Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Fostering Innovation and Investment in the Wireless Communications Market	)	GN Docket No. 09-157
	)	
A National Broadband Plan for Our Future	)	GN Docket No. 09-51
	)	

REPLY COMMENTS OF THE PUBLIC INTEREST SPECTRUM COALITION

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I. INTRODUCTION AND SUMMARY

On behalf of the Public Interest Spectrum Coalition, we are pleased to submit these reply comments regarding the Commission's Notice of Inquiry on Fostering Innovation and Investment in the Wireless Communications Market.[1] As the Commission noted, the market for wireless broadband services has been evolving at an extraordinarily rapid pace and is delivering new and empowering technologies to American consumers.[2] Most recently, this is reflected in an exploding consumer demand for mobile data with the increasing use and availability of smartphones and aircard modems.

The result of this data explosion has been a near unanimous call from wireless industry operators for more spectrum to meet demand. Currently wireless companies hold licenses for just over 500 MHz of spectrum. CTIA urged the Commission to commit to identifying and allocating a significant amount of exclusively-licensed spectrum – with a goal of at least an additional 800 MHz – for commercial wireless services.[3] This 800 MHz request is based entirely on a 2006 spectrum requirements study by the ITU.[4] Based on an elaborate modeling of emerging cellular technologies (such as LTE and WiMAX) and cell densities, ITU concluded that advanced market economies would require total allocations of roughly 1,300 MHz by 2015 and 1,720 by 2020.[5]

However, we believe that it is impractical, inefficient and ultimately anti-consumer to attempt to meet the growing demand for mobile data consumption primarily through traditional

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[1] *See* In the Matter of Fostering Innovation and Investment in the Wireless Communications Market; A National Broadband Plan for Our Future, *Notice of Inquiry*, GN Docket Nos. 09-157, 0951, FCC 09-66 (rel. Aug. 27, 2009) (the "*Notice*").
[2] *Id.*
[3] *See* Written Ex Parte Communication, CTIA-The Wireless Association, GN Docket 09-51, (filed Sept. 29, 2009), http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=7020039747,
[4] *Estimated Spectrum Bandwidth Requirements for the Future Development of IMY-2000 and IMT-Advanced*, Report ITU-R M2078 (2006).
[5] *Id.*

reallocations of exclusively-licensed spectrum by auction. While there is no question that the existing commercial wireless business model – based on exclusive licensing, tower-based hub/spoke channelization, centralized infrastructure and metered billing – will need more exclusive-use spectrum in the short-run to meet mobile data demand, it should be equally clear that this model is not sustainable longer term. As high-capacity wireline connections and a consumer's ability to purchase hybrid mobile devices becomes more prevalent, it is neither cost-effective nor pro-consumer to encourage a model whereby most mobile data would be transported over expensive licensed airwaves, and through relatively distant carrier-provisioned infrastructure, when most communication can flow short distances over unlicensed airwaves and consumer-provisioned backhaul.

Wise policy choices will be necessary to facilitate – and not impede – a market evolution toward these more spectrum-efficient and cost-effective "hybrid" or "heterogeneous" wireless broadband networks. In addition to easy and robust access to shared spectrum with varying propagation characteristics, the Commission's pending extension of *Carterfone* rules to mobile Internet access services will be critical to ensuring that consumers have the choice to use devices capable of automatically switching among multiple wireless networks based on the consumer's (and not the carrier's) preferences. We would expect that freed from carrier control, wireless device innovators will be motivated to offer consumers hybrid devices that can determine on the fly what connectivity is most economical for the consumer at a given time and place.

The commercial wireless provider, relying on limited but exclusively-licensed spectrum, and shouldering the capital costs for centralized infrastructure, should increasingly confine its role to being the "quality of service provider" within a heterogeneous network controlled by consumers at the edge. Consumers will happily pay for remote coverage, for needed mobility (connectivity on the move), or for the transport of latency-sensitive applications. But they should not pay an intermediary to send the bulk of their mobile data over the publicly-owned airwaves when there is a far more economic and spectrum-efficient alternative using local control over shared spectrum.

Therefore, in addition to reallocating bands cleared completely for exclusive licensing, the public interest in promoting pervasive connectivity, innovation and consumer welfare suggests that the FCC should also lay the groundwork for complementary spectrum access models that facilitate innovative wireless networks. To facilitate this wireless infrastructure, we believe it is essential for the Commission, the executive branch and Congress to explicitly support alternative models for spectrum access through:

- **Opportunistic Access to Bands that Cannot be Cleared Quickly**

In every community across the country, the vast majority of prime spectrum capacity lies fallow the majority of the time. At the same time, there are only a limited number of bands that can be cleared of incumbent use for reallocation via auction and exclusive licensing in any meaningful time frame. In underutilized bands where it is not practical to relocate current users, or where that would likely take many years, spectrum capacity can be made available more rapidly by opening the bands to "opportunistic access" on a secondary basis that requires the user to avoid causing harmful interference with the incumbent use. Underutilized federal bands should be an early focus for opportunistic access made possible by (a) adding frequencies to the TV Bands database; and (b) expanding the purpose of the CSEA Spectrum Relocation Trust to finance the modernization of federal systems to improve performance and facilitate spectrum sharing. Opportunistic access presumes, as does the TV white space Order, that cognitive radio devices are multi-band and capable of frequency hopping. Unlike licensed bands, where it is expensive and time-consuming to upgrade or clear off existing users, no legacy devices need to be tied to a particular frequency. Bands can be opened or closed for sharing – nationally, regionally, or locally – and even on short notice, without "stranding" any users or equipment.

- **Wholesale Access**

An allocation conditioned on leasing bandwidth or transmission to any ISP or application/service (e.g., for embedded connectivity) will promote market entry, roaming, competition and innovation. Spectrum made available in traditional one-off auctions are also often too expensive for small, local providers and start-ups; and even for more established carriers, the auction blocs may not correspond well to the target market. Auctioned spectrum is even less appealing to device and service providers – including an increasing number serving the need for embedded connectivity in "smart" energy, environmental, telemedicine and distance learning applications. Wholesale access allows for more intensive, flexible and efficient use of spectrum resources that also promotes robust competition among wireless operators and allows for innovative uses and products. Treasury could receive payments in perpetuity on such allocations – as a royalty on revenue, much as the Interior Department leases natural resources – rather than solely receiving revenues through a one-off auction. This approach would not preclude an auction, but would lower the barrier to entry, leaving more capital for infrastructure.

- **New Unlicensed Bands**

The public interest and emerging economic realities strongly dictate that a substantial share of newly-cleared spectrum be reallocated for unlicensed use on a national basis. These new unlicensed bands should include at least one very substantial and contiguous unlicensed band with superior propagation characteristics, below 1 GHz if feasible, as a means of diversifying the unlicensed spectrum ecosystem. The increasing need for shared spectrum as both an alternative and a complement to 4G carrier networks relying on licensed spectrum suggests that unlicensed networks need a similar combination of more total capacity, high-capacity (wide) channels and excellent propagation. Rural areas would benefit most from access to lower frequency unlicensed or licensed "lite" spectrum (such as the 3.65 GHz band) to promote greater wireless broadband from smaller operators. The history of innovation in the 2.4 GHz unlicensed band demonstrates that expanding unlicensed access will lead to new innovation by entrepreneurs followed by larger companies. New unlicensed bands could also provide a platform for the development of cooperative wireless devices and mesh networks.

- **Test-Beds to Spur Innovation**

One way to augment the FCC/NTIA "Test-Bed" is to make spectrum in bands corresponding to FCC-held licenses more readily available for commercial and/or technological trials. An example is the 2155-2180 MHz band, which is not likely to be assigned and built-out for a new use for many years. Opening additional FCC-held (and NTIA-held) bands could be implemented in tandem with the sort of expanded opportunistic access to a multiplicity of bands that could be managed through the TV Bands Database.

A critical step toward making substantially more spectrum capacity available for wireless broadband services and innovation is to make transparent how, where and when this publicly-owned resource is currently being used – or not used – by current public agency and private sector licensees. The White House direct a joint NTIA/FCC effort to undertake a comprehensive ***Inventory of the Airwaves*** so that policymakers, innovators and the public have a more complete, comprehensive inventory of what frequencies are *actually* in use, for what purpose, with what technology, at what locations, frequencies and times. Both government and private sector assignments and uses should be included in the map. Actual spectrum use measurements in a large and regionally diverse sampling of markets should be part of the Commission's broadband mapping exercise.

II. EXPANDING SPECTRUM USE AND AVAILABILITY

A. Foundational Principles and Successful Approaches

Over the past 15 years, the Commission has promoted wireless innovation by steadily moving spectrum policy away from static, command-and-control licensing toward a more productive mix of flexibly-licensed and unlicensed spectrum access. To accelerate and build on this trend, we believe the Commission can best promote innovation, consumer welfare and bedrock First Amendment principles by applying the following four foundational policies to spectrum management:

(1) ***Unlicensed and Opportunistic Access:*** Unleashing an abundance of spectrum and driving down its cost as an input for all things mobile is the single best means by which the Commission, the Administration and Congress can promote innovation and consumer welfare in wireless. Not every American, nor even every innovator and entrepreneur, can obtain a spectrum license – a constraint that is even more severe in a period of "scarce" licenses sold at high-price auctions. Nor can individuals avoid paying an intermediary to transmit bits over the air, or share a wired broadband connection, or communicate on a peer-to-peer mobile basis, without direct citizen access to the airwaves. Unlicensed bands – and opportunistic access to unused portions of even licensed bands – are proven means to meet these communication needs as well as to fuel the fires of innovation and entrepreneurship. As noted below, more shared spectrum access is both feasible and essential for consumers to realize the full benefits of the next generation of high-capacity and pervasive wireless connectivity.

(2) ***Flexible Yet Contingent Licensing:*** The Commission has wisely shifted to assigning spectrum with flexible service and technical rules, including the ability to more readily transfer and lease spectrum on secondary markets, which generally permits licensees to determine the technologies and business models based on market conditions. At the same time, in keeping with the Communications Act, licenses are temporary, confer no property rights and are contingent on serving the public interest. The Commission retains the ability to place appropriate public interest conditions on licenses, such as build-out, network neutrality and opportunistic access requirements. The Commission must continue to maintain and refine this balance between flexibility, on the one hand, and the imperative to manage the airwaves to optimize the public welfare, on the other.

(3) ***Competition Policy:*** Repurposing prime spectrum for new technologies and services is unlikely to serve the public interest sufficiently if wireless markets are overly consolidated or wireless incumbents exercise market power over the increasingly important adjacent markets for mobile devices, applications, web content and services online. The most important FCC policy promoting innovation and competition among commercial wireless networks was the imposition of a **spectrum cap** in 1994 to prevent undue consolidation as a result of auctions, which were new at the time. As a result of those caps, three or more competing carriers emerged in nearly all markets. Although making spectrum more abundant would be the best in theory to prevent consolidation harms, these comments make clear the practical obstacles to finding and allocating more spectrum for exclusively licensed uses. Therefore, re-imposing stricter caps should be

considered as the wireless market continues to consolidate.[6] Another critical aspect of competition policy is **consumer protection**. Extending strong *Carterfone* consumer choice rules to the wireless market is needed to make both primary and adjacent markets more competitive.[7]

(4) ***Increased Transparency:*** Although commonly thought of as a resource owned collectively by the American people, spectrum access rights and actual spectrum use are largely obscured from public view. As noted in more detail below, a detailed "inventory of the airwaves," including actual spectrum use measurements and monitoring, should be both a civic imperative as well as a critical step toward opening up the vast wasteland of underutilized bands that are a legacy from the era of traditional analog licensing.

In its comments in this docket, we note that AT&T put forward its own set of four "foundational" policies that it claims account for the supposedly unblemished success of today's commercial wireless industry. AT&T's set of principles essentially boils down to auctioning fully flexible spectrum, with property-like rights, and protecting licensees from interference. This incumbent carrier perspective ignores the need for an affirmative competition policy, the increasing benefits of unlicensed spectrum, and the tremendous potential to unlock fallow spectrum through technologies and policies that promote opportunistic access. Wireless innovation will result not only – or even principally – from the continued expansion of centrally-controlled networks, but increasingly from heterogeneous, user-provisioned networks in which consumers can control the degree to which they rely on unmediated/shared spectrum versus licensed spectrum services.

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[6] *See* Comments of Consumer Federation of America, Consumers Union, Free Press, Media Access Project, the New America Foundation, and Public Knowledge, WT Docket No. 09-66, at 23-26 (filed Sept. 30, 2009) ("Mobile Wireless Competition Comments").

[7] *Id.* at 17, 27.

B. Vastly Increasing Exclusively-Licensed Allocation is Unsustainable, Inefficient and Anti-Consumer

As smartphones with PC capabilities and broadband aircards gain access to faster 4G and LTE networks beginning next year, total wireless data consumption will increase geometrically. The iPhone has proven to be the canary in the proverbial spectrum coal mine: with the equivalent of a mobile computer and thousands applications to choose among, iPhone users consume between five and ten times the bandwidth as other Smartphone users – and hundreds of times the bandwidth of ordinary cell phones. At a recent FCC Broadband workshop on spectrum, a representative from AT&T noted there had been a nearly 5,000 percent increase in data traffic over their wireless networks over the last three years.[8] Cisco's annual projection of global Internet traffic predicts a 129% compound annual growth rate (CAGR) for mobile data over the next five years in North America (through 2013).[9]

The increasing market penetration and use of smartphones with capabilities similar to today's iPhone and G-1 may increase mobile data demand by a factor of 16 or more within five years (conservatively growing from approximately 3,700 to 62,000 terabytes – see figure 1 below).[10] The network capacity needed for mobile Internet applications will dwarf the capacity currently used for voice and texting, each of which are low-bandwidth applications. Furthermore, actual mobile data demand is likely to be far greater than even these estimates predict:

First, as noted above the smartphone data projection we assume is conservative. It assumes the penetration of devices with capabilities similar to today's iPhone will increase from 17% to 50% and that the average smartphone user will consume only as much data (400

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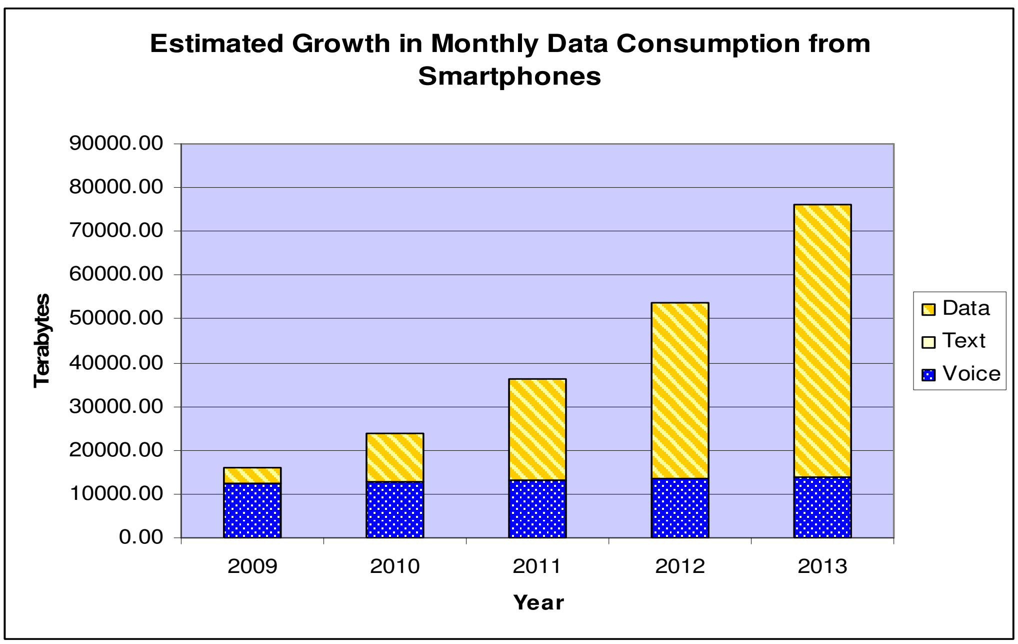
[8] Kris Rinne (AT&T), "The Fast Track to 4G Using HSPA and 700 MHz Spectrum, FCC National Broadband Plan Workshop, Sept. 16, 2009.

[9] *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update*, January 29, 2009, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf

[10] *See* Figure 1.

MB/month) as today's iPhone user. Second, this handset projection does not include the projected growth of mobile broadband aircards used with laptops, notebooks and netbooks. According to Cisco's study, a single laptop generates as much wireless data traffic as 450 basic-feature phones.[11] By comparison, a Blackberry generates as much traffic as 30 basic-feature phones. Cisco projects a 117% CAGR for aircards through 2013, with aircard/PC data consumption nearly as large as smartphone demand.[12] 4G data rates over low-frequency spectrum (which penetrates well indoors) may make wireless data substitution for low-demand (and/or lower-income) residential consumers quite compelling and common – just as cell phones

Figure 1*: Estimated Growth in Monthly Data Consumption from Smartphones



*The above chart represents a best effort estimate of the future growth in U.S. mobile data consumption as result of greater adoption of smartphones. Total mobile subscribership is assumed to grow at a rate of 3% per year. Growth rates for voice and text messages are assumed to be 3% per year and based upon monthly voice minutes and text messages reported from CTIA's 2009 Semi-Annual Wireless Industry Survey Results. Data consumption for smartphones is assumed to grow from an average of 80 MB/month in 2009 to 400 MB/month by 2013 (same as the average iPhone user today) and smartphone market penetration from 17% in 2009 to 50% in 2013. Although 123 billion text messages were sent per month during the first half of 2009, each message is just 160 bytes (total of 19 terabytes/month) and therefore is not visible on the chart.

[11] *Id.*
[12] *Id.*

are steadily replacing wired lines. Third, pervasive connectivity will rapidly become integrated in applications for sensing networks, health care (e.g., remote monitoring), energy conservation (e.g., smartgrid, home appliance networks), education, public safety, and e-government – much as devices like the Kindle are already embedding wireless connectivity.

1. Spectrum Alone will Not Absorb Growing Demand

Meeting consumer demand for mobile data will require some combination of four strategies:

- Increased spectrum access
- Smaller cell sizes
- More efficient wireless architectures/technologies
- More effective use of wired backhaul

While there is no question that the existing commercial wireless business model – based on exclusive licensing, tower-based hub/spoke channelization, centralized infrastructure and metered billing – will require more exclusive-use spectrum in the short-run to meet peak mobile data demand, it should be equally clear that this model is not sustainable longer term.

First, while it may be feasible to clear incumbents from approximately 200 MHz of spectrum within a few years, there appears to be no economically or politically feasible path to clearing the 800 MHz recently requested by CTIA, the Wireless Industry Association.[13] The CTIA projection appears to be based solely on a 2006 study by the International Telecommunications Union (ITU). The futility of meeting projected demand by clearing new bands for auction is highlighted by the fact that the ITU study estimated a considerably higher requirement for markets (such as the U.S.) that aim to sustain sufficient spectrum capacity for three or four competing ISPs in each market. The ITU's total spectrum requirement for three

[13] CTIA Comments, GN Docket Nos. 09-157, 09-51, at vi (filed Sept. 30, 2009); *see also* CTIA, Ex Parte Communication, GN Docket No. 09-51, at 1 (filed Sept. 29, 2009).

competing networks is 1,980 MHz by 2015 – and 2,240 MHz to support four competitive networks (see Figure 2 below). Clearing the additional 1,700 MHz of spectrum that ITU estimates would required to sustain robust competition among multiple networks and technologies within the same local area – and with propagation characteristics that ensure quality of service – does not seem feasible within a meaningful time frame. What is more likely to result from a policy premised solely on clearing bands and auctioning more exclusive licenses is a continuation of current trends: a sort of controlled scarcity that releases "just enough" spectrum, and does so at costs that deter competitive entry and innovation, while encouraging further industry consolidation and market power.

***Figure 2*: ITU Spectrum Requirements for High-Density Markets**

	1 network	2 networks	3 networks	4 networks	5 networks
Total Spectrum (MHz)	1720	1760	1980	2240	2500

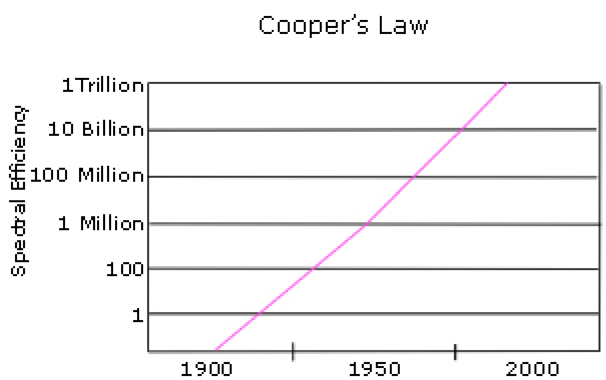
Source: *ITU, Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced* (2006).

Second, as the CTIA/Rysavy report observes, although LTE technology will be considerably more spectrum efficient than 3G (EV-DO and UMTS/HSPA), "there are both theoretical and practical limits to spectral efficiency and current systems are approaching those limits." The ITU's spectrum requirements study assumes that LTE in 2020 will already be at 75% of the theoretical limits imposed by Shannon's Law – yet still less efficient than WiFi "hot spots."[14]

Third, while the 802.16m (WiMAX) and LTE standards process anticipates further cell-plitting via "relay stations," there are practical limits to how close carriers can bring their owned

[14] Rysavy Research, *Mobile Broadband Spectrum Demand* (December 2008), at 14, 19.

infrastructure (transmitters and backhaul) to the individual user. According to CTIA data, over the two years since June 2007, total cell sites have increased just 14% (from 210,000 to 246,000). At the cusp of exploding demand for mobile data, the industry's cell site bottleneck is a real dilemma. Martin Cooper, leader of the team at Motorola that invented the first mobile phone, has calculated that frequency re-use is responsible for roughly 65 times as much of the improvement in total wireless utilization over the past 45 years as any improvement attributable to making more spectrum available.[15]



Cooper writes:

> Of the million times improvement in the last 45 years, roughly 25 times were the result of being able to use more spectrum, 5 times can be attributed to the ability to divide the radio spectrum into narrower slices — frequency division. Modulation techniques . . . take credit for another 5 times or so. The remaining sixteen hundred times improvement was the result of confining the area used for individual conversations to smaller and smaller areas — what we call spectrum re-use. The importance of spectrum re-use for making more effective use of the spectrum is even greater than reflected in these figures. Frequency division and the various modulation techniques have yielded about as much as we can ever expect. The gains we get are costly and these gains

[15] Martin Cooper, "Cooper's Law," ArrayComm, available at http://www.arraycomm.com/serve.php?page=Cooper.

often compromise voice quality. Shannon's Law teaches us that there is only so much information that can be delivered in a given bandwidth with a given signal-to-noise ratio.[16]

Finally, while more investment in special access can improve the capacity of towers and cells, it will be extremely cumbersome and expensive to bring carrier-provisioned backhaul to each and every carrier cell – and more so if the number of cell sites could plausibly grow in proportion to demand. In its Comments, AT&T in this proceeding opined that the industry "is going to need a *lot* more backhaul. Today 80 to 90 percent of all wireless cell sites are served by legacy copper T1s. . . . There is simply no way that copper T1s can support the huge increases in wireless traffic that are already under way."[17] While it is certainly encouraging to know that "[v]irtually all wireless carriers are currently mounting major campaigns to upgrade backhaul facilities to fiber,"[18] as with cell sites it appears impractical and redundant to bring carrier backhaul close to the typical consumer. Exacerbating the shortage of carrier-provisioned backhaul is the fact that the two dominant wireless carriers also dominate the market for special access through their wireline subsidiaries, which – absent fairly radical regulatory reform – will make it that much more costly and unlikely that their smaller national and regional competitors can keep pace.[19] All this is not to suggest that there will not be adequate backhaul capacity for pervasive connectivity; it just won't be primarily carrier-provisioned infrastructure. As high-capacity wireline connections become ubiquitous among both residences and business

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16 *Ibid.*

17 *See* Comments of AT&T Inc., GN Docket Nos. 09-157, 09-51, at 97-98 (filed Sept. 30, 2009) ("AT&T Comments").

18 *Ibid.*

19 *See, e.g.*, Reply Comments of Consumer Federation of America, Consumers Union, Free Press, Media Access Project, the New America Foundation, and Public Knowledge, WT Docket No. 09-66, at 5-6 (filed Oct. 22, 2009) ("Mobile Wireless Competition Reply Comments")

establishments, consumers will already be paying for backhaul that could be used to offload mobile data traffic at a point far closer to the user than the carrier infrastructure can be sited.

2. The Imperative for Hybrid/Heterogeneous Networks

As high-capacity wireline connections and a consumer's ability to purchase hybrid mobile devices becomes more prevalent, it is neither cost-effective nor pro-consumer to encourage a model in which most mobile data would be transported over expensive licensed airwaves, and through relatively distant carrier-provisioned infrastructure. Instead this data could and should flow short distances over unlicensed airwaves and consumer-provisioned backhaul. Recent experiments with femtocells and with services such as T-Mobile's *@Home* service – in which consumers pay an extra fee to have a share of their traffic routed by WiFi over their own wired Internet connection – reflect a growing realization that it will be most efficient to re-use spectrum down to the level of the personal cell, while utilizing consumer-provisioned wired connections.

In two recent papers, MIT researchers William Lehr and John Chapin describe the economic and engineering logic of this trend toward what they call "hybrid wireless broadband networks." They write:

> A hybrid wireless broadband access service is a high-capacity converged service implemented via multiple overlaid wireless networks, some of which share resources with other systems. . . . [Hybrid networks] combine multiple spectrum access models, for example dedicated spectrum (exclusively licensed) and shared spectrum (unlicensed). The set of flexible spectrum sharing models we anticipate to appear are collectively referred to as Dynamic Spectrum Access (DSA).

> [T]he inherent scarcity of spectrum pushes wireless architectures toward specialization and away from general-purpose designs in the quest for greater spectral efficiency. . . . We see the trend to greater sharing as both inevitable and desirable. However, the rate of increase of sharing and the eventual intensity of sharing and spectrum use depend on appropriate policy choices and research investments.[20]

As Lehr and Chapin opine, wise policy choices will be necessary to facilitate – and not impede – a market evolution toward these more spectrum-efficient and cost-effective hybrid networks. In addition to easy and robust access to shared spectrum with varying propagation characteristics, the Commission's pending extension of *Carterfone* rules to mobile Internet access services will be critical to ensuring that consumers have the choice to use devices capable of automatically switching between multiple wireless networks based on the consumer's (and not the carrier's) preferences. We would expect that freed from carrier control, wireless device innovators will be motivated to offer consumers hybrid devices that can determine on the fly what connectivity is most economical for the consumer at a given time and place.

The commercial wireless provider, relying on a necessarily limited amount of exclusively-licensed spectrum, and shouldering the capital costs for centralized infrastructure, should increasingly confine their role to being the "quality of service provider" within a heterogeneous network controlled by consumers at the edge. Consumers will happily pay for remote coverage, for needed mobility (connectivity on the move), or for the transport of latency-

[20] William H. Lehr and John M. Chapin, "Hybrid Wireless Broadband," Paper presented at t*he 37th Telecommunications Policy Research Conference (TPRC),* Arlington VA, September 2009, available at http://www.tprcweb.com/images/stories/papers/LehrchapinTPRC_2009.pdf; *see also* their earlier companion paper, William Lehr and John Chapin, "Divergent Evolutionary Paths for Wired and Wireless Broadband," invited paper presented to Workshop on Wireless Technologies: Enabling Innovation & Economic Growth, Georgetown Center for Business and Public Policy, Washington DC, April 17, 2009.

sensitive applications. But they should not need to pay an incumbent carrier or intermediary to send the bulk of their mobile data over the publicly-owned airwaves when there is a far more economic and spectrum-efficient alternative using local control over shared spectrum. Consumer welfare and economic efficiency will be enhanced by cognitive and cooperative devices that default where feasible to a local, very low-power network transmitting on unlicensed or other shared spectrum. Indeed, as more shared spectrum enables more cognitive and cooperative devices, mobile consumers can more readily hop to wireline transit on a P2P basis even when away from open WiFi ports.[21]

C. New Spectrum Access Models

Within a decade it is quite likely that the typical American will spend more hours each week on mobile than on wired Internet connections. Demand for spectrum will outpace availability under current spectrum management policies. Meanwhile, in every community across the country, large swaths of valuable spectrum lie fallow the majority of the time. This underutilized spectrum represents enormous, untapped, public capacity for high-speed and pervasive broadband connectivity. Therefore it is vital both for the national broadband plan and for a sustainable, long term spectrum plan to consider policies that will encourage more intensive and efficient use of the nation's spectrum resources.

Despite the Commission's acknowledgment that traditional "command and control" spectrum management is outdated and inefficient,[22] the federal government has continued to approach spectrum allocation in a piecemeal fashion that reinforces the conventional wisdom

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[21] *See id.* at 25 (noting that the prospect of paying carriers a premium for femtocells, just so that the customer can avoid using the carriers' infrastructure, hardly seems like a good deal for consumers).

[22] *See* Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium, *Policy Statement,* 14 FCC Rcd 19868 (1999); *see also Notice*, Statement of Commissioner Robert M. McDowell.

that spectrum is a scare resource in need of central management. The reality is that it is only government permission to use spectrum, in the form of licenses that is scarce. Spectrum capacity itself is abundant. Indeed, while actual spectrum measurement studies are difficult to find, those in studies that are available and in the public domain have demonstrated that even in the so-called "beachfront" frequencies below 3 GHz, the vast majority of frequency bands are not being used in most locations and at most times.

In spectrum measurement studies for the New America Foundation (2003), and in a larger study funded by the National Science Foundation (2004), Mark McHenry, a former manager of DARPA's NeXt Generation spectrum program, found that even in Manhattan and in Washington D.C. near the White House, less than 20 percent of the frequency bands below 3 GHz were in use over the course of a business day.[23] McHenry's NSF study demonstrated in a mix of urban, suburban and exurban areas that the vast majority of the most valuable spectrum bands are vacant or unused for the majority of the time.[24] The highest occupancy rate on the prime beachfront spectrum below 3 GHz was just 13 percent in New York City, while the average across locations studied was just 6 percent. Across the country, this underutilized spectrum represents an enormous untapped capacity for broadband; particularly in rural areas

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[23] Mark McHenry, "Dupont Circle Spectrum Utilization During Peak Hours, A Collaborative Effort of The New America Foundation and The Shared Spectrum Company," New America Foundation Issue Brief (2003), available at http://www.newamerica.net/files/archive/Doc_File_183_1.pdf. Mark McHenry, "NSF Spectrum Occupancy Measurements: Project Summary," Shared Spectrum Company (August 2005)), available at http://www.sharedspectrum.com/measurements/. McHenry's 2005 study collected frequency use data in six locations along the East coast in 2004 and documented an average total spectrum use of less than 10%. Specific findings over a day-long period included: 3.4% in Great Falls, Virginia; 6.9% in Vienna, Virginia (location 1); 11.4% in Arlington, Virginia; 13.1% in New York City; 1.0% in Green Back, West Virginia; and 11.7% in Vienna, Virginia (location 2). The New York City measurements were taken during a national party convention (when a far higher-than-average use of law enforcement and federal agency spectrum would be expected), yet the vast majority of the public airwaves still remains unused

[24] *See* "Spectrum Occupancy Measurements," Shared Spectrum Company, available at. http://www.sharedspectrum.com/measurements/.

where average usage of "beachfront" spectrum is in the low single digits.[25] Indeed, the Commission's Spectrum Policy Task Force Report recognized this opportunity in 2002:

> Preliminary data and general observations indicate that many portions of the radio spectrum are not in use for significant periods of time, and that spectrum use of these "white spaces" (both temporal and geographic) can be increased significantly...
>
> Often technologies such as software-defined radio are called "smart" or "opportunistic" technologies because, due to their operational flexibility, software-defined radios can search the radio spectrum, sense the environment, and operate in spectrum not in use by others...
>
> That is, because their operations are so agile and can be changed nearly instantaneously, they can operate for short periods of time in unused spectrum.[26]

It is indisputable that a variety of "smart radio" technologies (e.g., geolocation, sensing and dynamic frequency selection) and spectrum management tools (e.g., the forthcoming TV Bands Database, beaconing) will support dynamic, shared use of a large number of federal and non-federal bands with little risk of interference to incumbents.[27] At the outset, however, we want to clarify our expectation that frequency bands that are intensively and efficiently in use – such as the bands used for CMRS – are the least suitable candidates for spectrum band sharing, except possibly in geographic areas that are not built out. We note that certain industry commenters, including CTIA and AT&T, made strenuous arguments against opportunistic access

[25] *See* Tugba Erpek, Mark Lofquist, and Ken Patton, "Spectrum Occupancy Measurements Loring Commerce Centre Limestone, Maine September 18-20, 2007" Shared Spectrum Company (2006), available http://www.sharedspectrum.com/measurements/download/Loring_Spectrum_Occupancy_Measurements_v2_3.pdf.
[26] FCC, Spectrum Policy Task Force Report, Washington, DC: November 2002, at 3, 4, 14.
[27] Indeed, even parties such as AT&T – which disputes the efficacy of cognitive technologies in bands that incumbent wireless carriers control and use on an exclusive basis – proclaim their "full[ ] support" for "experimentation with cognitive radio and other developing technologies in uncongested spectrum bands." *See* AT&T Comments at 9.

to the bands they license.[28] AT&T characterizes cognitive radio access to fallow capacity as "forced spectrum sharing," as if the managed use of unused capacity on a non-interfering basis would somehow impose a burden on the licensee (we assume it would not). Regardless, these concerns seem completely unfounded vis-à-vis bands occupied by cellular providers. There are many hundreds of MHz of other high-quality spectrum that is far more lightly-used and better suited to opportunistic access of unused capacity than are the PCS and other bands used by the commercial wireless industry.

What follows is a description of several alternatives to band clearing and exclusive licensing that could open spectrum capacity to a far greater degree, to a far larger and more diverse set of users, and in a manner that facilitates far greater innovation in spectrum efficiency and business models.

1. Opportunistic Access to Unused Capacity

In some bands, Congress or the Commission may determine that it is feasible to relocate incumbent users to accommodate the reassignment of frequencies on an exclusively licensed basis, as occurred with the 90 MHz of federal and broadcast auxiliary spectrum cleared under the Commercial Spectrum Enhancement Act of 2004. But in a far larger number of bands – where it either not practical to relocate current band users or where that would likely take many years, spectrum capacity can be made available more rapidly by opening the bands to "opportunistic access" on a secondary basis, and pursuant to requirements that the secondary user must avoid causing harmful interference to the incumbent use.

Opportunistic access could be particularly useful given the lumpiness of spectrum demand by geography and population density (e.g., rural vs. suburban vs. urban). The greatest

[28] *See* AT&T, NOI Comments at 75-86; CTIA, NOI Comments at 80-82.

needs for capacity are not nationwide or around the clock, but primarily urban and during peak use periods. Rather than an entire network needing additional spectrum, it may be a few cells that are substantial oversubscribed and would benefit from having access to additional spectrum for short period of time.

The most promising mechanism for making substantial new allocations of spectrum available for wireless broadband deployments and other innovation is to leverage the TV Bands Database, which the Commission's Office of Engineering and Technology will certify as means of identifying and accessing available "white space" channels not in use in discrete geographic locations across the nation's 210 local TV markets. Under the Report & Order adopted unanimously by the Commission in November 2008, [29] both fixed and mobile broadband devices will be allowed to operate on an unlicensed basis on unused DTV channels ("white space") provided that the devices have GPS and the capability to periodically check an online database of available TV channel frequencies in that discrete geographic location. TV band white space devices (WSDs) will be required to query a national database to determine available channels at their current location before transmit capabilities are engaged.

There appears to be no reason to limit the functionality of the TV Bands Database to the TV band frequencies – and no reason not to add more fallow bandwidth to the "common pool" that is parceled out via the TV white space geolocate and look-up system. If a potentially useful frequency band is not being used at particular locations (e.g., used in New York City but not in West Virginia), or is being used only at certain times or at certain altitudes or angles of reception, then that currently wasted spectrum capacity could at a minimum be listed in the Database for opportunistic access, subject to whatever power limits or other conditions would be

[29] Unlicensed Operation in the TV Broadcast Bands, *Second Report and Order and Memorandum Opinion and Order*, ET Docket No. 04-186, ET Docket No. 02-380, FCC 08-260 (released November 14, 2008) ("*TVWS Order*").

necessary to avoid harmful interference to sensitive incumbent operations. Under the Order, the TV Bands Database is likely to rely on a Repository Service (a data repository that contains information on all the Protected Entities – i.e., licensed users – as well as on the registered devices and systems seeking access to the band) and on one or more Query Services (which will refer to a daily or even real-time copy of the Database to give operators of devices and systems a list of channels available for use at their actual GPS coordinates).[30]

Although location and time are only two of the dimensions along which underutilized frequency bands can be shared dynamically by "smart" radio technologies and protocols,[31] adding other bands to the TVWS Database could ultimately increase available spectrum capacity by hundreds of megahertz or more, particularly in rural areas where measured spectrum usage below 3 GHz is in the low single digits today. The Commission's access rules for TV white space anticipates the use of frequency-hopping, multi-band radios, which are increasingly common and affordable in commercial mobile systems. Device makers and service providers would simply choose the combination of frequencies most appropriate to their needs. Devices (whether fixed access points or mobile handsets) would scan and select the clearest frequency from among those that their devices can be tuned to utilize.

Both federal and non-federal bands should be added to the Database, with access to each band subject to conditions that are tailored to avoid harmful interference to existing, licensed use. For example, the ability to opportunistically share military radar bands is technically very different than sharing a band used primarily for fixed services, such as satellite or point-to-point

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[30] *See Ex Parte* Filing of the White Spaces Database Group, in ET Docket No. 04-186, April 10, 2009, which outlines a potential architecture for the Database as proposed by a broad-based industry and consumer consortium that includes Comsearch, Dell, Fox, Google, Microsoft, Motorola, MSTV, NetLogix, Neustar and the Public Interest Spectrum Coalition.

[31] *See, e.g.,* Robert J. Matheson, "Flexible Spectrum Use Rights," 8 Journal of Communications and Networks 144, June 2006, *available at http://www.its.bldrdoc.gov/pub/ntia-rpt/05-418/05-418_matheson.pdf.*

microwave links, or a trunked land mobile radio system. One feature that facilitates the Pentagon's willingness to allow dynamic sharing of radar frequencies in the 5 GHz band is that unlike television reception, radar poses no "hidden node" challenge to spectrum sensing and Dynamic Frequency Selection technologies because the transmitter and receiver are co-located. In a fixed service band, by contrast, sensing may be less reliable than simply calculating the availability of frequencies in discrete locations based on the listing of protected transmit sites.

Kevin Werbach, a professor at the Wharton School and a former FCC technologist, suggests that "properly designed, this system [the TV Bands Database] could be the basis for a distributed dynamic routing database, analogous to the DNS (Domain Name System) on the wired Internet."[32] He also correctly observes that:

> To achieve such a result, however, the database must not be limited to White Space devices alone. The FCC and industry must also take care to avoid the mistakes and failings of the current DNS infrastructure. These include the imposition of artificial scarcities, the creation of a private monopolist, and the bureaucratization of technical management functions.

Bands reserved for federal agency use seem particularly well-suited for opportunistic access for a variety of reasons. Among the reasons are that federal bands are at least nominally controlled by NTIA and, unlike a private sector licensee, the Department of Commerce and other federal users can be expected to balance their own needs with the public interest in expanding available wireless broadband capacity. The military in particular has both very wide bands of spectrum that are unused in most locations on most days – and the ability to enforce priority-in-

[32] Kevin Werbach, "A Domain Name System (DNS) in the Air," blogpost at CircleID.com, May 21, 2009, http://www.circleid.com/posts/20090521_addressing_system_for_next_wireless_internet/. Professor Werbach is currently writing a more indepth paper on this topic for publication by the New America Foundation (forthcoming).

use over opportunistic private sector users during the occasional emergency that justifies reserving those bands. Indeed, the Department of Defense (DoD) has done exactly that in the past – opening up extensive military radar bands for passive sharing with low-power unlicensed users equipped with 'smart radio' technology that is able to sense if radar is operating and vacate the channel in under one second.[33]

It is important to be clear that just because a frequency band is not fully or frequently utilized in a particular geographic area – which is what the McHenry/NSF spectrum measurements indicate – does not mean it is not serving its assigned purpose, or that its incumbent users can be relocated. Many military bands in particular are assigned for mission-critical training and emergency purposes that are episodic or geographically limited in nature. While in many such cases "clearing" a band of its current licensee and reassigning it exclusively to private sector licensees cannot be justified, there is nevertheless tremendous communications capacity that could be productively used at no cost or harm to the incumbent – just as the military today shares several radar bands with unlicensed users of low-power unlicensed devices.[34]

At the same time, even a band that would register as "occupied" over the course of a day or week may still have tremendous unused spectrum capacity. A band of frequencies can be "white" (underutilized) and potentially shared on a number of different dimensions. Retired NTIA engineer Robert Matheson described seven dimensions that define the potential capacity of a given band of spectrum – and the potential for dynamic, or flexible, spectrum usage rights – as illustrated in Table 3 below:

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[33] For a brief history of how DoD shares radar bands with the private sector, and a proposal describing how federal agencies can take affirmative steps to facilitate expanded and more efficient band sharing, see Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Governmment Spectrum," Wireless Future Program Issue Brief #25, New America Foundation (June 2009), at 4-6.
[34] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Governmment Spectrum," Wireless Future Program Issue Brief #26, New America Foundation (June 2009).

Table 3. Electrospace Model: Dimensions of Spectrum Sharing[35]

Quantity	*Units*	*No. of Dimensions*
Frequency	kHz, MHz or GHz	1
Time	seconds, hours, months	1
Spatial Location	latitude, longitude, altitude	3
Angle of Arrival	azimuth, elevation angle	2

While this model describes what may be considered the theoretical potential for squeezing the maximum communications capacity out of a band of spectrum, it also highlights the inefficiency of today's two-dimensional spectrum "zoning" policies. Even without relying on the relatively expensive technologies required to share underutilized bands along many simultaneous directions, it is clear that with today's technology, a competent "inventory" of the airwaves would reveal sufficient data to allow policymakers to facilitate more efficient use of currently wasted spectrum capacity.

Unique Advantages of a Dynamic Spectrum Access Database

Building on the TV Bands Database (TVBD) has a number of other distinct advantages, particularly if it is utilized for opportunistic access:

[35] Robert J. Matheson, "Flexible Spectrum Use Rights," *Journal of Communications and Networks*, 8 (June 2006), 144, available at http://www.its.bldrdoc.gov/pub/ntia-rpt/05-418/05-418_matheson.pdf.
See also Robert J. Matheson, "The Electrospace Model as a Tool for Spectrum Management," NTIA Institute for Telecommunications Sciences, presented at ISART 2003. Matheson adapted his Electrospace Model from the work a quarter-century earlier of W. R. Hinchman. *See* W.R. Hinchman, "Use and Management of Electrospace: A New Concept of the Radio Resource," in *Proc. IEEE ICC'69*, 1969.

First, the "assignment" of bands for opportunistic access need not be permanent, or even long-term. A band can be added, or withdrawn, or limited to a particular geographic area or time of day, at any time. Under the TV white space rules, the Commission reserves the option to license additional TV stations, thereby "delisting" a vacant channel from the Database in that particular local market area. Opportunistic access presumes that devices will increasingly be multi-band and capable of frequency hopping. Unlike licensed bands, where it is expensive and time-consuming to upgrade or clear off existing users, no white space devices need to be tied to a particular frequency. Bands can be opened or closed for sharing – nationally, regionally, or locally – and even on short notice, without "stranding" any users or equipment.

Second, building on the TVBD model provides the Commission the policy flexibility to make spectrum available on a temporary basis when spectrum today is wasted simply because there is no alternative to the virtually all-or-nothing ethos of long-term exclusive licensing. For example, for years the Commission has struggled with the issue of how best to reallocate the very sparsely-used AWS-3 band at 2155 – 2180 MHz. With a geolocate database in place, any fallow band could be listed for immediate access – and then delisted (or restricted in additional ways) if and when a new licensee has been selected and builds out.

Third, opportunistic access using a geolocate database addresses the vexing problem of valuable licenses that are not built out, particularly in rural areas, by moving to a "use it share it" condition (rather than a more draconian "use it or lose it" rule).[36] For example, there are PCS, AWS and EBS frequency blocs that are not being used and may never be built out for economic reasons in rural and small town areas. These unused frequencies could be made available to local broadband providers, such as small rural WISPs, RLECs and community networks, on an

[36] *See Notice* ¶ 33. While the "use it or share it" approach fosters many benefits, there still may be situations in which a long-term failure to build out should indeed result in loss of a license under rules similar to those imposed on certain 700 MHz Band commercial licensees. *See id.* & n.29.

opportunistic basis. In addition to expanding available spectrum capacity, this would have the additional benefit of making licensee build-out and spectrum usage more transparent, especially if these frequencies were available for opportunistic use up until such time as a licensee or lessee actually builds out and commences operations – not merely until such time as a licensee expresses an intention to enter into a lease. Such advances would be a boon for rural broadband deployment in particular, since those are the areas with the most valuable spectrum lying fallow.

Another distinct advantage of a geolocate database is that access to different bands can be subject to different (and changeable) operating rules. There is no need for one-size-fits-all access to opportunistically available spectrum. Each listed frequency band can carry its own "rules of the road" with respect to maximum signal power, leakage into adjoining bands, or even the times of day or angle of transmission that would be allowed. This would permit the Commission, where appropriate, to factor in conditions that protect incumbent services, not only on the same frequency, but on adjacent frequencies. It would also allow the Commission to foster innovation with respect to new network architectures – such as conditioning access to some bands on more spectrum-efficient cooperative mesh protocols, rather than on the standard 802.11 contention-based protocols.[37] The TV Bands Database will demonstrate a simple version of this capability. For example, while both fixed and mobile devices will receive lists of available TV channels based on geolocation, the mobile devices will be limited to far lower power levels on all channels, while the fixed devices will not be permitted to transmit on channels immediately adjacent to licensed TV stations.

Finally, the database permission approach could also ensure that there is never a "tragedy of the commons" on a particular band. For example, the database could give permission to access certain bands only in exchange for micro-payments to certain licensees that need to be

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[37] *See* Comments of Powerwave Technologies Inc., GN Docket Nos. 09-157, 09-151 (filed Sept. 24, 2009).

compensated for offering opportunistic access (e.g., as an incentive or compensation for a licensee's investment in more interference-resistant receivers, or for other affirmative measures to facilitate shared access).[38] Payments would be tantamount to user fees and could be collected upfront (as FCC device certification fees) or on an ongoing, real-time basis. With respect to a feared "tragedy of the commons," transmitters seeking a list of permitted channels could also be required to report back the frequency they choose to use and the duration of their transmission. While utilizing the geolocate database to perform such traffic cop functions would require a virtually real-time database that is a step beyond the resource contemplated in the 2008 TVWS Order, such a database technologically feasible to add that capability as needed.

Eli Noam first suggested micro-payments as a safeguard against potential congestion on the most desirable bands (or in the highest demand markets, such as New York or L.A).[39] More recently, Google Telecomm Policy Counsel Rick Whitt suggested that web-based technologies could now support a real-time auction of frequency slots on an automated and fairly low-cost basis, just as Google conducts real-time auctions matching advertisers to search terms: "For every query using Google's search engine, the company separately performs its own real-time auction to determine the market price of a particular advertisement linked to a particular search term. In the same way, an auction could be performed for a radio transmission in a pertinent place and time to determine the economic value the market would support for that

[38] It's important to note in this regard that licensing under the Communications Act does not contemplate exhaustive rights to the spectrum capacity on a band, but rather the right to use the designated frequency to the extent needed to provide a communications service that serves the public interest. Unused spectrum capacity on any band, in any location, remains public property. Therefore, even without waiting for license renewal, the Commission can at any time permit use of the otherwise wasted spectrum capacity on a non-interfering basis.

[39] Eli Noam, "Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism: Taking the Next Step to Open Spectrum Access," *Journal of Law & Economics*,, Vol. 41(2), at 765-90 (1998), available at http://www.citi.columbia.edu/elinoam/articles/SPECTRM1.htm; *see also* Eli Noam, "Taking the Next Step Beyond Spectrum Auctions: Open Spectrum Access," *IEEE Communications,* Vol. 33(12), December 1995.

transmission."[40] Commission staff have also demonstrated theoretically that efficiency can be improved if "a given band of spectrum is treated as a common pool resource in the absence of excessive spectrum congestion, but is treated as an excludable private good in the presence of such congestions."[41]

It's important to note in this regard that while micro-payments could be useful as a prophylactic against extreme congestion, there is no reason the Commission should assume either that congestion is inevitable, or that legacy licensees need to be 'bribed' to permit public use of otherwise wasted capacity. While spectrum capacity could certainly become constrained in absolute terms in our wireless future, we are nowhere near that point. With a majority of the spectrum below 3.1 GHz available even in New York City at any particular time, the only near-term risk of congestion would be the result of the Commission failure to move quickly or aggressively enough to stock the proposed TV Bands Database (or a similar frequency clearinghouse) with underutilized frequencies.

Nor should spectrum incumbents expect to be 'bribed' for relinquishing any supposed rights to squat on fallow spectrum. The Communications Act specifies that licensing is temporary and that it does not contemplate granting exhaustive rights to the spectrum capacity assigned with any band. By law, what is licensed is the *temporary* right to use the designated frequency *to the extent needed* to provide a communications service that serves the public interest. Unused spectrum capacity on any band, in any location, remains public property and subject to new conditions the Commission determines will serve the public interest. Therefore, even without waiting for license renewal, the Commission can at any time permit use of the

[40] Richard S. Whitt, Google *Ex Parte* filing, WC Docket No. 06-150 (Service Rules for the 700 MHz Spectrum Auction) (filed May 21, 2007), Appendix A, at 6. S*ee also* Google Inc., Comments in NOI on Wireless Innovation and Investment, GN Docket No. 09-157 (filed Sept. 30, 2009), at 11.
[41] Mark M. Bykowski, et al., "Enhancing Spectrum's Value Through Market-informed Congestion Etiquettes," FCC/OSP Working Paper Series No. 41, February 2008.

otherwise wasted spectrum capacity on a non-interfering basis. Indeed, as Eli Noam wrote over a decade ago, the government has an obligation not to create any unnecessary barriers to citizen communication, particularly over government-controlled conduits such as the airwaves that are intrinsically a public forum:

> [S]pectrum access is traffic control, not real estate development. It's about flows, not stocks. . . .
>
> The emergence of technologies that make it possible for multiple users of spectrum to cohabit and move around frequencies has profound effects. It is not just that it is arguably a more efficient system . . . But, more importantly, it is *constitutionally* the stronger system. . . . Electronic speech is protected by the First Amendment's Free Speech Clause. Therefore the state may abridge it only in pursuance of a "compelling state interest" and through the "least restrictive means" that "must be carefully tailored to achieve such interest."[42]

Broaden the Federal Spectrum Relocation Fund into a 'Spectrum Efficiency Fund'

Nowhere is spectrum underutilization and the potential for expanded and robust sharing more evident than in many of the bands reserved for use by the federal government itself.[43] Unfortunately, just like private sector licensees (particularly those that received their licenses for free), federal agencies have little incentive to undertake the costs – or the risks – associated with upgrading systems to promote spectrum efficiency. The FCC, in coordination with NTIA, should investigate and recommend ways in which federal and non-federal spectrum incumbents

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[42] Noam, "Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism: Taking the Next Step to Open Spectrum Access," *Journal of Law & Economics*,, Vol. 41(2), at 765-90 (1998), available at http://www.citi.columbia.edu/elinoam/articles/SPECTRM1.htm.

[43] For an in-depth discussion of the utilization of federal spectrum and policy recommendations for reallocation of this underutilized spectrum, *see* Victor Pickard and Sascha D. Meinrath, "Revitalizing the Public Airwaves: Opportunistic Reuse of Government Spectrum," Wireless Future Working Paper, New America Foundation (June 2009), also forthcoming in *International Journal of Communications* (2009).

can take *affirmative steps* to enable more intensive access and band-sharing by other users. Although the DoD, for example, has begun sharing military radar bands with low-power unlicensed operations, government users are entirely passive and take no affirmative steps to facilitate private sector use of lightly-used bands.

Michael Marcus, a retired chief spectrum engineer at the FCC, suggests that it's time to require that new and upgraded federal systems be designed and procured with the broader public interest in spectrum access in mind.[44] As Marcus observes:

> What both generations of federal band sharing have most in common is that government users are entirely passive; they do nothing to facilitate private sector use of these lightly-used bands. Shared use is permitted, but only to a very limited degree that places the entire burden on private industry to 'work around' federal systems to avoid interference. . . . However, a third generation of sharing could be based on new technologies for federal government radio systems that are designed with sharing in mind and that can actually *facilitate* sharing.[45]

We believe that the most effective incentive – and win-win scenario – for the military and other federal agencies would be a streamlined source of funding to modernize systems to facilitate spectrum efficiency, band sharing, and even frequency migration where feasible. There is such a potential source: the Spectrum Relocation Fund created by Congress under the Commercial Spectrum Enhancement Act (CSEA) of 2004.[46] The CSEA earmarked revenue from the auction of certain federal bands to AWS licensees into a Spectrum Relocation Fund.

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[44] *See* Michael J. Marcus, "New Approaches to Private Sector Sharing of Federal Government Spectrum," Issue Brief #26, New America Foundation (June 2009).
[45] *Id. at* 4-5.
[46] Commercial Spectrum Enhancement Act, Pub. L. No. 108-494, 118 Stat. 3986, Title II (2004) (codified in various sections of Title 47 of the United States Code) ("CSEA").

That fund remains available to reimburse federal agencies out of spectrum auction proceeds for the cost of relocating their operations from certain "eligible frequencies" that have been reallocated from federal to non-federal use.[47] If the purposes of the Spectrum Relocation Fund were broadened – turning it into a sort of revolving fund for modernizing federal systems not only to migrate off some bands entirely, but to facilitate the shared or more efficient use of other federal bands, agencies would have the incentive of an off-budget upgrade of their capabilities. Enhancing agency budgets with revenue tied to the purpose of upgrading to state-of-the-art equipment, we believe, would prove to be a far stronger and more focused incentive than giving agencies the option to lease unused capacity on secondary markets (which, if it ever generated more than trivial amounts of revenue, could not be counted on to increase the agency's overall resources since OMB or Congressional appropriators could view it as an offset).

As there is legislation pending that promises to streamline the CSEA band-clearing process,[48] the FCC and Administration should support an additional provision to expand the purposes of the Fund. A revised CSEA that expands the Spectrum Relocation Fund into a "Spectrum Efficiency Fund" – and maintains it as a sort of revolving fund. – would promote all of the benefits described above. Moreover, if there were any legitimate concern about auction revenues being insufficient for such purposes, Congress could revise the CSEA to direct that devices certified to operate on the newly-shared bands opened due to expenditures from the Fund pay a one-time certification fee to help replenish the Fund.

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[47] CSEA §§ 201-209. Eligible frequencies comprise four bands specified in CSEA (the 216-220 MHz, 1432-1435 MHz, 1710-1755 MHz and 2385-2390 MHz bands), as well as any other band of frequencies reallocated from federal use to non-federal use after January 1, 2003, and assigned by the Commission through competitive bidding. *Id.* § 202 (codified at 47 U.S.C. § 923(g)(2)).

[48] *Spectrum Relocation Improvement Act of 2009*, H.R. 3019, 111th Congress, introduced by Reps. Jay Inslee, Fred Upton, Rick Boucher (June 24, 2009).

2. Wholesale Access Models

Another access model the Commission should consider in light of increased demand for spectrum is wholesale access. Given the minimum availability of contiguous blocks of spectrum in the prime frequencies and the difficulty of clearing contiguous spectrum bands, the amount of spectrum for typical wide-area licensing may be insufficient to sustain multiple operators in the same area. Spectrum made available in traditional one-off auctions are often too expensive for small, local providers and start-ups; and even for more established carriers, the auction blocs may not correspond well to the target market. Auctioned spectrum is even less appealing to device and service providers – including an increasing number serving the need for embedded connectivity in "smart" energy, environmental, telemedicine and distance learning applications. Wholesale access allows for more intensive, flexible and efficient use of spectrum resources while also that also promotes robust competition among wireless operators and allows for innovative uses and products.

From an efficiency standpoint wholesale access to a single network is superior to promoting competition via dividing spectrum into small blocks with providers on multiple channels.[49] First, efficiency arises from the sharing, by multiple providers, of a single platform or infrastructure. The construction and deployment of just one network, engineered to allow many providers to use it, rather than a number of redundant networks, substantially reduces the capital and operations cost *per bit transmitted*.[50] In addition, it is more difficult and costly to seamlessly create the same capability over multiple smaller channels than with the larger

[49] An Engineering Assessment of Select Technical Issues Raised in the 700 MHz Proceeding, Columbia Telecommunications Corporation, WT Docket No. 06-150, May 2007, http://www.newamerica.net/files/700%20MHz%2007-05-23filing%20on%20FNPRM.pdf.
[50] *Id.*

channel.[51] Second, it allows for more efficient use of the spectrum by limiting the amount of wasted, idle spectrum set-aside for guard bands and mitigation of RF interference among individual providers/bands. Third, as speeds scale in proportion to increases in channel size, a potentially larger shared block of spectrum will allow each provider to offer a higher theoretical maximum speed to their customers.[52] For example, LTE can facilitate download speeds of up to 15 mbps on a 10 MHz channel, whereas HSPA could only provide download speeds of up to 3.75 mbps on a 5 MHz channel.[53] Finally, there is no technical limit to the number of retail competitors, while an exclusive band plan limits competition to the number of spectrum blocks provided for commercial use.[54]

Wholesale access on a network can come in a variety forms. Typically in the U.S. firms have purchased bandwidth or capacity in bulk on a provider's network. Wholesale access in the U.S. is currently limited to IP uses or M2M such as Amazon's Kindle, which uses both Sprint and AT&T's network,[55] in part because such services do not directly compete with an operator's core business. This type of access can also facilitate the development of mobile virtual network operators (MVNOs). The products they offer may not always be perfect substitutes to MNOs, rather MVNOs often develop retail services to target market segments that MNOs may be uninterested in trying to reach.[56] Among the first in the U.S. was Virgin Mobile, which

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[51] *Id.*
[52] *Id.*
[53] *See* Table 2, Rysavy Research, *Mobile Broadband Spectrum Demand* (December 2008) at 14.
[54] An Engineering Assessment of Select Technical Issues Raised in the 700 MHz Proceeding, *supra note* 49.
[55] "Amazon stops selling Sprint-powered Kindle," *cnet News.com*, October 22, 2009, http://news.cnet.com/8301-17938_105-10381325-1.html.
[56] Aniruddha Banerjee and Christian M. Dippon, "Voluntary Relationships Among Mobile Network Operators and Mobile Virtual Network Operators: An Economic Explanation," January 29, 2009, 5, http://www.nera.com/image/PUB_Voluntary_Relationships_IEP_Feb2009.pdf.

concentrated on prepaid phone services.[57] MVNOs such as Tracfone, do not purchase wholesale access to capacity on the network, but rather resell pre-paid wireless services from operators such as AT&T and Verizon.[58]

In *comments* during the Commission's deliberation on the auction of the 700 MHz band, PISC proposed that wireless operators in that spectrum band provide transmission services at wholesale rates at a gateway, either between the tower and the backhaul network or between the backhaul network and core network (or, if necessary, between the licensee's core network and the broader "cloud").[59] Service level agreements between the network operator and another service provider would dictate service attributes such as the number of users support, maximum bandwidth supported, and quality of service. [60] This type of wholesale access would allow for a much greater diversity in wireless services providers, allowing one provider to offer a bundle of services including telephony, video, and Internet access, another only voice and data, and the third exclusively a video content provider.[61]

Japan's Ministry of Information and Communication (MIC) has pursued a similar policy and taken a proactive approach to promoting wholesale access for MVNOs.[62] Based on its *Mobile Business Revitalization Plan*[63] the MIC requested current mobile phone operators to promote cooperation with MVNOs and sound development of telecommunications by providing

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[57] Virgin Mobile was recently purchased by its wholesale partner, Sprint Wireless. "Sprint Buys Virgin Mobile, the Last MVNO," Wi-Fi Net News, July 28, 2009, http://wifinetnews.com/archives/2009/07/sprint_buys_virgin_mobile.html

[58] "TracFone Reselling Both Verizon and AT&T," Gerson Lerhman Group, October 15, 2009, http://www.glgroup.com/News/TracFone-Reselling-Both-Verizon-and-ATT-44170.html

[59] Comments Of The *Ad Hoc* Public Interest Spectrum Coalition, WT Docket No. 06-150, May 23, 2007, 13 – 17, http://www.newamerica.net/files/700%20MHz%2007-05-23filing%20on%20FNPRM.pdf.

[60] An Engineering Assessment of Select Technical Issues Raised in the 700 MHz Proceeding, *supra note* 49.

[61] *Id.*

[62] Japan Communications launches MVNO service, *TeleGeography's CommsUpdate*, August 8, 2008, http://www.telegeography.com/cu/article.php?article_id=24493.

[63] *Mobile Business Revitalization Plan*, Japan Ministry of Internal Affairs and Communications, September 21, 2007 (translated), http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Releases/Telecommunications/pdf/news070921_2_ap.pdf

for wholesale access to their wireless bandwidth and telecommunication equipment.[64] Among the requirements of MNOs:

- Develop a standard plan for wholesale telecommunications service and to clarify and announce centralized contact points for MVNOs[65] and disclose standard terms and conditions and charges for wholesale.
- Respond as promptly as possible and provide services on equal and fair basis when carriers submit applications.[66] MNOs can also set individual terms and conditions with each MVNO. However, any specific rules set by MNOs apply to every applicant.

In addition, The MIC is authorized to ask MNOs to change their rules concerning wireless wholesale if MNOs set rules to discriminate or prevent MVNOs from legal business operations or the rules are harmful to the public.[67] MVNOs have to submit applications to the MIC concerning wireless wholesale for providing wireless services.[68] If MNOs and MVNOs have conflict regarding charges, terms and conditions, they can file petition to the MIC and Telecommunications Business Dispute Settlement Commission for judgment.[69]

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[64] *Guideline Concerning Applications of the Telecommunications Business Law and the Radio Law pertaining to MVNO,* Japan Ministry of Internal Affairs and Communications, May 2008, http://www.soumu.go.jp/menu_news/s-news/2008/pdf/080519_1_bt1.pdf .

[65] "Mobile Phone Operators Requested to Disclose Information on Standard Plan Development for Wholesale Telecommunications Service and Clarify and Announce Centralized Contact Points for MVNOs," Japan Ministry of Internal Affairs and Communications, May 19, 2008, http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Releases/Telecommunications/news080519_3.html.

[66] Japan Ministry of Internal Affairs and Communications Business Law article 6. p.5 http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Resources/laws/TBL/TBL-index.html

[67] *Guideline Concerning Applications of the Telecommunications Business Law and the Radio Law pertaining to MVNO,* Footnote 17, *supra note* 64.

[68] Japan Ministry of Internal Affairs and Communications Business Law Telecom Business Law article 9, Article 16-1, p7-8: http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Resources/laws/TBL/TBL-index.html. *See also* Radio Law, article 70 (Law No. 131 of May 2, 1950) As amended last by: Law No. 48 of June 15, 2001 p.44. http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Resources/laws/2001RL.pdf.

[69] Japan Ministry of Internal Affairs and Communications Business Law (Law No. 86 of December 25, 1984), amended last by: Law No. 125 of July 24, 2003. Article 35-1,3,4,(p.23) article 38 (p.35) and article39 (p.35), article 156-2(p.69), article 154 (p.69), http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Resources/laws/TBL/TBL-index.html.

Among the recent outcomes of Japan's new policies is a partnership between Hewlett Packard (HP) and Japan Communications (JCI), an MVNO operator . HP is planning to sell laptops, netbooks, and touchscreen tablets with 100 minutes of free airtime and a built-in, pay-as-you-go wireless system.[70] HP will rent access from JCI, who does not own base stations or antennas and instead purchases wholesale access from Japanese wireless operator, DoCoMo.[71] Consumers can buy connectivity on a pay-as-you-go basis from Japan Communications, but it is branded as an HP service.[72] The partnership could spur thousands of imitators offering pay-as-you go wireless services for all kinds of new devices that use the web or require data connectivity. In addition, the success of pre-paid mobile phones for increasing penetration of mobile voice to low-income resident could be duplicated for wireless Internet access through laptops and netbooks.

Band Managers and Real-Time Auction Access

Another policy variant of wholesale access is a band manager (either a public or licensed private entity) that could sell access to increments of spectrum capacity on the basis of desired frequency, power, time, and geography – all of which could vary widely by user. The system could work similar to trunking that is utilized by public safety, wherein spectrum is utilized as a common pool.[73] If the government wanted to collect revenue for this spectrum from a private band manager/operator (whether by RFP or auction), payments could be collected as a share of

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[70] Kenji Hall, "HP Shakes Up Japan's Wireless Market," *Business Week*, August 6, 2009. http://www.businessweek.com/globalbiz/content/aug2009/gb2009086_649413.htm
[71] Japan Communications launches MVNO service, *TeleGeography's CommsUpdate*, August 8, 2008, http://www.telegeography.com/cu/article.php?article_id=24493**.**
[72] Kenneth Carter, "Japan Communications' New Business Model," http://kennethrcarter.com/CoolStuff/2009/10/japan-communications-new-business-model/.
[73] *See* "Trunked Radio System," *Wikipedia,* http://en.wikipedia.org/wiki/Trunked_radio_system.

proceeds in perpetuity (as royalties). As Google suggests in its Comments, real-time auctions for access to this bandwidth "could be managed via the Internet by a central Clearinghouse. Payments would be made in perpetuity as the spectrum is being used, rather than months or even years in advance as under the current auction-first, build-later model."[74]

Real-time auctions could be integrated in the future at two separate levels of the network: first, among retail service providers within an open access spectrum allotment, and second, between the service providers in the open access band and those in other spectral bands.[75] Dynamic spectrum auctions could be particularly useful given the aforementioned lumpiness of demand for spectrum. At a given time, a provider may only need additional spectral capacity in a specific area, for a short amount of time, to handle an increase in traffic. In the same way that opportunistic access could be used to fill these short-term spectral needs (as described in the section above), dynamic auctions could allow MNOs, MVNOs, or other entities to purchase spectrum use with micropayments.

The benefits of this over existing one-off auctions are three-fold: First, it lowers entry costs for new entrants, local providers and other firms embedding connectivity as an input to another product by limiting the need for the significant amount of upfront capital required by typical one-off auctions. Second, it ensures that returns to the government for use of public spectrum resources reflect the current value of resource. In a one-off auction, the value of spectrum at auction is reflective of the current value to a winning bidder, not its value five to ten years later, when an increased demand for spectral capacity would have yielded a higher auction value for the resource. Third, the shorter the auction cycles, the greater the potential throughput or capacity resulting from the spectrum. For example, one study of dynamic auctions found that

[74] *See* Comments of Google Inc., GN Docket Nos. 09-157, 09-51, at 11 (filed Sept. 30, 2009).
[75] An Engineering Assessment of Select Technical Issues Raised in the 700 MHz Proceeding, *supra note* 49.

performing auctions every 50 minutes can double the system throughput of a system compared to those using 300 minutes.[76] While conventional auction items cannot be reused among multiple bidders, dynamic spectrum auctions can exploit spatial reuse by multiple bidders to maximize its usage.[77]

Real-time auctions of could facilitate spectrum trading that applies pricing based incentives to motivate users to sell and lease under-utilized spectrum.[78] For example carriers could have the right to negotiate for highly dynamic access to each other's spectrum.[79] Such negotiation might allow each carrier comparable incursions into the other's spectrum, or the carrier making greater use of its neighbor's spectrum might pay for the privilege.[80] It becomes even more efficient if several cellular carriers have collocated transmitters to serve the same cell. At a given time, one provider may be at peak capacity, and therefore forced to block any additional calls. Meanwhile, other providers may have idle spectrum at that moment that could be used for the new call.[81]

3. New Unlicensed Bands

While a number of bands can and should be cleared for reallocation on the basis of exclusive licensing – whether or not conditioned by wholesale access or other requirements – we believe that the public interest and emerging economic realities strongly dictate that a substantial share of newly-cleared spectrum be reallocated for unlicensed use on a national basis. These new unlicensed bands should include at least one very substantial and contiguous unlicensed

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[76] Xia Zhou, Shravan Mettu†, Heather Zheng, Elizabeth M. Belding, "Traffic-Driven Dynamic Spectrum Auctions," 2, http://www.cs.ucsb.edu/~htzheng/publications/pdfs/sdr08.pdf.
[77] *Id,*. 2
[78] Sorabh Gandhi, Chiranjeeb Buragohain*, Lili Cao, Haitao Zheng, Subhash Suri, "Towards Real-Time Dynamic Spectrum Auctions," 1, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.129.9683&rep=rep1&type=pdf.
[79] Jon M. Peha, "Sharing Spectrum through Spectrum Policy Reform and Cognitive Radio," 13, http://research.microsoft.com/en-us/um/redmond/events/cognetsummit/papers/Peha_Proc_of_IEEE.pdf.
[80] I*d.*
[81] *Id,* 12.

band with superior propagation characteristics, below 1 GHz if feasible, as a means of diversifying the unlicensed spectrum ecosystem (which is primarily at higher frequencies that are less useful for mobile broadband) and offering potential data rates that will complement licensed 4G mobile offerings.

There are a number of reasons that any substantial clearing and reallocation of presently assigned bands should include a new and largely exclusively unlicensed band with superior propagation characteristics. First, as argued above, heterogenous networks relying on micro-cells, shared spectrum and self-provisioned wired backhaul will be the most cost- and spectrum-efficient way to accommodate both pervasive and very high-capacity wireless mobile data consumption in the future. The long-term trend in both licensed CMRS provision, as well as in consumer choice for mobile data, is clear: There is a steady shift to lower and lower power services because this makes most efficient use of the most expensive (exclusively-licensed) spectrum. The gradual shift from 3G to 4G technologies, combined with moving fiber and other high-capacity wired backhaul into or close to the premises, also points in this direction. Without low-power networks – and most data off-loaded to consumer-provisioned LANs – it is not likely that multiple, competing ISPs can provide next generation service to the home and office. Since unlicensed applications have thrived at low power, we believe this transition to low power service favors unlicensed over licensed allocations.[82] The potential for gigabit-capacity wireless LANs in schools, offices, high-density residential areas and elsewhere is hobbled without more unlicensed spectrum.[83]

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[82] James H. Johnston and J.H. Snider, "Breaking the Chains: Unlicensed Spectrum as a Last-Mile Broadband Solution," Spectrum Series Working Paper #7, Washington, DC: New America Foundation, June 2003.

[83] *Id.* See also "One Gigabit or Bust Initiative: A Broadband Vision for California," Los Alamitos, CA: Cenic, May 2003.

Second, the increasing need for shared spectrum as both an alternative and a complement to carrier networks relying on licensed spectrum suggests that unlicensed networks need a similar combination of more total capacity, high-capacity (wide) channels and excellent propagation. Although the 2.4 GHz band, despite heavy use, is rarely 'congested,' spectrum at that frequency and at low power has inherent limitations with respect to penetration inside buildings, through foliage, and over long distances in rural and other less densely-populated areas. The capital cost to provide good meshed network coverage over a square mile at 2.4 GHz versus 700 MHz has been estimated, in studies by Intel and others, to be at least four times higher.[84] Of course, unlicensed access to the TV "white space" channels will meet the need for shared spectrum with superior propagation to a degree. However, although useful for many purposes, as currently configured the utility of the TV white spaces for broadband Internet access is severely constrained in several respects: channels are very narrow (less than 6 MHz) and rarely contiguous across a region; moreover, the permitted power levels for personal/portable devices is far lower than in other WiFi bands (40 mW on adjacent channels, 50 mW on non-adjacent) and the geolocation database requirement adds costs as well.

Third, in a proceeding where the government is deciding whether to continue to require exclusive licenses to communicate on a band, it must do so for a good reason and in a manner that promotes First Amendment values. Because only the practical need to manage scarcity can justify licensing exclusive access to the airwaves,[85] the Commission should seek to minimize the need for licenses and expand direct citizen access to the spectrum wherever possible. This constitutional imperative gathers increasing force as cognitive radio technologies and other

[84] *See* Chris Knudsen and Masud Kibria, "Capital Expenditure Implications of Spectrum Assets in Semi-rural Environments," Intel Corporation (unpublished internal study, version 3.4), October 2004.
[85] See *Red Lion Broadcasting Co., Inc. v. FCC*, 395 U.S. 367, 387-95 (1969).

mechanisms (such as a geolocation database that can play 'traffic cop') demonstrate an ability to permit "communication without permission" while still avoiding harmful interference.

Finally, and most directly relevant to this inquiry, the history of innovation in the 2.4 GHz unlicensed band demonstrates that expanding unlicensed access will lead to new innovation by entrepreneurs followed by larger companies. Today, the unlicensed bands are at the center of telecommunications innovation. For example, in 2004 the majority of Wi-Fi chipsets were destined for PCs and notebook computers. By 2008, only half were used for that purpose, with significant proportions going into smartphones and other consumer electronics devices. Projections for 2012 show that shipments of Wi-Fi for use in both these latter categories are set to overtake those destined for PCs and notebooks, which will account for only 20 percent of chipsets. The same cannot be said for licensed cellular technology.[86]

Such innovation is the result of low barriers to entry, allowing for more and smaller manufacturers of equipment, quicker upgrade cycles and end-user purchasing versus carrier control.[87] In any given unlicensed band, an almost unlimited number of devices and business models can freely compete. The result has been an explosion of consumer choice, with the average American now having more unlicensed than licensed radio devices.[88] Unlicensed spectrum provides an unmediated, low-cost conduit for an increasing diversity of networks, devices and applications that are not only generating billions of dollars each year in equipment sales, but expanding consumer welfare by a multiple of this amount.

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[86] Richard Thanki, "The economic value generated by current and future allocations of unlicensed spectrum," *Perspective Associates*, September 8, 2009, 40, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=7020039036.
[87] *Id.*
[88] *See, e.g.,* Kenneth Carter, et al. "Unlicensed and Unshackled: A Joint OET-OSP White Paper on Unlicensed Devices and Their Regulatory Issues," OSP Working Paper #39, Washington, DC: FCC, May 2003.

Since the Commission ruling to allow the use of direct sequence spread spectrum (DSSS) technology for communications in the ISM bands, formerly known as the "junk" bands, unlicensed spectrum has served as an incubator of innovation. The most prominent impact has been the spread and ubiquitous use of Wi-Fi networking. From wireless local area networks (WLAN) to metro area Wi-Fi networks, Wi-Fi chips have ended up in everything from mobile phones, netbooks and portable media players, TVs and cameras,[89] and even bathroom scales.[90] From 2005 to 2008, nearly 1 billion Wi-Fi chipsets were sold.[91] This growth is likely to continue, with sales likely to reach around 1.5 billion devices a year by 2014.[92]

The value and importance of Wi-Fi is only further underscored by the increasing use of unlicensed spectrum by cellular companies to offload traffic from smartphones, such as the iPhone, off of their networks that rely on exclusively licensed spectrum. According to ABI, 44 percent of smartphones currently have Wi-Fi built in and 90 percent are expected to incorporate Wi-Fi by 2014. ABI predicts that the number of Wi-Fi enabled mobile phone shipments per year will reach 141 million in 2009 and 520 million by 2014.[93]

Although, licensed operators have largely been dismissive of the importance of unlicensed spectrum, they have substantially benefited from it recently. For the first three months of 2009, AT&T reported 10.5 million Wi-Fi connections on its hotspot network, more than triple the number during the first quarter of 2008 – and more than half the 20 million total

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[89] Thanki, 18, *supra note* 86.
[90] http://nexus404.com/Blog/2009/07/28/withings-wiscale-wi-fi-bathroom-scale-monitor-your-weight-loss-and-body-fat-using-iphone-app/
[91] Represent an estimate based on Wi-Fi chipsets sales reported by Wi-Fi Alliance. See, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=20, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=262, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=643, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=770
[92] Thanki, 18, *supra note* 86.
[93] "Wi-Fi is now a must-have for mobile phones; User affinity to drive annual shipments to 300 million in 2011," Wi-Fi Alliance, April 1, 2009, http://www.wi-fi.org/news_articles.php?f=media_news&news_id=795.

Wi-Fi connections during all of 2008.[94] During the second quarter of 2009, AT&T handled nearly 15 million Wi-Fi connections — a 41 percent increase over the first quarter.[95]

Wi-Fi has been essential to the growth in popularity of smartphones such as the iPhone and served to substantially lighten the capacity load on often under-provisioned licensed wireless networks.[96] According to an AdMobile report from November 2008, 42% of iPhone requests were made on WiFi networks, notably higher than most other WiFi capable phones which average between 10 - 20%.[97] JiWire reported that in the first half of 2009, there was a 79% increase in mobile device ad requests on public Wi-Fi hotspots. Apple mobile devices including the iPhone and iPod Touch, represented 97.83% of the public Wi-Fi mobile device ad requests from January to June 2009.[98] In a census from Meraki that compared activity seen by a single set of randomly selected wireless access points in North America in 2008 and 2009, the number of Research In Motion (RIM) devices observed in North America grew by 419% from 2008 to 2009, and Nokia devices grew by 114%. In 2008, RIM devices represented just 2% of all devices observed, but grew dramatically to 8% for 2009.[99]

In many respects, smartphone users prefer the Wi-Fi network over their operators network. In a 2009 survey from Devicescape, the overwhelming majority of smartphone users

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[94] Andrew Berg, "Wi-Fi & the Need for Cheap Ubiquity," *Wireless Week*, August 1, 2009, http://www.wirelessweek.com/Articles/2009/08/Wi-Fi-Need-Cheap-Ubiquity/.
[95] Om Malik, "With iPhone, Wi-Fi Use Grows on AT&T Networks," *GigaOm*, August 20, 2009, http://gigaom.com/2009/08/20/with-iphone-wi-fi-use-grows-on-att-networks/.
[96] *See* Mobile Wireless Competition Reply Comments at 25.
[97] AdMob Mobile Metrics Report, November 2008, http://metrics.admob.com/wp-content/uploads/2009/04/mobile_metrics_nov_08.pdf.
[98] JiWire Mobile Audience Insights Report, January-June 2009, http://www.jiwire.com/downloads/pdf/JiWire_MobileAudienceInsights_1H09.pdf.
[99] Meraki Wireless Census Reveals Bold Shifts in Type and Number of Wireless Devices in Use in North America, Meraki, August 18, 2009, http://meraki.com/press-releases/2009/08/18/meraki-wireless-census-reveals-bold-shifts-in-type-and-number-of-wireless-devices-in-use-in-north-america/.

(81 percent) prefer using Wi-Fi over 3G for browsing Web sites, downloading data, Google searches and sending e-mail.[100]

The growing use of Wi-Fi enabled smartphones has led several carriers (at least those not conflicted by a fear of cannibalizing wireline phone revenue) to develop a hybrid broadband business model that integrates unlicensed Wi-Fi access with licensed wireless or even wired broadband. For example a new service from T-Mobile combines BlackBerry phones from Research In Motion with Wi-Fi – allowing corporate BlackBerry users to get rid of their desktop phone as their BlackBerries will revert to the Wi-Fi network from cellular within the office – or anywhere else they have access to a Wi-Fi network.[101] T-Mobile is promising uninterrupted service: if a user moves out of a Wi-Fi zone during a conversation, the call will automatically switch to T-Mobile USA's cellular network."[102] Cablevision is rapidly expanding its installation of Wi-Fi access points throughout the most trafficked portions of its service area to enable mobile connectivity for its wireline subscribers at no extra charge. The system is available at many Long Island train stations and other outdoor spaces, and Cablevision is building it into indoor commercial spaces.

Beyond Wi-Fi unlicensed spectrum has spurred a number of other important and innovative technologies. Wireless personal area networks (WPANs), using technologies such as Bluetooth, is now found in most cellular phones, as well as portable computers, video game consoles and wireless blood pressure monitors, stethoscopes, weight scales and other devices.[103] A newer variant of Bluetooth, the IEEE standard 802.15.4 that focuses on low-cost, low-speed ubiquitous communication between devices, is now being utilized for home automation, smart

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[100] Devicescape Wi-Fi Report™, Q1, 2009, http://www.devicescape.com/learn/assets/docs/ds-wfr-1Q-09.pdf.
[101] "T-Mobile USA kicks off corporate Wi-Fi push," Reuters, Oct. 5, 2005, http://www.reuters.com/article/technologyNews/idUSTRE5940GK20091005.
[102] *Id.*
[103] Thanki at 13, *supra note* 86

energy use, building automation, health care devices, remote controls, wireless sensors and process control and automation.[104] Almost one billion Bluetooth chipsets were sold in 2008 and estimates project that sales are likely to increase significantly by 2014 to almost 2.4 billion units per year.[105]

Radio-frequency identification (RFID) tags operating in a number of unlicensed bands are incorporated into any number of objects for the purposes of identification and tracking. RFID have been enormously beneficial to businesses and hospitals. RFID tags are utilized for supply chain management, asset tracking, medical applications (linking a patient with key drugs, etc.), tracking for entrance management or security, manufacturing tracking of parts during manufacture, retail tracking, transport payments (such as Washington DC's SmarTrip system), warehouses real-time inventory, livestock tracking and timing sports event timing to track athletes as they start a race and pass the finish line[106] According to IDTechEx the global market for RFID (Radio Frequency Identification) tags is estimated at $5.56 billion.[107]

Unlicensed Spectrum Generates Substantial Consumer Welfare

The enormous innovation facilitated by unlicensed spectrum has generated substantial consumer welfare. Given the considerable breadth of unlicensed devices and multiplicity of uses, it has been difficult for economists to develop a comprehensive estimate of the welfare created by unlicensed spectrum. Unlike licensed spectrum for cellular networks, which is limited to just the market for mobile voice, data and devices, unlicensed spectrum encompasses a number of different markets. Moreover, since the use of unlicensed spectrum is mostly

[104] *Id.* at 13 – 14.
[105] *Id.* at 21.
[106] *Id.*, Figure 4, at 11
[107] "RFID Tag Sales Soar," *Backbone Magazine*, October 1, 2009, http://www.backbonemag.com/Magazine/Backspace_10010905.asp

unmediated – and unmetered – there are few market transactions, except for the purchase of off-the-shelf equipment that shows how much consumers value its use. For example, although WiFi clearly allows tens of millions of households to more readily (and simultaneously) share a single Internet access subscription among multiple PCs and household members, there is no easy way to value the billions of extra hours of Internet access this permits in a rapidly-rising share of homes, businesses, schools, libraries and other businesses. Despite this challenge, several recent studies have quantified the welfare benefits of certain uses of unlicensed spectrum.

A study by USC economist Ergin Bayrak of the benefits of wireless home networking through Wi-Fi, estimated that unlicensed spectrum created considerable consumer welfare on the order of $18 billion.[108] A more comprehensive study by Richard Thanki, an economist at Perspective Associates, measured the economic value that is generated by three existing applications using unlicensed spectrum:

- The value of generated by wireless broadband within homes (using an alternative methodology to that employed by Europe Economics),
- The value generated by voice applications and wireless electronic health record (EHR) applications using Wi-Fi in hospitals, and
- The value generated by RFID tags for in-store item-level tagging in the clothing retail sector[109]

The report found that Wi-Fi usage in the home, used only for the purpose of broadband extension, generated anywhere between $4.3 and $12.6 billion in annual economic value for consumers in the United States.[110] A second benefit is that Wi-Fi also may have also increased

[108] Ergin Bayrak , Welfare Effects of Spectrum Management Regimes, SoCal NEGT Symposium, October 1, 2009, http://medianetlab.ee.ucla.edu/SocalNEGT/slides/SoCal%20NEGT%20presentation_ergin_bayrak.pdf.
[109] Thanki, 22, *supra note* 86,
[110] *Id* at 27.

the adoption of broadband by anywhere between 4.3 to 9.8 million households by making it more economical.[111] The analysis only accounted for the value that consumers might place on the ability to use wireless broadband in the home, and did not include the consumer value of online gaming using consoles, the ability to stream rich media content and large files around the home, nor any other of a vast number of applications increasingly downloaded and used on smartphones over Wi-Fi networks.[112]

The increase in producer surplus generated by the use of voice over Wi-Fi and wireless EHR systems for hospital services was estimated at $91 to 152 billion, or an annualized $9.6 to $16.1 billion a year between 2009 and 2025.[113] As the report notes: "These cost savings represent savings in the time of healthcare professionals which could translate into lower prices for the purchasers of healthcare, the ability to provide similar care for more patients, or be 'reinvested' into higher quality care."[114] The estimate of the benefit to the U.S. economy as a result of RFID tagging in the clothing-retail sectors between 2009 and 2025 was $2.0 to $8.1 billion per year.[115] Together, the three unlicensed applications may generate $16 to $37 billion per year in economic value for the U.S. economy over the next 15 years.[116]

Unlicensed Bands with Cooperative Mesh Protocol

Beyond allocating new dedicated unlicensed bands below 1 GHz, the Commission should consider designating one or more bands for cooperative, unlicensed devices, at least on an experimental basis. The Part 15 rules governing such a band would presumably remain low-

[111] *Id.*
[112] *Id.*
[113] *Id* at 31.
[114] *Id.*
[115] *Id* at 34.
[116] *Id.*

power, but provide a band where ad hoc mesh networks could thrive under a cooperative rather than a contention-based set of protocols. In such an unlicensed commons, policy would require that all devices actively communicate and cooperate with each other to more efficiently share available frequency/time slots to transmit, to identify the shortest path to available backhaul, and ideally to route packets for other devices.[117] Further these devices could auto-configure into a mesh network, and carry each other's traffic. Such cooperation can increase the capacity of a system as more devices are added, and the distance between devices decreases, creating smaller and smaller cells.[118] We believe that such systems, whether operating on unlicensed bands or subject to a licensed band manager, have tremendous potential not only for peer-to-peer applications, but also to augment the capacity of "shared spectrum" we believe will be needed and beneficial to offload the rapidly rising tide of mobile data demand (as described above).

In this regard we commend the Commission's attention to the comments filed in this docket by Powerwave Technologies, describing what it calls a new class of "cognitive" *and* "cooperative" ad hoc mesh networking technologies that have developed primarily out of military research programs, such as DARPA's NeXt Generation (XG) and the Army's current WNaN (Wireless Network After Next) programs. Both the Army and companies such as Powerwave are already field testing broadband wireless mobile ad hoc networks (MANET), using small format radios, that promise to be far more spectrally efficient than either traditional cellular architectures or even WiFi systems. As PowerWave states in its comments:

> MANET networks take the concept of cell size reduction to its limit case where the cell phone is the cell. MANET radios coordinate amongst themselves to share spectrum and effectuate interference avoidance in ways that can increase spectral reuse . . . to levels far

[117] Peha at 7, *supra note* 79.
[118] *Id.*

greater than current [cellular] base station and and WiFi-type technical architectures. Since these radios are designed to "whisper" they allow many more parallel transmissions within a given geographic area….[119]

Powerwave notes an important distinction between systems that are merely "cognitive" (such as the dynamic frequency selection required of devices sharing upper 5 GHz spectrum with military radar, or the channel-selection capability required in the unlicensed TV white space channels to avoid interference) and systems designed to be cognitive and "cooperative":

> Effective operation of a smart "cooperative" radio system . . . requires all associated "smart" radios operating in that band to interoperate to come level and be equivalently capable regarding basic shared frequency use cooperation and coordination. Whereas a "cognitive" radio . . . can detect and avoid interfering with the other radios . . . Cooperative radios can drive spectrum utilization to extremely high livels of data throughput saturation in a given band . . ..[120]

4. Testbeds to Spur Innovation

Finally, the *Notice* in ¶30, if there are additional options for providing specialized spectrum access for innovation that would augment the Commission's existing practice of granting Special Temporary Authority (STAs), or access to the spectrum "Test-Bed" created jointly with NTIA.[121] One possibility would be to make spectrum in bands corresponding to FCC-held licenses more readily available for commercial and/or technological trials under certain circumstances. An example of a band prime for such potential use is the 2155-2180 MHz

[119] Powerwave Technologies Inc., Comments in NOI on Wireless Innovation and Investment, GN Dockeet 09-157 (Sept. 24, 2009), at 3.
[120] *Ibid.*
[121] See NOI at 9 and n. 23.

band, which is not likely to be re-assigned and built out for years. The 700 MHz D block presents a similar situation, since analog TV has turned off but the Commission is a considerable distance from both assigning and certifying devices to occupy the band in most of the nation. It seems that significant trials for new network architectures or technologies could take place on these "orphaned" bands without disrupting incumbent services or even using limited "test-bed" capacity already set aside for these purposes by the FCC and NTIA.

Opening additional bands overseen by the FCC and NTIA to such use could take place in tandem with expanded opportunistic access to a multiplicity of bands managed through the TV Bands Database, as described above. One of the biggest drawbacks to a large-scale trial on bands pending reassignment (such as the D Block or 2155-2180 MHz bands) is that the innovator is not likely to retain access to the band long-term. However, if an innovator built multi-band, cognitive radio capability into its tests, deployed devices could later be given permission to access another band (or combination of bands) in the future. Systems designed around the MANET architecture described just above would appear to be a good example of a technology that could receive access to an unused band on a temporary and contingent basis, but have the capability to utilize different bands in the future. This also reflects a virtue of the sort of opportunistic access inherent in the TV Bands database: Not every band available through the geolocation database needs to be subject to the same set of operating rules and protocols; and, moreover, those rules and the devices given permission to access a particular band can evolve over time without "stranding" legacy equipment.

III. METHODS FOR FACILITATING MORE EFFICIENT, SHARED USE OF UNDERUTILIZED SPECTRUM

Nowhere is spectrum underutilization more evident than in many of the bands reserved for use by the federal government itself.[122] It is estimated that the federal government exclusively controls over 13 percent of all allocated spectrum bands and has primary access to shared bands comprising 56 56 percent of all other bands.[123] Federal spectrum bands between 225 and 400 MHz, 902 and 1850 MHz (particularly 1755 to 1850 MHz), and smaller bands at 108 – 174 and 400 – 450 MHz, appear virtually unused in most areas at most times, particularly in the more densely populated areas of the country with insufficient capacity for future demand for wireless broadband data services. While most of these bands could not be cleared and reallocated, since they serve critical national security and other functions, they could undoubtedly be shared far more intensively by taking advantage of the sort of cognitive radio technologies, sensing and geolocation techniques noted above. One of the biggest obstacles, particularly in the federal bands, is the lack transparency with respect to actual use and the types of systems and technologies that need to be accommodated to facilitate greater private sector access. We believe that the Commission should take a far more pro-active role, both under its own powers and in collaboration with the NTIA, to achieve far greater transparency and use of underutilized federal bands.

A. Increase Transparency of Spectrum Assignments and Actual Utilization

A critical step toward making substantially more spectrum capacity available for wireless broadband services and innovation is to determine and disclose how, where and when this publicly-owned resource is currently being used – or not used – by current public agency and

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[122] For an in-depth discussion of the utilization of federal spectrum and policy recommendations for reallocation of this underutilized spectrum, *see* Victor Pickard and Sascha D. Meinrath, "Revitalizing the Public Airwaves: Opportunistic Reuse of Government Spectrum," Wireless Future Working Paper, New America Foundation (June 2009), also forthcoming in *International Journal of Communications* (2009).

[123] Jonathan E. Nuechterlein & Philip J. Weiser, *Digital Crossroads: American Telecommunications Policy in the Internet Age,* MIT Press: Cambridge, MA (2005).

private sector licensees. The Commission and the public need to have a more complete, comprehensive inventory of what frequencies are *actually* in use, for what purpose, with what technology, at what locations, frequencies and times. Both government and private sector assignments and uses should be included in the map. Actual spectrum use measurements in a large and regionally diverse sampling of markets should be part of the Commission's broadband mapping exercise.

We have recommended that the White House direct a joint NTIA/FCC effort to undertake a comprehensive ***Inventory of the Airwaves*** that maps and makes publicly available how our public spectrum resource is being utilized or underutilized in at least the most valuable bands below 6 GHz.[124] In addition to signaling the importance of pervasive connectivity to the economy and American competitiveness, White House leadership is necessary to secure the full cooperation of departments and agencies across the government.

Spectrum mapping would help facilitate expanded access to broadband providers in at least three ways:

- First, more complete and transparent frequency-by-location data online will improve the functioning of secondary markets for spectrum license transfers and leasing.
- Second, it will provide information on what will be required to clear some heavily underutilized bands, so that they can be reassigned for commercial use.

[124] *See* "Ex Parte Comments of New America Foundation," GN Docket No. 09-29, Federal Communications Commission, March 25, 2009, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520203629, *see also* "Comments of the New America Foundation, Public Knowledge and Media Access Project, GN. Docket No. 09-51, Federal Communication Commission, June 8, 2009, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520220266 .

- Third, it will reveal the far greater number of frequency bands that could be made available for opportunistic access in discrete geographic areas, at certain times of day or year, or at certain altitudes or directions of arrival (azimuth, elevation).

Rural areas would be the most likely and immediate beneficiaries of a mapping of the U.S. spectrum capabilities. Wireless remains the most cost-effective and rapid means by which to bring broadband access to rural residents. It will quickly become clear that particular frequency bands are either completely unused or grossly underutilized in many rural markets. A web-map of spectrum utilization on a localized basis (such as by Rural Service Area and Metropolitan Statistical Area) would provide the Commission or Congress with the information it needs to reallocate or at least to open frequencies for non-interfering use by rural broadband providers, as well as for wireless innovation more broadly. Already, thousands of locally-grown Wireless Internet Service Providers (WISPs), Rural LECs, public utilities, NGOs and local governments are utilizing wireless technology in conjunction with unlicensed spectrum to bring wireless broadband to unserved and underserved rural areas across the country. A substantial obstacle these small and local providers face in attempting to expand and scale-up their networks is access to additional spectrum.

It is also important that any federal spectrum mapping include actual and ongoing spectrum use measurements at a large and diverse sample of rural, urban and suburban locations around the nation. The NTIA did actual spectrum measurement studies in a number of locations in the mid-1990s, but virtually none in recent years. Indeed, one of the recommendations of the Presidential Task Force on spectrum policy in 2004 called for "spot compliance checks" and "signal measurement surveys" to check the accuracy of NTIA's records and provide the information needed to "evaluate the utility of underutilized spectrum."[125] The Task Force recommended that:

> To ensure that the current uses of radiocommunication systems are as efficient as possible . . . NTIA should evaluate all spectrum use by the federal government over a five-year period to determine spectrum efficiency and effectiveness. **The review should include spot compliance checks and signal measurement surveys to verify the accuracy of the records of the Government Master File (GMF), identify congestion and instances of duplicative operations that could be combined, and evaluate the utility of underutilized spectrum.** NTIA should use the results of these reviews in the development of new and improved spectrum management policies, and the Federal Strategic Spectrum Plan.[126]

B. The Role of the FCC and Executive Branch Agencies with Regard to Federal Spectrum

It is important to clarify the authority of the FCC with regard to "federal spectrum," as well as to fully understand the role of the NTIA and other federal agencies. Whatever understandings exist between agencies, whatever policies have arisen as useful or practical, the formulation of proper policy must begin with an understanding of statutory authority.

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125 The Task Force was part of the Spectrum Policy Initiative initiated by President Bush in 2003 and led by NTIA. U.S. Department of Commerce, *Spectrum Policy for the 21st Century–The President's Spectrum Policy Initiative: Report 1, Recommendations of the Federal Government Spectrum Task Force* (June 2004), at http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm; *see also* http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report2_06242004.htm; National Telecommunications and Information Administration (May 29, 2003); "Presidential Memorandum on Spectrum Policy for the 21st Century," available at http://www.ntia.doc.gov/ntiahome/frnotices/2004/PresMemoonSpectrumPolicy.htm.

126 *Ibid. See also* National Telecommunications and Information Administration (May 29, 2003). "Presidential Memorandum on Spectrum Policy for the 21st Century," available at http://www.ntia.doc.gov/ntiahome/frnotices/2004/PresMemoonSpectrumPolicy.htm.

As a statutory matter, there is no such thing as "federal spectrum" distinct from "commercial" spectrum. Bands may be allocated "on a primary basis for Federal Government use," 47 U.S.C. § 927(b), but this does not restrict the FCC's ability to authorize additional, non-interfering uses. Under the Communications Act, and as modified National Telecommunications and Information Agency Organization Act (NTIA Act), the FCC grants ***licenses*** to non-federal users. 47 U.S.C. §301. By contrast, the power to authorize use of spectrum to federal users is assigned by statute to the President, 47 U.S.C. §305(a). In 1992, Congress ratified the delegation of this authority to the Assistant Secretary of NTIA, 47 U.S.C. § 902(b). The Commission may, therefore, authorize non-interfering use of "federal spectrum" under its own authority, and may even authorize interfering uses subject to certain conditions. *See* 47 U.S.C. § 323, § 903(e).

Congress, however, has expressed a desire for the FCC to coordinate with the NTIA rather than proceed by unilateral action. Indeed, 47 U.S.C. § 922 requires the Chairman of the FCC and the Assistant Secretary to meet "at least biannually" to discuss "actions necessary to promote the efficient use of the spectrum, including spectrum management techniques to promote shared use of the spectrum that does not cause harmful interference as a means of increasing commercial access." § 922(4). Congress further demonstrated a desire to expand mixed use of frequencies primarily allocated for federal use through coordination between the Department of Commerce and the Commission by authorizing the Secretary of Commerce to, "at any time allow frequencies allocated on a primary basis for Federal Government use to be used by non-Federal licensees on a mixed-use basis for the purpose of facilitating the prompt implementation of new technologies or services or for other purposes." §927(2). Congress explicitly instructed NTIA to modify its regulations to facilitate the "prompt and impartial consideration of such requests," §903(b)(5), subject to rules and procedures developed by the FCC. §903(e).[127]

IV. CONCLUSION

The increasing availability and popularity of high-speed wireless Internet access is driving a likely explosion in mobile data consumption. Meeting this demand – and achieving pervasive connectivity at affordable prices for all Americans – will require new directions in spectrum and wireless policies. We believe that it is impractical, inefficient and ultimately anti-consumer to attempt to meet the growing demand for mobile data consumption primarily through traditional reallocations of exclusively-licensed spectrum by auction. Wise policy choices will be necessary to facilitate – and not impede – a market evolution toward more spectrum-efficient and cost-effective "hybrid" or "heterogeneous" wireless broadband networks that empower consumers to rely primarily on shared spectrum and self-provisioned backhaul. Policies that unlock spectrum abundance – through opportunistic access to unused capacity, new dedicated unlicensed bands and wholesale access bands – will promote both pervasive connectivity and world-class innovation. The Commission will remain on the right track if it adheres to four foundational principles during the historic period that lies just ahead: More unlicensed and opportunistic access to the public airwaves; fully flexible licensing that remains subject to public interest obligations; a proactive competition and consumer protection policy; and complete

[127] Although Section 903(e) states that an entity must obtain a "license" as a precondition of operating a "radio station utilizing a frequency authorized for the use of government stations," the Commission has previously founded that the term "license" is sufficiently broad so as to include operation of properly certified Part 15 "unlicensed" devices pursuant to rules and limitations adopted by the Commission. In re Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, Second Report and Order and Second Memorandum Opinion and Order, 19 F.C.C.R. 24,558 at ¶¶ 75–76. (2004) *See also* 47 U.S.C. § 3(42) (2000) (defining "license"). Likewise, the Administrative Procedures Act defines license as "the whole or a part of an agency permit, certificate, approval, registration, charter, membership, statutory exemption or other form of permission." 5 U.S.C. § 551(8) (2000)

transparency, particularly with respect to an inventory of the airwaves. We look forward in assisting the Commission as it carries out this important work.

Respectfully Submitted,
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