ADDRESSING BROADBAND REALLOCATION AND THE RURAL/URBAN BROADBAND GAP

Applied Policy Project – 2020

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DISCLAIMER

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other entity.

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EXECUTIVE SUMMARY

Broadband access has evolved from a luxury good into something resembling a utility. These days, reliable and high-speed internet access is nearly as essential to private citizens and businesses as water, heat, or electricity. The interconnectivity benefits to broadband access are vast. Where once there were extraordinary barriers to entry in the global marketplace, now small businesses can conduct business worldwide for nearly no cost. Access to information has never been more readily available; that a typical grade-schooler can digest both breaking world news and social media from the palm of his hand is a testament to the power of the digital revolution.

Not all are seeing the benefits of broadband access, however. Today, only 67% of rural Americans have reliable access to broadband, causing important sectors of the rural economy to lag behind the rest of the United States. To expand broadband access to rural America, the Obama administration issued the National Broadband Plan in 2010, but implementation of the plan has focused mostly on spectra reallocation, which has not yielded the results that it anticipated. The rural/urban broadband gap remains.

Furthermore, there are serious national security concerns with broadband reallocation, as the Department of Defense uses broadband for a myriad of critical purposes. Command, control, communications, battlefield imaging, radar, air traffic, and much more. As spectra are reallocated from the DoD to public ISPs, the risk to these systems increases.

There exists a need to balance equity concerns with the concerns of national security. The balance between the two is the central focus of this report. Below, I outline a brief history of telecom in the United States, current regulatory schemes, and my understanding of the broadband landscape especially in rural America. I then propose several alternatives, including repacking incentives, technological intervention, and the creation of a state-run ISP, that might deter further broadband reallocation while still increasing coverage to underserved communities. The most attractive alternative will be the one that strikes the proper balance between equity and national security, while also taking into account the difficulty in surviving a political battle in Congress, the FCC, and potentially the courts. Naturally, cost-effectiveness is of great importance as well, but I anticipate alternatives that minimize spectra reallocation will have cost-effectiveness built in.

I ultimately recommend a new repacking project as the best alternative to reduce the number of spectra repurposed from the DoD and reduce costs to enter rural broadband markets.

PROBLEM

The National Broadband plan has ordered the federal government to "make available a total of 500 MHz of federal and non-federal spectrum over the next 10 years, suitable for both mobile and fixed wireless broadband use" (DoD, 2018). **This broadband reallocation scheme poses significant risks to national security.** Much of the requested spectra comes from Department of Defense sources. The DoD uses broadband technology for radar, communications, and other battlefield imaging purposes. It is essential to national security and to military service members that these technologies remain available and useful in their current capacity.

Spectra are by their nature rival and excludable goods. When a user transmits over a spectrum, other users can transmit as well, but neither benefits from this arrangement; multiple transmissions result in interference. Furthermore, spectra are exclusive in that other users are usually prohibited from transmitting across a spectrum unless they are licensed to do so. Unauthorized transmission can result in legal action or FCC penalties. Specialized equipment is also required for a user to transmit, further increasing the upfront cost of utilizing spectra. Given these properties of spectra, it is prudent to use market-based incentives to increase spectra utilization efficiency.

Broadband reallocation by spectrum auction is useful, but there are inefficiencies laden within the current reallocation regime that, if corrected, would reduce the demand for DoD spectra. For example, many cell providers are often barred from bidding on spectra. This has the unintended effect of pushing licenses to providers that are unwilling or unable to provide services to groups in most need of broadband access such as rural Americans. Problems within the spectrum auction process must be solved in order to curb demand for government owned spectra and mitigate the risk to national security posed by broadband cuts within the DoD.

COST TO SOCIETY

There are two primary costs to society that are worth considering. First, there is the cost to society posed by the increased national security risk for reduced broadband capabilities on the part of the DoD. This is difficult to quantify; the DoD's capacity to use broadband systems is not publicly available. Still, some assumptions can be made. There are known costs of broadband spectra from FCC auctions. Furthermore, there are known costs of military acquisitions, including "Command, Control, Communications, Computers, and Intelligence (C4I) Systems" (Comptroller, 2018). Assuming that a percentage of these systems are unusable due to a lack of available broadband, I can derive an estimate of the cost of the systems in addition to the value of the lost broadband itself.

Furthermore, there are costs to the public if broadband spectra are not allocated more efficiently. This cost can be quantified as a loss in economic productivity due to a lack of broadband access. The loss in economic productivity can take many forms, including lost wages, loss of time, increased logistical costs, and more.

Google's chief economist estimates that the average internet user exacts $500 per year in productivity and services from broadband access (Bedard, 2016). Furthermore, "the value that American consumers place on free content and services found on the Internet was between $2,500 and $3,800 in 2006. According to the same kind of study carried out in Europe, this value almost doubled from 2010 to 2013." 37% of the 60 million Americans living in rural areas do not have access to broadband. Taking the numbers from the European study in 2013, we can assume that the cost to society represented as a lack of economic productivity is somewhere between $11,100,000,000/year and $16,872,000,000/year.

The DoD requests a minimum of $500,000,000/year for "warfighter-information network" instruments (Comptroller, 2018). One can assume that this cost will increase if broadband becomes scarcely available to the DoD. At least in the short term, I estimate that these costs will increase markedly, up to $750 million to account for needed changes from broadband to other systems. This is in line with a 2002 report that the federal government spent nearly 750 million (2020 dollars) to upgrade radio systems following spectra disbursement. Furthermore, the defense budget calls for over $5 billion/year for command, control, and other communications services (Washington Technology, 2002). Further assessment is needed to isolate the impact that spectrum reallocation might have on command and control, but the relevant systems that would be impacted are communications and especially air traffic control. Finally, spectra disbursement is costly to the DoD based on the value of the spectra itself. For example, the NTIA has identified 100 MHz of spectra in the 3450-3550 MHz range for sharing and disbursement. Given the spectra's likely application for 5G technology, this range of spectra could easily be worth $7-10 billion (Eggerton, 2020).

BACKGROUND - ELECTROMAGNETIC SPECTRUM

Beginning in the mid-1880s, German scientists theorized that when electricity passed through a wire that it would give off "invisible light under certain conditions" (Spiker, 2000). Several decades later, Heinrich Hertz became the first to transmit electromagnetic waves through the air (Hertz, 1892). Hertz' work would inform the beginnings of study into waves and the electromagnetic spectrum.

The array of all light that propagates through free space comprises the electromagnetic spectrum. Electromagnetic waves have properties that make them desirable to consumers. For example, waves with long wavelengths can travel long distances without being disturbed by other electromagnetic radiation. This is why radio waves commonly transmit in the 50-150MHz band. Conversely, high energy waves like X-rays propagate at a rate of $3*10^{16}$ Hz, making them able to penetrate soft tissue and provide physicians with skeletal imaging. This is illustrative of the different potential uses of waves, where the only key difference between a radio wave and an x-ray is the amount of energy the wave carries.

As technology has improved, scientists have harnessed the different properties of waves to transmit data. A waveform can correspond to a 1 or 0 (among others), and sending combinations of 1's and 0's allows for near-limitless combinations of different data in binary code.

BROADBAND MARKET LANDSCAPE

The growth in demand of wireless technology has been spurred mostly through "the growth of mobile telephony and, more recently, mobile data" (Eisenbach, 2011). In 1985, there were fewer than 100,000 mobile phone users in the United States. This figure increased sharply in the early to mid-90's before beginning to level off in the later 2000's (potentially due to the global recession of 2007). Today, the market for cell phones approaches saturation, with the Pew Research Center claiming that 96% of Americans today own a cell phone (Pew Research Center, 2019).

With the increase in cell phone use has come an exponential increase in wireless data use. In the early 1990's, cell phones were quite literally "mobile phones," with no strings attached. Today, smartphones can connect to the internet, stream video, send files, and much more. There is more data passing between Americans than has ever been recorded in history. But, the full benefits of such interconnectivity have only been realized through the effective use of broadband spectra.

What is typically referred to as broadband spectra are a range of spectra between 300 MHz and 3 GHz that are most optimal for data transfer over great distances. What makes broadband sufficiently more advantageous than radio for data transfer is the marked increase in energy and complexity of the wave than a radio wave; thus, broadband facilitates the transfer of both more data and more complex signals.

Broadband technologies promise much in the way of economic opportunity. Principally, broadband internet access has leveled the playing field for small businesses that otherwise would not have access to larger markets. As MEI puts it, “the Internet gives small and medium-sized enterprises access to the global marketplace. Hal Varian, Google’s chief economist, invented the term “micro multinational” to describe how the Internet puts small companies on equal footing with large corporations. Even when they are very small, it is easier and easier for companies to compete in the global marketplace without having a physical presence in other countries.” (Bedard, 2016). Moreover, the internet bridges many onerous logistical barriers for small businesses that might stall operations. MEI surmises these benefits as well, writing that “the complex mosaic of services and platforms that is the Internet also offers solutions in terms of office automation, shipping, and logistical support that were not so long ago restricted to large corporations, and does so at a fraction of the cost of traditional methods.”

The benefits of internet innovation have not been equitably distributed to all Americans, however. According to a Pew Research Center poll conducted in 2019, 63% of rural Americans have home broadband systems, compared with 75% of urban Americans and 79% of suburban Americans (Perrin, 2019). To address this issue, which has existed for some time, the Obama administration directed the FCC to make available broadband spectra from government sources in 2010 with an expected completion date of 2020.

Broadband access has fallen behind in rural America due to supply-side and demand-side failures (CRS, 2019). On the supply side, internet providers struggle to make a return on investments in rural broadband markets given the comparatively high cost to build broadband infrastructure compared to urban markets. It costs nearly the same for an internet provider to serve a multi-unit apartment building in the city as it does to serve a single household in the country. This is because the distance between the data center and the customer is often much larger in rural America, which drives costs up for the ISP. Furthermore, there is a perceived lack of demand for “very high” broadband speeds in rural America, which could help to offset costs to service providers. Rural Americans typically place high value on broadband, but do not see a benefit to paying extra for speeds in excess of 10 MB/s. Based on the perceived lack of demand for premium speeds, ISPs are reluctant to provide rural services without incentives.

BROADBAND: GOVERNANCE AND REGULATION

Universal internet access has been a priority of the federal government at least since early widespread adoption of internet systems in 1996. The underlying legal framework pushing for universal broadband adoption stretches back to the 1934 Communications Act, creating the FCC. From the FCC's website, "The Federal Communications Commission was created by the Communications Act of 1934. Universal service was one of the core mandates of that legislation, the purpose of which included making "available…to all the people of the United States…a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges." (FCC, 2020). The Act outlined the interest of the federal government to protect and regulate the use and distribution of public airways, a common property resource. The principles outlined in the 1934 Act have for the most part remained to this day, with the notable exception of the Fairness Doctrine that was partially struck down by the Supreme Court in 1985 and then totally repealed by the FCC in 1987.

The FCC acts as both a legislating body and a regulatory agency. Both mandates come from authority given by Congress, and the FCC exercises both forms of authority through its rulemaking process. For example, the FCC ordered television providers to switch from analog to digital signals in the mid-2000s, a process that is still ongoing. In this case, Congress passed a broad statute ordering analog signals to be shut down; the FCC then issued a "legislative rule" reaffirming this order and outlining specific steps to enact the shutdowns. The FCC also issues non-legislative rules that fall into three categories: interpretive rules, policy statements, and organizational rules. Rules falling into the latter category are similar to the type that might be issued by an executive agency.

The FCC rulemaking process is very similar to the process for other executive agencies. First, the agency issues a notice of proposed rulemaking, which is followed by a period of public comment. The comment period extends to oral and written presentations to leading members of the agency. Because of the technical nature of FCC business, the vast majority of rules then undergo a period of peer review from experts outside of the agency or any affiliation with the proposed rule. Notably, the FCC is somewhat limited in the changes it can make to a proposed rule. Federal courts have ruled that changes to FCC rules must have been logically anticipated from public comment and peer review, otherwise the FCC must propose a separate and new rule. Finally, after a rule is published in the federal register it is often subject to review by the courts, or a private entity will request a waiver to a rule. In either case, the rule may be subject to further scrutiny and revision. Given the amount of resources the FCC delegates to administrative action, it has delegated much of its policy and advisory authority to the NTIA (FCC, 2019).

As telecom became increasingly more complicated, especially as cable tv and phone service became more widespread, the National Telecommunications and Information Administration was created to act as the FCC's policy and research arm in 1978. The NTIA "serves as the President's principal advisor on telecommunications policy," and as such its mandate includes spectrum allocation and internet access more broadly. Spectrum allocation is at the forefront of NTIA’s mission, and the NTIA produces a national spectrum strategy that aims to achieve more efficient allocation of spectra, especially between the federal government and the public. It is this strategic framework that the NTIA operates under to identify spectra for auction from the Defense Department.

The process to acquire spectra from government sources is relatively straightforward. First, the NTIA identifies a “package” of spectra for reallocation. Then, the FCC holds an auction for the spectra. Phone companies and internet service providers are typically the biggest players at a spectra auction. These auctions can be known to generate substantial revenues. For example, a recent mmWave auction for 5g providers raised $7.5 billion (Fletcher, 2020). The winner of a spectra bid is granted a “lease” from the FCC for exclusive use of the spectra. To solidify the exclusivity of spectra, but also to ensure stable connections for users, the FCC prohibits transmission over a frequency by those who are not lease holders.

NATIONAL SECURITY INTERESTS

The federal government, but especially the Department of Defense, relies on the electromagnetic spectrum in-step with growing use of advanced technology. Radar was invented in 1935, and it was immediately implemented in warfare with the outbreak of World War Two in 1939 (Watson, 2009). Radar was essential for locating enemy ships and aircraft during the war, and more sophisticated forms of radar are in use today for similar commercial and military purposes. For example, advanced radar systems are used today to track objects such as satellites and ballistic missiles in space. Other systems include LIDAR, a system similar to radar that uses the visible light spectrum for imaging, communications, and signals intelligence systems that collect emissions spectrum data from adversaries (Congressional Research Service, 2019). In contemporary use, standard command and control (C2) functions rely heavily on broadband, and service disruption may result in consequences ranging from limited testing and training capabilities to diminished battlefield effectiveness. A report from the NTIA outlines the DoD’s use of a small band of spectra, the 300 MHz band:

> *DoD supports a variety of missions within this band as a result of its historic availability for military operations and the propagation benefits of the lower ultra-high frequency (UHF) range. DoD uses the 225-399.9 MHz band to maintain vital command and control (C2) and communications on a global scale as well as within a theater of operations. Specific missions include flight operations, tactical training, installation and sustaining base, test and training range operations, and contingency command and control.*

National Security interests often conflict with the interests of the public at large. This conflict has a long history in American jurisprudence. In *Dennis v. US*, the defense of Free Speech was subordinate to the interest of national security when leaders of the Communist party were convicted of advocating to overthrow the US government (Oyez, n.d.). Furthermore, the Supreme Court recognized the right of the State to keep information vital to national security secret in *United States v. Reynolds* (1952). The Court is not always willing to hold in favor of the government when it comes to National Security interests, however. In 1971, the Court ruled against "prior restraint" when releasing the infamous Pentagon Papers to the public; in *US. V. Nixon*, (1974) the President's claim of executive privilege undergirded by national security interest was not found to be substantial enough to outweigh the public's interest in Presidential tapes. Broadband access between the public and the federal government represent a new issue in this prevailing conflict. Recently, the Executive has made it a priority to set aside broadband spectra for the public to more easily provide access to regions of the United States that have experienced the most difficulty in securing broadband access. The sharing of broadband spectra presents an easily-recognized but not-so-easily solved problem of determining which party has the greater need – and therefore access – of the spectra.

TECHNOLOGY

Normally, EM spectra are leased to individual users. As US systems have become more reliant on broadband technology, allocating EM frequencies to individual users has become increasingly inefficient (Holland et al, 2012). Additionally, the technologies themselves have grown more capable of using broadband spectra efficiently over time.

Dynamic Spectrum Access technology functions by managing which users can access EM spectra under a prioritization scheme (Song et al, 2012). This technology can be implemented to solve the problem of balancing competing interests and reduce inefficiencies inherent in the current system. However, the technology itself is still new, and presents its own set of policy problems. There are three well-documented forms of Dynamic Spectrum Access that reappear multiple times in the literature. These are known as interweaving, overlay, and underlay access. Each method proposes a unique solution to the problem and includes its own unique tradeoffs.

TYPES OF DSA

Interweave: This is the prominent form of currently available DSA technology. DSA users are assigned either "Primary" or "Secondary" status. The secondary user "uses the cognitive radio to sense the surrounding spectrum environment, then selects one or more idle spectrum band(s), and switches the cognitive radio to the selected band(s) to transmit" (Song et al, 2012). When the primary user transmits on the spectrum, the secondary user is unable to do so. This establishes a clear prioritization hierarchy between primary and secondary users. In the DoD's interest, this method could be used to prohibit civilian interference on a frequency when military assets are used.

Underlay: Dynamic Spectrum Access can also be achieved through an "underlay" framework. When users transmit data over a frequency, it can cause interference to other users on the spectrum. Cognitive radio systems (Wang et al, 2015) monitor and control the level of interference between primary and secondary users. This framework prohibits interference from a secondary user over a certain threshold (Hu et al, 2012). Thus, efficient functionality of a spectrum is achieved by prohibiting transmission from a secondary user when the user causes excessive interference. This framework potentially promotes spectrum sharing from both the public and the federal government when the public's activities do not demand excessive EMS resources.

Overlay: The overlay model is similar in form to the underlay model in that both permit secondary users and primary users to transmit data over the same spectrum simultaneously. However, the overlay model prioritizes primary user performance - here meaning transmission fidelity - over other metrics (Jiang et al, 2013). Secondary users under an overlay system commit resources to improving primary user transmission fidelity, primarily by "donating" transmission power to a primary receiver (Song et al, 2012).

CRITERIA

Evaluation of broadband reallocation alternatives will be based on several criteria. As the central points-at-issue for this report, national security and equity will be weighed the most heavily, followed by political feasibility, implementation, and cost effectiveness.

CRITERION 1 – POLITICAL FEASIBILITY

This criterion highlights the importance of the likelihood that the proposed alternative will be executed by relevant actors. The actors of importance are those in charge of spectrum allocation and auctioning; in this case, those actors are the FCC and the NTIA.

The FCC is charged with auctioning spectra according to the mandate set by the National Broadband Plan. The NTIA is tasked with identifying spectra for auction. Political feasibility will be assessed according to the likelihood that these agencies will implement proposed alternatives.

An alternative is likely to be politically feasible if a) the alternative does not conflict with the National Broadband Plan by b) continuing to make spectra available from DoD/federal sources. Any alternative that limits spectra disbursement or otherwise impedes the NBP is likely to be infeasible.

CRITERION 2 – EQUITY

Equity focuses the analysis on the need of the public for access to broadband spectra. Broadband access to rural communities is of special importance given the well-documented lack of internet access in many parts of rural America.

The central assumption of this criterion is that current spectra allocations have created an inequitable circumstance. The federal government maintains control of highly-coveted broadband spectra, and urban areas of the United States are afforded easier access to broadband given the cost effectiveness associated with broadband expansion in densely populated areas.

A shift in broadband allocation that increases the proportion of rural Americans with access to broadband against the proportion of urban Americans with access to broadband will score higher on this criterion. Conversely, an alternative that does not improve outcomes for rural communities will not score as high on this criterion.

CRITERION 3 – COST-EFFECTIVENESS

There are numerous forecasted costs to broadband reallocation. Among these costs are: restructuring of DoD broadband systems, creation of new broadband networks in rural America, administrative costs associated with broadband auctions, etc. Cost-effective alternatives minimize these costs while also maximizing positive outcomes. Given the outcomes of interest, there are diminishing returns associated with costly alternatives, even when those alternatives may yield stronger outcome-maximizing results.

Examples of cost-effective alternatives may vary. The costliest alternatives will likely necessitate large amounts of spectra disbursement, or broad stroke government subsidy for ISPs. It is essential that alternatives balance the total benefit to the broadband landscape without leveraging excessive resources from the federal government, the general public, or the private sector.

CRITERION 4 – NATIONAL SECURITY

Opposing the interest in expanded access to broadband to rural communities is the need to ensure military broadband systems, especially battlefield imaging systems (radar), are able to function smoothly. As broadband spectra are disbursed from DoD control, there is greater risk of interference or inoperability of such systems.

Alternatives that preserve the integrity of DoD spectra will inherently score higher on this criterion. Additionally, alternatives that maintain operability standards of US military systems will receive a stronger score. By contrast, alternatives that expose military systems to performance degradation will receive a lower score.

CRITERION 5 – IMPLEMENTATION

This criterion assesses the ability of the relevant agencies (mostly the FCC) to implement a proposed alternative. An alternative needs to be politically feasible to survive Congressional scrutiny and the FCC rulemaking process, but it needs to be implementable for FCC tools to enact it. Furthermore, cooperation from the private sector is paramount when considering new FCC rules; a rule that meets heavy opposition from the private sector is unlikely to achieve widespread implementation or solve a nationwide problem. ISPs can seek waivers to rules or pursue litigation to prevent enforcement of rules, and avoiding these avenues is critical for smooth implementation.

An alternative that proposes a change in policy without creating a new program, driving up costs, or otherwise creating market barriers in the broadband landscape is more likely to achieve a high score on this criterion. By contrast, an alternative that is likely to meet heavy opposition from the private sector, whose efforts are necessary for widespread implementation, will likely score lower on this criterion.

ALTERNATIVES

I propose a series of alternatives to correct for inefficiencies in the broadband market. These alternatives are designed to minimize reallocation of spectra, especially from federal government/DoD sources, while still holding to the central mission of the National Broadband Plan to expand broadband access to rural Americans in a cost-effective manner.

DSA TECHNOLOGY

To correct for inefficiencies in the spectrum reallocation process, some have encouraged more widespread implementation of Dynamic Spectrum Access technologies. DSA sharing allows primary and secondary users to seamlessly share spectra on an as-needed basis.

DSA technology works by designating a primary user and any secondary user(s). The primary user can transmit across a spectrum as-needed. The secondary user senses the Electromagnetic environment (EME) for an opportunity to transmit, sending its package when it will not cause an undue burden on the primary user. There are several mechanisms that are conducive to a DSA sharing system. Some systems allow the secondary user to transmit at the same time as the primary user, provided that the primary user does not suffer interference above a certain threshold, and other systems allow the secondary user to augment the primary user's signal while also allowing both to transmit simultaneously.

This corrects for inefficiencies in the market for spectra by reducing the need for wholesale leases on broadband spectrum and encouraging bargaining between spectrum owners and potential users. With fewer auctions, this will likely also mean that fewer spectra will be disbursed by the federal government, thus abating the risk to national security. Unfortunately, DSA technologies are fairly new, and the costs and feasibility of implementing DSA technology on a broad scale are unclear. Furthermore, there are concerns about the reliability of spectrum sensing technologies that enable DSA environments to function efficiently; sensing inaccuracy can cause interference and thus inefficiency.

COMPETITIVE BIDDING REFORM

In a 2015 FCC auction, both AT&T and Verizon were excluded from bidding on spectrum in the 600 MHz range due to their vast control of low-band spectrum. This type of rule poses a number of issues. First, it lowers the reservation price for a package of spectra significantly if major players such as AT&T and Verizon are unable to participate in a spectrum auction. With a lower reservation price, fewer revenues are raised from auctions, and leaseholders are less incentivized to surrender their leases for auction. Additionally, preventing certain organizations from bidding on spectra forces those organizations to devote resources to other (potentially lower-quality) spectra, creating the possibility of misallocation.

The FCC is not making meaningful progress to solving the rural/urban broadband gap by trying to force competition between smaller players in the broadband market. The current market landscape is such that there are high upfront costs to providing rural Americans with reliable access to broadband. In many cases, major corporations such as AT&T and Verizon are the only ones able to shoulder these high upfront costs. Therefore, I propose that major corporations be permitted to bid on a greater share of the spectra than they are currently permitted, producing a more competitive auction. The ideal end-result of this alternative is that a greater number of competitive auctions will both incentivize further spectra auctioning and spectra reallocation towards communities in need.

The main drawback to this alternative is the risk of monopolistic behavior from major broadband corporations, as this is clearly the intention of the FCC by forbidding companies like AT&T and Verizon from bidding on certain spectra. If such corporations can obtain control of a number of spectrum above a certain threshold, they can price discriminate at the expense of the consumer. Furthermore there is the risk I discussed above that the reservation price might not increase when competitors with more capital participate in the auction, as bidders with less capital might not bother bidding on the spectrum if they will certainly not win the bid.

STRENGTHEN INSURANCE INCENTIVES

In order to hold a spectrum auction, those who hold a lease on a spectrum must surrender their lease voluntarily. For example, in 2015 there were a series of spectra auctions that were previously owned by TV stations. The lease owners were incentivized to surrender their lease with the promise of reimbursement by the federal government for participating in “repacking.” Repacking involves reimbursing the lease owner for the costs to change to a lower broadband frequency in exchange for their lease on a higher-frequency spectrum. Congress appropriated nearly $2 billion in 2015 for this endeavor, but costs of repacking exceeded expectations. Because TV stations were not reimbursed on time, confidence in repacking was not very high, and getting leaseholders to surrender their licenses voluntarily has been difficult. Strengthening repacking programs and expanding them to other holders of broadband spectrum, like radio stations, is an attractive option for a number of reasons.

First and foremost, making leaseholders whole following the surrender of their broadband lease is a strong method to incentivize broadband reallocation from private sector sources rather than from sources such as the DoD. Furthermore, the DoD only owns about 18% of spectra desirable by major broadband companies, so repurposing spectra from other sources promises to be a more efficient avenue for reallocation. Repacking also increases efficiency in the broadband market by moving broadband operators who can operate on lower frequencies to those frequencies, while allowing operators who cannot operate at a lower frequency to do so at the range that they can. Unfortunately, as I have stated above, the costs of repacking have proved to be higher than originally anticipated, and expansion of repacking to other private broadband sectors will only increase the costs of repacking.

CREATION OF A FEDERAL INTERNET SERVICE PROVIDER

This alternative proposes to mimic the efforts of many European nations who have state-run internet service. France, for example, has achieved 100% broadband adoption nationwide, even in rural areas, through state-funded internet support (Yeates, 2018). This program would require Congressional authorization, but would certainly be administered by the FCC.

There are several considerations to this alternative. First, creation of a state-funded ISP would likely meet opposition from private sector broadband providers who would not seek to compete against the federal government. The level of opposition is not clear, however, due to the perceived demand-side failures in the rural broadband market that I have mentioned above. If broadband providers are not providing service to rural Americans due to the lack of demand for premium speeds, it is possible that they will not resist the federal government providing the service in their absence. Additionally, this alternative is costly, as it necessitates the (a) creation of a new program, (b) creation of new internet infrastructure, and (c) long-term service and maintenance costs. As broadband technology improves, it is likely that costs, especially service costs, will increase as rural Americans move to adopt “very fast” or “ultra fast” broadband technology.

This alternative may have the unintended consequence of forcing more robust competition in the rural broadband market. The rural/urban broadband gap has been aggravated by a lack of profitability in the rural market for all but the largest ISPs that can shoulder the high upfront costs to enter the market. Depending on the form that a state-run ISP takes, private providers might emulate the public provider if the latter proves to be profitable. Conversely, If the state-run ISP fails, but private providers enter the market to fill the void, this would constitute a net benefit for rural Americans overall.

STATUS QUO

This is the baseline case. Without intervention, spectra will continue to be auctioned, primarily from federal government (but especially DoD) sources. The federal government controls 18% of the highly-coveted spectra in the 300MHz band, with the Department of Defense using these bands for radar, battlefield imaging, and communications.

The baseline case is not necessarily a bad outcome, but it is certainly not the most efficient outcome. With intervention, it is likely that a solution can be reached that limits disbursement of DoD spectra while also bringing high-speed broadband to communities that are still in need of it.

KEY FINDINGS AND ANALYSIS

	Equity	National Security	Cost-Effectiveness	Political Feasibility	Implementations
Relaxed Auction Guidelines	Low	Medium	$88.05/person	High	High
Repacking Incentives	Medium	Medium	$88.24/person	High	High
DSA Technology	Low	High	$0.03/person	Medium	Low
State-Run ISP	High	Low	$2707.41/person	Low	Low
Status Quo	Low	Low	N/A	High	High

DSA

Each alternative presents its own strengths and weaknesses. Ultimately, the alternative best-suited to address the gap in rural/urban broadband coverage while maintaining a balanced focus to preserving national security assets will excel at least in some way across all criteria.

DSA Technology is an attractive option to revolutionize the spectrum market, potentially reducing the need for spectrum auctions by as much as 75%. But, the theory is still untested. My analysis finds that the spectrum sensing technologies are not nearly as costly as I originally anticipated. Spectrum sensing receivers could be used in data centers nationwide for as little as $1000 per center. However, the competitive interplay between ISPs presents significant political challenges to the idea of widespread dynamic spectrum access. Currently, ISPs have sole transmitting authority through leases granted by the FCC. Were DSA technologies implemented, the ISPs would have the capability to use competitor spectra. This would almost certainly lower costs across the board, but it would diminish the value of the initial investment that the ISP made in bidding on the spectra. After all, the AWS-3 spectrum auction in 2015 raised nearly $45 billion in revenues. If competitors are given free reign to transmit over each other's' spectra, there may be attempts to recuperate the lost value from the exclusivity of the spectra.

Additionally, it is not clear if DSA interplay on a scale so large as the national internet infrastructure is currently possible. The nascent technology might not be sophisticated enough to prevent intolerable levels of interference, which would ruin any benefit that the technology promises to deliver in the form of cost-savings. Given these factors, I rate DSA technology as "low" on implementation, but "medium" in political feasibility, as the FCC has given plenty of thought to spectrum sharing ideas.

STATE-RUN ISP

Moreover, the idea of a State-Run ISP is one that has gained much attention in certain municipalities across the United States, but also on the national level abroad in Europe. For example, Longmont, Colorado boasts a gigabit-speed municipal internet service called NextLight, offering its users speeds that rival Google Fiber, Verizon Fios, and others, for between 50 and 80 dollars a month. Bringing in revenues of 15 million/year, but generating other benefits that I estimate in total to be nearly 90 million/year, the idea of a state-run ISP is worthy of consideration.

Unfortunately, the logistics of setting up and operating a state-run ISP are too costly to be feasible at this time. I estimate the upfront costs of setting up such an ISP to rural communities at $22 billion/year for 5 years just to run the cabling the sufficient amount, but this is almost certainly an underestimate as the costs to run cabling to rural communities is much higher per household than it is in urban communities. I then estimated the costs of running over 1000 data centers, including staffing, for 5 years afterwards. All told, the costs just to establish such an ISP would total nearly $100 billion, which is very likely an underestimate. At over $2,000 per person to service everybody needing broadband access, this option is not cost effective.

RELAXED AUCTION GUIDELINES

After facing backlash for setting aside 30 MHz of spectrum that AT&T and Verizon could not bid on, the FCC was forced to come back to the table to avoid legal pressure. The most recent spectrum auctions have been open to full competition, but internet coverage to rural America has not expanded in-step with greater spectrum access for these large corporations.

I estimate only small costs associated with permitting full and open bidding of spectra (roughly $3 billion) that come from lost revenues of small networks attempting to bid on the spectra that are priced out of the auction by AT&T, Verizon, and the like.

Ultimately, this alternative does very little to ameliorate the conditions of rural Americans, but it does reduce the misallocation of spectra to providers that are completely unable to provide services to underserved areas. I weigh that the prevented misallocation prevents the need for more spectrum auctions somewhat, earning this alternative a “medium” score in National Security.

Repacking Incentives

Some misallocation of spectra is due to the advancements in technology that have been made since television networks emerged after World War II. TV providers at the time transmitted over spectra that they had access to, but new technologies allow those providers to move to a lower frequency while maintaining transmission fidelity.

Further repacking projects would yield critically-needed spectra from the private sector as opposed to the federal government, and reduce costs for ISPs trying to enter rural markets. I estimate the costs of a new repacking project at $2.7 billion, as this was the price tag for a repacking project in the late 2000s. I include an additional $250 million to cover unforeseen expenses, but in all this price tag is probably an overestimate, as repacking schemes have gotten better at sampling the costs of reoutfitting provider infrastructure in the last 15 years. All told, this is a cost-effective option that reduces the need for spectra from the DoD, cuts costs to enter rural markets, and is a proven solution to spectrum scarcity that the FCC has practiced in the past.

RECOMMENDATION

I recommend that a new repacking project be issued to move TV and Radio providers to spectra that might otherwise be used for internet service. This alternative relieves the demand for spectra from the DoD who might otherwise use the spectra for telecommunications, radar, air traffic control, missile guidance, and other critical purposes. Furthermore, it cuts costs to ISPs that might try to enter rural markets by reducing the demand for spectrum auctions, the primary upfront cost for small providers trying to provide internet services. This is an all-around good solution to spectrum scarcity and rural broadband access.

IMPLEMENTATION

Repacking projects begin when the FCC makes a request for the voluntary surrender of licenses from TV and Radio providers. TV providers who voluntarily surrender their licenses are promised a share of the take of revenues as an incentive for moving to a lower frequency. Based on the response rate, the FCC samples providers who voluntarily surrender their spectrum to determine the total costs of repacking across surrendering providers. Repacking costs vary; some providers may need a total infrastructural overhaul, while others may only need a receiver upgrade (not very costly). Accurate sampling is important to determine the total cost of repacking; if the appropriations are not sufficient to make providers whole, they are not incentivized to participate in the program.

After repacking is complete, the spectra are sold at an FCC auction, with a portion of the proceeds set aside for repacking costs. Other proceeds might be set aside as well, including monies for alerting subscribers to channel changes, for example. If repacking costs exceed expected values, money can either be taken out of proceeds from the auction or appropriated through Congress.

APPENDICES

APPENDIX 1: NUMBER OF HOUSEHOLDS WITHOUT INTERNET ACCESS, BY STATE

Alabama	321,359
Alaska	**24,576**
Arizona	288,885
Arkansas	212,223
California	1,147,228
Colorado	180,142
Connecticut	141,561
Delaware	35,433
District of Columbia	34,300
Florida	872,333
Georgia	503,557

Hawaii	52,435
Idaho	63,457
Illinois	581,667
Indiana	367,029
Iowa	163,715
Kansas	138,127
Kentucky	**257,178**
Louisiana	314,291
Maine	70,704
Maryland	206,151
Massachusetts	251,566
Michigan	**507,279**
Minnesota	220,139
Mississippi	226,003
Missouri	333,351
Montana	59,563
Nebraska	87,932
Nevada	132,839
New Hampshire	43,854
New Jersey	325,686
New Mexico	152,709

New York	888,661
North Carolina	544,299
North Dakota	42,019
Ohio	**586,602**
Oklahoma	224,688
Oregon	141,058
Pennsylvania	666,091
Puerto Rico	**416,176**
Rhode Island	50,081
South Carolina	290,601
South Dakota	50,755
Tennessee	395,020
Texas	**1,231,590**
Utah	60,468
Vermont	29,942
Virginia	360,402
Washington	218,837
West Virginia	132,877
Wisconsin	295,118
Wyoming	24,916

APPENDIX 2: COST-EFFECTIVENESS OF STATE-RUN ISP

	Costs
Year	
1	22000000000
2	22000000000
3	22000000000
4	22000000000
5	22000000000
6	632040000
7	632040000
8	632040000
9	632040000
10	632040000
Net Present Value	$92,052,039,280.56
Cost-Effectiveness	$2,707.41

APPENDIX 3: COST-EFFECTIVENESS OF DSA TECHNOLOGY

DSA Technology	Costs
Year	
1	230000
2	230000
3	230000
4	230000
5	230000
6	0
7	0
8	0
9	0
10	0
Net Present Value	$1,009,058.59
Cost-Effectiveness	$0.03

APPENDIX 4: COST-EFFECTIVENESS OF RELAXED BIDDING RESTRICTIONS

Relaxed Bidding Restrictions		
Year		Cost
	1	3000000000
	2	0
	3	0
	4	0
	5	0
	6	0
	7	0
	8	0
	9	0
	10	0
Net Present Value		$3,000,000,000
Cost-Effectiveness		$88.24

APPENDIX 5: COST-EFFECTIVENESS OF REPACKING INCENTIVES

Repacking Incentives	
Year	Costs
1	2670000000
2	250000000
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
Net Present Value	$2,993,644,859.81
Cost-Effectiveness	$88.05

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