of radio, using it for communicating news information at faster speeds and lower prices than the telegraph or telephone, which was publically wrapped in humanitarian concerns, such as the potential for international diplomacy and greater understanding between countries.

A second imaginary had the U.S. Navy at the center of radio. Between 1899 and 1912, the U.S. Navy became one of the largest clients of radio communication, for ship-to-ship and ship-to-land communications, although it did take time for them to adopt it. Some viewed that American radio lacked international standing because of the lack of the U.S. government promotion of wireless compared to other European nations and advocated a greater role for the government in radio. President Roosevelt's naval activism also showed his desire for a strong and powerful navy, and he became concerned about radio interference caused by the press and private wireless operators as he learned about how radio interference caused the Russians problems in the Russo-Japanese war. In 1904 a government board, the Interdepartmental Board

[26]Douglas, Susan. *Inventing American Broadcasting, 1899-1922*. Baltimore, MD: Johns Hopkins University Press, 198.
[27]Douglas (1987) 22

of Wireless Telegraphy, suggested that the Navy should manage radio in the U.S., proposing legislation disallowing private companies to erect stations where there is interference with a Naval station, and urged for the licensing of private stations under the Department of Commerce. The press view conflicted with this vision, as the press stood to benefit financially more from private use of wireless and condemned this plan as a “takeover” of radio.

A third imaginary of radio had amateur users at the center. Amateur radio users, mostly young men, had access to crystal radio receivers, and were able to use it to communicate and listen to each other, envisioning radio as a way for “the people” to communicate, and serve as a vehicle for social and individual progress. Amateur wireless clubs were created across the country, and at first created an informal wireless network, eventually forming the American Radio Relay League in 1914. This view clashed with that of the Navy: while there were more amateur operators than Navy operators, a number of amateur users deliberately sent false or obscene messages to the Navy, such as a false signal for help for a sinking ship. This caused the Navy to desire restricting the activity of amateur radio users.

Around 1910, several hearings and bills were created in Congress to try to figure out how to best manage spectrum. The problem space begun to be defined – should radio be administered by one man, a wireless czar, or by many people? Should this administration have autocratic or bureaucratic management powers? Yet Congress did not see the conflicts about radio spectrum as one about the public interest, or one that concerned the general population, so no bills were passed into law. Views about the role of radio and the public shifted, however, after the sinking of the Titanic in 1912.

Radio Act of 1912

The Radio Act of 1912 addressed the question of "Who has the right to transmit?," a controversy which had been slowly brewing during the previous decade. After the sinking of the Titanic, Congress began to view the need for more formal procedures of transmitting and receiving distress calls, and that regulation of radio spectrum was needed in order for government (and corporate) institutions to serve the public with uninterrupted wireless service. Not seen in this vision were amateur users. While both Congress and amateur users felt that radio needs to benefit "the people," amateur users felt that they represented "the people," while Congress believed that amateur users bring more harm to "the people" by creating wasteful and dangerous interference, and that "the people" were best served by some form of government stewardship over spectrum.

The Radio Act of 1912 required that all radio operators be licensed, that stations adhere to certain wavelength allocations, that distress calls have the highest priority, and that the Secretary of Commerce has the power to issue licenses and make other regulations. Amateurs were taken out of mainstream radio usage, demoted to only being allowed to use short wavelengths, seen as useless at the time. The Act also adopted some international radio standards, such as the wavelength used for distress calls and the adoption of SOS as the distress call. The act also specified certain wavelengths for the U.S. government to use, and increased the Navy's hegemony over the radio system by allowing them to receive and transmit commercial messages in areas without commercial towers.

During World War I, the Navy took over all radio stations in the United States. Secretary of the Navy Josephus Daniels believed that radio was a natural monopoly, and would best function as a monopoly run by the government. To some extent, this was also wrapped in a nationalistic view, as at the time, the only private company with the capacity to take control of radio was Marconi, a non-American company.

While total government control did not last past World War I, the idea of radio as a natural monopoly stayed, as RCA, as a sanctioned monopoly ruled radio manufacturing and much of radio communications, along with its corporate allies GE, Westinghouse, and AT&T, tied together by the cross-licensing of radio patents. This was supported by the government, as the Navy gave patents it held in long distance wireless to the private companies.

Despite the relocation of amateurs to short wavelengths, they continued to work with radio, promoting the idea of broadcasting radio rather than using it for point to point communications. Soon broadcasting expanded beyond just individual amateur users, as stores, schools, and other establishments began setting up their own broadcast stations. However, there were only two wavelengths that could be used, 200 or 360 meters, and radio congestion and interference soon became intolerable. Interestingly, in some areas, broadcasters attempted to overcome this problem by having informal agreements to time share; taking turns to broadcast on the same wavelength. But the number of new broadcasters operating radios posed a new problem to be solved.

By this point, the predominant imaginary around spectrum stabilizes – that it is a common property resource that all Americans have an interest in, but it needs Federal Government custodians. The Federal Government sees the public interest as best served by predominantly licensing spectrum to commercial operators. The Radio Act of 1912 formalizes the erasure of the amateur users' sociotechnical imaginary around radio, and subsequent actions after WWI establish private corporations as the main voices behind radio. The question of how to manage spectrum is not completely settled, but major problems are seen with interference in the commons-like regime when broadcasters all had to share the same frequencies. This main framing of spectrum is present through many subsequent government actions surrounding spectrum.

FORMATIVE YEARS (1912 – 1934): THE *RADIO ACT OF 1912* TO THE *1934 COMMUNICATIONS ACT*

Radio Act of 1927 and the FRC

The dominant imaginary of spectrum associated broadcast radio with commercialism. Westinghouse created the first broadcasting station KDKA in 1920, and many other companies and stores followed by creating their own radio stations. A variety of ideas were proposed about how to fund radio, but by the mid 1920's, advertising became the predominant method. The Commerce Department originally allocated only one band for broadcasting, later adding a second band to ease congestion. Power requirements for the second band meant that mostly richer users, often companies and corporations, could afford to move to the second band, leaving the multitude of broadcasting amateurs and local groups on the first band. Yet eventually both bands become congested to intolerable levels.

In response to the overcrowding and interference of broadcasters in just two bands, and because the Commerce Department did not have the authority to act, the Radio Act of 1927 created the Federal Radio Commission to bring order to the system by licensing spectrum and maintaining government stewardship, but not ownership, over radio spectrum, using the standard of the "public interest, convenience, or necessity." It also began to split responsibilities between government and non-government users of radio spectrum, by having the Commission be in charge of non-government stations, and the Secretary of Commerce be in charge of certain aspects of government stations.

The FRC's actions favored commercial broadcasting, following the dominant imaginary around spectrum. The FRC widened the broadcast band, and allocated some regional and local channels, but also 40 "clear channels," a series of high powered nationwide stations. For these, the FRC preferred commercial stations over stations that were meant to express religious, political, or socioeconomic viewpoints.[28] In general, the FRC issued licenses to well-financed commercial stations over non-commercial stations. The FRC publicly justified this by saying that spectrum scarcity meant "general purpose" commercial stations better served the public than "propaganda" non-profit stations, though implicitly, the licensing system that the FRC established was only profitable through commercial advertising.[29] Since commercial interests like RCA controlled much of radio, finding a way to make radio profitable was an implicit goal of the regulatory regime.

The FRC had a public interest goal as well, to stabilize usage of the airwaves in the "public convenience, interest, or necessity," a generally stated term. This is partly based in the scarcity rationale for managing spectrum. A diversity of speech and viewpoints is good for a democratic society, but because spectrum is seen as "scarce," not everyone can speak, so the government imposes rules and limits who can use the airwaves. At this point, licensees do not get property rights to spectrum, but act as trustees to the publicly owned airwaves. Two imaginaries start to form around the idea of the "public good." The first is based in localism. Each licensee is a local station that would engage in its own programming, not part of a national

[28] Ismail, Sherille. (2011) Transformative Choices: A Review of 70 Years of FCC Decisions. Journal of Information Policy.

[29] Ismail (2011)

network, and therefore responds to the local community's interests, and is contributing to the "public good." The second is focused around national programming and nationwide broadcasting – this is view of corporate broadcasters, who could use economies of scale and advertising to create profitable businesses. Hoover also praised efforts to provide for nationwide broadcasting, implicitly supporting the network-affiliate system that started to develop.[30] The rules of the 1927 Act are in accordance with the first imaginary, assuming that local stations would engage in their own programming, yet it did not change the emerging structure of broadcasting, which was moving toward the second imaginary, building networks to gain more viewers and more advertising money.[31] These differences would cause conflicts later on.

The (failure of the) 1930s reform movement

The 1930's reform movement represents an alternative imaginary of radio, imagining a wider range of actors involved in radio, a different way to manage spectrum, and a differing idea of what the "public good" represents. Many in the reform movement were educators who wanted a larger role in broadcasting. In the 1920s, colleges and universities had launched stations, but financial pressures, unfavorable assignments, interference from other stations had started to push many out of broadcasting. They formed the National Committee on Education by Radio in 1930. After being pushed to the side after the 1927 Act, they hoped for greater acknowledgement in the 1934 Act. The FRC interpreted "public good" as good to advertisers while educational broadcasters were categorized as "special interests" and given part-time channel assignments, generally confined to daytime hours and low power.[32]

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[30] Horwitz, Robert Britt. *The irony of regulatory reform: The deregulation of American telecommunications*. Oxford University Press, 1989. 115
[31] Horwitz (1989), 121
[32] Barnouw, Erik. 1968. *The Golden Web: A History of Broadcasting in the United States – Volume II – 1933 to 1953.* Oxford University Press, New York. 23

The goals of the reform movement are represented in Congress by the Wagner-Hatfield amendment during the discussion of the 1934 Act. The amendment would redistribute channels from the current model, nulling all licenses and allowing the new FCC to redistribute channels such that one-fourth of channels would be allotted "to educational, religious, agricultural, labor, cooperative, and similar non-profit-making associations."[33] Senator Hatfield attacked the commercial "pollution of the air," while other proponents attacked the FRC's use basing channel allocation on financial resources, which benefitted corporate broadcasters. This alternative spectrum management plan of 25% of stations for non-profit purposes, wider view of actors in radio, and different interpretation of "public good" exemplify the reform movement's imaginary about radio.

Opponents of the amendment included many of the incumbent broadcasters who benefitted under the system created by the 1927 Act. The broadcast lobby, in the form of the group the National Association of Broadcasters, helped defeat the congressional amendment. The newly created FCC investigated the issue, and reported that commercial broadcasters had the ability to cover educational and non-profit needs, and just needed "cooperation in good faith." While broadcasters did make some effort, such as hiring public service directors and liaisons with non-profit groups, the reform movement failed in its goal of allocating 25% of stations to non-profit purposes.[34] By the 1930's, educators did not have any clout or power in radio and had to accept channels in experimental bands, yet to be developed for commercial purposes.[35]

[33] Barnouw (1968) 24.
[34] Barnouw (1968), 26-27.
[35] McChesney, Robert Waterman. *Rich media, poor democracy: Communication politics in dubious times*. University of Illinois Press, 1999.

Communications Act of 1934

The Communications Act of 1934 established the Federal Communications Commission, replacing the FRC, assuming powers over radio and with other telecommunications systems like the telephone network. While the FCC gives out licenses to stations, section 305 of the Act gave the President power to assign frequencies to government owned stations, creating the basis of separation between Federal and non-federal radio users. As discussed, the imaginary represented by the education reformers and amateurs was relegated to the side, while the predominant imaginary envisioning radio with commercial broadcasting actors was once again formalized into law. The defeat helps show the growing importance and power of the broadcast lobby. Further helping them was a 1932 FRC report that concluded that radio was a healthy industry, with commercial advertising playing a key role. By the time the FCC was created, the basic commercial broadcasting industry's structures were already defined, and the act predominantly left this in place.[36] The 1934 Act also set the precedent for dividing the authority over spectrum use for federal government uses and non-federal uses. The executive branch maintained authority over managing federal uses of spectrum, while the newly created FCC managed non-federal uses.

Unlicensed Devices

Since 1912, radio operators were required to have some type of government licensing. By 1938, the FCC found that there may have been an oversight in the Communications Act of 1934. While the FCC was tasked with licensing spectrum to individual entities, the Act failed to recognize that nearly all devices that use electricity emit some type of electromagnetic waves, though usually at very low power levels. Rather than requiring the FCC to regulate every

[36] Horwitz (1989), 90

individual electrical device, such as record players, the FCC created a set of rules allowing those devices to be created and used, reasoning that if emissions were weak enough and within a short enough range considered unmeasurable, they would not rise to the level of "harmful interference."[37] Specified maximum signals were later set. In the 1938 rules, most unlicensed devices were designed to operate in either medium frequency (0.3-3 MHz) or high frequency (3-30 MHz) bands.[38] These rules became known as the Part 15 rules, which were the basis of later decisions regarding unlicensed uses of spectrum. However, at this point, this was not a central concern for the FCC. It still fit in with the FCC's goals of preventing harmful interference.

COMMERCIAL BROADCASTING (ca 1934 – 1960s): INTRODUCING FM RADIO AND TELEVISION

With the relegation of amateur users to non-prime parts of the spectrum and the growth of the broadcast lobby, commercial broadcasters and the FCC are the predominant actors during this period, which was not heavily contested. However as new spectrum using technologies were created, imaginaries about these new technologies formed, conflicting in notions of the "public interest" and how to best manage the spectrum. Often in this period, there are two pairs of sociotechnical imaginaries that interact and conflict with each other. The first pair is the continuation of two imaginaries from the 1920s concerning the spectrum management and the "public good." Often the FCC supports an imaginary of local broadcasters whose connection to the community and diversity would create programming in the "public interest." Contrast to this is the actions of incumbent broadcasters, who support an imaginary of national networks. The second pair of imaginaries concerns new technologies. The FCC and the incumbent technology users generally support an imaginary where they desire to protect the chief broadcasting system

[37] Carter, Kenneth R. "Unlicensed to kill: a brief history of the Part 15 rules." *info*11.5 (2009): 8-18.
[38] Carter (2009).

(AM radio at first, later very-high-frequency (VHF) television too), and treat new innovations as ancillary systems. This is contrasted to the supporters of the new technologies, such as FM radio, ultra-high-frequency (UHF) television, and Community Antenna television (CATV, later Cable television), who saw their systems as central to or even replacements for the chief broadcasting system.

Licensing Stations

After the Communications Act of 1934, the FCC was now in charge of licensing radio stations. In 1934, a licensee acquired no property rights, and only had use during the time of the license (up to 3 years, but often 6 months). The FCC could renew the license if it felt the "public interest, convenience, or necessity" would be served. The FCC could not censor broadcasts a priori, but could consider past programming in determining public interest, convenience, or necessity. While technically licenses did not have property rights and could not be sold, station equipment could be sold, and was often sold as a proxy at many times the value of the equipment.[39] Erik Barnouw argues in *A History of Broadcasting in the United States* that the 1934 Act reinforced an invalid premise from the 1927 law, that American broadcasting was a local responsibility exercised by individual station licensees, when actually little local autonomy existed and most control belonged to networks, advertising agencies, and sponsors, who were removed from the licensing and renewal process, thus the FCC's focus on licensing and renewal didn't concern itself with the "main arena" of broadcasting.[40] Likewise, Robert Horwitz in *The Irony of Regulatory Reform* writes that the FCC's fundamental regulatory principle was localism[41] – the FCC was mandated to extend radio service in an equitable fashion to all people

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[39] Barnouw (1968), 30-31
[40] Barnouw, (1968), 33.
[41] Horwitz (1989).

in the US by licensing stations, the regulatory structure promotes many local broadcast outlets at local power (rather than having a limited number of national superpower stations) – so FCC sees the local broadcaster as the base of the broadcast system; the local station responds to the local community needs. The FCC held the imaginary of local broadcasting stations creating diversity, representing the "public good." While the economic structure of commercial radio promoted the broadcast network imaginary, the FCC used its power to try to promote the imaginary it held.

FCC Commissioner James Fly (from 1939-1944) focused on station ownership, believing that diversity of station ownership would create a more vigorous forum of ideas. [42] Fly believed in an active role for the FCC and was an anti-trust advocate. The chain broadcasting investigation ("monopoly probe") by the FCC in 1941, recommended divorcing NBC-blue and NBC-red, and giving local stations more control in determining "network time" and "station time." NBC and CBS, and the National Association of Broadcasters strongly opposed the recommendations, even calling it "the destruction of the existing system of broadcasting." The FCC also promoted its ideal of the "public interest" through content rules, such as the Mayflower Doctrine in 1941, supporting content neutrality by forbidding licensees from editorializing content. This was later expressed as the Fairness Doctrine in 1949, stating that broadcasters must present a "balanced" treatment of controversial issues of public importance.

FM Radio

Engineer Edwin Howard Armstrong developed FM radio for David Sarnoff and RCA in 1934 as a static-free type of radio transmission by modulating the frequency of radio waves. Armstrong and FM supporters represented an imaginary where FM radio would replace AM radio. FM radio had technical advantages by having less static interference, but the technology

[42] Barnouw (1968), 188.

also allowed stations to exist closer to other stations on the same frequency, potentially allowing for more stations to broadcast, and help provide more content and broadcasters in rural areas.

Yet the imaginary held by incumbent radio powers, particularly RCA, viewed the advent of FM radio as ancillary at best. As a replacement service, FM radio would threaten RCA's power over AM radio.

The FCC's actions in regard to FM were the results of two imaginaries – firstly its vision of local broadcasters, and secondly, a commitment to continue with the AM system. At first the FCC gave Armstrong a license for an experimental FM station in 1936. In 1940, the FCC allocated 35 channels for FM in the 42-50 kHz bands, but as an additional service to AM, not a replacement for it. Seeking to avoid the monopoly problem that occurred with NBC in AM radio and create local diversity, the FCC set ownership limits on FM. Furthermore, in 1945 they set limits on FM power and antenna heights, limiting the range of stations, but justified by trying to maximize the number of single local FM markets. Additionally, the FCC allocated the 42-43 kHz band for educational use.

It was almost a forgone conclusion that broadcasting would be a commercial enterprise, but FM radio could not compete with AM radio on an economic basis, as FM radio broadcasters could not achieve the same scales of economy as AM broadcasters. Worsening matters, in 1944-1945, the FCC moved the FM bands to the 88-197 kHz range (due to flawed testimony about sunspot activity and FM interference). While this provided FM with more channels, it hurt FM economically by rendering both broadcasting and receiving equipment useless. The mainstream broadcasting industry community also opposed this move, predominantly because companies saw it as a precedent for moving their television frequency assignments. By the 1950s, FM began to falter, and the FCC encouraged AM owners to duplicate their programming on FM, removing ownership rules. In this sense, FM became an ancillary service to AM, and was largely taken over by the AM interests that the FCC wanted to prevent in the first place.

TV Broadcasting

Unlike radio or telephony, which existed before the FCC's creation, television was a new system that the FCC could regulate from the ground up. However, in *The Irony of Regulatory Reform*, Horwitz argues that the despite an envisioned "freer" system, the FCC tied its own hands with spectrum allocation, creating an inadequate technical structure, succumbing to the pressures of industry, and resulting in a 3 network oligopoly.[43]

The television broadcasting system was predominantly a product of an imaginary by commercial interests. Most people envisioned that television would only be established once industry-wide standards were set for set-makers and broadcasters. In 1935, David Sarnoff wanted RCA to push for television, to encourage the FCC to adopt RCA's standards, and to allocate the required spectrum. Radio companies were the groups investing in television, so their previous ideals and imaginary of a commercially supported broadcast system translated from radio to television. The FCC at first gave television "experimental" status, while waiting for agreement on technical standards. The FCC authorized commercial operation in 1941 (allowing sponsors or the selling of air time), in part to allow operators to recoup some costs invested in developing television, although they continued to leave technical decisions to industry. Without consensus, the FCC helped form the National Television Systems Committee (NTSC) in 1941, which proposed technical standards, allocating television services in the very high frequency (VHF) band, and using FM radio for audio. There was debate about television standards, particularly after WWII. RCA and its supporters wanted to continue the pre-war standards, while CBS and its

[43] Horwitz (1989).

supporters wanted to move television to the ultra-high-frequency (UHF) band, which could support CBS's color television technology, and because UHF had room for at least 30 channels, being more competitive. The Radio Technical Planning Board did not think the CBS color system was viable and wanted to continue the RCA pre-war standards, but expand the number of channels in the VHF band to 26. In 1945, the FCC accepted this logic but only partially implemented it because of spectrum demand. They allocated 13 VHF channels for television, and a portion of the UHF band for experimental television purposes, implicitly acknowledging that they want to see more competition than 13 channels. In that sense, the rationale behind the decision falls in line with the FCC's localism imaginary, that they can create more channels, and more local diversity to serve the public interest.

Yet problems with technical interference occurred with the FCC's plan, and they froze processing on new applications for television stations from 1948-1952. The FCC then laid out a plan in 1949 envisioning television as a local service, distributed equally across the nation, predominantly broadcasting in the VHF bands (with the option of UHF for more channels), partitioning licenses into local geographic areas. But because they tried to implement their vision of local broadcasters based on geography, not population, most local stations did not have the economies of scale that network television stations would have, and could not support themselves in the commercial system. This system allowed the rise of the 3 network oligopoly.

Again, the FCC's imaginary of protecting incumbent broadcasting systems was expressed. UHF broadcasting was undermined, partly because the economics of television broadcasting and local areas meant that extra UHF channels were often not needed, but also because the FCC did not want to move to pre-1948 freeze television channels in the VHF band. Thus the UHF had a hard time obtaining profitable network programming as CBS and NBC often used VHF affiliate stations. By 1961, there were only 39 UHF stations, most operating at a loss, and even then, less than 10% of the nation's television sets could receive them. The FCC's original hope for UHF to create a nationwide competitive system of diverse programming failed.

Amateurs and Alternative Movements

While the range of actors in most mainstream spectrum and telecommunications debates remained limited to the government and commercial interests, radio amateurs were still active and had their own imaginary around low powered radio, particularly in college. In 1936, as students at Brown found that a campus-wide metal network like heating or power systems could be used as the antenna of a very low powered broadcast system. Just 2-10 Watts would let the station be picked up in dorm rooms. Many similar stations sprang up at colleges; student broadcasters picked any available frequency assuming that the FCC had no jurisdiction over a station confined to a campus. However, licensed stations persuaded the FCC to take jurisdiction over these stations due to some technical problems caused by the college stations. At the same time, the college stations were becoming institutionalized into the system perpetuated by the commercial broadcasting imaginary, attracting local and even national sponsors. The Brown students formed the Intercollegiate Broadcasting System, similar to the organizations and lobbying groups created by other radio stations.[44]

Unlicensed Devices

While not a major concern for the FCC, the FCC expanded the use of unlicensed devices during this time period. As the initial unlicensed bands filled up, equipment manufacturers pressed the FCC to allow unlicensed operations on more bands. In particular, higher frequency waves propagate shorter distances, and manufacturers wanted to create devices utilizing these

[44] Barnouw (1968), 114.

frequencies. In 1955, an order of the FCC addressed unlicensed operation from 30-890 MHz, arguing that unlicensed spectrum could be used as long as those radio devices to not cause harmful interference. If electromagnetic radiation could be kept within certain limits, then it was considered that the device did not cause harmful interference.[45]

REFORM MOVEMENTS (ca 1960s – 1970s): BROADCAST REFORM MOVEMENT AND CABLE TELEVISION

Broadcast Reform Movement

The broadcast reform movement of the1960s, occurring at the same time as other activist movements in American civil society, was largely concerned about broadening the range of actors involved in broadcasting, and changing the conception of “the public good” or the “public interest.” This case marked the beginning of widening regulatory and judicial processes to regular citizens by granting legal “standing” to citizens, enabling new political issues to be discussed in the public area.[46] Prior to the case, there was no way for citizens to publicly challenge broadcast licenses as determined by the FCC beyond filing a complaint about the licensee which more than often had no effect or impact. Only those with property interests, namely those claiming economic injury and electrical interference, had standing before the FCC. The tensions surrounding who should be allowed to have a voice in communications and broadcasting debates came to the surface in the 1966 case *Office of Communication of the United Church of Christ v. Federal Communications Commission*, which expanded the definition of who has legal “standing” to argue before the FCC.

[45] Carter (2009).

[46] Horwitz, Robert. "Broadcast reform revisited: Reverend Everett C. Parker and the “standing” case (office of communication of the United church of Christ v. Federal Communications Commission)." *Communication Review (The)* 2.3 (1997): 311-348.

One sociotechnical imaginary was held by those favoring the status quo, including broadcast station WLBT in Jackson, Mississippi, and several people at the FCC. This imaginary believed that regulatory agencies, particularly the FCC, acted in and represented the public interest, and thus the interest of the public is already represented and integrated into regulatory processes. This meant that they had a narrow view of what constituted legitimate actors in this space, codified by the notion of who was allowed standing before the FCC. In practice, standing before the FCC was restricted to parties with a property interest affected by government action, property meaning those claiming economic injury or electrical interference. Those without property interests were considered already protected by the FCC. Horwitz writes that these standards "were built on a fundamental acceptance of the agency as the arbiter of an objective, value-free technical rationality."

An alternative sociotechnical imaginary was held by the reform groups. Their belief was that the existing regulatory system did not adequately protect the "public interest," in this case, station WBLT did not give fair coverage to African Americans, but more generally it was seen that the FCC's authority alone was not sufficient in protecting and promoting the public interest. This view imagined those without direct property interests to still have standing before the FCC. The growth of the movement of reform groups was influenced by other broader social change movements during the time, like the Civil Rights movement. The reform groups had several strategies to accomplish their goals: challenging the license renewals of existing broadcast stations that they felt did not serve the public interest; secure a right to at least limited citizen access to the airwaves; and look to new technologies to alleviate ongoing problems and limits in the broadcasting system, such as cable television. [47] The case *Office of Communication* was ultimately decided in favor of expanding who had right to legal standing, opening it up to citizens. This allowed citizen activists to take greater roles in the license renewal process, and forced broadcasters to adapt to local demands, especially those of minority groups.[48]

Beyond the broadcast reform groups is another imaginary that goes further than the aforementioned reform groups, which is that of unlicensed "pirate radio" advocates, who were often associated with community radio stations.[49] This view also saw the predominantly commercial system of broadcast licensing in the United States as not serving the public interest by not truly representing free speech. The Public Broadcasting Act of 1967 established the Corporation for Public Broadcasting and National Public Radio (NPR). NPR required affiliates to meet certain budgetary and professional criteria. When they had trouble getting affiliates, they asked the FCC to help make room for high-powered stations meeting their criteria by shutting down low powered noncommercial FM stations, many of which were community stations which lost their voice by either integrating into NPR as an affiliate or shutting down. Yet "pirate radio" groups advocated for local, unlicensed community broadcasts, not affiliated with NPR. Many of the proponents of unlicensed broadcasting were also related to the counterculture movement, supporting unlicensed radio stations that played music beyond the Top 40 hits and more closely represented local interests. The usual response by the FCC was to shut down these unlicensed stations once they were discovered, such as WRAD, which in 1969 was broadcasted in Yonkers, New York, from a modified military surplus transmitter from a person's basement. The FCC shut down the station a few weeks after it started broadcasting.

[47] Horwitz (1989), 19.
[48] Horwitz, (1997).
[49] Soley, Lawrence. Free Radio: Electronic Civil Disobedience. Westview Press, Boulder, Colorado, 1999.

Cable TV

Cable television has its origins in Community Antenna TV (CATV). In the late 1960s cable was championed as a "new technology," though Community Antenna TV had existed since the 1950s. It was developed during the FCC's freeze on licensing new television stations, and allowed towns without any or only a couple of stations and channels to bring in television programming from further away. Yet at this time, the FCC was trying to promote UHF television as a way to include more voices on television and solve problems around serving the "public interest," and saw CATV as a threat to the success of UHF television's chances. The FCC's primary sociotechnical imaginary saw traditional broadcast technology and UHF television technology as the future of television, and as the way to serve the "public interest." Thus the FCC limited cable systems to try to protect UHF, and classified cable television as a service adjunct to conventional television. Yet the CATV industry grew, and formed its own association, the National Community Television Association, and the awareness began to spread about the possibility of creating a subscription system in the future.

During the 1960s and 1970s, citizen groups, think tanks, and a White House Presidential Task Force on Communications Policy began to see cable TV in a new light. The sociotechnical imaginary held by this group was rooted in similar goals as the FCC, creating a television system that served the "public interest," but these groups saw cable TV as the central technology, rather than UHF television. Ideas that began being associated with cable were that it was more participatory and democratic by allowing more channels and voices to participate, that it had an appeal to local government, educators, seniors, and minority and excluded groups. Many of the ideas being associated with cable were also the ideas promoted by the broadcast reform movement, and the imaginaries and spheres of the broadcast reform movement and the cable movement began to merge. Cable, not UHF, would be the solution to problems in conventional commercial broadcasting. Furthermore, the Rand Corporation published reports in the 1970s exploring the technical promises of cable, and the role of the FCC's regulations in stifling cable's potential. The political clout of cable began to grow as well, as the CATV industry morphed into the cable industry, experiencing growth and the creation of a cable lobby. In 1972, the FCC changed its rules surrounding cable, which amounted to a compromise between the two competing imaginaries surrounding the future of television. The new cable rules still protected conventional broadcasters, but introduced a greater degree of liberalization for cable, allowing them to more easily enter markets to compete with conventional television broadcasting.

Unlicensed Devices

In addition to new technologies like cable television, new technologies were also being developed in the unlicensed spectrum bands, such as wireless microphones, garage door openers, cassette recorders, retail store anti-theft systems, and cordless telephones. These devices were permitted by the FCC, which would make additional modifications to part 15 rules, incrementally adopting device-specific regulations.[50] Though over time, these *ad hoc* changes created a complicated and less cohesive set of Part 15 rules.

NEW CHANGES (ca 1970s – PRESENT): DEREGULATION

Deregulation

Starting in the 1970s and continuing through this time period, a wider movement of government deregulation began to spread. Politically, deregulation was looked upon favorably by both political parties. Liberals saw deregulation of government agencies as a solution to regulatory capture and entrenched corporate power, while conservatives saw deregulation as a

[50] Carter (2009).

solution to bureaucratic regulatory agencies causing economic inefficiency.[51] Many infrastructural industries were deregulated, such as airlines, railroads, banking, and telecommunications. Often deregulation was seen to serve the public interest by adding competition, relaxing rules, and by simplifying the problems new technologies posed to old regulations. [52] The actions of the FCC during this time took place within this context. However, different imaginaries emerged regarding how deregulation could occur with regard to spectrum.

Formation of the NTIA

As established in the Communications Act of 1934, the management of federal and non-federal uses of spectrum differed; the executive branch managed federal uses of spectrum while the FCC managed non-federal uses of spectrum. This dual organization continued, when the National Telecommunications and Information Administration (NTIA) was formed at the Department of Commerce in 1978 to manage federal uses of spectrum.

Changes to Allocation

Regarding spectrum, deregulation meant finding alternative methods of allocating spectrum rather than having hearings by the FCC. The predominant sociotechnical imaginary around spectrum during this time period was to introduce market mechanisms into spectrum and telecommunications. In 1969, Arthur de Vany published the Stanford Law Review paper, “A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study” one of the earlier arguments proposing to use market mechanisms as a way to more efficiently allocate spectrum than the FCC’s assignments. During the Reagan administration in the 1980s, the FCC’s concept of the public interest began to shift, from the “perception of broadcasters as community trustees” to “a view of broadcasters as marketplace

[51] Horwitz (1989).
[52] Horwitz (1989).

participants," that communications policy should try to maximize the services the public desires from a scarce resource.[53] This could include mechanisms such as spectrum auctions, and the sales and resales of licenses. This was the vision of the FCC chair Mark Fowler and his chief aide Daniel Brenner in 1982. The actual implementation of this vision by the FCC was slower and more piecemeal, but got rid of many regulations, such as content regulations, structural regulations, and commercial length limits in the broadcasting industry. The Omnibus Budget Reconciliation Act of 1993 formalized and directed the FCC to use spectrum auctions to allocate spectrum, introducing market mechanisms into the allocation process. The shift to market-based regulations also helped solidify the interpretation of spectrum licenses as property rights.

Beyond broadcasting, this imaginary of integrating markets into spectrum and communications regulation affected the internet. In 1992, the NTIA envisioned the internet, then controlled by the National Science Foundation, as an "information superhighway" – a decentralized network, universally accessible, but fully private. This was realized by 1994, when the National Science Foundation's funding for the internet stopped, and private ISPs began to grow.

Telecommunications Act of 1996

Because of the ad hoc nature of FCC regulations over the previous half century, and introduction of new technologies that posed problems for old regulations, an overhaul of the Communications Act of 1934 was undertaken, which resulted in the Telecommunications Act of 1996. In the Congressional debates, there were many corporate and incumbent interests who took part, particularly through the use of money through political action committees (PACs). Phone companies and cable companies were often represented by corporate funds, while mass

[53] Aufderheide, Patricia. *Communications policy and the public interest: The Telecommunications Act of 1996*. Guilford Press, 1999.

media, programmers, and distributers contributed individual funds. [54] Unrepresented by PAC money were consumer groups, religious groups, minority groups, the disabled, and other constituencies, and they had less of a voice during this debate, ironically, similar to the actors involved in the debates around the 1934 Act.

One of the shifts in the 1996 Act was enabling a shift toward digital TV broadcasting. In *Communications Policy and the Public Interest*, Pat Aufderheide explains this as a convergence, as digital TV could conceivably be interchangeable with a PC, becoming an entry point to the internet, and satellite and cable could offer hundreds of digital channels. By this time, this is a corporate, not community view of cable. In theory, more channels could suggest the potential for more diversity, although incumbent broadcasters benefitted more than potential new entrants. For instance, Rupert Murdoch received 6 MHz of additional spectrum to broadcast in both analog and digital at a discounted price, without any strings attached. Overall, the process of writing the 1996 Act responded much more to incumbent and corporate interests over those of other groups.

Cellular Services, Unlicensed Spectrum and Spectrum Sharing

While Bell Labs introduced the concept of cellular networks in 1947, it was not until the 1970s when the FCC began setting aside spectrum to be operated by carriers for telephony, and 1982 when they began accepting applications for licenses.[55] The first round of applications was evaluated based on engineering and business plans provided by applicants, while later rounds were allocated based on a lottery system. [56] This became known as first generation (1G) cellular technology. In the late 1980s and early 1990s, the cellular telecommunications industry began

[54] Aufderheide (1999).
[55] Lemstra, W., and V. Hayes. "License-exempt: Wi-Fi complement to 3G."*Telematics and Informatics* 26.3 (2009): 227-239.
[56] Lemstra, Hayes (2009).

looking for ways to increase network capacity, which eventually became known as 2G. Qualcomm pitched a new concept called code division multiple access (CDMA), with a theoretical increase of 40 times the capacity, but it was a new and untested technology. The industry decided to mainly pursue a revised time division multiple access (TDMA) specification, which was a revised specification of what was already in place, and made upgrades easier. However, the industry association recommended the continuation of developing CDMA, leading to PCS PrimeCo, Airtouch and Sprint to adopt CDMA by 1995. [57] The success of SMS messaging on 2G networks indicated the possibilities for data transfer over cellular networks. The standards for developing 3G equipment began being developed between 1986 and 1999.[58]

As mentioned earlier, the FCC's Part 15 rules regulate unlicensed devices at low power. But by the 1980s, the ad hoc nature of these rules and introduction of new devices that could operate at higher frequencies than the Part 15 rules originally anticipated meant that the rules were poised for an overhaul. This fits in with the broader context of deregulation at this time. In 1985, an FCC decision opened up bands previously designated for industry, science, and medicine (ISM) to unlicensed devices operating at very low power. A 1989 revision to the Part 15 rules created a more flexible environment to develop unlicensed devices as long as the device meets certain emission limits within certain bands, which were also increased – though new "restricted" bands were also created to protect sensitive and federal radio uses.[59] These unlicensed bands can be seen as an early type of spectrum sharing, as multiple users must share a single band with each other. Through the 1990s, new devices were created that used digital

[57] Lemstra, Hayes (2009).
[58] Lemstra, Hayes (2009).
[59] Carter (2009).

modulation techniques to transmit information, such as Wi-Fi and other wireless computer to computer communications.[60]

The beginning of Wi-Fi, or more broadly, wireless local area networks (WLAN), started after the 1985 FCC decision to allow the operation of low power unlicensed devices in the ISM bands. The National Cash Register Company began taking the lead in 1987, to find a wireless solution to the problem of rewiring cash registers when department stores reconfigured their sales floors.[61] The IEEE 802.11 group was soon created, and the first IEEE 802.11 standards allowing WLANs were released in 1997.[62] These standards have been improved over time to increase the data rates of transmissions.

The growth of unlicensed spectrum uses led to the development of an alternate sociotechnical imaginary promoting the idea of a spectrum commons, rather than a property-like view of spectrum. Instead of assigning property rights to spectrum, it could be shared as a common resource among many users.[63] While unlicensed operations do not necessarily prevent the tragedy of the commons from occurring, the FCC's regulations by limiting the power of unlicensed devices mitigates the occurrence of harmful interference. Both the spectrum commons and property views of spectrum occur within the context of deregulation and the exploration of alternate ways of managing spectrum, but in their pure form can be seen to represent two different types of future imaginaries around the future of spectrum.

LESSONS LEARNED

Over the past century of radio spectrum history in the United States, considerable dynamism and change has occurred in the technical, regulatory, and social landscape of

[60] Carter (2009).
[61] Lemstra, Hayes (2009).
[62] Lemstra, Hayes (2009).
[63] Carter (2009).

spectrum. The relative standing, power, and legitimacy of stakeholders, such as the military, amateur radio users, educators, and commercial broadcasters, have shifted over time. The emergence of new technologies, practices, and actors over time further contributes to the rapid change in the space. The emergence of FM radio, broadcast television, cable television, reform groups, and the deregulatory movement all contribute to moments of contestation and signal the variability in the spectrum landscape. These changes affected and reflected broader changes in American society, particularly as spectrum technologies and practices became more tightly integrated and adopted in everyday life.

Nevertheless, several overarching themes begin to emerge along the dimensions of sociotechnical imaginaries of spectrum. While the realization of these dimensions change over time, the dimensions themselves remain consistent. First, the number of stakeholders involved in spectrum debates has fluctuated, particularly the voices of amateur users, community groups, and consumer groups, in terms of legal standing, political clout, and funding. In contrast, the voice of regulators and industry lobby groups has remained much more constant. Before the Radio Act of 1912, the press, the U.S. Navy, and amateurs were the main users of radio, and each represented a different sociotechnical imaginary about the future of radio, and who would control it. While the Navy took control of radio during WWI, by the 1920s, regulation favored commercial broadcasters, and amateurs were limited in their ability to access spectrum. In the 1930s, educators tried unsuccessfully to reform radio, representing an imaginary where non-profit groups had much more influence and access to spectrum. The emergence of new spectrum-using technologies such as FM Radio and Television led to the co-production of regulations favoring commercial broadcasters on those platforms. The 1960's broadcast reform movement was more successful, having its roots in a broader social imaginary influencing other activist movements in

American society during that time period. However, the Telecommunications Act of 1996 was predominantly influenced by corporate commercial interests, particularly through financial donations.

Second, the conception of the “public interest” changes, though for most of the last century until the 1980s, it has been associated with diversity of voice, programming, and ownership. The need for the FCC to look out for the public interest is rooted in the concept that the spectrum belongs to the public, but managed by the FCC. Often new technologies were seen by the FCC, such as FM, TV, and Cable as potential ways to help solve problems around the “public interest” from older incumbent systems, but the desire to protect and improve the incumbent system often led to initial decisions that ended up hampering the new technologies. The FCC also tended to envision a system made up of diverse local broadcasters and acted from that viewpoint, but often that did not match the imaginaries held by the broadcast licensees, and did not match the empirical situation at the time. While sociotechnical imaginaries are rooted in some conception of what is “good,” in the history of spectrum, the definition of “good,” or the “public good,” has itself been contested on a rather regular basis.

Third, new ideas build off the current and historical regulatory and technological environment. Likewise, sociotechnical imaginaries are shaped by prior regulations and technologies. For example, unlicensed spectrum and spectrum sharing are not new ideas. This is important to remember as some advocates of spectrum sharing regimes portray sharing spectrum as a relatively new and novel idea. Unlicensed spectrum and spectrum sharing have existed for over three quarters of a century, formalized shortly after the 1934 Act, although the use of unlicensed spectrum has widened over time. Its prominence in dominant imaginaries, however, has changed over time; at first it was seen an ancillary to the main objective of the FCC, but over time it has become more important to their central goals. Furthermore the emergence of new technologies and regulations were interpreted through beliefs about current technologies and regulations. When CBS wanted to move television to the UHF band to support color broadcasting, institutional momentum tried to keep television in its current VHF band. Similarly while CDMA cellular standards may have had technical advantages, TDMA standards were more widely adopted at first because of their similarities to older standards.

And fourth, different ways of conceptualizing spectrum management have existed, affecting the on-the-ground policy decisions made by Federal agencies. These decisions represent different sociotechnical imaginaries about spectrum. These different imaginaries are particularly salient during periods of emergence or contestation of new phenomena. Before the Radio Act of 1912, it was not clear to the public or policymakers whether spectrum should be regulated at all, and if it should, it was still not clear how it would be administered. Even once decided that spectrum should be regulated, there was greater contention between a more commons-like plan and a more centrally controlled plan. The Radio Act of 1912 established a central licensing system, which started under the Department of Commerce, until the establishment of the Federal radio Commission in 1927 and the FCC in 1934. While the centrally controlled management regime, headed by the FCC, lasted until the 1980s, more recently debates between a commons-like and property-like management regime have occurred, as have debates about the need for a central regulator to protect licensees from interference. However, some aspects of spectrum imaginaries have changed little. The main dimension of the dominant national spectrum imaginary that has not changed since 1912 is that preventing wireless interference is the role of the government. The way in which the government should do this, however, has been contested. For the stakeholder dimension of the dominant imaginary, commercial interests have held a place of power since the 1920s. Yet at several points, particularly in the 1930s and 1960s, this has been contested due to the resurgence of reform movements.

There are many dimensions to sociotechnical imaginaries surrounding spectrum, such as the stakeholders to be involved, what the "public good" is, the current historical context , and how spectrum should be managed and its direct policy implications. While the dimensions of spectrum sociotechnical imaginaries remain constant, the realization of these dimensions has changed over time. The variety of technologies, services, actors, policies, and practices in the spectrum space contributes to shifting visions for spectrum over time. By using sociotechnical imaginaries and their associated dimensions, we can look at tensions among, shifts in, and staying power of various realizations of dimensions, creating a mapping of the historical sociotechnical terrain which we can use to help understand what is currently occurring in spectrum debates. Sociotechnical imaginaries are particularly salient during periods of emergence, contestation, and stabilization. These three phases have been seen repeatedly throughout the history of spectrum. Sociotechnical imaginaries help understand how states interact with other actors through the policy making process, and how those policies help define the purposes of technology. They help provide insight and deeper understanding by being able to capture the sociotechnical complexities and mutual interaction between technology, policy, and broader sociocultural factors during each of these phases. Sociotechnical imaginaries help provide insight into these phases in contemporary debates as well. Current spectrum debates represent the emergence of new regulatory and technical possibilities, and contestation over what imaginary should be the dominant one. Though it is still an unsettled debate, the outcome of the contestation may coalesce and stabilize into a new imaginary around spectrum.

FRAMING THE PRESENT DAY PROBLEM: THE SPECTRUM CRUNCH

Contemporary spectrum debates are generally motivated by the problem of the “spectrum crunch”; that spectrum is in short supply and more is needed to meet the United States’ growing demand for wireless devices and services. The types of technologies, practices, and regulations needed to ameliorate this problem are contested. Further adding to the debate is the emergence of new technologies and proposed regulatory regimes. Their ability to effectively help solve the spectrum crunch is likewise contested.

The FCC’s 2010 National Broadband Plan frames spectrum as a resource that needs to be expanded, due to increased demand for broadband connectivity and broadband applications, as well as a large increase in ubiquitous “smart” devices which communicate using spectrum. They also frame the problem economically, citing economic benefits due to greater technological innovation with the expansion of spectrum for broadband. They use this framing of the problem to call for expanded auctions to reallocate and repurpose spectrum, and making more spectrum available specifically for broadband uses. [64] The problem and looming threat of the spectrum crunch is voiced by a wide variety of stakeholders. Former FCC Chairperson Julius Genachowski explicitly referred to the spectrum crunch in several statements, including in a 2012 speech when he said:

> It's actually our mobile broadband success that’s driving the biggest challenge we face to having a strategic bandwidth advantage in mobile – the spectrum crunch. … Spectrum is finite, at least with current and foreseeable technologies. Just as we must pursue future-oriented energy technologies and policies, we have no choice on our airwaves: we must make better, more efficient use of spectrum.[65]

[64] Federal Communications Commission. "Connecting America: The national broadband plan." (2010). 73

[65] Genachowski, Julius. “Winning the Global Bandwidth Race: Opportunities and Challenges for Mobile Broadband.” Prepared Remarks. University of Pennsylvania. October 4, 2012. http://www.fcc.gov/document/chairman-genachowski-winning-global-bandwidth-race (Accessed April 12, 2014)

In 2010, President Obama issued a memorandum entitled "Unleashing the Wireless Broadband Revolution," requiring the Federal Government to make 500 MHz of [Federally-held] spectrum available for broadband use because of the greater demand for broadband services and a lack of available spectrum. The memorandum links the availability of spectrum to increased technological innovation and greater economic competitiveness as a nation, while it poses that American will lose its leadership in technological innovation and economic power if it does not increase its wireless broadband capabilities.[66] The 2012 report by the President's Council of Advisor on Science and Technology (PCAST) is based upon the same spectrum crunch viewpoint, saying that "[By 2020] wireless technologies are expected to contribute $4.5 trillion to the global economy through the expansion of existing business and the creation of new opportunities. This growth has created unprecedented demand for commercial access to wireless spectrum."[67] The report makes recommendations to create a regulatory and technical environment in which Federal-users can share their spectrum holdings with commercial-users, in order to use spectrum more efficiently.

Non-governmental groups also refer to a coming spectrum crunch as an underlying basis for many of their positions regarding spectrum. For instance, AT&T praised a 2013 bill, the Federal Incentive Act, which would allow the NTIA to offer federal agencies incentives to release unused spectrum for auction, by saying that "the approaching spectrum crunch calls for unique proposals like this."[68] In public comments to the FCC, the National Cable &

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[66] "Presidential Memorandum: Unleashing the Wireless Broadband Revolution." June 28, 2010. http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution (Accessed April 14, 2014).

[67] PCAST. Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth. July, 2012.

[68] McKone, Tim. AT&T Statement on Bipartisan Spectrum and FCC Reform Legislation. 2013. http://www.attpublicpolicy.com/fcc/att-statement-on-bipartisan-spectrum-and-fcc-reform-legislation/ (Accessed February 11, 2014).

Telecommunications Association cites a spectrum crunch specifically in the current Wi-Fi band (2.4 GHz), which is "becoming congested and interference-prone in larger markets." They cite the dramatic increase of Wi-Fi use as leading to this crunch. [69] In public comments to the FCC, Microsoft and Google discuss rising spectrum needs in unlicensed spectrum in particular, due to an increase in wireless internet access, machine to machine communications, health devices, and other applications, noting that "To maintain the exceptional growth and economic contribution of the unlicensed wireless sector, the FCC must designate diverse frequencies for use by unlicensed technologies."[70] In a report published by Time Warner Cable and the New America foundation, a public policy think tank, they write that "there is a looming limit to the number of frequency bands below 3 GHz that can be reallocated, by auction or otherwise, to exclusively licensed use."[71] One main problem is that licensed spectrum has already been allocated and assigned. There is no "new" spectrum to be found. Furthermore, not all spectrum is the same – different frequencies of spectrum have different physical properties, such as how they propagate. Thus, while it is possible for the FCC to clear "new" spectrum by reallocating spectrum for different uses, and moving or consolidating different users to other areas of the spectrum, not all services and applications will physically work on other frequencies. Furthermore, there are costs associated with spectrum licensees needing to modify their equipment in order to work on the newly assigned frequencies. The variety of allocations and full use of the spectrum can be seen in Figure 1, the NTIA's frequency allocation chart.

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[69] Comments of the National Cable & Telecommunications Association. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112072 (Accessed March 20, 2013).
[70] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112070 (Accessed March 30, 2013).
[71] Calabrese, Michael. "Solving the "Spectrum Crunch": Unlicensed Spectrum on a High-Fiber Diet." New America Foundation, and Time Warner Cable Research Program on Digital Communications. 2013.

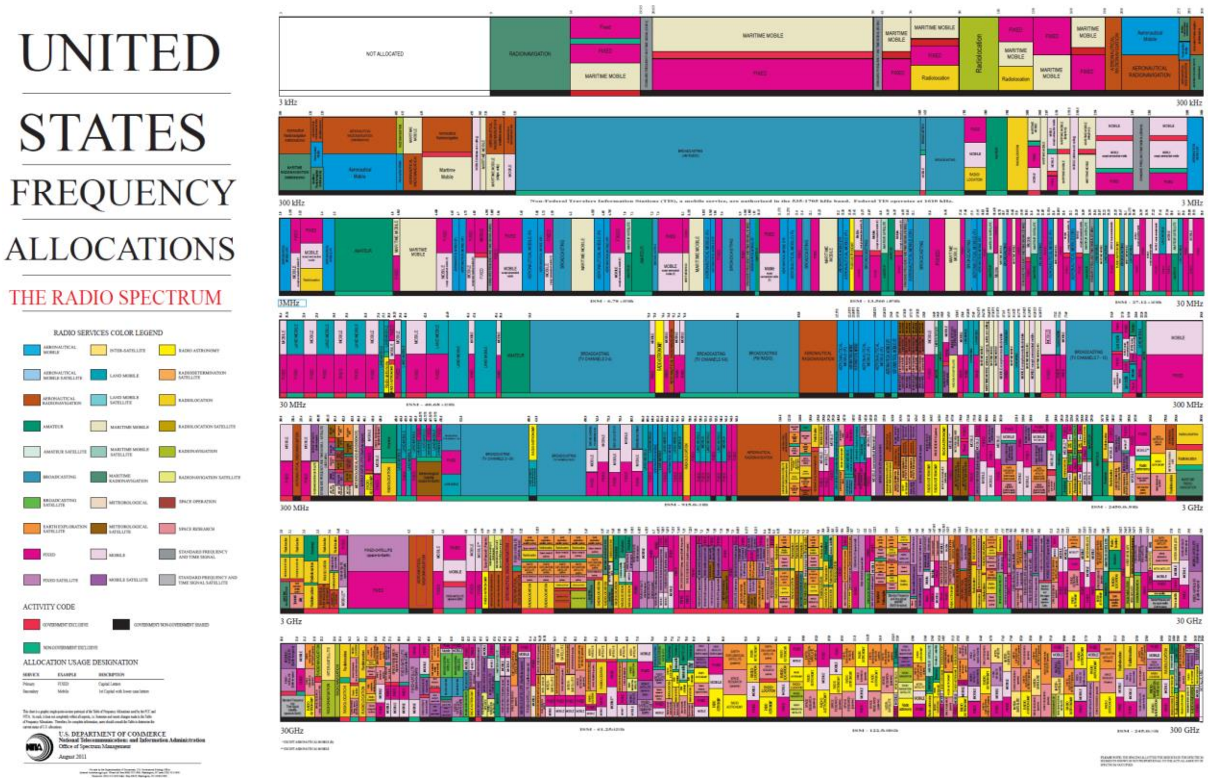

Figure 1. Spectrum allocation chart as of 2011.[72]

The problem of the spectrum crunch is generally portrayed as a problem of supply and demand: there is a limited supply of valuable spectrum, and a very high demand due to a societal increase in wireless services and applications, ranging from cell phones to Wi-Fi to smart devices. This problem is primarily seen in a lack of available of licensed spectrum, but examples of congestion in unlicensed spectrum point to a spectrum crunch in unlicensed spectrum as well. Often the consequences of the spectrum crunch are linked to the economic health of the United States. There is a threat that a lack of spectrum will lead to a slowdown in U.S. technological innovation, and slowdown in economic activity. There are also concerns that consumers will be hurt if they are not able to access the wireless services and applications that they desire.

[72] National Telecommunications & Information Administration. United States Frequency Allocation Chart. http://www.ntia.doc.gov/page/2011/united-states-frequency-allocation-chart (Accessed April 12, 2014).

OTHER FRAMINGS OF SPECTRUM PROBLEMS

Alongside this dominant framing, however, are other important contemporary spectrum concerns. One of these is the question of industry concentration in spectrum holdings, which is prevalent when deciding the rules of who gets to participate in FCC spectrum auctions, and rules surrounding the auctions, such as if a limit on spectrum holdings should be imposed. If one or two licensees have licenses that cover most of the spectrum, then that could lead to a lack of competition. A 2012 policy paper from the New America Foundation argues that greater competition needs to be encouraged in the broadband industry, including mobile and wireless broadband. To encourage this competition, they recommend structuring spectrum auctions to foster competition and make it easier for new market entrants, allowing licensed spectrum to be shared with others if the licensee does not do anything with it in a "use it or share it" model, and enforce interoperability in the smartphone market to lower barriers to switching mobile providers.[73] In another example, for an upcoming spectrum auction, different industry players are advocating for different geographic sized areas that licenses will cover. Larger carriers like Verizon want licenses to cover larger areas to help expand nationwide LTE networks, while smaller carriers represented by the Competitive Carriers Association (CCA) argue that large geographic areas makes it harder for smaller carriers to gain entry and stay competitive with the large carriers' spectrum holdings.[74]

There are also people who critique the notion that the spectrum crunch exists. Some people are skeptical that mobile wireless is the correct solution for providing broadband access in

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[73] Hussain, Hibah, Kehl, Danielle, Lennett, Benjamin, and Patrick Lucey. "Capping the Nation's Broadband Future?" New America Foundation. December 2012.

[74] Goldstein, Phil. Verizon, CCA wrangle over size of licenses for 600 MHz auction. *Fierce Wireless*. (January 10, 2014). http://www.fiercewireless.com/story/verizon-cca-wrangle-over-size-licenses-600-mhz-auction/2014-01-10 (Accessed February 4, 2014).

the United States, and that wired infrastructure would be a better investment. [75] Perhaps the discourse around the benefits of spectrum leads people to expect more of it than is actually possible. Others also dispute the evidence for the spectrum crunch, writing that problems related to a shortage of spectrum may be not systematic, but local problems at certain locations and times, or claiming that metrics defining spectrum congestion are no clearly defined.[76] Some argue that there is not a physical spectrum crunch as much a technical and physical problem as it is a policy problem, that current policy management is inefficient.[77]

Nevertheless, the majority of the discourse surrounding spectrum assumes that the spectrum crunch is a possibility and that such a spectrum crunch would be harmful to the United States. For the purposes of this paper, the spectrum crunch is broadly defined as a sociotechnical problem. Given current technologies and policies, the increased demand for spectrum will likely not be met in the near future, thus both technological and policy solutions should be pursued. Even if the spectrum crunch detractors' arguments have merit, the spectrum crunch has become a pervasive framing for discussing spectrum management, with deep ramifications for the kinds of policy options and technologies through which spectrum use and management are to be achieved. The spectrum crunch has emerged as a relatively new problem, sometime around a decade into the 21st century, and the best solution or best types of solutions for how to address this problem is being contested. Nevertheless, this problem is situated in an environment shaped by the history of spectrum, picking up and reinterpreting past contours of spectrum debates. The technical problem of spectrum congestion and desire for Federal action seems similar to the

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[75] Noam, Eli. "Let Them Eat Cellphones: Why mobile wireless is no solution for broadband." *Journal of Information Policy* 1 (2012).

[76] De Vries, J.P., et al. "The Emperor has no Problem: Is Wi-fi spectrum really congested?" *TPRC 2013.* (2013).

[77] Talbot, David. "The Spectrum Crunch That Wasn't." MIT Technology Review. (November 2012). http://www.technologyreview.com/review/507486/the-spectrum-crunch-that-wasnt/ (Accessed April 14, 2014).

problems of broadcaster congestion in the 1920s. The emergence of new technologies that may help solve the spectrum crunch by allowing spectrum sharing is analogous to the emergence of past spectrum-using technologies like FM radio or broadcast television. Likewise, the emergence of new standards is analogous to the emergence of standards like color television and the CDMA versus TDMA cellular standard debate. Contemporary debates about property-rights based licensed regimes versus commons unlicensed regulatory regimes to alleviate the spectrum crunch builds upon historical debates about the best type of regulatory regime to manage spectrum. Defining the "public interest" and what stakeholders have a legitimate interest in spectrum are again contested. These qualities make current spectrum issues related to the spectrum crunch a good place to use the sociotechnical imaginary framework. In fact, the debates about how to best address the spectrum crunch can be seen as the emergence of a new sociotechnical imaginary about the future of spectrum management and spectrum use.

PROPOSED SOLUTIONS

Both regulatory and technical solutions have been proposed to solve the problem of the spectrum crisis. These solutions are not necessarily mutually exclusive, and in practice a combination of various technical and various regulatory solutions will be needed. However, some technical and regulatory solutions better align with each other than others.

Policy Centered Solutions

There are three general approaches to policy reform: 1) increasing the use of market based solutions, as exemplified by spectrum licenses and auctions; 2) expanding the notion of a spectrum commons, as exemplified by unlicensed spectrum; and 3) some type of policy environment allowing spectrum sharing, which could take many forms.[78,79] While as a conceptual tool, it is easier to understand these three approaches separately, in reality, all three approaches are being pursued simultaneously. The use of one solution does not preclude the use of another solution in general. However, within a certain band of spectrum, there may be one dominant policy approach.

Some parts of the FCC's strategies can be undertaken without committing to a single policy solution. For instance, expanding both licensed and unlicensed spectrum may require the FCC to reallocate certain bands of spectrum, such as changing the use of a band from broadcast TV to mobile services, or reallocating bands from Federal allocations to commercial applications.[80]

Market Solutions

The National Broadband Plan includes recommendations for the FCC to address the spectrum crunch using market solutions, often reinforcing a property-rights model to spectrum management. These solutions try to make the market work more efficiently in an effort to more efficiently assign spectrum for optimal use. The National Broadband Plan recommends that the FCC take a another look at creating secondary markets, allowing spectrum licensees to buy, sell, or rent spectrum in a secondary market, perhaps ideally creating the most value and efficient use for that section of licensed spectrum. [81] The National Broadband Plan also recommends that Congress should allow the FCC to conduct incentive auctions to reallocate spectrum, expanding the amount of available spectrum for necessary uses. An incentive auction is a market based

[78] Peha, Jon M. "Emerging technology and spectrum policy reform." ITU Workshop on Market Mechanisms for Spectrum Management (2007) .
[79] Wildman, Steven S., Johannes M. Bauer, and Carol Ting. "Spectrum governance regimes: efficiency properties and policy choices." *info* 8.2 (2006): 83-96.
[80] FCC (2010), 86
[81] FCC (2010), 83

mechanism where incumbent spectrum holders give up their licenses in exchange for a portion of the proceeds realized by the auction of their licenses.[82] A 2003 paper by Bill Lehr and Lee McKnight discuss simultaneously advancing 3G (licensed) and Wi-Fi (unlicensed) infrastructure.[83] One finding was that secondary markets for licensed spectrum may create more competition. Furthermore, while licensees may have to follow rigid rules, perhaps exclusive use and the predictability of being protected from interference that comes from a license can provide some services that Wi-Fi cannot.

Commons Solutions

A commons solution promotes spectrum as a common resource, rather than a piece of property. This is often realized through unlicensed spectrum regimes. The National Broadband Plan recommends that the FCC should free up a new contiguous nationwide band for unlicensed use, similar to the Part 15 rules, or the 2.4 GHz band where Wi-Fi, Bluetooth, and other unlicensed services are located.[84] Yochai Benkler argues for open wireless strategies in a 2012 article.[85] He finds that spectrum licenses are “limited by transaction costs and strategic intervention in the design and ongoing enforcement of rights” and that open wireless tends to innovate more rapidly. Regarding broadband, he finds that as of 2012, 30-40% of internet traffic is offloaded from 3G and 4G networks onto Wi-Fi, in unlicensed, openly shared spectrum. He argues that wireless internet providers like AT&T are not able to secure enough spectrum through auctions and secondary markets, and that increasing the amount of unlicensed spectrum will help solve this problem.

[82] FCC (2010), 81
[83] Lehr, William and McKnight, Lee W. Wireless Internet access: 3G vs. WiFi? *Telecommunications Policy*. (2003). 27(5-6). 351-370.
[84] FCC (2010), 95
[85] Benkler, Yochai. Open Wireless vs. Lincensed Spectrum: Evidence from Market Adoption. *Harvard Journal of Law and Technology.* 26(1). Fall 2012.

Sharing Solutions

The National Broadband Plan broadly stipulates that the FCC should spur further development and deployment of what it terms "opportunistic uses" of radio spectrum.[86] This portrays a certain form of spectrum sharing. Rather than operating in a strictly licensed or unlicensed environment, a device operating in a shared environment needs some way to tell when or where it is opportunistic to transmit information. Because this is being approached as a relatively novel and emerging way of regulating spectrum on a widespread basis, there are many different proposals and lines of research of how spectrum can be shared, both technically and in regulation. Jon Peha describes several possible spectrum sharing regimes consisting of a primary user and secondary user or users. [87] The primary user would have higher protection rights from interference. Secondary users would be able to use the same spectrum as long as their operations do not interfere with the primary users. This could be accomplished in several ways: for example, secondary user devices could access a database to see if they are currently in a location where primary user devices are not operating, or secondary user devices could "talk" directly to primary user devices to see if it is opportunistic to use the spectrum. The secondary users could operate under a licensed or unlicensed regime. The PCAST Spectrum Sharing report[88] offers another example of a spectrum sharing regime, describing a system of Federal and non-Federal users sharing spectrum. In this case, the Federal users would often be the primary users, while non-Federal users would be secondary. There are many possible problems that arise in spectrum sharing, such as what types of technologies should be used to implement a spectrum sharing

[86] FCC (2010), 95.
[87] Peha (2007).
[88] PCAST (2012).

regime, how should secondary users be regulated, and who, if anyone, should get priority access to spectrum.

Technology Centered Solutions

While technology centered solutions are listed separately, they are intertwined with the policy centered solutions. The technologies are not solutions in themselves, but need to be enabled by policy and regulation. In turn, the adoption of these technologies helps support certain policies and regulations.

White Spaces Databases

White space is spectrum that has been allocated for a use, but is not being used or is unassigned in a specific geographic location. This spectrum can be used for other purposes without impact on the primary usage.[89] White space databases, tested in 2008 and first commercially deployed in 2012,[90] allow devices to contact the database and see where, when, and on what frequencies it is safe to transmit without interfering with primary users. These devices will then transmit accordingly. Thus, white space databases help encourage spectrum sharing policy regimes. The databases were first used to share spectrum allocated television spectrum, but have since been also used to share spectrum allocated to Federal radar systems and medical devices.[91] Databases allow central organization to multiple devices that want to use the same spectrum in the same geographic area. Beyond the creation of the databases, other technical protocols need to be developed to help promote its use. For white space databases, an

[89] PCAST (2012).
[90] PCAST (2012).
[91] PCAST (2012).

IETF group called Protocol to Access White Space database (PAWS) is working on standards to allow devices to access databases.[92]

Cognitive Radio

Cognitive radio is similar to white spaces databases, except rather than using a centralized control mechanism, a device by itself can sense if other devices are transmitting on the same frequency and in the same location, helping to determine when it is opportune to transmit signals. When combined with dynamic frequency selection (DFS), cognitive radios can sense if primary users are transmitting on several frequencies, and then pick to transmit signals on a frequency that is not currently being used. Cognitive radios can also be used to support sharing policy regimes. For example, cognitive radio and dynamic frequency selection allow 5.8 GHz Wi-Fi device to "detect and avoid military radars."[93]

Time Division Duplex

Time Division Duplex (TDD) is a method of transmitting and receiving signals. As opposed to Frequency Division Duplex (FDD), which requires a one frequency to send signals and one frequency to receive signals, TDD can send and receive signals on the same frequency, so it is a more efficient way to use spectrum. TDD technologies could work with any type of policy solution. For example, Wi-Fi, implemented on unlicensed spectrum, and 4G, implemented on licensed spectrum, can be both be implemented using TDD (although 4G can also be implemented using FDD).[94]

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[92] Protocol to Access WS Database https://datatracker.ietf.org/wg/paws/charter/ (Accessed April 14, 2014).
[93] PCAST, (2012).
[94] Comments of Sprint Nextel Corporation. (January 25, 2013) http://apps.fcc.gov/ecfs/document/view?id=7022112071 (Accessed March 20, 2014).

TWO CASE STUDIES

The following are two cases that have occurred since 2012. Both explore the FCC's Notice of Proposed Rule Making process, where the FCC solicits public comments on a proposed set of rules before finalizing and adopting them. This process will allow us to see at least the public statements of groups involved in spectrum debates, and help us map out the positions of different groups. Both examples discuss spectrum sharing, albeit in different contexts.

The first case primarily describes the expansion of licensed spectrum, but asks how primary licensed users can share spectrum with unlicensed secondary users. The second case primarily describes the expansion of unlicensed spectrum, but also asks how unlicensed devices can share spectrum with incumbent services still located in the same band. Each case is explained through a brief background, some of the major viewpoints on the case, and then a discussion relating the debate to deeper framings and sociotechnical imaginaries. Together, these cases provide evidence of the emergence of a new sociotechnical imaginary concerning the future of spectrum.

CASE 1: THE INCENTIVE AUCTION

In October 2012, the FCC issued a Notice of Proposed Rulemaking (NPRM) concerning "Expanding the Economic and Innovation of Spectrum Through Incentive Auctions."[95] The FCC intended to free additional spectrum by conducting an incentive auction, a different type of auction than they normally use.[96] Incentive auctions, first proposed in the 2010 National

[95] Federal Communications Commission. "Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions." 2012. http://www.fcc.gov/document/broadcast-television-spectrum-incentive-auction-nprm (Accessed March 11, 2014).

[96] Note: The FCC has been conducting auctions to allocate spectrum since 1994, after Congress gave them the authority to do so in the 1993 Omnibus Budget Reconciliation Act, using bidding as a more efficient way to assign

Broadband Plan, are a tool to repurpose spectrum by encouraging spectrum licensees to relinquish their spectrum usage rights in exchange for getting a portion of the proceeds from an auction of the repurposed spectrum to new licensees.[97] To help free up additional spectrum in the Ultra High Frequency (UHF) band, the FCC plans to conduct a reverse auction for broadcast television licensees to submit bids to relinquish spectrum usage rights in exchange for payments, then repack the broadcast spectrum for other uses, and then conduct a forward auction of licenses for the newly repurposed spectrum.

Currently within the UHF band that the FCC is discussing, broadcast television channels are allocated in 6 MHz blocks. TV channels 14 through 36 are located between 470 MHz to 608 MHz, and channels 38 through 51 are located between 614 MHz to 698 MHz. Channel 37, from 608 to 614 MHz, is dedicated to radio astronomy, receiving cosmic radio waves for scientific observation.[98] In 2009, full power broadcast television stations transitioned from analog to digital broadcast, which allowed greater efficiencies in spectrum usage, providing the opportunity for stations to provide multiple programming streams within one 6 MHz channel.[99] Most stations are classified as full power and have interference protection rights. Some channels operate under lower power, classified as Class A stations, which must meet special requirements in their programming. A third type of broadcast station exists, termed low power television stations (LPTV), which are mostly used for local and educational purposes. These stations use spectrum

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licenses than comparative hearings or lotteries. Traditionally, these consist of “forward” auctions, where the FCC has first allocated a band or bands or spectrum for a type of use, possibly clearing incumbent users, and then auctioning license assignments to the highest bidder. In this case, incumbent users may be forcibly cleared in order to create areas of spectrum to auction. In contrast, the incentive auction tries to incentivize incumbent users to voluntarily relinquish their current spectrum holdings in a “reverse” auction by giving them part of the proceeds from the forward auction. (http://wireless.fcc.gov/auctions/default.htm?job=about_auctions)

[97] FCC (2010), 81-82.

[98] National Telecommunications and Information Administraion (2011).

[99] FCC (2012), “Expanding the Economic and Innovation Opportunities”

on a “secondary” basis to full power stations, with similar power limits as Class A stations, except LPTV cannot cause interference with reception of Class A stations, and LPTV stations do not have the same protection interference rights as full power and Class A stations.[100]

Under the broadcasting rules, wireless microphones are allowed to use spectrum in vacant channels the broadcast television bands on a secondary, non-interference basis, without the need for a license. More recently in 2008 and 2010, the FCC opened up white spaces – geographic areas where specific channels are not being used by television or other protected services – to low powered unlicensed devices in general.[101]

The reallocating and auction of UHF band spectrum, mostly in the 600 MHz range, present several opportunities. Lower frequencies, such as those under 1 GHz (1000 MHz) have unique propagation characteristics: they travel well over longer distances, and can penetrate buildings,[102] which makes it quite favorable for building or expanding rural, regional, and nationwide cellular broadband networks and Wi-Fi networks. There are opportunities in deciding auction participation rules, the strategy of reallocating spectrum, and in the future regulations for the repackaged spectrum that may affect what types of groups have access to spectrum, and what types of access they have. Seen as one of the last larger auctions of lower frequency spectrum less than 1 GHz in the near future,[103] many groups with an interest in lower frequency spectrum and its propagation characteristics are clamoring to provide input in the process.

[100] FCC (2012), “Expanding the Economic and Innovation Opportunities”
[101] FCC (2012), “Expanding the Economic and Innovation Opportunities”
[102] Comments of WhiteSpace Alliance (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111388 (Accessed March 20, 2014).
[103] Comments of AT&T Inc. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112023 (Accessed May 20, 2014).

The FCC Proposal

The idea of using incentive auctions to help meet the United States' spectrum needs was first described in the 2010 National Broadband Plan, and Title VI of the Middle Class Tax Relief and Job Creation Act of 2012,[104] also known as the Spectrum Act, gave the FCC the authority to conduct incentive auctions, and directed the FCC to use incentive auctions in the broadcast television band.

There are three parts to the FCC's incentive auction. The first is a reverse auction, allowing broadcast television licensees to submit bids to relinquish spectrum in exchange for payments, funded by the later forward auction of new licenses, where "payments" may include a combination of moving from UHF to VHF spectrum, sharing a channel with another broadcaster, or receiving cash payments. The second part is a repacking of the newly obtained spectrum, and creating the new rules of use for these bands. The last part is the forward auction of new licenses for the spectrum. A successful auction requires the interplay between all three components – broadcasters are more likely to be willing to give up spectrum if they believe enough revenue will be raised in the forward auction for payments while potential new licensees are more likely to participate in the forward auction if they believe that enough broadcasters will relinquish spectrum and if they believe the new rules governing the band are favorable.

Because this is the first time the FCC is conducting an incentive auction, this process exemplifies the emergence of a new policy tool, and the contention among different stakeholder groups, providing a rich ground to study. The FCC seeks comments on many issues, including comments on the auction design of both the forward and reverse auction, methodologies for the repacking process, how to organize the new bands, where and how white space and unlicensed

[104] Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6406, 126 Stat. 156, 231 (2012), 47 U.S.C. § 1453 (Spectrum Act)

operations should fit into the picture, and what issues may arise in another broadcaster transition. Because of the complexity of the incentive auction, there are many debates, which could be explored in a paper in itself. More salient to the discussion of sociotechnical imaginaries, particularly concerning broadband access, are questions regarding the relative value of licensed and unlicensed spectrum regimes, and how different actors in the debate define “efficient” spectrum management, their different beliefs and trust in spectrum management technologies, and their conception of the public interest.

The FCC proposes establishing the 600 MHz band using 5 MHz blocks, as they suggest that likely technologies to be operated on this spectrum will be implemented as variants of Frequency Division Duplex (FDD), such as 3G and 4G, Wideband-Code Division Multiple Access (W-CDMA), High Speed Packet Access (HPSA). Operated in this way, FDD standards require a pair of 5 MHz blocks, one for uplink signals, and one for downlink signals. Long Term Evolution (LTE) supports multiple block sizes, including 5 MHz.[105] With these assumptions, the FCC proposes generally organizing the 600 MHz band in a way shown in Figure 2. Depending on how much spectrum is cleared, the FCC would start at channel 36 (608 MHz) going down in 5MHz blocks for downlinks, and start at channel 51 (698 MHz) going down in 5 MHz blocks for uplinks. The bottom of the uplink and downlink bands would have a guard band to protect continuing TV channels from interference. The figure also shows the continued existence of channel 37 for radio astronomy, though the FCC is also considering moving radio astronomy to another spectrum assignment. The space between the uplink and downlink bands is called the “duplex gap,” an area of spectrum that helps prevent interference between uplink and downlink signals.

[105] FCC (2012), “Expanding the Economic and Innovation Opportunities”

Complicating matters is that the amount of available spectrum will differ in different geographic locations, as a different number of TV broadcasting stations will be willing to give up their spectrum in each location. The FCC would like to auction spectrum in pairs (a 5 MHz uplink and a 5 MHz downlink band for each licensee), though depending on what is made available through reverse auctions, there may be additional leftover spectrum less than 5 MHz wide, or extra available space that cannot be paired. This means that different locations will have different band plans – different allocations of spectrum, depending on what spectrum is available in each location. Too many different band plans can cause problems for interoperability, because the frequencies on which devices can operate could be substantially different in different location. The FCC is hoping to reduce the number of band plans by creating band plan "families," in order to promote greater interoperability. Auction 73, which took place in 2008 to license blocks in the 700 MHz range, led to interoperability problems, creating further motivation for the FCC to investigate the potential effects of interoperability as a result of the incentive auction. Uneven license dispersion and differing technical rules resulting from Auction 73 have led to interoperability and deployment problems in the 700 MHz band.[106] [107]

[106] Comments of MetroPCS Communications, Inc. (2013). http://apps.fcc.gov/ecfs/document/view?id=7022112239 (Accessed March 20, 2014).

[107] Federal Communications Commission. Promoting Interoperability in the 700 MHz Band. 2012. http://www.fcc.gov/rulemaking/12-69 (Accessed March 20, 2014).

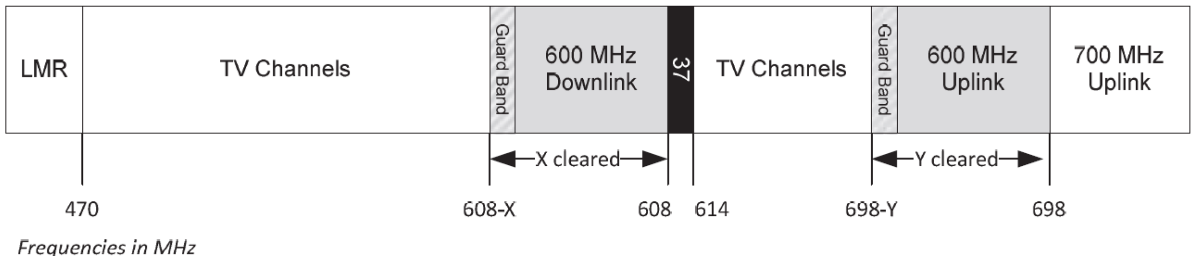

Figure 2: A possible band plan of the 600 MHz band as proposed by the FCC.[108] The "duplex gap" (unlabeled) is anything in between the uplink and downlink bands, in this case channel 37 and TV channels between 608 to 698-y MHz. In other band plans, the duplex gap could just consist of a guard band, or just channel 37, which is used for radio astronomy.

The auctioning of 600 MHz spectrum provides the opportunity to greatly increase the capacity of wireless broadband networks, whether based in licensed spectrum for mobile broadband, or unlicensed spectrum for Wi-Fi. However, there are several potential risks. Broadcasters and potential licensees both need to be believe that the other will actively participate in their respective auctions. The FCC then also needs them to actually participate in the auction, to get enough new spectrum and to get enough bids for new licenses. Another potential risk is that of market concentration in mobile broadband carriers, as Verizon and AT&T already have substantial spectrum holdings compared to their competitors.

The FCC frames their proposal in several ways. In the opening, the FCC writes:

> In key areas, the United States leads the world in wireless infrastructure and innovation…But usage of our wireless networks is skyrocketing, dramatically increasing demands on both licensed and unlicensed spectrum…Our country faces a major challenge to ensure that the speed, capacity, and accessibility of our wireless networks keeps pace with these demands in the years ahead…Meeting this challenge is essential to continuing U.S. leadership in technological innovation, growing our economy, and maintaining our global competitiveness.[109]

[108] FCC (2012), "Expanding the Economic and Innovation Opportunities"
[109] FCC (2012), "Expanding the Economic and Innovation Opportunities"

The proposal is clearly framed as part of the spectrum crunch – that an increased demand in wireless networks requires more licensed and unlicensed spectrum. The use of wireless spectrum is linked to economic growth in the United States, as well as supporting a narrative of the United States as a leader in technological innovation. Discussing the new policy tool of incentive auctions, the FCC writes:

> The incentive auction idea is the latest in a series of world-leading spectrum policies pioneered in the U.S., including unlicensed spectrum uses such as WiFi, Bluetooth, near field communication, and other innovations and the original FCC spectrum auctions in the 1990s.[110]

This links the incentive auction to a lineage of policy tools used to manage spectrum, which are framed as innovations in themselves. Past policies that they mention, such as unlicensed spectrum for Wi-Fi and spectrum auctions have been largely successful, and embedded into the everyday working nature of FCC policy. Linking incentive auctions to US policy innovation represents the hopes and potential that the FCC sees for incentive auctions to becoming a normal policy tool in the future. The FCC's discussion of spectrum discusses a hierarchy of broadcasters, which is codified in the regulations too through differences between full power, Class A, and low power stations. Moreover, the entire incentive auction implies another hierarchy, that wireless broadband services are more important and valuable to the future of the United States than broadcasting channels, as it is the broadcasters that face the challenge of releasing spectrum or moving their services to other parts of the spectrum.

The responses by various stakeholders to this NPRM take many forms and are concerned with many different aspects of the proposal. The stakeholder comments can be broadly categorized into several general categories of arguments, combining social and technical claims in various, sometimes conflicting, arguments. These categories are groups that want to increase

[110] FCC (2012), "Expanding the Economic and Innovation Opportunities"

the availability of licensed spectrum, groups that want to increase the availability of unlicensed spectrum, and those with other viewpoints and concerns.

Broader Licensed Spectrum

Groups that strongly support the expansion of licensed spectrum for internet and communications use by repurposing broadcast spectrum are generally telecommunications companies and wireless providers, such as Verizon, AT&T, and MetroPCS. Groups representing device manufacturers and other related stakeholders also support the expansion of licensed spectrum, such as the Telecommunications Industry Association, Mobile Future, and the Consumer Electronics Organization.

These groups agree with the FCC's proposal to organize the cleared spectrum into 5MHz blocks, and pairing uplink and downlink spectrum for auction. Verizon writes that pairing uplink and downlink spectrum helps ensure that "cleared spectrum is technically and economically attractive to the wireless industry" which is "crucial to a successful forward auction that maximizes participation by existing and new service providers."[111] The Consumer Electronics Association states that "5 MHz building blocks are most compatible with several current and emerging wireless broadband technologies," and that carriers have deployed networks using blocks of spectrum in multiples of 5 MHz even if the block is more than 5 MHz wide, because current standards work well with devices using 5 MHz.[112] Similarly, they state that "most mobile broadband technologies operate on paired spectrum allocations [one for uplink and one for downlink] … Paired allocations will therefore best facilitate the deployment of new wireless

[111] Comments of Verizon and Verizon Wireless (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111976 (Accessed March 20, 2014).
[112] Comments of the Consumer Electronics Association. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111851 (Accessed March 20, 2014).

broadband services"[113] These arguments are sociotechnical, and recognize the role of existing technical standards and practices. Existing standards use 5 MHz channels, which makes 5 MHz bands more desirable and likely easier to implement. Many current technologies communicate using Frequency Division Duplex (FDD), requiring an uplink and downlink block of spectrum. Verizon also presents an economic argument, indicating that repackaging spectrum along these guidelines will make new spectrum licenses valuable, attracting bidders, making the financial aspects of the auction a success.

Groups supporting expanded licensed spectrum for wireless services discuss their concerns about interference and desire for protection in several ways. First, they seek protection from interference caused any remaining broadcasters, encourage modifications to the band plan to protect mobile broadband providers. For example, AT&T writes that allowing television stations to broadcast from within the duplex gap "would create a risk of substantial intermodulation interference in a variety of downlink frequencies."[114] Secondly, they support clearing other secondary operations from the 600 MHz band, such as unlicensed microphone operations. Verizon writes that "to avoid interference problems that would reduce the attractiveness of the spectrum to mobile operators, the Commission should promptly begin clearing wireless microphone … operations from the spectrum to be repurposed."[115] Lastly, they argue that new technologies are not necessarily the solution to interference concerns. While interference from adjacent channels can be managed through certain technologies, AT&T cites other types of interference unlikely to "be sufficiently and efficiently alleviated through the use

[113] Comments of the Consumer Electronics Association. (January 25 2013).
[114] Comments of AT&T Inc. (January 25, 2013).
[115] Comments of Verizon and Verizon Wireless (January 25, 2013).

of filters, guard bands, or similar techniques."[116] In a similar comment about the limits of current technologies to reduce interference, the Consumer Electronics Association states that the FCC should be "conservative" and "pragmatic," and that band sizes "should be sized consistent with today's filter technology, not for future, aspirational technologies."[117]

These arguments regarding interference make use of several types of reasoning. First is an argument about the economic attractiveness of spectrum, especially considering the needs to the forward auction to raise significant amounts of money. Greater certainty about that interference can be avoided in a band increases its economic value to would-be bidders. Second is an argument about perceived shortcomings in current technologies used to manage interference. They imply that new technologies to manage interference may be risky or not as able to prevent interference to the degree that their proponents claim. Interference policies should be grounded in current prevention technologies, not what possible future prevention technologies may exist. Third is an implicit argument that a hierarchy of spectrum uses exists, with wireless broadband services higher than secondary users, such as wireless microphones which pose interference threats and need to be cleared, and higher than existing broadcasters. Concerns about interference with broadcasters is framed as the threat of possible interference caused by existing broadcasters with newly licensed bands for wireless services.

These groups also raise concerns about the possibility of allowing unlicensed TV white spaces devices to operate in new white spaces and in guard bands, and the risks entailed with that possibility. These concerns and discussion of risks can be seen in both general discussions about TV white space devices, and in technical discussions about the size of guard bands. The

[116] Comments of AT&T Inc. (January 25, 2013).
[117] Comments of the Consumer Electronics Association. (January 25, 2013).

Telecommunications Industry Association notes that the technical operations of TV white spaces may differ in a new regime, and potentially poses several risks:

> A guard band adjacent to the 600 MHz mobile broadband uplink spectrum will face a different challenge [than the current TV white space regime]. … Further engineering analysis and testing would be necessary to determine the technical feasibility of that approach in the context of adjacent mobile communications services. Absent certainty that a database-driven regime will fully protect operations…potential participants in the forward auction may limit the size of their bids or even refuse to participate altogether. [If unlicensed devices present] unanticipated technical flaws … the end result could be underutilized spectrum for the long term.[118]

Further supporting this view, MetroPCS favors using any leftover spectrum not packaged into a 5 MHz band for either a smaller width band to be auctioned or for a guard band, but not for use by white space devices. This discussion of white space devices in general touches upon technical risks feared by these groups, and the potential for interference by unlicensed devices. In response, they call for technical evidence that shows a system using a database policy will adequately protect their operations. They also link the perceived risks of interference by white spaces devices to a lack of economic certainty, again suggesting that it may lead to a less optimal auction.

These concerns about unlicensed devices can be seen in more technical discussions about guard band sizes as well. MetroPCS proposes reducing the guard band size from 6 MHz to 3 MHz, arguing that "rather than reserve critical spectrum resources for possible future unlicensed use, the Commission should address the acute problem before it – the serious spectrum crunch– and the dire need of commercial operators for additional spectrum."[119] Similarly, the Telecommunications Industry Association proposes that newly created guard bands should not be used for unlicensed uses, but instead "Licensing the guard band would simplify the challenges

[118] Comments of the Telecommunications Industry Association. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112013 (Accessed March 20, 2014).
[119] Comments of MetroPCS Communications, Inc. (2013).

faced by broadcasters and primary mobile service providers that might suffer interference from users operating in the guard band."[120] Likewise, the group Mobile Future acknowledges that while unlicensed spectrum is useful "particularly in certain spectrum bands such as 900 MHz, 2.4 GHz, and 5 GHz," the 600 MHz band is different; it "is prime spectrum for the provision of mobile broadband services, so the guard bands should be limited in size to what is necessary to mitigate harmful interference, rather than attempting to maximize unlicensed spectrum use"[121] These arguments build upon the economic reasoning of uncertainty and risk. Yet, it also is set within a deeper framing positioning licensed spectrum for wireless services as a better use of 600 MHz spectrum than unlicensed spectrum, thus the creation of guard bands should maximize the amount of space for new licensees, and protect them from interference.

Regarding interoperability and other potential regulations, most of these groups agree that the FCC should not impose an interoperability mandate in the 600 MHz band and that the FCC should try to keep the rules of use as flexible as possible. Mobile Future cites technical reasons to show that the risk of hindering interoperability is less than in the 700 MHz band, thus the FCC should not impose a mandate. "Since the proposed band plan…would not place mobile operations adjacent to broadcast operations, the issues that have hindered interoperability from a technical perspective in the 700 MHz band should not be present."[122] They also make the same argument by reasoning that technical standards should be set by a broader community. "An interoperability mandate would undermine the technical standards-setting process for equipment and devices, substituting… [the FCC's] judgment for the painstakingly achieved broad technical

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[120] Comments of the Telecommunications Industry Association. (January 25, 2013).
[121] Comments of Mobile Future. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111797 (Accessed March 20, 2014).
[122] Comments of Mobile Future. (January 25, 2013).

consensus in the standards process."[123] At a broad level, these arguments are rooted in the idea that regulation can become burdensome to licensees. The imagined role for the FCC here is to set the stage to allow interoperability through its repackaging process, but it should not directly mandate interoperability through regulation. Their view also portrays standards setting organizations, and the processes that they go through as more favorable than the FCC, portraying standards setting groups as reaching a more democratic consensus than the singular rule of the FCC.

In discussing the rules of the forward auction, most groups in this category argue that there should be no limitations in who gets to participate. Even though other groups raise concerns about industry concentration of spectrum holdings, those concerns are not generally shared among these groups. Verizon writes that industry concentration is not a concern because "Over 80 percent of the U.S. population lives… with access to three or more mobile broadband providers, and over 90 percent lives in … with access to two or more."[124] Verizon also writes that limitations on auction participants would ultimately hurt consumers. "Restricting bidders … would harm competition and consumers because at least some portion of the available spectrum would likely go to providers other than those that value it most and are most likely to deploy it productively."[125] AT&T goes further, saying that "excluding well-capitalized carriers from fully participating in this auction would undermine forward-auction competition, suppress bid levels, and threaten outright auction failure."[126] The main stated reasoning behind these arguments is economic – restricting participants in the auction reduces its economic efficiency, with the potential to not earn as high revenues. The resulting economic efficiencies in spectrum usage are

[123] Comments of Mobile Future. (January 25, 2013).
[124] Comments of Verizon and Verizon Wireless (January 25, 2013).
[125] Comments of Verizon and Verizon Wireless (January 25, 2013).
[126] Comments of AT&T Inc. (January 25, 2013).

linked to hurting the American consumer, who may not be getting the most value out of the spectrum. Again, the possibility of risking the success of the incentive auction is presented as a possible consequence of restricting auction participants. The risk of industry concentration is dismissed by Verizon and AT&T, although due to their current spectrum holdings, they would likely be forbidden from participating in the auction if the FCC limited auction participants based on concentration.

The arguments and reasoning of the groups that promote expanding licensed uses of 600 MHz spectrum are based in several broader framings. The first of these is the spectrum crunch. Every group mentioned above frames their argument through the spectrum crunch and need for more spectrum. For example, Verizon states that:

> The growth of the wireless sector depends on a sufficient supply of spectrum. Consumers, businesses, public safety and governments at all levels are increasingly using and benefiting from the rapid technology advances in wireless, such as the construction of new 4G networks that will enable even more services that advance consumer welfare.[127]

Other groups provide similar statements, using the spectrum crunch to advocate the need for more licensed spectrum offerings. The value of spectrum is often described by citing examples of economic value and innovation spurred by wireless services such as the mobile phone market, linking the expansion of licensed spectrum to U.S. economic growth and technological leadership.

Secondly, the incentive auction is framed as having very high stakes. This is partly due to the fact that most lower frequency spectrum less than 1 GHz is already assigned and allocated, and this auction represents one of the last chances for the foreseeable future for groups to obtain licenses for wireless broadband services in these frequencies. AT&T writes “This is the last

[127] Comments of Verizon and Verizon Wireless (January 25, 2013).

spectrum auction of comparable scope that the Commission will conduct for many years, and the decisions the Commission makes here will have economic and technological consequences lasting a generation"[128] The unique propagation properties of 600 MHz spectrum make it useful for deploying large scale networks, penetrating buildings, or for large rural areas. Whoever is able to get significant amounts of spectrum in the auction will likely have a large advantage in building or expanding their wireless networks. Beyond the technical-related stakes of the 600 MHz band, there are social stakes in the incentive auction process. As this is the first time an incentive auction is being used, the FCC stands to gain much more if a successful auction occurs. The groups discussed in this section frame a successful auction predominantly using economic values. This framing means that these groups tend to focus on certain indicators to define success, such as getting the maximum amount of spectrum allocated for licensed bands, allowing as broad participation as possible, encouraging participation by increasing market certainty and technical certainty, and by maximizing the amount of money earned through the auction process.

Third, these proposals are framed within a conception that values some type of hierarchy in access to spectrum, at least within the 600 MHz bands. Licensed operations are seen as the gold standard of managing spectrum, compared to unlicensed operations like white space devices, which are described in terms of uncertainty and risk, leading to proposals to limit or exclude unlicensed operations in the 600 MHz bands. Furthermore, the comments and proposals are framed by a second type of hierarchy that values wireless broadband as a better use of spectrum than TV broadcasting. The Telecommunications Industry Association argues that "rather than requiring the FCC to "replicate" existing broadcast TV signals within a smaller TV

[128] Comments of AT&T Inc. (January 25, 2013).

band, lawmakers now have directed the Commission to "reasonably" protect the signals of TV licensees who wish to continue broadcasting."[129] This implies that TV broadcasters could be subject to more interference than wireless broadband, and that licensed wireless broadband providers thus have strong interference protection rights than TV broadcasters. This leads to proposals that place the values and concerns of wireless broadband providers first. The interests of TV broadcasters are considered to the extent that they need to be put into a situation where giving up their current broadcasting spectrum is a desirable opportunity. Again seen from an economic perspective, enticing TV broadcasters to relinquish their spectrum is also part of the framing when groups argue for maximizing profit from the forward auction.

Alternate Concerns Surrounding Licensed Spectrum

It is important to note that not all groups that support expanding licensed spectrum for wireless broadband services come to the same conclusions as the groups in the preceding section. In particular, Sprint Nextel, a smaller mobile carrier relative to Verizon and AT&T, supports maximizing the amount of spectrum for licensed auction, but provides different social and technical framings, leading to different propositions. In particular, they cite a figure that AT&T and Verizon as jointly using 75 percent of commercially licensed spectrum below 1 GHz, and an even higher percentage in top markets.[130] This concern about spectrum holding concentration motivates many of Sprint's comments and proposals.

These concerns and alternate proposals are most readily seen in Sprint's discussion about auction rules. In discussion the auction goals, Sprint states:

> The Commission should establish a goal of maximizing the amount of spectrum that can be auctioned for…as many wireless operators as possible to obtain useful spectrum. Focusing on this goal will not only result in increased revenues to fund the statutory

[129] Comments of the Telecommunications Industry Association. (January 25, 2013).
[130] Comments of Sprint Nextel Corporation. (January 25, 2013)

> objectives Congress identified in the Spectrum Act; it can ensure that competitors (and potential entrants) heretofore unable to assemble a competitive mix of high, medium, and, crucially, low band spectrum (i.e., spectrum below 1 GHz) have a genuine opportunity to do so.[131]

Sprint also recommends that the FCC implement a cap on spectrum holdings below 1 GHz, "potentially imposing a limit on the amount of spectrum any bidder can acquire in the incentive auctions – particularly for bidders already possessing undue concentration of low-band spectrum licenses."[132] Even through Sprint supports having a wide range of competitors in the auction, maximizing revenue is not their only motivation. They particularly focus the opportunity for a wide number of competitors and new entrants who do not currently have access to large amounts of UHF spectrum to have a real chance at getting a license. The Public Interest Spectrum Coalition (PISC) – made up of policy institutes and public interest groups National America Foundation, Consumer Federation of America, Public Knowledge, and National Hispanic Media Coalition – raises the same concerns. They state that:

> The harsh reality for potential wireless entrants and competitive carriers is that not all spectrum is created equal. At present, the two dominant carriers already control more than four-fifths of the available spectrum below 1 GHz. Coverage is most important for potential market entrants and existing competitive carriers trying to establish a national or regional LTE network[133]

This auction is important because as stated earlier, it is likely the last auction in the foreseeable future for companies to get access to spectrum in the 600 MHz range, and given its propagation properties, it is very valuable for creating wireless broadband networks. Those who receive licenses from the auction will have a lot of advantages in deploying broadband networks, and Sprint and PISC want competitors beyond Verizon and AT&T to have the opportunity to do

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131 Comments of Sprint Nextel Corporation. (January 25, 2013)

132 Comments of Sprint Nextel Corporation. (January 25, 2013)

133 Comments of Public Interest Spectrum Coalition. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112381 (Accessed March 20, 2014).

so. Sprint claims that this environment, "having multiple competitors with a meaningful quantity of low-band spectrum enables them to realize better operating economies and thereby compete more effectively, resulting in more innovation and more competitive pricing for consumers."[134] Sprint makes an economic argument, but in the context of having multiple competitors obtaining licenses, rather than just multiple competitors during the auction. While the framing of economic competition resulting in innovation and consumer benefits is similar to the framing used by groups in the previous section, Sprint's promotes the role of competition after the licenses have been auctioned, and by promotes greater intervention by the FCC in creating this environment.

Sprint also questions the assumption that spectrum should be repacked into band plans that will serve and promote FDD based technologies. They propose that the FCC consider a band plan based on Time-Division Duplexing (TDD), auctioning spectrum in 10 MHz blocks. Unlike FDD, TDD does not require a two separate uplink and downlink channels; instead, uplink and downlink information can both be transmitted within the same band of spectrum. Regarding TDD, Sprint writes:

> Spectrum management agencies…worldwide have adopted TDD technology precisely because of its amenability for complex (and constrained) spectrum allocations – TDD has been called the "global solution for unpaired spectrum." Where spectrum is scarce, artificially bifurcating a band into dedicated uplink and downlink channels, with intervening duplex gaps, makes little spectrum policy sense. The spectrum efficiency and deployment viability of TDD is indisputable.[135]

TDD would use guard bands to avoid interference with the neighboring operations in the 700 MHz band and the channel 37 radio astronomy operations. Furthermore, a band plan based on

[134] Comments of Sprint Nextel Corporation (January 25, 2013).
[135] Comments of Sprint Nextel Corporation. (January 25, 2013)

TDD standards provides flexibility and simplifies expansion of more cleared spectrum, because there is no need to pair 2 separate uplink and downlink bands.

Creating a band plan based on TDD standards is likely to benefit newer market competitors who do not already have spectrum holdings. Sprint notes that “an FDD allocation makes sense only for operators already possessing spectrum with similar propagation characteristics – that is, only operators that have either acquired a paired 600 MHz license or that have 700 MHz licenses.”[136] Competitors or new entrants will likely not have a paired 600 MHz license or a 700 MHz license. Like Sprint’s proposed auction rules, their proposal for TDD standards is argued in part upon the desire to increase competition among mobile service providers, and provide a chance for smaller or new operators to become more competitive. Their argument for TDD is also based in certain hopes and representations of TDD standards and technologies. FDD has existed for some time, and has been the prior standard, embedded into current policy and technological device designs. TDD represents a new path. Referring to TDD as the “global solution for unpaired spectrum,” and citing its use by other spectrum management agencies, Sprint is framing TDD as the standard of the future. It is the standard that other countries are beginning to use, and it is framed as a standard that can be used to more efficiently manage spectrum in light of the spectrum crunch.

Like the other groups promoting greater licensed uses of spectrum, Sprint recognizes the spectrum crunch in the framing of their argument, both the economic and innovation benefits of spectrum, and the need to provide more spectrum for licensed operations. Yet Sprint’s argument is also framed by a deeper value focused around market competition and anti-concentration. Both

[136] Comments of Sprint Nextel Corporation. (January 25, 2013)

their proposals regarding auction rules and the technical standards are based on the belief that greater competition is needed in the wireless services market.

Also framing Sprint's proposals is the implicit view that the FCC needs to take more of an activist role in the incentive auction. Sprint is asking the FCC to proactively limit either participants in the spectrum auction, or the amount of spectrum a licensee can hold, and they are asking the FCC to consider mandating a new transmission standard. The willingness to allow the FCC to take these actions is motivated by a belief that greater competition is needed to prevent market concentration, and that the FCC has the power and responsibility to do so. The belief in the value of competition to prevent market concentration is also shared by the policy and public interest groups represented by PISC.

Sprint is also willing to express interest in shifting to a new technical standard, TDD, even though there is institutional momentum against it. This willingness expresses a hope in the potential positive possibilities of TDD standard and technologies, again rooted in the belief that TDD standards will help encourage competition and lessen market concentration. Furthermore, a band plan based on TDD standards would raise different questions than a band plan based on FDD. The problem of having a duplex gap no longer exists, although questions about how large to make guard bands persists. Different types of interference questions may be raised. Because the organization of the spectrum is different under TDD, it also raises questions about the notion of "spectrum efficiency." An efficient distribution of licensed operators and guard bands under a band plan based on FDD standards might look very different than a band plan based on TDD standards. The FDD versus TDD debate seems to have similar features to the TDMA versus CDMA cellular debate, in that the first standard represents an improvement on the existing standard, and the latter represents a more dramatic change that may have more technical benefits, but would require a lot of modification to existing equipment.

Increasing Unlicensed Spectrum Through White Spaces and Sharing

Many stakeholder groups see the incentive auction's repacking process as an opportunity to expand the usage of white spaces or other cognitive spectrum sharing technologies in order to increase unlicensed spectrum in the TV bands, in particular to use for Wi-Fi or other internet service. These include groups involved in promoting Wi-Fi and spectrum sharing technologies, such as the White Spaces Alliance, cognitive radio company xG Technology, spectrum sharing devices company Spectrum Bridge, and standards setting group IEEE 802. This set of stakeholders also includes the National Cable & Telecommunications Association, internet application companies such as Google and Microsoft, and a collection of public interest organizations in the Public Interest Spectrum Coalition. Together, they generally advocate using the guard bands between licensed blocks for unlicensed services. Many groups also advocate that if licensed spectrum holders are not using their spectrum, it should be shared with unlicensed devices, picking up the motto "use it or share it."

These stakeholders recognize that the auction is primarily concerned with creating licensed spectrum, and portray unlicensed operations as coexisting with licensed operations. Microsoft and Google state that "One without the other [licensed and unlicensed spectrum] simply will not allow U.S. businesses to meet accelerating consumer demand for wireless products and services,"[137] and the Public Interest Spectrum Coalition (PISC) states that "the ability to access sufficient amounts of unlicensed spectrum… is a complement and cost saving to

[137] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013).

both commercial wireless carriers and to wireline ISPs."[138] However, groups in favor of expanding unlicensed spectrum describe the actions the FCC could take to make the 600 MHz band friendlier for unlicensed devices, such as allowing unlicensed devices to operate in guard bands or encouraging sharing between licensed and unlicensed users.

White space spectrum proponents point out the investment that has been put into developing technologies, policy, and standards for white spaces, encouraging the FCC to continue using and expanding white spaces. Microsoft and Google write that:

> The Commission already has devoted substantial resources to white spaces deployment, including conducting multiple workshops... testing and approving database administrators for commercial use, and certifying white spaces equipment ... In parallel, industry has made substantial investments in reliance on the FCC's approval of TV Band White Space devices, and is continuing to develop innovative white spaces solutions. Indeed, the IEEE has already finalized one standard for white spaces operation (IEEE 802.22) and is nearing completion of another (IEEE 802.11af).[139]

Similarly, the White Spaces Alliance points out the emergence of white space based standards, including IEEE 802.22, 4G-WhiteSpace, IETF PAWS, and the White Space Alliance Wi-FAR specification, allowing a 22 Mbps broadband connection to be sent wirelessly up to 19 miles on a 6 MHz channel.[140] The discussion of the emergence of standards and role of investment helps legitimize the use of white spaces. It also helps to portray white space database technologies and policies as having forward momentum among both government and industry stakeholders. The repackaging of TV broadcast spectrum poses a potential threat to existing deployment white space databases. Presenting white spaces as a sociotechnical system that has forward momentum and investment by many stakeholders supports the argument that the FCC should ensure the continued viability of white spaces in the repackaged TV broadcast band.

[138] Comments of Public Interest Spectrum Coalition.
[139] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013).
[140] Comments of WhiteSpace Alliance (January 25, 2013).

Proponents of more unlicensed spectrum propose allowing unlicensed usage in the duplex gap and guard bands. Currently the FCC has proposed 6 MHz guard bands, although some licensed spectrum proponents suggest using smaller guard bands to free up more spectrum for licenses. Alternatively, unlicensed spectrum proponents state that because current white space devices are deployed based on 6 MHz TV channels, “Guard bands need to be 6MHz as a minimum to allow deployed TVBDs [unlicensed devices] to continue to operate.”[141] Furthermore, if there is more flexibility, other nation’s TV standards use 8 MHz channels, and there may be benefits to increasing guard band sizes to 8 MHz to take advantage of manufacturers developing products for worldwide markets.[142] In order to make use of 6 MHz for white space devices, and in order to provide protection to licensed uplink and downlink signals, the White Spaces Alliance suggests guard bands being 10 to 12 MHz wide.[143] Thus the decision about how wide guard bands should be is not purely a technical decision, but also one about what types of policies, management strategies, and technology deployments can be implemented.

Proponents of unlicensed spectrum tend to place a lot of hope and promise in the potential of future technologies in general. They trust that technologies like white space devices or cognitive radio work or will work well enough to alleviate interference concerns. While the FCC’s plan is mainly focused on traditional high power mobile networks, this is also “the exact moment when wireless device manufacturers and carriers are reconsidering such network designs because of the cost and performance benefits of small-cell networks.”[144] Some proponents argue that “a TDD plan would be much more efficient and effective use of this

141 Comments of Spectrum Bridge, Inc. (January 23, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022110952 (Accessed March 20, 2014).
142 Comments of Spectrum Bridge, Inc. (January 23, 2013).
143 Comments of WhiteSpace Alliance (January 25, 2013).
144 Comments of the National Cable & Telecommunications Association. (January 25, 2013).

spectrum than a band plan that has its roots in legacy 2-way voice telephony applications"[145] TDD standards may also be more compatible with white space devices. These implicitly suggest that considerations being made for licensed proponents are lagging compared to the technological progress that is occurring, and perhaps not in line with the way technologies will develop in the future. Similar beliefs exist about the positive potential for new technologies to accurately and safely manage interference concerns. The IEEE 802 group states that "Channel 37 should be made available for unlicensed use, while putting the Radio Astronomy and Wireless Medical Telemetry Systems in the database service where they can be protected."[146] The xG Technology group writes that "Cognitive radios that work autonomously through sensing of the RF environment offer the best opportunity to construct networks that are robust and reliable."[147] The benefits of using databases or cognitive radio are touted in their ability to coordinate unlicensed devices among each other, and coordinate the sharing of unlicensed and licensed spectrum.

Like the licensed spectrum proponents, stakeholders encouraging the growth of unlicensed spectrum discuss the value of the 600 MHz spectrum propagation technologies. Microsoft and Google write that "its superior propagation characteristics for wide-range, non-line of sight operations, will facilitate further broadband expansion by WISPs [wireless internet service providers] into areas least likely to be served by traditional ISPs."[148] The propagation properties are good for sending internet signals, such as Wi-Fi. Expanding unlicensed spectrum may allow the provision of broadband service in underserved rural areas without access to

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[145] Comments of Spectrum Bridge, Inc. (January 23, 2013).
[146] Comments of IEEE 802 (January 21, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022109061 (Accessed March 20, 2014).
[147] Response of xG Technology, Inc. To Notice of Proposed Rule Making. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111712 (Accessed March 20, 2014).
[148] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013).

wireline broadband. The potential for expanding broadband access is discussed by several groups. The IEEE 802 group has been developing standards to support wireless regional area network,[149] supporting geographically widespread Wi-Fi-like networks. Furthermore, the Public Interest Spectrum Coalition writes:

> The nation's more than 2,000 WISPs…rely primarily on unlicensed spectrum to extend Internet connectivity to unserved and underserved areas …The unique propagation qualities [in this band] allow it to cover far larger rural areas at lower cost. The ability of WISPs to access unlicensed spectrum without competitive bidding eliminates a significant barrier to entry, thereby benefiting consumers who would not otherwise have access to fixed broadband services[150]

Because the high costs of auctions present a barrier to entry, these WISPs would likely not exist under a purely licensed spectrum regime. In this framing, PISC views WISPs as viable alternatives to wireline service providers and licensed mobile carriers for spreading broadband access. This argument is rooted by framing the public interest in spectrum as being tied to having access to high speed internet services, rather than linking the public interest to the maximum possible profit from the incentive auction process.

Lastly, many proponents of unlicensed spectrum also support spectrum sharing between licensed and unlicensed spectrum. In particular, if a license holder is not actively using their band of spectrum, it should be opened up and shared with unlicensed devices. A white spaces database would control access to these bands, and deny unlicensed devices access to licensed spectrum where licensees have begun operations. This view has been termed "use it or share it." This proposal is seen as a more efficient use of spectrum. PISC notes that "Even after the forward incentive auction is completed, large portions of 600 MHz band spectrum will remain

[149] Comments of IEEE 802 (January 21, 2013).
[150] Comments of Public Interest Spectrum Coalition. (January 25, 2013).

unused in large portions of the country for many years."[151] Google and Microsoft write that "In order to promote robust and efficient use of the 600 MHz band, the Commission should therefore harness the white spaces databases to include frequencies where 600 MHz licensees have not yet begun operations, and permit unlicensed operations"[152] The White Spaces Alliance notes that this is consistent with the vision expressed in the 2012 PCAST Spectrum Sharing Report, that "The norm for spectrum use should be sharing, not exclusivity."[153] This is a relativity novel idea, as previously the norm for spectrum use was exclusive licensed use. While the PCAST report was referring to sharing between Federal and commercial users, the broader notion that spectrum sharing should be seen as the norm is expressed by multiple stakeholders to support sharing between licensed and unlicensed users. Moreover, the focus on sharing as the norm provides a different conception of what licensed spectrum means. IEEE 802 argues for decoupling the perceived connection between licensed spectrum and exclusive use, saying "spectrum should not remain unused if there are radio technologies that can make opportunistic use of the spectrum. Licensed use should emphasize interference protection rather than exclusive use."[154] These stakeholders are promoting more than just a set of policies, but a different conception of how spectrum should be used and different conception of values determine the definition of "efficiency." This set of sharing proposals is also enabled by the development of white space database technologies, allowing the coordination and management of unlicensed devices, and enabled by these stakeholders' belief that the white space database technologies work and can be expanded to become a normal part of spectrum usage, not just an experimental technology.

[151] Comments of Public Interest Spectrum Coalition. (January 25, 2013).
[152] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013).
[153] PCAST (2012).
[154] Comments of IEEE 802 (January 21, 2013).

The promoters of expanding unlicensed spectrum and spectrum sharing base their arguments upon a set of deeper beliefs, assumptions, and values. Again, the spectrum crunch is cited as motivation for expanding unlicensed services, particularly the congestion experienced in the 2.4 GHz band, which is primarily used for Wi-Fi and is becoming exhausted and interference-prone in larger markets.[155] The spectrum crunch is seen as urgent and real, motivating the need to use more spectrum for unlicensed uses.

Secondly, while unlicensed spectrum does not raise funds from auctions, positive externalities from the use of unlicensed spectrum are cited as contributing greatly to the nation's economy. PISC describes these benefits, that "the unlicensed economy is thriving, creating jobs, delivering broadband to unserved areas, and meeting the explosion of consumer wireless data demand with low-cost and small cell spectrum re-use."[156] Microsoft and Google believe "the public benefit from this economic growth will dwarf the direct revenues the Commission could ever hope to generate through an auction."[157] And the National Cable & Telecommunications Association highlights the innovation involved in creating a robust unlicensed economy, stating that "entrepreneurs and innovators were able to make use of underutilized or "garbage" spectrum to provide consumers with a host of new services."[158] Describing unlicensed spectrum and white spaces as "garbage" spectrum and citing the ability to create new wireless services from it points to a belief in technical innovation, and that unlicensed spectrum has opened up an environment for innovation.

Third, the promotion of unlicensed spectrum is based upon a conception of the public interest that promotes public access to broadband services. Because the financial barriers to entry

[155] Comments of the National Cable & Telecommunications Association. (January 25, 2013).
[156] Comments of Public Interest Spectrum Coalition. (January 25, 2013).
[157] Comments of Google Inc. and Microsoft Corporation. (January 25, 2013).
[158] Comments of the National Cable & Telecommunications Association. (January 25, 2013).

are much lower in unlicensed spectrum than in licensed spectrum, expanding unlicensed spectrum access to allow more WISPs to enter the marketplace is consistent with this definition of the public interest. Also, the belief that the public should have greater access to broadband services motivates the creation of wireless broadband enabling technical standards, the creation of which is then used to help support the expansion of unlicensed spectrum.

Together, beliefs about the scope of positive externalities of unlicensed spectrum and beliefs about public access create a different conception of what is the most “efficient” way to manage spectrum. The most efficient way to manage spectrum would be to allow unlicensed operations wherever possible. This is represented in debates over how wide to make guard bands – unlicensed supporters believe that guard bands wide enough to allow meaningful unlicensed spectrum usage would be “efficient,” because efficiency is framed as how much usable unlicensed spectrum is available.

Fourth, the arguments encouraging a broader use of unlicensed spectrum are framed in a broader belief in the ability of new technologies that will enable greater unlicensed spectrum use. This framing also encompass the beliefs that the regulations and standards that enable these unlicensed spectrum technologies are also gaining momentum through their adoption and investment into them. This can be seen in the citing and proposal of newer standards, such as IEEE 802 white space standards and using TDD instead of FDD for organizing the band. Together, the regulatory and technical systems enabling greater unlicensed spectrum use represent the future. This leads these actors to have faith in technologies that opponents claim are unproven or may incur risks, such as the widespread use of white spaces databases, or the increased use of cognitive radios, to allow coordination between unlicensed devices and licensed devices. With this understanding, current and older standards and technologies, such as FDD, are portrayed as less efficient ways to manage spectrum and implied to be outdated. This framing also corresponds with citing an unlicensed spectrum environment as an incubator for technological innovation, creating positive future externalities, connected with a belief in the positive impact and positive potential of new technologies.

Lastly, the “use it or share it” mentality is a relatively new idea, in part enabled by the development of new technologies and standards that allow spectrum sharing, but it represents a large shift in how spectrum is viewed, and a powerful framing device with many implications as to how spectrum should be managed. While before, licensed spectrum for exclusive use was seen as the normal way to allocate spectrum, and while unlicensed spectrum existed, it was an exception rather than the rule, and designated in only a few bands. The “use it or share it” framing elevates unlicensed spectrum regimes to the level of licensed spectrum regimes, allowing both regimes to be seen as normal and complementary to each other. Rather than being on the fringes or seen as experimental and ancillary, unlicensed spectrum regimes are posited as being near the center of spectrum management. This framing changes the calculus of the definition of “efficiency” – an efficient spectrum management plan that only uses licensed spectrum could look very different than an efficient spectrum management plan that utilizes both licensed and unlicensed spectrum techniques. Discourses stemming from a belief in licensed spectrum tend to portray efficiency as an economic argument, that spectrum management is effective if the licensee who values the spectrum the most is able to obtain it in the spectrum auction, and emphasizes interference protection as enhancing the value of spectrum by providing a level of certainty. Discourses stemming from a “use it or share it” belief tend to portray efficiency as how much of the spectrum is actively being used across time and geographic location, and the more spectrum that can be used in more places, likely utilizing newer management technologies to reduce interference like databases and cognitive radio, enhances efficiency.

Other Viewpoints

Many other stakeholders cite other concerns or have alternate proposals regarding the FCC's proposed incentive auction. While they have less immediate relevance to spectrum use for wireless broadband services, they are worth briefly mentioning to highlight other interpretations of the FCC's plan and other approaches to spectrum management if wireless broadband services were not valued as highly. The National Academy of Science Committee on Radio Frequencies argues for the need for interference protection because the physical properties of cosmic radiation means detection systems are very susceptible to interference, although they are open to using a database solution to share spectrum with unlicensed devices in geographic areas unused by radio astronomy.[159] Their arguments are based on the valuing of scientific research, and that it is a legitimate and beneficial use of spectrum. Broadcasters note that the process of repacking spectrum from broadcast to internet use may present more challenges than the analog to digital TV conversion.[160] Low power TV stations by regulatory classification are entitled to less protection from interference than other types of broadcasters. Many are also community- or education-based, and may not have the money and resources to make equipment changes required to broadcast from different frequencies. Many proponents of low power TV oppose the FCC's proposal, arguing that it is an assault on first amendment free speech rights of the broadcasters and the public, that it is against the public interest by reducing local programming

[159] Comments of the National Academy of Sciences' Committee on Radio Frequencies. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111201 (Accessed March 20, 2014).

[160] Comments of the Association of Public Television Stations, Corporation for Public Broadcasting, and Public Broadcasting Service (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022112268 (Accessed April 10, 2014).

and local jobs, and raise questions about the authenticity of the spectrum crunch, citing possible technical solutions to gain greater efficiency out of spectrum already used for wireless internet.[161] They question whether the spectrum crunch is real, and if it is, if it needs to be solved by using policies and technologies that could interfere or harm low power TV. These comments question the assumed value underlying the proposal that that finding spectrum to use for wireless internet is more important than using spectrum for television broadcasting.

Discussion

Using sociotechnical imaginaries to view the debates surrounding the incentive auctions enables insight that goes beyond an analysis of stakeholder positions. The FCC's NPRM about the spectrum auction represents a moment of sociotechnical emergence and contestation. First it is important to note that these debates are in fact sociotechnical, that they contain intertwined technical and social factors. For instance, the physical properties of spectrum, allowing the transmission of information across long distances, is connected with the types of services that are valued and could be implemented in those bands, such as TV broadcasting, internet through wireless carriers, and internet through Wi-Fi. Furthermore, mutual relationships exist between technologies, standards, and regulations. Different groups may stand to benefit from the adoption or codification of certain sets of technologies, standards, and regulations. In some ways, the development of standards and regulations are predicated by technological developments, such as the development of white spaces databases enabled the development standards and regulations allowing spectrum sharing in certain areas. Likewise, the adoption of standards and regulations can help spur the development of technologies in certain directions. The broader environment includes broader social factors as well, such as the amount of trust various actors place in

[161] Comments of the School Board of Miami-Dade County, Florida. (January 25, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022111827 (Accessed April 10, 2014).

technologies, standards, and regulations. The sociotechnical debates surrounding the proposed incentive auction are debates about what the future of spectrum management should look like, and what the future of wireless services will look like. Different groups imagine these futures differently, based on some set of underlying values with some notion of the public good.

This case represents a moment of emergence and contestation, providing the opportunity to use sociotechnical imaginaries to analyze the case. The incentive auction represents the emergence of a new policy tool. As this process will set the stage in these bands of spectrum for years, even decades to come, many groups contest its rules in order to try to shape a new emerging sociotechnical imaginary about how lower frequency spectrum should be used and managed in the future. The emergence of this sociotechnical imaginary can be seen through the contestation of several deeper dimensions framing the imaginary.

Implicitly, one of the dimensions of this debate involves contestation over how much power and authority the FCC has in shaping this sociotechnical imaginary, and to what extent it should even play a role in shaping that imaginary, particularly with the emergence of the incentive auction as a new policy tool. In the repacking process, some argue that the FCC be more active in promoting a certain future imaginary by using regulations and the power to reallocate spectrum in order to actively create a new regulatory and technological environment, such as requiring interoperability or the use of TDD technologies. At another extreme, the FCC could be act more passively, allowing other stakeholders to build their future imaginary through market forces.

The dimension of a more active or passive FCC relates to a broader dimension of who the stakeholders will be in this new imaginary. While the FCC, proponents of licensed and unlicensed wireless internet services, and the associated device makers and service providers are generally mentioned as stakeholders, other groups' validity as stakeholders is contested. The ability for radio astronomy researchers and TV broadcasters, particularly low power local and educational TV broadcasters, to remain active stakeholders in the emerging imaginary is contested, as the resulting regulatory structure could exclude them from the conversation. The debate over the role of low power TV broadcasters and other potentially marginalized users in the future of spectrum use is similar to historical debates about the role of low power local radio broadcasters, radio educator groups, and other groups historically marginalized in spectrum debates. And while both licensed and unlicensed proponents will likely be recognized as the major stakeholders in this new imaginary, they disagree about which group should have a greater role in shaping the technical and regulatory environment of the imaginary.

A dimension framing this imaginary is the value of "efficiency," and how to define it. Because of the framing of the spectrum crunch, most stakeholders agree that spectrum needs to be used more efficiently. While most stakeholders promote the value of efficiency, deeper values lead to different interpretations and definitions of efficiency, which can be seen in contention between promoters of licensed and unlicensed spectrum. Efficiency could also be thought of in terms of how much spectrum is actively being used across a certain band of frequencies, across a period of time, or across a geographic area. Efficiency can be thought of in terms of economics and property, by matching a supply and demand of spectrum licenses. In this case, the question of how to calculate economic value can be contested – how much should auction revenues be valued compared to the potential positive externalities gained by spectrum-using services. These debates help explain why a standard that may be seen as the most efficient in one aspect, such as the technically efficient TDD, may not be adopted or required, similarly to historical cellular debates between CDMA and TDMA standards.

Related to the dimension of efficiency is the dimension of what constitutes the public good. Some may associate the public good with the most efficient use of spectrum, though as discussed the definition of efficiency is contested as well. But some may associate the public good with other qualities, such as public access to broadband internet connections, public access to television or creating a competitive environment by preventing market concentration. It is possible that implementing spectrum management techniques and regulation to promote certain definitions of the public good may not result in the most "efficient" use of spectrum. There is a normative desire to be efficient and to promote the public good, but defining and interpreting what that means is contested, even potentially putting the value of the public good in conflict with the value of efficiency. Part of creating the sociotechnical imaginary is working out these debates and attempting to reconcile these differences.

The imaginary also has a contested technological component. Spectrum management technologies that allow unlicensed devices to share spectrum with licensed devices, like white spaces databases or cognitive radios and the associated standards, enable an imagined future of widespread unlicensed spectrum use and ubiquitous Wi-Fi, particularly in rural areas. At the same time, beliefs about the need for or reliability of current technologies and standards such as TV broadcasting, 3G, 4G, and LTE present an alternative imagined future. Part of the emergence of this sociotechnical imaginary is the debate over what sets of technologies and standards will be seen as central and integral to UHF spectrum use. This debate is reflected in the regulatory rules for these bands, as regulatory rules and band plans may favor the use of certain technological systems over others.

This case continues the historical themes discussed in the historical section of the paper of the paper. First, the number of stakeholders involved in spectrum debates has fluctuated over time. Similarly in this case of an emerging imaginary, there are different conceptions of who will constitute a legitimate stakeholder, and which stakeholders should have more influence. It appears that low power broadcasters' role of stakeholder may be diminished, parallel to the historical sidelining of educators in radio broadcasting reform. Second, questions about how to define the "public interest" are still contested, with differing implications for what type of technical and regulatory environment should exist to serve that public interest. Third, the current debates about UHF broadcast spectrum build upon past actions, technologies, and regulations. The legacy of the broadcast TV system needs to be addressed if broadcast TV spectrum is to be repurposed for wireless internet services, as well as the legacy of the historical norm of granting exclusive use licenses to allow spectrum use. Also, technologies and standards that are historically and currently used for wireless internet, such as FDD, have an effect on the debate. Lastly, this is placed within a larger debate over how to best manage spectrum, mostly seen in a debate between unlicensed and licensed spectrum management. Any solution will not be purely one or the other, but will combined unlicensed and licensed spectrum together. However, questions and contention still exists regarding to what extent they should coexist, and if one should be valued more than the other or should both management systems should be seen equally valued.

CASE 2: UNLICENSED SPECTRUM

In February 2013, the FCC issued a notice of proposed rulemaking regarding "Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band."[162] The FCC intended to revisit the rules governing U-NII

[162] Federal Communications Commission. "Revision of Part 15 of the Commission's Rules to Permit Unlicesned National Information Infrastructure (U-NII) Devices in the 5 GHz Band." February 2013. http://www.fcc.gov/document/5-ghz-unlicensed-spectrum-unii (Accessed March 10, 2014).

devices operating in the 5 GHz bands, which were first written in 1997. With more experience, different technologies, and different policy foci, it is pertinent to revisit these rules.

The FCC's Part 15 rules govern the operation of unlicensed devices – devices that can operate without individual licenses as long as they follow rules intended to not cause interference for other devices operating within and adjacent to these bands. Thus unlicensed devices are generally required to operate at low power over relatively short distances. The current rules for U-NII Devices in the 5 GHz band were adopted by the FCC, creating several U-NII bands, with different operating rules for each band, as seen in Figure 3.

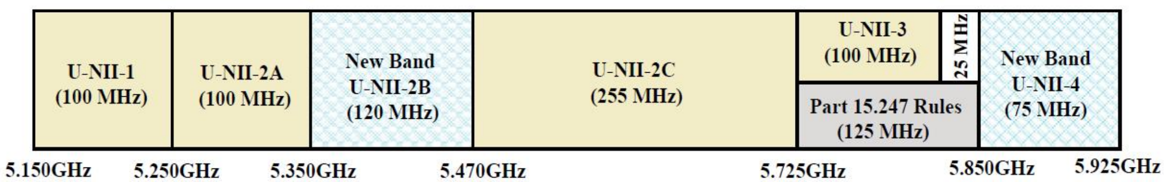

Figure 3 – Current U-NII Bands and new bands proposed by the FCC in the NPRM[163]

U-NII-1 spans 5.150 GHz to 5.250 GHz, and unlicensed devices in this band operate indoors at very low power. U-NII-2A (5.250 GHz to 5.350 GHz) and U-NII-2C (5.470 GHz to 5.725 GHz) allows indoor or outdoor usage, at higher power than U-NII-1, but they must use dynamic frequency selection (DFS) to avoid interference with incumbent radar operators and satellite control services by sensing the spectrum and only operating on frequencies not in use by the incumbent services. Part 15.247 rules governing 5.725 GHz to 5.850 GHz covers the use of spread spectrum technologies, though the FCC thought that the rules were similar enough to U-NII rules that they created the U-NII-3 band in mostly the same space, allowing manufacturers to decide whether Part 15.247 or U-NII rules best make sense when building devices that use that band of spectrum.

[163] FCC, "Revision of Part 15 of the Commission's Rules" (2013).

Title VI of the Middle Class Tax Relief and Job Creation Act of 2012,[164] which the FCC terms the Spectrum Act, asks the FCC to look into expanding U-NII rules into the 5.350 GHz to 5.470 GHz band and the 5.850 to 5.925 GHz band, dubbed U-NII-2B and U-NII-4, respectively. Incumbent services in the U-NII-2B band include federal radar systems, federal and non-federal satellite services, weather radar, and uses by local TV stations to provide weather maps and warnings to viewers. Incumbent services in the U-NII-4 band include federal radar systems, fixed satellite services, amateur radio, and the Intelligent Transportation Service (ITS) implementing Dedicated Short Range Communications Service (DSRC) systems, used for automobile and transportation safety. The DSRC use was designated by the FCC in 1999 for automobile safety uses, such as vehicle-to-vehicle wireless communications that may warn drivers of impending dangerous conditions, or help make the vehicle take evasive action. Some form of spectrum sharing and mitigation of interference between incumbent users and U-NII devices in these bands may have to be investigated.

The FCC sees several potential opportunities in revising the U-NII rules, and issues that they may need to solve. Having more contiguous spectrum for unlicensed devices is seen as a benefit. One new opportunity is the possible adoption of the IEEE 802.11ac Wi-Fi standard, which would uses wider bandwidth, up to 160 MHz, to allow services with higher speeds, up to 1 Gigabit per second. The FCC argues that 160 MHz is available for IEEE 802.11ac services, but what is most problematic is that each of the U-NII bands has different policies, so if that 160 MHz were spread across two or more U-NII bands, it could potentially fall under two different sets of rules. A current issue that the FCC identifies is an "increase in interference incidences in U-NII bands that are caused by users unlawfully modifying and operating unlicensed devices

[164] Middle Class Tax Relief and Job Creation Act of 2012.

that have not been certified to meet the required technical rules for these bands."[165] Many manufacturers create devices are able to work across all the U-NII bands, and use software configurations to transmit or receive on a specific band. If users change the software configurations, they may cause the devices to operate in bands where the device causes harmful interference.

The FCC Proposal

The FCC sought comment on its proposal to do several things. They wanted to expand U-NII-3 from 5.725 GHz to 5.850 GHz, adding 25 MHz more to that band, and create the new U-NII-2B and -4 bands, adding 195 MHz of spectrum for unlicensed use. They also wanted to reconcile the differences in power limits and indoor and outdoor location limits in the U-NII-1 and -2A bands, to create 200 MHz of contiguous spectrum that is regulated in the same way, making it easier to deploy systems. They also sought comment on how to prevent unlawful modification of unlicensed devices, the types of compliance issues that may arise under new rules, and how to curtail interference on incumbent operations.

The FCC proposal is framed in several ways. Even though the term "Unlicensed National Information Infrastructure" was termed in 1997 during the Clinton Administration, the continued use of that phrase indicates that the services in these bands are still framed as national infrastructure, with some type of purpose for the public good, rather than being called "Unlicensed Applications" or "Unlicensed Services." The proposal is also framed in a way that indicates that these actions will help foster innovation and economic growth. This is partly because the proceeding helps satisfy a requirement written in the "Middle Class Tax Relief and Job Creation Act of 2012" and because the FCC states that they believe these changes "would

[165] FCC, "Revision of Part 15 of the Commission's Rules" (2013).

continue to foster the development of new and innovative unlicensed devices, and increase wireless broadband access and investment."[166] The FCC also frames this proposal using language of the spectrum crunch, rooted in a desire to expand broadband connectivity and meet rising demand for spectrum. They cite the 2010 FCC National Broadband Plan and the June 2010 Presidential Memo asking the FCC and NTIA to make 500 MHz of spectrum available for broadband use by 2020. They are mindful of incumbent operators as well. In the NPRM, the FCC writes that they "take the first steps toward ensuring the U-NII bands continue to meet the demand for broadband spectrum, while ensuring protection of authorized operations."[167]

The responses by various stakeholders to this NPRM take many forms and are concerned with many different aspects of the proposal. While their individual comments, proposals, and counter-proposals differ, they can be categorized into several general categories of arguments: those bringing up the theme of public safety, those who discuss improving broadband adoption and connectivity through increasing unlicensed spectrum, and groups with other concerns. They combine social and technical claims in different, sometimes opposing, ways to construct their arguments.

Public Safety

Public safety is a theme brought up in two ways. The first is how the proposal may present a threat to public safety by creating interference with existing incumbent services. The second is how unlicensed Wi-Fi devices can improve public health and safety.

Incumbents and Public Safety Interference

Several stakeholders with interests in incumbent uses of spectrum in the 5 GHz bands provide comments and arguments rooted in concerns that interference by unlicensed devices

[166] FCC, "Revision of Part 15 of the Commission's Rules" (2013), ¶2
[167] FCC, "Revision of Part 15 of the Commission's Rules" (2013), ¶20

could propose a threat to public safety. These stakeholders tend to fall into two groups. The first includes stakeholders involved in using Dedicated Short Range Communications (DSRC) systems, such as automobile makers like General Motors, the American Association of State Highway & Transportation Officials (AASHTO), and companies that manufacture components needed for DSRC systems such as chip producer Qualcomm. They currently operate in the 5.850 to 5.925 GHz band (U-NII-4), which the FCC is considering to open up for unlicensed use. The second group includes stakeholders involved in weather radar systems, such as the National Association of Broadcasters. These systems operate in the 5.350 GHz to 5.470 GHZ band (U-NII-2B), which the FCC is also considering opening up for unlicensed use.

Both groups of stakeholders cite interference concerns with the FCC's proposal, from U-NII devices operating in the same spectrum band, from U-NII devices operating in adjacent spectrum bands, or from people illegally modifying the software of U-NII devices. They encourage the FCC to complete more thorough technical testing of sharing, in order to mitigate these interference concerns. Furthermore, AASHTO and General Motors want relevant stakeholders to be afforded the opportunity to weigh into the debate, which General Motors describes as "Federal agencies, industry-standards organizations, and equipment manufacturers, along with automakers."[168] Similarly, the National Association Broadcasters cites a history of U-NII devices causing harmful interference and calls for the consideration of using technical solutions to manage interference, such as using spectrum-sensing technologies, geolocation databases, and software security to prevent user modification of devices.[169] Qualcomm, as a manufacturer of chips for both Wi-Fi and DSRC devices recognizes the need for more Wi-Fi

[168] Comments of General Motors Company. (May 24, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022417459 (Accessed March 16, 2014).
[169] Comments of the National Association of Broadcasters. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418770 (Accessed March 16, 2014).

spectrum, but puts forward a suggestion they frame as a compromise, sectioning the uppermost 20 to 30 MHz of current DSRC spectrum for exclusive DSRC use, so that companies can safely continue to develop DSRC systems without having to worry about harmful interference effects, or wait for the time-consuming process of testing for interference effects.[170]

These arguments are mostly based in traditional concerns around harmful interference. The DSRC stakeholders and weather radar stakeholders operate as current incumbents in their respective bands, and raise concerns about the effects of unlicensed devices on DSRC system and weather radar systems and communications, respectively. The Qualcomm argument also discusses concerns about uncertainty about the interference effects, and uncertainty that the testing process brings. They believe that their plan of saving 20 to 30 MHz for exclusive DSRC use is useful because "the roll out of the DSRC safety services can and should proceed unabated, and the FCC and NTIA can focus their efforts on whether the lower 45 to 55 MHz may be shared by non-critical DSRC uses and Wi-Fi without harmful interference."[171] AASHTO also provides a technical argument, discussing the power limitations for DSRC systems under current regulations and other operating details, providing examples of how possible interference signals may interrupt DSRC services.

These arguments are generally presented within a broader framing emphasizing the value of public safety. In particular, these stakeholders argue that potential harmful interference presented by unlicensed devices could compromise public safety by disrupting their spectrum-using services. General Motors writes:

> DSRC technologies have the potential to greatly reduce the 6 million crashes and more than 30,000 deaths that occur on U.S. roadways annually. DSRC holds great promise for

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[170] Comments of Qualcomm Incorporated (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418821 (Accessed March 16, 2014).
[171] Comments of Qualcomm Incorporated (May 28, 2013).

> saving lives, and tremendous progress has been made toward its widespread deployment. … Quite simply, the 5.9 GHz band is essential for connected vehicle safety applications, and these enhanced safety features contain stringent communication requirements that must be protected.[172]

Making a similar argument regarding weather radar, the National Association of Broadcasters writes:

> These weather radar systems provide advanced weather information, including up-to-the-minute updates on severe weather, which local broadcast stations share with the public during newscasts and coverage of emergencies. As the recent tornado strike in Oklahoma made abundantly clear, accurate weather data that can be rapidly delivered to local communities is a critical public safety priority.[173]

They are linking the role of weather information, particularly during natural disasters, and their use of spectrum, to show the importance of their services to public safety. This is reflected in current regulations, as the AASHTO notes that "Current FCC rules require that DSRC messages involving public safety and safety of life be given the highest priority among all DSRC traffic."[174] The value of public safety is already integrated into existing technical regulations, and these stakeholders rely on that value to make their argument.

There is also a secondary argument relating to the value of fairness as seen by incumbents. The FCC designated spectrum for DSRC in 1999, and there was no expectation that companies developing DSRC technologies would have to share spectrum with U-NII technologies. There is an implicit argument by the DSRC stakeholders that FCC's proposed regulatory changes to expand unlicensed spectrum usage will hurt incumbent systems that had no need to expect interference from unlicensed devices. General Motors writes that "significant resources have already gone into the development of standards and technologies that will form

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[172] Comments of General Motors Company. (May 24, 2013).
[173] Comments of the National Association of Broadcasters. (May 28, 2013).
[174] Comments of the American Assocation of State Highway & Transportation Officials. (May 28. 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418817 (Accessed March 16, 2014).

the foundation for DSRC's widespread deployment."[175] This implies that regulatory changes that result in harmful interference could jeopardize investment in current systems. Similarly, Qualcomm's argument that about 20 to 30 MHz should be reserved for exclusive use for DSRC also implies the need for stability in the regulatory and technical landscape in order for innovative and progressive developments in DSRC to occur.

Unlicensed Spectrum for Public Safety

Other stakeholders, such as the Association for the Advancement of Medical Instrumentation (AAMI) argue that unlicensed spectrum needs to be implemented in a way that promotes public safety, namely the safe operation of medical devices. The AAMI broadly supports the FCC's proposal because of the growing use of healthcare applications that require spectrum, such as mobile body area network sensors and other Wi-Fi using medical devices, and predicted increase in demand for these applications. However, they offer an amendment to the FCC's plan, proposing that in the potentially new bands for unlicensed devices, U-NII-2B and U-NII-4, that healthcare facilities have "prioritized access" or have a "controlled interference" environment with more managed unlicensed access. They argue that this would be under limited circumstances, such as limiting these rules to the geographic area around hospitals. Such a proposal to allow healthcare facilities to have priority access to spectrum or control the level of interference would require both policy changes and technical enforcement mechanisms, such as a database similar to TV white spaces, or sensing based technology.

The AAMI's reasoning lies in the belief of the critical nature of medical devices. They state that "Some of these applications critically affect patient and/or public safety and ideally require controlled RF environments where the spectrum utilization can be actively managed to

[175] Comments of General Motors Company. (May 24, 2013).

reduce harmful interference" and that they are submitting their comments and proposal because of a concern about "*patient safety, where 'mission critical' is 'life critical,'* and where human beings are counting on wireless medical devices for critical life support."[176] Failures in these devices can lead to patient death. Thus the AAMI sees the FCC's plan to expand the use of unlicensed spectrum as an opportunity for protecting public and patient safety, by crafting rules and standards in these new unlicensed bands to create safety zones for healthcare devices to operate with no or limited interference. Like the DSRC and weather radar incumbents, the AAMI's arguments are based upon the same social value of public safety, but because of some of the technical differences between medical devices, DSRC, and weather radar, their comments and proposals have somewhat different recommendations. The AAMI also frames their argument around the larger issue of prioritized access, that some users of spectrum should have a higher priority of access than others. In this case, the medical devices themselves constitute the spectrum users, though the circumstances in which they should have higher priority are limited to certain geographical near where they are operating.

Improving Broadband Connectivity through Wi-F and Unlicensed Spectrum

Many groups generally support the FCC's proposal to expand unlicensed spectrum and see it as a way to expand broadband access via Wi-Fi, and support the proposal for both technical and regulatory reasons. However, even among groups that support the expansion of unlicensed spectrum to provide Wi-Fi, comments differ in technical and policy arguments, particularly in discussing the rules that should govern unlicensed use the 5 GHz bands and potential restrictions on allowing device software to be modified by user. The problem of the spectrum crunch and potential to increase Wi-Fi connectivity through the new 802.11ac standard are central to many

[176] Comments of the Association for the Advancement of Medical Instrumentation (AAMI). (May 24, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022417216 (Accessed March 16, 2014).

arguments in favor of expanding allocations of and harmonizing rules of unlicensed spectrum in the 5 GHz bands. Motorola Mobility writes "In total, with the new additions, the Commission could unleash up to four 160 megahertz channels or nine 80 megahertz channels across the 5 GHz band using the new standard, making significant progress in addressing the country's exploding spectrum demands."[177] In regards to the spectrum crunch, Google and Microsoft jointly write that "In particular, although 2.4 GHz unlicensed spectrum is being used very efficiently, it has become saturated during certain times of day in heavily trafficked areas such as city centers, apartment buildings, and public venues."[178] The importance of increasing Wi-Fi connectivity is broadly framed by an innovation argument that the potential for more spectrum for Wi-Fi will lead to greater innovation in spectrum-using devices. Some groups spoke about a belief in Wi-Fi's ability to create greater effects than foster economic innovation, and have a greater societal effect, enhancing people's quality of life. This is seen in the Wi-Fi Alliance's comment that "Wi-Fi technology has positively affected American consumers and businesses beyond the scope of phones, personal computers and consumer electronics by reaching a variety of new sectors, including health and fitness, automotive, and smart energy"[179] Some groups also spoke about the ability for more Wi-Fi spectrum to help provide access to broadband for more people, as Google and Microsoft write that the proposal can "increase the availability and bandwidth of broadband connections throughout the United States."[180]

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[177] Comments of Motorola Mobility LLC. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418844 (Accessed March 16, 2014).
[178] Comments of Google Inc. and Microsoft Corporation. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418845 (Accessed March 16, 2014).
[179] Comments of Wi-Fi Alliance. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418809 (Accessed March 16, 2014).
[180] Comments of Google Inc. and Microsoft Corporation. (May 28, 2013).

Broadly, the supporters of expanding unlicensed spectrum, particularly for Wi-Fi, see the need to harmonize rules among at least some of the various U-NII bands. Currently, the 802.11ac standard using channels that are 160 MHz wide would only be able to have one channel in the U-NII bands because there is only one block of contiguous spectrum with the similar enough operating rules that is more than 160 MHz wide. Expanding unlicensed spectrum to the new U-NII-2B and U-NII-4 bands, combined with harmonizing the operating rules for the U-NII bands could provide enough contiguous spectrum to allow up to four 160 MHz channels using the 802.11ac Wi-Fi standard. Support for harmonizing operating rules, such as power and location limits is mostly rooted in the ability to then implement the 802.11ac standard. Groups support harmonization from other basis as well, such as these comments from Motorola Mobility:

> A more unified and streamlined regulatory structure will reduce costs and complexity in equipment manufacture and promote the growth of the U-NII market…Technologies will have myriad uses that are vastly different from what reasonably could have been predicted when the U-NII-1 rules were first adopted in 1997…Restricting these operations to indoor-only operations or applying unnecessarily stringent power restrictions could prevent the development of important applications that would serve the public interest.[181]

Together, these comments point to several broader framings that Motorola uses in its argument. The first is an economic argument that harmonizing the operating rules will allow for greater economic growth and innovation. Second, there is a belief that the power limit rules for the U-NII-1 band, set in 1997, were overly conservative and are now outdated. These outdated rules are constraining the possibilities for new technologies, while at the same time it is implied that new technological advances like spectrum sharing technologies can mitigate interference concerns present in 1997. Lastly, Motorola Mobility cites the public interest as being harmed without harmonization, implicitly linking growth in Wi-Fi to serving the public interest.

[181] Comments of Motorola Mobility LLC. (May 28, 2013).

Related to harmonization is the need for the FCC to create certain procedures to protect current incumbent operators, like Doppler weather radar and DSRC services. While supporters of expanding unlicensed spectrum operations are cognizant of the need to protect incumbents, they generally tend to be less conservative when discussing the need for unlicensed devices to dynamically sense incumbent operations. Google and Microsoft state that instead of being required to use Dynamic Frequency Selection as a sharing tool, the FCC "should consider giving users of unlicensed 5 GHz spectrum flexibility to utilize alternative sharing technologies, such as geolocation database solutions. Such alternatives may be less costly than DFS to implement, and could avoid the service delays associated with DFS channel availability checks."[182] Shared Spectrum Company, a company that builds technologies that enables spectrum sharing, take a similarly less conservative position regarding a proposed requirement to limit users' ability to tamper with software on devices. They write that "such a requirement [preventing users tampering with software] may prove counter-productive. Adding requirements such as this may actually impede further deployment of Wi-Fi and other unlicensed services."[183] Instead, they propose that the FCC should promote an increase on technologies such as sensing-based devices or geolocation devices. The Microsoft, Google, and Shared Spectrum Company statements are rooted in beliefs about the possibilities and capabilities of a variety of spectrum sharing technologies – these technologies will work well enough to mitigate incumbent operators' concerns about interference. The comments are also rooted in a belief that the FCC does not need to regulate a particular type of sharing or sensing technology, because companies should have

[182] Comments of Google Inc. and Microsoft Corporation. (May 28, 2013).
[183] Comments of Shared Spectrum Company. (2013). http://apps.fcc.gov/ecfs/document/view?id=7022418765 (Accessed March 16, 2014).

the flexibility to choose what works for them, and the belief that the technical environment is such that there are multiple ways to share or sense spectrum usage in technically proficient ways.

Other groups oppose strict rules for protecting incumbent operators for other reasons. Cisco writes:

> Other proposals advanced in the Notice in the name of protecting TDWR, such as requiring a geo-location database or mandating adjacent channel sensing or imposing more stringent unwanted emissions limits, should be rejected. These additional requirements seek to "fix" problems that have not materialized despite years of experience in U-NII/radar sharing. Imposing additional requirements on U-NII devices is unnecessary to protect TDWR and would unnecessarily subject manufacturers to additional costs that ultimately would be borne by the public.[184]

This argument is rooted in a belief that incumbent operators are being too conservative in the protections measures that they desire. Cisco also links this over-conservatism to the public, indicating that the public will bear additional costs resulting from unnecessary protection requirements.

Interestingly, some groups in opposing stricter dynamic frequency sensing rules link the proposed regulations to the technical design of new devices, and their potential user-facing and economic impacts. Motorola Mobility writes:

> DFS has negative impacts on device design, cost, and operation. For example, DFS scanning algorithms consume significant power and take a long time to scan the band. These issues are of particular concern for battery-operated devices, which will grow increasingly common with the proliferation of smaller, portable, P2P uses. As such, DFS should be required only in physical locations and frequency ranges where actually necessary to protect radar operations, and not across the entire U-NII-2A and U-NII-2C band segments nationwide.[185]

This statement provides an example of how regulations can enable or constrain the possibilities of technical design. A regulatory regime that requires DFS scanning nationwide for any device

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[184] Comments of Cisco Systems, Inc. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418886 (Accessed March 16, 2014).

[185] Comments of Motorola Mobility LLC. (May 28, 2013).

operating in U-NII-2A or U-NII-2C would lead to a set of technologies that operate differently than a regulatory regime not requiring DFS scanning, or only requiring it in certain locations. These design differences, such as battery life, could affect the types of applications users could use the devices for.

It is worth noting that not all supporters of the FCC's plan share the same beliefs in the details. For example, Cisco agrees with a more conservative sensing rule that the FCC should "require that every U-NII devices include DFS functionality if it is capable of initiating a network in a U-NII band that is subject to a DFS requirement."[186] Similarly, the Wi-Fi Alliance agrees about the FCC's proposal to restrict user modification of devices that "manufacturers should ensure that reconfiguring firmware or software which affects regulatory compliance, by someone other than the manufacturer or authorized by the manufacturer, is made very difficult."[187] These are based upon examination of prior incidents of harmful interference experienced by incumbents, and the belief that in the future, similar incidents of interference can be prevented by taking these regulatory measures.

As mentioned above, several broader framings help inform the viewpoints and comments expressed by groups supporting the FCC's expansion of unlicensed spectrum. These often include the motivation of needing to solve the spectrum crunch of not having enough spectrum for unlicensed applications, particularly Wi-Fi. These comments are also often rooted in the belief that unlicensed spectrum and an increase in Wi-Fi will be linked to an increase in economic activity and an increase in innovation. These groups also represent hopes and positive beliefs about the possibilities and capabilities of spectrum sharing technologies, resulting in

[186] Comments of Cisco Systems, Inc. (May 28, 2013).
[187] Comments of Wi-Fi Alliance. (May 28, 2013).

advocacy for more flexible regulations surrounding interference management because of the belief that these technologies will be able to satisfactorily mitigate harmful interference.

Beyond Unlicensed Spectrum

Not all groups fully embraced the FCC's proposal to expand unlicensed spectrum. The Consumer Electronics Association (CEA), a major trade association representing consumer electronics and information technology companies, had a mildly positive response to the FCC's proposal, supporting the plan and seeing potential in expanding unlicensed spectrum, but also providing the caveat that the FCC should continue to aggressively work to reallocate spectrum for exclusive commercial use. The CEA writes how unlicensed spectrum and a single set of technical rules for 5 GHz devices can help foster innovation by "lowering barriers to entry" and "reducing costs and speeding deployment."[188] However, they also argue that the FCC needs to go beyond expanding unlicensed spectrum, writing:

> The Commission should move as quickly as possible to make additional unlicensed spectrum available in the 5 GHz band, but it should consider this proceeding as only one of many tools in its tool belt to address spectrum needs... Furthermore, not all advanced sharing technologies have been commercially deployed and proven. Some of these advanced dynamic spectrum sharing approaches may, in the future, be well suited for certain frequency bands and uses, but implementation of such dynamic spectrum sharing technology must not slow the Commission's pursuit of other means to address the spectrum crunch, including clearing and reallocation of spectrum for exclusive commercial use. This proceeding should support, not supplant, the FCC's efforts to clear and reallocate spectrum for exclusive licensed use.[189]

Like others, their argument is framed by the notion of the spectrum crunch, that companies making electronic devices will need more spectrum to operate in. The arguments raised by the CEA regarding uncertainty of dynamic spectrum sharing approaches, and insistence on the continuation of reallocating exclusive licensed use spectrum support particular beliefs about the

[188] Comments of the Consumer Electonics Association. (May 28, 2013). http://apps.fcc.gov/ecfs/document/view?id=7022418787 (Accessed March 16, 2014).
[189] Comments of the Consumer Electonics Association. (May 28, 2013).

regulatory and technical possibilities of spectrum. While the CEA does not discount the potential economic and technical innovation benefits of having unlicensed spectrum, the call for continued exclusive licensed spectrum casts the exclusive licensed model as being the standard model. They cast some doubt and uncertainty on the technical capabilities of spectrum sharing technologies that could allow more widespread unlicensed use, and imply that the uncertainty could hamper new technical innovation.

Other Concerns

Several other commenters and groups provide concerns that do not align as well with the above mentioned groups, but are worth considering. One is the European Space Agency, which uses spectrum in the U-NII-2B band to communicate with satellites. They request that no national regulations are approved before the ITU-R finishes compatibilities studies about spectrum sharing and the protection of incumbent uses, and a decision about spectrum use is made at the 2015 World Radiocommunication Conference.[190] They argue that if the FCC makes new national regulations before then, the current ITU-R technical studies regarding interference in these bands will have to be modified to accommodate changing national regulations. This touches upon the international nature of spectrum regulation, as well as a reciprocating relationship between creating public policy and conducting technical studies.

Another commenting group is the American Radio Relay League (ARRL), the national association for amateur radio. The Amateur Radio Service has a secondary allocation of spectrum in the U-NII-4 band. They are concerned about the possible interference effects from the aggregate and ubiquitous use of unlicensed devices in the same band. They comment that moving forward, “the proper procedure in a multiple-use band such as 5850-5925 MHz…is to

[190] Comments by the European Space Agency to the FCC Notice of Proposed Rulemaking. (2013). http://apps.fcc.gov/ecfs/document/view?id=7022287038 (Accessed March 14, 2014).

have all stakeholders engage in meetings to develop compatible sharing protocols *before* rules are enacted to effectuate the new sharing plan."[191] While this sounds similar to stakeholder meetings encouraged by other groups, the ARRL likely has the broadest conception of who constitutes stakeholders. The ARRL's viewpoint is worth mentioning because they have a view of stakeholders that also includes amateur individual users of spectrum, not just larger device manufacturing or application creating companies.

DISCUSSION

Analyzing the debates around 5 GHz spectrum through the lens of sociotechnical imaginaries provides insight beyond alternative modes of stakeholder or discourse analysis. The FCC's NPRM is an example of a moment of sociotechnical emergence and contestation. As a moment of emergence, the push to increase unlicensed spectrum in the 5 GHz band is in part predicated on the development of new technologies such as dynamic frequency selection and geolocation databases that would allow spectrum sharing between new unlicensed devices and prior incumbent devices. If these new technologies are able to live up to the claims their proponents advocate, it means that some of the concerns about interference and restrictions imposed upon unlicensed devices in 1997 are now outdated due to new technological capabilities. Furthermore, the development of new standards, such as the 802.11ac Wi-Fi standard, provides an impetus to make these changes in the 5 GHz bands. Lastly, the broader social context, such as the recent growth consumer demand for Wi-Fi and mobile internet applications, motivate the proposed changes. Together, the combination of changes and new developments in technology, standards, and consumer demand come together to present a moment of emergence regarding new possibilities in unlicensed spectrum.

[191] Reply Comments of ARRL, The National Assocation for Amateur Radio. (July 24, 2013). http://apps.fcc.gov/ecfs/document/view?id=7520933148 (Accessed March 16, 2014).

As seen through the intensity and disparity of stakeholder positions, contestation often accompanies moments of emergence in sociotechnical imaginaries. Through the combination of emergence and contestation, the NPRM process in the U-NII bands represents the emergence and construction of a new imaginary about unlicensed spectrum, and about its future. The contestation between stakeholder comments shows different ways they conceive the technologies and regulations, how potential risks and benefits are perceived, and what future possibilities are imagined. This contestation opens up some of the deeper dimensions along which this new imaginary is being framed. The values of economic growth and innovation underlie most stakeholders' arguments; spectrum management is seen as a way to grow the United States' economy and promote technological innovation. Yet this underlying value can be interpreted and acted upon in different, even conflicting, ways. Some groups present a vision of the future where access to unlicensed spectrum presents an environment with easy access and low barriers to entry, ripe for innovation and continued consumer demand and growth. Other groups present an alternate vision of the future where unlicensed devices present unknown factors and need to be restricted, or the growth of unlicensed spectrum itself needs to be restricted, in order to preserve an environment with enough certainty that companies are willing to invest money into building and innovating new devices.

Another dimension along which the imaginary is being framed is the value of access, and what types of access different stakeholders should receive. This can be seen in contention between current incumbent spectrum users and potential new unlicensed device users. While it is generally agreed that incumbents deserve some degree of protection from interference, there is debate over to what degree incumbents should be protected. These differences are also tied to contrasting beliefs about the capabilities of technologies that allowing spectrum sharing, such as dynamic frequency sensing or geolocation databases. There is also contention between unlicensed devices about how the value of access should be implemented. Some argue for a particular hierarchy of access, relating public safety to having preferential access to spectrum, or having special protections from interference.

A dimension related to access is that of who the stakeholders are moving forward. While device manufacturers, standards setting organizations, and application developers are consistently mentioned as stakeholders, there are other groups whose status as valid stakeholders may be more contested. These may include amateur radio users, device users with the potential to modify the software of devices, and international spectrum users. While they all would like a place in the future imaginary built around unlicensed spectrum, it is possible that they may find themselves excluded. This may parallel the historical sidelining of amateur radio users, and help reinforce historical conceptions of commercial users being the dominant stakeholders in spectrum debates.

There is also a technological component of the imaginary that is contested and emerging. Spectrum sharing technologies have developed that allow an imagined future of spectrum sharing to become a reality. Likewise, the development of the 802.11ac standard was prompted by an imagined future about creating ubiquitous Wi-Fi, but now that the standard exists like an artifact, it contributed to building a new emerging imaginary about the future of Wi-Fi. DSRC, weather radar, and Wi-Fi technologies will now have to co-exist. Contentions between varying perceptions of stability, and risk and benefits of these technologies inform the imaginary. This can be seen in contention over what regulation and what technical measures are required to prevent harmful interference, as well as contention over what types of technical testing needs to occur to ensure sharing occurs without interference. Furthermore, this highlights the historical relationship between technological standards and policy. Similar to how CBS wanted certain regulatory changes to move television from the VHF to UHF band to implement color television, certain regulatory changes such as the harmonization of U-NII rules would help enable the implementation of the IEEE 802.11ac standard.

This case continues some of the themes seen in spectrum sociotechnical imaginaries in the historical section of the paper. Again, questions and contention exist about who the stakeholders in creating spectrum policy are. Secondly, there are also questions about what is in the public interest, which is at least alluded to by many of the commenters, if not directly described. The public interest is conceived in multiple ways. One common view is economic, seeing public interest as the consumer's interest: competition, lower prices, and innovation in the marketplace all serve the public consumer's interest. Another view is centered on public safety: the widespread adoption of services that protect public safety during disasters or in a medical context are vital to the public interest. Another view is that broadband connectivity is akin to a utility and that expanding connectivity via Wi-Fi is in the public interest. While these views about the public interest are not necessarily mutually exclusive, they do compete to be integrated into the emerging sociotechnical imaginary.

Further complicating the situation is that the FCC is not starting from scratch – they must create new rules in the context of addressing legacy rules and devices built for the old environment. Lastly, the emerging imaginary is working through the question of how spectrum should be managed. Licensed-, unlicensed-, and sharing- based spectrum management regimes are not mutually exclusive, as seen in the 5 GHz case, where all three exist at the same time. Sharing is employed so that unlicensed devices can operate in the same spectrum as licensed incumbent users. Working out the coexistence of these regimes relies on sorting out many conflicting social and technical components, such as asking to what degree incumbents need to be protected from interference, and what technical solutions and regulations are needed to provide that protection.

CONCLUSION

This thesis has described some of the complexities and intricacies of spectrum debates, both historical and contemporary. The multitude of changes, developments, and disagreements in the regulatory, standards, and technical arenas are interconnected. Sociotechnical imaginaries help us make sense of some of the complexities of spectrum debates. Using the basis of co-production allows us to view technologies, regulation, and the larger societal context and framing as mutually shaping each other. Furthermore, sociotechnical imaginaries are particularly salient at moments of emergence, contestation, and stabilization. These processes are seen in the history of spectrum, such as the emergence, contestation, and eventual stabilization of the sociotechnical systems and related imaginaries of the FCC, FM radio, TV broadcasting, and cable TV. As seen through the contemporary case studies, emergence and contestation are present today as well. A new sociotechnical imaginary about the future of spectrum is emerging, framed by the broader problem of the spectrum crunch. Spectrum sharing technologies and regulations are likely to be a significant component in this new imaginary, yet the ways in which spectrum sharing may be implemented are contested. Stakeholders have different deeply held beliefs and imaginations about the future of spectrum, based upon different values and frameworks. These are extrapolated into competing regulatory and technical recommendations, leading to intense debate and contestation.

While spectrum debates provide a rich variety of changes in the technical, regulatory, and social landscape surrounding spectrum, four main qualities and dimensions of spectrum sociotechnical imaginaries have been prevalent during the historical and contemporary discussion. The first is an understanding of what stakeholders count or should be considered legitimate in spectrum debates. For example, amateurs' radio users' role as legitimate stakeholders has been historically contested at several moments. In current debates, the position of licensed spectrum advocates, unlicensed spectrum advocates, and incumbent licensees as stakeholders has been contested. The second is a conception of what the "public interest" is. Sociotechnical imaginaries contain a normative dimension of something that constitutes the "public good," or "public interest," but the definition and conception of the "public interest" can change. Historically, we see how "public interest" has often been linked to diversity in programming and voice on the airwaves. However in contemporary debates, "public interest" is instead often linked to economic arguments and competition definitions of "efficiency." The third point emerging from the analysis above is that sociotechnical imaginaries build on, mobilize, and are sometimes constrained by deep historical legacies. What happens in the present is affected by current and past technologies and standards, and the associated beliefs and imaginaries around them. This can be seen historically during the emergence of new technologies such as FM Radio, TV Broadcasting, and Cable TV, which were initially interpreted through the imaginaries of previously existing technologies before new imaginaries could emerge around them. In contemporary debates this is seen in some of the hesitancy to embrace new spectrum sharing technologies, or focus on possible interference risks that could occur if the FCC creates regulations imagining certain new technologies at the center of spectrum use. Finally, all of these dynamics have real and direct consequences for immediate questions around the management of spectrum that agencies like the FCC and other policy actors face every day. Historically, there have been tensions between advocates of property-rights models and advocates of commons models. Those still exist today, between unlicensed and licensed spectrum. While spectrum sharing has the potential for unlicensed and licensed users to coexist in the same band, there are still issues, regulations, and standards that have not been settled.

Thus sociotechnical imaginaries provide insight and help us open and understand debates surrounding emerging technologies and regulations. In particular, sociotechnical imaginaries help us understand the role of states, state policies, and the policy making process in defining the purposes of technology, and in turn, how technologies are used to reinforce certain future visions of the nation, society, and the good life. Sociotechnical imaginaries are able to capture the complexity of these debates, which have interconnected technical, policy, regulatory, and broader sociocultural aspects. They also help us understand processes of sociotechnical contestation at a deeper level and are particularly salient during moments of emergence, contestation, and stabilization. Debate between stakeholder positions does not stem from simple differences in "interests" and the arguments mobilized to justify or pursue them, but from differences in deeply held beliefs and worldviews that inform stakeholders' imagined social and technical futures about spectrum. The outcome of these negotiations may eventually coalesce around a new sociotechnical imaginary around spectrum, which will be worked out on an ongoing basis moving forward.

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Appendix I: Acronyms

AAMI – Association for the Advancement of Medical Instrumentation

AASHTO – American Association of State Highway & Transportation Officials

CATV – Community Antenna Television (later Cable Television)

CDMA – Code Division Multiple Access

CEA – Consumer Electronics Association

DFS – Dynamic Frequency Selection

DSRC – Dedicated Short Range Communications Service

FCC – Federal Communications Commission

FRC – Federal Radio Commission

FDD – Frequency division duplex

GHz – Gigahertz (1000 Megahertz)

IEEE – Institute of Electrical and Electronics Engineers

ISP – Internet Service Provider

LPTV – Low Power TV

MHz - Megahertz

NPRM – Notice of Proposed Rulemaking

NTIA – National Telecommunications & Information Administration

PCAST – President's Council of Advisors on Science & Technology

PISC – Public Interest Spectrum Coalition

TDD – Time division duplex

TDMA – Time division multiple access

TVBD – Television band devices

UHF – Ultra high frequency (300 MHz to 3 GHz)

U-NII – Unlicensed National Information Infrastructure

VHF – Very high frequency (30 MHz to 300 MHz)

WISP – Wireless Internet Service Provider