ITIF | INFORMATION TECHNOLOGY & INNOVATION FOUNDATION

Good and Bad Reasons for Allocating Spectrum to Licensed, Unlicensed, Shared, and Satellite Uses

JOE KANE AND JESSICA DINE | OCTOBER 2023

Policymakers inundated with self-serving arguments for specific spectrum allocation need ways to evaluate which actually advance the public interest. By focusing on the goal of productive spectrum use, one can differentiate between reasoning that would enhance productivity and that which would only advance private interests.

KEY TAKEAWAYS

- Licensed spectrum is good for providing the certainty needed to sustain wireless applications that require large, sustained investments. Revenue from license auctions is a side effect, not a goal in itself.
- Unlicensed spectrum is a good way to prevent usage rights from becoming too fragmented. But increases in congestion—or for that matter, analogies to public parks—do not support allocating the marginal spectrum band to unlicensed use.
- Shared spectrum is a good way to leverage technology to enhance productivity, especially when a band cannot practically be cleared and auctioned. But the limitations inherent in many sharing regimes are a cost, not a benefit.
- Satellite spectrum has largely existed in a parallel universe to terrestrial spectrum debates; however, technological convergence provides opportunities to incorporate it into traditional networking and learn lessons from its unique history.

CONTENTS

Key Takeaways 1
Introduction 3
Good Reasons for Licensed Spectrum 3
- Internalizing Externalities 3
- Providing Certainty 3

Bad Reasons for Licensed Spectrum 4
- Auction Revenue 4

Good Reasons for Unlicensed Spectrum 5
- Avoiding the Tragedy of the Anticommons 5
- Bad Reasons for Unlicensed Spectrum 6
- Unlicensed Spectrum Use Is Important and Needs Better Access 6
- Old Unlicensed Spectrum Bands Are Congested 7
- It's Like Public Parks 8

Good Reasons for Shared Spectrum 9
- A Band Is Unclearable for Exclusive Licensing 10
- Technological Advances 10

Bad Reasons for Shared Spectrum 11
- Preference for Limitations 11
- Greater Variety of Bidders, Licensees, or Users 12

Whither Satellite? 12
- Satellite Spectrum Has Been a Parallel Universe 12
- Coordination Among Satellite Operators Could Yield Lessons 13

Conclusion 14
Endnotes 15

INTRODUCTION

Many of those involved in spectrum policy endorse a "balanced" approach to choosing whether to make a band licensed, unlicensed, or dynamically shared. But there is little clarity regarding how we should allocate the marginal band. Every industry proffers arguments for the allocations that benefit it most, but this results in a mishmash of motivated reasoning that is of little help to policymakers seeking to be honest brokers.

This report evaluates common arguments for each broad category of allocation and provides concrete guidance for the circumstances that make each of the three regimes desirable. Throughout, the lodestar of productivity is our aim: Under what circumstances do particular allocations enhance productivity?

This goal is distinct from supporting any particular business or industry. Though firms have their own reasons to advocate for particular policies, policymakers must be able to determine when self-interest and public interest align versus when they are at odds. Resisting the bad reasons and embracing the good ones will in turn better align public and private interests, since private parties will know that they are unlikely to win policy victories without showing how their proposals benefit overall spectrum productivity.

GOOD REASONS FOR LICENSED SPECTRUM

Once we recognize that the right to transmit and receive radio frequencies is a scarce resource like any other, it is reasonable to consider the kind of property-based market that productively allocates other scarce resources. The legal underpinnings of the opposite view—that spectrum is unique in its scarcity and so cannot be allocated by markets—are wrong.[1] Scarcity is a prerequisite, not barrier, to the operation of a market for rights.[2] The now-substantial history of spectrum auctions, leases, and secondary market deals demonstrates their feasibility. Political, not economic, factors have been the main drag on the process.

Licensees being able to profit from enhancing the efficiency of their spectrum and suffering an opportunity cost for not doing so is a powerful system to promote spectrum productivity.

Internalizing Externalities

As in other markets, a central function of property rights in spectrum use is to force licensees to internalize the costs and benefits of their actions.[3] A licensee that efficiently employs its rights will profit from being able to sell high-quality service and perhaps lease or sell excess capacity. A licensee that wastes bandwidth will likely lose in the market to more efficient companies. This dynamic in turn incentivizes investments in technologies that increase the capabilities and efficiency of the hardware and software that drive wireless productivity. In short, licensees being able to profit from enhancing the efficiency of their spectrum and suffering an opportunity cost for not doing so is a powerful system to promote spectrum productivity.

Providing Certainty

To the extent that it makes sense to describe spectrum as a material, it is a raw material.[4] It requires up-front investments in order to become productive. Consumers demand reliable wireless services; the app economy, for example, would not flourish if there were a substantial chance of widespread outages. No one would go to an event relying on Uber for the return trip if

there were a substantial chance their mobile network would not be available to find them a ride home. Because of consumers' preferences, investors will also demand wireless service providers make their products reliable. A license (particularly an exclusive license) is a clear definition of the rights the Federal Communications Commission (FCC) will enforce for the licensee. This definition of rights and legal remedy is the strongest way to ensure the certainty of spectrum access necessary for wireless companies to provide the reliable services that consumers and capital markets demand.

A caveat to this point is that the superior certainty provided by exclusive licenses is always relative to existing technology's ability to create alternative arrangements of rights.[5] If, for example, a dynamic sensing system could provide licensed-like certainty of access at a time scale that is negligible from the perspective of a primary user, then this factor would become a wash in choosing the most productive spectrum allocation. Indeed, a system in which society gets all the productivity of a licensee plus the additional productivity of opportunistic users is superior to one that permits use by the licensee alone.[6] The question is one of technical capabilities to realize that state of affairs, not one of policy preference.

BAD REASONS FOR LICENSED SPECTRUM

Auction Revenue

One of the most politically popular justifications for more exclusively licensed spectrum is, from a public policy perspective, also one of the worst. It is true that the good aspects of licensed spectrum make it likely to generate large amounts of revenue at an auction.[7] But it is the market mechanism (including tradability on secondary markets) and the type of rights embodied by an exclusive license that make it a productive allocation. It is important to distinguish the core value of a spectrum license from the mechanism that gets that license into the marketplace. The value of the spectrum in its use is what matters, and policymakers should elect the distribution mechanism suited to deliver the most productive allocation, even if it doesn't raise as much revenue.

A small piece of the much larger pie offered by thriving wireless services and the applications they enable is a better long-run source of revenue than a single cut of an auction.

To be sure, auctions generate large chunks of revenue for the federal government, but it is a mistake to view revenue as a goal in itself. Revenue is useful as a means to public policy ends. But productive use of spectrum is such an end. To compromise long-run spectrum productivity in order to get a one-time deposit to the Treasury Department kills the golden goose.

Moreover, a more productive wireless economy will itself produce revenue for the Treasury since the government gets to tax the revenue of that economy. Indeed, the businesses and entire market sectors enabled by productive spectrum allocation bring in billions to federal coffers. Ongoing taxes on the $825 billion gross domestic product (GDP) occasioned by licensed spectrum, not to mention the taxable incomes indirectly increased by the value of wireless connectivity, will quickly overtake even large spectrum auctions.[8] And, indeed, these fiscal benefits are not limited to exclusively licensed spectrum. If unlicensed allocations are more productive, the taxable income they generate also goes to the Treasury even though there wasn't a government auction. A small piece of the much larger pie offered by thriving wireless services

and the applications they enable is a better long-run source of revenue than a single cut of an auction if that auction diminishes spectrum use in the future. Therefore, revenue-seeking policymakers should again return to the goal of spectrum productivity rather than myopically focusing on auction revenue.

GOOD REASONS FOR UNLICENSED SPECTRUM

Avoiding the Tragedy of the Anticommons

Unlicensed spectrum has an important place in a vibrant spectral economy. Unlicensed access can help foster innovation, lower barriers to entry, and enable popular interfaces such as Wi-Fi and Bluetooth, which in turn have become integral to the overall spectrum landscape.[9] It allows a diverse and growing network of connected devices the relatively frictionless ability to connect to consumers. Indeed, Wi-Fi connections are at the end of most wireline Internet access such that they complement the extensive private and federal investments of the last decades.[10]

Since many current wireless use cases, such as video streaming or demoing the newest app, do not require guaranteed reliability of spectrum access, the benefits of free access to unlicensed spectrum can balance out the threat of interference or overcrowding. The volume and diversity of applications that run in unlicensed bands can balance its inherent limitations.

While Ronald Coase's argument against command-and-control regulation of spectrum is sometimes misunderstood as claiming private property and bargaining will automatically solve all ills, in reality, Coase affirmatively argued that the costs of running a market for property rights can outweigh the efficiency gains from market allocation.[11] The choice of whether to run a market for a resource has trade-offs like any other choice. Yes, markets are the best way to synthesize disparate information to determine the most productive use of scarce resources. But markets aren't free; they entail transaction costs to create rights and enforce and bargain over them. When the costs of running a market exceed the inefficiencies from not running one, a nonmarket access regime is preferrable.

The standard argument for property rights as opposed to a commons is that open access is subject to the "tragedy of the commons" in which overuse of a resource becomes unproductive when no individual user has an incentive to economize. Since unlicensed users have no claim to the excess capacity generated by efficient use, there is no incentive to take the costly steps that would increase efficiency. But tragedy does not befall every commons. With the right structures and non-market rules for use, one can effectively govern a commons.[12] Indeed, unlicensed spectrum is not a pure open-access regime. Technical rules and protocols govern how devices operate. For example, devices employing listen-before-talk intentionally limit their own ability to "shout" over all other users to prevent the band from becoming unusable to everyone. The choice of frequencies also affects the viability of unlicensed spectrum: Frequencies that propagate short distances can, in effect, be geographically separated since they don't go through walls and into receivers far away in other buildings.

In addition to avoiding the Charybdis of commons tragedies, unlicensed spectrum can also avoid the Scylla of anticommons tragedies. Just as insufficient property rights can lead to overconsumption of a resource, property rights that are too numerous can create a fragmented market that grinds to a halt, leaving productive capacity on the table.[13] This tragedy of the anticommons is essentially a particular instance of when the costs of markets outweigh their

benefits. Theoretically, the FCC could auction spectrum for each individual home and have each homeowner license the 2.4 and 5 GHz bands for flexible use. But rights that end at one's walls are not very valuable to those outside those walls, and the burden of selling spectrum usage rights to prove that fact is likely not worth it. It is true that licensed spectrum often serves a similar function within a home; in "dead zones" of a house or in a congested apartment building, one may have more luck connecting to a nationwide mobile carrier than to a router in the closet, but these limitations do not necessarily overwhelm the benefits of easy access to the spectrum between one's laptop and the router in one's home office.

These trade-offs reveal that the manner and location of unlicensed use often determine whether the costs of licensing are worth the benefits. The risk of competing uses jostling for the same frequencies in the same place at the same time declines as geographical and temporal space between users increases. Indeed, many current unlicensed uses are defined around some sort of spatial separation. Wi-Fi bringing Internet to separate devices within individual houses, for example, or a Bluetooth connection linking one user's AirPods and iPhone, are predicated on a discrete use in one discrete location, and these limits are imposed by the choice of relatively low power limits and frequencies that don't propagate very far. In these circumstances, and when technology allows, an unlicensed user may be able to perform as reliably as a licensed one because of the lack of relevant competing uses.

When the costs of running a market exceed the inefficiencies from not running one, a nonmarket access regime is preferrable.

This technical difference can help policymakers determine where and when unlicensed spectrum makes the most sense. The quantity of spectrum allocated to unlicensed use should increase as the number of devices using it decreases—for example, if the population declines. Also, more spectrum should be allocated to unlicensed use as the range of applications decreases, which in turn suggests there should be more unlicensed spectrum in very high-frequency bands than in low ones since higher-frequency radio waves typically propagate shorter distances. In contrast, wide unlicensed networks over a densely populated city might be more prone to excessive interference and better suited for licensed access.

Bad Reasons for Unlicensed Spectrum

Unlicensed Spectrum Use Is Important and Needs Better Access

One commonly cited claim is that unlicensed spectrum's uses are important and valuable, and therefore more bandwidth should be freed up to ensure more reliable access to it.[14] The problem with this argument is that *licensed spectrum* exists precisely for those who can't operate under the uncertainties associated with unlicensed spectrum.[15] The flip side of unlicensed access's flexibility and easy access is that unlicensed access is by nature less reliable—because everybody else can jostle for those benefits, too. The "price" of free access to unlicensed spectrum is that users sacrifice guaranteed protection from interference. Getting reliable access to unlicensed spectrum essentially means taking advantage of licensed spectrum's benefits with none of the costs.

It is at best imprecise to refer to the beneficial uses of unlicensed spectrum as a reason for more of it, since unlicensed spectrum lacks the exact mechanism that helps determine the best use of

a given band.[16] Market-based allocation uses pricing to determine the most valuable spectral use.

Unlicensed spectrum, by definition, avoids this process, so allocating unlicensed spectrum becomes a guessing game of what use might be most valuable where. The question for spectrum policy is not whether uses in a particular band are good, but rather how to determine which arrangements of rights produce the most productive outcome among mutually exclusive goods.

Getting reliable access to unlicensed spectrum essentially means taking advantage of licensed spectrum's benefits with none of the costs.

There will always be winners, losers, and interference generated by competing unlicensed uses. Expanding the pool of unlicensed access will not change that fact: These trade-offs are borne of the fact that spectrum access is a scarce resource. "Increase the quantity" is not a sustainable or economic solution to competing uses between scarce resources. The trade-offs do not disappear simply by increasing the quantity of the resource available. Rather, those trade-offs can be reconciled by competition between individuals with control of the resource—the very thing that unlicensed allocations preclude. In this sense, stakeholders that argue for more unlicensed spectrum—on the grounds that more bandwidth is needed for unlicensed use cases that rely on continuous, reliable access to spectrum—are really making the case that those use cases need licensed, not unlicensed, spectrum.

Old Unlicensed Spectrum Bands Are Congested

Some make the parallel argument that overcrowding on unlicensed bands signals the need for more room. Unlicensed proponents have long argued that more unlicensed spectrum is needed to ease congestion on existing bands.[17] But this similarly points to a solution more in the vein of creating a licensed framework than expanding the pool of unlicensed. The solution to an overgrazed field isn't the opening of a second field under the same policy regime; it is to change the institutional structure to incentivize economization. Likewise, too much interference or congestion suggests that the unlicensed bandwidth isn't adequately governed by rules over power levels, setting frequency specifications, or other technical protocols that succeed in managing communal use. It may signal that applications in those bands need different rules, not just more of the same, to function properly.

Indeed, nascent "private networks" built around 5G are evidence of the ways in which a more licensed-like approach is needed to repair the unsuitability for unlicensed spectrum for many applications. Amazon Web Services (AWS), for example, offers a private 5G service for interested customers among whose major selling points are the ability to bypass the network congestion of Wi-Fi on unlicensed spectrum and guaranteed regular, high-quality service.[18] Particularly as the Internet of Things (IoT) diversifies and expands, enterprises have begun to rely more often on private networks as a more secure, reliable alternative, with users seeking to escape the chaos of unlicensed spectrum access by sequestering themselves in their own private networks.[19]

Unlicensed spectrum still supports a strong wireless economy, but congestion in current bands isn't itself necessarily proof of the need for more unlicensed spectrum now.

It's Like Public Parks

The recognition that spectrum access is a scarce economic resource like any other has spawned policy arguments that analogize spectrum to those other resources, most notably land. So while proponents of licensed spectrum extol the virtues of property rights to land, unlicensed proponents remind them of the glories of public parks that are free to everyone. Indeed, unlicensed advocates routinely use the private yard/public parks analogy to differentiate between licensed and unlicensed spectrum and the number of consumers served by each.[20] The implication here is that public parks are an unalloyed good that the public can always benefit from more of, and therefore so is unlicensed spectrum.

It is true that there are important parallels between land and spectrum. Both are valuable resources that can be parceled out to various users, and both can be more productively used with improvements in technology.[21] Neighboring uses can have real consequences for the "owner" of a particular plot of each, whether through the pollution emitted by a paper mill or interference generated by a particularly noisy spectrum-using device (or, on the flip side, the inconvenience of a downstairs apartment dweller—or receiver in a neighboring band—with unreasonably sensitive hearing).

The governing policies for both are quite similar as well. The concept of "private ownership" suggests rights such as the ability to exclude others from the use of one's plot, to determine how that property will be used, and to transfer those rights to another when both parties desire.[22] Both spectrum and land ownership have similar limitations on some of these rights. Zoning laws inhibit a property owner's freedom of choice to do *anything* with a particular plot of land, or to sell it to anyone, just as the FCC dictates certain uses for certain bands.[23] Privately owned land in the United States can be appropriated by the government under its power of "eminent domain" just as the FCC can reallocate swaths of spectrum when it determines the spectrum could be better used in some other way.[24] Users inflicting a "nuisance" on a landowner or "interference" on their spectral neighbors are sometimes, but not always, forced to curb their imposition—and in both cases, disputes are resolved by accounting for factors such as the amount of interference, reasonable expectations of either party, and the best outcome for society.[25]

However, there are also important distinctions between spectrum and land. Most obvious is that spectrum is not property in the same way as land is: Buying a license to a particular band is merely buying the right to use that band in a particular way for a particular amount of time.[26] As the technological landscape changes, the ever-present threat of auctions and reallocations means "ownership" of spectrum comes with less of a promise of longevity than does ownership of a plot of land. Spectral transfers are also subject to the FCC's approval of their societal benefits in a way that land transfers normally are not, and the fact that many technologies are built for specific uses in certain bands means that the costs of repurposing spectrum can be extremely high.[27] Since spectral use can be divided in time as well as in space, unused spectrum at a moment in time is a lost resource that can never be regained, and spectrum can be divided temporally and geographically into much smaller pieces than would be realistic for a piece of land.[28]

The important distinction here is between privately and publicly owned land, and between licensed and unlicensed spectrum. Crucially, unlicensed does not mean ungoverned in the same

way geographical public commons are not "anything goes." Even in publicly owned spaces, rules of good behavior still apply. Citizens have access to public parks and roads but not in any manner at any time. Speed limits, prohibitions against indecent or bothersome behaviors, and the like all exist to facilitate peaceful use among the greatest number of people. In unlicensed bands, standards for frequency and power level help allow coexistence between numerous diverse devices.

But the benefits of public parks are not fully analogous to unlicensed spectrum, though there is significant overlap. The main benefits of public parks are threefold: They provide green space for those who cannot afford to or do not want to purchase their own, which means they serve a larger, more varied population than can a private yard—and in doing so, they also provide the potential for interactions between random individuals.[29] They also generate positive spillover effects such as ecological benefits, aesthetic improvements, and increases in home values in proximity to a park.[30] Unlicensed spectrum provides benefits for users who gain free access to spectrum and to other spectrum users who can rely on unlicensed spectrum to offload traffic—but most spectrum users wouldn't want it as a neighbor. The mere existence of public parks, regardless of their use, creates benefits, while the main value of unlicensed spectrum is in its effective and creative use.[31]

Even public parks, though they provide more direct intrinsic value than does unlicensed spectrum, are capable of being misplaced or over-saturating a landscape. Part of their value is contingent on people using them, which means designing parks with proximity to residential areas and accounting for the culture and needs of a community.[32] It is possible to have huge sections of dedicated parkland that nonetheless are poorly designed or incorrectly placed and do not fulfil their purpose. It is also possible that, in some cases, these less-effective parks may better serve society as land for privately owned businesses.

While the applicability of land analogies to spectrum depends on the context, we can evaluate specifically the analogy that supports a greater quantity of unlicensed spectrum based on its similarity to public parks. Common estimates put the land allocated to parks and other public spaces in a city at around 15–30 percent.[33] Even when public roads are included with parks and commons as public spaces, the total recommended percentage caps off at around 50 percent.[34] The proportion of unlicensed to licensed spectrum is likely greater than that: One CTIA estimate, for example, puts the amount of unlicensed mid-band spectrum at seven times that of licensed.[35] A city with seven times more space allotted to public roads and parks than to privately owned property would likely fall quickly into disarray. If there is a lesson to be taken from comparing spectrum use to public/private land allocation, it is that the best allocation has a complementary, intentional mix of both, and the marginal allocation should favor balance, not ever-greater unlicensed spectrum.

GOOD REASONS FOR SHARED SPECTRUM

"Shared spectrum" is a loaded term, since parties often have diverse sharing regimes in mind when invoking it. At one level, however, all spectrum is shared. Even exclusively licensed spectrum is shared among the customers of the licensee. As an allocation, however, shared spectrum usually means spectrum that is used by disparate parties without aligned incentives to internalize externalities. Therefore, interference management must occur through regulation and technological choices. Even within this definition, there is a broad taxonomy of options.[36]

Policymakers should demand conceptual clarity as to what "sharing" means for a given band and whether it is preferrable to alternatives.

A Band Is Unclearable for Exclusive Licensing

Spectrum policy increasingly wrestles with the fact that empty or easily clearable bands are no longer common. While the advantages of exclusive licensing in promoting productive use call for substantial attempts to align incentives to clear especially federal users from bands that would be more productive elsewhere, doing so is not always politically or technically feasible.[37] In those cases, productivity is better served when there are additional uses employing some form of sharing mechanism rather than leaving potential capacity unused. The coexistence of multiple users can take place via geographic, frequency, or time separation. Today's spectrum allocation debates often revolve around the choice of dynamic sharing systems in which rights to use the spectrum vary in a way controlled by a centralized system that takes inputs from databases or environmental sensors.[38]

A key benefit of sharing systems in federal bands is that they can be designed around existing federal functions.[39] Policymakers and advocates should not discount the value of federal services themselves in calculating trade-offs of alternative spectrum allocations. For instance, in the Citizens Broadband Radio Service (CBRS) band (3,550–3,700 MHz), a dynamic sharing system added commercial mobile uses underneath naval radars which have priority. Proponents of exclusively licensed spectrum lament the opportunity cost of not clearing out incumbent radar to realize the high economic value of exclusive licenses in that band, as evidenced by the auction price for exclusive licenses in the next-higher frequency band compared with the auction for Priority Access Licenses (subject to preemption by the Navy) in the CBRS band.[40] A straight comparison of auction revenue for each type of license, however, undercounts the value of CBRS because it assumes that exclusive licenses were a possibility.

Productivity is better served when there are additional uses employing some form of sharing mechanism rather than leaving potential capacity unused.

To be sure, whether naval radar could use a different or smaller band is up for debate, and one should not naively believe every incumbent's claim that only the status quo is feasible. But, at the same time, the Navy's radar activities have value. We should not pretend there is no need for the federal incumbent's mission such that clearing a band is always simply a power struggle without real trade-offs. In general, policymakers should be skeptical of self-serving claims of unclearability and conduct their own analyses, including by coordinating with federal incumbents to share classified information through proper channels, but they should also recognize that at some point the cost of clearing exceeds its benefits. Where the trade-off flips, however, is a case-by-case analysis subject to context such as the specific incumbent and the technological sharing alternatives.

Technological Advances

The technical capabilities of a sharing system are key to the choice of allocation. Improved sharing technologies can make sharing of bands more feasible than maintaining only a single user. Time-based sharing, for example, started by dividing use by quarter hours in 1912, but now signals can trade off use of a frequency in millisecond timeframes. If sharing required giving up

15 minutes every hour, that likely would harm productivity. But if it means adding an extra packet every hundred milliseconds, that is more likely to be a cheaper way to add throughput than clearing an incumbent entirely. Technological advances in time and other spectrum domains can enable more granular divisions that reduce wasted capacity and, thus, enhance productivity. In short, improved technology can reduce the cost at which clearing is no longer the best option for productive use.

So even if exclusive licenses are, on the margin, more productive than current sharing technology, that reality is contingent on current technology. Sustainably productive spectrum use entails investments to push the frontier of sharing technology, including dynamic sharing systems, so that they can approach and eventually exceed the capabilities of exclusively licensed spectrum on its own. Older sharing regimes have evolved considerably. The forthcoming Incumbent Informing Capability will be more advanced than early TV whitespace databases, and automated frequency coordination holds promise for better management of unlicensed spectrum than earlier versions required in portions of the 5 GHz band.[41]

Dynamic sharing could even become the first-best allocation if technological advances enable a generalized use-or-share framework. There can be little objection, from a policy perspective, to allowing additional uses of a licensed band that does not cause harmful interference to the licensee. In some ways, proponents of exclusively licensed spectrum already acknowledge the feasibility of such a system in their objections that "sharing" is a misnomer for CBRS since the real regime is that the Department of Defense (DOD) does whatever it wants without ever having to share with lower priority users, such as Priority Access License (PAL) owners.[42] But a true use-or-share regime would place mobile wireless carriers in the position they now envy in DOD: the right to operate at full power whenever they want in a license area with others simply getting the "scraps." It would be odd if rights deemed outrageously expansive when held by the federal government were somehow dangerously weak in the hands of commercial interests. At the same time, sharing proponents ought not complain about such an arrangement given their insistence that the rights conferred by PALs are excellent for business.

BAD REASONS FOR SHARED SPECTRUM

Preference for Limitations

Shared spectrum often comes with limitations necessary to facilitate multiple users without aligned incentives. For example, power levels permitted in the CBRS band are 327 times lower than those in the exclusively licensed band just above it.[43] Some proponents of particular sharing arrangements frame their support as though their own services would be enabled by these limitations.[44] But that skips too many steps. Licensees can always transmit at lower power or in smaller areas than their license permits. And if that is a more valuable way to use spectrum, parties with such business models would win at auction of full-powered licensed spectrum since they expect to make more money than from alternative uses. Furthermore, even if the licensee does not want to buy an entire full-power, large-area license, it could lease a segment from a high-power operator for its more limited needs.

None of this requires the imposition of unusually limited licenses by the FCC at the outset. If a low-power user is not winning in the auction or reaching a secondary market deal with another licensee, that is evidence that the more limited use is less productive than the alternative

(otherwise, the limited user would have outbid all others). Severe power limitations in the name of sharing are effective at diminishing the value of spectrum for traditionally full-powered uses, such as nationwide mobile networks. But that outcome is merely a zero-sum conception that invites policymakers to put a thumb on the scale for certain industries or business models at the expense of others. Policymakers should decline that invitation.

Artificially reducing the usability of spectrum makes it less productive rather than more, and for that reason, the more attainable price tag is a bad sign for productivity, not a good one.

Greater Variety of Bidders, Licensees, or Users

A parallel argument to the preference for limitations inherent in many dynamic sharing systems touts the number and variety of particular users or applications it invites. This argument again gets things backward. The concept of productivity dictates that the "right" uses and users are those who value the spectrum most. It is not a sound rejoinder to the benefits of exclusive licenses that they are mostly used by large mobile network operators.[45] It could be that the uses to which mobile network operators put spectrum is the most valuable to society. Making licenses less valuable with unnecessary operation limitations will lower prices for rights to operate under those limitations, which will garner more interest than if high prices put licenses out of reach.

But it would be a mistake to view the uses of the devalued spectrum as superior to the unseen lost productivity from feasible full power use. A city block is not made more valuable by breaking windows and punching holes in roofs and restricting future development, even though doing so would reduce its sale price and put it within the budget of more potential buyers. Likewise, artificially reducing the usability of spectrum makes it less productive rather than more, and for that reason, the more attainable price tag is bad sign for productivity, not a good one. Therefore, the focus ought to be on how the spectrum is used, rather than on the variety of operators or devices present in a shared band.[46]

WHITHER SATELLITE?

To date, spectrum allocation in a given band has been a choice between alternative terrestrial regimes. But satellite services continue to grow in a separate regulatory universe. Trends in wireless business and technology, however, suggest that convergence between terrestrial and satellite services is on the horizon.[47]

The advent of viable low-Earth orbit (LEO) satellite constellations has the potential to disrupt normal market dynamics for home broadband and be a complement to mobile wireless networks. Starlink, for example, now offers home broadband service with comparable speed and latency to terrestrial offerings.[48] Mobile network operators are increasingly partnering with satellite companies to provide supplemental connectivity anywhere in the world.[49] A greater role for satellite service in conventional wireless applications invites questions about the quantity of and rules for spectrum available for satellite use.

Satellite Spectrum Has Been a Parallel Universe

While policy battles have raged over competing allocations of spectrum for terrestrial use, these generally do not consider the addition of satellite services. Likewise, satellite services have

operated either in a separate spectrum or in frequencies with very different regulatory regimes than those considered by any of the above terrestrial allocations.

Satellite services do not pay for their licenses, and they share spectrum in a way that is, in one sense, more radical than terrestrial sharing proponents consider. Satellites often, for example, transmit in the same band everywhere in the continental United States. Satellites and Earth stations are subject to extensive FCC regulation, so they are not unlicensed; however, they do exhibit some of the features that make a kind of radical open access feasible.[50] Compared with terrestrial mobile services, for example, satellite services have relatively few deployed devices and customers. These characteristics make it easier to coordinate disparate use cases without interrupting anyone else's service. To some extent, this parallel regulatory regime is a consequence of the technical differences between terrestrial and satellite uses. Satellites, especially at geostationary altitude, can "see" more of the Earth than any terrestrial system, so it makes more sense to prevent interference by separating the satellites than by parceling licenses to geographic subdivisions on the ground. Satellite beams cover a large area and rely on ground receivers to tune in to the proper transmission. Satellite transmissions also travel long distances and through the Earth's atmosphere, which results in their downlink (space-to-Earth) transmissions being relatively weak. This phenomenon reduces the probability of interference on the ground but sometimes necessitates especially large or sensitive equipment to communicate successfully.

As the satellite economy develops, however, conflicts will likely become more common, and the FCC will need rules to adjudicate them. The FCC has recently adopted rules to define the type and degree of protection incumbent nongeostationary constellations can expect from newcomers.[51] Prior rules were built around the assumption that space was essentially a nation-state domain and that any commercial use would be limited. This proceeding illustrates that the time to figure out the rules for the space economy has come.

In some bands licensed for terrestrial use, satellite services are permitted in a peripheral way, subject to restrictive rules for geographic areas. Here, convergence portends significant changes in the relationship between different types of services. The FCC has launched a proceeding on "supplemental coverage from space" meant to account for the capabilities of satellites to communicate directly with consumer smartphones and other devices. Indeed, some such service is already operational, and terrestrial mobile networks are inking deals with satellite companies to provide supplemental service to their customers. As mobile networks and satellite constellations begin to do business together—rather than existing in separate spheres—the incentive to view allocations as zero sum declines. Indeed, this shift is more of a reason to take literally the idea of flexible use licenses rather than ceasing flexibility at Earth's atmosphere.

Coordination Among Satellite Operators Could Yield Lessons

Observing the parallel universe of satellite spectrum policy could be a source of lessons for spectrum policy more generally. For example, despite reliance on sharing rather than exclusive licensing, satellite companies routinely coordinate their operations voluntarily to avoid interference conflicts. Perhaps this suggests that there is more room for negotiation at the boundaries of spectrum interference disputes than is normally assumed. At the same time, successful coordination without licenses also calls into question why congestion in unlicensed spectrum is not mitigated through similar voluntary coordination among users.

The conditions under which this cooperation occurs could be instructive, however. There are relatively few satellite companies, and their operations take place over long distances without the opportunity to readily adjust technical components. This restricted range of options may create game-theoretical conditions that grease the wheels of negotiations and make it easier to envision cooperative practices that enable mutual benefit over repeated negotiations. Furthermore, FCC rules for satellites are designed to encourage coordination with the threat of more onerous compromises if parties do not reach an agreement. This structure contrasts with secondary markets in terrestrial spectrum in which the terms of licenses (e.g., extensive buildout requirements) and restrictions on transfers are the norm.

On the other hand, the satellite marketplace is far smaller and less pervasive than terrestrial networks are today. While this fact is likely influenced by the availability of technology to provide frequent access to orbit, a more robust evaluation of the success or failure of satellite spectrum policy will require more time for the market to develop.

CONCLUSION

Since all spectrum allocations have their benefits and costs, policymakers must always consider the trade-offs and think on the margin. There is no one best spectrum allocation in the abstract. The state of existing allocations, the services that surround a given band, and the political context all constrain possible options. But policymakers and those who seek to sway them ought to lean more on the "good" reasons outlined herein and stop pushing the "bad" ones. Doing so will result in a more productive use of the airwaves, which is in the long-run interest of everyone.

About the Authors

Joe Kane is director of broadband and spectrum policy at ITIF. Previously, he was a technology policy fellow at the R Street Institute, where he covered spectrum policy, broadband deployment and regulation, competition, and consumer protection. Earlier, Kane was a graduate research fellow at the Mercatus Center, where he worked on Internet policy issues, telecom regulation, and the role of the FCC, where he interned in the office of Chairman Ajit Pai. He holds a J.D. from The Catholic University of America, a master's in economics from George Mason University, and a bachelor's in political science from Grove City College.

Jessica Dine is a broadband policy analyst at ITIF. She holds a B.A. in economics and philosophy from Grinnell College.

About ITIF

The Information Technology and Innovation Foundation (ITIF) is an independent 501(c)(3) nonprofit, nonpartisan research and educational institute that has been recognized repeatedly as the world's leading think tank for science and technology policy. Its mission is to formulate, evaluate, and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress. For more information, visit itif.org/about.

ENDNOTES

1. *National Broadcasting Co. v. United States*, 319 U.S. 190 (1943).
2. Lionel Robbins, "An Essay on the Nature and Significance of Economic Science," London: MacMillan and Co, (1935).
3. "The Coase Theorem," *Marginal Revolution University,* March 18, 2015, https://mru.org/courses/principles-economics-microeconomics/coase-theorem-example.
4. *But see,* Jean Pierre De Vries and Jeffrey Westling, "Not a Scarce Natural Resource: Alternatives to Spectrum-Think" (October 2, 2017), available at SSRN: https://ssrn.com/abstract=2943502 or http://dx.doi.org/10.2139/ssrn.2943502.
5. Joe Kane, "Spectrum Sharing: Holy Grail or False Hope?" (ITIF, July 2022), https://itif.org/publications/2022/07/05/spectrum-sharing-holy-grail-or-false-hope/.
6. *See generally,* Michael Calabrese, "Use it or Share It: A New Default Policy for Spectrum Management" (January 7, 2021), TPRC48: The 48th Research Conference on Communication, Information and Internet Policy, available at SSRN: https://ssrn.com/abstract=3762098 or http://dx.doi.org/10.2139/ssrn.3762098.
7. Federal Communications Commission (FCC), "Auction 97: Advanced Wireless Services (AWS-3)," accessed July 2023, https://www.fcc.gov/auction/97; FCC, "Broadcast Incentive Auction and Post-Auction Transition," updated May 2017, https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions; FCC, "Auction 107: 3.7 GHz Service," accessed July 2023, https://www.fcc.gov/auction/107.
8. CTIA – The Wireless Association, "U.S. Wireless Industry, Powered by Licensed Spectrum, Contributes $825 Billion to America's Economy Annually, According to New Report," press release, December 7, 2022, https://www.ctia.org/news/u-s-wireless-industry-powered-by-licensed-spectrum-contributes-825-billionto-americas-economy-annually-according-to-new-report.
9. Gary Shapiro, "Benefits of unlicensed spectrum," *The Hill*, June 2014, https://thehill.com/blogs/congress-blog/technology/209214-benefits-of-unlicensed-spectrum/.
10. Doug Brake, "Coase and WiFi: The Law and Economics of Unlicensed Spectrum" (ITIF, January 2015), 8, https://itif.org/publications/2015/01/12/coase-and-wifi-law-and-economics-unlicensed-spectrum/.
11. Ronald Coase, "The Nature of the Firm," *Economica* (1937) http://rochelleterman.com/ir/sites/default/files/Coase%201937.pdf; Deirdre McCloskey "The so-called Coase theorem," *Eastern Economic Journal*, vol. 24(3): 367-371 (1998), https://www.jstor.org/stable/40325879.
12. Jerry Brito, "The Spectrum Commons in Theory and Practice," *Stanford Technology Law Review 1* (2007): 1, https://jerrybrito.com/pdf/2007StanTechLRev1.pdf; Elinor Ostrom, "Governing the Commons: The Evolution of Institutions for Collective Action" (Canto Classics. Cambridge: Cambridge University Press, 2015), doi:10.1017/CBO9781316423936.
13. Michael A. Heller, "The Tragedy of the Anticommons: Property in the Transition from Marx to Markets," University of Michigan Law School Scholarship Repository (1998), https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1608&context=articles.
14. COMMENTS OF CHARTER COMMUNICATIONS, INC., in the matter of Development of a National Spectrum Strategy, NTIA Docket No. 230308-0068, April 17, 2023, https://ntia.gov/sites/default/files/publications/charter_communications.pdf.
15. Joe Kane, "The role of markets in spectrum policy" (R Street, June 2018), https://www.rstreet.org/research/the-roles-of-markets-in-spectrum-policy/.
16. Ibid.

17. Teralyn Whipple, "Make More Unlicensed Spectrum Available for Increasing Demand for Wi-Fi Use: Panelists," *Broadband Breakfast*, June 27, 2022, https://broadbandbreakfast.com/2022/06/make-moreunlicensed-spectrum-available-for-increasing-demand-for-wi-fi-use/; Terry Ngo, "WHY WI-FI STINKS—AND HOW TO FIX IT," *IEEE Spectrum*, June 28, 2016, https://spectrum.ieee.org/why-wifi-stinksand-how-to-fix-it.
18. Monica Alleven, "Amazon launches AWS Private 5G using CBRS," *Fierce Wireless*, August 12, 2022, https://www.fiercewireless.com/private-wireless/amazon-launches-aws-private-5g-using-cbrs.
19. Tom McLaughlin, "How Private Cellular Networks Can Support Industrial IoT Connectivity," *Machine Design*, March 17, 2021, https://www.machinedesign.com/automation-iiot/article/21158294/how-privatecellular-networks-can-support-industrial-iot-connectivity.
20. "Apples and Oranges: The Value of Licensed and Unlicensed Spectrum," WifiForward, November 4, 2022, https://wififorward.org/news/apples-and-oranges-the-value-of-licensed-and-unlicensed-spectrum/.
21. John W. Berresford and Wayne A. Leighton, "The Law of Property and the Law of Spectrum: A Critical Comparison," *CommLaw Conspectus - Journal of Communications Law and Policy*, Vol. 13, No. 1, (2004), available at SSRN: https://ssrn.com/abstract=1494380.
22. Ibid, 5.
23. Ibid.
24. Ibid.
25. Ibid.
26. Ibid, 36.
27. Ibid; Brake, "The Law and Economics of Unlicensed Spectrum."
28. Brake, "The Law and Economics of Unlicensed Spectrum."
29. Paul M. Sherer, *The Benefits of Parks: Why America Needs More City Parks and Open Space,* The Trust for Public Land, 2006, https://conservationtools.org/library_items/729-the-benefits-of-parks-why-americaneeds-more-city-parks-and-open-space.
30. Ibid.
31. Lincoln R. Larson, Viniece Jennings, and Scott A. Cloutier, "Public Parks and Wellbeing in Urban Areas of the United States," *PLoS One*, 11(4):e0153211. (2016); doi: 10.1371/journal.pone.0153211. PMID: 27054887; PMCID: PMC4824524, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4824524/.
32. Taisa Way, "Are public parks an unalloyed good? Not always," *Fast Company*, November 2018, https://www.fastcompany.com/90270674/are-public-parks-an-unalloyed-good-not-always.
33. "Typical Percentage of Land Uses," Useful Community Development, accessed July 2023, https://www.useful-community-development.org/typical-percentage-of-land-uses.html.
34. Gregory Scruggs, "How Much Public Space Does a City Need?" *Next City*, January 7, 2015, https://nextcity.org/urbanist-news/how-much-public-space-does-a-city-need-UN-Habitat-joan-clos-50percent.
35. "Spectrum Allocation in the United States: An analysis of the current state of radio spectrum allocation across key stakeholders, the increasing need for licensed spectrum, and potential paths forward," Accenture, commissioned by CTIA, (2022), https://api.ctia.org/wp-content/uploads/2022/09/Spectrum-Allocation-inthe-United-States-2022.09.pdf pg 18
36. John Leibovitz and Ruth Milkman, "Taking Stock of Spectrum Sharing" (September 3, 2021), available at SSRN: https://ssrn.com/abstract=3916386 or http://dx.doi.org/10.2139/ssrn.3916386.

37. Joe Kane and Jessica Dine, "Building on Uncle Sam's "Beachfront" Spectrum: Six Ways to Align Incentives to Make Better Use of the Airwaves" (ITIF, January 2023), https://itif.org/publications/2023/01/30/sixways-to-align-incentives-to-make-better-use-of-the-airwaves/.
38. *See e.g.,* FCC, "3.5 GHz Band Overview," accessed April 3, 2023, https://www.fcc.gov/wireless/bureaudivisions/mobility-division/35-ghz-band/35-ghz-band-overview.
39. MARTHA DEGRASSE, "No news is good news: CBRS players report no interference," Light Reading, October 28, 2020, https://www.lightreading.com/aiautomation/no-news-is-good-news-cbrs-players-reportno-interference/d/d-id/765000#close-modal.
40. Roger Entner, "Lessons from spectrum auctions: Entner," *Fierce Wireless*, February 11, 2021, https://www.fiercewireless.com/regulatory/lessons-from-spectrum-auctions-entner.
41. Michael DiFrancisco et al., "INCUMBENT INFORMING CAPABILITY (IIC) FOR TIME-BASED SPECTRUM SHARING," NTIA Report, February 22, 2021, https://www.ntia.gov/sites/default/files/publications/iic_for_time-based_spectrum_sharing_0.pdf.
42. *See e.g.,* Roger Entner, Twitter (December 12, 2022), https://twitter.com/RogerEntner/status/1602325062194962432.
43. "5G Mid-Band Spectrum Deployment," Rysavy Research, February 2021, https://rysavyresearch.files.wordpress.com/2021/02/2021-02-5g-mid-band-spectrum-deployment.pdf.
44. Elizabeth Andrion et al., Coalition Letter Re. Re: Facilitating Shared Use in the 3100-3550 MHz Band, WT Docket No. 19-348; Promoting Investment in the 3550-3700 MHz Band, GN Docket No. 17-258, July 1, 2021, https://www.fcc.gov/ecfs/document/1070125607136/1; COMMENTS OF OPEN TECHNOLOGY INSTITUTE AT NEW AMERICA and PUBLIC KNOWLEDGE, In the Matter of Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband of Other Expanded Use, GN Docket No. 22-352, December 12, 2022, 7-8, https://www.fcc.gov/ecfs/document/121361124072/1.
45. REPLY COMMENTS OF NCTA—THE INTERNET & TELEVISION ASSOCIATION, In the Matter of Expanding Use of the 12.7-13.25 GHz Band for Mobile Broadband or Other Expanded Use, GN Docket No. 22352, January 10, 2023, https://www.fcc.gov/ecfs/document/1011075199463/1.
46. Douglas Boulware et al., "An Analysis of Aggregate CBRS SAS Data from April 2021 to January 2023," Institute for Telecommunications Science, May 2023, https://its.ntia.gov/publications/details.aspx?pub=3311.
47. Sue Marek, "AT&T leases spectrum to AST SpaceMobile," *Fierce Wireless*, May 12, 2023, https://www.fiercewireless.com/wireless/att-leases-spectrum-astmobile-satellite-cellular-service; Monica Alleven, "T-Mobile, SpaceX promise 'end of dead zones' with cell phones connected to satellites," *Fierce Wireless*, August 25, 2022, https://www.fiercewireless.com/wireless/t-mobile-spacex-promise-end-deadzones-cell-phones-connected-satellites; Linda Hardesty, "Apple iPhone 14 will have emergency satellite connectivity," *Fierce Wireless*, September 7, 2022, https://www.fiercewireless.com/wireless/apple-iphone14-will-have-emergency-satellite-connectivity; Linda Hardesty, "2022 sees satellite-to-mobile get real with Lynk, AST SpaceMobile, Apple and others," *Fierce Wireless*, December 19, 2022, https://www.fiercewireless.com/wireless/2022-sees-satellite-mobile-get-real-lynk-ast-spacemobile-appleand-others.
48. Isla McKetta, "How Starlink's Satellite Internet Stacks Up Against HughesNet and Viasat around the Globe," Ookla, August 4, 2021, https://www.ookla.com/articles/starlink-hughesnet-viasat-performance-q22021.

49. “Operators are partnering with LEO satellite providers to harness new revenue growth opportunities.” Analysys Mason, January 2022, https://www.analysysmason.com/research/content/articles/leo-satellitearticle-rma18/.
50. FCC, ”Further Streamlining Part 25 Rules Governing Satellite Services,” Report and Order, Docket No. 18-314, adopted on November 8, 2020, https://www.fcc.gov/document/fcc-streamlines-licensing-rulesmany-satellite-operators.
51. FCC, “FCC Adopts New Rules for Satellite System Spectrum Sharing.” news release, adopted April 20, 2023, https://www.fcc.gov/document/fcc-adopts-new-rules-satellite-system-spectrum-sharing.