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April 25, 2014

Hon. Fred Upton
Chairman
Energy and Commerce Committee
US House of Representatives 2125 Rayburn House Office Building
Washington, DC 20515
Hon. Greg Walden

Chairman
Communications and Technology Subcommittee
Energy and Commerce Committee
US House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

Re: Spectrum Policy

Dear Chairman Upton and Chairman Walden:

I am an American who studies the economics of the internet and telecommunications at a European university. This position allows me the opportunity to reflect on spectrum policies of other countries compared to the US. The views in this letter are my own.

It is undisputed that the US leads the world on a number of important mobile and wireless measures, including the number of mobile broadband subscriptions, diversification of mobile technologies, the number of 4G/LTE smartphones sold, and the proliferation of mobile applications. CTIA the Wireless Association observes that key achievements have been made even in just the last five years, including growing from zero to some 50 million 4G/LTE subscriptions. Smartphone subscriptions have increased from 41 million to more than 150 million. The iPad didn't exist in 2009, but 220 million have been sold since. Meanwhile the number of apps has increased from 150,000 to 4 million. Mobile penetration increased from the already high 89 percent to 110 percent. The amount of SMS and MMS have doubled. This short list of accomplishments doesn't begin to describe the advancements being launched in entirely new industries of m-health, m-education, and m-transportation.

The market-oriented spectrum policy reforms adopted by Congress and operationalized by the FCC over the past two decades have generated enormous benefits for consumers, and are one of the main reasons the U.S. now has the world's most advanced mobile wireless services. Market-based spectrum allocation has allowed spectrum to flow away from inefficient uses to more highly valued ones and thus made possible the explosive growth of mobile broadband.

But more needs to be done. America's global leadership in wireless rests on the effective optimization of one asset above all: spectrum.

The US has taken advantage of technologies to improve the utilization of spectrum, but relying on efficiency enhancement alone is not enough. The supply of spectrum is fixed, and it needs to be allocated and utilized more efficiently.

A suboptimal approach to spectrum management may "satisfice" for the moment, but it is not strategic for the long term. The US faces an exploding demand for mobile data. Wireless carriers don't even have 16 percent of the airwaves that are best suited for mobile broadband.[1] The government has the lion share and is undisputedly an inefficient user

This situation of squandered spectrum is a great concern to the nation and a threat to future economic growth and global competitiveness. Citing the National Telecommunications and Information Administration's Office of Spectrum Management, the President's Council on Advisors for Science and Technology explains the situation.

> *Federal agencies have exclusive use of 18.1% (629 MHz) of the frequencies between 225 and 3700 MHz (traditionally referred to as the "beachfront frequencies"), while non-Federal users have exclusive licenses to 30.4% (1058 MHz). The remaining 51.5% is shared, with Federal use primary and private sector use secondary. Approximately 80% of the shared allocation—or 40% of the total—have a "dominant" Federal use (e.g., radar, aeronautical telemetry) that under the current coordination regime effectively precludes substantial commercial use of those bands. In other words, nearly 60% of the beachfront frequencies are predominantly allocated to Federal uses.*[2]

Therefore I applaud your committee's leadership to take action on the important issue of spectrum.

The Office of Science and Technology Policy (OSTP) also deserves commendation for its request for information on behalf of the White House Spectrum Policy Team to solicit ways to provide greater incentives for agencies to share or relinquish spectrum.

Federal spectrum holdings are assigned to some 60 federal agencies which don't necessarily have the information or incentives to steward their use of the resource. Given the importance of spectrum to the nation's economic health and security, a rational spectrum policy to recover unused and underutilized spectrum is in order. A Consumer Electronics Association study suggests there is a $1 trillion business opportunity in converting some $62 billion worth of spectrum. Mobile telephony is just one of many areas where high value use can be substituted for low value use, bringing greater efficiency and economic welfare.

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[1] http://mobilefuture.org/infographic_growing_demand_for_wireless_spectrum/

[2] President's Council on Advisors for Science and Technology, "Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth," July 2012. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pd; Karl Nebbia, Director, NTIA Office of Spectrum Management, presentation to the Commerce Spectrum Management Advisory Committee (CSMAC), Dec. 9, 2009.

To be sure, it can be difficult to get agencies to relinquish spectrum that they don't use. To that end, Congress needs to pursue a carrots and sticks approach. The carrots can include incentive auctions. Sticks can be reclaiming the spectrum. However a viable middle road is getting agencies to pay fees for spectrum.

The key theoretical notion underpinning agencies paying fees for spectrum is that federal agencies procure other resources through the market and competitive processes. There is no justification that spectrum, one of the most valuable inputs, should not be part of that process.

Federal agencies use the General Services Administration (GSA) to procure their inputs of land and capital. They go to labor markets to hire employees. Agencies already have experience using markets, and this suggests that a GSA-like agency could also manage the allocation of spectrum. As government agencies do in the UK and Australia, American agencies can pay annual fees for spectrum, like any other inputs. An additional benefit of this process and the establishment of such a GSA-like entity would be to create transparency with a centralized database of all spectrum.

One suggestion by the Technology Policy Institute is a Government Spectrum Ownership Corporation (GSOC) would own and administer federal spectrum through annual fees. Surplus spectrum could be sold or rented to the private sector, as well as additional spectrum purchased.[3]

Lessons from the UK, New Zealand, and Australia suggest that spectrum fees can work. Though new regimes take time to develop and require audit and revision, within 2-3 years of launch, these countries were able to realize that government agencies paying annual fees for spectrum.

In any event, spectrum held by agencies that is not being used should be put up for auction as soon as possible. The academic theory introduced by Herzel, formalized by Coase, and demonstrated successively with auctions, is that those who value spectrum most will pay the most for it and thereby put it to the most productive use. Americans should be interested in maximizing the revenue of spectrum auctions because revenue can be used to purchase and invest in important social goods. For example, auction proceeds could be used to fund FirstNet, a nationwide public safety network.

Following are comments to some of your questions to inform the development with spectrum policy. Thank you for your commitment to the important endeavor of modernizing America's Communications Act.

[3] http://www.techpolicyinstitute.org/files/increasing_spectrum_for_broadband1.pdf

Response to questions 1 and 10

The move to make government more efficient through consolidation and re-conception of agencies is supported broadly by Americans and is hardly unprecedented. Other countries have undergone a similar reorganization of their telecom regulatory authorities precisely to improve the delivery of government services, maximize regulatory efficiency, and achieve cost savings.

Communications regulation needs to be transitioned from the current silo-based, sector specific paradigm to a modern, technology-neutral, competition-oriented approach. The functions of the Federal Communications Commission are duplicative of functions performed by other agencies. Functions and resources should be rationalized effectively and redeployed to the appropriate agencies, or bundled into a specific and perhaps new agency for the management of spectrum.

To be sure, the FCC has valuable expertise in managing spectrum allocation. However the agency, perhaps inevitably, is subject to politics and regulatory capture. This political pressure leads to tinkering with auction rules to favor some parties over others. This lack of transparency, predictability, and standardization does not make for a fair auction and does not serve the interest of the American people.

As I discussed in the first submission[4] for Communications Act Update in cooperation with scholars affiliated with the American Enterprise Institute, the FCC and NTIA are developing duplicative competencies. Spectrum management is a discrete function which belongs in a stand-alone agency, perhaps combined with the government spectrum functions currently performed by NTIA. Congress should consider different forms for this agency, including a semi-autonomous entity with sufficient authority to reassign underutilized spectrum from government to private sector use, the aforementioned GSOC for example.

A single agency with jurisdiction over allocation of spectrum for both commercial and government use could help to correct the current over-allocation of spectrum to lightly-used and technologically stagnant government systems. A national spectrum service in the spirit of the GSA should have the power to reallocate spectrum from government to the commercial sector, to conduct auctions, and to perform other functions currently executed by the FCC or NTIA to manage spectrum in the public interest.

[4] http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2388723

Question 3 on Spectrum Sharing

While sharing has a role in spectrum policy, the US should certainly not give up the valuable efforts to auction relinquished spectrum for licensed use. Indeed the United Kingdom realizes 84 percent of its spectrum being traded,[5] and where necessary, the government has seized spectrum from uncooperative government agencies.

A number of economists and engineers have observed the downsides of spectrum sharing. Faulhaber and Farber estimate that sharing can reduce the value of a spectrum by 60 percent.[6] Cooper suggests that a sharing requirement made the 700 MHz band D block spectrum so unattractive that no commercial actor would take it up.[7] Moreover, in a seminal analysis of spectrum auctions in 25 countries, Hazlett and Munoz conclude that auctions overwhelmingly support consumer welfare, greater than other methods of spectrum allocation, including sharing. They estimate a lost opportunity of $67 billion in consumer welfare over 6 years for the failure to include an additional 30 MHz in the C block auction in 1996.[8]

Both sharing and relinquishing spectrum to market mechanisms are two important paths that the US needs to pursue. Sharing is seen as a solution to working with reluctant agencies that won't relinquish spectrum. However other countries, particularly the UK, New Zealand, and Australia, all with similar legal traditions to the US, have developed national markets with relinquished spectrum. The recovered spectrum is auctioned, traded, and leased. Compared to the US where some 60 percent of prime spectrum is held by government agencies unavailable to private users, in the UK over 75 percent of spectrum is available to all comers. Of this, 46 percent is occupied by private users and 29 percent is shared by private and public users.[9] Public actors occupy just 25 percent. There is no reason why the US cannot and should not develop this toolkit of capabilities. No agency should be able to handcuff the wireless future and supersede the American citizens it serves

In instances where sharing is at play overlay licenses are a possible solution to some of the challenges mentioned. An overlay license is a flexible-use license which encourages the new service provider and incumbent to find voluntary settlements to the shared spectrum. The license is awarded in an auction where the new entrant wins primary rights with the incumbent holding secondary rights. There is

[5] Ofcom, "Spectrum Management Strategy: Ofcom's approach to and priorities for spectrum management over the next ten years", 2013 http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/summary/spectrum_management_strategy.pdf

[6] Faulhaber, Gerard R and David J. Farber. "The Open Internet: A Customer-Centric Framework". International Journal of Communication 4 (2010). http://ijoc.org/index.php/ijoc/article/viewFile/727/411

[7] Cooper, Seth L. "Sharing Licensed Spectrum with Government Lessens Prospects for Wireless Broadband", The Free State Foundation, March 4, 2013, Vol. 8, No.7. http://www.freestatefoundation.org/images/Sharing_Licensed_Spectrum_with_Government_Lessens_Prospects_for_Wireless_Broadband_030413.pdf

[8] Hazlett, Thomas W. and Roberto E. Munoz. "A welfare analysis of spectrum allocation policies", RAND Journal of Economics Vol. 40, No. 3, Autumn 2009 http://mason.gmu.edu/~thazlett/pubs/Hazlett.Munoz.RandJournalofEconomics.pdf

[9] Ibid

generally a deadline in which the incumbent needs to vacate the band. For further discussion see "Reclaiming Federal Spectrum: Proposals and Recommendations."[10]

Question 4

It can take 6-10 years to reallocate spectrum. Spectrum is needed today, and so there is an imperative to add more to the pipeline immediately. Congress has pursued a number of important activities, but executive orders may be necessary to expedite the process.

The command and control approach has the advantage of removing political pressure and temptation for any political actor to influence the process to relinquish spectrum. The Base Realignment and Closure (BRAC) project facilitated the difficult process of closing bases in phases following the Cold War. The US needs to take the same approach with spectrum, also known as BRAC the spectrum. A helpful discussion of this is available in "Getting Away from Gosplan: A BRAC like effort is need to repurpose federal spectrum."[11]

Spectrum is a scarce, valuable resource which should not be free. It should be reclaimed quickly with a minimum of fuss and priced in the market. The drawn out process of engaging with agency stakeholders is not productive. Dr. Phillipa Marks, key architect of the UK and New Zealand policy, has observed that the US has been too lenient with agencies and "too incremental" in its approach to spectrum[12]. Other countries have used executive power to force the parties to give up the spectrum.

Sometimes a hegemon is needed to bring order for the greater good. The Federal government works this way to organize the 50 states, and a similar discipline can be applied to Federal agencies. One success story for Congress was the 1993 Omnibus Budget Reconciliation Act, which in addition to introducing the legislation that allowed competitive bidding for spectrum, reinforced the role of the federal government to ensure a national telecommunications market. Mobile operators were able to take advantage of one set of systems and processes to serve the entire country, rather than having to roll out state by state. Had the states taken the lead, it is likely that there would have been 50 different, potentially conflicting, sets of regulatory obligations. The US would probably be in the situation where the European Union is today, with a fragmented market, limited scale, and few global internet companies. The EU with 28 nations, 17 languages and 11 currencies, is hardly a physical single market, let alone a digital one.

America's de facto single market is one of its key assets. Bringing spectrum into the national market can only improve competitiveness.

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[10] Skorup, Brent. "Reclaiming Federal Spectrum: Proposals and Recommendations". Mercatus Center, George Mason University, May 2013. http://mercatus.org/sites/default/files/Skorup_FederalSpectrum_v1%5B1%5D.pdf

[11] Skorup, Brent. "Getting Away from Gosplan: A BRAC like effort is need to repurpose federal spectrum" Regulation, Winter 2013-2014. http://object.cato.org/sites/cato.org/files/serials/files/regulation/2014/1/regulation-v36n4-7.pdf

[12] Presentation of Phillipa Marks, RadComms Conference, Australian Communications & Media Authority 2011. http://www.youtube.com/watch?v=VfErJk3Qhko Scroll to 27 minutes

Question 5

Price is a valuable signal, and it should not be ignored. Expectation of revenues, provided that it is a reliable figure, is important information to create a transparent auction. Also, it is important to remember that maximizing revenue from the auction serves the valuable goal of raising money for the government which it can use for a variety of important public programs.

Question 6

While the economics and politics to share and relinquish spectrum are important, policymakers should not forget the engineering elements in designing optimal spectrum policy. An excellent paper on the "Technical Principles of Spectrum Allocation"[13] offers valuable guidance on this front.

In certain instances, there are logical opportunities for reorganization and pairing which could substantially increase revenue. As an example of a way to reduce costs and eliminate the need to displace non-federal incumbents, NTIA in a letter to the FCC expressed their support of the Department of Defense vacating the 1755-1780 MHz spectrum so that it can be paired with the 2155-2180 MHz band (AWS-3 band) – maximizing revenue potential during the upcoming AWS auction and marking progress in the effort to free up government-held spectrum for commercial use. The Department of Defense could then be allocated the 2025-2110 MHz band.[14] Putting the two bands together "would yield substantially greater auction revenues than if those bands were auctioned separately", a group of senators wrote in a letter to Defense Secretary Chuck Hagel, Commerce Secretary Penny Pritzker and former acting FCC Chairwoman Mignon Clyburn.[15] It is important that the Defense Department work with spectrum stakeholders to effect this transition in time for the February 2015 auction.

Question 7

The FCC defines an incentive auction as a voluntary, market-based means of repurposing much-needed spectrum for flexible use, including mobile services.[16]

The effort for incentive auctions should be applauded, and Congress has intended for there to be an open auction. But the original good idea has been marred in a few recent occasions. It is not possible to have a bona fide auction if arbitrary and capricious conditions are added to the auction (not allowing certain players to bid, restricting participating etc). Such practices distort the information and incentives of the agencies that are foregoing the spectrum. Without having a true reflection of the market value or the buyers interested in the spectrum, agencies can't get a clear sense of the value they

[13] Bennett, Richard. "Technical Principles of Spectrum Allocation", TPRC 41: The 41st Research Conference on Communication, Information and Internet Policy 2013 http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2240625
[14] http://www.ntia.doc.gov/files/ntia/publications/ntia_aws-3_ltr_11252013_.pdf
[15] http://op.bna.com/der.nsf/id/sbay-9c4qb5/$File/Senate%201755%20letter%20to%20DOD%20DOC%20FCC.pdf
[16] http://www.fcc.gov/incentiveauctions

are relinquishing and what returns they can expect in future. The spectrum auction has to be held in good faith and with transparency in order to work. H.R. 3674 had this in mind. [17]

Question 8

Use it or lose it requirements are a good idea. The FCC might also explore rewarding longer license life as an incentive for providers to achieve certain goals such as build out in rural areas. For example, providers could receive an additional 10 years for their spectrum license if they agree to serve remote areas. Both the operator and the regulator can calculate the net present value of the spectrum versus capital investment (capex) needed for additional investment.

Thank you again for the opportunity to comment.

Respectfully submitted,

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[17] http://beta.congress.gov/bill/113th/house-bill/3674

April 25, 2014

The Honorable Fred Upton
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The Honorable Greg Walden
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Washington, DC 20515

Re: Modernizing U.S. Spectrum Policy – Response to White Paper #2

Dear Chairman Upton and Chairman Walden,

The Advanced Communications Law & Policy Institute (ACLP) at New York Law School respectfully submits the following comments in response to the Committee's white paper titled, "Modernizing U.S. Spectrum Policy." We appreciate the opportunity to make this submission and commend the Committee for launching its inquiry into updating the nation's telecommunications laws.

Should you or your staff have any questions, please do not hesitate to contact us.

Respectfully submitted,

/s/ Charles M. Davidson
CHARLES M. DAVIDSON, DIRECTOR

/s/ Michael J. Santorelli
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To: The Honorable Chairman Upton and the Honorable Chairman Walden, Energy & Commerce Committee, U.S. House of Representatives

From: Charles M. Davidson & Michael J. Santorelli, ACLP at New York Law School

Re: Foundational Principles for Modernizing U.S. Spectrum Policy

Date: April 25, 2014

The House Energy & Commerce Committee is to be commended for evaluating the extent to which laws and policies impacting the allocation and use of spectrum need to be updated. Rationalizing the existing framework for mobile services with the "21st century communications landscape" is critical to ensuring that this space, which has emerged as a vital and vibrant segment of the U.S. economy, continues to grow and evolve.[1]

Over the last decade, the U.S. wireless market has blossomed thanks to enormous capital commitments by service providers to build out faster, more reliable and more ubiquitous mobile data networks. In turn, wide availability of next-generation networks has fueled innovation in the device and content segments, creating an effervescent ecosystem of innovation. This ecosystem continues to provide consumers with access to what they demand the most: mobile broadband connectivity anytime, anywhere.

As policymakers consider how to modernize the nation's wireless policies, it is essential that stakeholders acknowledge and appreciate the role that the prevailing regulatory framework has played in facilitating such enormous positive consumer and social welfare gains. *These gains stem directly from a carefully calibrated and bipartisan national regulatory approach that has long been minimalist in nature.*[2] To the extent that modifications are needed at this point in time, they should focus first and foremost on preserving the competitive and innovative contours of the interconnected mobile ecosystem. The foundation that has supported these many gains is spectrum, the lifeblood of every wireless service. As discussed below, there are numerous opportunities for Congress to amend its laws to unleash even more spectrum into the marketplace. But reform efforts should not end there. Concomitant with these revisions, Congress should also seize the opportunity to revisit vital complementary laws and policies that impact how firms are able to leverage spectrum assets. Such a comprehensive approach is necessary to foster even more robust competition and innovation throughout this space.

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[1] *See Modernizing U.S. Spectrum Policy,* April 1, 2014, Energy & Commerce Committee, U.S. House of Representatives, *available at* http://energycommerce.house.gov/sites/republicans.energycommerce.house.gov/files/analysis/CommActUpdate/20140401WhitePaper-Spectrum.pdf ("*Modernizing U.S. Spectrum Policy*").

[2] For a comprehensive discussion of how these laws and policies evolved, *see* Charles M. Davidson & Michael J. Santorelli, *Seizing the Mobile Moment: Spectrum Allocation Policy for the Wireless Broadband Century*, 19 CommLaw Conspectus 1 (2010), *available at* http://commlaw.cua.edu/res/docs/articles/v19/19-1/05-v19-1-REVISED-DavidsonSantorelli-Final.pdf ("*Seizing the Mobile Moment*").

To these ends, we respectfully submit the following set of foundational principles that we hope will inform the Committee's efforts to modernize U.S. spectrum policy. As discussed in more detail below, these principles are:

1. To ensure that new policies are properly calibrated and impactful, seek to fully understand the contours, dynamism, and fluidity of the modern mobile ecosystem. (p. 2)

2. Err on the side of facilitating more spectrum availability, not less. (p. 5)

3. Flexibility should be a cornerstone of new policies impacting spectrum allocation, the sources of new spectrum, and how licensees can use spectrum resources. (p. 8)

4. Reform efforts should also encompass policies impacting the equally as important physical components of wireless networks (i.e., those aspects that harness the spectrum and make it useful to consumers). (p. 9)

5. More sharply define regulatory roles for and jurisdiction of relevant federal, state, and local entities. (p. 10)

Each principle is expanded upon below.

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PRINCIPLE #1

To ensure that new policies are properly calibrated and impactful, seek to fully understand the contours, dynamism, and fluidity of the modern mobile ecosystem.

Until recently, the dynamics of the wireless sector were relatively straightforward: carriers obtained spectrum licenses, invested capital in building networks, and sought a return on those investments by offering voice and data services to customers. Similarly, handset manufacturers designed a range of mobile devices to meet the needs of a rather diverse subscriber base. Over time, many of these devices would become "smarter" and more advanced, reflecting consumer preferences for mobile broadband data services. With regard to the content accessed by consumers on their phones, it was generally a mobile version of existing online services or represented a non-voice method for communicating on the go (e.g., texting, emailing, and instant messaging).[3] In short, bright lines separated

[3] *See, e.g.,* John Horrigan, *Mobile Access to Data and Information*, at p. 2, Pew Internet & American Life Project (March 2008), *available at* http://pewinternet.org/~/media//Files/Reports/2008/PIP_Mobile.Data.Access.pdf.pdf.

firms in each of these distinct spaces. Cross-sector partnerships existed (e.g., between handset developers and service providers), but, for the most part, firms tended to focus on competing within their immediate market.[4]

Policymaking in the wireless space was similarly straightforward. Although nuanced in many ways, legislative and regulatory responses by Congress and the Federal Communications Commission (FCC) to changes in the marketplace were fairly consistent. Both were eager to facilitate further growth of the sector. As noted in the White Paper, Congress on a number of occasions over the last few decades has updated the nation's communications laws in an effort to unlock more spectrum and to provide the FCC with the authority needed to properly allocate these scarce resources.[5]

In the past few years, however, these dynamics have begun to change in fundamental ways, raising a number of questions about the ability of policy to accommodate further growth. The nature of competition and innovation in what is now an interconnected ecosystem[6] has been dramatically altered by:

- The rapid rise of smartphones powered by operating systems that enable a universe of cutting-edge add-ons, the use of which can be monetized in numerous ways; and

- The deployment of next-generation mobile broadband networks, which support faster and more reliable Internet connectivity.

Numerous firms now compete across sectors for the attention – and dollars – of consumers as they seek to position themselves as the primary facilitator of the mobile experience.

The emergence of the modern mobile ecosystem has been swift, and it continues to evolve at a very rapid pace. At the end of 2009, approximately 60 percent of the U.S. land mass was covered by 3G wireless service.[7] More importantly, only two percent of the population "lived in an area with no [3G] provider."[8] Such near-ubiquity of mobile broadband service represented the culmination of tens of billions of dollars in investment by service providers, which was spurred along by growing consumer demand for faster and more robust wireless Internet connectivity. The availability of additional spectrum resources

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[4] *See, e.g.,* Thomas Hazlett, *Modular Confines of Mobile Networks: Are iPhones iPhony?,* 19 Sup. Ct. Econ. Rev. 67 (2011) (providing an overview of how the ecosystem has developed).

[5] *See generally Modernizing U.S. Spectrum Policy.*

[6] *See, e.g.,* Thomas Hazlett, David Teece and Leonard Waverman, *Walled Garden Rivalry: The Creation of Mobile Network Ecosystems*, George Mason University Law and Economics Research Paper Series 11-50 (Nov. 2011), *available at* http://www.law.gmu.edu/assets/files/publications/working_papers/1150WalledGardenRivalry.pdf.

[7] *See Connecting America: The National Broadband Plan*, at p. 22, FCC (March 2010) (citing data from American Roamer).

[8] *Id.*

capable of supporting these network upgrades and expansions, especially swaths in the AWS and 700 MHz bands, was also essential.[9] However, service providers continued to press forward by announcing plans for fourth-generation (4G) networks, which promised faster speeds for consumers and better spectral efficiency for carriers.[10] To date, these newer networks have been deployed in dozens of cities across the U.S. by service providers; nationwide coverage is expected once more spectrum is made available.[11]

In response to such widespread availability of next-generation mobile networks, use of wireless broadband has increased significantly in recent years. In December 2008, only about a quarter of all high-speed lines in service were mobile (26.5 million out of a total of 102 million connections).[12] But by December 2012, mobile broadband connections represented almost two-thirds of all high-speed connections (169 million out of 261.7 million).[13] Adoption of mobile broadband-enabled mobile devices increased at a similarly rapid pace. The penetration rate for smartphones eclipsed 50 percent in 2012, up from single digits in 2007,[14] and rose to 65 percent by the end of 2013.[15] Consumer adoption of newer mobile broadband devices like tablets has also skyrocketed, increasing from almost zero in 2010 to 44 percent in December 2013.[16]

The other major component of this burgeoning ecosystem – mobile content – has emerged as an equally potent force and competitor in the wireless space. In particular, the operating systems powering modern smartphones and tablets, along with the software underlying the hundreds of thousands of apps available for use on these devices, represent powerful gateways for managing the mobile user experience. As a result, these software inputs have become platforms for innovation that are driving investment, generating consumer welfare gains, and spurring economic development throughout the country.[17] Tens of billions of apps have been downloaded to date from Apple's App Store, Google's Android Market,

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[9] *Seizing the Mobile Moment* at p. 39-44.

[10] *National Broadband Plan* at p. 22.

[11] For an overview of 4G service offerings as of January 2014, *see* Kevin Fitchard, *The State of LTE in the U.S.: How the Carriers' 4G Networks Stack Up,* Jan. 30, 2014, GigaOm, *available at* http://gigaom.com/2014/01/30/4g-vs-4g-comparing-lte-networks-in-the-us/.

[12] *See Internet Access Services: Status as of Dec. 31, 2012,* at Table 1, FCC (Dec. 2013).

[13] *Id.*

[14] *See, e.g., America's New Mobile Majority: A Look at Smartphone Owners in the U.S.*, May 7, 2012, Nielsen Wire, http://blog.nielsen.com/nielsenwire/?p=31688.

[15] *See* Press Release, *comScore Reports December 2013 U.S. Smartphone Subscriber Market Share*, Feb. 4, 2014, comScore, *available at* https://www.comscore.com/Insights/Press_Releases/2014/2/comScore_Reports_December_2013_US_Smartphone_Subscriber_Market_Share.

[16] *See* Press Release, *Tablet Ownership Rate Reaches New High of 44 Percent, According to CEA's Tablet Report*, Jan. 27, 2014, Consumer Electronics, *available at* http://www.ce.org/News/News-Releases/Press-Releases/2013-Press-Releases/Tablet-Ownership-Rate-Reaches-New-High-of-44-Perce.aspx.

[17] *See, e.g.,* Michael Mandel, *Where the Jobs Are: The App Economy*, TechNet (Feb. 2012), *available at* http://www.technet.org/wp-content/uploads/2012/02/TechNet-App-Economy-Jobs-Study.pdf.

BlackBerry's App World, and elsewhere. It has been estimated that this segment alone is directly and indirectly responsible for 466,000 jobs across the United States.[18]

The market dynamics and the interplay between segments of the mobile ecosystem discussed above provide essential context for efforts to unlock more spectrum and support continued experimentation with business models and new products. The cause-and-effect of traditional spectrum allocation policymaking has become much more complex as firms throughout the ecosystem – not just carriers – compete for consumers' attention and loyalty. *Spectrum is now more than just a network input: it is an enabler of innovation that generates a much more diverse range of economic and social returns for a broader array of stakeholders.* These include not only returns on investment in networks and services by carriers, device manufacturers, and content creators, but also new opportunities for employment in the app economy and for receiving critical services, like real-time telemedicine or digital education services, in a more convenient, personalized, and affordable manner.[19]

In short, while the core components of the national regulatory framework for wireless services remains viable, the new contours of competition and innovation in the modern mobile broadband ecosystem require similarly forward-looking and flexible policies to accommodate continued growth and experimentation. Ideas for developing these are provided in the following sections.

PRINCIPLE #2

Err on the side of facilitating more spectrum availability, not less.

Foremost among the policy implications of a more expansive and competitive wireless sector is a need to facilitate swifter access to critical mobile broadband enablers namely spectrum. While carriers have long called for additional spectrum, the need for substantially more has become dire in the wake of the mobile data revolution. In 2010, the FCC and numerous other stakeholders agreed that a looming spectrum crisis required swift and comprehensive action on the part of the federal government to free up 500 MHz of new spectrum for mobile broadband purposes.[20] In the absence of such an infusion, the FCC at the time predicted that "mobile data demand will exhaust spectrum resources within the

[18] *Id.* at p. 1.

[19] The race to capitalize on rising consumer demand for and use of mobile data services and on the ability of these services to disrupt entire sectors has driven stakeholders throughout the ecosystem to explore new opportunities in non-communications markets. These experiments make economic sense since, by one estimate, increased wireless "service provision and system integration" into sectors like healthcare could result in significant new revenue opportunities. *See, e.g.,* Press Release, *Proliferation of Connected Devices will create a $1.2tr Revenue Opportunity for Operators by 2020*, Oct. 10, 2011, GSM World, http://www.gsm.org/newsroom/press-releases/2011/6491.htm. More importantly, these efforts will yield a range of new benefits to consumers and will help realize critical national imperatives around broadband.

[20] *National Broadband Plan* at p. 75; *Presidential Memorandum: Unleashing the Wireless Broadband Revolution*, June 28, 2010, The White House, *available at* http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

next five years."[21] While Congress, the FCC, and other federal entities have worked together in recent years to identify and make available a sizeable swath of new spectrum resources for licensed and unlicensed uses, much more needs to be done to unlock even more spectrum in the near term and develop a new approach to spectrum allocation that can continue to introduce more and better spectrum into the marketplace.

To these ends, there are several aspects of the current approach to spectrum allocation that should be revisited from the perspective of making more, not less, spectrum available for mobile broadband purposes. These include:

- *Federal Spectrum.* The pressing need for additional spectrum in the short term has underscored the need to reexamine policies impacting how the federal government uses its considerable spectrum holdings. This is critical because, historically, these resources have been underused and oftentimes sit fallow.[22] However, reallocating these portions of the airwaves have proven to be extremely time consuming and politically fraught endeavors.[23] As a result, there is much uncertainty regarding whether and how this spectrum might be used to meet current needs.[24] Moreover, in the absence of firmer policies around repurposing this spectrum, some entities might delay or simply refuse to clear certain bands. In recent years, many federal agencies, like the Department of Defense, have acquiesced to calls for using underutilized spectrum assets for wireless broadband.[25] This represents significant progress, provided, of course, that these entities hasten the manner in which they vacate spectrum bands or otherwise prepare to share them with service providers. Additional legislation may still be necessary, though, to clarify federal policies and imperatives around the ability of the FCC and NTIA to repurpose these valuable spectrum resources.

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[21] *See Mobile Broadband: The Benefits of Additional Spectrum*, at p. 26, FCC (Oct. 2010), *available at* http://download.broadband.gov/plan/fcc-staff-technical-paper-mobile-broadband-benefits-of-additional-spectrum.pdf.

[22] *Seizing the Mobile Moment* at p. 55-56.

[23] *Id. See also National Broadband Plan* at p. 79.

[24] *See, e.g., Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*, Report to the President, President's Council of Advisors on Science and Technology (July 2012), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf ("PCAST finds that clearing and reallocation of Federal spectrum is not a sustainable basis for spectrum policy due to the high cost, lengthy time to implement, and disruption to the Federal mission. Further, although some have proclaimed that clearing and reallocation will result in significant net revenue to the government, we do not anticipate that will be the case for Federal spectrum." *Id.* at p. vi); *Cf.* Larry Downes, *Feds to Mobile Users: Drop Dead*, July 30, 2012, CNET, *available at* http://news.cnet.com/8301-1035_3-57481929-94/feds-to-mobile-users-drop-dead/?tag=rtcol;FD.posts (arguing that "The federal government is slinking away from a promise by President Obama to free up badly-needed radio spectrum for mobile users and the already over-taxed networks that serve them.").

[25] *See An Assessment of the Viability of Accommodating Wireless Broadband in the 1755-1850 MHz Band*, National Telecommunications & Information Administration, U.S. Department of Commerce (March 2012), *available at* http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.

- *Broadcast Spectrum.* Television broadcasters collectively control some 300 MHz of spectrum.[26] In an effort to put these valuable resources to more productive uses and to support continued deployment of next-generation wireless network infrastructure, Congress in 2012 passed legislation expressly authorizing the FCC to reallocate broadcast spectrum to mobile service providers via incentive auctions.[27] This process could provide upwards of 120 MHz of new spectrum for mobile broadband. Though considerable, a range of factors prevent even more broadcast spectrum from being repurposed.[28] In addition, since these auctions are voluntary, there is no guarantee that the FCC will be able to auction off the maximum 120 MHz. Even so, the rapidly changing economics of the broadcast sector could present an opportunity for policymakers to further clarify and recalibrate the rights that broadcasters have in what by all accounts is prime spectrum.[29]

- *FCC Policies Impacting Commercial Efforts to Acquire Additional Spectrum.* In the absence of new spectrum, carriers have attempted to plug gaps in their networks by acquiring spectrum via mergers and secondary market transactions. The scale and scope of many of these transactions, however, have challenged existing FCC policies vis-à-vis mergers and secondary market swaps.[30] Consequently, there might be a need for further legislative clarity regarding the scope and contours of FCC policies and processes related to wireless merger review and secondary markets for spectrum.

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[26] *See In the Matter of Innovation in the Broadcast Television Bands: Allocations, Channel Sharing and Improvements to VHF*, Report and Order, at ¶ 4, ET Docket No. 10-235, FCC 12-45 (rel. April 27, 2012).

[27] *See Middle Class Tax Relief and Job Creation Act of 2012*, Pub. L. No. 112-96 ("*Spectrum Act*").

[28] *See, e.g.,* Mike Dano, *TV Broadcasters Remain Wary of 600 MHz Incentive Auction*, March 26, 2014, Fierce Wireless, *available at* http://www.fiercewireless.com/story/tv-broadcasters-remain-wary-600-mhz-incentive-auction/2014-03-26.

[29] The economics of television broadcasting are in flux. On the one hand, broadcasters, in an effort to offset slumping advertising revenues, are increasingly seeking to leverage their resources – their content, their audience, and their geographic reach – to extract higher retransmission fees from video providers (i.e., cable and satellite companies). These new revenues are expected to grow considerably over the next few years, which suggest that spectrum will remain a highly valued asset for broadcasters. On the other hand, new and emerging services like Aereo, if found to be operating legally, could serve to greatly undermine the broadcasting business model, which in turn would likely decrease the perceived (and actual) value of spectrum for broadcasters. For an overview of the debate over retransmission fees, *see* Roger Yu, *Retransmission Fee Race Poses Questions for TV Viewers,* Aug. 2, 2013, USA Today, *available at* http://www.usatoday.com/story/money/business/2013/07/14/tv-retrans-fees/2512233/. For discussion of the potential impact of services like Aereo on broadcast television and the ongoing legal battles between the two, *see* Brent Kendall, *Aereo, U.S. Broadcasters to Square off at the Supreme Court,* April 22, 2014, Wall St. Journal.

[30] For a general critique of the FCC merger review process, *see* Philip J. Weiser, *Reexamining the Legacy of Dual Regulation: Reforming Dual Merger Review by the DOJ and the FCC*, 61 Fed. Comm. L. J. 1 (2008). For discussion of opportunities to bolster the FCC's secondary market policies, *see Seizing the Mobile Moment* at p. 63-65.

Ultimately, many existing spectrum policies continue to preserve expansive rights for uses that many consumers no longer prefer or demand. In order to provide innovators with the amount of spectrum needed to support current and future uses, policymakers will have to reorient allocation frameworks around modern consumer preferences – i.e., mobile broadband.

PRINCIPLE #3

Flexibility should be a cornerstone of new policies impacting spectrum allocation, the sources of new spectrum, and how licensees can use spectrum resources.

When creating policies to unlock an even steadier stream of robust spectrum assets for use in the mobile broadband context, Congress should seek to ensure that any new or revised frameworks are sufficiently flexible vis-à-vis how airwaves are sourced, allocated, and used.

One of the only positive trends to emerge from the short-term spectrum crunch described above was near-universal support for an all-of-the-above approach to harnessing even the tiniest slivers of available airwaves. Although many carriers still prefer licensed spectrum above all else, a growing number of firms that provide wireless services support a range of alternative approaches to using spectrum. These include unlicensed uses (e.g., Wi-Fi) and spectrum sharing arrangements with public and private licensees.[31] Wi-Fi in particular has emerged as a popular and effective on-ramp to the Internet for consumers and an off-ramp for wireless service providers looking to alleviate congestion on their data networks.[32] Spectrum sharing, on the other hand, has proven to be somewhat more controversial. While embraced by many, some fear that such an approach could undermine prevailing notions of property rights in spectrum, which have developed and inured in the ecosystem over the last few decades.[33]

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[31] Over the last few months, the FCC has acted to advance both types of uses. *See In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5GHz Band*, FCC 14-30, ET Docket No. 13-49 (rel. April 1, 2014) (allocating additional spectrum for Wi-Fi and other unlicensed uses); *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*. FCC 14-49, GN Docket No. 12-354 (rel. April 23, 2014) (proposing rules to advance certain spectrum sharing arrangements).

[32] For a comprehensive evaluation of the many benefits associated with Wi-Fi, *see generally* Raul Katz, *Assessment of the Economic Value of Unlicensed Spectrum in the United States*, WiFiForward (Jan. 2014), *available at* http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf.

[33] The literature on property rights in spectrum is vast. For an historical overview, *see* Howard A. Shelanski and Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 J. of L. & Econ. 581 (1998). For more recent analyses of the property rights approach and alternatives, *see, e.g.,* Jerry Brito, *The Spectrum Commons in Theory and Practice*, 2007 Stan. Tech. L. Rev. 1 (2007); Philip J. Weiser & Dale Hatfield, *Spectrum Policy Reform and the Next Frontier of Property Rights*, 15 Geo. Mason L. Rev. 549 (2008); Kevin Werbach, *The Wasteland: Anticommons, White Spaces, and the Fallacy of Spectrum*, 53 Ariz. L. Rev. 213 (2011).

In the short term, these non-traditional approaches to spectrum allocation and use are providing a critical stopgap as the FCC and others continue their efforts to identify and make available new spectrum resources.[34] Indeed, the ability to experiment with new ways of delivering services has resulted in widespread support for continued flexibility in identifying and using spectrum going forward. To the extent possible, Congress should seek to enshrine this preference in updated policies impacting the allocation of the nation's airwaves.

Similarly, there are opportunities to provide innovators with more flexibility in how they use licensed spectrum. In the Spectrum Act, Congress called on the FCC to promote more flexible use of spectrum.[35] Additional guidance regarding the scope of flexibility could be warranted to ensure that this imperative is adopted by the Commission on a permanent basis going forward. Part of these efforts should include new policies to bolster secondary markets for spectrum. At present, the FCC continues to maintain a number of restrictions on transactions in the secondary market. For example, leasing and transfers are allowed so long as lessees adhere to the same set of usage rules as the incumbent lessee.[36] This means that reallocation of spectrum is not allowed via secondary market transactions.[37] Providing licensees with more flexibility by liberalizing the type and nature of allowed transactions would ensure that spectrum assets are ultimately put to their highest valued uses.

PRINCIPLE #4

Reform efforts should also encompass policies impacting the equally as important physical components of wireless networks (i.e., those aspects that harness the spectrum and make it useful to consumers).

Increasing the amount of spectrum is only part of the solution to supporting continued progress in the U.S. mobile space. Another major component is revising policies impacting the deployment of the physical infrastructure of wireless networks.

In general, states and municipalities retain primary authority over the zoning of land within their borders and how local rights-of-way are managed.[38] In the wireless context, "operators must generally obtain State and local zoning approvals before building wireless towers or attaching equipment to pre-existing structures."[39] An example of a "structure"

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[34] In the recent past, some wireless carriers have experimented with shared spectrum. *See, e.g.,* Jasmin Melvin, *Regulators OK T-Mobile Testing of Shared Use of Airwaves*, Aug. 16, 2012, Reuters, *available at* http://www.reuters.com/article/2012/08/15/us-usa-spectrum-sharing-idUSBRE87E15620120815.

[35] *See Middle Class Tax Relief and Job Creation Act of 2012*, Pub. L. No. 112-96, 126 Stat. 156 (2012).

[36] *See In re Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Second Report and Order, 19 F.C.C.R. 17503, ¶¶ 100-108 (July 8, 2004).

[37] *See, e.g.* Thomas W. Hazlett, *Property Rights and Wireless License Values*, 51 J.L. & ECON. 563, 566 n.5 (2008).

[38] 47 U.S.C. 332 (c) (7) preserves local zoning authority subject to certain limitations, which are set forth in 47 U.S.C. 332 (c) (7) (b) (i-v).

[39] *See In the Matter of Petition for Declaratory Ruling to Clarify Provisions of Section 332(c)(7)(B) to Ensure Timely Siting Review and to Preempt Under Section 253 State and Local Ordinances that Classify All Wireless*

critical to network build-out is a utility pole, which serves as a hub for various broadband service providers (e.g., cable and wireless). Such a piecemeal approach to securing the necessary approvals for the deployment of critical network infrastructure has proven to be slow and costly. In response, the federal government has acted on several occasions to help streamline these processes and otherwise ensure that excessive bureaucracy does not unnecessarily slow new network deployment. Efforts have included the adoption of a shot clock by the FCC that requires local zoning authorities to process siting requests in a reasonable and timely manner;[40] a Presidential order to facilitate speedier wireless network build-out on federal lands;[41] provisions in the Spectrum Act to further accelerate review and approval procedures;[42] and additional FCC inquiries into related aspects of network construction.[43]

These are all steps in the right direction. Indeed, they have garnered nearly universal support among stakeholders in the mobile ecosystem and have proven to be effective in helping to simplify the complex and multifaceted process of building the infrastructure that harnesses spectrum and makes it useful to consumers. Even so, there is also widespread agreement that more needs to be done. To that end, in its *National Broadband Plan* the FCC recommended that it work to "establish a comprehensive timeline for each step of the…access process and reform the process for resolving disputes regarding infrastructure access."[44] Equally as important, it called on Congress to amend the Communications Act to assure a "harmonized" process going forward.[45] Congress should heed this recommendation and push forward with additional reforms to the daunting array of laws, policies, rules, and regulations impacting wireless network construction and expansion.

PRINCIPLE #5

More sharply define regulatory roles for and jurisdiction of relevant federal, state, and local entities.

Policymaking in the wireless space over the last several decades has, in many ways, been an ongoing process of recalibrating the regulatory roles and jurisdiction of relevant federal, state, and local entities to better reflect the realities of the modern marketplace.

Siting Proposals as Requiring a Variance, Declaratory Ruling, WT Docket No. 08-165, 24 F.C.C.R. 13994 (2009), *recon. denied*, 25 FCC Rcd 11157 (2010), *aff'd sub nom. City of Arlington, Texas v. FCC*, 668 F.3d 229 (5th Cir. 2012), *aff'd*, 133 S.Ct. 1863 (2013).

[40] *Id.* at ¶ 4.

[41] *See Accelerating Broadband Infrastructure Deployment*, Executive Order 13616, 77 Fed. Reg. 36903 (June 20, 2012).

[42] *Spectrum Act* at section 6409.

[43] *See In the Matter of Acceleration of Broadband Deployment by Improving Wireless Facilities Siting Policies*, FCC 13-122, WT Docket No. 13-238 (rel. Sept. 26, 2013).

[44] *National Broadband Plan* at p. 111.

[45] *Id*. at p. 112-113.

The original regulatory structure devised by the FCC, which was set forth in an order in 1981 enabling the first commercial wireless networks to be built, set forth a dual federal-state framework to govern this emerging market.[46] Even though the FCC stated that the goal for cellular service was to develop nationwide calling capabilities, it also initially thought that the states could play a constructive, complementary role in supporting further development of wireless services. To this end, while the Commission identified the many economic and practical efficiencies inherent in a national approach to this new service (e.g., price and product competition "through lower equipment costs and greater equipment selection"), the states were free to regulate this new service as a common carrier,[47] largely because the FCC did not expect significant jurisdictional tensions or problems to arise.[48]

The market would go on to grow rapidly over the next few years. In response, the FCC continued to tinker with its regulatory approach. For example, in 1988 the Commission amended its rules to encourage "the development of new digital equipment that [would] enable the industry to increase capacity of existing channels to serve an ever-increasing number of customers on a finite amount of spectrum."[49] But the FCC could only go so far in the absence of guidance and additional grants of authority from Congress. For example, as a result of FCC inaction and a lack of clear statutory guidance, dozens of states elected to directly regulate wireless service. Indeed, by the mid-1980s, "twenty-nine states had not banned regulation, either by law or by de facto bans on [wireless] regulation promulgated by their public utility commissions."[50] The result was a patchwork of price and entry regulation across much of the country.[51] The practical impact on wireless network development was the creation of numerous legal and regulatory impediments to continued service improvement that, while surmountable, increased costs for service providers.[52]

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[46] *In the Matter of An Inquiry Into the Use of the Bands 825–845 MHz and 870–890 MHz for Cellular Communications Systems; and Amendment of Parts 2 and 22 of the Commission's Rules Relative to Cellular Communications Systems*, Report and Order, 86 F.C.C.2d 469 (1981).

[47] *Id.* at 503-505. This was especially true after *La. Pub. Serv. Comm'n. v. FCC*, 476 U.S. 355 (1986).

[48] *Commission's Rules Relative to Cellular Communications Systems* at 505 (noting that "It is conceivable that a state could delay implementation of cellular service or frustrate the competitive market structure established in this proceeding by refusing to find more than one cellular applicant in any geographic area qualified to provide service. We do not expect this to be the case.").

[49] *See In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services,* First Report, 10 F.C.C.R. 8844, ¶ 16 (1995) (citing *Amendment of Parts 2 and 22 of the Commission's Rules to Permit Liberalization of Technology and Auxiliary Service Offerings in the Domestic Public Cellular Radio Telecommunications Service*, Report & Order, 3 FCC Rcd 7033 (1988)).

[50] *See* Babette E.L. Boliek, *Wireless Net Neutrality Regulation and the Problem with Pricing: An Empirical, Cautionary Tale*, 16 Mich. Telecomm. & Tech. L. Rev. 1, 28 (2010).

[51] *Id.* at 28-32 (providing an overview of various state-level regulatory approaches).

[52] *See, e.g.,* Leonard J. Kennedy & Heather A. Purcell, *Section 332 of the Communications Act of 1934: A Federal Regulatory Framework That Is "Hog Tight, Horse High, and Bull Strong,"* 50 FED. COMM. L.J. 550, 559-561 (1998).

In 1993, Congress passed legislation that fundamentally altered the evolution of the wireless ecosystem. By that time, Congress had become "more aware of the barriers to entry and obstacles to growth presented by state regulation."[53] Moreover, it was also evident that the prevailing regulatory approach at the time, especially with regard to the FCC's ability to allocate spectrum, could not support further growth and maturation of the sector.[54] In response, Congress adopted a national regulatory framework that preempted most, but not all, state-level regulation.[55] The legislation also empowered the FCC to allocate spectrum via auctions instead of a lottery.[56]

Over the next few years, the FCC would have many occasions to interpret this new grant of power, and in many instances, it adhered to the deregulatory spirit of the law. For example, the Commission received and denied several petitions by states to continue regulating wireless prices.[57] It also elected to forbear from applying many common carrier regulations to wireless service, reasoning that overburdening providers in this evolving space with these rules risked impeding competition.[58]

Ever since, Congress and the FCC have continued to sharpen the contours of regulatory authority and regulation in the mobile space. For example, as previously discussed, both Congress and the FCC have acted on several occasions to streamline state and local processes impacting wireless network deployment. Congress has also delegated additional authority to the FCC vis-à-vis its ability to reallocate certain kinds of spectrum and engage in incentive auctions. Similarly, many state legislatures have acted to clarify the regulatory authority of their public utility commissions over wireless services.[59]

In short, the general balance of authority that has resulted from these various recalibration efforts has been very effective. Together, they have successfully preserved a regulatory approach to new and emerging wireless services that is national in scope and minimalist in nature. The market and consumers have both benefited as a result. Even so, there are still many opportunities to further clarify the contours of regulatory authority in this space.

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[53] *Id.* at p. 559.

[54] *See, e.g., Seizing the Mobile Moment* at p. 32-33 (describing market and regulatory conditions at the time).

[55] *See Omnibus Budget Reconciliation Act of 1993*, Pub. L. No. 103-66, § 6002(b), 107 Stat. 312, 392 (codified in relevant part at 47 U.S.C. § 332).

[56] *Id.* (codified in relevant part at 47 U.S.C. § 309 (j)).

[57] *See, e.g.,* Charles D. Cosson, *You Say You Want a Revolution? Fact and Fiction Regarding Broadband CMRS and Local Competition,* 7 CommLaw Conspectus 233, 254 (1999).

[58] *See, e.g., In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services,* Second Report 9 F.C.C.R. 1411, 1475-1476 (1994).

[59] For an overview of recent efforts, *see generally* Sherry Lichtenberg, *Telecommunications Deregulation: Updating the Scorecard for 2013*, National Regulatory Research Institute (May 2013), *available at* http://nrri.org/documents/317330/0e3a5988-6f57-492d-8ce5-70926cfe68f4.

For example, uncertainty remains about the exact to which states could regulate "other terms and conditions" of wireless service.[60] This ambiguous grant of authority was carved out of the national regulatory framework that was adopted in the early 1990s. Since that time, the states have attempted to explore the outer bounds of this authority by attempting to regulate certain aspects of wireless service that they argue falls in this amorphous category.[61] As the already rich array of mobile broadband-enabled services continues to mushroom and seep ever further into nearly every aspect of daily life, Congress should act to clarify or eliminate this authority in an effort to close what could become a back-door to inefficient piecemeal state regulation of inherently borderless services.

In addition, Congress should examine how it might sharpen the contours of the FCC's delegated authority in the context of policymaking impacting how service providers manage their networks. To date, the FCC has wisely avoided trying to implement "network neutrality" rules on mobile service providers.[62] Adopting such restrictions on how carriers elect to manage their networks would likely make spectrum needs more acute, by foreclosing critical congestion management techniques, and could undermine, rather than promote, continued innovation in this space.[63] Accordingly, Congress should explore whether and how to enshrine this hands-off approach to wireless network management in an effort to promote continued business model experimentation aimed at overcoming any traffic or congestion challenges that might arise.

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[60] 47 U.S.C. § 332 (c)(3)(A) ("…no State or local government shall have any authority to regulate the entry of or the rates charged by any commercial mobile service or any private mobile service, except that this paragraph shall not prohibit a State from regulating the *other terms and conditions* of commercial mobile services. Nothing in this subparagraph shall exempt providers of commercial mobile services (where such services are a substitute for land line telephone exchange service for a substantial portion of the communications within such State) from requirements imposed by a State commission on all providers of telecommunications services necessary to ensure the universal availability of telecommunications service at affordable rates." (emphasis added)).

[61] For discussion of the positive and negative impacts of various approaches to regulatory federalism in the wireless space, *see* Tony Clark & Michael J. Santorelli, *Federalism in Wireless Regulation: A New Model for a New World*, ACLP Scholarship Series, New York Law School (Feb. 2009), *available at* http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/Clark-Santorelli-Wireless-Federalism-February-2009.pdf.

[62] *See e.g.,* Phil Goldstein, *FCC's Proposed New Net Neutrality Rules Won't Apply to Wireless,* April 24, 2014, Fierce Wireless, *available at* http://www.fiercewireless.com/story/fccs-proposed-new-net-neutrality-rules-wont-apply-wireless/2014-04-24.

[63] *See, e.g., Seizing the Mobile Moment* at p. 70-72.

ALTON DREW CONSULTING

April 18, 2014

The Honorable Fred Upton, Chairman
The Honorable Greg Walden, Communications and Technology Subcommittee Chairman
U.S. House Committee on Energy and Commerce
2125 Rayburn House Office Building
Washington, DC 20515

Dear Chairmen Upton and Walden:

This letter is in response to your second call for comments on the update of the Communications Act of 1934 as amended by the Telecommunications Act of 1996 ("Act"). An updated Act should not only provide broadband access to providers with clear guidance as to the rules of the road, but it should ensure that the road is not littered with debris from a 20th century regulatory framework. Through legislation and rulemaking, Congress and the FCC have worked to increase the amount of spectrum available to commercial providers.

Now is the time for Congress to go another step further by ensuring that an update of the Act sends a clear message to the FCC to the take steps necessary for increasing the amount of commercially available spectrum to providers that are ready to put this finite and valuable resource to its best use.

Increasing the amount of spectrum available for commercial use should be viewed as an investment in the value the wireless industry brings to the American economy. According to CTIA-The Wireless Association, in terms of contribution to gross domestic product, the wireless industry is now larger than the publishing, agriculture, hotels and lodging, air transportation, motion picture and recording, and motor vehicle manufacturing industry segments and rivals the computer system design services as well as the oil and gas extraction industries.

Job seekers have benefited from the growth and size of the wireless industry. CTIA reports that the wireless industry gained 1.6 million new jobs between 2007 and 2011. Meanwhile the rest of the economy saw private sector jobs fall by 5.3 million during what was arguably the worst economic downturn since the 1930s.

And while prices for wireless services have fallen 93% between 2008 and 2013, the United States, contrary to critics right here at home, leads the rest of the world in mobile broadband speeds. Again, according to CTIA the average mobile broadband speed in the U.S. in 2012 was 2.6 Mbps, the fastest in the world, and double the speeds seen in Europe.

American enterprise is exceptional because of America's exceptional emphasis on innovation. The wireless industry helps to set standards of innovative excellence. An example of this excellence is the wireless industry's rollout of 4G Long Term Evolution (LTE) technology and the devices that use it. According to data from CTIA, the number of 4G LTE-connected devices was 33.1 million devices in 2012. That number represented a 273% increase in devices that year. By the end of 2013, that number increased to 62.5 million.

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This small sample of industry data supports the argument that there is a thirst for services provided by wireless carriers; that consumers place a value on the services they receive from all carriers, whether they be large national carriers such as AT&T, Verizon, T-Mobile, or Sprint, or smaller carriers such as Boost Mobile, Virgin Mobile, or C-Beyond.

There is competition in the wireless eco-system, and consumer demand for innovative, flexible services, pricing, and data plans motivate a demand for spectrum that is just as value driven. Any mechanism for providing wireless carriers with access to additional spectrum must recognize the value the market delivers to consumers and the initiatives carriers take to bring value to the market.

One mechanism that will provide quality spectrum to wireless carriers is the pending incentive auction. While the FCC has certainly conducted spectrum auctions before, it has never done one like this complex, two-sided auction. During the first part, or the reverse auction, television broadcasters will give up their licenses if they are confident that they'll be adequately compensated for doing so. Then during the forward auction, wireless carriers will bid on the spectrum. Part of the proceeds from the revenue of the forward auction will compensate the broadcasters; hence their interest in a bidding process that maximizes revenue. However, carriers like T-Mobile and Sprint and their advocates have been advocating for restrictions on the amount of spectrum that AT&T and Verizon may bid on. What would be the consequences of implementing a policy that restricts AT&T and Verizon's participation in the auction?

One consequence would be less revenue, which translates into less money to compensate the broadcasters, less money for deficit reduction, and potentially not enough funding a long-awaited national broadband first responder network. How big would the risk of leaving dollars on the table be? If we use past auctions as examples, leaving AT&T and Verizon out would have resulted in revenues being 45% lower in the 700 MHz auction and 16% lower in the AWS-1 auction.

Another consequence would be less spectrum available for commercial use. Data referenced above points to the value of the wireless industry to the economy and to consumers. Consumer demand for spectrum is rising and will continue to do so as mobile plays a bigger role in the education, healthcare, and energy sectors, not to mention our day-to-day personal and professional lives. The industry needs more spectrum to serve its customers as their needs increase.

Also, another mechanism that could provide quality spectrum to wireless carriers is a federal incentive auction as proposed in HR 3674, the Federal Spectrum Incentive Act. The bill would create a spectrum fund, and proceeds from the fund could be used to offset sequester cuts, among other uses. The bill has been with the House Sub-Committee on Intelligence, Emerging Threats, and Capabilities for three months, and it's time to move it forward.

I believe the broadcast television incentive auction and the federal agency incentive auction as defined in HR 3674 are great opportunities to create pathways for wireless carriers to get access to spectrum.

Should you or your staff need to contact me, I may be reached at 410.463.0582

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Principles to Rationalize Spectrum Policy

Will Rinehart
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Introduction

The architecture of the Internet has been dramatically redrawn in the last decade. Consumer demand for video and other streaming services has changed the traditionally hierarchical Internet into a flat network. All the while, smart regulation in wireless undertaken by successive administrations has begun to yield fruit. The United States undertook the first spectrum auction in 1994 and has since repeated the successful sales, sparking dynamism in the sector.

A number of policy experts claim that wired fiber to the home is the end technology that broadband policy should be cabined around. However, by many estimates, wireless data usage will ultimately exceed wired usage to become the preferred method of accessing the Internet and other advanced communication services.[1] The United States is a country on the go, and there is no reason to think that our broadband future has to be wired, if we get our policies right.

In part, the Energy and Commerce Committee is aiming to do just that, by releasing the second of four papers in an effort to update the Telecommunications Act for the digital age. This comment is a response to that prompt, and more clearly focuses on four of the questions:

- What should be done to encourage efficient use of spectrum by government users?
- What other steps can be taken to increase the amount of commercially available spectrum?
- Should all Federal Communications Commission (FCC) licenses be flexible use? In what instances should the Commission exercise control over the service offered? How can the Act enable better use of spectrum, either flexible or specified?
- What structural changes, if any, should be made to the FCC to promote efficiency and predictability in spectrum licensing?

Spectrum policy in the United States developed from a hodgepodge of government regimes and giveaways, resulting in an amalgamation of a spectrum map. Policymakers now face a daunting task. In order to repurpose spectrum for the most efficient means, some actors in the system will have to give up their holdings, including broadcasters, civilian agencies, and military entities. Given the regulatory history and the problems we face now, the FCC should create a regime that is able to meet the flexible needs of tomorrow, so that the current holdings can be adapted to future needs. While some dream of a world without spectrum scarcity made so by technology, that world is far off.

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[1] VNI Mobile Forecast Highlights, 2013 – 2018, Cisco, http://www.cisco.com/c/dam/assets/sol/sp/vni/forecast_highlights_mobile/index.html

With increased pressure from the industry to reform and demands, the FCC should structure spectrum policy on four major principles:

- Aim to maximize the total social and economic value of spectrum;
- Rationalize spectrum policies;
- Be agnostic about auction outcomes; and
- Ensure secondary markets can work efficiently.

Though there are those who would want to change it, these principles have been with the agency from the beginning. Even the FCC recognized that micromanaging spectrum outcomes could be disastrous, and said it should "rely on market forces to ensure economically efficient use of spectrum."[2] The path forward is clearer than most are willing to admit, but what is missing is the political will to ensure it occurs.

A Picture of Industry Competition and the Spectrum Constraint Problem

Mobile telephony has taken off dramatically in the last decade due to a number of key developments. Mobile phone ownership is now nearly ubiquitous, as over 90 percent of Americans own a cell phone. Smartphones are similarly being adopted at a quick pace. From May 2011 to January 2014, ownership of these phones jumped from 35 percent to 58 percent.[3] Part of the success is due to the competition among the four national carriers. For over 92% of the population, there is a choice among 4 or more providers. Moreover, while the overall Consumer Price Index increased by 40 percent between 1997 and 2012, Wireless Telephone Services CPI has declined nearly 40 percent. These various dimensions of competition and the generous benefits carriers have been willing to shell out in order to break contracts have given consumers reasons to switch, as evidenced by the churn rate.[4]

Few areas of the economy have seen the growth numbers that wireless data can claim. Just last year, the United States' consumer mobile data traffic grew 80 percent, nearly 2.5 times faster than fixed IP traffic. Projections by Cisco suggest that this frenzied clip is unlikely to end, with an estimated 8-fold growth from 2013 to 2018. In other words, the entire industry should expect a compound annual growth rate of 50 percent for the next five years.[5]

One of the most important inputs to this dynamic market, spectrum, is running out. The spectrum map has been enclosed, so the FCC cannot readily auction off new spectrum unless current users are moved

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[2] Gregory L. Rosston and Jeffrey S. Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, Jan. 1997, Federal Communications Commission, http://wireless.fcc.gov/auctions/data/papersAndStudies/spectrum.txt

[3] *Device Ownership Over Time*, Pew Research Internet Project, http://www.pewinternet.org/data-trend/mobile/device-ownership/

[4] *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Service,* March, 21, 2013, Federal Communications Commission http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-13-34A1.pdf

[5] *VNI Mobile Forecast Highlights, 2013 – 2018*, Cisco, http://www.cisco.com/c/dam/assets/sol/sp/vni/forecast_highlights_mobile/index.html

off their holdings. Reallocating users to different parts of the band poses its own series of highly fraught technical and political issues, in addition to huge costs. Wireless companies are partly routing around the problem of spectrum constraint by building cell sites in selected areas, but in the long run, it will lead to relative overcapitalization and higher costs for everyone.

The need for stable, predictable, and manageable spectrum resources has long been a problem for wireless companies, and they have been willing to bear substantial costs to obtain additional spectrum. Increasingly, however, regulatory uncertainty has added a new dimension. Generally, companies have two options to get new chunks of the airwaves, either through auction or the secondary market. The FCC has set up roadblocks such as restrictions on auctions and on buying for the two largest players, AT&T and Verizon. Ending these practices will go a long way to ensure that consumers receive the kind of service increases they have come to expect.

In one section of the prompt, the Energy and Commerce Committee, asked, "What structural changes, if any, should be made to the FCC to promote efficiency and predictability in spectrum licensing?" In part, the question can be answered by a quip from Ithiel de Sola Pool from the 1980s: "The time has come to bury the old cliché that spectrum is a scarce resource. It is an abundant resource, but a squandered and misused one."[6] The Commission needs to rationalize its approach on a number of fronts.

The Government Spectrum Problem

1926 was a watershed year for spectrum allocation. In the decade previous, amateur radio popped up, and the first commercial radio broadcasts began. In the absence of government regulations, de facto property rights were being established by those who got to the space first, by so called first priority of use. Court cases changed this trajectory, spurring Herbert Hoover, then Secretary of the Commerce Department, to stop supporting priority in use claims. Interference became the norm as new upstarts tried to poach popular radio stations' frequencies. Congress soon passed the Radio Act of 1927, establishing the Federal Radio Agency (FRA) which had stewardship of the spectrum. The successor agency we all know, the FCC, continues in the footsteps of the FRA and determines how various frequencies are used and who could use them through the license system.

The regulatory structure changed little over the years. As TV broadcasting and satellite each came into their own, the FCC allocated generous portions of the spectrum to companies in those industries without much fanfare and with the expectation that they would be renewed. For example, nearly 330 Mhz of spectrum was set aside for UHF television, which is equivalent to about half of all spectrum dedicated to wireless.[7] Yet, the experience was not successful, and large portions of the band have since been vacated for reassignment for mobile use.

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[6] Ithiel de Sola Pool, *Technologies of Freedom*

[7] Gerald R. Faulhaber and David Farber, *Spectrum Management: Property Rights, Markets and the Commons*, http://assets.wharton.upenn.edu/~faulhabe/SPECTRUM_MANAGEMENTv51.pdf

The story of "wireless cable's" 198 Mhz allocation features many of the same elements as the UHF story. Both narratives have been retold over and again in the annuals of FCC spectrum history.[8] The combined result of these decisions is a spectrum map that is a hodgepodge of discretely carved out fiefdoms for specific uses. The extreme specificity by the FCC in how licenses could be used and for what purpose at one point ran 1330 pages in the Code of Federal Regulations.[9] Yet, the arguments in favor of special purpose network carve outs have passed their prime. Defining exact uses for spectrum means that repurposing the bands requires a redefinition for the license use. Recognizing these problems, the FCC now issues flexible use licenses. While it is important to define spectrum allocations to conform to international standards, there are few if any reasons why the FCC should stray from this new regulatory direction. As a long term goal, the FCC should work towards the creation of a single network by phasing out existing application specific licenses.

Implementing this long term goal will require the clarification of the rights of spectrum license holders. Poor receiver standards derailed the deployment of LightSquared. Formally, Lightsquared was a satellite communications company, who saw an opportunity to convert their spectrum holdings from satellite transmission to a terrestrial wireless network. After getting approval from the FCC to build their network in 2004, the company was able to secure over $4 billion to create a carrier network.[10] All of this was rolling along smoothly until GPS manufacturers began complaining about interference. Poor receiver standards, that is, poorly made GPS devices, were the cause of the interference, but the FCC could not find a solution and shut down LightSquared's network. The company eventually filed for bankruptcy in 2012, but the episode explains just how disastrous ill-defined rights in spectrum licenses can be.

Generous allocations of spectrum were not just reserved for companies. Governmental agencies also received large swaths of the airwaves. In total, more than 1500 MHz is reserved by the U.S. federal government for agency use. Agencies are not forced to internalize the actual market cost of spectrum. Separated from the larger market, inefficiency abounds. Of course, to their defense, government agencies have gone a long way to reallocate and merge, especially on the 1755 to 1780 band, which will soon come to auction. Moreover, if the case of the iPhone's Siri app is instructive, new applications can drive up demand sharply, so it is only natural for the government especially to be reluctant to release spectrum which it might desperately need for tomorrow's applications.

Nevertheless, the government needs to fully bear the market cost of spectrum, as any other consumer, and should transition to a fully market based system. One option that has been floated is a Government Spectrum Ownership Corporation (GSOC), which would act much like the federal agency that manages federal real estate, the Government Services Administration (GSA). The GSOC would become the owner

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[8] Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, The Spectrum Auction Faux Pas, And The Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy,* Harvard Journal of Law & Technology 14 (2).

[9] Bruce Owen, *The Internet Challenge Television*

[10] Tiffany Kary and Michael Bathon, *LightSquared Files Bankruptcy After Network Blocked*, Bloomberg, May 14, 2012, http://www.bloomberg.com/news/2012-05-14/lightsquared-failed-wireless-venture-files-for-bankruptcy.html

of all government spectrums and would lease it to government users at market rates. In turn, the GSOC could sell (or rent) surplus spectrum to the private sector, and purchase additional spectrum as needed.[11]

In the meantime, the NTIA should conduct a comprehensive audit of the government's spectrum holdings to create a comprehensive inventory of the country's total spectrum licenses. Additionally, the audit would be undertaken with the ultimate purpose of privatizing federal, state, and local spectrum holdings. Work can begin by giving companies more certainty in the regulatory regime as well as lifting restrictions on spectrum auctions.[12]

Transaction Review and the Spectrum Screen

As wireless companies have become more anxious to add to their spectrum, acquiring smaller carriers has become an approach. But because the FCC has power over spectrum holdings, it similarly has the ability to review the spectrum transactions. One of the tools the FCC has used to determine if a deal should go through or not is the spectrum screen. If a transaction gives the company control over less than a third of the important spectrum in a market, then it is claimed to be competitive, which ends the competitive analysis. If however, the merged entity goes over this limit, then further analysis is conducted. As Geoffrey Manne and Larry Downes have explained,

> "Given the changing dynamics of the mobile marketplace, any spectrum screen would need to be regularly reviewed and clearly articulated, but the FCC continues to make its adjustments more-or-less randomly. There's no actual methodology—or none expressed—as to how adjustment decisions are made. For example, BRS spectrum is included in the spectrum screen in some markets, but not in others, and EBS spectrum is not included in the spectrum screen at all. Because Clearwire's network uses only these two spectrum bands, Sprint's holdings in Clearwire are excluded from the screen."[13]

In the AT&T andT-Mobile deal, the screen was made as an important linchpin in the FCC's argument against the merger. As Downes first reported, the staff made a significant adjustment to the screen during the deal, producing failure in 274 of roughly 700 markets. Without the adjustment, the transaction would have failed in only 192 markets. The ordeal pushed the FCC toward releasing an NPRM on the issue. Because of the power that the spectrum screen has over transaction review, the four large carriers have been fervently discussing the issue. But the antitrust theories underlying the

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[11] Thomas M. Lenard, Lawrence J. White, and James L. Riso, *Increasing Spectrum for Broadband: What Are The Options?*, Feb. 2010, http://www.techpolicyinstitute.org/files/increasing_spectrum_for_broadband1.pdf

[12] Richard Bennett, *Powering the Mobile Revolution: Principles of Spectrum Allocation*, The Information Technology & Innovation Foundation, July 31, 2012, http://www.itif.org/publications/powering-mobile-revolution-principles-spectrum-allocation

[13] Larry Downes and Geoffrey Manne, *The FCC's Unstructured Role in Transaction Reviews*, CPI Antitrust Chronicle Oct. 2012 (1)

spectrum screen have long been replaced. So, the FCC should reject the spectrum screen, which is based in outdated HHI and instead move towards a rule of reason approach for transaction review.[14]

Spectrum Auctions

As part of the Middle Class Tax Relief Act, Congress gave authority to the FCC to conduct the incentive auction, the first of its kind that conducts two simultaneous spectrum sales. While the original goal for the auction was 120 Mhz of "beachfront" spectrum, estimates have had a downward trajectory as of late, and now are in the range of 60-80 MHz. Importantly, the agency has been toying with limiting the entry by the two largest companies, Verizon and AT&T. In a paper authored by Coleman Bazelon and Douglas Holtz-Eakin, President of the American Action Forum, imposing spectrum limits were found to reduce auction revenues by up to 40 percent, lower auction proceeds from $31 billion to $19 billion, and impair the first responder network it is intended to fund.[15] The findings were replicated across a number of studies and the results have all been similar.[16]

Auctions designed to achieve stated policy goals through restrictive or preferential auction participation rules have largely been unsuccessful. Limits on participation have resulted in distorted prices, misallocation spectrum, and severe competitive issues in the post-auction market. Discriminatory participation rules, including the US experience with the C and F Blocks of the PCS band, have delayed the deployment of spectrum by an average of seven years, which has adversely harmed competition.[17] In this late stage of the game, it is not clear that the FCC should be messing with a recipe that has worked in the past. Free entry has allowed small and regional players to come to the market, and it has been instrumental in getting spectrum to where it is really needed--consumers.

FCC Chairman Tom Wheeler justified the limits on the grounds of public interest, claiming that the current marketplace lacks competition and is merely the result of historical contingency. However, Sprint's investment missteps with WiMax and T-Mobile's lack of bidding in the last round of auctions adds depth to this historical contingency. As noted previously, the industry is actually described as having falling prices, accelerating output, technological dynamism, surging investment, and multidimensional competition. All of this is a far cry from a non-competitive landscape.

As FCC Commissioner Robert McDowell warned US lawmakers:

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[14] Matt Starr, Geoffrey A. Manne, and Berin Szoka, *"The Spectrum Must Flow!": The Need for Rule of Reason Analysis of Spectrum Transfers at the FCC*, Nov. 28, 2012, http://apps.fcc.gov/ecfs/document/view?id=7022068538

[15] Coleman Bazelon and Douglas Holtz-Eakin, *Bidding Restrictions and the Incentive Auctions*, April 30, 2013, http://www.gcbpp.org/files/Academic_Papers/EconImplicationsSpectrumFINAL.pdf

[16] Robert Earle and David W, Sosa, *Spectrum Auctions Around the World: An Assessment of International Experiences with Auction Restrictions*, July 2013, http://mobilefuture.org/wp-content/uploads/2013/07/Spectrum-Auctions-Around-The-World.pdf
http://mobilefuture.org/wp-content/uploads/2013/07/Spectrum-Auctions-Around-The-World.pdf

[17] Fred Campbell, *Maximizing the Success of the Incentive Auction*, Nov. 4, 2013, http://www.broadcastcoalition.org/uploads/auction_whitepaper_10_31_2013_FINAL_revised_v2.pdf

> "I am hopeful that the Commission will not put America's positive momentum in the wireless area at risk as we explore the myriad options related to the incentive auctions. History teaches us that past regulatory efforts to micromanage the wireless market, despite presumed good intentions, have resulted in harmful unintended consequences."[18]

Conclusion

The path forward is clearer than most are willing to admit, but what is missing is the political will to ensure it occurs. Consumers are demanding wireless services. To ensure that this innovative sector continues to develop, the FCC needs to rationalize spectrum policies and be agnostic about auction outcomes, so that spectrum is efficiently reallocated through the primary and secondary markets.

[18] Robert McDowell, *Keeping the New Broadband Spectrum Law on Track*, Dec. 12, 2012 http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-317905A1.pdf

Date: April 25, 2014

To: Committee on Energy and Commerce,
United States House of Representatives

From: Richard Bennett, Visiting Fellow, American Enterprise Institute,
Washington, DC

Subject: Modernizing U.S. Spectrum Policy

This is in response to your ten questions on spectrum policy in the White Paper dated April 1, 2014.

1. *What structural changes, if any, should be made to the FCC to promote efficiency and predictability in spectrum licensing?*

   The FCC's mandate is both too broad and too narrow with respect to licensing. It's too broad because it fails to encompass federal spectrum assignments. An alternate way of addressing federal spectrum use is described in the attached draft, "Blueprint for a Federal Spectrum Service."

2. *What role should unlicensed spectrum play in the wireless ecosystem? How should unlicensed spectrum be allocated and managed for long-term sustainability and flexibility?*

   Unlicensed is currently a one-way gate; once a swath of spectrum is declared unlicensed, its terms of use are impossible to alter and it can't be re-purposed for a higher use. This is already causing problems in the 2.4 GHz band, as both analog and digital systems coexist and interfere with each other (analog baby monitors vs. digital Wi-Fi and Bluetooth systems) and more recent versions of Wi-Fi must coexist with legacy versions that degrade the performance of the more advanced protocols. Unlicensed should best be reconsidered as no-fee license that carries a greater set of terms and conditions than it carries today. One option is to grant a Wi-Fi license for a nominal fee to an organization such as the Wi-Fi Alliance that would enable it to make rules that would require the phase-out of obsolete systems and other adjustments and adaptations.

   Low-cost licenses are important in many settings, but they need not be completely free. There is nothing wrong, in principle, with taxing each Wi-Fi device at point of sale.

3. *What should be done to encourage efficient use of spectrum by government users?*

   This question is addressed by the attached paper, "Blueprint for a Federal

Spectrum Service." In brief, federal spectrum should be transferred to a federally charted corporation mandated to reduce the federal spectrum footprint by 75% over a ten year period.

4. *What other steps can be taken to increase the amount of commercially available spectrum?*

   In addition to the over-allocation of spectrum to federal systems, spectrum is over-allocated to satellite-based systems and to TV broadcasting. The Spectrum Incentive Auction system, if it proves effective, can be applied to the satellite assignments as well. Generally speaking, satellite systems must be segregated from licensed, terrestrial systems except those used for low power unlicensed applications. At present, it appears that the Spectrum rights map must be rationalized to place similarly powerful allocations closer together, but advanced filters may alter the status quo.

5. *Should the Act permit the FCC to use expected auction revenue as the basis for a public interest finding? What criteria should the FCC consider as part of its analysis?*

   Yes, auction revenues are in the public interest and should be considered. The FCC should also consider the ability of licensed systems to serve a broader range of applications, to serve applications more efficiently, and to advance along the technology curve more quickly than non-licensed and un-licensed systems. See the attached paper "Technical Principles of Spectrum Allocation", 2013. *TPRC 41: The 41st Research Conference on Communication, Information and Internet Policy*. Available at SSRN: http://ssrn.com/abstract=2240625

6. *Should all FCC licenses be flexible use? In what instances should the Commission exercise control over the service offered? How can the Act enable better use of spectrum, either flexible or specified?*

   When spectrum is licensed and auction, the terms and conditions of its use need only be specified in technical terms as the auction and subsequent market transfers ensure appropriate use. The Commission, or its successor agency, need only concern itself with interference dynamics, which are partly a function of receiver design. In general, the flexible use model is the most beneficial because it allows continual re-assignment as technologies, markets, and needs change.

7. *What principles should Congress and the FCC consider when addressing spectrum aggregation limits? How has the converging marketplace and growing demand for services changed the discussion of spectrum aggregation?*

   In general, problems of market concentration are antitrust matters best

policed by the Federal Trade Commission and Justice Department after the fact. The FCC has not demonstrated the advanced powers of extra-sensory perception necessary to predict market dynamics many years in the future.

8. [*Should the Act impose build-out requirements?*]

   The larger question is what the Act can do to promote competition and the effective use of spectrum. Many license holders have not deployed spectrum until they've been able to acquire a considerable portfolio covering a large geographic footprint. When a license holder is actively acquiring spectrum, there is no reason for the Act to require immediate deployment. Spectrum is a valuable asset, so there's no reason in principle for speculation in spectrum to be constrained any more severely than speculation in foodstuffs, oil, or water is constrained. Short of severe harm to the public, investors should be allowed to explore a range of strategies.

9. *What is the best balance between mitigating interference concerns and avoiding limiting flexibility in the future? Can engineering and forward-looking spectrum strategies account for the possibility of unanticipated technologies and uses in adjacent spectrum bands? How do we promote flexibility without unreasonably increasing the cost of services and devices? Does the Act provide the FCC tools to address this problem?*

   The current discussion about receiver standards is at a very high level; indeed, some would describe it as little more than hand waving. The issue is that receiver standards depend in the precise definition of a "harm claim threshold" which is no different, in practice, from a transmit power profile. Receivers are only affected by transmissions, so to characterize the noise environment in which receiver must or may operate is also to characterize a transmitter. The only exception would be in terms of peculiar inter-modulation noise, second and third harmonics, and combinations of the effects of multiple transmitters that would be extremely difficult to adjudicate. The Act should be sensitive to advanced research on receiver standards, but as of this moment there is very little substance in the "harm claim threshold" arena.

   It is perfectly sensible, however, for license holders in adjacent frequencies or geographies to mutually agree upon modification to their license terms. These negotiations should generally be encouraged by the Act. It should also empower the Commission or its successor to deal with the holdout problem where modifications to licenses are concerned. Without the ability to modify license terms, it will be impractical to gather licenses in appropriate frequencies by power level.

10. *What role should NTIA play in the licensing and management of spectrum? Is their current role appropriate and necessary, given the potentially duplicative*

functions of the FCC and NTIA in spectrum allocation and assignment?

The fragmentation of spectrum allocation responsibilities between the FCC and NTIA is harmful and counter-productive. In addition, NTIA lacks the power to effectively police spectrum use by federal agencies as the inefficient use of spectrum by agencies proves. NTIA and the FCC's spectrum authority should be consolidated in a single agency that also has the power to improve government spectrum use, conduct auctions, and sponsor research and development.

Technical Principles of Spectrum Allocation

BY RICHARD BENNETT

SEPTEMBER 2013

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OVERVIEW AND SUMMARY

Historically, spectrum allocation has been an ad hoc, piecemeal system driven by the logic of the moment: A commercial enterprise or government agency with an idea requested a spectrum allocation from the relevant regulator. If the regulator saw merit in the idea, the regulator looked into its inventory of unassigned radio frequencies and allocated the best available fit. In some cases, the process of spectrum assignment has been initiated by the regulator itself; sometimes to good effect (Wi-Fi™) and sometimes not (Ultra-Wideband).

Regulators require a comprehensive set of spectrum management principles.

It's now clear that spectrum allocation and management is an ongoing process that will benefit from guidance by a set of fundamental, technology-based principles. Rather than simply re-assigning spectrum from legacy systems to mobile networks, policymakers need to reform the system that has created a critical shortage of spectrum in the most dynamic sector of the economy while over-allocating spectrum to wasteful and obsolete systems. The spectrum crisis is an opportunity for fundamental reform in the logic of spectrum assignment that will make future adjustments faster and less painful.

A more rational system of spectrum assignment would respect the technical principles that are evident in the operation of actual high-demand, high-performance, and high-efficiency wireless networks today and in the near future. In brief, these principles are:

1. Upgrade and Repack: When upgrades to existing systems will free up spectrum for additional uses, as was the case in the DTV transition, require the upgrade and reassign the excess.
2. Strive for Sharing: Prefer assignments that serve multiple users, as general-purpose commercial networks do, over those for single users, as some government systems do.
3. Reward Application Flexibility: Prefer assignments that support a variety of applications over those that support a single application.
4. Optimize Dynamic Capacity Assignment: Prefer networks that allow capacity to be adjusted on demand to those that allocate capacity statically.
5. Permit Technology Upgrade Flexibility: Allow technology upgrades without permission and with a minimum of coordination.
6. Recognize Aggregation Efficiency: Prefer large allocations over small ones to minimize guardband losses.
7. Create Facilities-Based Competition: Allocate spectrum to multiple systems of the same general kind in order to create market competition and technical resiliency.
8. Reward High-Performance Receivers: Favor systems of high-performance receivers over those that can't tolerate common sources of RF noise, and penalize low-performance receivers.

9. Allocate in All Relevant Dimensions: Allocate "patches" of spectrum by frequency, power level, place, transmission direction, beam spread, modulation, coding, and time.
10. Promote New Technologies: Use rules modification and market transactions rather than exclusive allocation as a means of enabling future generations of spectrum technologies.

These allocation principles flow from a particular vision of the empirical knowledge about radio frequency spectrum, the current state of the art in radio engineering, and the likely timeline of new developments in radio engineering. They are explained in more detail in the main text.

Application of these principles to spectrum allocation disputes will help resolve case-by-case disputes in an optimal manner. Ideally, we should be able to score each spectrum dispute according to the number of principles it follows. This method enables us to determine the extent to which regulators are moving spectrum policy forward or backward. The examination of selected current controversies illustrates this method of analysis at work.

The demand for spectrum is largely created by new wireless applications. The most important example of the demand is the vast pool of applications that have been created for smartphones and intelligent infrastructure such as the "smart grid" and machine-to-machine applications. Demand for wireless data capacity—bandwidth—roughly doubles each year or two.

Bandwidth is often compared to highway capacity, but a better analogy is food production: We can always build more roads, but we can't increase the supply of arable land or of spectrum nearly as easily. We increase the food supply by bringing more acreage into agricultural use, by improving agricultural technologies such as genetically engineered seed, chemical fertilizers, herbicides and pesticides, and by employing sound soil and crop management practices. Similarly, wireless bandwidth is increased by putting more patches of spectrum to use, developing technologies that increase bits/hertz usage efficiency, and managing network traffic responsibly. Each of these three practices is necessary, and each produces widespread societal benefits.

Spectrum research and development is extremely important, but in the short to medium term technology is not going to resolve the spectrum crunch on its own. Research is advancing along two principal lines:

1. Researchers in the Software-Defined Radio/Cognitive Radio/Dynamic Spectrum Access (DSA) field are developing techniques that allow access to unused or lightly-used patches of spectrum. These techniques should be understood as an alternative or a supplement to traditional regulator practices that assign spectrum to license holders who may not use their allocations fully at all times. In practice, DSA needs to be connected to an authorization database such as the White Spaces Database that provides go/no go information to prospective network operators, and the decisions that his database implements flow from a spectrum allocation policy. To be optimally effective, these systems need knowledge of real-time and potential spectrum demand as well, but the time scale for his knowledge is on the order of microseconds, well beyond the ability of authorization databases that

conventionally update once a day.

This branch of research is frequently touted as increasing spectrum efficiency, but this description needs clarification. DSA actually aims to improve *allocation efficiency* by enabling a larger pool of potential users to contend for access to the spectrum. While this can be beneficial, it does not improve *usage efficiency*, the amount of information per unit of spectrum (bits/hertz) that can be transmitted and received over a given patch of spectrum. In other words, these technologies address the problem of putting otherwise idle spectrum to use, and do not address the problem of making spectrum use more efficient when it actually takes place.

2. Research on spectrum efficiency develops techniques that allow for greater bits/hertz *usage efficiency*. This line of research concentrates on techniques that govern the ways that bits are represented on wireless networks, the nature of antennas, and the coding and scheduling systems that enable multiple users to share a given patch of spectrum in an orderly manner. Usage efficiency research aims to ensure that communicating a message of a given size takes ever decreasing quantities of time and spectrum.

   Most of the practical advances in the use of RF spectrum by commercial and other public systems are the result of research on *usage efficiency*: Packet radio, modulation systems such as Orthogonal Frequency Division Multiplexing (OFDM) and Quadrature Amplitude Modulation (QAM), Multiple-Input Multiple-Output (MIMO) antenna systems, scheduling/coding systems such Code Division Multiple Access (CDMA), and speculative modulation systems such as Orbital Angular Momentum (OAM).

Lawmakers and regulators concerned with spectrum allocation have no choice but to meet the current spectrum crisis by making better use of current technology.

Spectrum research doesn't absolve policymakers from identifying more spectrum for wireless data systems. To the contrary, DSA technology depends on a pre-existing spectrum allocation policy as it is primarily a means of supplementing conventional allocation policy with secondary allocations based on complex, multi-level allocation policies. Advanced research on usage efficiency is not currently mature enough to make allocation decisions unnecessary, even if it may be someday. If and when that were to occur, policymakers would still be required to address the vexing problem of the billions of less advanced systems that remain on the air with a transition plan to better technology. Similarly, DSA methods are not sufficiently advanced as to allow *extreme sharing*: There is no practical means for multiple users in the same locale and on the same frequency band to transmit packets at the same time and direction other than code division; code division requires a degree of coordination that unlicensed systems do not currently implement.

Consequently, lawmakers and regulators concerned with spectrum allocation have no choice but to meet the *current* spectrum crisis by making better use of *current* technology. This requires repurposing and reallocating the pool of spectrum best able to meet the needs of the mobile revolution, a job that is best undertaken by adopting principles that reflect the best understanding of spectrum usage technology as it is today and as it will be in the next five to ten years.

Recent spectrum controversies don't always reflect clear and consistent decision making. Grading the decisions that have been made or will be made soon in this area yields the

following results with a scoring system that ranks each decision on a scale ranging from +10 to -10, where +10 is most desirable:

- Leave DTV Channel 51 live while imposing interoperability on 700 MHz B and C block license holders: -8
- Take DTV Channel 51 off the air: +8
- Remove 800 MHz internal guard bands: +10
- Convert government fixed point microwave to fiber backhaul: +10
- Replace Military Tactical Radio Relay with fiber: +10
- Move government video surveillance to a commercial carrier: +6
- Adopt PCAST spectrum sharing recommendation: +5
- Reassign LightSquared spectrum to wideband GPS: -1
- Adopt FCC Medical Body Area Networks plan: 0
- Allow Verizon to purchase SpectrumCo licenses: +7

Policymakers should generally strive for decisions that earn six points or more, and avoid decisions that earn less than three points in the absence of extenuating circumstances not captured by our grading system.

The spectrum agenda needs to proceed along two parallel time lines: In the short term, policymakers need to make more spectrum available for use by high-demand applications such as mobile broadband, and for the long term they need to support basic and applied research on spectrum to relieve capacity constraints. There is no downside in assuming that the spectrum crunch is real and that the long-awaited technical advances that promise to resolve it will not arrive for a very long time. There is an enormous potential downside in assuming that a technology solution that does not require re-allocating spectrum already exists or is just around the corner, however. The prudent course is to deal with today's problems today while actively supporting the technology that we will use tomorrow. It's also important to equip policy makers and spectrum users with the tools that will enable them to deal with tomorrow's problems in a way that leverages tomorrow's technologies.

SPECTRUM TUTORIAL

This paper offers a spectrum allocation grading system that reflects operational principles in modern mobile broadband networks, the facts of wireless engineering, and established principles of economics. This is a search for a data-based policy framework.

In this milieu where claims and forecasts consistently outpace the capabilities of existing technology, it's difficult to evaluate the basis on which predictions about spectrum technology are made. Consequently, it's necessary to review tutorial information on wireless technology to help policy thinkers evaluate some of the technical claims that surround this debate. Following the tutorial, the policy analysis resumes.

What is Spectrum?

The term "spectrum" is used in this paper and in the policy discourse generally as shorthand for "the spectrum of radio frequency radiation." The radio frequencies of

interest to commercial networking providers span the range of electromagnetic energy from 500 MHz to 4 GHz, although radio frequency spectrum (RF spectrum) in general ranges down to 15 KHz and up to the GHz range. The following briefly describes key properties of RF Spectrum.

The Nature of Spectrum

Electromagnetic radiation (EMR) is a produced by the charged particles (electrons) in atoms. It is a property of all matter, and manifests as waves of energy. EMR in its pure form consists of sine waves of various frequencies, and the modification of these waves by transmitters allows them to convey information.

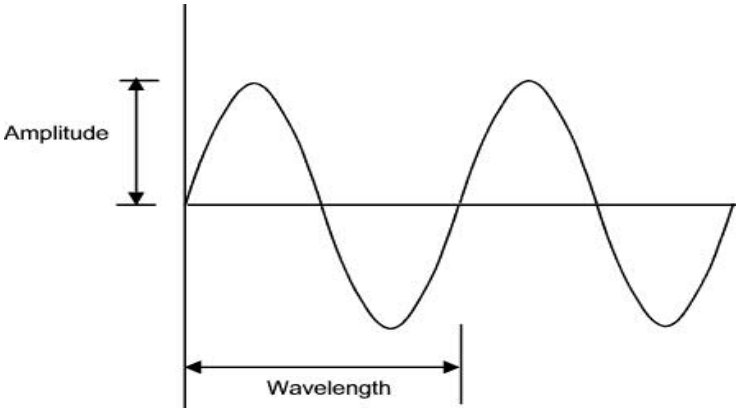

Figure 1: Pure Sine Wave Repeated

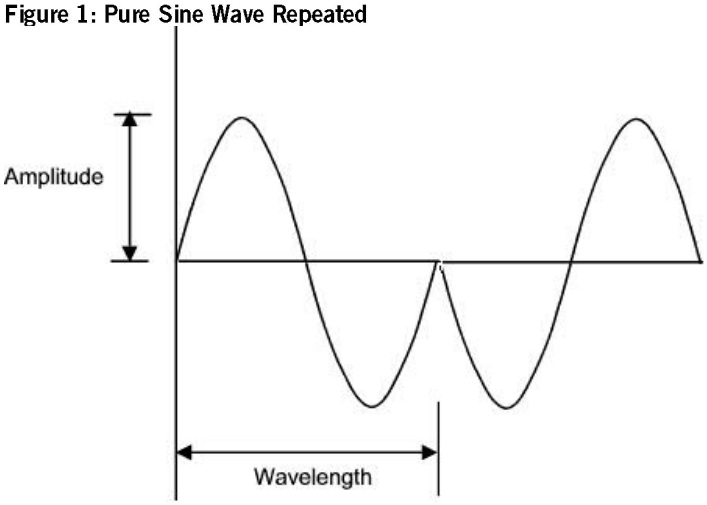

Figure 2: Sine Wave Followed by Inverted Sine Wave

Figure 1: Pure Sine Wave Repeated illustrates the repetition of a pure sine wave, while

Figure 2 shows a modification that can be used to carry information. The first sine wave in Figure 2 might be used to convey a bit with value “one,” while the second wave could convey a “zero” bit. Of course, real systems are much more sophisticated than this, conveying as many as 1024 bits (or more) with a single modification of the original sine wave.

EMR generally degrades with distance as waves disperse and react to features of the environment and the atmosphere. Spectrum in the 500 MHz frequency has a wavelength

of six feet, which allows waves to pass through windows, which are generally much less disturbing to EMR than building walls. Spectrum above 4 GHz range has a wavelength of less than three inches, which causes it to be reflected from (bounced off) most tree leaves. The spectrum between 500 MHz and 4 GHz is most valuable for commercial two-way radio systems such as cellular broadband because of these properties and the size of the antennas that transmit and receive such frequencies.

The Nature of Interference

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1. A transmitter
2. A second transmitter or an obstacle that alters transmissions
3. A receiver located in a specific position

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Figure 3: Rainbows are Caused by Interference (Credit: Wikipedia)

We see rainbows because the signal transmitted by the Sun is refracted by drops of rain that split visible light into its spectral components, the different colors of visible light. The observer located in just the right place sees the rainbow overlaid on the background of normal visible light, but other observers in other locations don't see the rainbow.

A radio receiver experiences a similar effect when radio interference takes place. In one form of interference, a signal is refracted into elements that arrive at the receiver at different times, one taking a direct path and others taking indirect paths because they bounce off obstacles such as walls, bridges, or foliage. If the receiver is smart, it can recognize that the information carried by the direct signal is the same as the information carried by the indirect signals and recombine them. This capability is exploited by Orthogonal Frequency Division Multiplexing (OFDM) radios.

A more difficult kind of interference is produced by discrete transmitters showering a given receiver with information in the same format at the same time. The information is ambiguous in most instances, because the receiver can't differentiate the ones and zeros until each message is processed, and the messages can't be processed without extracting

ones and zeros from the raw energy it receives. We experience a similar problem in group conversations when two or more people speak at the same time.

Smart radios can disambiguate some of this sort of interference, but not all of it. One approach to smart radio design scrambles messages at the transmitter with a code known to both the transmitter and the intended receiver, so that the application of the code extracts good information and rejects bad. Such systems can even be used to some utility when both messages are intended for the same receiver, as in Code Division Multiple Access (CDMA) systems.

Advances in signal processing will extend the ability of radio systems to focus on meaningful information and reject noise for quite some time to come.

Spectrum Sharing

Radio communication networks share spectrum in two major ways:

1. Regulators assign durable usage rights to patches of the frequency spectrum in various places to particular operators for years at a time; and
2. Operators assign transient usage rights to particular users and applications for fractions of seconds at a time.

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The term "spectrum efficiency" is used in both contexts, but it has very different meanings when used so broadly. Engineering understands spectrum efficiency in terms of bits per hertz, and this measure is only meaningful in the "cooked" context, after spectrum has been assigned to an operator in a durable manner.

"Opportunistic spectrum access" is actually an advance in the regulatory context rather than in the operational one. It's difficult to measure "bits per hertz" when hertz is an unbounded variable. It's an intermediate between exclusive spectrum licensing (by auction or otherwise) and unlicensed access, but it leans toward unlicensed in practice. The sharing of licensed spectrum is generally more efficient in bits/hertz than unlicensed spectrum: Licensed systems reach 95% utilization, while unlicensed systems such as Wi-Fi™ operate well below 50% utilization. Wi-Fi™ has many virtues – flexibility and simplicity in particular – but technical efficiency is not one of them.

Licensed, commercial networks achieve high utilization by scheduling spectrum access from a common vantage point, a tremendous technical advantage over the "every man for himself" Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) spectrum access system used by Wi-Fi™. Overcoming access inefficiency is also a challenge for White Spaces systems when multiple providers seek to utilize common frequencies, but it's not an insurmountable one. In practice, it will be resolved by a combination of game theory and straightforward negotiation.

One concentration of research on spectrum sharing is the "multiple access problem" that addresses the desired use of a given patch of spectrum by multiple parties at the same time. Approaches to this problem include directional radio beams, coding systems that can be easily distinguished, and game theory models for explicit sharing. These technologies are known as beam forming, Spatial Division Multiple Access (SDMA) and Multiple User

Multiple Input Multiple Output (MU-MIMO). Commercial systems are developing advanced forms of Sharing by Contract such as "Authorized Shared Access" (ASA), which allows for shared use of spectrum using cognitive radio technologies (geo-location databases, sensing, etc.) based on an individual authorization model of spectrum rights.[1] Market transactions are also a very practical means of addressing this problem.

Drivers of Spectrum Demand

In 2011 more smartphones were sold than personal computers.[2] Only half of Americans have smartphones so far, so the trend toward smartphone and tablet adoption will continue for some time. One day appliances and other devices will come to have smartphone capability built in, so the number of smartphones will exceed the population by several times. This will change the both the Internet and the cellular networks quite dramatically. The Internet is used by some two billion people, but we can expect that number to triple within the next three to five years. The growth in the use of smartphones and the mobile Internet is even more rapid than the boom we saw in Internet growth at the turn of the century.[3]

Figure 4: Google Glass (Credit: Google)

Smartphone users use many of the same applications that we use on laptop and desktop systems for personal productivity, information browsing, education and entertainment, but they also use applications that are enabled by mobility itself. There has already been a shift in shopping habits during the holiday buying season as smartphone users share information about products, stocks in local stores, lines, and prices.[4] Thanks to web sites such as Zillow and Redfin, shopping for housing is a completely different experience today than it was even two years ago, as buyers can drive neighborhoods, see which houses are for sale or rent, view pictures of their layout, and even analyze their purchase history without leaving the car. Those who walk, run, or cycle for exercise can map their routes, count their steps, monitor their speed, distance, and heart rate, and estimate calorie burn with mobile exercise apps such as Map My Workout, Endomondo and RunKeeper that connect to social networks and cloud computing facilities.

In April, Facebook acquired Instagram, a photo sharing service with only 13 employees, for a billion dollars, largely because Instagram has acquired 40 million users in only 16 months of operation. Another social picture sharing service, Pinterest, is the third largest social network only two years after its formation.[5]

"Mobile Augmented Reality" is a new application category that extracts information from massive databases in the Cloud relevant to a user's location, activity, and preferences; it moves video streams between the user and the Cloud in both directions, sometimes from "Smart Spectacles" that combine a video camera and display screen such as Laster Technologies' *IEEE Spectrum* 2011 Technology of the Year winner or Google Glass. All of these applications require mobile bandwidth supplied by spectrum and wireless technology—the more the better—and as they are truly mobile there are limited

opportunities to offload their spectrum needs to short distance Wi-Fi™ networks. The spectrum needs of tablets are more in line with those of the laptops they're replacing, however as tablets are "nomadic" devices that we use in stationary fashion from multiple locations. The spectrum needs of tablets are generally met with Wi-Fi™ today.

THE SPECTRUM CRUNCH

The National Broadband Plan famously forecasts a need for 300 MHz of spectrum for commercial, mobile networks by 2015, and an additional 200 MHz for various purposes by 2020. Current allocations assign 475 MHz to mobile broadband[6] and 350 MHz to unlicensed Wi-Fi™ and Bluetooth.[7]

This estimate is low because we've seen that network applications are generally able to make use of all available bandwidth: Residential broadband connections, for example, are roughly ten times faster than they were in the late 1990s, and many of these connections are unshared.

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Mobile social networks are using infrastructure initially designed for low bandwidth telephone service. Video sharing applications will consume ten times as much capacity per minute as telephony with the best compression we can use. Cellular networks in major cities are running close to capacity during peak periods already. From 2006 to 2009, the first three years the iPhone was available on the AT&T network, traffic grew 5000%.[8] This figure probably represents users spending five times as many minutes on their iPhones as they spent on their dumb phones, and performing tasks that are ten times as data-intensive. AT&T forecasts a need for eight to 10 times as much data capacity over the next five years as it can carry today.[9] Some of this capacity can be met by improvements in spectrum efficiency (mainly in terms of coding advances), some by increased tower deployment, and some by small cells, but much of it depends on more spectrum.

Figure 5: Augmented Reality in a Contact Lens (Credit: Raygun Studio)

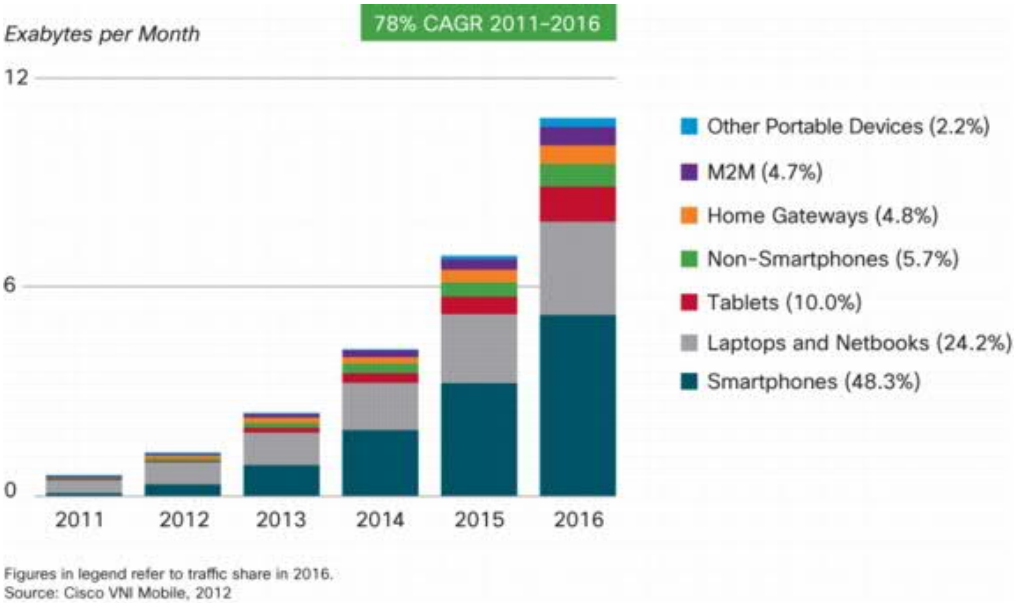

Figure 6: Cisco Mobile Data Forecast by Year and Device (Credit: Cisco)

The balance between these methods is largely economic. Increased spectrum is the least expensive option, building towers the most expensive, and the costs of more spectrum are ultimately born by users. Some analysts believe that advances in technology alone will meet the demand, but this projection ignores the fact that historical advances in spectrum efficiency follow Cooper's Law, doubling every 30 months, while increases in demand follow Moore's Law, doubling every 18 months.[10] Left to its own devices, technology will fail to meet consumer needs.

The most efficient users of spectrum on a per-user basis over wide areas are the large networks. AT&T and Verizon get by with 0.86 and 0.93 MHz per million subscribers, while Sprint/Clearwire holds 3.72 MHz per million, according to Bernstein Research.[11]

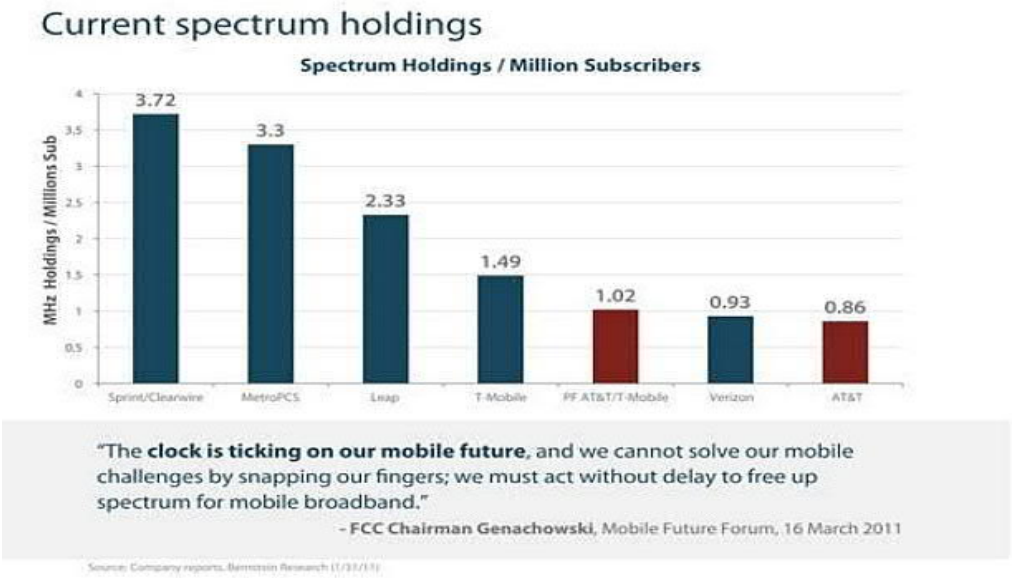

Figure 7: Spectrum Holdings (Credit: Bernstein Research)[12]

If we can't find spectrum to meet the needs of mobile users as they transition to smartphones, tablets, mobile social applications, augmented reality, and sensor networks, innovation will stall and economic growth will slow. The FCC forecasts that these effects will become visible on a broad scale as early as 2012, but they're already apparent in New York and San Francisco.[13]

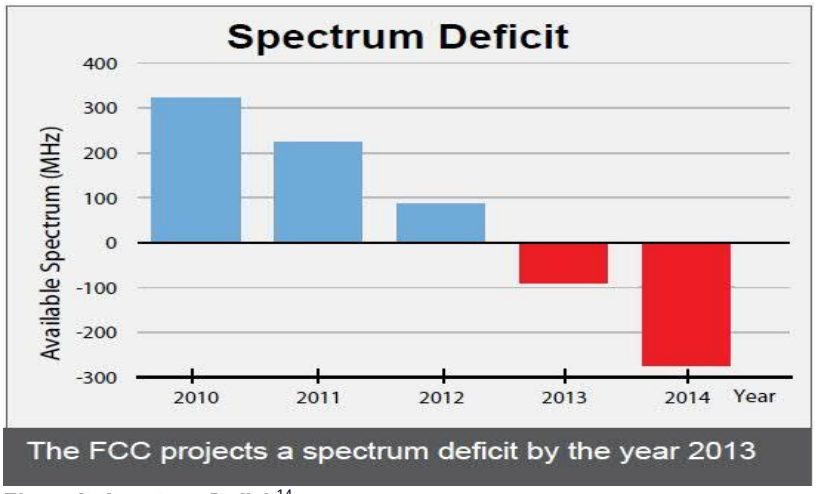

Figure 8: Spectrum Deficit[14]

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MEETING THE NEED FOR SPECTRUM

The general problem with spectrum allocation around the world is the 100 year history of assigning spectrum to applications rather than to networks. The following diagram illustrates the complexity of the U.S. spectrum allocation system. A more ideal system would have many fewer allocations, each for a substantially larger amount of spectrum.[15]

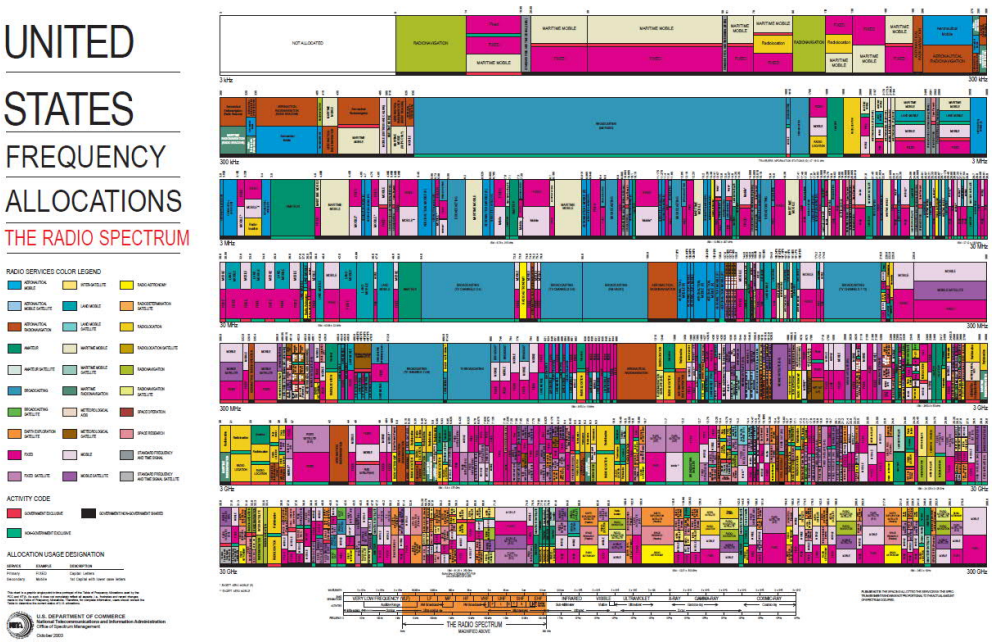

Figure 9: U.S. Frequency Allocations (Credit: NTIA)

From the application perspective, spectrum sharing on commercial networks is a solved problem. We don't have one network for Instagram and another for Pinterest, we have one group of networks that handle a wide range of applications. What we're doing with such technologies as Dynamic Spectrum Access and Authorized Shared Access is reversing the effects of historical spectrum allocation policy. When successful, these approaches will create networks that resemble commercial networks in their application support. This is a way of putting the Humpty-Dumpty of primitive spectrum allocations back together again.

In order to meet the need for network capacity, carriers will supply more spectrum per user. The easiest way to do this is to offload the cellular network onto femtocells and Wi-Fi™ networks, but this is a limited strategy because Wi-Fi™ networks are often overloaded themselves, and in the best conditions Wi-Fi™ fails to meet the needs of mobility.

Wi-Fi™ is a nomadic network, not a truly mobile one, and femtocells have similar characteristics. The small cells that will help relieve the crunch are deployed outdoors on frequencies that coordinate with the macro cells on which the cellular network is based. Building micro cells within the macro cellular fabric is a bricks-and-mortar exercise that requires massive investment and zoning approval to be successful.[16]

Technical Means: Improving Usage Efficiency

As previously mentioned, critics of the spectrum crunch construct correctly argue that advances in wireless technology will meet the bandwidth needs of mobile users even if regulators fail to re-allocate spectrum from legacy applications to mobile networks.

This prediction is true because technology will continue to improve for the foreseeable future, so it's inevitable that some future technology will permit the current allocation of spectrum to meet current user needs for bandwidth. The prediction is also false because it fails to account for the time required for such technical advances to be developed and fully deployed as well as for the growth in user demand that will take place along the way.

We can just as easily predict that the Chicago Cubs will win the World Series. In September of 1908, this would have been a sound prediction, but less so fifty or a hundred years later. It's still likely that the Cubs will win the Series *someday*, but we don't know when that day will come.

Cubs fans don't need to know precisely when their team will triumph—as Cubs fan George Will says, they greet every spring like a second marriage, with the triumph of hope over experience—but makers of World Series winner memorabilia do. The key question for spectrum policy is *when* advances in spectrum technology will begin to produce efficiency gains in excess of increases in user demand for bandwidth.

Unfortunately, no one knows the answer to this question. Even Marty Cooper, one the more bullish advocates of the notion that technology alone will solve the bandwidth crunch, doesn't see much happening for ten years.[17] In technology industry terms, the ten year planning horizon is equivalent to "infinity" because few firms plan beyond the next two to three years. Here's one analysis of planning horizons generally:

> The five-year planning horizon that used to be typical of traditional strategic plans is no longer feasible. The pace of changes in technology and changes in the business environment warrant no more than three years' planning horizon. Beyond that time frame, it is reasonable to assume that the business environment and available technology will be so different that a new strategy will be required.[18]

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Consequently, network operators require the ability to upgrade the actual capacity of their networks without waiting for hoped-for new technologies. In the event that the great breakthrough happens sooner than expected, they're likely to adopt it regardless.

The most curious part of the argument for regulator inaction is the tacit assumption that the current allocation system of spectrum by application is somehow ideal. Our experience with the transition from analog to digital TV contradicts this assumption. When the FCC required TV broadcasters to shift from the analog NTSC standard to digital ATSC, consumers gained access to high-resolution images and sound, and the FCC was able to reclaim half the spectrum previously allocated to analog TV for auction to mobile broadband, to create a public safety network, and for deployment as unlicensed White Spaces systems.

A similar pattern exists across the range of legacy spectrum assignments. The government currently uses 130 MHz for video surveillance, most of it with analog cameras. Converting these systems to digital reduces their spectrum footprint by 75%, and opens the opportunity of sharing with commercial and government systems such as First Net. There is no downside to assuming that the spectrum crunch is real and acting accordingly.

The following reviews some notable opportunities for increased spectrum efficiency and utility and their likely timelines.

Distributed Antenna Systems

In conjunction with the National Association of Telecommunications Officers and Advisors (NATOA) the FCC held a workshop on Distributed Antenna Systems on February 1, 2012.[19] Distributed antenna systems are much more than the name implies. These systems allow a particular antenna array to be shared by multiple users, at the

In fact, DAS simply uses conventional technology on a shared antenna mast, which is already par for the course in wireless network deployment.

expense of digital signal processing equipment in each antenna that is dependent on the particular modulation and coding of the information format in use by each user. They are attractive to community broadband advocates because they allow municipal networks to share facilities used by commercial systems and to municipalities because they reduce the number of unsightly cell towers that must be deployed. They're also attractive to operators because they reduce permitting overhead, but it's hard to argue that they increase bits/hertz efficiency. In fact, DAS simply uses conventional technology on a shared antenna mast, which is already par for the course in wireless network deployment.

Small Cells

LTE enables the deployment of small cells by design. The general notion for LTE network design is to embed small cells in high-density locations within the large cell coverage area.

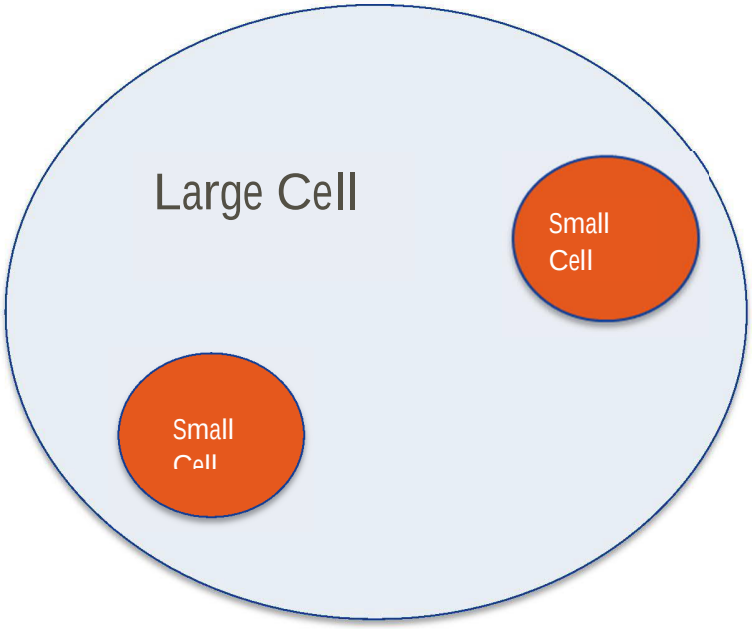

Figure 10: LTE Small Cell Architecture

For this architecture to be most effective, the small cells need to be able to use different radio frequencies than the large cell. If all three cells use the same frequencies, they need to be tightly coordinated to operate at all, and when operating, they fail to meet desired performance goals. Embedded small cells do not eliminate the need for additional spectrum, they're provide a way of using it. Spectrum needs of small cells are taken from alternate antenna sectors today, but this situation isn't ideal.

Personal Cells

Personal cells, or femtocells, are a widely used alternative to Wi-Fi™ for local service within a home or office. They're primary useful where both Wi-Fi™ performance and cell reception are poor. They don't directly address of the needs of mobile users but they do relieve mobile spectrum from a significant source of load. A channel that would be used both indoors and outdoors can be effectively converted to exclusive outdoor use if enough femtocells are deployed.

Coding Systems

Code Division Multiple Access (CDMA) is a system that uses a combination of spread-spectrum and coding to permit the use of a common set of frequencies by a group of users. CDMA is a very effective system in contrast with scheduled Time Division Multiple Access (TDMA) because it has faster response time. It's also effective by comparison with Frequency Division Multiple Access (FDMA) because it uses more of available spectrum. Most of the benefits of CDMA are already achieved in LTE networks.

Orthogonal Frequency Division Multiple Access (OFDMA) is an alternative to CDMA is uses properties of OFDM to combine data streams from multiple users on a common frequency. Its principal advantages are ease of implementation in systems that use MIMO, and potentially greater immunity to multipath interference. It's primarily used by Wi-Max.[20]

Smart Antennas

Space-Division Multiple Access (SDMA) is a system that effectively sends a radio beam to a receiver in such a focused way that other receivers don't see it. This is accomplished through a combination of multiple antennas that focus on a single partner and coding systems that provide additional per-unit separation such as CDMA or OFDMA.

To be fully effective, SDMA needs to be implemented by both the base station and the mobile device, but mobile implementation increases battery drain. The tradeoff between battery life and signal processing is a feature of all systems that increase bits/hertz efficiency by applying more signal processing, which leads wireless engineers to calculate mobile network efficiency in terms of bits/hertz/battery life. Marty Cooper is a strong advocate of smart antennas.

Twisted Vortex Beams

A promising new technology known as "twisted vortex beam transmission" that uses Orbital Angular Momentum (OAM) is described in an academic paper in *Nature Photonics*. Unfortunately, this system has been poorly explained to the lay public by the tech blogs.[21] Sebastian Anthony of *Extreme Tech* claimed that twisted vortex represents an infinite capacity wireless system:

> According to Thide, OAM should allow us to twist together an "infinite number" of conventional transmission protocols without using any more spectrum. In theory, we should be able to take 10 (or 100 or 1000 or…) WiFi or LTE signals and twist them into a single beam, increasing throughput by 10 (or 100 or 1000 or…) times. For fiber networks, where we still have a lot of spare capacity, this isn't all that exciting—but for wireless networks, where we've virtually run out of useful spectrum, twisted radio waves could provide an instant, future-proof solution. For the networking nerds, Willner's OAM link has a spectral efficiency of 95.7 bits per hertz; LTE maxes out at 16.32 bits/Hz; 802.11n is 2.4 bits/Hz. Digital TV (DVB-T) is just 0.55 bits/Hz.[22]

Samuel K. Moore of IEEE Spectrum provided a less optimistic description of the system:

> Beams with different orbital angular momentum can be transmitted together on the same beam and then distinguished from each other at a receiver as if they had been sent on separate channels.

> The communications technology could find a home in satellite communication links, in short free-space optical links on earth (such as between buildings in a city), or maybe in fiber optic cables (which the engineers say is their next step).
>
> Orbital angular momentum has been studied intensively at optical wavelengths, but recently physicists have been trying to apply it to radio frequencies. Scientists in Europe claimed the first twisted RF communications earlier this year. But others question whether twisted RF is really different from other multiple-input-multiple-output radio techniques.[23]

While the *Nature* article describes a visible light system that operates well beyond the reach of the 500 MHz – 4 GHz range desired for mobile broadband, similar research has been conducted in Italy with an RF system that shows OAM working in the 2.4 GHz Wi-Fi domain as well, a very exciting development.[24]

There is some disagreement about where we are with OAM systems at the moment and the hyping by the blogs doesn't help, but the idea holds enormous research promise. Its first uses will be very basic, point-to-point applications such as short distance backhaul, but a world of possibilities may lie beyond the first step.

Policy Means: Increasing Allocation Efficiency

Policymakers have a number of means to correct inefficient allocation of spectrum usage rights.

Minimizing Guard Bands

The spectrum chart has hard boundaries between allocations, but electro-magnetic energy spills outside its intended boundaries. Regulators require that spectrum users observe quiet zones or "guard bands" at the boundaries of their allocations to minimize this effect, and each guard band is an allocation waste. Guard bands must be wider when a high-energy user such as mobile broadband neighbors a low-energy user such as GPS. Relocating low-energy users to adjoining frequencies reduces this effect, but this is hard to accomplish in practice for both technical and political reasons.

Dynamic Sharing with Occasional Users

Dynamic Spectrum Access (DSA) addresses the allocation inefficiency that arises in the case of occasional users. For example, some military spectrum supports training exercises, so it's not used on a continual basis. In principle, this spectrum can be shared with other users to good effect when training exercises are not underway. Similarly, the White Spaces (dead space between TV channels) can be used by public networks in many areas on a more long-lasting basis, because the practice is to allocate TV stations in each market to non-contiguous channels.

While there's an excellent case for using the stable White Spaces for public networking, it remains to be seen whether the military's training spectrum has the same potential. One question that time-based sharing raises is what the secondary user does when it can't find spectrum to use. Perhaps secondary users will piece together coherent networks out of multiple secondary allocations. Another question concerns network Quality of Service (QoS). Cellular telephony depends on predictable access to spectrum to ensure voice quality, but systems of non-exclusive access to spectrum are generally unable to ensure

QoS. Hence, the viability of the primary cellular application is questionable over DSA systems.

Revoking Legacy Allocations

A third allocation inefficiency arises when a historically popular use of spectrum loses its appeal but retains its allocation. This is the situation with OTA TV, mobile satellite phones, and a number of educational and local government allocations. This kind of allocation inefficiency is best resolved by regulator action to revoke the allocation and allow a more appealing user to take control of the spectrum. This may be accomplished by administrative fiat, by an "incentive auction," or by voluntary license transfer (as in the case of the Clearwire network, largely run on educational spectrum transferred by the original licensee).

While correcting allocation inefficiencies is primarily the job of the regulator, technology can ease the transition from the old to the new user. Frequency-agile SDRs and authorization databases are tools that regulators can leverage in making slow transitions to new allocations.

The most immediate and long-lasting means of making effective use of spectrum that was once allocated to an application that no longer has broad appeal are market-based systems of straightforward license transfer. These solutions encompass the formal auction of spectrum usage rights as well as a direct sale from the old license holder to the new one. The FCC has a system of market-by-market spectrum screens, limits on market concentration that provide guidance on license transfers. This system is meant to preserve competition.

The Value of Unlicensed Spectrum

Unlicensed systems such as Wi-Fi™ and semi-unlicensed systems such as White Spaces networking are not as much about increasing the bits/hertz efficiency of spectrum use as they are about increasing the utilization of spectrum that would otherwise go to waste. This is a tremendous benefit to consumers, of course. Before Wi-Fi™, the 2.4 GHz spectrum was only used by microwave ovens, and it now hosts a variety of applications and hundreds of millions of users.

Wi-Fi™ is very effective at off-loading nomadic use from the cellular network, most dramatically for users of tablets and laptops. White Space networking has the potential to offload voice and text messaging for mobile users as well, but practical deployments of such systems are sparse. AIR.U, a consortium of universities too small to qualify for the Gig.U initiative, announced plans recently to operate pilot networks in 2012.[25] We look forward to evaluating the results of these pilots, but it's too soon to tell how much capacity they will add to the mobile ecosystem and how well they'll mesh with existing systems. The coordination of Gig.U and AIR.U suggest that nomadic users in the participating institutions hope to gain performance upgrades over their current experience on Wi-Fi™ and cable networks.

Wi-Fi™ Alliance members have begun to ship access points conforming to the 802.11ac standard that supports operation in the 5.8 GHz band at speeds up to 1 Gigabit/second.[26] This standard is primarily useful for nomadic applications over short distances on the order

of 50 feet. It's not a mobile system, but it can offload voice, text, and video streaming in stationary settings.[27]

PRINCIPLES OF SPECTRUM ALLOCATION

We propose a grading system for spectrum actions based on the current facts about spectrum usage systems and an educated set of predictions about the direction and promise of new technologies currently in development. It consists of ten factors, not currently prioritized or weighted.

1. Upgrade and Repack: The most desirable allocations are those that can be repurposed as needs change, and it's reasonable to treat most historical allocations as candidates for repurposing at some point. Spectrum policy must recognize that today's problem is one of redeployment and multiple use rather than new Greenfield assignment. As we saw in the LightSquared controversy, incumbents (especially those in the government sector) automatically resist rule changes for adjacent bands with the potential to interfere with legacy systems, but such rule changes are unavoidable. And as we saw in the digital TV channel reallocation, incumbents often resist societally rational reallocations. Redeployment often depends on upgrades to existing systems, and there should not be general resistance to making such changes, especially when upgrades to existing systems increase their capability while freeing up spectrum for other uses.

2. Strive for Sharing: The most desirable allocations are those that can be shared by large numbers of people. Commercial Mobile Networks (CMN) are one very good example of efficient spectrum sharing: The larger networks, operated by Verizon and AT&T in the United States, support approximately 100 million users with 100 MHz of spectrum, for a sharing factor of one hertz per user. Wi-Fi™ has similar efficiency, with some 300 million U.S. users on 300 MHz of spectrum. In contrast, broadcast television consumes 10 hertz per actual user.

3. Reward Application Flexibility: The most desirable allocations are those that can be shared by large numbers of applications. Both CMN and Wi-Fi™ networks host a variety of applications, allowing end users to make the ultimate choice of applications in real time. These networks support the whole range of applications permitted by the Internet Protocol and the roaming limitations of each technology. In contrast, most historical spectrum allocations have been made to single-purpose systems such as AM/FM radio, TV, satellite TV and radio, and taxi networks.

4. Optimize Dynamic Capacity Assignment: The most desirable allocations bring supply and demand into balance. Modern networks allow for capacity assignments to follow demand by flexible definition of units of internal allocation (commonly called "channels.") For example, Wi-Fi™ channels can be units of 20MHz, 40 MHz (802.11n) or substantially more (802.11ac), while LTE networks can work with channel bandwidths from 2.5 to 40 MHz or more.

5. Permit Technology Upgrade Flexibility: The most desirable allocations are those that can easily be improved. In the old spectrum regime, regulators often stipulated technology choices for spectrum users by fiat, epitomized by the European requirement for carriers to use GSM for 2G phone service. This practice prevents the deployment of more advanced systems such as CDMA and LTE. Rational Allocation permits

technology upgrade without permission, and indeed expects that all technologies will have limited lifespans as better technologies are developed that replace older ones.

6. Recognize Aggregation Efficiency: The most desirable allocations are those that minimize boundary waste. The fundamental distinction among spectrum sharing technologies distinguishes the sharing done within a particular spectrum-based network and from the sharing between networks. This can be conceptualized as the sharing of "cooked" spectrum in the first case and "raw" spectrum in the second case. Every network that supports multiple users and multiple applications is an exercise in sharing "cooked" spectrum, and the greater the pool of spectrum for a given network, the greater the potential for sharing. Hence, large allocations have an efficiency advantage over small ones, as they can support large user populations and diverse applications.

7. Create Facilities-Based Competition: The most desirable allocations are those that promote an efficient level of competition. While a small number of networks leads to more efficient sharing (and to investment efficiency), a larger number of networks produces competition advantageous to consumers, but only up to a point.[28] In the most extreme case, a single network is most efficient from the standpoint of sharing and investment, while an infinite number of networks would produce maximum competition at the expense of efficiency. This principle is therefore in conflict with the previous one and the two must be held in tension as we seek the ideal number of networks, a number that may be larger than two and smaller than six in many instances. In industries in which a key input is limited, as is the case in mobile networking, the number of sustainable competitors is also limited. We don't know a priori what the ideal number is, but good way to estimate it is to continually review the rate of technical improvement and costs of usage.

8. Reward High-Performance Receivers: The most desirable allocations are those that require high performance receivers. Spectrum sharing is optimized by high-performance receivers with the ability to tune into the signals intended for them and to reject or ignore all other signals. While spectrum regulation is always written in terms of transmission rights, every statement of transmission rights is inherently a statement about the ability of nearby receivers to function in the presence of such transmissions as the regulation permits. Contrary to the beliefs of some spectrum idealists that the rejection of unwanted signals is simply a matter of digital engineering, every spectrum system is fundamentally analog and must be carefully engineered to work in a specific power, propagation, and noise environment. It's proper for regulators to require greater performance of spectrum receivers year after year. Each generation of cellular technology has better noise immunity than the preceding one, for example. Taking down legacy receivers that exhibit insufficient ability to reject or filter adjoining signals has proved to be a difficult problem for regulators, as the Light Squared case illustrates.

9. Allocate in all Relevant Dimensions: The most desirable allocations are those that make use of all relevant dimensions of allocation. Traditional spectrum allocations don't fully reflect the variety of ways that spectrum can be used. The traditional methods allocate by frequency, power level, and place, but spectrum can also be distinguished by direction of transmission, beam spread, modulation, coding, and time. As more advanced technologies are developed, allocation principles should come

to recognize these dimensions. The TV White Spaces notion is a step in this direction, adding time to the factors that condition spectrum usage rights. The "electrospace" model uses all relevant dimensions.[29]

10. Promote New Technologies: The most desirable allocations are those that speed the path to new technologies. One of the most important roles the FCC's spectrum policy has played over the years is to create markets for new communication technologies such as satellite, cellular, Wi-Fi™ and ultra-wideband by allocating spectrum for their use ahead of actual network deployment. This function will continue, but in a more subtle way. Rules modification rather than exclusive allocation is the best means of enabling the next generation of spectrum technologies.

USING THE PRINCIPLES TO ADDRESS CURRENT SPECTRUM CONTROVERSIES

Current and recent controversies over spectrum include disputes over device interoperability in the 700 MHz band, legacy guardband requirements in the 800 MHz band, the dispute between LightSquared and GPS manufacturers, the debate over government applications in the 1.7GHz band, the assignment of application-specific spectrum for medical monitoring equipment, the use of the 700 MHz D block for a national public safety network, and the proposed transfer of 20 MHz of AWS-1 spectrum from SpectrumCo to Verizon.[30] The record in recent spectrum controversies is decidedly mixed between successful, forward-looking resolutions and backward-looking ones that reduce spectrum innovation.

The record in recent spectrum controversies is decidedly mixed between successful, forward-looking resolutions and backward-looking ones that reduce spectrum innovation.

700 MHz Device Interoperability

The FCC is considering new rules for mobile devices that operate in the 700 MHz band per a Notice of Proposed Rulemaking (NPRM) titled "Promoting Interoperability in the 700 MHz Commercial Spectrum." It's unusual for the agency to impose rules on devices built by such firms as Apple, Samsung, Nokia and others, so there is sharp disagreement about whether it actually has the authority to do such a thing. However, it's worthwhile to examine the proposed rules on the assumption that the FCC can find the authority.

The background is somewhat complex. The FCC's last big spectrum auction took place in 2008 when the "digital dividend" freed up some airwaves that had formerly been used by analog television. Digital TV channels can be placed closer together than analog channels were, so a more efficient packing scheme made this spectrum available for sale. The spectrum was arranged in five blocks, called A-E, in two ranges, low and high. Most of the blocks consisted of pairs, separated to allow transmission on one half of the pair while the other half was doing reception, but the E block was unpaired. The D block was not successfully auctioned as the FCC wished to sell a single nationwide license for it and the reserve price wasn't met, but it has since been given to public safety.

The following map shows how the pairing works:

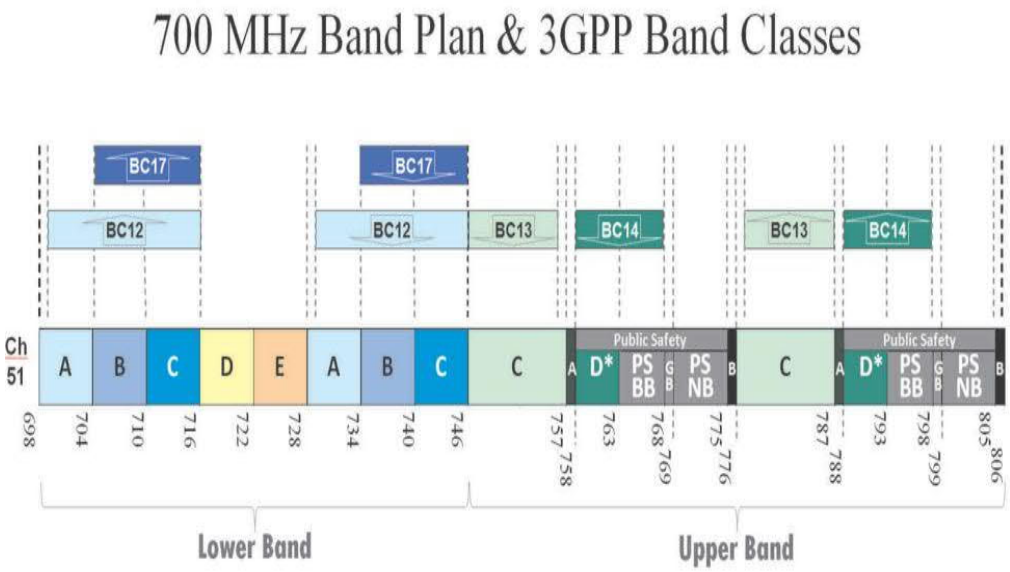

Figure 11: 700 MHz Band Classes (Credit: FCC)

AT&T paid a significant premium to be free of the net neutrality rules and the interference caused by the high power TV transmitters on Channel 51 in the urban markets, and the regional carriers who could live with channel 51 got a discount.

Note that the A block consists of 6 MHz next to Channel 51 at 698 – 704 MHz and another 6 MHz from 728 – 734 MHz, that the E block is a single slice without a pair, and that there is C block spectrum in both the lower band and the upper band, with the upper band (downlink) slices twice as wide as the lower band (uplink) slices.

The A-C blocks sold for wildly different prices because the A and C blocks had significant restrictions that the B block didn't: the A block was directly adjacent to active TV transmitters on Channel 51 is most urban markets, and the FCC imposed artificial net neutrality restrictions on the C block in accord with the fashion of the time. The average prices by MHz per million population ("megahertz pop" in regulatory parlance) were:

Block	A	B	C
Bandwidth	12 MHz	12 MHz	22 MHz
Type	paired	paired	paired
Partition	176	734	12
Price ($/MHz-pop)	$1.16	$2.68	$0.76

Figure 12: Auction Returns[31]

The biggest winner of B block spectrum was AT&T, the biggest winner of C block spectrum was Verizon, and the A block was mainly won by regional networks such as MetroPCS, US Cellular, and Cellular South. AT&T paid a significant premium to be free of the net neutrality rules and the interference caused by the high power TV transmitters on Channel 51 in the urban markets, and the regional carriers who could live with Channel 51 got a discount; Verizon arguably did best of all by accepting the net neutrality rules. The assumption of flexibility played a big role in determining the auction price.

Here's a map of the Channel 51 transmission contour:

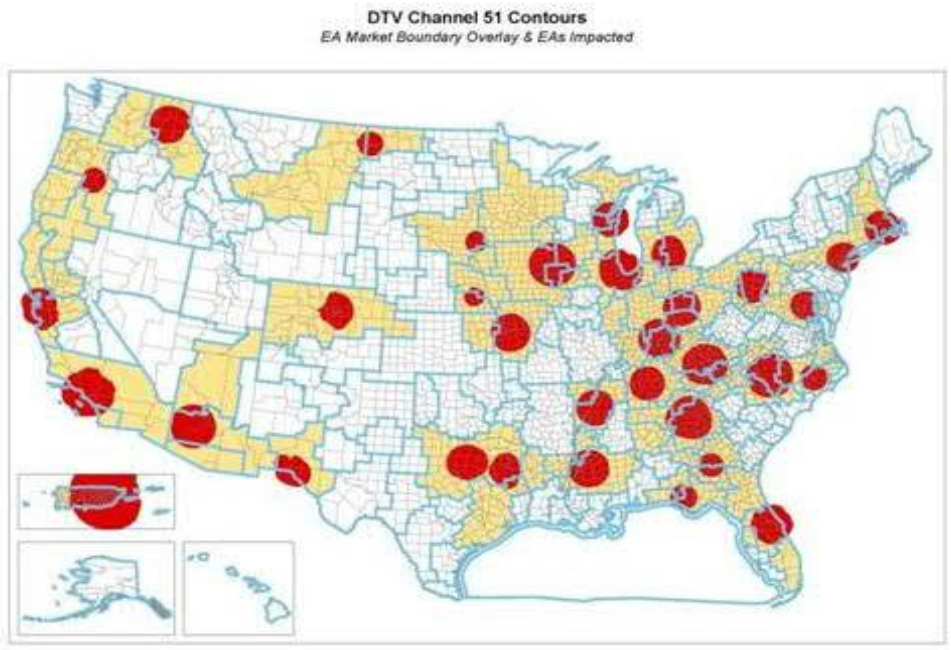

Figure 13: Channel 51 Contours (in red) Against A Block Service Areas (in yellow)(Credit: FCC)

Spectrum is harmonized around the world according to "Band Classes" devised by 3GPP, the standards body that defines such things as LTE, the new 4G standard that's hitting the U.S. market now in a big way and starting to appear in the rest of the world in a much smaller way. There are three band classes of interest for 700 MHz, identified in the first diagram as BC 12, BC 17, and BC 13. Note that Band Class 17 is a subset of Band Class 12 that excludes the discount A Block, and BC 13 is distinct and non-overlapping with classes 12 and 17.

At this stage, AT&T plans to resell devices conforming to Band Class 17 and Verizon to resell devices conforming to Band Class 13 (in the upper C Block). These devices will be able to use their native, licensed networks only, which means they won't be capable of roaming onto other networks (except insofar as these devices may support other frequencies as well). Hence the notion of "interoperability:" 700 MHz devices will not roam or "interoperate" with other band classes and networks but the ones they're built for.

This worries the small carriers who bought A Block spectrum at a discount because they would like to use the same devices that AT&T and Verizon resell rather than more specialized devices tuned to their A Block frequency and also capable of roaming onto the B and C blocks. Cellular South (now known as "C Spire") is the only regional network to offer the iPhone to its customers so the entire group of A Block winners is somewhat disadvantaged in terms of the very best devices, but there are a few Android devices adapted to their networks: MetroPCS offers LTE today with such devices. Chips are available to support Band Class 12 so there is not an insurmountable technical hurdle to building Band Class 12 devices. Making them work well is a different matter, however.

Leaving aside the question of the propriety of the FCC essentially requiring AT&T and Verizon to subsidize handsets for the A Block carriers and focusing in the technical details raises some interesting issues.

We learned from the LightSquared issue that it's never good to be dependent on a low-power signal when you have a neighbor who uses a high powered one. Even though the signals are distinguishable from each other in terms of their patterns of digital bits, the radio energy of a high power transmitter confuses receivers designed for low power signals. Every radio receiver has to operate over a wide range of power levels because signal strength typically erodes with distance as radio waves spread, Radio receivers generally amplify received signals to "normal" signal strength internally using an "automatic gain control" circuit that measures received signal strength and boosts the signal by a variable amount to the reference level. When a radio receives two signals at once, one strong and one weak, it boosts both by the same degree but not to the same level. When there is a significant disparity, only the stronger signal can be decoded, so sophisticated digital signal processing techniques are not effective.

As radio waves decay with distance, they give off interference energy above the frequency of the original signal, and this can be significant when the power difference is great between the lower and higher powered transmissions. When multiple transmissions interact, receivers can experience "Inter-modulation" (IM) distortion, defined by Wikipedia as:

> …the amplitude modulation of signals containing two or more different frequencies in a system with nonlinearities. The intermodulation between each frequency component will form additional signals at frequencies that are not just at harmonic frequencies (integer multiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies.[32]

For clarity, the follow page contains a diagram of IM distortion. The diagram shows IM distortion as the two smaller spikes the left and right of the two big spikes that represent the signals. The IM spikes in this example are significantly stronger than the background signals represented by the more solid lines.

There are a few ways to work around IM distortion. The easiest is to raise signal power, which is accomplished in cellular systems by siting towers in a ring around the IM distortion source and by increasing the battery draw in mobile devices. There are limits to this approach because towers are expensive and cellular systems are very low power compared to those TV transmitters on Channel 51.

Engineers hired by the regional carriers seeking to encumber 700 MHz handsets with A Block support claim that three towers close to each TV tower will do the job, but AT&T's engineers put the number closer to 12. Another way is to add filters to the devices, which raise the cost and increase the battery drain, and yet another is to use more sophisticated signal processing, which once again reduces battery life. All of these methods require extensive field testing, so there is a significant overhead in terms of the time to market for new devices.

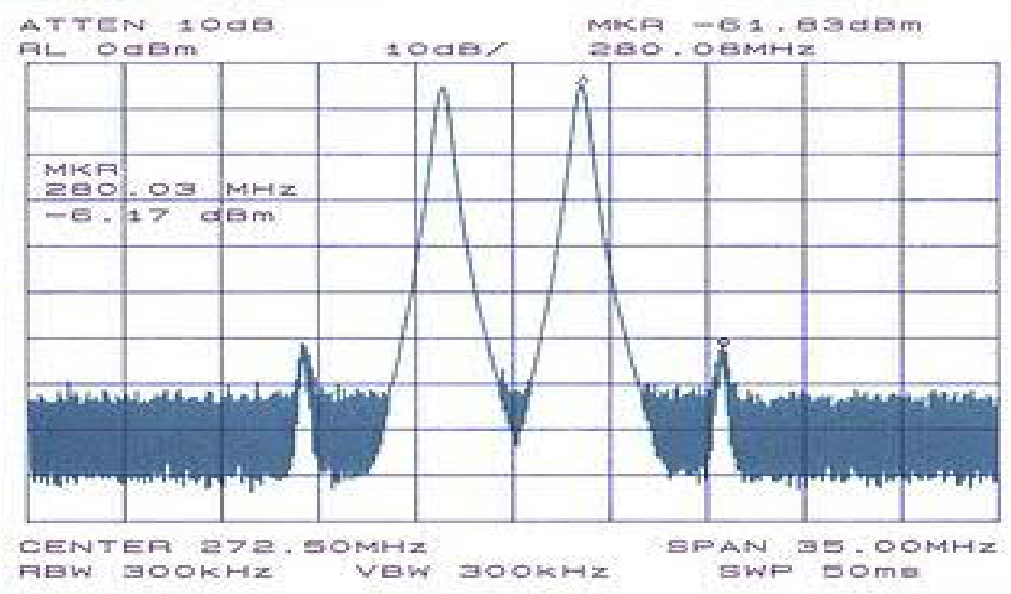

Figure 14: Inter-modulation Distortion (Credit: Wikipedia)

As it stands, the A Block licensees have the power to buy as much interoperability as they want from the companies that build their smartphones.

This analysis brings us to this question: Is it reasonable for the FCC to add expense to the smartphones that AT&T and Verizon sell (meaning that millions of consumers would pay more), to reduce their battery life, and to delay the introduction of new devices built by Apple, the Android device producers, and the Nokia/Microsoft partnership in order to enable roaming between regional networks and national ones? "Reasonable" is in the eye of the beholder, of course.

From the point of view of the regional network providers, the proposed interoperability rule costs nothing and impairs the users of the national networks, so it's good. For the national network providers, the rule increases costs and prices, irritating customers, so it's bad. For device manufacturers, it impairs their ability to get new devices to market so it's bad. The "interoperability" mandate will also stress the analog engineering skills of the device makers in an area where they don't need any more problems. Analog engineers are in short supply, which is evident every time a smartphone shows poor antenna performance.

The cheapest and easiest way around this problem would be for the FCC to adopt the same solution they went for in the LightSquared case: They can take Channel 51 off the air. With the interference source gone, Apple can simply build all of their 700 MHz devices to function on the A, B, and upper C blocks without special testing and engineering for the A Block. If the FCC doesn't want to do this, we'll have to evaluate whether their reasons for keeping Channel 51 alive are more compelling than the reasons the device manufacturers have for not wanting to filter the interference it spills into the A Block. The alternatives for current programming on Channel 51 are relocation to another frequency or limiting distribution to cable, satellite, and Internet streaming.

As it stands, the A Block licensees have the power to buy as much interoperability as they want from the companies that build their smartphones. They're going to pay higher prices for these Swiss Army knife phones than the more narrowly tailored phones used by the national carriers, but they got a deal on their spectrum, after all.

The FCC is looking for precise estimates of the costs of an interoperability mandate, but they're only part of the story given the agency's assumptions. The chief underlying assumption seems to be that the consumer buys a smartphone and keeps it for a decade or more, roaming at will and changing carriers every time a great deal is available. This is clearly not the way the smartphone market works today, or we wouldn't see people camping out at the Apple store to get the newest iPhone.

This proceeding has the feel of "Wireless Carterfone," an attempt to re-live the glory days of 1969 when the courts and the FCC correctly required an interoperability interface to the telephone network. While that decision led to cheaper and more plentiful fax machines, modems, and answering machines, it's not really parallel to the situation we have in the rapidly-changing world of cellular technology. We have to think about how this mandate will affect the roll-out of 5G and 6G services as well as faster and better smartphones even if we can convince ourselves that it makes sense to have the national carriers subsidize the regionals, because it is likely to delay the transition to more advanced systems.

While the issue hasn't been resolved, the part that we're concerned about will either leave Channel 51 on the air or take it off the air. Any interoperability mandate will be mainly conditioned by this decision.

Leaving Channel 51 on the air has the following effects:

1. Upgrade and Repack: Retarded
2. Sharing: Retarded
3. Application Flexibility: Retarded
4. Dynamic Capacity Assignment: Retarded
5. Technology Upgrade Flexibility: Retarded
6. Aggregation Efficiency: Retarded
7. Facilities-Based Competition: Retarded
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Retarded
10. Promotion of New Technologies: Retarded

Total Score: -8

Consequently, leaving Channel 51 on the air scores -8, assuming we weight all factors equally and score +1 for each aspect that advances spectrum utility, 0 for neutral factors, and -1 for each aspect that retards it.

The most compelling alternative is to re-purpose Channel 51 for mobile broadband by joining it with the lower A block. The scores for this outcome are radically different:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced

4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Advanced
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Retarded
10. Promotion of New Technologies: Advanced

Total Score: +8

Repurposing Channel 51 from legacy over the air (OTA) DTV to mobile broadband scores +8. Given this scoring, there's no need to consider the question of whether an interoperability mandate should be applied to phones supplied by the large carriers on the B and C blocks or the small carriers on the A block, as taking Channel 51 off the air renders that discussion moot.

Advocates of OTA TV insist that taking a TV channel off the air is bad for the public interest, but that argument isn't persuasive. The public's overriding interest in questions of technology innovation is best served by moving networking technology in the direction that our ten factor test indicates: It provides for a better consumer experience, more consumer choice, and greater competition among providers. Leaving spectrum assigned free OTA TV, especially minor channels like 51, does none of these things, and in fact simply serves as a fourth outlet for the same programming, after cable TV, Digital Broadcast Satellite TV, and Internet TV.

800 MHz Guardbands

The FCC recently granted a petition from Sprint for an update of the rules on the use of the 800 MHz Specialized Mobile Radio (SMR) band:[33]

> Sprint has frequencies in the 800MHz SMR (Specialized Mobile Radio) band that so far have been dedicated to the iDEN network, which delivers the narrowband 2G service that Sprint acquired by buying Nextel in 2005. When the FCC carried out a rebanding project several years ago to eliminate interference between iDEN and public safety radios, it decided that services on those frequencies couldn't use channels wider than 25KHz. That channel width can't support anything more than a narrowband service such as iDEN, which delivers average throughput of 20Kbps (bits per second) to 30Kbps.[34]

The SMR network was a push-to-talk "walkie-talkie" network that permitted narrow-band voice communication between subscribers. FCC regulations for the use of the spectrum drawn in 2005 divided the spectrum into 25 KHz (not MHz) channels and further required that each channel have a "guardband" of low energy at the edges. These restrictions were drawn out of respect for expected receiver performance characteristics, and made it impossible for the current owner of the spectrum, Sprint, to implement cellular service. The FCC relaxed but did not eliminate the guardband requirement. Some

restrictions remain in place to protect legacy public safety equipment operating in the SMR band until a nationwide public safety network is operational.

This proceeding covered a set of issues very similar to those raised in the LightSquared proceeding concerning the ability of installed equipment to reject the signals generated by the new application. The FCC's resolution took the older equipment off the air, for the most part. In such cases, this is the correct resolution.

Converting the spectrum used by the old SMR network into general-purpose 4G mobile use earns the highest score, +10:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Advanced
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Advanced
10. Promotion of New Technologies: Advanced

The best source for additional commercial spectrum is government applications.

Total Score: +10

The alternative (leaving the *status quo* intact) would earn the opposite score on each criterion. Hence, the FCC's action was correct.

Government Spectrum Use: 1.7 GHz Band

The best source for additional commercial spectrum is government applications. Most analysts say that the U.S. government has assigned 300 MHz more prime spectrum to itself than our European neighbors; this spectrum is managed by NTIA.[35] While the U.S. leads the world in the deployment of fourth generation LTE networks, we lag the world in the allocation of spectrum to LTE networks, and this overly generous allocation to the federal government is one reason why.

The recent NTIA report, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band*, is good news and bad news for the reassignment of government spectrum.[36] The good news is that some government agencies are taking the exercise seriously and doing their best to increase the amount of spectrum available for general-purpose commercial networks. The NTIA says the entire band can be made available within ten years, and significant portions of it much earlier.

They caution that some sharing is going to be necessary for quite some time in a few areas, but they're hoping that the sharing is something both the commercial sector and the government can live with. The bad news is that DOD and the FBI still insist they have applications of such importance that they can't live without the allocations of spectrum

they currently have. It's likely that the negotiations between the civilian agencies and the NTIA involved spectrum experts while those that took place with the DOD and DOJ involved non-technical administrators. That's at least what the report seems to indicate.

The 1755 – 1850 spectrum band is important because it's been assigned internationally for mobile broadband, so there are tremendous benefits to U.S. firms and consumers if we can use it for that purpose. The estimated relocation costs provided by DOJ and DOD are unreasonably high considering that all the equipment they've currently got should be replaced within five to ten years as a matter of course anyway (and doing so would increase their respective agency performance), and this exercise has already been ongoing for ten years. NTIA notes that the international assignment of paired spectrum differs from the U.S. carriers' proposed use with respect to uplink and downlink, and that this isn't an important difference as the ability to use paired spectrum depends on direction-independent antennas and digital signal processors.

A detailed examination of the assignments follows.

Fixed Point-to-Point Microwave

The first application, fixed point-to-point microwave, should raise a red flag immediately because nearly all its 360 allocations can be probably be replaced by a wireline or commercial alternative. Point-to-point microwave is a virtual wire whose history pre-dates fiber optics and it's a laggard in terms of performance and quality.

The report excuses these allocations as being cheaper or higher quality than commercial or wireline alternatives, but that analysis only works if you value the spectrum at zero. Replacing 95 percent of these allocations with fiber backhaul could end up being a net positive for the government because they could over-provision and lease dark fiber to the commercial sector. The only rational application for fixed point-to-point microwave in most cases is connecting mountain tops in rural areas where there's no plausible case for fiber, but this is probably not the government's typical use case.

Converting fixed point microwave to fiber backhaul and auctioning the spectrum for commercial use earns the maximum score, +10:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Advanced
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Advanced
10. Promotion of New Technologies: Advanced

Total Score: +10

Commercial use of this spectrum could involve point-to-point microwave, point-to-multipoint, or mobile, according to the preference of the commercial license holder, and the spectrum could also be deployed to the public on an unlicensed basis.

Military Tactical Radio Relay

Per the NTIA report, "Tactical Radio Relay is a…generic class of transportable fixed microwave systems that support Army, Navy, and Marine Corps training at a number of sites and on tactical operational missions." These systems have a somewhat stronger use case that fixed microwave. The purpose of these allocations should be to connect a training network to a fiber terminal, and it would be very surprising if DOD needs the 579 separate allocations it has for this application to support active training missions. Even if they had hundreds of training missions going on at the same time, they're not in the same place so there's no practical reason for so many exclusive allocations. This is another category of microwave, and there are commercial systems and higher frequencies available to support it that aren't appealing to mobile networks. In fact many of these systems are indistinguishable from commercial mobile broadband systems in function and purpose.

Most of these 579 allocations duplicate commercial systems. Hence the same grading would apply as to the previous application, +10:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Advanced
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Advanced
10. Promotion of New Technologies: Advanced

Total Score: +10

Air to Ground Systems

This category includes the military's Air Combat Training System, Precision Guided Munitions, Tracking, Telemetry, and Commanding Systems, Unmanned Aerial Systems, and Aeronautical Mobile Telemetry. These systems are used for training, testing, and operation of fighter/bombers and similar systems. They used dedicated, exclusive spectrum assignments within the U.S. and whatever is available in real combat conditions. It seems that the major problem with these allocations is systems that require specific frequencies on which to operate. Combat systems have to be capable of operating overseas, in countries that have not made specific allocations of spectrum to invading armed forces, so there must be a difference between combat training systems and actual combat systems. A flexible use

system that allowed for sharing could free up several hundred allocations and improve the flexibility and utility of real combat systems.

While the details of these systems aren't known in detail, it's safe to assume that they aren't radically different in principle from more generic systems of air-to-ground communication that could be used by the general public through commercial carriers. Transitioning these applications from their present form to a more generic form that shares spectrum and technology with civilian users would earn a high score, and leaving them in the present form would earn a low score.

Video Surveillance

Of all the applications in the NTIA report, this is the most puzzling. The report declares: "DHS, DOJ, and the Treasury state they need to retain up to 30 MHz of contiguous spectrum for surveillance in the 1780-1850 MHz band pending the successful development of new technology and the availability of spectrum in the comparable bands." This is a commendable reduction from the 130 MHz that the government currently uses for video surveillance of American citizens in cases involving suspected terrorists, tax evaders, and other criminals, but video bits are not so special that they need their own network.

Commercial networks can easily accommodate the needs of law enforcement for transporting video bits. We know this because they just as they transport video bits for consumers every day. There is little justification for putting 30 MHz of contiguous spectrum on hold just after allocating the 700 MHz D Block to the nationwide public safety network that's about to be built. The NTIA needs to say "no" to this application, resoundingly. Sharing video transport with commercial systems would earn a score of +6:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Neutral
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Neutral
7. Facilities-Based Competition: Advanced
8. High-Performance Receivers: Neutral
9. Use of all Relevant Dimensions: Neutral
10. Promotion of New Technologies: Advanced

Total Score: +6

Initial PCAST Recommendations

While the ice is beginning to melt around some federal spectrum allocations in the 1755 – 1850 MHz band, the most significant development is not covered by the NTIA's report. This is the public/private initiative to promote effective sharing of spectrum between government, commercial interests, and unlicensed users. The President's Council of Advisors on Science and Technology (PCAST) released an update to its spectrum

investigation on May 25, 2012, outlining this plan.[37] The update was followed with a more a detailed and radical report on July 20, 2012.[38]

The PCAST update recommends a system be developed that would allow for the sharing of spectrum currently held by the government through a database system according to three priorities:

1. The primary user—the government—has first right of access.
2. If there is no government demand, the spectrum can be employed by a licensed user.
3. If there is neither a government nor a licensed user, the spectrum can be employed by an unlicensed user.

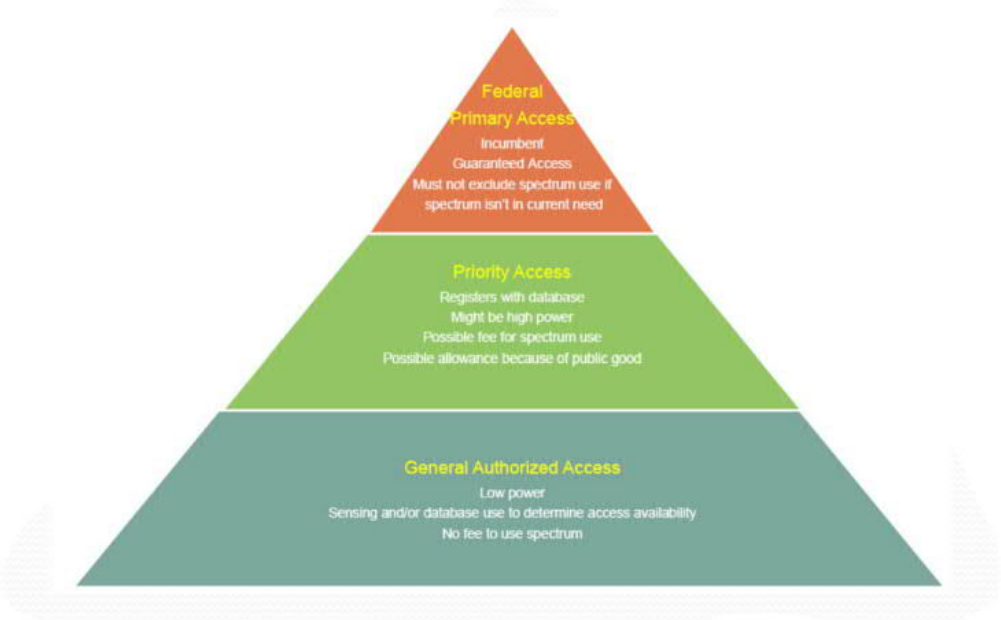

Figure 15: PCAST Sharing Hierarchy (Credit: PCAST)

The PCAST system described in the update would earn high scores in most criteria, but not top scores. As PCAST recognizes, the system allows government agencies to continue operating current systems that don't permit sharing by simply asserting "Federal Primary Access" privilege to a particular band of spectrum for use by a legacy system at all times. In this scenario, the spectrum would be shared in name only, and this is not a desirable scenario. Federal agencies would still need to be motivated to participate in this system in a positive manner by increasing their use efficiency and reducing their spectrum occupancy time.

PCAST proposes the development of a "Spectrum Currency" system and the creation of a "Spectrum Efficiency Fund" to motivate efficient sharing in recognition of their system's shortcomings. PCAST also recommends the creation of a White House-based Spectrum Management Team (SMT) consisting of the U.S. Chief Technology Officer, the National Security Staff, Office of Management and Budget, National Economic Council and NTIA to oversee management of federal spectrum. The composition of this committee suggests

that we may shortly find ourselves with a *Spectrum Czar* who oversees government spectrum use, which would not be a bad thing.

In order for an oversight committee of this sort to be effective, it needs to have the power to suspend and revoke federal usage rights to particular patches of spectrum. Without this power, the committee is simply a paper tiger.

While spectrum sharing is frequently confused with efficiency in the press and in much policy discourse, this is a mistake. Sharing can be efficient or inefficient, depending in the characteristics of the signals that sharers transmit and receive. While PCAST makes a step forward by taking a stand in favor of spectrum sharing by federal and non-federal users, this step doesn't go very far. We grade the PCAST update +5:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Neutral
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Neutral
7. Facilities-Based Competition: Neutral
8. High-Performance Receivers: Neutral
9. Use of all Relevant Dimensions: Advanced
10. Promotion of New Technologies: Neutral

Spectrum sharing is frequently confused with efficiency in the press and in much policy discourse, but this is a mistake. Sharing can be efficient or inefficient.

Total Score: +5

PCAST Spectrum Superhighway

The final PCAST report proposes the creation of a 1000 MHz National Spectrum Superhighway based on Dynamic Spectrum Access (DSA), a poor solution to the immediate spectrum needs of American citizens.[39] The urgent issue for spectrum policy makers is how to manage the ever-growing Federal appetite for spectrum without slowing economic growth and impairing the wireless services that consumers have embraced. While the PCAST update offers suggestions for better managing Federal spectrum, the final report doesn't adequately answer the critical question because it fails to distinguish practical systems from speculative and unproven ones.

The system that it proposes would unduly burden American consumers and network providers by making their entire joint investment in wireless handsets and infrastructure obsolete. At the same time, it would protect all Federal users (primarily the military,) from any disruption to present operations, regardless of how inefficient current systems may be. This is not the proper balance.

The most astonishing claim made by the report is that "the traditional practice of clearing government-held spectrum of Federal users and auctioning it for commercial use is not sustainable." On the basis of this assertion, the PCAST report embarks on a thought experiment toward a new method of allocating spectrum which it terms "a new spectrum

architecture and a corresponding shift in the architecture of future radio systems that use it [that] can multiply the effective capacity of spectrum by a factor of 1,000."

Claims of this magnitude should be supported by reams of empirical and analytical data, but the 162 page report offers no data at all to support its presumption that the auction system (which has been employed by the FCC only since 1994) is not "sustainable" or even to define the parameters of "sustainability."

The auction system doesn't need to meet the needs of spectrum users indefinitely, it only needs to provide a rational way to re-allocate spectrum from low-demand and low-value uses to those that the public values more highly until we have practical means of simultaneously sharing spectrum at the same times, places, and frequencies without undue interference. Our forthcoming report, "Powering the Mobile Revolution: Principles of Spectrum Allocation" describes these technologies and the timeline for their deployment.

The only system that has ever been effective at increasing the supply of usable spectrum is one that upgrades legacy systems, such as the old analog TV broadcast system, to up-to-date digital systems with greater bits/hertz information efficiency. The best of these modern digital systems conform to international standards such as LTE and Wi-Fi that foster the creation of supporting industries in silicon chips, handsets, base stations, antennas, and software.

The PCAST report rejects this approach in favor of new technologies that would favor interference tolerance over efficiency: "Reductions in the transmitted bits/Hertz reduce the interference footprint as a ratio of the communications range. Transmit waveforms should transition from maximizing the bits/Hertz in scarce spectrum to instead optimizing for spectrum reuse." Spectrum experts will naturally take issue with this finding, which is also not supported by evidence.

PCAST places enormous faith in the ability of geo-location databases to improve the usability of spectrum, consistent with the proposed White Spaces system that will rely on such databases when deployed. The White Spaces system enables fallow spectrum to be harvested and put to productive use, just as Wi-Fi enables consumers to operate their own wireless networks at home and in the enterprise. But these systems are a complement to commercial wireless networks rather than a replacement. In areas where there is no fallow spectrum in the frequency and power ranges that can be used by consumer devices conforming to international standards, no database or opportunistic access system can supply it.

It's important for legislators and regulators to ensure that consumers have an adequate supply of spectrum for short-distance Wi-Fi networks which are also under stress in many areas. The White Spaces system is likewise a worthwhile system that must be allocated sufficient spectrum to either succeed or fail in real operational settings. But neither the proven value of Wi-Fi nor the potential value of geo-location systems warrants PCAST's rash desire to put all of the nation's spectrum assets in one basket. Advances in technology are often messy and disruptive, so it's much more sensible to continue pursuing a multi-faceted strategy that allows technologies to compete on the basis of the value they offer consumers than to tilt the scales in favor of one and only one system.

Geo-location databases are a very important tool for managing unlicensed spectrum; they offer a means of forcing obsolete devices such as the early Wi-Fi adapters off the air in favor of better and more recent systems. They permit the rapid deployment of networks in emergencies and in unserved and underserved areas. Very importantly, these databases can be used to implement sharing policies that and can handle overload from licensed networks of various kinds.

It's a mistake to assume, however, that these devices mandate any particular policies about spectrum allocation. Geo-location databases are tools for implementing policy, not a form of policy in their own right.

In particular, the Spectrum Superhighway concept proposed by PCAST lacks capabilities to provide mobile voice users with the Quality of Service support that current cellular networks provide. It is thus a step in the wrong direction from the system described the Update. We grade the PCAST Spectrum Superhighway +2, three points less than the Update:

1. Upgrade and Repack: Retarded
2. Sharing: Advanced
3. Application Flexibility: Retarded
4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Neutral
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Retarded
8. High-Performance Receivers: Advanced
9. Use of all Relevant Dimensions: Neutral
10. Promotion of New Technologies: Advanced

Total Score: +3

LightSquared and GPS

On February 14, 2012 NTIA sent a letter to the FCC declaring that "there is no practical way to mitigate the potential interference" between the proposed LightSquared network and GPS.[40] The NTIA letter followed a round of testing in which 25 percent of tested devices were not affected by transmissions from the LightSquared network. These devices had in fact found a way to mitigate actual interference, but the other 75 percent had not.[41] The GPS industry had been on notice since 2003 that changes in the rules for spectrum adjacent to GPS frequencies were in the offing, and had agreed to the proposed rules as late as 2009.[42] While the industry had agreed to a new neighbor in formal filings with the FCC, product engineering practices continued unchanged in most firms, however.

There are two main problems with the design of GPS receivers that affect their ability to operate in spectrum adjacent to a terrestrial mobile broadband network such as the one proposed by LightSquared. The first of these is a design decision made by manufacturers of High-Precision GPS (HPGPS) systems such as the John Deere "StarFire" system to look

for three digital signals carried on different frequencies through a common analog filter. John Deere's presentation to the FCC illustrates the problem.[43]

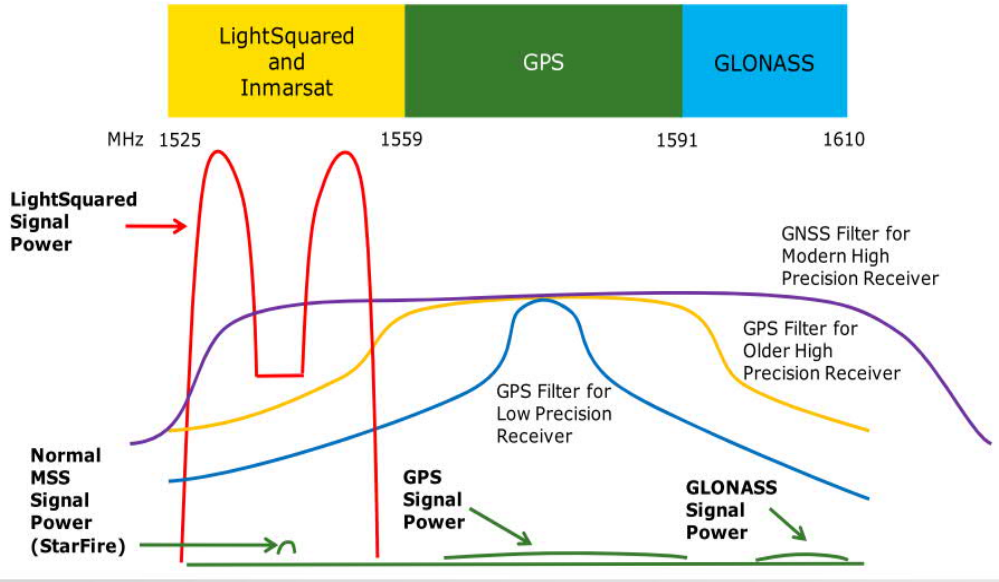

Figure 16: Location of StarFire Augmentation Signal (Credit: John Deere)

As we explained in our filing with the FCC on this matter, the problem that arises in a system such as this one is that the StarFire receiver hears both the GPS signal and the StarFire signal indiscriminately, as illustrated by the curve labeled "GNSS Filter for Modern High Precision Receiver."[44]

Such a front end will amplify the entire range from StarFire to GPS, including the upper LS band (as well as part of the lower LS band, according to Deere's diagram) unless it's equipped with pre-correlator filters that cancel signals in the intermediate bands.

The result of this amplification is to effectively deafen the receiver to both GPS and StarFire, due to receiver saturation that comes about from the amplification of the higher-energy LS signal, a signal that can and should be filtered. This sort of saturation can be overcome by separating the analog front end for the StarFire receiver from the front end of the GPS receiver. It can also be overcome with a notch filter across the upper LS frequency, but HPGPS providers have not needed to employ such filters before now as a practical matter.

In other words, the common analog front end amplifies the LS allocation when it should be filtered, a very bad design indeed and one that blatantly violates design guidelines issued by the DOD's 2008 "Global Positioning System Standard Positioning Service Performance Standard."[45]

A second problem arises with consumer GPS receivers with respect to LightSquared. The GPS signal is very faint at the reception end. Each GPS satellite is located in geo-synchronous orbit 22,000 miles above the surface of the Earth, and each signal is dispersed across a wide geographic area. Because the signal is so weak, many manufacturers of stand-alone GPS receivers (those that are not part of smartphones) have chosen to bend the rules

for receiver design by listening to a wider channel than the authorized frequencies for the GPS signal. As the signal spreads out and degrades in its path through the atmosphere, it flattens and disperses into neighboring frequencies, so a wider reception window captures more signal than one that strictly follows the rules, in the same way that a large window lets more sunlight into a house than a small one does.

But just as large, open windows may permit us to see and hear things that we'd rather not see and hear, so too does the relaxed reception window in the stand-alone GPS receiver permit the device to capture unwanted signals from neighboring services. When the nature of the neighboring service changes, as would have been in the case with changing LS from a satellite-based service to a terrestrial one, a receiver that employs this engineering trick ceases to function. The 75% of GPS receivers who failed the test are designed as just described. The 25% that passed testing are probably smartphones that were designed to capture cellular signals and GPS at the same time, with the appropriate circuitry to disambiguate the two signals. There is consequently no way to re-purpose the LS spectrum without replacing millions of GPS receivers in the United States alone, but LS argues that GPS manufacturers were put on notice in 2003 that just such a wide-scale replacement would one day become necessary, as mentioned.

Many manufacturers of stand-alone GPS receivers have chosen to bend the rules for receiver design by listening to a wider channel than the authorized frequencies for the GPS signal.

Disputes such as this one can only be resolved by setting long term goals and sticking to them, a hard feat to accomplish in a policy milieu where every regulatory action is colored by politics and devoid of a technical framework. The FCC and the GPS industry would do well to devise a second generation GPS system with greater efficiency and noise immunity, and to develop a plan for the phase out of the current system. Fortunately, such planning is underway, although it maintains a "backward compatibility" requirement that's essentially counter-productive as it prevents or retards necessary upgrades to existing, obsolete equipment.[46] The spectrum dividend we reaped from the conversion from analog to digital TV would not have occurred if the new DTV system had maintained backward compatibility with analog TV, after all.

A correct resolution of the LS/GPS controversy would have shared the responsibilities for sharing a general spectrum neighborhood between the two parties and improved them both. The resolution that was reached simply pushed LS into bankruptcy and left the *status quo* intact. Consequently, it earns a low -1 score even though it preserved the functioning of consumer GPS equipment and a poorly-designed HPGPS system:

1. Upgrade and Repack: Advanced
2. Sharing: Neutral
3. Application Flexibility: Retarded
4. Dynamic Capacity Assignment: Neutral
5. Technology Upgrade Flexibility: Retarded
6. Aggregation Efficiency: Neutral
7. Facilities-Based Competition: Neutral
8. High-Performance Receivers: Neutral
9. Use of all Relevant Dimensions: Neutral

10. Promotion of New Technologies: Neutral

Total Score: -1.

Medical Body Area Networks

On May 24, 2012 the FCC issued an order dedicating 40 MHz to Medical Body Area Networks (MBAN) in the 2360-2400 MHz band.[47] As in in the case of TV White Spaces, the FCC seeks to create a database of registered users and uses for purposes of controlling interference with the licensed incumbent service, which in this case is Aeronautical Mobile Telemetry (AMT).

The MBAN proceeding follows a request from GE Healthcare (GEHC) to modify existing Part 95 rules for "MedRadio" that use spectrum in the 401 – 406 MHz, 413 – 419 MHz, 426 – 432 MHz, 438 – 444 MHz, and 451 – 457 MHz bands, all on a secondary basis. GEHC does not desire much more spectrum than the previous rules allowed; it wants wider channels (as did Sprint in the 800 MHz matter) in a frequency range adjacent to Wi-Fi™ in order to use slightly modified Wi-Fi™ parts to build its sensors and hubs, but the order limits channel width to 5 MHz.

It's also reasonable to ask why the FCC carved out a secondary use in the sweet spot for mobile broadband (500 MHz to 3 GHz) instead of assigning less desired spectrum above 3 GHz.

The FCC's order follows a cross-industry agreement between healthcare firms (GEHC and Philips Healthcare) and the Aerospace and Flight Test Radio Coordinating Council, but no broader group of stakeholders. It's a marvel of micromanagement that specifies the operation of MBAN networks at a non-productive level of detail. Medical sensors using MBAN spectrum are forbidden from communicating directly with each other, for example; they can only pass information to and from sensor hubs. Sensor hubs are similarly forbidden from communicating with each other; they may communicate with medical sensors wirelessly and with hospital local area networks (LANs) by non-MBAN means. These architectural stipulations are completely irrelevant to legitimate interference concerns and would appear to serve secondary interests, if they serve any interests at all. The prohibition of mesh networks is justified by the order on security grounds, but it's a ridiculously crude means of securing a network.

Given the desire of GEHC and other potential builders of MBANs to re-purpose Wi-Fi™ chips for this new service and its adjacency to Wi-Fi™, it's reasonable to ask why the FCC didn't simply add the 40 MHz to the existing Wi-Fi™ allocation with transmit power rules protecting AMT. This would have resulted in a 50 percent increase in spectrum available to Wi-Fi™ users in the adjacent 2400 MHz to 2480 MHz band.

The answer is that the FCC desired to create a system for more orderly sharing of bandwidth than is typical in Wi-Fi™ networks. Although Wi-Fi™ can operate as a highly controlled system with high Quality of Service provision under the Point Coordination Function, this is not a common mode of operation.[48] Essentially, the FCC's MBAN order uses authorization and architecture to specify a mode of operation for MBAN networks that has been described in a more effective and efficient way at a higher level of system design by LAN standards. It fortunately leaves complex questions of frequency, time, and coding allocation within the MBAN allocation to the imagination of the user even if it ties their hands with respect to the direction and routing of communications.

It's also reasonable to ask why the FCC carved out a secondary use in the sweet spot for mobile broadband (500 MHz to 3 GHz) instead of assigning less desired spectrum above 3

GHz. There are, after all, Wi-Fi™ chips that operate in both the 3.6 GHz band (802.11y) and in the 5.8 GHz band (802.11a, 802.11n, and 802.11ac). This question is not addressed by the order, but the FCC is certainly aware that spectrum in this range is prized by both licensed and unlicensed users.

As it is, MBANs will probably not be authorized in Arecibo, Puerto Rico because of potential interference with radio astronomy operations, and in other areas they will operate at low power so as not to cause too many problems for amateur radio operators and the aforementioned incumbent AMT services. Consequently, the MBAN order is large step backward in terms of the logic of spectrum allocation, although it's not as bad as it might have been since use of the spectrum is controlled by an authorization data base that allows for the implementation of additional rules. The order is not at all straightforward.

Allocation of spectrum in such a historically backward way—it's an order that hearkens back to the era in which the FCC allocated by application instead of technical characteristics—earns a low score of 0 in our system:

1. Upgrade and Repack: Neutral
2. Sharing: Advanced
3. Application Flexibility: Retarded
4. Dynamic Capacity Assignment: Neutral
5. Technology Upgrade Flexibility: Retarded
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Neutral
8. High-Performance Receivers: Neutral
9. Use of all Relevant Dimensions: Advanced
10. Promotion of New Technologies: Retarded

Total Score: 0

Verizon/SpectrumCo Transaction

On January 11, 2012, the FCC opened a docket to review the proposed sale of 20 MHz of spectrum in the AWS-1 band from the "SpectrumCo" cable company joint venture (and from former SpectrumCo member Cox Communications) to Verizon Wireless, a joint venture of Verizon Communications and Vodaphone.[49]

The cable companies purchased the licenses in order to build a mobile broadband network that would compete with AT&T, Verizon, T-Mobile, and Sprint, but soon discovered that the skills required to do that were outside their expertise; as a result, the spectrum is currently lying fallow.

Verizon offered to buy the SpectrumCo licenses as part of a complex transaction that would also allow them to bundle mobile phone service with cable broadband for sale to their customers, and which would also allow the cable companies to offer similar "quad play" bundles to their customers. A great deal of the discussion of the transaction focuses

on the bundling aspect, but that's really quite distinct from the spectrum transaction. The FCC has business examining cross-marketing deals, but the rules that apply are very different from those that apply to spectrum.

Verizon has an immediate and pressing need for more spectrum because it has aggressively deployed LTE across the U.S. Verizon Wireless is now the world leader in LTE deployment, and the U.S. as a whole has 70 percent of the global LTE users.

The FCC has been urged Sprint and T-Mobile and friendly interest groups to block the transaction, although a recent transaction with T-Mobile has muted their criticism. With these technical and political facts at work, it's unacceptable to allow these 122 licenses to go to waste. The FCC has tools to examine spectrum concentration known as "spectrum screens" that should be applied to the transaction without modification that makes it more difficult for the carriers who are investing most heavily in new technology to reap marketplace advantages. We urged the FCC to approve the spectrum transaction and to review the separate business deal between the parties on its own.[50]

Assuming that the transaction is approved without destructive conditions, it would earn a high score of 7 simply for allowing currently unused spectrum to be put to use in a highly productive way:

1. Upgrade and Repack: Advanced
2. Sharing: Advanced
3. Application Flexibility: Advanced
4. Dynamic Capacity Assignment: Advanced
5. Technology Upgrade Flexibility: Advanced
6. Aggregation Efficiency: Advanced
7. Facilities-Based Competition: Neutral
8. High-Performance Receivers: Neutral
9. Use of all Relevant Dimensions: Neutral
10. Promotion of New Technologies: Advanced

Total Score: +7

This transaction compares very favorably against the MBAN and LightSquared matters.

THE SPECTRUM RESEARCH AGENDA

As Figure 9 indicates, the general problem of spectrum policy today is fragmentation: Regulators have assigned every patch of desirable spectrum but demand continues to rise. Technology continues to improve, but advances will be most effective if fragmentation is corrected. The easy way to do this is to take spectrum away from low-value applications (such as the government's dedicated video surveillance frequencies, many lightly-used satellite services, and over-the-air TV) and assign it to high-value commercial networks by auction. Sharing is inherent in commercial networks; it's how they make money and they're very good at it. Research on better ways of using spectrum will allow policymakers to correct inefficient historical allocations and enable more effective sharing in the future.

Allocation Efficiency

Unlicensed radio systems are most effective over short distances: Bluetooth and Wi-Fi™ are their signature accomplishments. These systems manage spectrum access at the network edge using contention-based Medium Access Control (MAC) protocols that become less efficient as network distances and data rates increase. Licensed commercial systems employ centrally-managed spectrum access scheduling controls that are effective at a broad range of speeds over longer distances, but at the cost of much greater planning and more complex infrastructure.[51] Each approach has distinct benefits and ideal deployment scenarios: We would not want to build nationwide networks with Wi-Fi™, and we would not want to centrally manage Bluetooth connections between smartphones and headsets.

Figure 17: Actual Overhead of IEEE 802.11n Carrier Sensing for Single Packets Sent at High Rate[52]

In addition to the spectrum sharing that licensed commercial networks and unlicensed networks already do, research has developed (and will continue to develop) systems that coordinate spectrum use among networks themselves. The best known of such systems are the Dynamic Spectrum Access (DSA) and Authorized Shared Access (ASA) systems described previously. These systems simply coordinate spectrum access among and between network operators where idle spectrum exists and sharing agreements of some kind are in force.

In order for these systems to function, the pool of idle spectrum can be used by capable devices when certain conditions are met and an operator claims the spectrum, either with government permission (as is the case in the White Spaces systems), or in accord with a commercial agreement between network operators in other cases, or in terms of an informal agreement in yet other cases. The act of claiming the spectrum makes the network operational, and once this takes place, the process of network operator-mediated sharing among applications follows, with potentially as much efficiency as commercial licensed networks exhibit over a broad range of operating conditions.

These systems will prove beneficial in the short to medium term, until we reach the point where there is no longer any idle spectrum to claim and assign dynamically. At that point, advances in spectrum sharing will depend on more advanced and more beneficial technologies that that allow a single frequency to be shared among multiple *simultaneous* users. We don't do this today, and we won't do this with DSA and ASA.

In DSA and ASA systems, as with common commercial systems, users take turns accessing spectrum in round-robin fashion, typically for a few milliseconds at a time. In other words, conventional packet radio systems, whether licensed or unlicensed, fixed or dynamic, only permit the transmission of one packet of data at a time in a given place, time, and frequency.[53] DSA and ASA systems reduce to the effects of this fundamental limitation by

marshaling more spectrum to each location. The next stage in spectrum engineering is systems that allow for multiple packet transmissions in each time and place on the same range of spectrum.

The most fertile test bed for DSA operations research is the vast pool of lightly-used and locally-used government spectrum. Many government systems that use spectrum only do so occasionally and in specific locations, so this spectrum is ripe for use by both commercial and non-commercial systems in other times and places. The IEEE 802.11y variant of Wi-Fi™ is a good example of the dynamic sharing of government spectrum.[54]

Recent developments in for sharing experiments in the 3 – 4 GHz band are an interesting way to develop practical sharing systems without sacrificing prime mobile spectrum. A joint letter to the FCC signed by AT&T and Google supports the concept.[55]

The Limits of Highly-Touted Spectrum Technologies

Software-Defined Radio/ Cognitive Radio/Dynamic Spectrum Access (DSA), a fifteen-year-old idea, has become the poster child for "new technologies" offered as the solution to the spectrum crunch by pundits who declare radio interference a myth that disappears as radios become smarter.[56] These forecasts are eerily similar to George Gilder's claims of a looming bandwidth glut in the 1990s that would make "bandwidth too cheap to meter."[57]

Cognitive radio, a fifteen-year-old idea, has become the poster child for "new technologies" offered as the solution to the spectrum crunch.

For example, cell phone pioneer Marty Cooper touted SDR at a meeting of the FCC's Technology Advisory Council:

> "If you look at the future of what is happening to cell phone designs, we're getting within our sights the possibility of building a cell phone that's totally software configurable. And when that happens, it will be possible to reach for any channel that exists for any specific user. And when you combine that with (you knew I was going to say smart antennas) you now can get not only wide frequency coverage but geographic coverage. And when you achieve that (and it's going to take ten years) all of the work that you're doing in spectrum allocation is going to be irrelevant. There's going to be so much spectrum that we're not going to know what to do with it all."[58]

Similar claims have been made for many years, each projecting five to ten years into the future and we can expect them to continue. Meanwhile, fundamental problems of coordination between DSA systems remain unresolved.

In reality, fifteen years and six billion dollars' worth of research and development by the DOD on the Joint Tactical Radio System (JTRS) SDR have failed to produce a practical system because SDR is a bet against Moore's Law, a fundamentally troublesome approach:

> Since JTRS started, we've seen some advances in software-defined radio technology. NASA is testing SDR as part of its Space Telecommunications Radio System, and it will put an experimental SDR on the International Space Station. Aspects of SDR technology have been used in Wi-Fi devices and cellular phones—for example, the iPhone. But SDR as conceived by the JTRS effort hasn't been widely adopted in the commercial realm, and remains largely the realm of hobbyists, with kits like GNU Radio.
>
> While JTRS's SDR approach focused on making one radio that could do everything with FPGAs, *it was actually a bet against Moore's Law*—that it would be cheaper and

> easier to have one radio you could add new waveforms to than simply buying another radio. But it turns out, as the consumer wireless market has proven, that it may be cheaper to make lots of single-purpose radios that plug together and get tossed when there's an upgrade.
>
> When JTRS began, there was no WiFi, no 3G or no 4G wireless, and commercial radio communications was relatively expensive. But the consumer industry didn't even look at SDR as a way to keep its products relevant in the future. No, ASIC-based digital signal processors are cheap, and new products also tend to include faster chips and new hardware features; people prefer buying a new $100 WiFi router when some future 802.11z protocol appears instead of buying a $3,000 wireless router today that is "future proofed" (and you can't really call anything based on CORBA "future proofed").
>
> Without a solid radio product, then, the Army has started to look at options like tactical cellular networks for short-range communications, using proven commercial technology mounted on vehicles and even aerostats (tethered blimps) to create bubbles of connectivity at speeds the waveforms defined a decade ago can't even handle.[59]

The concept of cognitive radio directly conflicts with regulatory enhancements such as receiver performance standards because it opens the receiver portal wider, exactly what we don't want in cases of GPS/mobile broadband co-existence such as the LightSquared matter.

There are other options on the wireless engineering horizon that will increase bits/hertz efficiency by such a radical factor that the spectrum crunch will certainly become manageable and may ultimately fade from the policy agenda. Rather than focusing on the permission structure for spectrum use, these advances create opportunities for actual concurrent use of the same spectrum, in the same place, at the same time, by multiple parties.

Commercial systems already exist that accomplish this goal in a basic way, such as CDMA. More advanced systems have been demonstrated in the research setting that use quantum effects such as Orbital Angular Momentum (OAM) with the potential to increase spectrum re-use efficiency by several orders of magnitude—perhaps thousands or millions of times better than we can do now. These systems address the problem of spectrum scarcity in the orderly, civilian environment, while cognitive radio is more suitable for combat conditions when its problems are worked out. Both OAM and SDR are probably years away from practical use in any case.

Usage Efficiency

Truly simultaneous spectrum use requires transmissions to be effectively focused or cloaked from each other so as not to create discernible interference; these systems can be called Simultaneous Shared Access (SSA). One way of doing this is Space-Division Multiple Access (SDMA), a system that effectively sends a radio beam to a receiver in such a focused way that other receivers don't see it. Another system for simultaneous sharing would be an advanced form of Code Division Multiple Access (CDMA), a system that scrambles transmissions so that only the intended receiver can unscramble them, and other potential receivers automatically filter them out. Current CDMA systems reduce the data rates of

simultaneous transmissions relative to theoretical capacity; advanced CDMA would be less limited in this respect.

Yet another method is Ultra-Wideband (UWB), a system that uses very wide radio channels "underneath" conventional narrow channels. While conventional cellular channels are 5, 10, or 20 MHz wide, UWB channels are spread over 500 MHz or more, so the UWB energy is very faint to cellular receivers. UWB transmissions are also pulsed to as to appear more like sporadic noise to conventional receivers. Therefore, UWB transmissions blend into the background noise filtered by narrowband receivers by design. Of these three approaches, only CDMA has proved a commercial success so far, but its sharing efficiency is not infinitely scalable as some advocates have claimed.

Orbital Angular Momentum (OAM) multiplexing systems also show promise for achieving SSA. These systems appear to be infinitely scalable, which is the Holy Grail of spectrum sharing.

Research spending should focus on Simultaneous Sharing. It would be prudent to organize research funding for simultaneous sharing under a coherent National Science Foundation program. The best way to do this may be to create an NSF Engineering Research Center (ERC) for simultaneous sharing similar to the research centers that already exist in the Microelectronics, Sensing, and Information Technology area, such as the ERCs for Integrated Access Networks, Extreme Ultraviolet Science and Technology, Collaborative Adaptive Sensing of the Atmosphere, and Mid-Infrared Technologies for Health and the Environment.

A report released by the White House Council of Economic Advisors in February 2012, *The Economic Benefits of New Spectrum for Wireless Broadband*, touts the benefits of "research on standards, technologies, and applications to advance wireless public safety communications." While such research is clearly necessary and beneficial, we should acknowledge that it is low-risk applied research with a known outcome. In addition to applied research, we need to support pure research on SSA that can potentially push the boundaries of mobile networking to the next stage.

The research agenda can be organized on a timeline between short-, medium-, and long-term initiatives, as follows:

Short term	Reallocation by auction or license transfer
Medium term	Dynamic Allocation and Sharing
Long term	Simultaneous Shared Access using OAM or similar means

Table 1: Timeline of Initiatives

When SSA is fully developed and non-SSA receivers are replaced by SSA-capable ones, the problem of spectrum allocation and management will become much simpler than it is today.

GOING FORWARD

The spectrum crunch created by the exploding adoption of smart phones and data-intensive applications is real and immediate. The ability of commercial LTE and LTE Advanced networks to keep pace with demand is a gating factor what will either accelerate innovation in the mobile space or retard it. This ability depends on continued technology innovation, but it also depends on the repurposing of the spectrum currently allocated to legacy wireless applications to newer forms of technology. Currently, only 20 percent of the spectrum in the range from 500 MHz to 3 GHz is assigned to mobile broadband networks, and the justification for continuing to use the remaining 80 per cent for legacy purposes is thin in many instances.

In the future, advances in wireless technology will enable more efficient bits/hertz utilization of spectrum assigned to mobile networks, and regulator bypass will enable more spectrum to be used opportunistically. While these technologies are certain to come to pass in some form, the timeline for their maturity it not consistent with present needs for additional spectrum. Consequently, spectrum policymakers must be mindful of three time lines for spectrum allocation:

Spectrum policymakers must be mindful of two time lines for spectrum allocation, immediate and long term.

1. The present crisis which actually began in 2007 with the release of the first iPhone and growing use of smart phones; and
2. The medium term period where we learn how to achieve efficient sharing among occasional, opportunistic, and authorized users of common spectrum allocations; and
3. The longer term scenario in which major advances in wireless technology will be ready for deployment in ten years or so.

The solution to the present crisis involves making the best use of the technologies that are suitable for immediate use and enhancements to the regulatory system that enable opportunistic use and shared access where it's practical. The longer term scenario is served by a combination of research support and spectrum policies that allow for flexible use as new technologies come to the fore that can be implemented in due course.

The spectrum of the greatest interest for commerical systems is assigned to a variety of uses already, many of which will function just as well below 500 MHz or above 4 GHz. For clarity, we include the detail on the allocaiton in this range from the NTIA chart. Sharing these frequencies has the most utility for general public users of smartphones and similar systems.

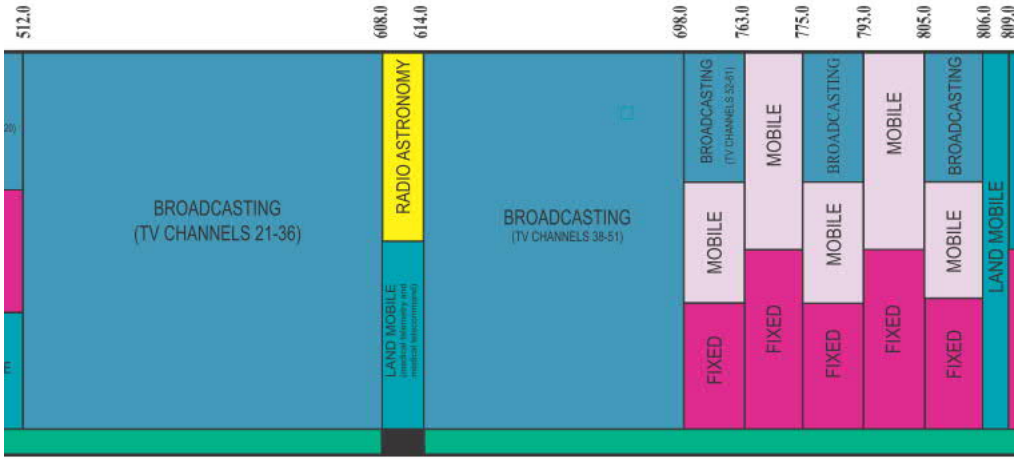

Figure 18: 500 MHz – 809 MHz (Credit: NTIA)

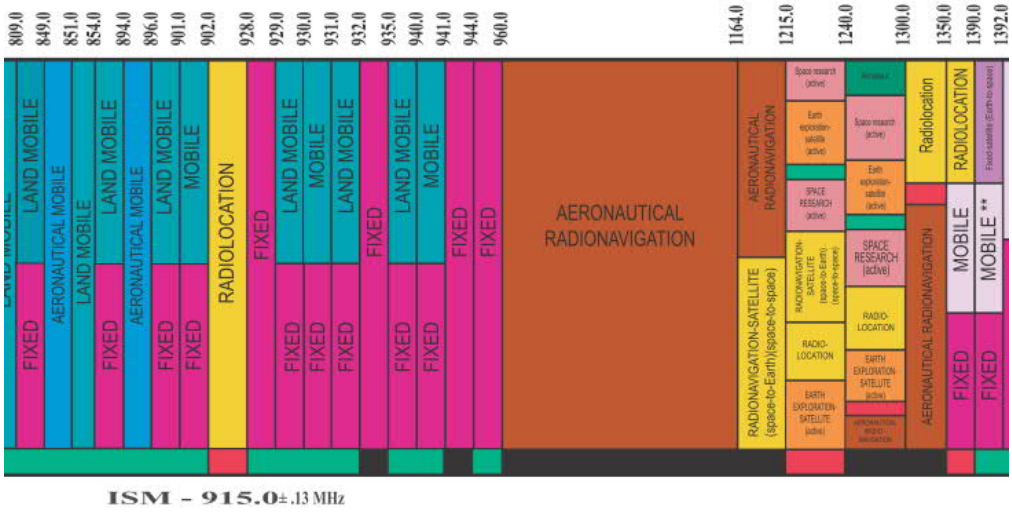

Figure 19: 809 MHz – 1392 MHz (Credit: NTIA)

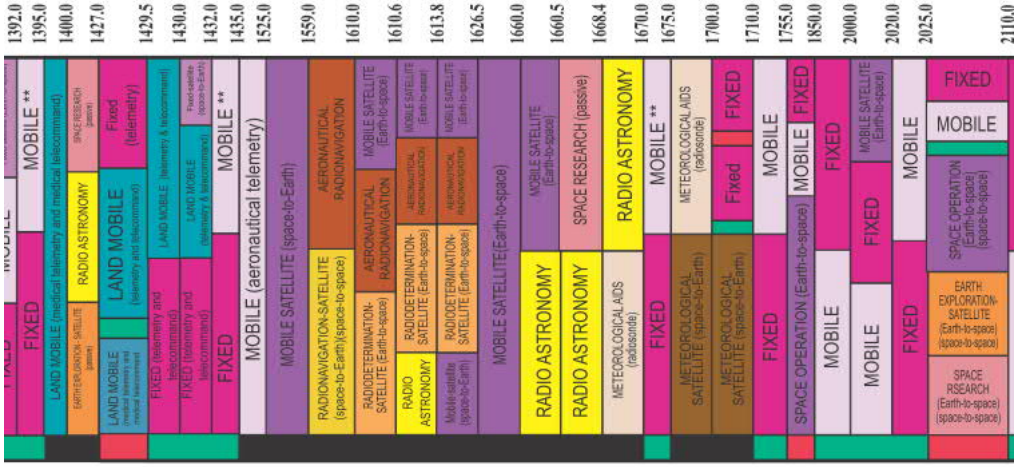

Figure 20: 1392 – 2100 MHz (Credit: NTIA)

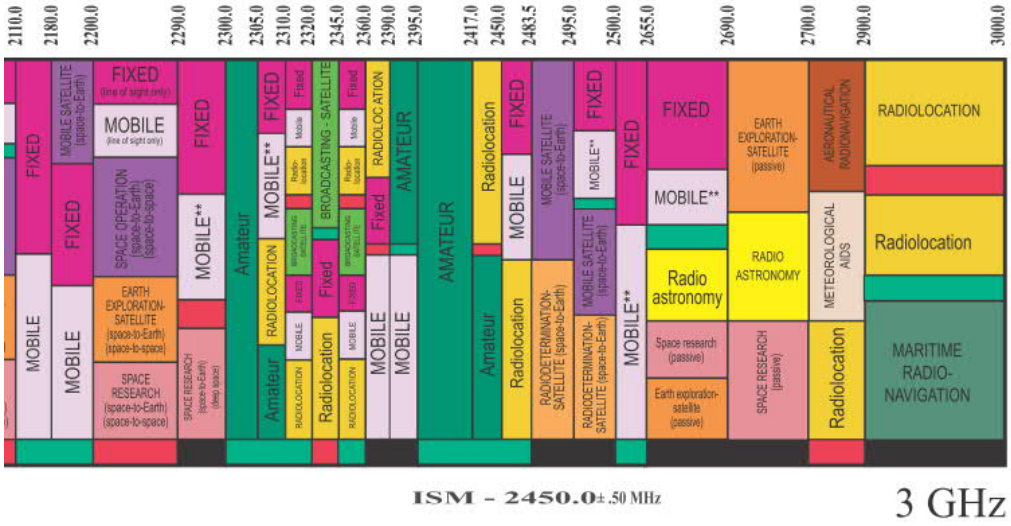

Figure 21: 2100 – 3GHz MHz (Credit: NTIA)

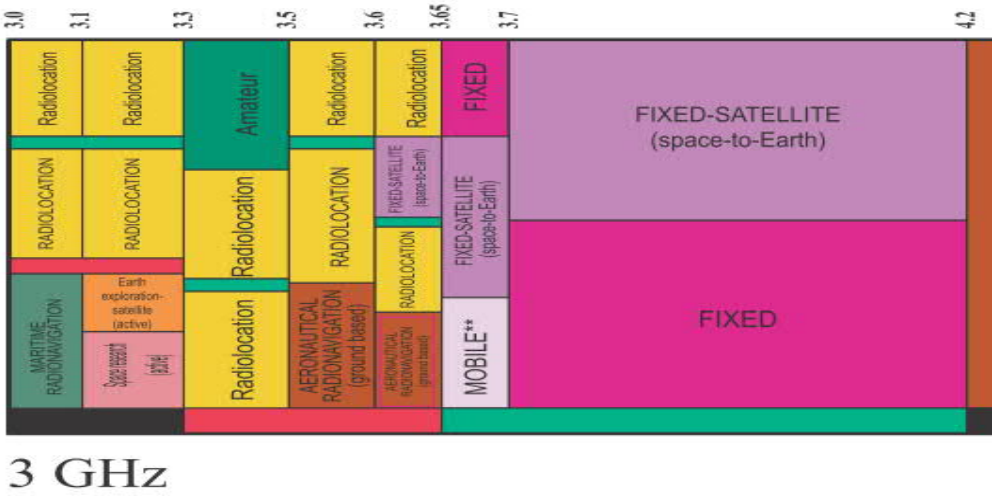

Figure 22: 3 GHz – 4 GHz MHz (Credit: NTIA)

CONCLUSION

Despite the many challenges we face in converting our system of spectrum assignment from one of administrative fiat to a pragmatic and dynamic system of continual economic stimulus, the rewards are great. The nations that lead the way in the deployment of advanced technologies stand to reap the benefits that increased efficiency and innovation brings to economic growth.

While it has become routine for policy advocates to criticize the United States for its supposedly low position in traditional rankings of wired broadband speed despite the progress we've made since our 2009 low point, we're the clear leader in LTE adoption.[60] LTE is very significant step in the evolution of mobile networking not only for its radio technology but also because it's a system entirely based on Internet Protocol that stands to not only increase the capacity of mobile networks but to make the Internet itself a more reliable and robust system.

Continued leadership in LTE depends on the continued release of spectrum to the most successful commercial networks through reassignment of government applications and the transfer of licenses from declining systems such as MSS and OTA television broadcasting to high-value mobile broadband. Leadership in the systems that will take the place of LTE and LTE Advanced depends on increased investment in the technologies for simultaneous spectrum sharing that will ultimately relieve the spectrum crunch once and for all. We should not delude ourselves into believing that a magic technology is going to drop out of the sky any day now that will resolve spectrum conflicts once and for all without any work on the part of policymakers. Policy has to work with reality.

Since the introduction of the iPhone in 2007, mobile data traffic on the AT&T network in the U.S. has increased by 8000 per cent. Android is the fastest growing smartphone platform, and on average Android users consume even more data capacity than iPhone users. The National Broadband Plan recommended the use of incentive auctions to re-allocate 120 MHz of radio frequency spectrum currently assigned to broadcast television to mobile broadband. The reasoning for this recommendation is very clear: The demand for mobile broadband has grown rapidly since the advent of the iPhone, while the demand for broadcast television declined sharply since the advent of cable TV. High-demand systems such as mobile broadband should have first call on spectrum in the 500 MHz – 3 GHz range.

We should not delude ourselves into believing that a magic technology is going to drop out of the sky any day now that will resolve spectrum conflicts once and for all without any work on the part of policymakers. Policy has to work with reality.

Incentive auctions are a general purpose mechanism meant to accelerate the reassignment of spectrum the FCC has licensed to specific users for specific periods of time, but they're not enough: direct license transfers and commercial sharing agreements are also important. Exclusive use of spectrum by government agencies must be scrutinized for opportunities to upgrade applications to modern standards and shift them to commercial networks where feasible, and sharing of spectrum between government and commercial users must be implemented in other cases, especially above 3 GHz.

A thorough, detailed review of legacy spectrum allocations must be an ongoing part of the duties of the FCC and NTIA for the foreseeable future. Ongoing research and a more sophisticated approach to spectrum reallocation are needed to ensure that the U.S. maintains leadership where were currently lead and that we regain it in other areas of spectrum technology.

ENDNOTES

1. "RSPG Consultation on Cognitive Technologies: Qualcomm and Nokia Joint Response" (Qualcomm and Nokia, January 2011), http://rspg.groups.eu.int/consultations/consultation_cognitiv_2010/qualcomm_nokia_0114.pdf.
2. Henry Blodget and Alex Cocotas, "The Future of Mobile" (presented at the IGNITION WEST: Future of Mobile Conference, San Francisco, CA, March 22, 2012), http://www.businessinsider.com/the-future-of-mobile-deck-2012-3.
3. Mary Meeker, "Internet Trends 2011" (presented at the Web 2.0 Summit, San Francisco, CA, October 18, 2011), http://www.kpcb.com/insights/internet-trends-2011.
4. Richard Bennett, "Live Different: Susan Crawford's Broadband Blinkers," Innovation Files, December 5, 2011, http://www.innovationfiles.org/live-different-susan-crawfords-broadband-blinkers/.
5. Bill Tancer, *The 2012 Digital Marketer Trend and Benchmark Report* (Experian Marketing Services, 2012), http://go.experian.com/forms/experian-digital-marketer-2012.
6. Brad Reed, "LTE Spectrum: How Much Do the Big Carriers Have?," *Network World*, January 23, 2012, http://www.networkworld.com/news/2012/012312-lte-spectrum-255122.html?page=1.
7. Wikipedia, "List of WLAN Channels," encyclopedia, n.d., http://en.wikipedia.org/wiki/List_of_WLAN_channels.
8. Michelle Megna, "AT&T Faces 5,000 Percent Surge in Traffic," *InternetNews*, October 8, 2009, http://www.internetnews.com/mobility/article.php/3843001/ATampT+Faces+5000+Percent+Surge+in+Traffic.htm.
9. Kris Rinne, "Building the Nation's Most Advanced Mobile Broadband Experience" (presented at the AT&T CIO Executive Forum, Colorado Springs, CO, June 15, 2011), http://www.business.att.com/content/speeches/ATT_Mobility_Network_Evolution_KrisRinne.pdf.
10. "Martin Cooper (inventor)," *Wikipedia*, accessed January 13, 2010, http://en.wikipedia.org/wiki/Cooper%27s_Law.
11. Craig Moffett, *Company Reports* (Bernstein Research, January 11, 2011).
12. Image credit: Bernstein Research, used by permission from Craig Moffett
13. Michael Kleeman, *Point of View: Wireless Point of Disconnect* (San Diego, CA: Global Information Industry Center, October 2011), http://giic.ucsd.edu/pdf/pow_wireless_point_of_disconnect_2011.pdf.
14. Ibid.
15. Richard Bennett, *Spectrum Policy for Innovation* (Washington, D.C.: ITIF, September 2011), http://www.itif.org/files/2011-spectrum-policy-innovation.pdf.
16. Richard Bennett, *Going Mobile: Technology and Policy Issues in the Mobile Internet* (Washington, D.C.: ITIF, March 2010), http://itif.org/publications/going-mobile-technology-and-policy-issues-mobile-internet.
17. *Technological Advisory Council (TAC) Meeting* (Washington, DC: FCC, 2012), http://www.youtube.com/watch?v=bH4cSzoeNcM.
18. Anita Cassidy, *A practical guide to information systems strategic planning* (Boca Raton, FL: Auerbach Publications, 2006).
19. Augmenting Mobile Broadband in Your Community (Washington, D.C.: Federal Communications Commission, 2012), http://www.youtube.com/watch?v=65pEZbL_VGw&feature=plcp.
20. Hujun Yin and Siavash Alamouti, "OFDMA: A Broadband Wireless Access Technology" (IEEE, 2006), pg. 1–4, http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4534773.
21. "Light Orbital Angular Momentum," Wikipedia, n.d., http://en.wikipedia.org/wiki/Light_orbital_angular_momentum.
22. Sebastian Anthony, "Infinite-capacity Wireless Vortex Beams Carry 2.5 Terabits Per Second," Tech Tabloid, *ExtremeTech*, accessed June 30, 2012, http://www.extremetech.com/extreme/131640-infinite-capacity-wireless-vortex-beams-carry-2-5-terabits-per-second.
23. Samuel K. Moore, "Twisted Light Leads to 2.56 Tb/s Link," (technology analysis, Spectrum, June 26, 2012), http://spectrum.ieee.org/tech-talk/telecom/wireless/twisted-light-leads-to-256-tbs-link?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+IeeeSpectrum+%28IEEE+Spectrum%29&utm_content=Google+Reader.
24. Fabrizio Tamburini et al., "Encoding Many Channels on the Same Frequency Through Radio Vorticity: First Experimental Test," *New Journal of Physics* 14, no. 3 (March 2012): 033001.

25. AIR.U, "Consortium of Higher Education Groups, Microsoft and Google Launch Program to Deploy Big Bandwidth to Underserved College Communities," Press Release, June 26, 2012, http://newamerica.net/pressroom/2012/air.u.
26. "802.11ac," Tech Tabloid, *Engadget*, accessed June 30, 2012, http://www.engadget.com/tag/802.11ac/.
27. "IEEE 802.11ac," Wikipedia (Wikipedia, n.d.), http://en.wikipedia.org/wiki/IEEE_802.11ac#cite_note-2.
28. Robert D. Atkinson, "The Role of Competition in a National Broadband Policy," *Journal on Telecommunications and High Technology Law* 7, no. 1 (Winter 2009): pg. 1.
29. Robert Matheson and Adele C. Morris, "The Technical Basis for Spectrum Rights: Policies to Enhance Market Efficiency, " (Brookings Institution, March 3, 2011), http://www.brookings.edu/~/media/research/files/papers/2011/3/03%20spectrum%20rights%20matheson%20morris/0303_spectrum_rights_matheson_morris.pdf.
30. Some of these controversies were discussed in our previous report, Richard *Bennett, Spectrum Policy for Innovation*.
31. Peter Cramton, *700 MHz Device Flexibility Promotes Competition* (Rural Cellular Association, August 9, 2010), http://www.cramton.umd.edu/papers2010-2014/cramton-700-mhz-device-flexibility-promotes-competition.pdf.
32. "Intermodulation," encyclopedia, *Wikipedia*, accessed May 29, 2012, http://en.wikipedia.org/wiki/Intermodulation.
33. Federal Communications Commission, "Report and Order in the Matter of Improving Spectrum Efficiency Through Flexible Channel Spacing and Bandwidth Utilization for Economic Area-based 800 MHz Specialized Mobile Radio Licensees," May 24, 2012, http://transition.fcc.gov/Daily_Releases/Daily_Business/2012/db0524/FCC-12-55A1.pdf.
34. Stephen Lawson, "FCC Ruling on 800MHz Band a Boon for Sprint," *Computerworld*, May 25, 2012, http://www.computerworld.com/s/article/9227504/FCC_ruling_on_800MHz_band_a_boon_for_Sprint.
35. Ginger Conton, "Free the Spectrum Now," *CRM Magazine*, May 2002, http://www.destinationcrm.com/Articles/Older-Articles/The-Edge/Free-the-Spectrum-Now-45519.aspx.
36. John E. Bryson and Lawrence E. Strickling, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band* (Washington, D.C.: U.S. Department of Commerce, March 2012), http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.
37. President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth" (slide deck, Washington, D .C., May 2012), http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_may25.pdf.
38. President's Council of Advisors on Science and Technology, *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth* (Washington, DC, July 20, 2012), http://www.whitehouse.gov/administration/eop/ostp/pcast.
39. Ibid.
40. Lawrence E. Strickling, "NTIA LightSquared Letter" (NTIA, February 2012), http://apps.fcc.gov/ecfs/document/view?id=7021860324.
41. Richard Bennett, "Comments of the Information Technology and Innovation Foundation in the Matter of LightSquared Subsidiary LLC Request for Modification of Its Authority for an Ancillary Terrestrial Component" (Federal Communications Commission, August 2011), http://www.itif.org/files/2011-lightsquared-gps.pdf.
42. Susan Crawford, "Geo-Location, Geo-Location, Geo-Location: The Tragedy of Lightsquared," *Wired Magazine*, February 23, 2012, http://www.wired.com/epicenter/2012/02/pipeline-crawford-telecomm-goliath/all/1.
43. John Deere, "LightSquared Interference to GPS and StarFire ," May 26, 2011, http://www.gpsworld.com/machine-control-ag/precision-ag/john-deere-lightsquared-interference-report-11713.
44. Richard Bennett, "Comments of the Information Technology and Innovation Foundation in the Matter of LightSquared Subsidiary LLC Request for Modification of Its Authority for an Ancillary Terrestrial Component."

45. Assistant for GPS, Positioning, and Navigation, "Global Positioning System Standard Positioning Service Performance Standard" (United States Department of Defense, September 2008), http://www.pnt.gov/public/docs/2008/spsps2008.pdf.
46. Art Gower, "The System: The Promise of OCX," *GPS World*, September 1, 2008, http://www.gpsworld.com/gnss-system/the-system-the-promise-ocx-4251.
47. Federal Communications Commission, "Amendment of the Commission's Rules to Provide Spectrum for the Operation of Medical Body Area Networks," May 24, 2012, http://transition.fcc.gov/Daily_Releases/Daily_Business/2012/db0524/FCC-12-54A1.pdf.
48. "Point Coordination Function," Wikipedia, n.d., http://en.wikipedia.org/wiki/Point_coordination_function.
49. Federal Communications Commission, "Commission Opens Docket for Proposed Assignment of Licenses to Verizon Wireless from SpectrumCo and Cox TMI Wireless, LLC, and Designates these Applications as Permit-But-Disclose Under Commission's Ex Parte Rules", January 11, 2012, http://hraunfoss.fcc.gov /edocs_public/attachmatch/DA-12-35A1.pdf.
50. Richard Bennett, "Comments on Cellco Partnership D/B/A Verizon Wireless, SpectrumCo, LLC and Cox TMI Wireless, LLC For Consent To Assign Licenses and Authorizations" (technical report, ITIF, Washington, D.C., February 2012), http://www.itif.org/files/2012-verizon-tmi-licenses-authoriziation.pdf.
51. Richard Bennett, *Going Mobile: Technology and Policy Issues in the Mobile Internet.*
52. Ibid.
53. There are some exceptions to this rule, but they apply to systems that reduce packet radio data rates, such as CDMA.
54. Wikipedia, "IEEE 802.11y-2008," *Wikipedia*, accessed April 14, 2012, http://en.wikipedia.org/wiki/IEEE_802.11y-2008.
55. Joan Marsh and Austin Schlick, "Ex Parte Communication: Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Dkt. 12-354," August 6, 2013, http://apps.fcc.gov/ecfs/document/view?id=7520936221.
56. David Weinberger, "The Myth of Interference," *Salon.com*, March 12, 2003, http://www.salon.com/2003/03/12/spectrum/.
57. Kevin Kelly, "George Gilder: When Bandwidth Is Free," *Wired Magazine*, October 1993, http://www.wired.com/wired/archive/1.04/gilder.html.
58. Technological Advisory Council (TAC) Meeting (Washington, D.C.: Federal Communications Commission, 2012), http://www.youtube.com/watch?v=bH4cSzoeNcM.
59. Sean Gallagher, "How to Blow $6 Billion on a Tech Project," *Ars Technica*, June 18, 2012, http://arstechnica.com/information-technology/2012/06/how-to-blow-6-billion-on-a-tech-project/2/.
60. Richard Bennett, Luke A. Stewart, and Robert D. Atkinson, *The Whole Picture: Where America's Broadband Networks Really Stand* (Washington, DC: Information Technology and Innovation Foundation, February 12, 2013), http://www.itif.org/publications/whole-picture-where-america-s-broadband-networks-really-stand.

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NOTE

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Blueprint for a Federal Spectrum Service: A Very Rough Draft

April 24, 2014

Richard Bennett, Visiting Fellow, American Enterprise Institute

Overview

This draft presents some preliminary ideas on the use of a federally chartered corporation to transfer excess spectrum to the private sector. The spectrum in question is currently assigned by the federal government to itself and is used for federal purposes. Primarily, the plan calls for a mandatory redesign of federal systems in order to reduce their spectrum footprint, but also for the use of corporate funds to advanced research and development of spectrum-based systems and technologies. The corporation, the Federal Spectrum Service, would have a limited lifespan and a clear mandate to reduce the federal spectrum footprint by 75% over ten years.

Background

In previous papers[1], I've analyzed spectrum allocation from the standpoint of achieving spectrum efficiency, which is best measured in terms of bits per second per hertz per user. I've found the following:

- Licensed systems generally outperform unlicensed ones by a factor of 1.5:1 or more.

- Licensing is effective because a single spectrum manager can employ packet scheduling, which is able to allocate spectrum on demand up to 99% utilization, while unlicensed systems must rely on contention protocols that seldom allocate at more than 50% efficiency.

- The efficiency gap grows larger as the network service area increases: the contention protocols used by unlicensed networks work best when small numbers of devices share a time, space, and frequency slice, and work worst when a large number of contenders must compete for spectrum access. Unlicensed system cooperate poorly.

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[1] Chiefly in: Richard Bennett, "Technical Principles of Spectrum Allocation", 2013. *TPRC 41: The 41st Research Conference on Communication, Information and Internet Policy*. Available at SSRN: http://ssrn.com/abstract=2240625 or http://dx.doi.org/10.2139/ssrn.2240625 and Richard Bennett, *Powering the Mobile Revolution: Principles of Spectrum Allocation* (Washington, DC: Information Technology and Innovation Foundation, July 31, 2012), http://itif.org/events/powering-mobile-revolution-principles-spectrum-allocation.

- Latency aggravates the inefficiency of unlicensed networks: contention protocols all use some variation on "listen before talk," where the listening time is a function of edge-to-edge propagation time and therefore become less efficient in high latency conditions.

- It's generally known that wireless coverage is a function of power and frequency, where higher frequencies require more power to achieve coverage of a broad area than would lower frequencies.

- Frequencies lower than 3 GHz are preferable for battery powered mobile devices, while frequencies higher than 6 GHz are more suitable for long distance, stationary, point-to-point systems; intermediate frequencies are suitable for a variety of other uses, such as small mobile cells, nomadic, and low bandwidth machine-to-machine applications.

- 2.4 GHz spectrum has a special feature: because 2.4 GHz is resonant frequency of water, and water vapor is everywhere, this spectrum is only suitable for limited coverage systems such as Bluetooth, Wi-Fi, Garmin's ANT+, and medical body sensor systems. On the positive side, the limited propagation of 2.4 GHz signals enables easy re-use of the spectrum over short distances, the trick that makes unlicensed Wi-Fi and Bluetooth effective.

- Because water resonance does not exist across the full spectrum, unlicensed allocation is not a candidate for the general-purpose spectrum utilization model of the future: until coding systems advance to the point that they enable collision-free multiple access, scheduling must remain the norm. Consequently, we have many tools to meet the needs of stationary and nomadic systems, but only one for mobile: licensed spectrum with scheduling.

- Mobile networks are constrained by two primary factors: the growing demand for mobile data capacity and the cost of increasing capacity. Data capacity is function of gross spectrum and efficiency; if demand increases faster than technology increases efficiency, there's not way to satisfy it without throwing more spectrum at the problem.

- While a great deal of spectrum use by mobile devices is more nomadic than mobile – watching TV programs on an iPad – much demand is truly mobile, such as Mobile Augmented Reality. MAR applications cannot, as a general rule, be off-loaded to Wi-Fi.

- The least expensive way to increase mobile data capacity is the "sectorization" of existing antenna masts. When an antenna mast that once was divided into three sectors is divided into six sectors, capacity roughly

doubles, but only when the sectors don't interfere with each other. Non-interference generally requires more spectrum.

- Federal spectrum is over-allocated compared to commercial spectrum, and federal systems do not show increased efficiency over time the way that commercial ones do.

- A number of federal spectrum allocations are inappropriate or inefficient. The Defense Department and other agencies, for example, use spectrum for backhaul purposes that can be accomplished with wire, and other agencies use their authorizations for video surveillance that could easily be accommodated by public unlicensed or public licensed frequencies with greater security.

A number of analysts, such as Eisenach[2], Hazlett[3], and Lenard, White, and Riso[4], have observed that government's use of spectrum is insensitive to the positive effects of market forces. Government allocates more spectrum to itself than it does to commercial and other public uses, it allocates larger swathes, it requires less sharing, and it often uses spectrum to accomplish purposes that it could easily accomplish by other means. While spectrum-based systems in the private sector experience Moore's Law improvements in efficiency, power, and price, government systems stagnate and as a result the economy suffers.

The spectrum *status quo* is irrational. It's inconsistent, at best, for agencies of the federal government to harm the economy that serves the people they're chartered to protect.

The Federal Spectrum Service

There are at least three elements to this problem. Firstly, the government's use of spectrum needs to become motivated by incentives to use spectrum more efficiently, effectively, and rationally. This is an economic problem.

Secondly, and perhaps more importantly, government needs to be better informed regarding the means of using spectrum well in the present and near future. It's quite possible that government's reliance on obsolete systems has less to do with

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[2] Jeffrey Eisenach, "Spectrum Reallocation and the National Broadband Plan," *Federal Communications Law Journal* 64, no. 1 (December 2011), http://www.repository.law.indiana.edu/fclj/vol64/iss1/4/.

[3] Thomas Hazlett, "Tragedy TV: Rights Fragmentation and the Junk Band Problem," *Arizona Law Review*, 2011, http://www.arizonalawreview.org/pdf/53-1/53arizlrev83.pdf.

[4] Thomas M. Lenard, Lawrence J. White, and James L. Riso, "Increasing Spectrum for Broadband: What Are The Options?" (Technology Policy Institute, February 2010), https://www.techpolicyinstitute.org/files/increasing_spectrum_for_broadband1.pdf.

incentives than with ignorance. Incentives are important, but knowledge about the best means of serving the people with smart spectrum systems is also important. Government agencies are staffed by well-meaning people who may very well be performing poorly because they lack the knowledge to carry out their missions effectively.

Thirdly, government spectrum policy lacks clear goals and directions. Responsibility for spectrum use is dispersed across many agencies, each of which operates according to its own mission and mandate. While there have been opportunities to unite the discrete spectrum policies of the diverse federal agencies to a common set of goals, action has been scant. The National Broadband Plan called for the federal government to surrender a significant portion of its spectrum authorization, and the response from the White House was a timid plan for "sharing" between public and government spectrum systems that lacked detail, commitment, and practicality.

I propose the creation of a *Federal Spectrum Service* to address these three issues. The FSS could be chartered as a corporate entity distinct from the government with a specific mandate, similar in concept to the Postal Service. The FSS's charter whould focus on the overriding goal of reducing the federal spectrum footprint by 50% over a five-year period, and then reducing it a further 50% over another five-year period. At that point, it would be appropriate to evaluate its performance and either extend it, terminate it, or direct it toward a new goal.

Thus, the FSSs would be a profit-oriented organization with a special relationship with government agencies. Rather than having each government agency maintain its own group of spectrum experts with limited knowledge and experience and no power to re-allocate spectrum, as we do now, the FSS would be a consolidated pool of experts. It would be able to advise and direct each agency regarding the options that exist in terms of spectrum-based and non-spectrum-based communication systems, consolidate government systems, and make spectrum available for public use by improving the efficiency of government systems.

Where the FSS were to find gaps between agency needs and current capabilities, it could recommend the application of research funding to such problems if solutions are not in the horizon. Where if found that applied research has already been done but products have not yet reached the market, it could speed up the product development and release cycle by placing orders and advising developers of agency requirements. And where it found agencies under-performing their mandates by relying on obsolete equipment, it could require agencies to upgrade.

Perhaps most importantly, the FSS would be able to intervene in ill-fated agency boondoggles such as the DARPA Joint Tactical Radio System that cost the taxpayers

$6B and failed to deliver useful systems, by setting more realistic goals and terminating failing projects.[5]

The FSS would also need to oversee public allocations of spectrum currently made by the FCC. Its overriding concern should be the correction of imbalances in the allocation of spectrum to government systems, increasing the rate of progress in better government systems, and redesigning obsolete systems such as radar by replacing them with less resource-intensive and more powerful systems. Where public allocations are concerned, it would critically evaluate the need for special-purpose allocations such as those for Medical Body Area Networks and specialized automotive networks and determine whether general-purpose networks are up to the task.

FSS Mission and Methods

The mission of the FSS would be very broad, combining roles played by portions of today's FCC, NTIA, DARPA, National Science Foundation, Department of Transportation, and other agencies. It needs considerable power over agency use of spectrum if it's to overcome current patterns of conduct by the agencies. With respect to the nation as a whole, the FSS needs to be guided by a clear directive to promote economic growth and the public interest in constant, rapid improvement in the quality and performance of spectrum-based systems.

The overall mandate for the FSS is not substantially different from that envisioned by the framers of the Constitution for the 18th century postal system, both a source of revenue for the treasury and a vital stimulant to democracy and the private sector, but its goals would be much more specific.

Functions

The FSS would have a statutory charter to perform the following functions:

1. Assume default ownership of all radio frequency spectrum: licensed and unlicensed, public and private.
2. The power to grant and sell licenses to the use of spectrum and to issue regulations for both transmitters and receivers.
3. The power to operate spectrum-based equipment used by government agencies and to sub-contract network operations.
4. The power to monitor, audit, and catalog the use of spectrum by government agencies.
5. The power to unilaterally replace spectrum-related equipment used by government agencies.
6. The ability to direct research funding for spectrum and related subjects by research topic but not by designee.

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[5] Sean Gallagher, "How to Blow $6 Billion on a Tech Project," tech blog, *Ars Technica*, June 18, 2012, http://arstechnica.com/information-technology/2012/06/how-to-blow-6-billion-on-a-tech-project/2/.

7. The ability to purchase wired and wireless network equipment for use by government.
8. The ability to invest in firms developing wireless network equipment.

These functions and powers will be described in greater detail in an upcoming paper. Some additional detail is offered in the portions following.

Limits

In the normal course of operations, when an agency has an application to run that requires a spectrum allocation, it shall present a specification for the application to the FSS. The FSS shall respond with a proposal for running the application consisting of its specification of a method of meeting the application's needs while reducing its spectrum footprint.

Typically, the FSS specification would consider equipment, networks, and spectrum, including opportunities to share spectrum with the commercial sector, other agencies, or unlicensed systems. Sharing spectrum in this connection includes operating a virtual network over general-purpose facilities

If the agency wishes to use spectrum assigned to the federal government, it shall follow the FSS recommendation. If it does not agree with the FSS recommendation, it can contract with a commercial provider who has its own spectrum license and it may use unlicensed spectrum; but it may not operate equipment on a government frequency in a manner inconsistent with the FSS recommendation.

This provides the FSS with authority and also creates checks and balances on its power with the commercial/unlicensed escape clause. The funding for a commercial option comes from the agency's budget. The FSS is free to sub-license unused federal spectrum to commercial operators. When the FSS sub-licenses, the revenue it receives goes into its budget, and revenues in excess of expenses are returned to the treasury.

Guidelines and Financing

The FSS will operate under a guideline of reducing the federal spectrum footprint by 50% every five years, with freed spectrum going to the private sector as licensed or unlicensed assignments. After the first five-year period, the FSS's budget will come from spectrum licenses it sells at auction, the gains it makes from investments, license fees it collects by sub-licensing government spectrum, and license fees from intellectual property it finances.

Unresolved Issues

This is a very preliminary plan, which by its nature leaves a number of questions unanswered for the time being. These include the following:

1. **Expanding the federal mission:** While the overall goal of reducing the federal footprint is understandable, it does not address the desire of federal

agencies to implement new systems and applications that use spectrum to serve the people. If the goal of moving spectrum from government bands to commercial ones is rational because it enables more intense application development by the commercial sector, isn't it also rational to permit the development of new systems by the government? One partial answer is that the five-year goal is looser than commercial performance, where efficiency is doubled every 30 months. This leaves room for expanded missions and feeds the auction system at the same time, but it's not a total answer. Government needs to use spectrum with an eye toward utility as well as efficiency.

2. **Conflicts of interest:** A profit-motivated authority with the power to monetize federal spectrum will surely operate in its own interests where they conflict with those of government. If incentives are properly aligned, this is not necessarily a problem; otherwise it is.
3. **The insatiable appetite for unlicensed spectrum:** Advocates for unlicensed spectrum have proven themselves more adept at seeking and winning allocations from the FCC than at actually building and operating networks. How will the FSS assess the demand for additional licensed spectrum with the apparently insatiable appetite for additional unlicensed spectrum? What utility models address this trade-off?
4. **What becomes of the FSS at the end of its ten-year mandate?** It could effectively declare bankruptcy, be converted into a federal agency, or operate as an unrestricted commercial entity. Its consulting and rule-making functions would still be valuable even if it didn't have spectrum to license.
5. **How much government ownership, if any, should the FSS have?** It would certainly be desirable for taxpayers to enjoy some of the benefit of the FSS's profit-oriented activities.

Opinion Editorial: Stephen DeMaura, President

It is no secret that the U.S. job market could use a good boost. After years of struggling under the weight of heavy regulations and uncertainty, most Americans unfortunately have felt pains from the sluggish economy. But instead of doing everything they can to spur job creation, new technologies, and economic growth, policymakers in Washington are considering a proposal that could turn a forthcoming auction of broadcast spectrum – the lifeblood of the thriving mobile economy – from a tremendous opportunity for our economy and the nation's bottom line into an irreparable failure.

Spectrum auctions are nothing new to the FCC. This auction, however, is different because it will be a two-sided auction. First, broadcasters will have an opportunity to give up their spectrum, but they are hesitant to do so if the FCC places unwise bidding restrictions for the second phase of the auction involving the wireless industry. Wireless carriers will then bid on available spectrum, but only if they are allowed to without restrictions.

The wireless industry requires additional spectrum to serve its growing customer base and their growing reliance on mobile devices to go online, capture and stream video, and make use of other data-intensive services. For instance, a study done by eMarketer recently found that 64.3% of mobile users in 2014 will use their mobile device to access the Internet, and an estimated 79.2% of mobile users will use their device to access the Internet by 2017. These users are not just going online to surf the web, they are increasingly using mobile devices through the course of their work or using them to look for jobs.

After all, the U.S. wireless industry is valued at nearly $2 billion, which is larger than publishing, agriculture, hotels and lodging, air transportation, motion picture and recording and motor vehicle manufacturing industry segments. That equate to a lot of jobs – as in 3.8 million Americans are directly and indirectly employed by the wireless industry, and these are generally high-paying jobs.

For those reasons, ensuring the upcoming auction is designed to maximize the amount of spectrum that is freed up for commercial use is imperative.

Limiting who can bid or what they can bid on, as the FCC is currently considering, is a recipe for disaster. The best path to success is an open auction that puts all bidders on an equal footing. History and countless studies demonstrate this. Consider the 700 MHz auction: The FCC could not force companies to participate. Sprint and T-Mobile – the very same companies who are relentlessly lobbying the FCC to restrict AT&T and Verizon's ability to bid – sat out. Additionally, all but two of the winners from that auction were considered small bidders, and the D-Block did not have a buyer because the rules around it assumed Frontline would be the buyer, but Frontline dropped out. Clearly, open competition, not attempts to manage competition, lead to the best outcomes.

While there is much riding on the success of the incentive auction, more can and should be done to free up additional spectrum for more economically beneficial use like incentivizing the government to free up some of its vast, yet underused, spectrum.

The government has 60% of the spectrum that is best suited for mobile use, and it averages nine years to bring spectrum to market. Those statistics are unacceptable, especially as CTIA has said that bringing 500 MHz of spectrum to market by the end of the decade will create at least 350,000 new jobs. The White House has also recognized the need for "greater spectrum availability," noting that it "creates jobs for American innovators engaged in app development, content creation, and network design and build out."

Although, there has been some progress as spectrum used by the Department of Defense and others – the 1755-1780 MHz band – is set to be auctioned this fall as part of the AWS-3 auction.

Agencies and policymakers must build on this positive momentum and work toward freeing up more government spectrum so that we have a sustainable, long-term spectrum pipeline to fuel the mobile revolution. Coupled with free and open spectrum auctions, these commonsense policies could pay off in the form of renewed investment in the American economy, job creation, and even some revenue for the U.S. Treasury.

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April 25, 2014

Honorable Fred Upton
Chair
Committee on Energy & Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

Honorable Henry Waxman
Ranking Member
Committee on Energy & Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

Re: Comments to Committee on Energy & Commerce White Paper – "Modernizing U.S. Spectrum Policy"

Dear Chairman Upton and Ranking Member Waxman:

On behalf of AT&T Services, Inc., I am pleased to submit our comments to the Committee on Energy & Commerce's White Paper – Modernizing U.S. Spectrum Policy. We appreciate the Committee taking on this important effort.

We look forward to working with the Committee as this process moves forward.

Sincerely,

[redacted]

EA#1104605

Modernizing U.S. Spectrum Policy
House Committee on Energy & Commerce
April 25, 2014

As stated in our January 31, 2014 filing, AT&T commends the Members of the House Energy & Commerce Committee for undertaking this much-needed effort and welcomes the opportunity to contribute to the conversation on potential modernization of the Communications Act of 1934 ("the Act"). The focus of this White Paper – Spectrum Policy – raises one of the most significant issues of potential reform as the Committee conducts its review. The industry's continued ability to innovate and invest to meet the burgeoning demand for mobile data depends upon the availability of spectrum. As such, the issues that the Committee's questions concern– e.g., spectrum allocations and licensing; establishing and enforcing service rules; build-out requirements and operating parameters; and facilities siting – could produce devastating consequences to the nation's economy and investment if they are not handled correctly. It is in part for this reason that in our January 31st Comments, Spectrum Management was one of the five main principles AT&T submitted that a *new* Communications Act should be organized around.

As the Committee conducts its review of Spectrum Policy, there are several key principles that can help frame the discussion:

- The wireless industry is vigorously competitive. The facts set forth in the FCC's Annual Reports to Congress on wireless competition make that abundantly clear. As those reports document, subscribership is at an all-time high, output is increasing dramatically, investment is flourishing and did so even when the country was in the depths of recession; real per-unit prices continue to fall, innovation remains robust, consumer choice among equipment (e.g., handsets) and service plans is rising, and consumers are receiving much more for every dollar they spend and face no significant barriers to changing providers when they wish to do so. The rivalry among wireless providers is self-evident to any consumer that turns on her television and witnesses the heavy advertising by all carriers that are jockeying for an edge in this hotly competitive market.
- Exploding demand for wireless services means that significantly more spectrum must be made available. The FCC's National Broadband Plan concluded that "[i]n order to meet growing demand for wireless broadband services, and to ensure that America keeps pace with the global wireless revolution, 500 megahertz should be made newly available for mobile, fixed and unlicensed broadband use over the next ten years." *Connecting America: The National Broadband Plan,* Recommendation 5.8.

- Government review of spectrum acquisitions should be framed by the antitrust laws. Apart from antitrust considerations, there should be no restrictions on any carrier's ability to obtain additional spectrum through auctions or through the secondary markets. Policies that restrict spectrum acquisitions without a solid antitrust basis prevent carriers from serving their customers and growing their businesses and thereby diminish competition, investment and innovation. To reduce regulatory uncertainty, the FCC should utilize a spectrum screen in reviewing spectrum acquisitions. There should be a safe harbor for spectrum holdings that do not exceed the screen. Holdings that exceed the screen should be subject to further review, consistent with longstanding practice.
- All spectrum that is suitable and available to provide mobile wireless services should be included in the screen. Spectrum is "suitable" if it is technically capable of supporting mobile service, is licensed for mobile use, and is not so encumbered by other users such that it cannot be feasibly deployed for commercial mobile use. Spectrum is "available" if it will meet the suitability conditions in the near term, which the Commission has traditionally defined as within two years.
- Both licensed and unlicensed spectrum serve very important purposes and present opportunities for additional allocations:
  - Spectrum below 3 GHz is better suited for licensed services, particularly for mobile wireless broadband.
  - Spectrum above 3 GHz is better suited for unlicensed services
- Licenses should be exclusive use to the greatest extent possible. Exclusive use provides for certainty in operation, with defined rights and interference protection. This certainty incentivizes the investment necessary to build-out infrastructure.
- As the ability to allocate spectrum for exclusive use becomes more challenging, it may be necessary to consider spectrum sharing – but this should only be a last resort. While geographic sharing is well understood, sharing via database access and/or through sensing capabilities is less proven, particularly in the mobile environment. Care should be taken to ensure, to the extent that exclusive licensing is not possible, that sharing is feasible and permits efficient use of the spectrum.
- Spectrum management's role is first and foremost to manage interference. Advances in technology have allowed spectrum to be used more intensely and more efficiently. Ultimately though, there are many scenarios where technology cannot yet solve interference issues. The FCC and NTIA manage those issues today and should continue to do so in the future.

1. **As discussed in white paper #1 on Modernizing the Communications Act, the telecommunications industry has experienced a great deal of convergence in recent years. One result is that the current licensing structure at the FCC may no longer be the most efficient or appropriate method to maximize spectrum use. The FCC is**

responsible for licensing spectrum for a number of services, including public safety, fixed and mobile wireless, broadcast television and radio, and satellite. Although many of the processes are the same among these services, the licensing authority is housed in disparate bureaus. What structural changes, if any, should be made to the FCC to promote efficiency and predictability in spectrum licensing?

Today, there are different licensing requirements for different services, and there are even different requirements for similar services using different spectrum frequencies. Differences relate to such matters as the license term, licensed area, build out requirements, etc. In some cases, these differences are appropriate and necessary because of technological, economic or other issues. For that reason, it may well be that the different bureaus with expertise over the particular service remain best positioned to address the licensing requirements unique to that service and that a restructuring of the FCC is unnecessary from a pure licensing standpoint.

That said, however, retaining the expertise in the individual bureaus does not mean that the bureaus cannot work together more constructively. Standardization/reworking of the license format as suggested by the FCC's Process Reform Staff Working Group[1] and rationalization of the various bureaus that handle licensing should be considered in order to draw out any efficiencies that can be garnered. For example, there are some 'best of class' practices that the Wireless Bureau has followed that could and should be adopted by the other bureaus.

2. **Spectrum users are allowed to operate without an FCC license—subject to certain technical rules—in spectrum that is designated as "unlicensed." In 1985, the FCC opened up frequency bands, including the 2.4 GHz band, for unlicensed communications, and has since allocated other bands specifically for unlicensed operators. Users of unlicensed spectrum do not have exclusive use rights and are subject to interference by others. While operators do not need a license, they must abide by other regulatory safeguards, including authorization of equipment, accepting any interference and not causing harmful interference to others, and ceasing operations upon FCC notification. There is vigorous debate over the appropriate role for unlicensed spectrum in the wireless ecosystem, particularly following the passage of the Spectrum Act. The Act requires the FCC to auction all spectrum made available by the incentive auction, but allows for unlicensed use in guard bands. Some contend that there is an ample amount of unlicensed spectrum available and that assigning spectrum via exclusive licensing is the most effective, efficient, and economically responsible way to allocate spectrum. Others argue that repurposed spectrum should be allocated for unlicensed use for similar reasons. What role should unlicensed spectrum play in the wireless ecosystem? How should unlicensed spectrum be allocated and managed for**

[1] *See*, *Report on FCC Process Reform*, January 30, 2014, http://www.fcc.gov/document/process-reform-working-group-open-meeting-presentation

long-term sustainability and flexibility?

Unlicensed spectrum has a critical role in wireless communications and infrastructure. Aside from uses such as Bluetooth, remote controls, cordless telephones, garage door openers, and radio frequency identification (RFID) applications, unlicensed spectrum supports untethered Internet access in homes, businesses, and public spaces. In this way, unlicensed spectrum serves to extend wireless broadband coverage and usage. But there are also drawbacks to unlicensed usage that limit its utility. For example, to minimize interference, unlicensed spectrum is generally subject to power output limitations, which restrict the size of the areas it can serve. But even with those limitations, unlicensed use is still subject to interference in many instances, which can cause communications to be disrupted.

Because of the need to limit propagation of unlicensed signals, it makes little sense to use spectrum with high propagation capabilities for unlicensed services. For this reason, unlicensed operations are best suited to frequencies above 3 GHz, which do not offer the wider propagation characteristics of frequencies below 3 GHz. Keeping areas served by unlicensed spectrum relatively small when compared to licensed operations means that the unlicensed operations can reduce their vulnerability to uncoordinated devices operating on the unlicensed bands. In contrast, spectrum below 3 GHz propagates further and is well suited for licensed use. Exclusive licensing of that spectrum offers a much higher degree of interference protection and thereby creates greater incentives for the substantial capital investments required to support regional and nationwide network coverage.

Currently, the Commission has pending proceedings looking into how technology can increase the usefulness of spectrum above 3 GHz. One proceeding proposes a Spectrum Access System by which spectrum in the 3.5 GHz band can be shared among incumbent, "priority" and unlicensed users. Another proceeding has instituted changes in the rules governing unlicensed use of spectrum in the 5 GHz band. These changes will improve the operation of Unlicensed National Information Infrastructure devices while affording increased interference protection to radar devices operating in adjacent bands. These proceedings, and others like them, should continue to explore ways by which unlicensed spectrum above 3 GHz can be used with greater efficiency.

3. **Spectrum sharing is one proposed technological solution that addresses the issue of spectrum scarcity and encourages efficiency. There are multiple ways to share spectrum, including geographic sharing, temporal sharing, and sharing through dynamic spectrum access. In July 2012, the President's Council of Advisors on Science and Technology (PCAST) issued a report on ways to realize the full potential of government held spectrum. The report concluded that sharing is the most efficient way to utilize spectrum and directed the Secretary of Commerce to immediately identify 1,000 MHz of federal spectrum for shared use. However, others assert that spectrum**

sharing is only part of the solution to spectrum scarcity and that clearing unused or underused federal for exclusive commercial use is a vital part of any strategy for maximizing spectrum resources. In order to enable this sort of reallocation, bipartisan legislation has been introduced in the House that would allow government spectrum users an option to relinquish spectrum and receive a portion of net auction revenues instead of relocation costs, a structure similar to that of the broadcast television spectrum incentive auctions. What should be done to encourage efficient use of spectrum by government users?

Regarding spectrum below 3 GHz, AT&T agrees with the approach to sharing reflected in the Spectrum Act (§ 6701(j)): sharing should be employed generally as a last resort, when clearing and exclusive licensing are not feasible due to technical or cost constraints. One present example of spectrum that appears to meet that steep standard is the 1695-1710 MHz band. Typically, though, clearing and exclusive licensing are the best ways to incentivize the substantial level of commercial investment necessary to put spectrum to its highest and most productive use. For instance, such clearing and exclusive licensing provides the legal certainty, interference protection, and coordination minimization required to stimulate robust capital availability and expenditures.

Spectrum sharing likely will have to play a constructive role in maximizing efficient spectrum use, however. In that regard, the development of sharing technologies in the 3.5 GHz band is likely to provide important information regarding how well sharing will work, particularly when employing a database model. Apart from geographic sharing through the use of exclusion zones, spectrum sharing technologies and methodologies are in a nascent state. For example, use of a spectrum access system ("SAS") has not been tested, and spectrum sensing has not yet proven viable, especially in a low power mobile environment.

With respect to encouraging efficient use of spectrum by government users, the Institute for Defense Analyses Science and Policy Institute (IDA) recently issued a Report (pursuant to a contract with the Office of Science and Technology Policy in the Executive Office of the President (OSTP)) examining that subject.[2] Of the incentives reviewed in the Report, the approaches that AT&T believes hold the greatest promise are those that would provide for a general Spectrum Relocation Fund. These proposals would incentivize agencies to identify spectrum for relinquishment by providing them with funds – up front and independent of any particular auction – to allow them to engage in planning, research and development, to identify alternative frequencies suitable to their operations, to develop and test upgraded, more spectrum-efficient equipment, and to examine commercial, off-the-shelf (COTS) solutions. Current law provides for a Spectrum Relocation Fund (SRF) taken from the proceeds of spectrum auctions, but agencies may draw on the SRF only to cover the costs of relocation from the spectrum

[2] https://www.ida.org/upload/stpi/pdfs/p5102final.pdf

auctioned, and funding is only available after the auction has ended. An agency may be reluctant to incur the potentially significant up-front costs of evaluating whether current operations could be relocated, or whether more advanced, spectrum efficient equipment may be developed, if to do so would require them to draw funds from their annual appropriations, potentially impacting the agency's fundamental mission.

AT&T also agrees with recommendations made by CSMAC's Incentive Subcommittee and in the National Broadband Plan to broaden the uses to which spectrum relocation funding like the SRF may be applied. Moreover, AT&T recommends that the SRF be made a general fund. The auction revenues from the 2006 AWS spectrum auction, for example, greatly exceeded the eventual relocation costs. Under current law, these funds will eventually disappear from the SRF. AT&T recommends that Congress consider making the SRF a general fund, with any remaining auction revenues in the SRF available for agencies to explore whether other spectrum bands could be made available for commercial use. NTIA and/or the FCC could identify and prioritize federal spectrum allocations for possible reallocation to commercial use, and the affected agencies would be able to apply for funding from the general SRF to cover the up-front R&D costs necessary to evaluate alternative spectrum, equipment, or COTS solutions. And any funds received in this manner would be in addition to, not in lieu of, funds needed later to defray relocation costs.

In addition, AT&T supports exploring the approach contained in the Federal Spectrum Incentive Act proposed by Doris Matsui (D-CA) and Brett Guthrie (R-KY). Under the proposed legislation, agencies would be incentivized to relinquish or share federal spectrum by allowing them to receive one percent of the revenues generated from the auction of the reallocated spectrum. Under the proposed legislation, the revenue would not be duplicative of any funds drawn from the SRF – any funds received from the SRF would be subtracted from the agency's share of auction revenues. AT&T believes that this approach would provide an appropriate incentive to federal agencies. Indeed, higher percentages should be shared with agencies that relinquish, rather than share, their federal spectrum allocations. Furthermore, revenue received by an agency from the auction should be protected from being "zeroed out" in the budget process via funding cuts concerning other agency matters.

AT&T notes, however, that incentives that operate only on the "seller" side of a market are not likely, in and of themselves, to be completely effective. The spectrum bands agencies ultimately determine to offer may not be suited to the commercial uses that would most benefit the public interest. Moreover, agencies do not operate in accordance with a profit motive. Accordingly, incentives like the spectrum property rights proposals, on their own, may be inefficient in striking a proper balance in allocating spectrum bands between federal and commercial users. In addition, relying on individual agencies to determine which frequencies should be made

available to commercial users could result in band fragmentation, which could limit both the utility and value of any spectrum ultimately offered to commercial users.

For these reasons, it likely will be necessary to also explore and include some directed reallocation approaches to ensure that the needs of the public for commercial services that require spectrum use can be met while ensuring that the missions of the agencies are not compromised. The FCC is well-positioned to identify the bands best suited to serve commercial needs and to consider band plans and service rules that will guard against fragmentation or unwieldy sharing proposals that would impair the utility of reallocated spectrum. To ensure that cost/benefit decisions take into consideration all factors, including the need for commercial spectrum and the importance of spectrum allocations to the accomplishment of important federal goals, free (to the extent possible) of political pressures, it also may be useful to consider whether an independent commission, perhaps like the Defense Base Closure and Realignment Commission, might be well suited to consider how best to resolve the competing demands for spectrum between public and private sectors in a way that is both fair and fiscally responsible.

4. **Given the enormous economic benefits of innovation spurred by commercial spectrum availability, both the government and the private sector are concerned with making more spectrum available to meet commercial demand. When discussing available resources, the FCC considers spectrum to be "currently available" if providers have the legal authority to build out and provide services using that band, or "in the pipeline" if it is not currently available for commercial services but there are government plans to make it available to commercial providers within the next three years. Congress and the FCC have worked to increase the amount of spectrum available to commercial providers, including through the provisions for auctions and relocation in the Middle Class Tax Relief and Job Creation Act. What other steps can be taken to increase the amount of commercially available spectrum?**

Because the federal government is, by far, the largest user of spectrum, the steps described above in response to Question 3 to encourage federal users to relinquish their spectrum should be carefully examined as a means to increase the amount of commercially available spectrum. Moreover, Congress could more closely review and attempt to expedite the government processes already underway to identify spectrum bands suitable either for commercial use or for government relocation to clear spectrum for commercial use.[3] One way to facilitate those processes is to encourage open and constructive dialogue between government agencies and commercial wireless operators. The CSMAC process, for example, could assist in identifying which spectrum bands do and do not have commercial interest, and thus which spectrum bands should and should not be considered for government relocation. Furthermore, Congress could

[3] *See*, for example, http://www.ntia.doc.gov/report/2010/assessment-near-term-viability-accommodatingwireless-broadband-systems-1675-1710-mhz-17.

steer government agencies towards purchasing spectrum access from commercial providers whenever feasible, rather than operating their own systems on their own spectrum.

5. In order to issue spectrum licenses, the Communications Act requires the FCC to make an affirmative finding that granting the license serves the public interest, convenience, and necessity. Moreover, the Act prohibits the FCC from basing its finding on the expectation of auction revenues. Should the Act permit the FCC to use expected auction revenue as the basis for a public interest finding? What criteria should the FCC consider as part of its analysis?

A fundamental objective of competitive bidding is ensuring that spectrum is allocated efficiently, to its best and highest use, by awarding it to the party who places the highest value on the spectrum. 47 U.S.C. § 309(j)(3). Thus in establishing a competitive bidding process for spectrum auctions, the Communications Act has effectively, albeit not explicitly, directed that expected auction revenues be a basis for a public interest finding.

In this respect, 47 U.S.C. 309(j)(7)(A), which prohibits "expectation" of auction revenues from consideration in crafting auction rules regarding certain subjects, makes little sense. Simply put, since the core purpose of competitive bidding is to award licenses to those who value them most, as expressed by their bidding, it should be a given that auction revenues are fundamental to any public interest analysis. Reading 47 U.S.C § 309(j)(7)(A) too literally or broadly would thus contradict the core purpose of competitive bidding. Moreover, that provision, improperly construed, could artificially suppress auction revenues and thereby impede accomplishment of other crucial goals that Congress presently wants auctions to address – such as funding incumbent relocation, public safety network development, wireless technology research, and deficit reduction – and goals that Congress may in the future want auctions to address – including facilitating efficient use and relinquishment of spectrum by the federal government. Consequently, that provision should be read narrowly; and Congress should seriously consider revising or repealing it.

The importance of auction revenues is especially evident in the context of the upcoming 600 MHz incentive auction authorized by the Spectrum Act. In a typical auction, unlike the incentive auction, the Commission first defines the frequency blocks it commits to clear and simply asks carriers to bid for those blocks. If the auction rules are suboptimal, less money is deposited into the Treasury, but consumers nonetheless reap the benefits of greater bandwidth for mobile broadband applications. In the incentive auction, by contrast, the Commission must persuade a variety of auction participants to satisfy the statutory auction-closing criteria for any target level of spectrum: namely, forward-auction revenues must exceed winning reverse-auction bids plus administrative and estimated repacking costs. If they fall short of that benchmark, the Commission will have to settle for less cleared spectrum, and in the worst-case scenario, the auction could fail altogether.

That fact has profound consequences for the decisions the Commission makes in designing the forward and reverse auctions. Those decisions will determine not only how much money changes hands, and not only whether spectrum goes promptly to providers able to extract the most value from it, and not only whether substantial funds will become available for public safety network development and deficit reduction, but also *how much spectrum* is available to commercial wireless providers and their customers in the first place. Suboptimal decisions would not only reduce revenues, but deprive consumers of the primary benefit that Congress sought to achieve in the Spectrum Act: reallocating as much spectrum as possible for commercial mobile broadband services. Thus, the Commission must be able to consider revenue maximization as a factor in the incentive auction proceeding.

Another vital point flows ineluctably from the foregoing discussion: the FCC should not limit AT&T's – or any other entity's – ability to participate in the incentive auction. Not only would such a limitation be unlawful (Spectrum Act § 6404), it would be grossly unwise. Common sense – supported by substantial evidence in the FCC's incentive auction record – dictates that restricting auction participation would diminish auction revenues, threatening accomplishment of the Spectrum Act's goals described above.

Congress has expressly required the Commission to award spectrum through a system of competitive bidding. This is based on the assumption that market-based competition for licenses will result in an efficient allocation of spectrum that will serve the public interest. The adoption of competitive bidding carries with it the principle that spectrum licenses will be awarded to the highest bidders – those who contribute the most auction revenue – and that such a result is in the public interest. This is a clear Congressional mandate. For the FCC to disregard potential auction revenues when making rules regarding systems of competitive bidding would be illogical if not unlawful. To the extent that any provision of the Act can be properly read to prevent the FCC to base public interest findings on the expectation of auction revenues, that provision should be repealed as contrary to the Act's purpose of awarding spectrum through a system of competitive bidding.

6. **The FCC's existing process manages spectrum use through allocation and assignment—bands are allocated for specific services or classes of users, and licenses for use of specific portions of spectrum are assigned to entities. Many of the existing allocations were made because certain spectrum bands are better suited for certain uses. However, changes in technology have changed assumptions over the years. While restrictions have eased in recent years, there are still certain limited-use spectrum licenses. Flexible use licenses permit licensees to use their spectrum for any service, including wireless, broadcast, or satellite services. Should all FCC licenses be flexible use? In what instances should the Commission exercise control over the service offered? How can the Act enable better use of spectrum, either flexible or specified?**

In general, flexible use of spectrum is good policy because it increases the utility of the resource. Consistent with section 303(y) of the Communications Act of 1934, FCC policy currently permits flexible use in the SMR spectrum, in the 932 to 932.5 MHz and 941 to 941.5 MHz bands, and other spectrum bands, such as 700 MHz and Advanced Wireless Services spectrum, may be used for mobile telephone services similar to those provided using broadband PCS spectrum.

However, it is important to recognize that some uses of the same spectrum are not compatible and will produce harmful interference to one or both services. For example, having the same spectrum block used for a high-powered broadcast service in the same market as it is used for lower power mobile wireless service can lead to co-channel or adjacent channel interference just as the use of time division duplex and frequency division duplex in the same frequencies can produce interference. Obviously, while flexible use is to be encouraged, it should not, as a policy, be exalted over the risk of interference. The FCC's principal tool for exercising control over a spectrum block is to ensure that incompatible uses of spectrum are not permitted to cause interference to neighboring services.

7. **Finite supply and ever increasing demand have created the scarcity around which the FCC's regulatory controls are based. The FCC has placed limitations on spectrum holdings in a number of ways. In mobile wireless, the Commission has implemented policies that included the cellular cross-interest rule, the Personal Communications Service (PCS) cross-ownership rule, and the Commercial Mobile Radio Services spectrum cap. Currently, the Commission conducts a case-by-case analysis of spectrum aggregation for each entity. The two-part "spectrum screen" first analyzes changes in market concentration that would result from the proposed transaction, and then examines the amount of spectrum that is suitable and available on a market-by-market basis. Prompted by the passage of the Middle Class Tax Relief and Job Creation Act, the FCC initiated a proceeding to review existing policies regarding mobile spectrum holdings to determine whether they still satisfy the statutory goals of promoting competition and avoiding excessive concentration of licenses, given changes in technology, spectrum availability, and the overall marketplace. The FCC has considered other tools to try and enhance competition within the wireless services market. Among these are spectrum "set-asides," where blocks of spectrum are reserved for a particular type of bidder; bidding credits, which provide a discount on winning bids to small businesses or to specific groups like women and minorities to encourage bidding; and auction design, including reserve prices, package bidding, and proposed restrictions on bidder eligibility. Given the complexity of spectrum auctions, these policies have been criticized for altering the playing field and distorting outcomes. What principles should Congress and the FCC consider when addressing spectrum aggregation limits? How has the converging marketplace and growing demand for services changed the discussion of spectrum aggregation?**

The purpose of a spectrum screen is to identify spectrum holdings that could foreclose competition. This concern should be the touchstone of spectrum aggregation policy. Limiting auction participation without a finding that such limits are necessary to prevent market foreclosure will invariably reduce auction revenues and deprive the public of the highest and best use of the auctioned spectrum.

To address competition concerns potentially arising from spectrum aggregation, the FCC currently relies – to a large degree appropriately – on a case-by-case evaluation of spectrum transactions. Although the Commission had used various forms of spectrum caps, set-asides and other restrictions to try to regulate competition in the early days of wireless, once competition took hold, the Commission properly determined that such regulatory interventions would impede the development of competition by preventing spectrum acquisitions that would lead to greater scale, lower prices and increased competition. As a result, the Commission adopted a "case by case" approach designed to allow competitive, rather than regulatory outcomes.

In this case by case review, the FCC first employs a "spectrum screen" to determine whether a proposed transaction would result in a carrier aggregating more than approximately one-third of the total spectrum suitable and available for the provision of mobile services in any Cellular Market Area, or "CMA".[4] The FCC chose this one third trigger many years ago, and AT&T believes that this threshold is now, if anything, overly strict.

Until recently, spectrum aggregations of less than one third of the total available spectrum were deemed to present no threat to competition, and required no further analysis. Recently the FCC has suggested that it may not always follow such a "safe harbor" approach. If a proposed transaction would result in the aggregation of more than one third of the available spectrum, then regarding each of the CMAs where the spectrum screen has been exceeded, the FCC examines the totality of the circumstances to determine whether the potential harms to competition, innovation, and spectrum efficiency warrant remedial action, such as blocking the transaction, requiring spectrum divestitures, or imposing conditions.

AT&T believes the FCC should continue to utilize a spectrum screen in assessing spectrum acquisitions and that the current approach to the screen should be clarified and/or adjusted in five respects: (1) add to the "denominator" of the spectrum screen certain spectrum that is presently excluded despite being suitable and available for providing mobile services, such as the H Block, AWS-4 and especially so-called "BRS" and "EBS" spectrum in the 2.5 GHz band that is largely held by Sprint; (2) consider increasing the screen to a level above one-third of the available and suitable spectrum; (3) reaffirm that the screen will function as a true safe harbor; (4) reaffirm that, in instances in which the safe harbor is exceeded in a particular local market, the

[4] The FCC has not specifically determined the "relevant geographic market" for purposes of this antitrust-like review, but uses the CMA as a surrogate.

Commission will focus its inquiry solely on whether the acquisition of spectrum would foreclose competition in that local market; and (5) re-affirm that any divestitures required by the Commission's spectrum aggregation policy will be conducted at the spectrum holder's discretion. These adjustments would provide greater certainty to market participants and would avoid preventing transactions that are procompetitive, as caps and auction restrictions would do.

AT&T opposes several changes to the FCC's spectrum aggregation policies proposed by other parties. Specifically, (1) the FCC should not sacrifice the flexibility of the case-by-case approach by adopting a hard cap on the amount of spectrum that a carrier may possess in a given local market; (2) the FCC should not, for purposes of implementing the spectrum screen, weigh spectrum under 1 GHz (low frequency spectrum) more heavily than spectrum above 1 GHz (higher frequency spectrum), especially in a manner that would effectively deprive AT&T of the ability to acquire any meaningful amount of additional low frequency spectrum – via the incentive auction, other auctions, the secondary market, or otherwise; and (3) the Commission should not adopt a spectrum screen that applies to the nation as a whole as opposed to individual local markets.

Due to its dangerously deceptive simplicity, and its potential to cripple AT&T's ability to serve its existing customers and compete fairly for new customers, the proposal to weigh spectrum under 1 GHz more heavily than spectrum above 1 GHz merits further discussion. The mantra of the proposal's proponents is that low frequency spectrum propagates further than higher frequency spectrum. As a result, they claim, fewer cell sites are needed to build out low frequency spectrum than higher frequency spectrum. This argument is a red herring. First, while it is true that low frequency spectrum propagates further than higher frequency spectrum, in today's world that difference is becoming increasingly irrelevant. That is because to address the explosive growth of mobile broadband usage, all carriers must "densify" their network with more cell sites, regardless of whether they are using low frequency or higher frequency spectrum. From a practical standpoint, then, there is little cost savings to be gained by using low frequency versus higher frequency spectrum in the more densely populated areas where capacity constraints have necessitated the deployment of more cell sites. Simply, it is *capacity, not coverage,* needs that is driving infrastructure costs today.

Second, even in rural areas where it may cost less to deploy low frequency spectrum versus higher frequency spectrum, that difference should be immaterial to the FCC's spectrum screen because basic economic principles dictate that this cost difference will be reflected in the cost of the spectrum itself. In that regard, the cost of providing service is not just the cost of building cell sites, but the cost of acquiring spectrum *and* deploying infrastructure. And if one type of spectrum (e.g. higher frequency spectrum) is more expensive to deploy, that spectrum will cost less in the marketplace. Conversely, if another type of spectrum can be built out more cheaply, it will sell for a premium in the marketplace. Those who ask the FCC to consider low frequency

spectrum separately from higher frequency spectrum for purposes of its spectrum screen ignore this most basic of economic principles.

Third, the myopic focus on propagation potential ignores other differentiating characteristics between low frequency and high frequency spectrum, including those as to which higher frequency spectrum offers advantages. For example, there is more higher frequency spectrum available; thus it tends to be available in larger contiguous blocks, which are best for addressing capacity constraints and providing higher speeds. In addition, higher frequency spectrum offers equivalent antenna gain with smaller antennas. These are other examples, as well. The bottom line is that both low and high frequency spectrum can be used effectively – and are being used effectively – to compete in the marketplace. There is no basis for a separate low frequency screen or for skewing the screen by according greater weight to low frequency spectrum. Proposals to that end are thinly veiled efforts to game the FCC's screen to the advantage of carriers with thinner low frequency spectrum holdings and to the disadvantage of those with relatively greater amounts of such holdings.

8. **The FCC further promotes efficient use of spectrum through the build-out requirements and operating rules attached to licenses. Build-out rules require licensees to construct and activate infrastructure within a certain timeframe, or risk losing that license. The operating rules require some licensees to return a license if not used for any 12-month period after construction, promoting the active and continual use of spectrum. These provisions help to ensure that spectrum that is not fully utilized becomes available to those who will put it to dynamic use. Should the Act promote competitive and efficient use of spectrum in this way? How effective is the current Act in doing so? How effectively has the FCC used the tools at its disposal to encourage competition?**

The FCC's build-out requirements and operating rules have been effectively crafted, implemented, and enforced by the FCC to foster competition, promote secondary market transactions, and ensure timely and efficient use of spectrum. Where legitimate issues have arisen regarding technology or alleged impediments to spectrum use, the Commission has employed its discretion appropriately to permit the spectrum to be deployed. Accordingly, AT&T does not recommend any changes to the FCC's build-out requirements and operating rules at this time.

9. **As discussed above, interference can pose a major problem to efficient and full use of spectrum by providers. The FCC sets limits on transmissions, but doesn't regulate the receivers used by wireless devices to receive wanted signals and eliminate the noise coming from the other surrounding spectrum bands. Underperforming receivers can prevent a device from operating properly. While the FCC has used tools like guard bands to mitigate the potential for interference, recent examples of receiver overload have shown that these efforts may not be enough as demand for spectrum increases but**

resources become more and more constrained. Some have proposed receiver standards as a solution, but others argue that such a step could result in over-engineering and higher consumer prices. What is the best balance between mitigating interference concerns and avoiding limiting flexibility in the future? Can engineering and forward-looking spectrum strategies account for the possibility of unanticipated technologies and uses in adjacent spectrum bands? How do we promote flexibility without unreasonably increasing the cost of services and devices? Does the Act provide the FCC tools to address this problem?

Many interference issues can be managed and ameliorated by use of up-to-date filters that reject signals from adjacent channels. The devices that commercial mobile radio service ("CMRS") providers use on their networks and make available to their customers follow strict industry standards and are very effective at rejecting adjacent channel emissions. The effect of implementing these up-to-date filters is that the CMRS carriers can maximize the efficiency of their spectrum allocations. However, other receivers are not so efficient and fail to reject many adjacent channel emissions, resulting in a degradation of their service. The use of up-to-date devices with narrower filters would improve the service not only of these carriers but also of the carriers in adjacent bands who must now coordinate with their neighbors whose filtering is substandard. The result is that the efficient, neighboring carriers cannot make the best use of their frequencies.

Even with improved filtering by all carriers and users, guard bands will still remain necessary, particularly in instances when adjoining uses are incompatible. In this vein, like services should continue to be located adjacent to one another to permit each to exploit its frequency allocation as efficiently as possible by reducing the likelihood of interference. The Act gives the FCC a great deal of latitude and discretion to make these decisions, and no change to the Act appears needed to enable the Commission to discharge this obligation.

10. The other governing body of domestic spectrum use is the National Telecommunications and Information Administration (NTIA), which has the authority to assign spectrum frequencies to all federal government owned or operated radio stations under section 305 of the Communications Act. NTIA manages the federal government's use of spectrum, in coordination with the FCC. Distinctions between "federal" or "non-federal" bands of spectrum are administrative creations made through agreements between the FCC and NTIA. The Spectrum Act required NTIA to work with the FCC to identify specific bands for release to commercial use and how to repurpose resources from federal to commercial use, with priority given to options that assign spectrum for exclusive, non-federal use through competitive bidding. In a report on reducing duplication in the federal government, GAO identified spectrum management as 'fragmented' between NTIA and the FCC and urged coordination.[ ] What role should NTIA play in the licensing and management of spectrum? Is their

current role appropriate and necessary, given the potentially duplicative functions of the FCC and NTIA in spectrum allocation and assignment?

As noted, NTIA manages the federal government's use of spectrum while the FCC manages "non-federal" bands. Given the fact that there are ever increasing demands being placed on limited spectrum resources, the overall and coordinated management of the US Government's spectrum resources is critically important.

Both NTIA and the FCC have a role to play, and while the two agencies do coordinate their activities, there is always room for improvement and for greater transparency, particularly into the spectrum needs and uses of the constituent agencies that hold substantial amounts of spectrum.

Moreover, it is important that federal agencies relinquish their unused/underutilized spectrum resources and, if necessary, that those agencies be given the right incentive to do so. In that regard, AT&T has been supportive of measures like H.R. 3674*, "The Federal Spectrum Incentive Act*," which we believe provides a workable alternative to those agencies that have stopped using or have found alternative systems for their wireless communications needs by directly incenting agencies to clear spectrum for commercial auction. This will ultimately translate into economic growth, and, importantly, provide consumers with new and innovative mobile Internet services. The nation's growing spectrum needs call for unique proposals like this and others that will provide federal agencies the funding they need to research and develop new techniques and systems that will allow the agency to perform their mission.

Conclusion

AT&T commends the Committee for tackling Spectrum Policy as the second topic of discussion in its review of the Act. We look forward to continued cooperation and dialogue with Committee Members and Staff on the many important issues that will arise. And, most importantly, we are eager to help the Committee devise a statute that will fully unleash the competitive and innovative potential of the communications industry.

Comments of Atlantic Tele-Network, Inc., on the Committee on Energy and Commerce White Paper – Modernizing U.S. Spectrum Policy

Atlantic Tele-Network, Inc. (ATN) thanks the leaders of the Energy and Commerce Committee for issuing these white papers and for taking the time to solicit the views of industry in advance of an update of the Communications Act. This is a crucial process to determine what changes should be made to The Act to reflect current realities. While much has changed in today's telecommunications marketplace, there are some things which have not. It remains, for example, very much a challenge to serve consumers and businesses in hard to reach areas of the country. This was certainly true at the inception of the 1934 law, and as much as communications technology has changed, those geographical challenges still present our most significant obstacle.

ATN is a publicly-traded telecommunications company operating advanced wireline and wireless networks in North America and the Caribbean. Our expertise has always been in how to bring initial and improved service to underserved areas. Indeed, this remains our most important corporate mission and we have engaged in some very creative approaches to delivering value to those areas. We do this using a range of solutions – from mobile wireless and local exchange services to broadband internet and fiber optic services.

Because we are focused on underserved communities, in some cases bringing the first telecommunications service to an area, we have, of necessity, approached our investment in these projects with patience and a long-term view of the markets we serve. We keep a close eye on network quality and consumer demand to ensure that our activity aligns with what those communities need. And we like to bring the best local management to run our operations because they often know best the specific challenges of each geographic region we serve.

Like most carriers working to serve rural and remote areas, ATN has utilized funding programs where available to expand deployments further into unserved areas, however, our growth is more typically funded by reinvestment of profits from our various businesses. ATN targets private capital to drive broadband buildout in unserved and underserved areas. Spectrum policy decisions significantly impact the certainty, efficiency and targeting of these capital resources.

So, looking at some of the questions posed in the White Paper, we think we bring an unusual mix of insights:

- a deep understanding of wireless broadband networks;
- experience with the equipment used to construct those facilities;
- familiarity with the telecommunications network economics of a rural area;
- experience as a retail carrier and a current wholesale carrier in many western states; and,
- perspective of problem solver in exceptionally challenging telecommunications deployments.

We are uniquely suited to assess the challenges that a small entity focused on rural areas faces under the current system and to offer suggestions on how to address those.

We approached the Modernizing U.S. Spectrum Policy White Paper from this perspective and would like to focus our attention on Questions #4 (how to increase the amount of commercially available spectrum) and #8 (how to promote the efficient use of spectrum). Access to spectrum is a particular challenge for an entity like ATN. We have the capital and expertise to deploy in rural areas but we are often unable to build networks because of inadequate access to the most fundamental element necessary to deploy wireless services more broadly -- spectrum.

Licenses to use public spectrum resources are necessary but not always sufficient to construct facilities in the most hard to serve areas. ATN subsidiaries have successfully utilized federal support, such as USF and stimulus, identified for this purpose. But, it is equally important to look at other ways of promoting private investment. Some areas may be too remote to build without support, but plenty of others could still be sound investments if the proper incentives are in place.

The opportunity most relevant to spectrum policy in the Communications Act Update is to consider new approaches to incentivizing spectrum availability and use that will stimulate deployment of rural wireless broadband. Spectrum availability is very different in rural and urban areas. In most rural areas spectrum is licensed but going unused, so it is more of a question of how to (or *who* will) put it to use. In most urban areas, it is more of a competition question because those areas have multiple providers. In short, there is a difference between competition policy and deployment policy.

Operators that acquire spectrum in rural markets, perhaps as part of a larger spectrum purchase or larger sized geographic license, but don't plan immediately to build out facilities represent potential partners for companies that do want to build it out in the near term but lack the spectrum to do so. The task then becomes to incent those larger operators to make that spectrum available either by selling it on the secondary market or by leasing it and becoming active partners in a plan to build facilities in those underserved markets.

ATN has been successful working with some large operators to develop innovate approaches to build out rural areas with unused spectrum. These types of partnerships can be an effective way to ensure all spectrum is quickly put to its highest and best use. However, getting operators to consider these kinds of innovative approaches can be challenging. If more operators would agree to partition, disaggregate and lease spectrum to another operator with a more rural focus, it could provide significant benefit to rural and other underserved areas. We encourage the Committee to consider policies that encourage this kind of activity.

The FCC's rules governing buildout become key drivers of how that spectrum is used. By either accelerating the buildout timetable, or even delaying it in other cases, and then enforcing those timetables, buildout rules become perhaps the most important lever to increase spectrum availability and use. One potential focus of an update to the Communications Act should be to modernize the guidance and thinking on buildout requirements to create incentives to efficient spectrum use and rural availability.

In addition to a focus on buildout deadlines, we also think that other incentives could be offered and urge the Committee to consider the following.

- The "use it or lose it rules" are helpful, but should also encourage cooperation and partnerships. Rather than punishing companies that do not utilize the spectrum in rural markets, additional benefits can be identified to spur partnerships or secondary market activity to support rapid buildout in rural markets;
- Explore updating and expanding bidding credits for companies that engage in utilizing rural spectrum to deploy new services to unserved and underserved markets;
- Establish clear, reasonable and transparent benchmarks based on the percentage that must be built out by either leasing the spectrum to another company or by partnering with another company which wants to build out the geography;
- Provide longer license terms for those carriers who promote rural broadband buildout; and,
- Focus on particularly disadvantaged areas such as tribal lands to encourage deployment in addition to more traditional rural areas. Given the increased challenges we have faced on tribal lands, additional incentives and trials of proposed spectrum utilization incentives can help expand broadband services to tribal lands in the near future.

We are grateful to the committee for promoting a discussion of this important topic. We feel strongly that the next update of the Communications Act must accept the budget limitations of our federal and state resources. We are not going to be able to afford a Marshall Plan for rural wireless broadband networks. So we must start thinking more creatively about how to incent companies to use private capital to fund these builds. There is a business model that will work here, but expecting a rural business model to mirror the ones that are currently in use in urban markets misunderstands the cost limitations that rural areas present. The committee would be wise to look at convening hearings to look at exactly these questions and helping to develop consensus around a series of private sector solutions using existing levers of license terms, buildout requirements, and market partitioning. We look forward to working with the Chairman and the Committee to identify these incentives and to work diligently to enact them into law. There is much more that can be done to encourage rural wireless broadband buildout but new tools will need to be used to increase the availability of spectrum and promote its rapid and efficient use in rural communities. Challenges like the ones we are facing require bold ideas and a national commitment to making them work. We thank you for your attention to our comments.

For further information, please contact Doug Minster, Vice President, Government and Regulatory Affairs of Atlantic Tele-Network, Inc. at dminster@atni.com.

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April 25, 2014

Committee on Energy and Commerce
2125 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Upton and Chairman Walden:

On behalf of 300,000 supporters and activists across the nation, the Center for Individual Freedom (CFIF) commends the House Energy and Commerce Committee for turning its focus to spectrum policy as it conducts a thorough review of the Communications Act. As our previous comments stressed, CFIF believes a modern Act is long overdue, and the new Act should be rooted in market-based principles, eliminate antiquated silos to spur competition and incentivize private sector investment.

Spectrum is a scarce resource, and demand for it will only continue to rise as consumers increasingly rely on their mobile devices to do things like stream videos, get turn-by-turn directions, communicate with doctors via telemedicine and participate in e-learning. It is important to note that over half of all U.S. consumers possess a smartphone, and 36% of U.S. households have cut the cord entirely, relying only on wireless service. With smartphones requiring 50 times the amount of spectrum of a basic phone, and tablets using 120 times that amount, it's clear the impending supply versus demand imbalance – or spectrum crunch – poses a very real problem.

While progress is being made, more can and should be done to get additional spectrum into the pipeline for commercial use. For its part, the wireless industry has shown an unparalleled commitment to investment and innovation. It invests $94 per subscriber while the rest of the world invests $16, and for every $1 invested in wireless broadband, $7 - $10 is generated for U.S. gross domestic product (GDP). Out of that investment came the app economy, LTE deployment and other products and services that would once have been unimaginable, making the U.S. a global leader in wireless. Just imagine what could come next if more spectrum becomes available for licensed commercial use.

Regulators and policymakers should look to the government for such spectrum. Plans to auction the 1755-1780 MHz band this fall as part of the AWS-3 auction is an example of important progress, but the fact remains that the government currently holds about 60% of the spectrum that is best suited for mobile use. While it certainly has important needs for spectrum, the reality is that the government is an inefficient user and lacks an incentive to be more efficient. The government should consider volunteering to free up unused or underused spectrum for exclusive, licensed commercial use. Where that proves impractical, sharing

should be considered. It bears emphasizing, however, that while sharing could be a small part of a larger spectrum strategy, we should be wary of relying too heavily on it.

Another part of a broader spectrum strategy that warrants attention is the upcoming incentive auction. Congress was right to pass legislation granting the FCC auction authority, but Congressional intent for an open and fair incentive auction appears to be in danger as Sprint and T-Mobile continue to push for bidding restrictions that handicap Verizon and AT&T. A recent letter signed by nearly 80 House Democrats to FCC Chairman Tom Wheeler correctly makes the point that "inviting as many bidders as possible to compete in an open and fair auction on equal terms will allow for the full market price of spectrum to be realized… This approach will also ensure sufficient funding for the construction of a world class, high-speed wireless broadband public safety network and make available the spectrum needed to keep pace with the nations [sic] mobile broadband needs…"

Though the process of re-allocating spectrum may be complex, it's worth it. We are excited about the profound potential the wireless marketplace has to enable new social, economic and political realities for the citizens of America. Absent efficient spectrum allocation and management, however, critical investment and innovation in this space will be stifled. For these reasons, we encourage Congress to continue working towards viable solutions that will enable spectrum to be freed up for commercial use – all to the benefit of consumers and the economy.

We continue to applaud Chairmen Upton and Walden and their staff for their hard work on this important process, and look forward to working closely with the Committee as its work to modernize the Communications Act continues over the coming months.

Thank you for considering the views of our organization.

Sincerely,

Timothy H. Lee
Senior Vice President of Legal and Public Affairs

#CommActUpdate: Modernizing the Communications Act

Modernizing U.S. Spectrum Policy

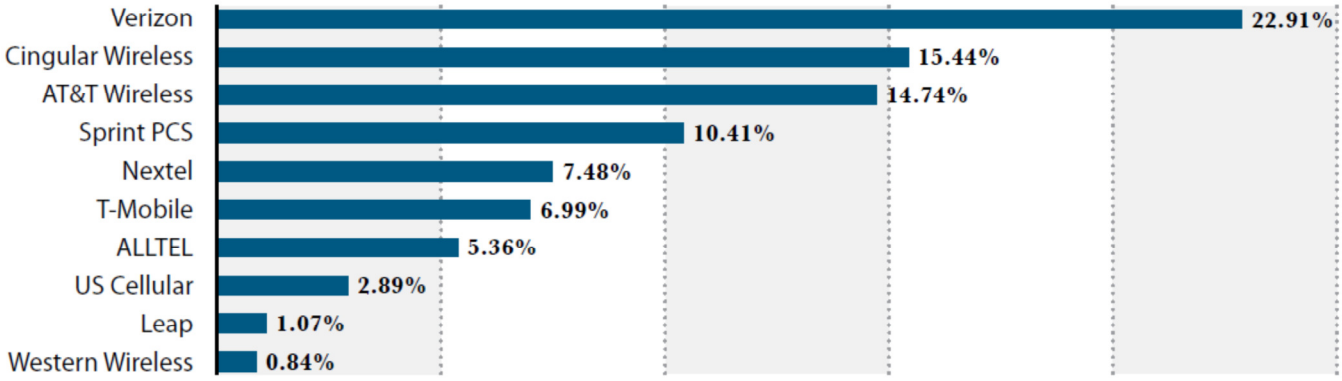
Comments of Competitive Carriers Association

Competitive Carriers Association ("CCA") submits these comments in response to the Energy and Commerce Committee's ("Committee") white paper on modernizing U.S. spectrum policy. CCA's membership comprises more than 100 competitive wireless providers ranging from small, rural carriers serving fewer than 5,000 customers to regional and national providers serving millions of customers. CCA also represents almost 200 Associate Members, consisting of small businesses, vendors, and suppliers that serve carriers of all sizes. Together, CCA's members represent a broad assortment of entities with a shared goal of a competitive wireless market as a critical driver of the U.S. economy. In a wireless world, spectrum policy is a threshold issue for communications competition.

Spectrum is the lifeblood of the wireless industry, and as the Federal Communications Commission ("FCC") has noted, "[a]ccess to spectrum is a precondition to the provision of mobile wireless services." The Committee's overview in its White Paper entitled "History of Spectrum Allocation, Regulation, and Licensing" details the policy progression for spectrum licensing regimes. For the wireless industry, this path follows the progression from a duopoly, where the Commission divided a total of 50 MHz of Cellular spectrum in each area among two carriers, to expanded competition, as competition-promoting spectrum policy including appropriately structured auctions made spectrum available for new competitors. FCC spectrum auctions gave rise to a host of new wireless carriers and sparked competition. It is not a coincidence that, following Congressional authorization for competitive spectrum auctions, the FCC's wireless competition reports to Congress marked growing or effective competition – with numerous carriers at the national and regional level innovating to provide expanded services at declining prices.

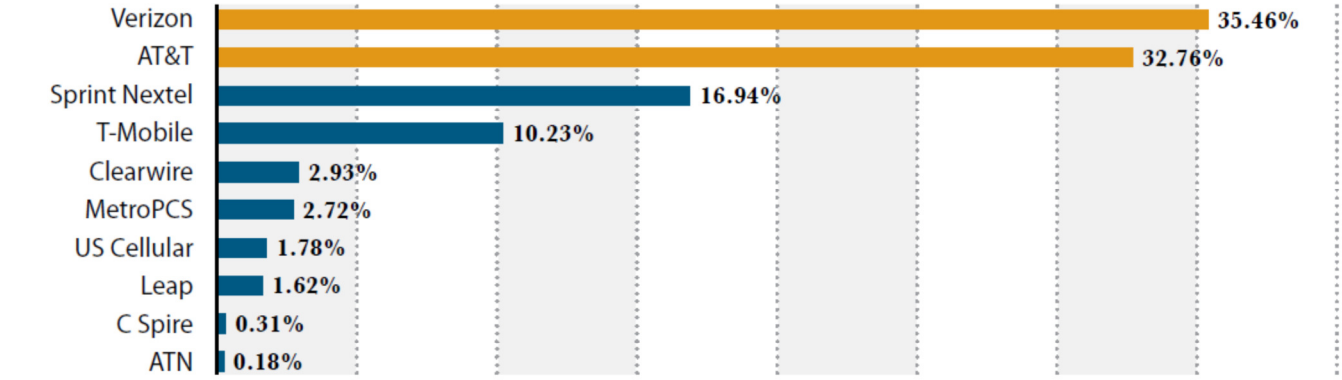
Unfortunately, the years since the last major spectrum auction have been marked by a wave of consolidation, and the competitive gains of the past two decades are in jeopardy as the industry marches towards a duopoly. From 2002 to 2012, the market share of the largest two carriers increased from under 40% to nearly 70%, and this dangerous consolidation trend continued throughout 2013.

Percentage of Top Ten Carriers' Subscriber Share, Year End 2002



Source: *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993*, Eighth Report, 18 FCC Rcd 14783 (2003).

Percentage of Top Ten Carriers' Subscriber Share, Year End 2012



Source: *FierceWireless*, Grading the Top 10 U.S. Carriers in the Fourth Quarter of 2012 (Mar. 15, 2013), *available at* http://www.fiercewireless.com/special-reports/grading-top-10-us-carriers-fourth-quarter-2012. Note that the fifth and sixth largest providers (Clearwire and MetroPCS, respectively) have since exited the marketplace, and the newly-minted sixth largest provider (Leap) is in negotiations to be acquired by AT&T. Additionally, Verizon posted 941,000 retail postpaid net additions in 2Q13; AT&T posted 551,000 additions for the same period. *See* Verizon Communications Investor Quarterly 2Q 2013 (July 18, 2013), *available at* http://www22.verizon.com/investor/DocServlet?doc=2013_2q_qb_vz.pdf; AT&T Inc. Investor Briefing 2Q 2013 (July 23, 2013), *available at* http://www.att.com/Investor/Earnings/2q13/ib_final_2q13.pdf.

Increased market share in an already concentrated wireless industry can be traced directly to aggregation of finite spectrum resources among the two dominant carriers, AT&T and Verizon. Policymakers must promote and implement competitive policies that prevent further consolidation of spectrum resources, and therefore further consolidation within the industry. Absent transparent and upfront spectrum rules, the largest two carriers will continue to aggregate spectrum, thwart access to other critical inputs, and eventually swallow their competitors. Without spectrum policies that promote competition, AT&T and Verizon will cement duopoly control over the market and a return to heavy-handed, utility-style regulation will be necessary to replicate the benefits of competition. Policymakers should act now to ensure consumers continue to enjoy the benefits of competition as mobile broadband use continues to expand.

All Other Critical Inputs Flow from Access to Spectrum

Access to spectrum determines access to all other inputs for providing mobile broadband services. An important, unique characteristic of the wireless industry is the need to secure a private license to use finite public spectrum resources to offer service to consumers. As a finite resource, no amount of capital, innovation, or luck can create new spectrum. Additionally, not all spectrum is created equal, and competitors must have mix of spectrum resources that reside within a healthy ecosystem to provide service. Without access to spectrum bands within a robust ecosystem, competitive carriers lack the scope and scale to access devices or roaming; both are needed to provide a competitive product.

To promote a competitive and open ecosystem, spectrum must be interoperable. Allowing market dominant carriers to frustrate interoperability and create walled-gardens for their spectrum holdings devalues taxpayer-owned, finite spectrum resources licensed to other, would-be competitors. Interoperability is the glue that holds an ecosystem together. Device interoperability is a prerequisite to a well-functioning market; it encourages innovation, increases consumer choice, and reduces costs for consumers by creating greater economies of scale. It also makes roaming technologically possible; non-interoperable devices simply cannot roam on other carriers' networks. Policymakers should continue to evaluate whether all carriers have sufficient, competitive access to both devices and roaming, but must take steps immediately to ensure competitive access to interoperable spectrum.

The concept of interoperability has been a cornerstone principle for wireless competition since the Cellular band was allocated for CMRS use. Recognizing the importance of interoperability on access to devices and roaming and the potential harm of dominant carrier control, the FCC's rules required that devices compatible with one of the two blocks of cellular spectrum must be compatible with the other block as well. Interoperability continued in each subsequent CMRS spectrum band, until AT&T balkanized the Lower 700 MHz band following the close of the auction. Restoration of interoperability last year was a critical step to allowing competitive carriers to utilize their nearly $2 billion spectrum investment. We must not repeat the mistake made in the Lower 700 MHz spectrum. When new spectrum is made available for mobile broadband use, policymakers must impose an upfront interoperability requirement.

Consolidate Spectrum Licensing Authority

In our initial comments on modernizing the Communications Act, CCA noted that policymakers should no longer divide communications laws and regulations into technology or service silos. Policymakers should consider promoting efficiency, predictability, and neutrality by consolidating spectrum licensing within one primary location.

Where the processes are the same among different services, it is inefficient for the authority to be housed in disparate bureaus at the FCC. Charging one office with primary responsibility for spectrum licensing allows for efficiency in processing applications and a central coordination point for the industry, federal users, and consumers. Reducing duplicative functions will stretch limited agency resources and reduce work by industry to interact with multiple offices and supports developing a highly-trained expert staff to process licenses. It is important, however, that a consolidated spectrum office consult with respective offices when making decisions with policy ramifications.

A central office for spectrum licensing provides a streamlined opportunity for further coordination with federal users through the National Telecommunications and Information Administration ("NTIA"). In the Spectrum Act, Congress directed NTIA to identify bands for reallocation from federal to commercial use. A division of labor where NTIA works with Federal users to identify and outline processes for clearing while the FCC structures a competitive auction and licensing mechanisms for commercial use allow efficient steps to reallocate spectrum to meet consumers' demands for mobile services. Part of this process going forward should be establishing a spectrum management plan for the Federal Government and continuing to build on NTIA's work to provide greater transparency regarding federal spectrum use, such as the recently launched www.spectrum.gov. NTIA and the FCC should build upon their work to reallocate the 1755-1780 MHz band for commercial use in the upcoming AWS3 auction and continue to identify and clear additional spectrum bands where possible.

While policymakers should consider all policy options to expand spectrum access, such as shared spectrum and unlicensed allocations, focus should remain on clearing, with a goal of establishing a pipeline of spectrum that will be made available going forward. Fortunately, you do not need to start from scratch, and there are several bipartisan proposed initiatives that merit consideration from policymakers, including:

- *S. 1776, the Rural Spectrum Accessibility Act*

  Sponsored by Senators Amy Klobuchar and Deb Fischer, this bill would direct the FCC to

establish a program to incentivize carriers to partition or disaggregate unused spectrum in rural areas for use by smaller and rural carriers to immediately put the spectrum to use to expand mobile broadband in rural areas.

- *H.R. 3674, the Federal Spectrum Incentive Act*
  Sponsored by Representatives Brett Guthrie and Doris Matsui, this bill would establish incentives for Federal users to participate in an auction to reallocate spectrum for commercial use.

As additional spectrum is reallocated for commercial use, the FCC should remain the clearinghouse and reassign newly reallocated spectrum through a competitive auctions with protections to promote competition and prevent spectrum aggregation. Policymakers should consider with skepticism proposals that permit direct sale of spectrum from one incumbent interest or industry to another to prevent gaming or circumvention of pro-competitive policies. The market only exists if it is open for access to all potential participants, not only the largest, dominant companies.

Maintain Consumer Benefits of Competitive Access to Spectrum

Any updates to the Communications Act should preserve the FCC's authority to structure procompetitive auctions. As directed by Congress, the FCC has successfully promoted competition through spectrum auctions while realizing billions of dollars in revenue for use of taxpayer-owned spectrum resources. In the Spectrum Act, Congress again reaffirmed FCC authority to "adopt and enforce rules of general applicability, including rules concerning spectrum aggregation that promote competition." Policymakers must ensure that all consumers and taxpayers realize the economic and innovative benefits of policies that promote competition. In addition to ensuring competitive access to interoperable spectrum, devices, and roaming, policymakers should consider procompetitive rules regarding spectrum holdings and aggregation, geographic license sizes, build-out requirements, bidding credits, interference mitigation, and other policies to promote competition.

Over time, and largely based on market conditions, the FCC has revised its spectrum aggregation rules, and is currently considering further changes to its "spectrum screen" in its mobile spectrum holdings proceeding. Congress should continue to direct the FCC to prevent aggregation that stifles competition and provide flexibility for the FCC to continue to update its policies to promote competition.

As it updates its spectrum screen, policymakers must consider certain guiding principles. Critically important with the broadcast incentive auction on the near horizon, policymakers should recognize the unique value of low band spectrum. Frequencies below 1 GHz have greater propagation characteristics that allow for more economical deployment of mobile broadband coverage that penetrates buildings and obstructions and reaches greater distances from a base station. This makes low band spectrum advantageous and necessary to provide a competitive offering in both urban and rural areas.

Currently, AT&T and Verizon control the great majority of available low band spectrum. The 600 MHz incentive auction presents the only near-term opportunity for competitive access to spectrum below 1 GHz, and policymakers should ensure that the auction is structured to promote competition and provide all carriers a meaningful opportunity to gain access to this spectrum. Taking into account national and local market share, the FCC should allow all carriers – including AT&T and Verizon – to bid for spectrum and gain access to spectrum in markets where needed, but not allow any one or two carriers to dominate the entire auction and foreclose competitor access.

Upfront spectrum aggregation rules provide greater certainty to the industry and investors then case-by-case review of proposed transactions. Accordingly, an updated spectrum screen should contain a rebuttable presumption that places the burden on the applicant to prove the public interest benefits. The screen should serve as a tool to promote competition, not a shield to protect further consolidation of market power to two dominant carriers.

Providing all carriers with a meaningful opportunity to access needed spectrum resources is not limited to updating the spectrum screen – the FCC must also ensure that geographic license sizes are sufficiently small for all carriers to access. Recent research demonstrates that spectrum auctions should use sufficiently small geographic license sizes, such as Cellular Market Areas (CMAs) or other small sizes as technically reasonable, to allow all potential bidders to participate in an auction while allowing larger carriers that value larger spectrum footprints to demonstrate that value by bidding on several licenses and aggregating a larger footprint (*see* Lehr and Musey, "Right-sizing Spectrum Auction Licenses," available at http://apps.fcc.gov/ecfs/document/view?id=7520959686).

The benefits that flow from using smaller geographic license sizes have long been recognized by Congress, and were again reaffirmed in the Spectrum Act. Congress said the FCC must consider using "licenses that cover geographic areas of a variety of different sizes." In December, Senator John Thune,

Ranking Member of the Senate Committee on Commerce, Science, and Transportation noted that "[a]nother way to encourage more bidder activity, and to benefit rural areas in particular, is to auction licenses in a variety of geographic sizes. At a previous hearing, our Committee heard that offering spectrum licenses covering smaller geographic areas can result in more bidders, more license winners, more revenue, and better service to rural areas. This approach appeared to work quite well in the 700 megahertz auction in 2008." As Senator Thune referenced, the CMA-based licenses auctioned in the 2008 700 MHz auction– the Lower B Block – generated more than twice the revenue of the Lower A Block licenses auctioned in Economic Areas (EAs) and more than triple the Regional Economic Areas Grouping (REAG) sized Upper C Block licenses. Making spectrum available in sufficiently small geographic areas is a true win-win, allowing all interested parties to participate in the auction and in turn generating more revenue for taxpayers and the Treasury.

Price of lower A and B Blocks and upper C Block in the 700 MHz auction (March 2008)

Block	A	B	C
Bandwidth	12 MHz	12 MHz	22 MHz
Type	paired	paired	paired
Partition	176	734	12
Price ($/MHz-pop)	$1.16	$2.68	$0.76

Buildout requirements are another opportunity for policymakers to prevent excessive aggregation or spectrum warehousing. Appropriately structured build-out requirements promote rapid deployment of services to consumers, and can also foster secondary market access to spectrum. Using sufficiently small geographic license sizes, Congress should urge the FCC to continue to use clear, predictable requirements to promote efficient deployment. Competitive carriers have supported strong, population-based buildout requirements. Geographic-based buildout requirements should also be considered, particularly in less dense areas. Geographic-based buildout requirements enable carriers to target rural areas without being penalized for deploying facilities in less populated areas and ensure that rural areas and consumers are not left behind. When imposing buildout requirements, however, policymakers also should provide flexibility where circumstances arise outside of a carrier's control, such as efforts by dominant carriers to thwart interoperability. Finally, build-out requirements should not be used by carriers with expansive coverage and nationwide market power to justify foreclosing competitive carriers from gaining access to spectrum in local markets.

Policies to promote competition should not be limited only to auction structure and spectrum holdings, but should be viewed more broadly to address interference to and from device and receiver standards. Policymakers should consider both carrots and sticks to enhance efficient use of spectrum. Where perceived interference issues can be mitigated through relocation opportunities, opportunities should not be statutorily foreclosed. Providing the FCC with the flexibility to address these issues could promote competition. For example, claimed interference issues between mobile broadband operations in the Lower 700 MHz Band and broadcast television services using channel 51 can be mitigated by allowing channel 51 broadcasters to relocate or exit prior to the incentive auction and maintain eligibility for participation.

Adopting procompetitive policies regarding access to spectrum ameliorates the need to consider expected auction revenues as the basis for a public interest finding, and the FCC should not be allowed to consider revenue alone when crafting auction rules. Congress appropriately directs the FCC to promote a competitive market, which results in greater economic benefit than any one-time infusion of revenue from a spectrum auction. Even the most optimistic estimates for one-time auction revenue up to $30 billion in net proceeds for the incentive auction are eclipsed by the economic value of competition to consumers of at least $20 billion *per year*, worth over $200 billion in total (*see* Lehr, "Benefits of Competition in Mobile Broadband Services," available at http://competitivecarriers.org/wp-content/uploads/2014/04/Lehr-Benefits-of-Competition-in-Mobile-Broadband-Services-as-filed-03....pdf).

Policymakers can and should modernize spectrum policy to restore and support enhanced competition in the wireless industry specifically and communications generally. Absent transparent and upfront steps to increase competition through competitive carrier access to needed spectrum, Congress and the FCC will be forced to face sobering decisions regarding implementing heavy-handed regulation in an attempt to replicate the competitive benefits lost as the industry consolidates into a duopoly. By acting now to support and promote competition through spectrum policy, policymakers increase access to the other inputs competitive carriers need to provide service. This results in the additional benefits of lower consumer cost, enhanced innovation, greater mobile broadband deployment nationwide, and significant economic benefits. Congress should support these goals.

COMPTEL's Response to Questions in House Energy and Commerce White Paper "Modernizing U.S. Spectrum Policy"

COMPTEL, the leading industry association for competitive communications service providers, submits its response to the questions in the Committee on Energy and Commerce's second white paper, which focuses on "Modernizing U.S. Spectrum Policy."

As COMPTEL stated in its response to the Committee's first white paper, "Modernizing the Communications Act,"[1] it is imperative that communications policy, including spectrum policy, ensures that the communications networks serve everyone, promotes competition, and makes certain all consumers have access to advanced services and technologies. These basic principles must apply across all communications platforms to ensure a free, competitive, and functioning communications marketplace.

It is also important to emphasize that the wireless and wireline markets are inextricably linked given the growth in applications and services that require tremendous amounts of bandwidth. The advances in wireless, specifically 4G/ LTE in today's marketplace, depend on the wireline network to handle the tremendous increase in data consumption that is predicted in the coming years. Cisco estimates that "[b]y 2017, almost 21 exabytes of mobile data traffic will be offloaded to the fixed network by means of Wi-Fi devices and femtocells each month. Without Wi-Fi and femtocell offload, total mobile data traffic would grow at a Compound Annual Growth Rate (CAGR) of 74 percent between 2012 and 2017 (16-fold growth), instead of the projected CAGR of 66 percent (13-fold growth)."[2]

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[1] *See* COMPTEL's response to House Energy and Commerce Committee *Modernizing the Communications Act* ("White Paper"), *available at* http://energycommerce.house.gov/sites/republicans.energycommerce.house.gov/files/analysis/CommActUpdate/WP1_Responses_21-40.pdf

[2] *See* Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017, *available at* http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

Forward-looking spectrum policy should ensure spectrum is commercially available, efficiently used, and enables a broad base of companies to compete in the marketplace to deliver the most advanced services and technologies to consumers. It is also important to note that emerging technologies that will be reliant on access to spectrum will require competitive spectrum policies to ensure that growth and investment are not stifled.

Regarding spectrum auctions, it is reasonable to adopt competitive bidding policies that ensure small and medium-sized companies have a sufficient opportunity to bid for high-value spectrum. It would be a failure of public policy to allow the same large companies that control the vast majority of incumbent wireline networks to control the vast majority of valuable spectrum, as well. Technological advancements throughout the industry have occurred as a result of competitive companies disrupting current market forces; offering the kind of innovative and advanced services that the largest of the incumbents are unwilling to provide.

Such innovation continues in the unlicensed spectrum market as well, especially as mobile applications and on-demand content have become more reliant on Wi-Fi connections. In particular, rural businesses and consumers can benefit where current wireline or mobile technologies are insufficient to deliver the high-bandwidth services that are becoming everyday necessities. It is important to note, however, that a proper balance must be struck between unlicensed and licensed spectrum policies.

Finally, in order to continue to promote the efficient use of spectrum, it is important that the build-out requirements and rules attached to licenses reflect the realities of the marketplace and the commercial viability of the spectrum being licensed. These requirements should be predictable and transparent and encourage continued investment in the technologies and infrastructure to maximize the use of the licensed spectrum.

Thank you for the opportunity to comment.

Alan Hill
Senior Vice President, Government Relations
COMPTEL

To: House Energy and Commerce Committee

From: Consumer Electronics Association

Date: April 25, 2014

Subject: White Paper – Modernizing U.S. Spectrum Policy

The Consumer Electronics Association ("CEA") appreciates the opportunity to provide these comments on the Committee's white paper regarding modernization of U.S. spectrum policy. The white paper poses a number of questions ranging in scope from broad policy principles to more narrowly targeted questions focused on discrete licensing matters. We have provided responsive comments to those issues which are of core significance to the consumer electronics industry as they directly impact innovation, investment, and economic growth.

Spectrum is the essential building block of the services and applications consumers increasingly demand. Our spectrum policies must promote efficient spectrum management, get spectrum to those who will put it to its best and highest use, enable flexible market-based services while ensuring licensed operations have protection from harmful interference, and encourage innovation, job creation, and investment.

Unlicensed Spectrum Plays a Critical Role in Addressing the Spectrum Crunch, Promoting Innovation, and Strengthening the Economy

Unlicensed spectrum, as a complement to licensed spectrum, is critical to enabling the provision of robust mobile broadband services. Unlicensed spectrum, especially in higher bands, plays an important role in addressing spectrum constraints and promotes innovation and investment.

Unlicensed spectrum promotes innovation by lowering the barriers to entry for service providers, application developers, and manufacturers. This distinct way to access spectrum "increases opportunity for entrepreneurs and other new market entrants to develop wireless innovations that may not have otherwise been possible under licensed spectrum models."[1] Indeed, unlicensed spectrum has "enabled innovation in devices at the 'edge' of the network."[2] The rocketing growth of devices that use Wi-Fi is a testament to this innovation. In 1999, the first Wi-Fi capable laptops were sold; as of 2013, 63 percent of U.S. households have Wi-Fi networks installed at home.[3] Today there are 4 billion Wi-Fi-enabled consumer electronics in use

[1] FCC, *Connecting America: The National Broadband Plan*, at 79 (Mar. 2010) ("National Broadband Plan").

[2] *Id*. at 79.

[3] Telecom Advisory Services, LLC, *Assessment of the Economic Value of Unlicensed Spectrum in the United States*, at 11, 14 (Feb. 2014), http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf ("TAC Analysis") (citing iGR, *U.S. Home Broadband and Wi-Fi Usage Forecast 2012*-2017 (June 2013)).

globally, representing an average of 7 Wi-Fi devices per Wi-Fi household.[4] CEA sales figures for the United States show that over 165 million Wi-Fi-enabled devices were sold in 2012, and predict that over 271 million such devices will be sold in the United States in 2016.[5] There will be over 7 billion Wi-Fi devices in use globally by 2017.[6]

Unlicensed spectrum has also spurred innovation in standards and platforms. While Wi-Fi is perhaps the best-known standard being used on unlicensed spectrum to provide broadband service, other popular standards using unlicensed spectrum include Bluetooth, ZigBee, Z-Wave, NFC, and wireless HD connections.[7] These technologies have opened new frontiers of communications for consumers and businesses.

Many carrier-enabled consumer devices such as smartphones and tablets can and do use unlicensed spectrum technologies such as Wi-Fi to transmit and receive data, helping to reduce congestion on licensed wireless networks and improving service.[8] Such offloading is important to spectrum-constrained service providers as a method to deliver content to customers without increasing demands on licensed wireless networks.[9] Cisco estimates that 45 percent of global mobile data traffic was offloaded through Wi-Fi in 2013, totaling 1.2 exabytes of data per month, and this will increase by more than 14 times to 17 exabytes by 2018.[10]

Finally, unlicensed spectrum encourages investment that further benefits our economy. In 2013, unlicensed technologies generated a total annual economic value of $222 billion, contributing $6.7 billion to the nation's gross domestic product.[11] Studies have estimated the global

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[4] Press Release, Strategy Analytics, *US Wi-Fi Households to Own Average of 11 Wi-Fi Devices in 2017 says Strategy Analytics* (Feb. 26, 2014), *available at* http://www.prnewswire.com/news-releases/us-wi-fi-households-to-own-average-of-11-wi-fi-devices-in-2017-says-strategy-analytics-247305921.html.

[5] CEA, U.S. Consumer Electronics Sales & Forecasts (Jan. 2013).

[6] *See supra* note 4.

[7] *See, e.g.*, Lou Frenzel, *The Fundamentals of Short-Range Wireless Technology*, ELECTRONIC DESIGN, Oct. 11, 2012, http://electronicdesign.com/communications/fundamentals-short-range-wireless-technology .

[8] Richard Thanki, *The Economic Significance of License-Exempt Spectrum to the Future of the Internet*, at 8-9 (June 2012). ("In the absence of Wi-Fi mobile operators would be forced to invest large sums in their networks or strictly curtail their users' usage.").

[9] *See* Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, *Notice of Proposed Rulemaking*, 28 FCC Rcd 1769, 1794 ¶ 79 (2013) (citation omitted) ("The availability of unlicensed Wi-Fi networks in many locations enables licensed wireless providers to take data traffic off of their networks, thus reducing network congestion and delivering a better overall quality of service.").

[10] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf.

[11] TAC Analysis at 72.

economic impact from connected devices (the majority of which will use unlicensed spectrum) will reach $4.5 trillion by 2020.[12]

The Federal Communications Commission (the "FCC" or "Commission") has effectively employed both licensed and unlicensed regulatory models – most recently in its successful efforts to make an additional 100 megahertz of unlicensed spectrum available in the 5 GHz band, and its work to provide up to 150 additional megahertz in the 3.5 GHz band through sophisticated sharing and novel licensing approaches. Congress should continue to afford the Commission the ability to promote innovation and efficient spectrum use through the allocation of additional unlicensed spectrum.

Meaningful Incentives for Efficient Federal Spectrum Use are Essential

Efficient use of spectrum by Federal users is essential to making that spectrum available for commercial uses while still preserving Federal users' ability to satisfy their missions. As CEA recently noted in its Comments on the Office of Science and Technology Policy's Request for Information,[13] Congress and the Executive Branch already have taken a number of actions to facilitate repurposing Federal spectrum to non-Federal use, but those actions must be implemented and more work must be done. In the absence of market forces, Government policy is the only driver of more efficient Federal use. This cannot be a one-time policy imperative, but must instead create a permanent structure that drives the sort of efficiency-enhancing behavior that we have seen time and again from the commercial sector.

In the 2012 Spectrum Act, Congress expedited the process of freeing up additional spectrum for mobile broadband by, among other things, requiring the FCC to auction and license 65 megahertz – including Federal spectrum – for non-Federal use by February 2015, and changing procedures for repurposing Federal spectrum.[14] Congress also amended the Commercial Spectrum Enhancement Act ("CSEA") to expand the costs Federal agencies can recover in connection with making spectrum available for non-Federal use on an exclusive or shared basis.[15] The Office of Management and Budget ("OMB") now requires Federal agencies to consider the economic value of the spectrum being used in their budget justifications for procurement of major systems, to evaluate whether spectrum sharing is possible, and to certify that commercial alternatives and non-spectrum dependent alternatives were considered.[16] The

[12] *See generally* GSMA, The Connected Life: A USD 4.5 Trillion Global Impact in 2020 (Feb. 2012), http://connectedlife.gsma.com/wp-content/uploads/2012/02/Global_Impact_2012.pdf.

[13] Response of CEA, FR Doc. 2014-03413, at 4 (filed Mar. 20, 2014); Office of Science and Technology Policy, *Notice of Request for Information*, 79 Fed. Reg. 9288 (Feb. 18, 2014).

[14] Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, §§ 6401(b) and 6701, 126 Stat. 156, 222-23, 245-52 (2012) ("2012 Spectrum Act").

[15] *See* 47 U.S.C. § 928.

[16] *See* Office of Management and Budget, *Preparation, Submission, and Execution of the Budget*, Circular No. A-11, §§ 31.12, 51.18 (Aug. 2012), *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/a11_-current_year/a_11_2012.pdf.

National Telecommunications Information Administration ("NTIA"), in coordination with the FCC, has made strides in identifying spectrum bands to evaluate for potential reallocation to commercial use.[17] The June 2013 Presidential Memorandum[18] included several directives to NTIA, OMB, and other governmental bodies aimed at the careful evaluation of Federal spectrum use, the consideration of spectrum bands for relocation or sharing, and improving the efficiency of Federal spectrum use.[19] Those directives should be implemented, agencies should be accountable for their spectrum use, and their spectrum efficiency should be a central factor in the procurement and budget processes as contemplated by the June 2013 Presidential Memorandum. For example, NTIA should act promptly to implement the pilot program to monitor Federal spectrum use, so that unused and underused bands may be identified and evaluated for reallocation to commercial use. NTIA's proposed 2015 budget includes funding for this pilot program. That funding should be authorized so the program may be implemented and consumers ultimately can realize the benefits of additional mobile broadband spectrum.

In addition to implementing existing directives, more meaningful incentives must be developed to encourage Federal users to relinquish and/or share some of their spectrum holdings. Incentive mechanisms must provide financial and/or operational benefits to the agencies, and enable them to maintain the communications capabilities necessary to meet their missions.

To be effective, any incentive mechanism must as a matter of course reimburse agencies for all costs reasonably incurred in relinquishing or sharing spectrum. While the CSEA allows agencies to recover relocation and sharing costs from a fund that is financed with revenues from the auction of that spectrum,[20] there are gaps in what agencies may recover. For example, the CSEA does not account for costs associated with relinquishing or sharing spectrum that is not auctioned and, while agencies may invest in state-of-the-art equipment, they are limited to acquiring comparable capabilities, and increases in functionalities must be incremental or incidental. Those remaining gaps in the CSEA should be closed, as suggested by the Commercial Spectrum Management Advisory Committee.[21]

Further, reimbursing agencies for their relocation and/or sharing costs alone will not effectively incentivize them to relinquish or share spectrum. Additional financial and/or operational benefits are necessary. Financial benefits could include direct payments to agencies that relinquish or share spectrum, with higher payments made to agencies that relinquish spectrum.

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[17] *See generally* 2012 Spectrum Act, § 6401; Rebecca Blank and Lawrence E. Strickling, Department of Commerce, *Identification of 15 Megahertz of Spectrum Between 1675 and 1710 MHz for Reallocation from Federal Use to Non-Federal Use Pursuant to Section 6401(a) of [the 2012 Spectrum Act]*, Report to the President (Feb, 2013), http://www.ntia.doc.gov/files/ntia/publications/1675-1710_mhz_report_to_president_02192013.pdf.

[18] Presidential Memorandum, *Expanding America's Leadership in Wireless Innovation*, 78 Fed. Reg. 37431 (June 20, 2013) ("June 2013 Presidential Memorandum").

[19] *Id*. at 37432-34 §§ 3, 4.

[20] *See* 47 U.S.C. §§ 923, 928.

[21] CSMAC Incentives Subcommittee Report, Jan. 11, 2011, *available at* http://www.ntia.doc.gov/files/ntia/-publications/incentivessubcomm_report_final_01112011.pdf.

As the white paper notes, one proposal is the Federal Spectrum Incentive Fund that would be created under H.R. 3674, which would allow agencies that relinquish spectrum to receive a percentage of the proceeds from the sale of that spectrum, and to use those resources to purchase updated technology and improved communications systems to meet their needs. Operational incentives could include assistance in testing and implementing new technologies, which would enable agencies to improve their capabilities and use spectrum more efficiently.

Additional Spectrum Must be Made Available for Commercial Use

In addition to repurposing Federal spectrum, the directives and recommendations outlined in the 2010 Presidential Memorandum and the National Broadband Plan regarding making additional spectrum available for broadband use should continue to be implemented. While a number of these action items have been accomplished, there is more work to be done to bring much needed spectrum resources to market.

The 2010 Presidential Memorandum directed NTIA and the FCC to work together to identify 500 megahertz of spectrum that could be made available for wireless broadband by 2020, with 300 megahertz of that spectrum to be made available by 2015.[22] The National Broadband Plan contained recommendations to that effect as well, and identified with specificity the 300 megahertz that could be made available within five years:[23]

National Broadband Plan Exhibit 5-E:
Actions and Timeline to Fulfill 300 Megahertz Goal by 2015

Band	Key Actions and Timing	Megahertz Made Available for Terrestrial Broadband
WCS	2010—Order	20
AWS 2/3	2010—Order 2011—Auction	60
D Block	2010—Order 2011—Auction	10
Mobile Satellite Services (MSS)	2010—L-Band and Big LEO Orders 2011—S-Band Order	90
Broadcast TV	2011—Order 2012/13—Auction 2015—Band transition/clearing	120
Total		**300**

[22] Presidential Memorandum, *Unleashing the Wireless Broadband Revolution*, 75 Fed. Reg. 38385, 38388 (June 28, 2010).

[23] National Broadband Plan at 84-85 and Exhibit 5-E.

Some, but not all, of the work to bring this 300 megahertz of spectrum to market has been completed. For example, the FCC modified its Wireless Communications Service rules to make an additional 20 megahertz of that spectrum available for broadband use.[24] The FCC adopted licensing rules to govern 10 megahertz of Advanced Wireless Service ("AWS") H Block spectrum (1915-1920 MHz/1995-2000 MHz) and recently auctioned that spectrum.[25] The FCC also has revised its rules to make 40 megahertz of spectrum in the S Band available for terrestrial broadband use,[26] and has initiated a rulemaking proceeding to consider rules that would authorize a low power mobile broadband service using Globalstar's Mobile Satellite Service spectrum at 2483.5-2495 MHz.[27]

More work remains to be done. Just last month, the FCC adopted rules to govern the AWS-3 band, which includes spectrum previously designed as AWS-2 and AWS-3 spectrum, as well as spectrum that has been reallocated from Federal to non-Federal use (1695-1710 MHz and 1755-1780 MHz/2155-2180 MHz). The FCC contemplates auctioning that spectrum as early as September 2014[28] in order to meet the licensing deadline established in the 2012 Spectrum Act.[29] The FCC should adhere to that schedule so that this spectrum may be timely licensed. However, just as importantly, the FCC, NTIA, Federal users, and industry must all work together to allow prompt access to the spectrum while protecting Federal incumbent operations (whether during agency transitions out of the band, or in the context of longer-term sharing arrangements). Reasonable protection zones are essential, and should be based on continued refinement of those areas based on expected and actual operating parameters of Federal and non-Federal systems.

The FCC likewise should move forward with its efforts to enable the 3550-3700 MHz band for shared use by Federal incumbents and commercial users. This process, too, will require

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[24] *See* Amendment of Part 27 of the Commission's Rules to Govern the Operation of Wireless Communications Services in the 2.3 GHz Band, *Report and Order and Second Report and Order*, 25 FCC Rcd 11710 (2010), *Order on Reconsideration*, 27 FCC Rcd 13651 (2012).

[25] Service Rules for Advanced Wireless Services H Block – Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 and 1995-2000 MHz Bands, *Report and Order*, 28 FCC Rcd 9483 (2013); Suction of H Block Licenses in the 1915-1920 MHz and 1995-2000 MHz Bands Closes; Winning Bidder Announced for Auction 96, *Public Notice*, DA 14-279 (rel. Feb. 28, 2014).

[26] Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands, *Report and Order and Order of Proposed Modification*, 27 FCC Rcd 16102 (2012).

[27] *See* Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems, *Notice of Proposed Rulemaking*, 28 FCC Rcd 15351 (2013).

[28] Amendment of the Commission's Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz Bands, *Report and Order*, FCC 14-31, ¶ 8 (rel. Mar. 31, 2014) (citing letter from Julius Genachowski, Chairman, FCC, to Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Department of Commerce, at 1 (Mar. 20, 2013)).

[29] 2012 Spectrum Act, § 6401(b).

collaboration between the FCC, NTIA, Federal users, and industry to enable commercial operations while protecting Federal incumbent operations.

Finally, the FCC is expected to adopt an order in its incentive auction proceeding at its May 15, 2014, open meeting. The FCC has indicated that, while the anticipated order will address many issues, a number of issues will be resolved through further notice and comment processes. The broadcast incentive auction is the first of its kind, and will continue to require significant resources and work to implement before its scheduled launch in 2015. Beyond implementing the auction itself, the FCC must work to coordinate broadcast and wireless broadband operations along the borders with our international neighbors, and also must undertake significant activities to enable implementation of channel sharing arrangements, repacking of broadcasters who choose to continue to operate over a full 6 megahertz channel, and other coexistence measures. The FCC must have access to the resources it needs to finish this important work and enable it to complete this ground-breaking process.

Work also should press ahead to make more than 500 megahertz available for mobile broadband by 2020 given that actual usage has exceeded the estimates that the National Broadband Plan's goals were based upon, and to complete evaluation of bands identified by NTIA for potential repurposing to non-Federal use. The Commission should consider licensed uses in lower bands that are well-suited for mobile broadband deployment, and promote network investment, marketability, availability, and consumer use.

Operating Rules Should Promote Flexible Use While Protecting Authorized Users

If spectrum is licensed, the FCC should continue to grant flexible use licenses, consistent with the approach it has taken over the past several years. The market-oriented flexible use policy paved the way for the substantial innovation, deployment, and growth that have characterized the wireless marketplace. It has enabled market forces to determine which innovative and effective applications, services, and devices to develop in order to maximize efficiency, in lieu of the traditional "command and control" approach. In less than three decades, the wireless industry has moved through multiple generations of air interfaces with remarkable improvements in efficiency, capacity, and features. This "no permission required to innovate" approach to spectrum policy has been a tremendous success and the pace of innovation continues to accelerate.

While flexible use policies offer tremendous consumer benefits, they must be complemented with appropriate protections against harmful interference to spur innovation and investment. As discussed in next section, the Commission should explore a harm claim threshold approach to address interference issues.

Harm Claim Thresholds Strike an Appropriate Balance Between Flexibility, Innovation, and Interference Protection

As demand for spectrum-based services continues to grow exponentially, it is essential to make more intensive use of available spectrum. Packing additional diverse uses into a finite amount of spectrum increases the risk of interference, which, if not addressed, can discourage investment

and innovation. While efforts to minimize interference have often focused on establishing transmitter power limits, in some scenarios receivers may also play a role.

The design and performance of receivers operated by Federal and non-Federal users – in particular, how well they handle interference from authorized transmitters in the band – affects spectrum efficiency and should be a part of the process to minimize harmful interference. While it is impossible to set operating parameters outside the context of consideration of a particular band, a general approach on receiver performance issues can and should be followed throughout. Specifically, as spectrum is more densely used, the emphasis should be on providing equipment designers with information on appropriate harm claim thresholds as opposed to mandated receiver standards. The FCC's Technological Advisory Council ("TAC") released a white paper last year and recently issued a subsequent paper to provide an introduction to the harm claim threshold concept, both of which address the role of receivers in the efficient use of spectrum.[30]

The TAC White Paper proposed, among other things, the use of harm claim thresholds to improve receiver performance to achieve more efficient use of spectrum. In essence, harm claim thresholds describe the environment in which a receiver must operate without specifying how the receiver must perform in that environment.[31] The harm claim threshold relies on a pre-established "received signal strength profile that, if exceeded at a specific percentage of locations and times within a measurement area, allows a claim for harmful interference to be made; or conversely, the interference below which an assignee has no enforcement recourse at the FCC."[32]

CEA supports investigating the use of harm claim thresholds, particularly in cases where diverse uses are operating in the same band.[33] These thresholds can give equipment manufacturers and service providers much needed predictability regarding the spectral environment they can expect when designing products and services, which is important in emerging technology markets because it enables new entrants to attract investment and drive innovation. Harm claim thresholds also preserve device manufacturers' and service providers' ability to evaluate receiver design trade-offs based upon market forces and technological considerations and can provide incentives to improve receiver performance. Finally, harm claim thresholds benefit consumers by allowing manufacturers to offer products that perform in a predictable and reliable fashion, without paying additional cost for a product based on arbitrary performance requirements.

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[30] FCC Technical Advisory Council, *Interference Limits Policy: The Use of Harm Claim Thresholds to Improve the Interference Tolerance of Wireless Systems* (Feb. 6, 2013) ("TAC White Paper"), *available at* http://transition.fcc.gov/bureaus/oet/tac/tacdocs/WhitePaperTACInterferenceLimitsv1.0.pdf; *see also*, FCC Technical Advisory Council, *Interference Limits Policy and Harm Claim Thresholds: An Introduction* (Mar. 5, 2014), *available at* http://transition.fcc.gov/oet/tac/tacdocs/reports/TACInterferenceLimitsIntrov1.0.pdf.

[31] TAC White Paper at 8.

[32] *Id*.

[33] CEA filed comments with the FCC supporting the TAC White Paper proposal for harm claim thresholds. *See* Comments of CEA, ET Docket No. 13-101 (filed July 22, 2013).

Harm claim thresholds and the underlying signal strength profiles on which they are based must be driven by consensus, technological factors, and industry expertise. There is no single set of general interference limits that would be appropriate to apply across all bands, all applications, and all standards. Harm claim thresholds and signal strength profiles must be established on a band-by-band basis and, as such, should be established only after industry stakeholder input.

Effective Management of Spectrum Assignment and Use is Critical

Effective management of spectrum assignment and use is essential as the demand for spectrum resources continues to grow. The Federal government itself has concluded that its spectrum management practices have not been adequate to promote efficient spectrum use.[34] While NTIA and other organizations are taking steps to implement the directives from the June 2013 Presidential Memorandum related to more efficient spectrum use, those measures must be carried out and enforced. In addition, NTIA and/or OMB should take a more active role in the agency procurement and budget processes to ensure that requests for spectrum in prime mobile bands are essential to meet the agencies' missions, that agencies are using the spectrum efficiently, and that the agencies' needs cannot be met through alternative means – including by the use of commercial off-the-shelf systems.

Further, as efforts continue to enable sharing between Federal spectrum users and non-Federal users, it may be more efficient and effective to locate the spectrum management function within a single organization. Wherever responsibility for spectrum management resides, it should be adequately funded and the organization must have the necessary resources (*e.g.*, employees, technology) and authority to perform this task in a transparent way.

We hope that this feedback provides useful insight into these spectrum policy issues that are of critical importance to the CE industry and the continued growth, innovation, and investment in our nation's communications ecosystem. We thank you for the opportunity to provide comment on this second white paper, and look forward to a continued dialogue on the important issues related to a potential update of the Communications Act. For more information or questions, please contact Julie Kearney, Vice President of Regulatory Affairs, at jkearney@ce.org or 703-907-7644; Alex Reynolds, Senior Manager and Regulatory Counsel, at areynolds@ce.org or 703-907-4169; or Veronica O'Connell, Vice President of Congressional Affairs, at voconnell@ce.org or 703-907-7577.

[34] T. Randolph Beard, *et al*., Phoenix Center Policy Paper Number 46, *Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources*, pp. 6 & 27, Phoenix Center (Fall 2013), *available at* http://www.phoenix-center.org/pcpp/PCPP46Final.pdf (citing Government Accountability Office, GAO-11-352, *Spectrum Management: NTIA Planning Processes Need Strengthening to promote Efficient Use of Spectrum by Federal Agencies* (Apr. 2012), *available at* http://www.gao.gov/new.items/d11352.pdf).

COUNCIL FOR CITIZENS AGAINST GOVERNMENT WASTE

Thomas A. Schatz
President

April 25, 2014

The Honorable Greg Walden
Chairman
Subcommittee on Communications and Technology
Committee on Energy and Commerce
U.S. House of Representatives
2123 Rayburn House Office Building
Washington, DC 20515

The Honorable Anna Eshoo
Ranking Member
Subcommittee on Communications and Technology
Committee on Energy and Commerce
U.S. House of Representatives
2123 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Walden and Ranking Member Eshoo,

On behalf of the more than one million members and supporters of the Council for Citizens Against Government Waste (CCAGW), I appreciate the work the Committee has undertaken on updating the Communications Act of 1934, and the open dialogue you have created in providing an opportunity for all to participate in the discussion of what a modern communications law would encompass.

I would like to submit the following responses to the questions posed by the Committee in its most recent white paper on "Modernizing U.S. Spectrum Policy." Should you have any questions, please feel free to contact either myself, or Deborah Collier, CAGW's director of technology and telecommunications policy at (202) 467-5300.

Sincerely,

Thomas Schatz

Council for Citizens Against Government Waste

Discussion and Questions:

1) **As discussed in white paper #1 on Modernizing the Communications Act, the telecommunications industry has experienced a great deal of convergence in recent years. One result is that the current licensing structure at the FCC may no longer be the most efficient or appropriate method to maximize spectrum use. The FCC is responsible for licensing spectrum for a number of services, including public safety, fixed and mobile wireless, broadcast television and radio, and satellite. Although many of the processes are the same among these services, the licensing authority is housed in disparate bureaus. What structural changes, if any, should be made to the FCC to promote efficiency and predictability in spectrum licensing?**

Response:

Under the current bureau structure, the Wireless Telecommunications bureau oversees the maintenance of the spectrum dashboard and spectrum map. However, the media bureau, international bureau, public safety and homeland security, wireline competition, and consumer and government affairs all have input and jurisdiction over the use of various spectrum licenses based on their overall responsibilities in coordinating between various agencies and entities that use spectrum. In addition, National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce also has responsibility in managing the federal government's use of spectrum to ensure that America's domestic and international spectrum needs are met while making efficient use of this limited resource. The FCC and NTIA must coordinate and collaborate to ensure that the nation's spectrum needs are met, while at the same time meeting their own individual mission goals.

Because of the scarcity of available spectrum for wireless use, including unlicensed spectrum, CCAGW believes that the committee needs to look beyond the FCC when reviewing spectrum responsibility and management. If it is economically and fiscally feasible, perhaps a consolidation of the roles and responsibilities of spectrum management could be merged into one federal agency in order to reduce overlapping missions and duplication. While NTIA plays an important role in managing government-held spectrum, as well as developing the FirstNet first responder network, these responsibilities, budget, and personnel could potentially be shifted to the FCC and managed under either one of its existing bureaus or in a newly restructured FCC by a bureau specifically charged with spectrum management, which would potentially reduce any duplication and waste in the programs. The FCC would be the responsible agency for oversight of federally held spectrum, coordinating future spectrum auctions and managing spectrum allocations, as well as maintaining the spectrum dashboard and spectrum map.

With such a consolidation of resources, the FCC would provide a more comprehensive approach to spectrum management and would be able to better understand the use or underuse of specific allocations, particularly within the federal government, in order to open up more spectrum for private sector use, while maintaining the public safety, defense, and homeland security missions of the federal government.

2) **Spectrum users are allowed to operate without an FCC license—subject to certain technical rules—in spectrum that is designated as "unlicensed." In 1985, the FCC opened up frequency bands, including the 2.4 GHz band, for unlicensed communications, and has since allocated other bands specifically for unlicensed operators. Users of unlicensed spectrum do not have exclusive use rights and are subject to interference by others. While operators do not need a license, they must abide by other regulatory safeguards, including authorization of equipment, accepting any interference and not causing harmful interference to others, and ceasing operations upon FCC notification.**

   There is vigorous debate over the appropriate role for unlicensed spectrum in the wireless ecosystem, particularly following the passage of the Spectrum Act. The Act requires the FCC to auction all spectrum made available by the incentive auction, but allows for unlicensed use in guard bands. Some contend that there is an ample amount of unlicensed spectrum available and that assigning spectrum via exclusive licensing is the most effective, efficient, and economically responsible way to allocate spectrum. Others argue that repurposed spectrum should be allocated for unlicensed use for similar reasons. What role should unlicensed spectrum play in the wireless ecosystem? How should unlicensed spectrum be allocated and managed for long-term sustainability and flexibility?

   Response:

   CCAGW believes that as Americans become increasingly dependent on the availability of unlicensed spectrum for various purposes including Internet research, watching videos over the Internet, and connecting to a blue-tooth enabled device, there is a heightened need for much of the spectrum currently found in the "white space" or unlicensed guard bands.

   Wi-Fi devices work over one of two spectrum bands, either 2.4 GHz or 5GHz, both of which are unlicensed. The 2.4 GHz band is most frequently used for industrial, scientific, and medical purposes, and it only has three non-overlapping channels. The 5 GHz band has been allocated by the FCC for the automotive industry, and satellite phones, as well as some government use, and it has 23 non-overlapping channels. While the 2.4 GHz spectrum has a wider network range than the 5 GHz range, it also has a higher level of interference due to the increasing amount of uses for Wi-Fi and other unlicensed spectrum.

The use of Wi-Fi and unlicensed spectrum has led to what is commonly called the Internet of Things (IoT), which was highlighted at the 2014 Consumer Electronics Show (CES). Among the newest gadgets on display at CES that are dependent on the availability of this spectrum are toothbrushes that provide information on how to clean teeth better, a tennis racket that records how many strokes a player takes, and a wireless dog collar that can help owners find their missing pets. These are just a few of the innovations being developed each day because of the availability of Wi-Fi and unlicensed spectrum. During his keynote speech at CES, Cisco CEO John Chambers predicted that IoT would become a $19 trillion market over the next several years.[1]

On February 20, 2013, the FCC proposed making additional spectrum available in the 5 GHz range for unlicensed broadband.[2] The automobile industry uses some of this spectrum, particularly in the 5850-5925 MHz range for its dedicated short range communications service systems, and the satellite phone industry uses the 5150-5250 MHz band. In comments submitted to the FCC on November 29, 2013, Globalstar, a provider of satellite phone services, indicated that opening up the 6 GHz bandwidth to unlicensed use outdoors would have a substantial, detrimental impact on their licensed two-way (duplex) mobile satellite service. However, it is important to note that at the end of 2012, the company provided duplex service to fewer than 85,000 customers worldwide.[3] In addition, a January 22, 2014 study by CableLabs and the University of Colorado found that satellite phone users could co-exist on this frequency without experiencing harmful interference from the expansion of Wi-Fi access to the 5 GHz band.[4]

Opening up the 5 GHz spectrum bandwidth to Wi-Fi and unlicensed applications provides an opportunity for new technology development and improved use of existing devices. The CableLabs study completes the public record needed for the FCC to make a decision on the use of this bandwidth for expanding Wi-Fi and unlicensed applications. Newer technologies that utilize Wi-Fi and other unlicensed spectrum make it essential that the spectrum allocation be expanded for the IoT.

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[1] Mohana Ravindranath, "Cisco CEO at CES 2014: Internet of Things is a $19 trillion opportunity," The Washington Post, January 8, 2014, http://www.washingtonpost.com/business/on-it/cisco-ceo-at-ces-2014-internet-of-things-is-a-19-trillion-opportunity/2014/01/08/8d456fba-789b-11e3-8963-b4b654bcc9b2_story.html.

[2] "FCC Proposes More Spectrum at 5 GHz for Unlicensed Broadband," ARRL, the National Association for Amateur Radio, February 27, 2014, http://www.arrl.org/news/fcc-proposes-more-spectrum-at-5-ghz-for-unlicensed-broadband.

[3] Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934 for the Fiscal Year Ended December 31, 2012, or Transition Report pursuant to Section 13 or 15(d) of the Security Exchange Act of 1934 for the Transition Period, Commission File Number 001-33117, Globalstar, Inc., p. 30, http://www.sec.gov/Archives/edgar/data/1366868/000114420413015324/v335533_10k.htm.

[4] Tammy Parker, "Cable group disputes Globalstar's arguments against against freeing 5.1 GHz band for Wi-Fi," *Fierce Wireless Tech*, January 23, 2014, http://www.fiercewireless.com/tech/story/cable-group-disputes-globalstars-arguments-against-freeing-51-ghz-band-wi-f/2014-01-22.

3) **Spectrum sharing is one proposed technological solution that addresses the issue of spectrum scarcity and encourages efficiency. There are multiple ways to share spectrum, including geographic sharing, temporal sharing, and sharing through dynamic spectrum access. In July 2012, the President's Council of Advisors on Science and Technology (PCAST) issued a report on ways to realize the full potential of government held spectrum. The report concluded that sharing is the most efficient way to utilize spectrum and directed the Secretary of Commerce to immediately identify 1,000 MHz of federal spectrum for shared use. However, others assert that spectrum sharing is only part of the solution to spectrum scarcity and that clearing unused or underused federal for exclusive commercial use is a vital part of any strategy for maximizing spectrum resources. In order to enable this sort of reallocation, bipartisan legislation has been introduced in the House that would allow government spectrum users an option to relinquish spectrum and receive a portion of net auction revenues instead of relocation costs, a structure similar to that of the broadcast television spectrum incentive auctions. What should be done to encourage efficient use of spectrum by government users?**

Response:

According to the NTIA, the U.S. government currently has exclusive rights to more than 638 MHz of spectrum and shares another 1,030 MHz with commercial users.[5] On January 3, 2013, FCC Commissioner Ajit Pai discussed the need for the federal government to relinquish some of its unused spectrum for mobile use.[6] According to Commissioner Pai, almost 60 percent of the spectrum best used for mobile devices is currently held by the federal government and unavailable for private use.

The July 2012 PCAST report offering recommendations on government and private entities envisioned a "spectrum super-highway" shared by both government and commercial entities, with the government having the ability to pre-empt the private sector for public safety, emergency medical rescue, or national security purposes. On September 12, 2012, the FCC announced it would begin implementing one of the PCAST recommendations to free up 100 MHz of spectrum in the 3.5 GHz band currently used for radar and allocating it for shared small cell use.[7]

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[5] Rebecca Blanks, Acting Secretary, Lawrence E. Strickling, Assistant Secretary for Communications and Information, "Third Interim Progress Report on the Ten-Year Plan and Timetable," National Telecommunications and Information Administration, U.S. Department of Commerce, November 2012, http://www.ntia.doc.gov/files/ntia/publications/third_interim_progress_report_final.pdf.

[6] Ajit Pai, "Too Much Government, Too Little Spectrum," Red State, January 3, 2013, http://www.redstate.com/ajitpai/2013/01/03/too-much-government-too-litte-spectrum/.

[7] Jon Brodkin, "FCC to Make Spectrum Sharing Reality, Whether Carriers Want It or Not," *Ars Technica*, September 14, 2012, http://arstechnica.com/business/2012/09/fcc-to-make-spectrum-sharing-reality-whether -carriers-want-it-or-not/.

However, not every agency may be willing to share spectrum with the private sector. On September 13, 2012, the House Energy and Commerce Subcommittee on Communications and Technology held a hearing on spectrum management. During this hearing, the Government Accountability Office (GAO) testified about existing barriers to sharing spectrum, including risk to an agency's mission, cost to both federal and non-federal users, use of spectrum frequencies by more than one agency or program, limited federal budgets prohibiting investments in new technology that would allow spectrum sharing, and a lengthy approval and enforcement process.[8] GAO also testified that, "While federal spectrum users often share spectrum among themselves, they may have little economic incentive to otherwise use spectrum efficiently, including sharing it with nonfederal users."[9]

Just as with the incentive auction process proposed to encourage broadcasters to relinquish their unused or underused spectrum to be repurposed for wireless use, Congress must encourage improved spectrum management within federal agencies and provide incentives for more efficient use. These incentives could include providing the agencies with a portion of any proceeds received through an auction of unused spectrum.

On June 26, 2013, the Mercatus Center at George Mason University released a study that examined various proposals for reclaiming federal bandwidth, which would expand the amount of underused mobile bandwidth for private sector use. According to the study, "reclaiming federal bandwidth has been painfully slow, and each year's delay results in billions of dollars of social cost and forgone auction revenue."[10]

The study proposed creating an agency similar to the military Base Closure and Realignment Commission (BRAC) for spectrum reform, which would identify federal and state agencies using spectrum and compel them to vacate the bandwidth. The study also recommended that Congress create an agency similar to the General Services Administration to manage federal spectrum and lease or sell excess bandwidth, while liberalizing federal allocations and pricing the bandwidth to provide an incentive to economize.[11]

Without additional spectrum for mobile communication and data, wireless networks will be unable to handle increased traffic. While the voluntary spectrum reverse auction is a first step toward providing more spectrum for

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[8] Mark L. Goldstein, Testimony before the House Energy and Commerce Subcommittee on Communications and Technology, "Spectrum Management: Federal Government's Use of Spectrum and preliminary Information on Spectrum Sharing," U.S. Government Accountability office, GAP-12-1018T, September 13, 2012, http://www.gao.gov/assets/650/648206.pdf.
[9] Ibid.
[10] Brent Skorup, "Reclaiming Federal Spectrum: Proposals and Recommendations," Mercatus Center, George Mason University, June 26, 2013, http://mercatus.org/publication/reclaiming-federal-spectrum-proposals-and-recommendations.
[11] Ibid.

mobile devices, unused spectrum currently allocated to federal agencies should be reviewed as a potential source for future auctions.

4) **Given the enormous economic benefits of innovation spurred by commercial spectrum availability, both the government and the private sector are concerned with making more spectrum available to meet commercial demand. When discussing available resources, the FCC considers spectrum to be "currently available" if providers have the legal authority to build out and provide services using that band, or "in the pipeline" if it is not currently available for commercial services but there are government plans to make it available to commercial providers within the next three years. Congress and the FCC have worked to increase the amount of spectrum available to commercial providers, including through the provisions for auctions and relocation in the Middle Class Tax Relief and Job Creation Act. What other steps can be taken to increase the amount of commercially available spectrum?**

   Response:

   As indicated in CCAGW's response to question 3, the federal government currently has exclusive rights to more than 638 MHz of spectrum and shares another 1,030 MHz with commercial users. Spectrum usage in each agency is a critical inventory management issue that the federal government must address in order to make educated decisions on the availability of spectrum for auction.

   CCAGW believes an annual or biannual review of government-held spectrum that is "in the pipeline" should be required of all federal agencies holding spectrum allocations, in order to determine whether this spectrum is viable for disbursement to the private sector in future spectrum auctions. In addition, a relaxation of the rules governing the secondary market for spectrum may be in order, so that companies with excess, unused spectrum would have the ability to trade out some of that spectrum in order to increase access to spectrum where it is needed most.

5) **In order to issue spectrum licenses, the Communications Act requires the FCC to make an affirmative finding that granting the license serves the public interest, convenience, and necessity. Moreover, the Act prohibits the FCC from basing its finding on the expectation of auction revenues. Should the Act permit the FCC to use expected auction revenue as the basis for a public interest finding? What criteria should the FCC consider as part of its analysis?**

   Response:

   As indicated by the Middle Class Tax Relief and Job Creation Act, one of the primary determinants for the upcoming spectrum auction is the attainment of

revenue to provide for a national public safety network, also known as FirstNet. CCAGW is greatly concerned that FCC Chairman Tom Wheeler plans to inhibit bids from larger communications carriers, such as AT&T and Verizon, so that other carriers would have the opportunity to purchase more spectrum at lower prices.[12] We believe that this ill-conceived decision stems from recommendations by the Department of Justice (DOJ) in its *Ex Parte* submission to the FCC on April 11, 2013.[13]

In its recommendations, DOJ proposed that the FCC adopt rules that prohibit or discourage larger mobile competitors from bidding on low-frequency spectrum in order to give small nationwide carriers the ability to purchase blocks of this spectrum. If, as Chairman Wheeler has announced the FCC will do, the agency uses the DOJ's criteria for selecting participants in the auction, it will do little to spread the amount of available spectrum across all carriers, instead placing the FCC in the position of picking winners and losers in the spectrum auction.

Ultimately, this plan will limit the proceeds available both for use for the FirstNet public safety network and to reduce the deficit. CCAGW believes that this decision could have been avoided if the FCC was required to include expected auction revenues as part of its formula for a public interest finding when developing auction procedures.

9) **As discussed above, interference can pose a major problem to efficient and full use of spectrum by providers. The FCC sets limits on transmissions, but doesn't regulate the receivers used by wireless devices to receive wanted signals and eliminate the noise coming from the other surrounding spectrum bands. Underperforming receivers can prevent a device from operating properly. While the FCC has used tools like guard bands to mitigate the potential for interference, recent examples of receiver overload have shown that these efforts may not be enough as demand for spectrum increases but resources become more and more constrained. Some have proposed receiver standards as a solution, but others argue that such a step could result in over-engineering and higher consumer prices. What is the best balance between mitigating interference concerns and avoiding limiting flexibility in the future? Can engineering and forward-looking spectrum strategies account for the possibility of unanticipated technologies and uses in adjacent spectrum bands? How do we promote flexibility without unreasonably increasing the cost of services and devices? Does the Act provide the FCC tools to address this problem?**

Response:

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[12] Ryan Knutson and Thomas Gryta, "Verizon, AT&T May Face Bidding Limits in Spectrum Auction," The Wall Street Journal, April 18, 2014, http://online.wsj.com/news/articles/SB10001424052702304626304579510154106120342.

[13] *Ex Parte* Submission of the United States Department of Justice, Docket No. 12-269 (filed April 11, 2013), http://apps.fcc.gov/ecfs/document/view?id=7022269624.

By dictating a set of standards into law, Congress would be addressing a problem that may not exist in the next several years. This is the same situation that the update to the Telecommunications Act of 1996, which in turn updated the Communications Act of 1934, seeks to address. A law can become obsolete because it is not technology or vendor neutral. Much like the regulations that impose restrictions on copper-wire and wireline communications which stymie innovation, standards to address specific interference issues will decrease innovation in the marketplace.

Barring a legislative or regulatory solution, interference issues will likely be addressed by the telecommunications industry based on consumer demand for interference avoidance measures. By allowing the free market to innovate to meet consumer demand, interference issues will be resolved more effectively. Should Congress set specific standards or require the FCC to set these standards, the decision to meet the standards will prevail, and the desire to innovate and improve beyond the standards will decline.

10) **The other governing body of domestic spectrum use is the National Telecommunications and Information Administration (NTIA), which has the authority to assign spectrum frequencies to all federal government owned or operated radio stations under section 305 of the Communications Act. NTIA manages the federal government's use of spectrum, in coordination with the FCC. Distinctions between "federal" or "non-federal" bands of spectrum are administrative creations made through agreements between the FCC and NTIA. The Spectrum Act required NTIA to work with the FCC to identify specific bands for release to commercial use and how to repurpose resources from federal to commercial use, with priority given to options that assign spectrum for exclusive, non-federal use through competitive bidding. In a report on reducing duplication in the federal government, GAO identified spectrum management as 'fragmented' between NTIA and the FCC and urged coordination. What role should NTIA play in the licensing and management of spectrum? Is their current role appropriate and necessary, given the potentially duplicative functions of the FCC and NTIA in spectrum allocation and assignment?**

Response:

Duplicative and overlapping programs plague the federal government, including the NTIA and the FCC sharing jurisdiction over spectrum management. CCAGW believes that there should be only one agency overseeing the allocation of spectrum within the federal government.

The FCC has several bureaus that are involved in spectrum management. As noted in CCAGW's response to Question 1, spectrum management should be consolidated within the FCC where possible, with the other bureaus reporting their spectrum needs. NTIA manages the federal government's use of spectrum

to ensure that America's domestic and international spectrum needs are met while making efficient use of this limited resource. The FCC and NTIA must coordinate and collaborate to ensure that the nation's spectrum needs are met, while at the same time meeting their own individual mission goals.

In addition to the FCC and NTIA, a number of other entities play a role in spectrum management. As noted by the GAO's "2012 Annual Report: Opportunities to Reduce Duplications, Overlap and Fragmentation, Achieve Savings, and Enhance Revenue," the Interdepartment Radio Advisory Committee (IRAC) and the Office of Management and Budget (OMB) are also involved in spectrum management. IRAC consists of 19 agencies that hold more than 90 percent of all federally assigned spectrum. This committee coordinates federal use of spectrum and provides NTIA policy advice on spectrum issues. OMB's role in spectrum management is through the federal budget process, and the agency has issued guidance for the use of spectrum-dependent systems by federal agencies.[14]

In its findings on spectrum management, the report notes that GAO had previously stated that "coordination challenges between NTIA and FCC have delayed efforts to repurpose spectrum for new commercial uses, and changes that affect existing users of spectrum can cause contentious stakeholder conflicts that cross the jurisdictions of both agencies, and can lead to protracted negotiations."[15]

By consolidating the roles and responsibilities of spectrum management into one federal agency, the federal government can avoid overlapping missions and duplication. While NTIA plays an important role in managing government held spectrum, as well as developing the FirstNet first responder network, these responsibilities, budget, and personnel could be shifted to the FCC under a new spectrum management bureau, thus reducing duplication and waste in the programs.

[14] U.S. Government Accountability Office, GAO-12-342SP: 2012 Annual Report: Opportunities to Reduce Duplications, Overlap and Fragmentation, Achieve Savings, and Enhance Revenue, February 28, 2012, p 89, http://www.gao.gov/assets/590/588818.pdf.
[15] Ibid.