Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Expanding the Economic and Innovation	)	GN Docket No. 12-268
Opportunities of Spectrum Through Incentive	)	
Auctions	)	
	)	

REPLY COMMENTS OF THE NATIONAL CABLE & TELECOMMUNICATIONS ASSOCIATION

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EXECUTIVE SUMMARY

As the initial comments filed in this proceeding make clear, the consumer and economic benefits of Wi-Fi services operating on unlicensed spectrum are staggering. Wi-Fi benefits consumers by expanding their ability to access broadband, both at home and on-the-go, as well as through cost savings associated with licensed wireless service offload. Given these public interest benefits, the Commission should adopt a balanced approach in the 600 MHz band by making adequate spectrum available for both licensed and unlicensed use. The Commission can do this by adopting the "Down from Channel 51" band plan with a duplex gap of at least 20 megahertz of contiguous spectrum that would be available for unlicensed use between the licensed wireless downlink and uplink spectrum allocations. This band plan recognizes the need for additional spectrum for both unlicensed and licensed uses, while providing appropriate protection from harmful interference.

In addition to providing sufficient unlicensed spectrum to enable the deployment of robust broadband service in the 600 MHz band, when deciding how best to allocate 600 MHz band spectrum the Commission should take care not to undermine the continued vitality of wireless microphones. The Commission could accomplish this by preserving the dedicated channels adjacent to channel 37 for wireless microphone use; by allowing wireless microphones to operate in channel 37; by allocating low-power wireless microphones priority use of the guard band between licensed wireless service and broadcast channel spectrum in the "Down from Channel 51" band plan; or by some other approach.

Finally, consistent with the Spectrum Act and the Commission's channel sharing rules, the Commission should ensure that cable operators' mandatory carriage burdens are not increased as a result of channel sharing or repacking.

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As the initial comments demonstrate, the Commission should adopt a band plan that balances the growing spectrum needs of both licensed and unlicensed wireless services. Specifically, the Commission should adopt the "Down from Channel 51" band plan with a duplex gap of at least 20 megahertz of contiguous spectrum available for unlicensed use between the licensed wireless downlink and uplink spectrum allocations. This proposal will provide the best means of protecting all services in the band from interference, while also allowing Wi-Fi and other unlicensed services to operate in the 600 MHz band.

I. THE COMMENTS DEMONSTRATE THE IMPORTANCE OF ENABLING WI-FI USE OF UNLICENSED SPECTRUM IN THE 600 MHZ BAND

The Commission has recognized – and no commenter disputes – the tremendous benefits to consumers and the economy that have been achieved through the allocation of spectrum for unlicensed use.[1] The range of new and previously unthought-of services is staggering, including, to name just a few, wireless healthcare monitoring devices, cordless phones and headsets, remote car door openers, barcode scanners, credit card payment machines, remote controls, smart utility

[1] *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, Notice of Proposed Rulemaking, 27 FCC Rcd 12357, 12437, ¶228 (2012) (*NPRM*) ("In recent years, unlicensed devices have become an essential component for providing short-range broadband connectivity that supports business communications, research, education, online shopping and other communications that are driving economic growth.").

meters, radio frequency identification (RFID), and Wi-Fi connectivity.[2] In addition to the myriad ways these services have improved people's lives, as the commenters point out, the unlicensed industry also generates tens of billions of dollars per year for the American economy.[3]

Perhaps the most significant unlicensed service is Wi-Fi. As noted in the initial comments, consumers increasingly rely on Wi-Fi to carry more Internet traffic to their devices and to receive fixed broadband service.[4] Consumers are also able to harness the benefits of Wi-Fi on-the-go, including in outdoor areas, thanks to substantial investments in Wi-Fi deployment by cable operators.[5] Commenters also agreed on the vast benefits of Wi-Fi offload for licensed wireless services.[6] The skyrocketing use of Wi-Fi, however, is creating congestion in existing unlicensed bands and thus an urgent need for additional unlicensed spectrum. The Commission has recognized this need for additional unlicensed spectrum and is considering ways to make more unlicensed spectrum available for Wi-Fi, for instance, in the 5 GHz band.[7]

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2 *See, e.g.*, CEA Comments at 26; Free Press Comments at 8-9; Google/Microsoft Comments at 7; Public Interest Spectrum Coalition Comments at 11.

3 Comcast/NBCUniversal Comments at 31-33; Consumer Federation of America Comments at 34-40; Free Press Comments at 8-11; Google/Microsoft Comments at 7-21; Public Interest Spectrum Coalition Comments at 8-11.

4 Comcast/NBCUniversal Comments at 31; Consumer Federation of America Comments at 15; NCTA Comments at 3.

5 Comcast/NBC Universal Comments at 33-34, 40-42, Google/Microsoft Comments at 19-21.

6 Comcast/NBCUniversal Comments at 35-37; Consumer Federation of America Comments at 15; Free Press Comments at 11-12; Google/Microsoft Comments at 13-16.

7 *Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, ET Docket No. 13-49, Notice of Proposed Rulemaking, FCC 13-22, ¶¶11, 18-20 (2013) (*5 GHz NPRM*); *id.* at 51 (Statement of Chairman Genachowski) ("Wi-Fi congestion is a very real and growing problem. Like licensed spectrum, demand for unlicensed spectrum threatens to outpace supply. The core challenge is the dramatically increased use of wireless devices, which require spectrum."); *id.* at 54 (Statement of Commissioner McDowell) ("The spectrum that is used for unlicensed Wi-Fi is also experiencing congestion, which will only increase in the coming years if we do not make appropriate bands, like the 5 GHz band, more attractive for investment and innovation."); *id.* at 55 (Statement of Commissioner Clyburn) ("The Nation's demand for unlicensed services has increased so dramatically that we need more spectrum to support these services. The 2.4 GHz band, while critical to the success of Wi-Fi and other unlicensed technologies, is increasingly congested particularly in major cities."); *id.* at 56 (Statement of Commissioner Rosenworcel) ("[I]t is no wonder that the search is on to find more spectrum for unlicensed services. It is a search that this

Additionally, allowing Wi-Fi providers access to lower frequency spectrum will enable the offering of more robust services that will most benefit consumers. Wi-Fi operators also need access to lower frequency spectrum to allow for increased coverage in both indoor and outdoor applications.[8] The 600 MHz spectrum possesses propagation and penetration characteristics that will be an important complement to the upper bands currently available for Wi-Fi.[9] Wi-Fi networks using 600 MHz spectrum can cover greater distances, which will be especially important for outdoor and less urban areas, and can more easily penetrate building walls and other potential obstructions. Consumers will thus be able to access Wi-Fi networks more ubiquitously in areas where sufficient 600 MHz unlicensed spectrum is made available.

II. THE "DOWN FROM CHANNEL 51" APPROACH – WITH A DUPLEX GAP OF AT LEAST 20 MEGAHERTZ – IS TECHNICALLY REASONABLE AND IS THE BEST WAY TO PROMOTE THE OBJECTIVES OF THE SPECTRUM ACT AND THE PUBLIC INTEREST

As discussed above, it is critically important to the development of robust Wi-Fi that spectrum be available in the 600 MHz band (as well as at higher frequencies). The issue then becomes how to ensure that the incentive auctions yield sufficient spectrum for such use. In its

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Commission needs to support, consistent with the law. Because good spectrum policy requires both licensed and unlicensed services—across multiple spectrum bands."); *id.* at 58 (Statement of Commissioner Pai) ("[C]onsumers are the ultimate beneficiaries of unlicensed-use technologies such as Wi-Fi and Bluetooth. Millions of Americans rely on Wi-Fi every day to connect their laptops, their smartphones, and their tablets to the Internet.").

[8] Five cable operators, Bright House Networks, Comcast's Xfinity service, Cox, Cablevision's Optimum service, and Time Warner Cable, provide customers with access to over 100,000 Wi-Fi hotspot access points in both indoor and outdoor locations. Cable Wi-Fi, http://www.cablewifi.com/ (last visited Mar. 1, 2013).

[9] *See, e.g.*, Free Press Comments at 10 ("The spectrum at issue in this proceeding has different characteristics from the higher frequency spectrum that has customarily been set aside for unlicensed use, and has the potential to generate even greater innovation and connectivity because of its superior propagation and ability to deliver non-line-of-sight coverage." (citing Richard Thanki, *The Economic Significance of Licence-Exempt Spectrum to the Future of the Internet*, 10-12, 17 (2012)); Google/Microsoft Comments at 24 ("Unlicensed access in the 600 MHz spectrum band therefore offers a substantial improvement for consumers and businesses that need longer-range communications and whole-home or whole-office coverage."); *see also* Dirk Grunwald and Kenneth Baker, *FCC Broadcast Incentive Auction: A Band Plan for Maximizing Spectrum Utility*, 9-14 (2013) (included as the Attachment to these reply comments).

initial comments, NCTA maintained that the optimal approach would be to adopt, with some modifications, the "Down from Channel 51" approach proposed as an alternative in the *NPRM*.[10]

A key element of that approach is that the entire "duplex gap" – the contiguous frequencies between the uplink and downlink portions of the spectrum cleared of broadcast channels – would be available for unlicensed use. NCTA explained that, as a technical matter, a single swath of contiguous channels in the duplex gap would facilitate a more robust and diverse array of unlicensed services than would multiple fragmented bands of channels, such as those in the "guard bands" separating wireless and broadcast channels. The availability of such contiguous spectrum in the 600 MHz band could provide the crucial low-frequency component of robust Wi-Fi service, provided that the duplex gap is of sufficient size.

There is broad support among commenting parties, including broadcasters and providers of licensed and unlicensed wireless services, for the "Down from Channel 51" approach as the alternative best suited to balancing the public policy objectives of fostering licensed *and* unlicensed wireless services, preserving viable over-the-air television service, and ensuring recovery of reverse-auction payments from forward-auction revenues.[11] To further explain why this is the case, we include with these reply comments a technical analysis by Professors Dirk Grunwald and Kenneth Baker of the University of Colorado.[12]

Grunwald and Baker show that a "Down from Channel 51" band plan that includes sufficient bandwidth in the duplex gap for robust Wi-Fi service is "technically reasonable" and will benefit all stakeholders:

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[10] NCTA Comments at 4-10; *NPRM*, 27 FCC Rcd at 12421, ¶178.

[11] *See*, *e.g.*, Sony Comments at 4; Qualcomm Comments at 4; GE Healthcare Comments at 29-31; CTIA Comments at 22; ABC Television Affiliates Association *et al*. Comments at 43-45; Comcast/NBCUniversal Comments at 20-24; National Association of Broadcasters Comments at 45-47; White Space Alliance Comments at 23-27.

[12] Attachment, Grunwald & Baker, *supra* note 9.

> Consumers will gain benefits associated with useful low-band WiFi-like services. Mobile operators will benefit from the attendant complementarities of licensed and unlicensed networks. All users of the band will enjoy greater interference protection, providing greater certainty for investment. These widespread benefits enhance the economic payoff of the incentive auction, both to the broader economy and to the revenue raised in the auction.[13]

Like other commenters who favor the use of the duplex gap for Wi-Fi service, Grunwald and Baker explain that the duplex gap must include *at least* 20 megahertz of bandwidth to be useful for such purposes:

> If the size of the unlicensed duplex gap is on the order of *20 MHz or greater*, all TV band device power categories should be enabled across all markets, even under current TVWS rules. This will enable coverage at low cost and a service that is attractive to consumers and industry alike. Our estimate is that a 20 MHz block will enable high-speed data throughputs on the order of 40-70 Mbps. These throughputs would increase with MIMO spatial multiplexing gains, which are becoming common with mobile broadband service and are already part of the 802.11af specification for WiFi like services in the TV bands.[14]

Moreover, as Comcast notes, a duplex gap of at least 20 megahertz for Wi-Fi is consistent with current Wi-Fi standards, which utilize 20 megahertz channels. Thus, the allocation of this amount of contiguous spectrum would allow service providers and device manufacturers to leverage the existing Wi-Fi ecosystem to develop services and devices using this spectrum in a timely and efficient manner.[15] Conversely, "[a]ny approach that does not meet this standard risks delaying – or foreclosing outright – the ability of service providers and device manufacturers to use the unlicensed spectrum in any meaningful or efficient way, to the detriment of consumers and business users."[16] Google and Microsoft support the deployment of

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[13] *Id.* at 31.

[14] *Id.* at 31-32 (emphasis added).

[15] Comcast/NBCUniversal Comments at 41.

[16] *Id.* at 42.

an even larger duplex gap of 28 megahertz, to enable robust and undegraded performance of unlicensed wireless services.[17]

While some parties argue against the allocation of 20 megahertz or more of contiguous spectrum in the duplex gap or elsewhere in the 600 MHz band for unlicensed services, they do not refute the notion that a lesser amount of spectrum would be unusable for the provision of Wi-Fi service. Instead, they generally dismiss or ignore the potential use of spectrum in the 600 MHz band for Wi-Fi or other unlicensed services.

Some, like the Telecommunications Industry Association (TIA), simply argue that, as a matter of law, all spectrum in the 600 MHz band except for guard bands necessary to prevent interference to licensed services must be designated for auction – i.e., there should be *no* spectrum set aside for unlicensed use outside minimally necessary guard bands.[18] As NCTA showed in its initial comments, and as discussed below, that simply is not the case. Others, like AT&T and Verizon, are concerned, as a matter of policy, only with protecting against interference between the uplink and downlink transmissions of licensed wireless services while ensuring the maximum amount of auctionable spectrum – without regard for the significant benefits to the public of enabling Wi-Fi and other unlicensed services to use low-frequency spectrum.[19] The duplex gap solution put forward in this proposal addresses those issues.

As Grunwald and Baker show, it is technically reasonable to implement such a duplex gap in the redesigned 600 MHz band. As illustrated in Figure 8 of their paper, reclaiming even as few as ten television channel frequencies between channels 37 and 51, the "Down from Channel 51" approach could still accommodate a 20 megahertz duplex gap between an ample

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[17] Google/Microsoft Comments at 37-39.

[18] TIA Comments at 10.

[19] AT&T Comments at 34; Verizon Comments at 19.

number of uplink and downlink channels.[20] Moreover, "[a]s the number of reclaimed channels increases, this unlicensed duplex gap is permitted to grow to 24 MHz. At 24 MHz, we can maintain a symmetric uplink and downlink bandwidth of 15+15 MHz above TV 37."[21] This is the optimal path to promoting the objectives of the Spectrum Act and the public interest.

Thus, the record is clear that if there is to be use of the spectrum gap to provide robust Wi-Fi and other unlicensed services, that gap must include at least 20 megahertz. The record also supports the conclusion that the provision of robust Wi-Fi as well as other unlicensed services depends upon the availability of sufficient spectrum in the 600 MHz band. Not only is implementation of a duplex gap of such size technically reasonable, it is decidedly in the public interest.

Wireless microphones: As the Commission considers how to acquire and allocate additional spectrum for wireless services, it should take care not to do so in a manner that undermines the continued vitality of an important wireless service that already provides valuable, and in some cases essential, services to the public – namely, wireless microphones. No commenting parties dispute that, as NCTA noted in its initial comments, wireless microphones contribute significant benefits and value to the public. Nevertheless, some fail to recognize the benefits of preserving some dedicated frequencies to ensure that low-powered wireless microphones can provide the high-quality audio necessary for media coverage of not only planned entertainment, sports and news events but also breaking news and emergencies.

Preserving the existing priority of wireless microphones over other television white spaces devices in the two channels adjacent to channel 37 remains a reasonable way of ensuring the availability of these important services. Allowing wireless microphones to operate in

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[20] Attachment, Grunwald & Baker, *supra* note 9, at 26.

[21] *Id.*

channel 37 (subject to rules and coordination procedures to prevent interference to existing users) would be another. Alternatively, low-power wireless microphones could, under the "Down from Channel 51" approach, be allocated priority use of the guard band (potentially six megahertz) between channels used for licensed wireless services and broadcast channels.

There may be more than one solution. But in fostering the deployment of new, innovative wireless services, it should not be necessary to impair the use of existing innovative uses like wireless microphones.

III. THE COMMISSION HAS CLEAR AUTHORITY TO DESIGNATE RECLAIMED SPECTRUM FOR UNLICENSED OPERATIONS

As NCTA explained in its initial comments, the Spectrum Act does not constrain the Commission from establishing a duplex gap between mobile wireless uplink and downlink bands that is sufficient for robust unlicensed operations. Even if the duplex gap is considered a guard band, the Commission's determination of the size of the gap need only be "no larger than is technically reasonable," a standard that demonstrates Congress's intent to provide the Commission with wide latitude regarding the size of guard bands in the reclaimed spectrum.[22] The Spectrum Act does not limit the Commission's broad authority to otherwise engage in reasonable spectrum planning, which in this case supports the designation of reclaimed broadcast spectrum for unlicensed use.

Other commenters agree that the Spectrum Act cannot be read in a vacuum: the Commission must still observe other directives in the Communications Act. For instance, as Comcast notes, section 303(g) of the Communications Act requires the Commission to "generally encourage the larger and more effective use of radio in the public interest."[23]

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[22] 47 U.S.C. § 1454(b).

[23] Comcast/NBCUniversal Comments at 43 (citing 47 U.S.C. § 303(g)).

Similarly, section 309(j) of the Communications Act directs the Commission, in designing auctions, to consider such factors as "the development and rapid deployment of new technologies, products and services," "promoting economic opportunity and competition," and "efficient and intensive use of the electromagnetic spectrum."[24] The establishment of a duplex gap or guard bands sufficient for Wi-Fi would further these goals.

Even if the Commission considers the duplex gap to be a guard band, and considers only the provisions and objectives of the Spectrum Act, the Commission has ample authority to create guard bands that will support advanced unlicensed operations. As other commenters recognized, by allowing the Commission to establish guard bands that are "technically reasonable" Congress gave the Commission flexibility to determine the appropriate size of those guard bands.[25] Like NCTA, Google and Microsoft demonstrate that Congress's use of the term "reasonable" gives an agency wide discretion to act, especially when an issue is technical and involves policy judgments at the core of its regulatory mission.[26]

In contrast, those commenters who argue that the Commission is without authority to allocate reclaimed spectrum for advanced unlicensed use either misread the Spectrum Act or

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[24] 47 U.S.C. § 309(j)(3).

[25] *See* Google/Microsoft Comments at 35 ("The plain meaning of 'technically reasonable' and judicial precedent combine to establish that Congress granted the Commission wide discretion in determining the size of any frequency range set aside for interference prevention."); *see also* Comcast/NBCUniversal Comments at 44 ("[T]he language in the Spectrum Act offers sufficient flexibility for the Commission to determine the appropriate sizes of the guard band and duplex gap."); Free Press Comments at 5 ("In adopting a standard of reasonableness rather than necessity, Congress explicitly delegated broad discretion to the Commission in the determination of guard band size"); CCIA Comments at 3 ("…the phrase ['technically reasonable'] invokes the Commission's expert discretion by requiring action that is 'reasonable', the pursuit of which routinely is granted considerable deference.").

[26] Google/Microsoft Comments at 36; *see also* Comcast/NBCUniversal Comments at 44 ("…by allowing the Commission to adopt technically *reasonable* guard bands, Congress employed statutory language that permits the Commission to consider other policy goals – including facilitating unlicensed use – as part of its analysis of what is reasonable to protect licensees."); CCIA Comments at 3 ("[T]he Commission retains broad discretion when adopting plans and rules for radio spectrum. The FCC 'is empowered by the Communications Act to foster innovative methods of exploiting the radio spectrum,' and as such 'functions as a policymaker and, inevitably, a seer – roles in which it will be accorded the greatest deference by a reviewing court.'" (citing *Telocator Network of America v. FCC*, 691 F.2d 525, 538 (D.C. Cir. 1982))).

infer a directive that does not exist. It is not true, as AT&T and others state, that the Commission must create guard bands that are no larger than technically *necessary*.[27] Instead, the plain wording of the Spectrum Act allows the Commission to create guard bands that are no larger than technically *reasonable*.[28] The difference between the two is meaningful. As Google and Microsoft point out, "[i]f Congress had intended to limit the Commission to setting guard bands that were as small as possible without creating harmful interference, it would have required the FCC to set guard bands that were no larger than technically *necessary* to prevent harmful interference. That it did not use that language (or any words to similar effect) is evidence that Congress intended to give the Commission the discretion to use its expert technical judgment to set appropriate guard band sizes."[29]

TIA similarly seeks to impose a narrower standard than Congress adopted. TIA argues that because one dictionary definition of "reasonable" is "not excessive or extreme," Congress's use of "technically reasonable" "dictate[s] that all spectrum other than the bare minimum required for interference protection be licensed via auction."[30] Because the Commission is given the authority to determine what is "reasonable," however, it does not follow that technically reasonable guard bands must be limited to the "bare minimum" required. Recourse to dictionary

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[27] AT&T Comments at 3; *see also* MetroPCS Comments at 24; High Tech Spectrum Coalition Comments at 7.

[28] 47 U.S.C. § 1454(b).

[29] Google/Microsoft Comments at 36; *see also* Comcast/NBCUniversal Comments at 44 ("In other words, by expressing the size of the guard bands in terms of what is 'technically reasonable,' rather than, for example, what is technically necessary, Congress granted the Commission significant flexibility both as to the size of the guard bands and as to the considerations that the Commission may factor into its decisions regarding guard bands."); CCIA Comments at 3 ("It bears emphasis that Congress did not choose the phrase 'technically *necessary*' in [the Spectrum Act], but rather it established a standard that calls on the Commission's expert discretion.").

[30] TIA Comments at 9-10.

definitions is inappropriate for interpreting the scope of the Commission's authority with respect to a core technical function like spectrum planning.[31]

It is also not the case, as several commenters allege, that Congress directed the Commission to clear as much 600 MHz band spectrum as possible for licensed use or that "as a statutory matter" the Commission must "maximize the spectrum available for licensed commercial broadband use."[32] While the Spectrum Act directs the Commission to make reclaimed broadcast spectrum available for assignment through auction,[33] the Commission routinely establishes duplex gaps in band plans for licensed services.[34] The two are complementary rather than mutually exclusive. The Spectrum Act also contemporaneously affirmed the Commission's authority to establish guard bands and to "permit [their] use for unlicensed use."[35] Both provisions of the law must be given effect. As Comcast notes, construing the two provisions together "allows the Commission to construe the applicable language to permit the adoption of a band plan that includes unlicensed spectrum."[36] Any other

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[31] *See, e.g.*, *Nat'l Cable & Telecomms. Ass'n v. Brand X Internet Servs.*, 545 U.S. 967, 1002-03 (2005) (where "technical, complex, and dynamic" rules are concerned, the Commission is in "a far better position to address these questions" to determine the meaning of a statute.); *WSTE-TV, Inc. v. F*CC, 566 F.2d 333, 338 (D.C. Cir. 1977) (reviewing a Commission broadcasting interference decision bearing in mind the deference owed to "the Commission's recognized expertise on . . . technical issues"). TIA is also wrong when it suggests that the legislative history supports its interpretation of the statutory text. TIA Comments at 9-10, nn. 32 & 33. The fact that the House version of the Spectrum Act did not contain provisions regarding the use of guard bands for unlicensed use shows exactly the opposite of what TIA suggests – that Congress affirmatively decided to make it clear that spectrum *could* be designated for unlicensed operations. *Cf. Middle Class Tax Relief and Job Creations Act of 2012*, H.R.3630, 112 Congress §§ 6001-6703 (2012).

[32] Cisco Comments at 3; *see also* AT&T Comments at 21; MetroPCS Comments at 24; High Tech Spectrum Coalition Comments at 6-7.

[33] 47 U.S.C. § 1452(a)(1).

[34] NCTA Comments at 11-12.

[35] 47 U.S.C. § 1454(a), (c).

[36] Comcast/NBCUniversal Comments at 42-43.

course would undermine Congress's clear expectation that some of the reclaimed spectrum would be used for unlicensed operations.[37]

As noted above and in NCTA's initial comments, moreover, the interpretation of the provisions of the Spectrum Act must be informed by the remainder of the Communications Act, under which the Commission has broad authority to determine how to allocate spectrum.[38] Thus, while the Spectrum Act designates how revenue generated in a forward auction of 600 MHz spectrum will be used,[39] it does not require the Commission to maximize those revenues, especially to the detriment of the public interest. As Comcast points out, the Commission is *precluded* from "bas[ing] a finding of public interest, convenience and necessity on the expectation of Federal revenues."[40]

IV. CABLE OPERATORS MUST BE HELD HARMLESS FROM ANY REPACKING OR CHANNEL SHARING

Several commenters urge the Commission to adopt policies that would increase the burdens on cable operators as a result of channel sharing or repacking. Such an outcome would be contrary to the Spectrum Act[41] and the Commission's sharing rules.[42] Congress intended to

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[37] Free Press Comments at 3-4.

[38] The High Tech Spectrum Coalition argues that because guard bands have a limited purpose – to prevent harmful interference – the Commission must limit their size to what is required to achieve that purpose. High Tech Spectrum Coalition Comments at 7. As noted above, however, the Commission must take account of its other spectrum management obligations under the Communications Act in considering the size and purpose of guard bands that best serve the public interest.

[39] *See e.g.*, 47 U.S.C. §§ 1427 (Initial Funding for First Responder Network Authority), 1441-1443 (Public Safety Commitments), 1452(b)(4)(A) (discussing payment of broadcaster relocation costs), 1457 (Public Safety Trust Fund).

[40] Comcast/NBCUniversal Comments at 43 (citing 47 U.S.C. § 309(j)(7)(A)).

[41] 47 U.S.C. § 1452(b)(4).

[42] *Innovation in the Broadcast Television Bands: Allocations, Channel Sharing and Improvements to VHF*, ET Docket No. 10-235, Report and Order, 27 FCC Rcd 4616 (2012) (*Channel Sharing Order*).

hold cable operators harmless from changes resulting from the Spectrum Act.[43] If there is any ambiguity about the Spectrum Act's meaning with respect to operators' carriage obligations post-repacking or channel sharing, the First Amendment requires the Commission to adopt an interpretation that minimizes these intrusions into cable's constitutionally protected editorial discretion.[44]

The Spectrum Act changed must-carry obligations for stations that share channels, providing that the sharing station must have been carried on November 30, 2010 *and* must still be eligible for carriage at its shared location.[45] But the Spectrum Act did not alter certain fundamental requirements that broadcasters must meet to be entitled to mandatory carriage. Section 614 of the Cable Act still requires a full power television station, to be eligible for carriage, to be located in the same market as the cable system and to "deliver [a good quality signal] to the principal headend of a cable system."[46] It still provides only limited carriage rights for low power television stations.[47] Some commenters propose rules that fly in the face of these requirements and should not be adopted.

For example, Tribune Company posits that "facilities changes required by the repack could result in a station no longer providing a good quality signal to a cable headend or satellite receive facility, necessitating alternative, usually expensive, signal delivery to maintain cable carriage."[48] Its solution – giving every broadcast station that continues operating after any

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[43] *See* DirecTV/Dish Comments at 4 ("Consistent with the Spectrum Act, the Commission should refrain from expanding or altering the mandatory carriage rights of broadcasters on MVPD systems.").

[44] *See Frisby v. Schultz*, 487 U.S. 474, 483 (1988) (it is a "well-established principle that statutes will be interpreted to avoid constitutional difficulties.").

[45] 47 U.S.C. § 1452(b)(4).

[46] 47 U.S.C. § 534(h)(1) (definition of "local commercial television station").

[47] *Id.* at (h)(2) (definition of "qualified low power station").

[48] Tribune Comments at 25.

repacking "the same cable carriage rights as it had on November 30, 2010"[49] – is contrary to the Cable Act. Section 614 of the Cable Act provides that a local television station invoking mandatory carriage is "responsible for the costs of delivery to the cable system a signal of good quality or a baseband video signal."[50] The Commission cannot sweep aside the "good quality signal" requirement any more than it can shift the costs of providing such a signal from the broadcaster seeking carriage to the cable operator. A broadcaster that no longer provides a signal of sufficient quality to the headend must find a way to send such a signal or forgo its carriage rights.[51]

The National Religious Broadcasters (NRB) ask the Commission to ignore another aspect of section 614 of the Cable Act – one that limits low power carriage to those LPTV stations that are "qualified low power television stations" meeting strict statutory criteria. NRB proposes to "automatically grant[] mandatory cable carriage status [to low power stations] at their new location/channel upon constructing their new facilities."[52] It urges that "[s]uch status should not be restricted by the standard criteria to be a 'qualified low power television station' under Section 76 of the Commission's rules."[53] The Commission is not free to ignore the Cable Act's strict eligibility criteria for low power carriage. Moreover, rather than expanding these limited carriage rights, as noted the Spectrum Act imposes an additional criterion in the case of channel-sharing: the low power station must have been entitled to carriage both at its November 2010

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[49] *Id.*

[50] 47 U.S.C. § 534(h) (definition of "local commercial television station").

[51] For similar reasons, the Commission cannot adopt Entravision's suggestion that the agency "revisit Part 76 and to provide that post-auction MVPD must-carry carriage will be on a DMA basis and not on a coverage contour basis." Entravision Comments at 12.

[52] NRB Comments at 8.

[53] *Id.*

location and at its new shared location. The Commission must reject NRB's proposal to disregard these restrictions.

MetroPCS is similarly off the mark in proposing that the Commission can use expanded cable carriage rights as a means to try to entice additional broadcasters to participate in the auction.[54] It suggests that the Commission consider granting a broadcaster the "same carriage rights"[55] regardless of where it ends up post-auction – or if it gives up over-the-air broadcasting altogether.[56] But the Commission is not free to ignore the statutory strictures on carriage as a means to encourage more broadcasters to relinquish their spectrum.[57]

Other commenters suggest that allowing broadcasters to share with stations outside their community of license would provide such encouragement. For example, Entravision urges that "to maximize broadcaster participation in the auction, the Commission should allow qualified Stations to change freely their communities of license within their Designated Market Areas ('DMAs'), including where the station may be the only station licensed to the community, waive the minimum coverage requirement in Section 73.625 of the Commission's Rules with respect to

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[54] MetroPCS Comments at 6 (proposing that "to encourage maximum participation, the Commission should allow broadcasters, whenever possible, to maximize their value by retaining these rights separate and apart from the spectrum that they relinquish in the reverse auction."). Moreover, as the Competitive Carriers Association (CCA) points out, these marketplace distortions could have the opposite effect by "artificially propping up the broadcast business model." CCA seeks a Commission inquiry into whether regulations, including must carry, "overprotect broadcast television and, in doing so, diminish the likelihood of broadcasters' participating in the auction." CCA Comments at 20.

[55] MetroPCS Comments at 6.

[56] *Id.* ("the Commission should explore whether there is a supportable legal basis for allowing broadcasters who have relinquished spectrum entirely, but continue to broadcast a feed, for example, over the Internet, to retain their must carry rights."). There would be no legal basis to require cable operators to carry signals that were not transmitted over the air. *See Turner Broad. Sys. v. FCC*, 520 U.S. 180 (1997) (the Court upheld the must carry provisions of the Cable Act only because they promoted the government's interest in preserving the availability of over-the-air broadcast stations.).

[57] *See* Comcast/NBCUniversal Comments at 46 (explaining that "broadcast stations that voluntarily agree to relinquish spectrum in order to share a television channel do not acquire any additional carriage rights as a result of the sharing arrangement. Specifically, the law requires that a station moving to a shared channel have the same carriage rights at its shared location that it would have at the same location were it not channel sharing.").

such Stations, and allow Stations to accomplish community coverage by alternative means including LPTV stations, DTS service, or multicast service using the facilities of another station."[58] But the Commission appropriately proposes to restrict changes to a station's community of license, recognizing, among other things, that doing so will "minimiz[e] the potential impact on MVPDs."[59]

If, contrary to the rules and the statutory requirements, the Commission were to adopt policies that increase the carriage obligations of cable systems, it would have serious implications for the Relocation Fund. The required carriage of a station at a shared location that otherwise was not carried on that particular system would entitle the operator to reimbursement for any costs that result from channel sharing.[60] Thus, if the rules were to allow wholesale moves that impact cable carriage, the costs incurred to carry these new stations would have to be reimbursed from the limited pool.[61]

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[58] Entravision Comments at 12.

[59] *NPRM*, 27 FCC Rcd at12386, ¶89. The channel sharing rules already require channel sharing stations "to continue to provide minimum coverage of their principal community of license." *Channel Sharing Order*, 27 FCC Rcd at 4629, ¶25.

[60] 47 U.S.C. § 1452(b)(4)(A)(ii)(III) (reimbursement for carriage of the signal of a broadcast television licensee that "voluntarily relinquishes spectrum usage rights …to share a television channel with another licensee"). The Commission provides no reason to differentiate between costs incurred in carrying a "channel sharing station from the shared location if the station previously did not qualify for carriage" on the system from any other costs that must be reimbursed. *NPRM*, 27 FCC Rcd at 12473, ¶352. The Spectrum Act provides for reimbursement to MVPDs to "continue to carry the signal of a broadcast licensee" that voluntarily or involuntarily relocates or repacks or shares a television channel. 47 U.S.C. § 1452(b)(4)(A)(ii). To the extent that the licensee chooses to share its station with another licensee, the operator should be reimbursed for any new costs associated with that carriage, including the costs that would be incurred to carry a new stream of video programming from another licensee at the shared location.

[61] *See* DirecTV/Dish Comments at 9.

CONCLUSION

For the reasons discussed above, in carrying out the requirements of the Spectrum Act the Commission should keep in mind the important benefits to consumers and the economy provided by unlicensed spectrum and should adopt the "Down from Channel 51" band plan with a duplex gap of sufficient size to support unlicensed devices. This approach would provide an appropriate balance between licensed and unlicensed uses of the 600 MHz band while providing interference protection for licensed services.

Respectfully submitted,

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ATTACHMENT

FCC Broadcast Incentive Auction

A Band Plan Framework for Maximizing Spectrum Utility

Dirk Grunwald and Kenneth Baker

Abstract

Wireless broadband has had enormous consumer benefit, and the mobile and WiFi ecosystems complement each other in the marketplace. The FCC's forthcoming incentive auction of broadcast spectrum is important to ensuring future growth of wireless broadband, and the allocation of spectrum in the "band plan" is a critical determinant. This paper critiques the FCC's proposed band plan as inadequate to the challenges facing wireless use, and proposes an alternative framework that benefits licensed and unlicensed broadband services, as well as television broadcasters, thus maximizing technology and economic benefits.

About the Authors

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Contents

1 Executive Summary

In the National Broadband Plan, the Federal Communications Commission recognized the critical importance of meeting growing consumer demand for wireless data services, and set a goal of making available an additional 500 MHz of spectrum to facilitate continued growth of wireless broadband. This goal was reinforced through an Executive Memorandum to federal agencies, in which the President directed that:

> *"…executive departments…make available a total of 500 MHz…suitable for both mobile and fixed wireless broadband use."*[1]

The FCC's Incentive Auction initiative, as progressed through the Notice of Proposed Rulemaking in the matter *Expanding the Economic and Innovation Opportunities Through Spectrum Auctions* (NPRM)[2], is an important opportunity to facilitate continued growth of the wireless ecosystem. By making available high-quality spectrum for new uses, consumers will benefit from more robust mobile services, and continued expansion of WiFi-like access.

The mobile and WiFi ecosystems are complementary, and together have given rise to the substantial growth of wireless services in the US and globally. To foster ongoing growth, spectrum policy must recognize the balance between the two. This is particularly true as the FCC considers how to structure an incentive auction of broadcast spectrum, and how newly available broadband spectrum should be structured in the band plan to maximize its utility for consumers and the broader economy.

The NPRM proposes a lead band plan and a number of alternatives, and poses questions on what band plan provides the greatest benefit. This paper critiques the FCC's lead band plan proposal and presents arguments for an alternative that

[1] *Presidential Memorandum: Unleashing the Wireless Broadband Revolution*, June 28, 2010, Office of the Press Secretary, The White House.

[2] FCC 12-118, released October 2, 2012.

maximizes the utility of the repurposed spectrum to meet growing consumer demand for wireless services.

In its 2012 NPRM to repurpose a portion of the broadcast band through incentive auction, the Commission noted that;

> *"…the spectrum reclaimed through the incentive auction will promote economic growth and enhance America's global competitiveness, increase the speed, capacity and ubiquity of mobile broadband service, such as 4G LTE and WiFi like networks, and accelerate the smartphone- and tablet-led mobile revolution, benefitting consumers and businesses throughout the country."*[3]

The Commission thus acknowledges the importance of low-band spectrum to meeting growing wireless demand, as well as the complementary nature of licensed and unlicensed networks. We will demonstrate that our alternative approach is better suited to meeting the FCC's goals than the lead proposal in the NPRM.

Our proposed approach, based on an alternative in the NPRM referred to as "Down from 51", ensures maximum value of recovered spectrum by promoting certainty in usage rights and interference protection for mobile and digital broadcast services, and promotes the growth of a rich ecosystem for both licensed and unlicensed mobile broadband devices by providing a universal, contiguous guard band.

Key to these benefits is the unique opportunity to ensure contiguous unlicensed low-band spectrum as a means of extending the benefits of WiFi to new applications and services, as well as the opportunity to simplify and adapt unlicensed access rules developed in the TV White Spaces for this newly available bandwidth.

By supporting the complementary nature of licensed and unlicensed networks and enhancing the interference protection provided to licensed services, the "Down from 51" band plan will maximize the technological and economic utility of spectrum repurposed through the FCC's broadcast incentive auction.

[3] FCC, 12-118, NPRM.

2 WiFi: Benefits Abound, Future Uncertain

2.1 WiFi Benefits the Licensed Ecosystem

The benefits of WiFi are well known. Some estimates place the annual economic value of unlicensed applications at close to $100 billion per year.[4] In a 2011 paper, Stanford economists Paul Milgrom, Jonathan Levin, and Assaf Eilat note that such estimates are conservative in that they do not account for the value of low barriers to entry for innovation that unlicensed spectrum entails.[5] In addition, it is apparent that WiFi not only benefits unlicensed applications, but it also complements the mobile ecosystem.

The mobile industry is going through a significant transformation as smartphones, tablets, and other devices place growing demands on the network. This growth in wireless services results from both mobile and WiFi access. The coverage and ubiquity of cellular networks, coupled with the capacity and offloading largely provided by WiFi, has enabled the emergence and adoption of smart phone devices and associated innovative technologies and business models.

Without both mobile and WiFi, it is unlikely that wireless demand would be growing so rapidly. Early mobile computing devices, such as the Palm Pilot and Microsoft PocketPC were hampered by their lack of wireless or limited by their WiFi-only capabilities. Devices that only used wireless telecommunications network, such as the Palm Treo and Blackberry phones were popular, but the smartphone revolution truly exploded when devices combined finally WiFi and broadband wireless networks.

Early adopters of the popular iPhone will recall the frustration in attempting to take advantage of a rich new feature set offered by the device when accessing the mobile

[4] Richard Thanki, "The Economic Significance of License-Exempt Spectrum to the Future of the Internet", June 2012.

[5] Milgrom, Levin, and Eilat, "The Case for Unlicensed Spectrum", October 2011.

network, and the importance of WiFi to full functionality of iPhone innovation. The ability to offload some data-intensive traffic to WiFi made those devices more useful and accelerated the adoption of carrier and WiFi based devices – a trend called "on-loading" in the industry.

This trend has benefited both consumers, who realize greater utility from wireless devices, and mobile carriers, who see growth in mobile broadband services at network costs far less than would be the case without WiFi.

Several studies have examined the economic benefits of increasing use of mobile technologies. In October 2010, the FCC published a white paper outlining the cost savings to mobile carriers resulting from new spectrum.[6] Similarly, offload of mobile traffic to WiFi networks enables more cost-efficient service of growing mobile data traffic. A 2012 report by Richard Thanki estimated the magnitude of this effect at up to $93 billion in 2012 alone.[7] By reducing mobile network costs and driving greater wireless growth, WiFi services offered over unlicensed spectrum therefore increase the value of licensed spectrum.

The complementary nature of unlicensed and licensed broadband networks will continue as wireless demand accelerates. This market dynamic necessitates a responsive public policy approach, balancing the availability of licensed and unlicensed spectrum.

2.2 Unlicensed Spectrum Is Critical to the Small-cell Future

Experience to date, Cooper's Law and analysis by key industry firms such as Qualcomm, illustrates that broader adoption of small-cells is critical to the success of mobile technologies, and that unlicensed spectrum will continue to play a significant role.

There are many ways to improve the broadband performance of radio networks, including improved coding, modulation, and increasing spectrum. But, as Cooper's

[6] "*Mobile Broadband: The Benefits of Additional Spectrum*", FCC Staff Technical Paper, Oct. 2010.

[7] Thanki, 2012.

Law shows, the most important factor is the organization or design of radio networks. Cooper's Law, named for Dr. Martin Cooper, states that more than 95% of the throughput improvements of radio networks over time arise from spectrum re-use[8] enabled by improved radio network design.

To understand Cooper's Law, think of a single LTE radio that operates at tremendous power (say 100MW) on 10MHz of spectrum. That radio might be received by an entire city, but now the 10MHz of bandwidth has to be shared by millions of people, leading to low average broadband speeds. Using a cellular network design in which many 200W cells are deployed around a city, that same 10MHz of spectrum may be used by hundreds of lower power cellular towers. These cell towers are far enough apart to minimize interference and the resulting network provides significantly more broadband performance at the cost of deploying more cellular towers. A similar increase in broadband performance can be achieved by deploying thousands of even lower power transmitters. Modern technology has enabled these transceivers to be small enough to be deployed inside homes and businesses.

The trend remains; as mobile broadband systems evolve, small-cells will drive the network architectures of the future. The wireless industry is currently deploying "Heterogeneous Networks" (HetNets) which involves a massive re-design of wireless networks towards small-cells. A HetNet combines wide-area cellular networks for coverage and smaller local networks for broadband performance. A recent white paper by Qualcomm[9] demonstrates that HetNets can provide a 500% to 2000% improvement in broadband performance *with no additional spectrum* and at significantly lower cost than expanding traditional "Tower and Power" cellular deployments.

[8] The term "spectrum re-use" generally refers to techniques employed to decrease the contention ratio (the number of users on a common access network) in wireless networks, often by growing network density, thus improving network performance.

[9] Qualcomm Inc., "New Neighborhood Femto Deployment Model", February 2012.

The "small-cell" networks studied by Qualcomm operate on licensed spectrum (using femtocell technology), but similar benefits have long been achieved using unlicensed spectrum and WiFi devices. Femtocell networks operate in licensed spectrum and provide a small-cell solely for the wireless carrier leasing that spectrum, whereas any number or class of devices can use WiFi's unlicensed spectrum. The unlicensed model has led to broad use of WiFi deployments in homes and businesses, dwarfing femtocell use. Juniper Research[10] estimates that 63% of wireless traffic generated by smartphones, feature-phones and tablets will be carried by small-cells by 2015 with the majority of that traffic - over 80% - carried by unlicensed WiFi.

Although WiFi uses unlicensed spectrum, there are a variety of market-based models to pay for deployment and broadband, ranging from free access, to subscriptions, to carrier-deployed WiFi networks. Key to the success of WiFi for broadband access has been the ubiquity of devices, the universal availability of the spectrum and the simplicity of installing and deploying devices. These features ensure that WiFi will continue to provide substantial benefit in the future, complementing the growth of mobile networks.

2.3 Existing WiFi Spectrum Has Limitations

Existing WiFi networks operate at low power on the unlicensed 2.4 GHz and 5 GHz bands. These frequency bands provide limited coverage both because WiFi operates at low power but also because those bands have higher *propagation loss* and higher *penetration loss*.

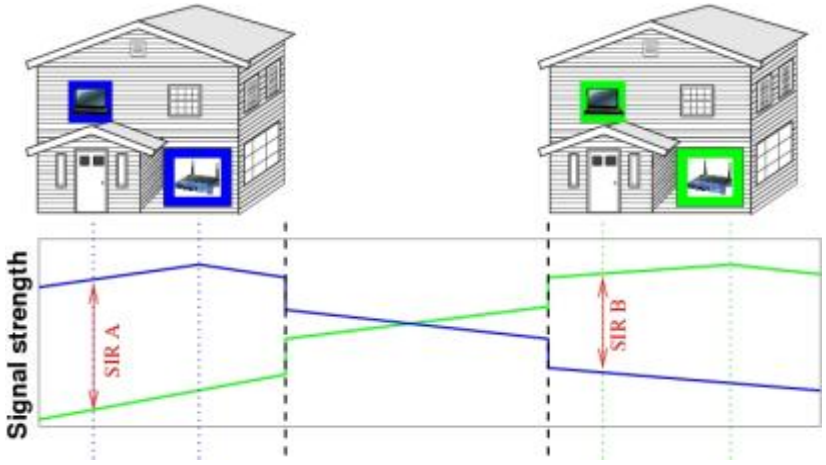
Propagation loss occurs naturally when wireless signal strength decreases over distance. The physics of radio wave propagation dictates that lower frequencies

[10] Nitin Bhas, "Data Offload and Onload", Juniper Research, March 31st, 2011. Available at http://www.juniperresearch.com/analyst-xpress-blog/2011/03/31/data-offload-onload/

have less propagation loss for a given distance than higher frequencies. Penetration loss occurs when a signal passes through a wall or other obstruction.[11]

Figure 1 illustrates these losses schematically. The signal from the right-most WiFi transmitter causes limited interference to the neighboring house on the left because the signal is diminished by walls (penetration loss) and the space between houses (propagation loss). Because WiFi in the 2.4 and 5 GHz bands has limited propagation and penetration, it excels as providing dense small-cell networks because it is difficult for one access point to penetrate into adjacent buildings and cause interference. However, this same trait makes it less suitable for wide area coverage.

Figure 1 – Schematic Illustration of Propagation and Penetration Loss



Despite relatively poor quality of the frequencies for wide-area networking, WiFi has been used in several city-wide wireless networks because of its simplicity and ubiquity. For example, Google runs a city-wide WiFi network in Mountain View, CA

[11] At a high level, free space path loss dictated by physics states that a radio emission signal fades proportional to $(\frac{4\pi}{c})^2 d^2 f^2$ for distance *d* and frequency *f*, meaning that doubling the frequency (or distance) decreases the signal by a factor of 4. Modeling the propagation of radio waves is remarkably complex, because models attempt to capture the characteristics of buildings, vegetation and many other aspects that affect propagation. See "*Bounding the error of Path Loss Models*" by Phillips, Sicker & Grunwald, *New Frontiers in Dynamic Spectrum Access Networks* (DYSPAN) 2011 for detailed analysis of a number of path loss models.

using access points mounted on light poles.[12] However, Google's customer materials note the inherent limitations of the frequencies it uses:

> *"GoogleWiFi has the strongest signal when you are outdoors. It is unlikely that a [2.4 GHz] WiFi-enabled laptop or a computer with a conventional WiFi card will work indoors in most locations"*[13]

Many applications of small-cell WiFi networks are similarly limited by propagation and penetration losses. For example, the thick interior walls and the scale of such buildings complicate deploying WiFi in hospitals, hotels, stadiums and subways.

Using lower frequencies – such as the 600 megahertz TV band - for a small-cell network would provide greater coverage and better building penetration for WiFi. Low-band unlicensed spectrum would complement the existing WiFi ecosystem by enabling greater ubiquity, further enhancing the consumer benefits accrued to date through WiFi access.

Further, the growing use of existing 2.4 GHz and 5 GHz WiFi spectrum gives rise to congestion in dense urban environments and shared or public locations.[14] This occurs despite the propagation and penetration losses described above, revealing how truly widespread WiFi technology use has become. WiFi congestion will only accelerate as the number of wireless devices continues to grow. Without additional spectrum, wireless consumers are likely to experience reduced performance, threatening the future of the wireless ecosystem.[15]

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[12] See http://wifi.google.com/ for information, including coverage maps.

[13] Google WiFi FAQ, http://support.google.com/wifi

[14] See, for example, Jonathan Cox, "WiFi devices crowd 2.4 GHz band; IT looks to 5 GHz", NetworkWorld, October 24, 2011.

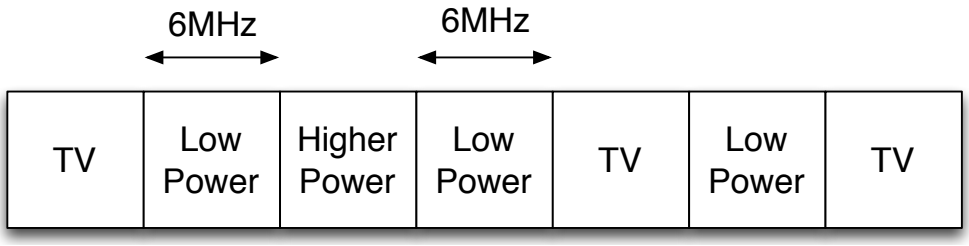
[15] Studies in 2007 estimated a total of 40,000,000 WiFi access points (APs) in the United States in 2007, with densities ranging between 1,854 APs/km^2 in Manhattan to 109 APs/km^2 in Las Vegas. That study directly measured more than 5.6M access points – see K. Jones and L. Liu, "What where wi: An analysis of millions of WiFi access points," in *Proc. IEEE PORTABLE*, Orlando, 2007. WiFi devices are also now used to determine location, and one such company (http://www.wefi.com) reports more than 150 million WiFi locations around the world.

2.4 FCC Recognizes Importance of Low-Band Unlicensed Spectrum

Recognizing the importance of low-band spectrum to the unlicensed ecosystem, the FCC has authorized unlicensed use of unused spectrum in the TV band, called "White Spaces" (TVWS). However, to protect incumbent services, a complex set of access rules is attached to such unlicensed use.

For example, as illustrated in Figure 2, the FCC regulations for TV Band White Space Devices allow low-power 40mW transmissions in the 6 MHz guard bands separating TV channels. Higher power transmissions (100mW and 1000mW) are allowed when separated by at least 6 MHz from active TV channels in a "second adjacent" channel.

Figure 2 – Allowed TV Band Device Rules



Since the number of TV channels varies considerably across the country, there is no *a priori* knowledge of TV channel assignments. TV Band devices operating at these higher powers must determine their location and contact a database for allowed channels before transmitting; lower power devices must first contact a higher power device before transmitting. Thus, even though operation is allowed in the TV guard bands, there is considerable complexity in the terms of access that has slowed the growth of this service.

Table 1 shows the frequency-dependent propagation differences for the TV band and the two common bands used for WiFi[16] -- all things being equal, radios operating at 650 MHz provide a 14-fold improvement in range, or 200-fold

[16] These quantities are calculated using the free-space path loss equation for different frequencies assuming all other characteristics of the radios remain constant. This results in a "best possible range increase" and actual differences in effective range depends on the environment (rain, snow), ground clutter (houses, trees) and other factors.

improvement in coverage area.[17] The advantage of low-band spectrum is even greater relative to the 5 GHz band – a 60x performance improvement.

Table 1 – Difference In Transmission Range For Different Frequencies

Frequency	Range Multiplier	
	5GHz	2.4GHz
5Ghz	1x	--
2.4GHz	4.3x	1x
650MHz	60x	14x

Figure 3 – Propagation Differences at 650MHz and 2.4GHz

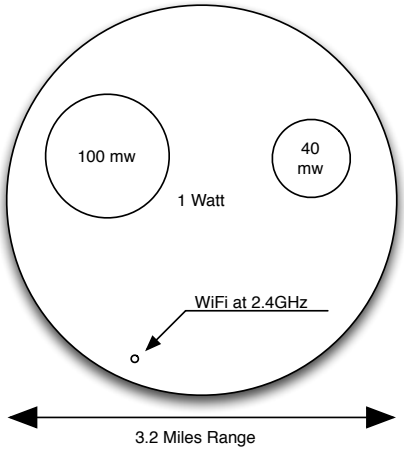


Table 1 describes the physical limitations of propagation loss assuming the radios involved are otherwise equal. In practice, regulators have established different transmission power limits for different devices and bands to manage interference. Figure 3 shows the comparative propagation differences arising from regulated power limits for different TV Band Devices and the common 2.4 GHz WiFi devices for actual radios.[18]

The 2.4 GHz and 5 GHz WiFi devices are useful for spectrum reuse, leading to great improvements in broadband speeds through many small-cells.[19] TV band devices are useful for coverage, filling in the regions that the higher frequency devices leave unserved. This greatly reduces the number of access points needed to cover a given

[17] Assuming the signal radiates in an omnidirectional pattern, a 14-fold increased transmission radius would result in a 14^2 or 196-fold transmission area.

[18] The 650 MHz radio device range was calculated using the link budget calculator for the Koos Technical Services radio product licensed to operate in the TV White Spaces. The 2.4GHz radio uses stated maximum ranges for commercial 2.4GHz access points. News reports by Koos Technical Services report longer ranges for their product (http://www.ktswireless.com/kts-wireless-agility-white-space-radio-wins-innovation-award-at-tesscos-innovation-showcase-2012/). Actual usable ranges would depend on terrain, ground clutter and interference.

[19] As noted previously, "spectrum re-use" refers to efforts to lower the contention ratio in wireless networks, or the number of users on a common access network. Because of the path and propagation loss of higher frequencies, contention ratios are generally lower than at lower frequencies, all else being equal.

area. For example, to cover an area equivalent to the propagation offered by a single 1W TV Band access point would require approximately 2900 2.4 GHz access points.[20] This suggests that low-band spectrum has the potential to deliver substantial benefits to consumers at efficient scale.

There are many situations where such coverage-focused "small-cell" networks would be useful counterparts to existing small-cell networks. Providing small-cell broadband coverage in city parks, parking lots, and construction yards is difficult because of the large areas involved. Providing coverage in hospitals, hotels and shopping malls is difficult because of the penetration loss caused by buildings. Operating WiFi-like networks in the TV Bands would address many of these coverage challenges, making WiFi more useful for consumers.

2.5 Lack of Spectrum Prevents White Spaces From Realizing Full Potential

The throughput realized over the coverage areas offered by low-band spectrum is influenced by the amount of bandwidth available. Modern WiFi systems operate in the range of ~1-10 bits/Hz depending on power levels and interference but largely independent of the frequencies used.[21] Thus, a single 6 MHz TVBD would have about 1/3 the broadband throughput of a single 20 MHz WiFi channel, and that throughput is shared over a large area because of the enhanced coverage of the lower frequencies. Increased spectrum would result in faster broadband.

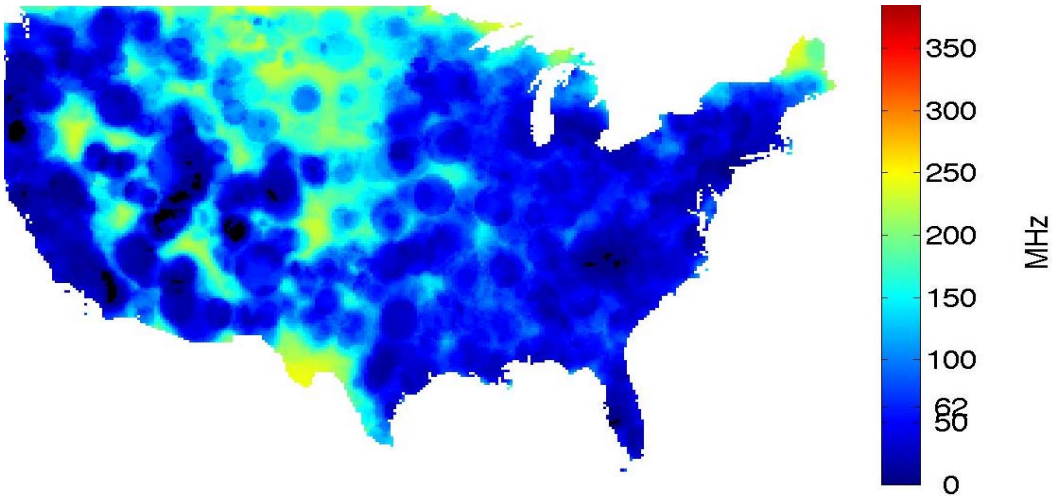
Standards bodies have envisioned supporting greater unlicensed bandwidth in low-band spectrum. Indeed, the IEEE 802.11af specification, which defines support for WiFi operation in the TV bands, incorporates 6, 7, 8, 12, 14, 16, 20, 40-MHz and larger operating bandwidths.

[20] Similarly, it would take an estimated 290 2.4 GHz WiFi access points to cover what 100mW TV Band access point would cover, or roughly 100 2.4 GHz WiFi access points to cover the same area as a single 40mW TV Band device.

[21] WiFi standards can also operate at considerably higher spectral efficiency through the use of multiple-antenna systems.

Unfortunately, availability of TV "White Spaces" spectrum is limited in many areas of the United States. There is significant bandwidth available in rural areas, which have limited incumbent TV channels, but there is much less bandwidth available in the less rural media-rich markets. Figure 4 shows how little bandwidth is available across the US, particularly in high-population areas, using results of an analysis of the available spectrum for a 100mW TV band device.

Figure 4 – Usable Spectrum In Which to Operate 100mW TV Band Device



The promise of efficient, scalable coverage of WiFi-like services offered through TVWS will continue to be limited by the lack of spectrum. Small-cell technologies such as WiFi are very cheap to deploy through a combination of ubiquity (volume manufacturing drives down cost), universal availability of the spectrum (simplifying the radio design) as well as the simplicity of installing and deploying the device. This is why WiFi offload has provided such a useful complement to carrier-provided wireless networks.[22]

[22] The ability to deploy WiFi networks in an *ad hoc* fashion has proven useful after disasters. After Hurricane Sandy hit New York in November 2012, hundreds of free WiFi spots provided communications access while cellular and phone systems were repaired. Citizens who had power and Internet service provided many of those WiFi hotspots and companies that run commercial WiFi hotspots, such as Time-Warner and Comcast, provided others. Mapping services such as https://sandycommsmap.crowdmap.com/ guided people to these resources.

TV Band Devices have the potential to extend the design options of small-cell networks by allowing consumers and wireless operators to balance coverage with throughput, but the lack of universally available spectrum, and the very limited (or non-existent) spectrum availability in urban areas will hamper the adoption of emerging technology standards, such as the 802.11af WiFi standard for the TV bands. Without sufficient spectrum to be useful and inexpensive, such technologies will likely remain rare and expensive.

Furthermore, to the extent that the FCC's Incentive Auction reduces and "packs" the 'core' TV band, it is likely to have a proportionally similar effect on available White Space spectrum. This reduces the opportunity to make effective use of WiFi in the TV bands. Without attention to the utility of unlicensed spectrum in 600 megahertz, the promise of the FCC's White Space initiative will be further complicated, and the benefits to consumers and the complementary mobile ecosystem will go unrealized.

3 Incentive Auction Key To Future of Unlicensed Spectrum

The FCC's stated goal of the NPRM is to:

> *…repurpose the maximum amount of UHF band spectrum for flexible licensed and unlicensed use in order to unleash investment and innovation, benefit consumers, drive economic growth, and enhance our global competitiveness, while at the same time preserving a healthy, diverse broadcast television service[23].*

The NRPM sought comment on band plans and strategies that would result in an incentive auction to repurpose TV spectrum in the 600 megahertz band for broadband services, as recommended in the National Broadband Plan and authorized by Congress in the Spectrum Act of 2012.[24] Further, the FCC noted that:

> *…spectrum reclaimed through the incentive auction will promote economic growth and enhance America's global competitiveness, increase the speed, capacity and ubiquity of mobile broadband service, such as 4G LTE and WiFi like networks, and accelerate the smartphone- and tablet-led mobile revolution, benefitting consumers and businesses throughout the country*[25]

Thus, the FCC acknowledges the complementary nature of mobile and WiFi to the growth of the wireless ecosystem, and the importance of the incentive auction to freeing low-band spectrum to facilitate continued growth.

3.1 Strong Economic Incentives Will Guide Spectrum Repurposing

The incentive auction allows existing TV operators to surrender their spectrum in return for a financial incentive; that spectrum is then available to be auctioned for broadband services. The exact amount of spectrum available for broadband access in each market will be determined in the auction, and the total amount of spectrum available from market-to-market may vary. Analysis from SNL Kagan and others

[23] FCC 12-118, NPRM, para. 10.

[24] The incentive auction is authorized by Title VI of the Middle Class Tax Relief and Job Creation Act of 2012, commonly known as the Spectrum Act.

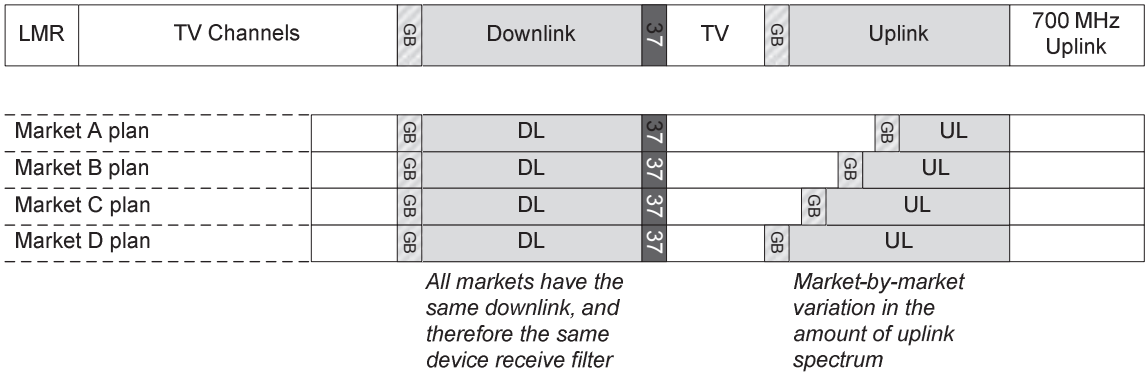
[25] NPRM, para. 4.

suggests that the economic opportunity for broadcasters is substantial, the demand for wireless broadband spectrum is strong, and significant spectrum will be repurposed across markets.[26]

3.2 Review of FCC Band Plan Proposal

The NPRM describes a number of possible band plans based on the range of possible vacated TV channels, including the possibility that different amounts of spectrum may be supplied in different markets. The strong economic incentives described above may help ameliorate this variability, but the FCC describes in the NPRM a number of additional constraints affecting possible band plans. These include, among other things, the mismatch in common spectrum allocation quanta for TV channels (6 MHz) and the presumed LTE broadband bands (5, 10 or 20 MHz),[27] the need for a *duplex gap* to separate downlink and uplink LTE services, and the need for guard bands to enable in-band coexistence between LTE and TV services.

Figure 5 –Suggested Band plan Family From the NPRM



These constraints lead the FCC to propose a band plan that splits the uplink and downlink spectrum, with TV broadcast in the mobile duplex gap. The potential for cross-market supply variability leads the FCC to adapt their approach to a *family* of

[26] See Robin Flynn, SNL Financial analysis "Broadcast incentive spectrum auctions: Gauging supply and demand", available at http://www.snl.com/InteractiveX/ArticleAbstract.aspx?id=16402326

[27] Although it is possible to operate LTE in 1.4 MHz and 3 MHz bandwidths, most commercial deployments use the more wider and more efficient 5, 10 and 20 MHz bands. The next-generation LTE-Advanced can use up to 100 MHz bands.

band plans, illustrated in Figure 5, that keep the downlink (cellular to handset) frequencies fixed below TV channel 37, and any variability in spectrum supply in the uplink (handset to cellular) at the higher frequencies. These band plans use 6 MHz guard bands to separate cellular and TV services and channel 37 is used as an implicit guard band.[28] The NRPM proposes that TV services would use the large duplex-gap between the uplink and downlink services.

In addition, the lead band plan proposal in the NPRM attempts to keep the downlink allocation consistent across all the possible markets in order to reduce the number and cost of filter banks used to reduce interference in handsets.

3.3 Guard Bands and Duplex Gaps Are Necessary To Reduce Interference

The Spectrum Act of 2012 specifies treatment of guard bands in the Incentive Auction, noting that, "*guard bands shall be no larger than is technically reasonable to prevent harmful interference between licensed services outside the guard bands*".[29] It is thus worthwhile to explore technology considerations related to guard band sizing, as well as related considerations with regard to duplex gaps.[30]

Many factors determine the size of guard bands, including the power level and physical proximity of different classes of devices, filters, network operation and other factors. A properly designed band plan can often use spectrum in guard bands for other purposes. Any 600 megahertz band plan must be compatible with adjacent services (such as the 700 megahertz band mobile service) and reduce interference between Digital TV and mobile devices. We propose a band plan that we believe best reduces interference risk for Digital TV devices and mobile networks, and still provides usable spectrum for low-power unlicensed devices.

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[28] The NPRM has many possible band plans, including ones in which TV 37 is used for LTE broadband; this diagram shows the most generic such plan.

[29] Section 6407, Public Law 112-96, Middle Class Tax Relief and Job Creation Act of 2012.

[30] Different technology considerations apply to the sizing of guard bands and duplex gaps, respectively. The Spectrum Act did not specify requirements related to duplex gaps; however, for completeness of the analysis technology considerations for each will be explored.

Guard bands are needed to protect licensed services because radios transmit both in the intended frequency range and in adjacent frequencies. The adjacent channel transmissions are at significantly lower signal strength than the intended frequencies but can still cause interference to a receiver if the receiver is either close by or the transmitter is operating at a high power.

Figure 6 – Example of Transmission Mask Showing Transmission Roll Off

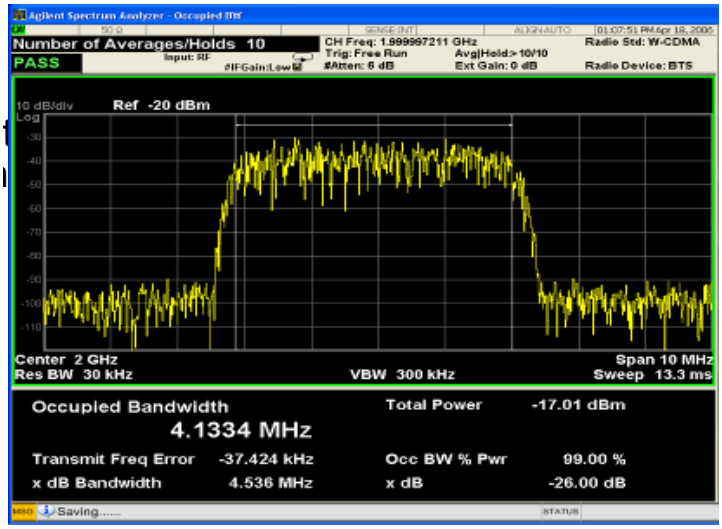


Figure 6 shows the transmission mask for an LTE device[31] operating at 2 GHz. The vertical axis shows transmission strength and the horizontal axis shows the frequency range being used. The signal in the central area is thousands of times stronger than the signal on the "skirt" of the transmission. The energy in the skirts can still cause interference to receivers operating on adjacent bands since receivers, by design, are sensitive to weak signal energy. The receiving radio can use a bandpass filter to eliminate some unwanted interference – this is done in cellular radios to reduce the interference from transmitters in frequencies adjacent to the intended frequency.

A receiving radio can also use a frequency much further away from the transmitter and use this "guard band" to reduce interference between the transmitter and the

[31] Figure 6 taken from *Generating and Analyzing LTE Signals,* Agilent Technologies presentation.

receiver. For example, the lower 700 megahertz LTE band uses 699-716 MHz for an uplink and 729-746 MHz for a downlink. TV channel 51 operates adjacent to the 699 MHz LTE uplink border. In areas where TV channel 51 is in active use, a cellular base station may not be able to distinguish a handset transmitting at 699 MHz because the high power TV transmission is still strong and without sufficient "roll off" (signal attenuation) into adjacent spectrum. Transmissions at lower power, such as other handsets transmitting across 699-716 MHz don't cause as much interference because the lower power transmission "rolls off" sufficiently to be below receiver sensitivity and thus produces less interference.

Frequency Division Duplex (FDD) radios transmit and receive at the same time and thus need an uplink to downlink frequency separation to protect the receiver from the transmitter on the same device. This separation is called a "duplex gap". The duplex gap is needed to reduce the handset's transmitter from interfering with the handset's receiver.[32] Duplex gaps are built into spectrum allocations and band plans for FDD systems. In the previous example, the spectrum separating the 699-716 MHz uplink from the 729-746 MHz downlink is a 30 MHz duplex gap. Any band plan in the 600 megahertz band would also need a duplex gap if the spectrum is to be used by LTE devices.

While both duplex gaps and guard bands are designed to reduce interference, each is guided by distinct technology considerations. Guard bands are designed to minimize interference between adjacent bands or services, while duplex gaps are designed to enable FDD systems without 'self-interference', or interference between the uplink and downlink of the same system. In both cases, the appropriate sizing of duplex gaps and guard bands are designed to filter interference at reasonable costs with existing technologies. Guard bands or duplex gaps that are smaller than currently-used technology will entail costs through reduced performance and increased – and more expensive – filtering technology .

[32] Similarly, the duplex gap allows the cellular base station to both transmit and receive simultaneously.

3.4 The Lead Proposal in the NPRM Would Not Result in the Most Effective Use of 600 MHz Spectrum for Wireless Broadband

We argue that the lead band plan proposed in the NPRM is not best suited to meet the FCC's stated goal of supporting continued growth of wireless broadband.,

As shown earlier, network design and small-cell devices, such as those used in Heterogeneous Networks (HetNets) being deployed by wireless carriers, greatly increase overall broadband performance and coverage – even with no additional spectrum. It is essential that the band plan adopted by the FCC address how the spectrum will be used to, as it states, "*increase the speed, capacity and ubiquity of mobile broadband service, such as 4G LTE and WiFi like networks*".

The lead band plan proposed in the NPRM is designed for a traditional "Tower and Power" network, while wireless device manufacturers and carriers are reconsidering such network designs because of the cost and performance benefits of small-cell networks. Although carriers can use femtocells to build these small-cell networks, history has shown that devices using shared spectrum, such as WiFi, have had quicker and broader adoption. The lead band plan in the NPRM only provides small blocks of spectrum for those WiFi-like devices, reducing their utility.

The lead band plan proposal is also driven by considerations around mobile filter technology. In particular, a key goal is to reduce the number of filter banks to ensure that handsets can be used across multiple LTE bands. Current mobile devices already use 6-7 filter banks and industry projections are that handsets will soon use 10 filter banks. However, filter technology is improving (meaning that a given filter bank may cover wider spectrum) and, at higher TV band repurposing levels, an additional 2-4 filter banks may be needed in the proposed 600 megahertz band plan. The alternative band plan we propose uses no more filter banks than the lead band plan in the NPRM.

Further, to the extent that multiple filter banks are likely at higher levels of repurposing, proliferation of band classes gives rise to interoperability concerns, as

seen in the 700 megahertz band.[33] However, the use of unlicensed, shared spectrum has inherent benefits to interoperability. Our recommended band plan therefore encourages interoperability and competition.

Additionally, the NPRM band plan provides a greater potential for interference risk to TV and mobile broadband. This is because the NPRM band plan provides a greater number of adjacencies between digital television (DTV) spectrum and mobile broadband spectrum. Our proposal provides a better isolation between these services by segregating the DTV spectrum to one side and the mobile broadband spectrum to the other side.

While it is possible for carriers to devote licensed spectrum to small-cell designs, there has been significantly less deployment of femtocell devices, which use licensed spectrum, than WiFi devices, which used shared, unlicensed spectrum.[34] In the current market, femtocell devices operate in a single carrier's spectrum and only provide coverage for devices from a single carrier.[35] By comparison, devices from many carriers can use a single WiFi device, and the wireless industry is actively working to improve security and provide better roaming on WiFi.[36]

To meet the goals of the Spectrum Act and NPRM, there must be an allocation of sufficiently capable, shared, unlicensed spectrum. The NPRM indicates that the two 6 MHz guard bands and the implicit guard band in TV 37 could be used for unlicensed operation. However, the mechanism for coexistence with radio astronomy and wireless medical telemetry systems in channel 37 is unspecified, raising significant questions about its utility for unlicensed operations. In effect,

[33] See FCC 12-69, "Promoting Interoperability in the 700 MHz Band", Notice of Proposed Rulemaking, released March 21, 2012.

[34] Juniper Research estimates that 90% of mobile offload in 2012 was to WiFi, with only 10% to femtocells. See "Data Offload and Onload", Juniper Research, March 31st, 2011.

[35] It is possible that Femtocells can be modified to serve multiple carriers across multiple frequency bands, but we are unaware of deployed networks using such devices.

[36] For example, the HotSpot 2.0 standard simplifies logging into and paying for WiFi network access. See http://www.cisco.com/en/US/solutions/collateral/ns341/ns524/ns673/white_paper_c11-649337.html for details.

therefore, the lead band plan appears to offer as little as 12 MHz for unlicensed devices.

Moreover, the fragmented nature of the unlicensed spectrum in the FCC's proposal greatly reduces the utility of even the limited amount of spectrum that would be made available for this purpose. For example, if the existing TV White Spaces regulations were applied (though that need not be the case in contiguous unlicensed spectrum), the only devices that can operate in these bands are 40mW devices (*e.g.* a tablet or laptop). Per TVWS rules, those devices can only operate after being contacted by a Mode-II master-device -- typically a higher-power 100 mW or 1 W TV band access point, which cannot transmit with only 6MHz available under current rules.[37] Without the ability to operate WiFi-like networks in those guard bands, their utility will be greatly diminished.

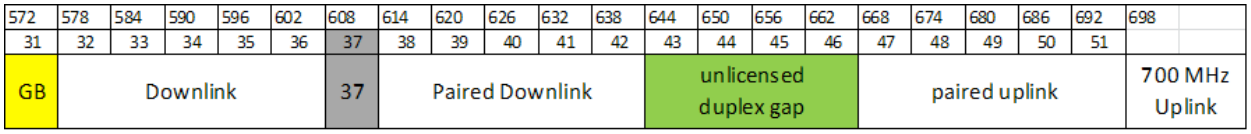
We propose a plan with a single, larger contiguous unlicensed band that would provide many more options when deploying small-cell devices, reducing the costs of deploying coverage-oriented access points by factors of thousands, while simultaneously better protecting mobile and TV services.

[37] It is technically possible for access points to operate at lower power after contacting the spectrum database, but this mode of operation is not explicitly described in existing regulation.

4 Proposed Band Plan: “Down from 51”

Crafting a compatible band plan that allocates a contiguous unlicensed band will allow low, medium and high-powered unlicensed use of the spectrum while meeting the goals of maximizing the value of licensed spectrum. This is achievable because, in offering greater ability to offload to unlicensed networks using the guard band, complementary new technologies and applications can be deployed at low cost, benefiting the mobile ecosystem. In addition, by providing greater interference protection, our proposed approach will likely increase the value of licenses at auction. Adoption of our proposed band plan will enable this growth in part by simplifying the existing TVWS rules.

Figure 7 – Proposed “Down from 51” Band plan



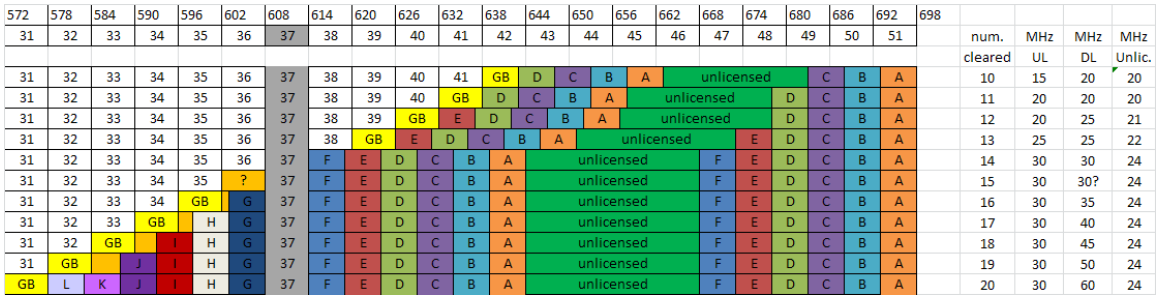
We maintain that the basic “Down from 51” band plan, shown in Figure 7, is more consistent with the RF environment that will exist with the adoption of small-cells and the coming Heterogeneous Network architectures in both the licensed and unlicensed spectrum. This is in part because there is consolidation of DTV services into the lower portions of the band, reducing the opportunity for TV bands to interfere with LTE base stations or handsets.

In a HetNet scenario, mobile broadband small-cells (down link transmitters) can exist in close proximity to TV band devices in the home. These small-cells could exist in either licensed (femtocell) or unlicensed (WiFi-like) spectrum. While these small-cells are not of great power, their proximity ensures that the propagation loss is not as great as it would be for an external, tower based, macro cell. Unlike the primary

proposal in the NPRM, a "Down from 51" band plan minimizes the amount of broadband spectrum that is adjacent to TV band spectrum.

In addition to providing greater interference protection to licensed services, this band plan allocation makes the guard bands more useful for unlicensed use. This is a direct result of capturing a dedicated duplex gap for unlicensed services as well as the sequestration of TV band services to the lower portion of the available spectrum with appropriate guard band separation. This is in contrast to the NPRM's lead proposal in which incumbent TV band services are held both above and below the Channel 37 demarcation.

Figure 8 - Proposed Allocation Strategy as a Function of Number of Cleared Channels[38]



Our proposed band plan can vary with the number of cleared TV channels, consistent with the FCC's desire to accommodate the potential for varying supply across markets. The example shown in Figure 8 proposes at least a minimum of 20 MHz of unlicensed spectrum in the case of 10 TV channels being reclaimed.[39] As the number of reclaimed channels increases, this unlicensed duplex gap is permitted to grow to 24 MHz. At 24 MHz, we can maintain a symmetric uplink and downlink

[38] The figure shown retains channel 37 services in place; however, this proposal can be adapted to move radio astronomy and wireless medical telemetry if desired. The principles of a sufficient duplex gap and common unlicensed bandwidth nationwide continue to apply.

[39] Given the voluntary nature of the incentive auction, it is not possible to know in advance how many TV channels will be repurposed. However, analysis from SNL Kagan and others suggest economic incentives for broadcasters to contribute spectrum is strong (see Flynn, 2013). Therefore, we present 60 MHz as the low end of our band plan range.

bandwidth of 15+15 MHz above TV 37. Notice that TV 37 serves as a *de facto* guard band when all 14 channels between TV 37 and TV 51 are cleared.

As shown, a 20 MHz duplex gap enables the creation of a nationwide common unlicensed spectral component in the upper portion (seen in Figure 8 in what was TV channel 46) that can be used as a control channel for unlicensed service media access control. This common frequency for unlicensed use, available nationwide, is crucial to simplifying the TVWS rules surrounding unlicensed access in force today. For example, a common unlicensed frequency can enable constant broadcast of channel availability to all unlicensed devices, obviating some of the 'cease operation' requirements that affect devices under current rules.[40] Since all markets will newly enjoy unlicensed access, dynamic protocols designed to protect primary services in today's TV band need not apply.

Unlicensed bandwidth of 20 MHz or greater would enable data throughput rates for viable services, including licensed service offload, to be deployed. Twenty MHz is consistent with the 'building blocks' of the WiFi chipset ecosystem, complementing existing WiFi deployments, improving scale economics, and helping speed benefits to consumers. Having a consistent, nationwide "control channel" can lead to simplified deployment methods of TV band devices. These benefits, in-turn, can further decrease the cost of and increase the volume of unlicensed devices, reducing the cost of components for both licensed and unlicensed devices alike.

4.1 Technical Justification for "Down from 51" Band Plan

We have reviewed technology considerations around guard band and duplex gap sizing, which we have followed in the development of our recommended band plan. In order to avoid impacting performance and to avoid unnecessary costs, it is essential that guard bands and duplex gaps are no smaller than current technology allows. In addition, larger duplex gaps can benefit mobile by enabling wider passband filters. As the duplex gap size increases, passband bandwidth can increase

[40] 'Cease operation' rules vary by type of device. For example, a 'Mode I' (client) device must cease operation if it cannot contact a 'Mode II' or Fixed (master) device every 60 seconds. See 47 CFR 15, Subpart H, for current TV band device rules.

proportionally. Our proposed band plan has many other benefits that will help ensure full utilization of repurposed broadcast spectrum.

The sequestration of TV band services to the lower portion of the recovered spectrum better protects these services from adjacent channel interference. Similarly, the mobile broadband services are better protected from TV band devices and transmitters. This plan also enables asymmetric uplink and downlink bandwidth allocations for the licensed services if so desired. Additionally, the allocation is flexible with regard to the possible reallocation of TV 37 radio astronomy and Wireless Medical Telemetry Service (WMTS).

The NPRM band plan proposal was cautious regarding potential variations of recovered spectrum across markets. The "Down from 51" plan is also flexible to accommodate this concern. If a good deal of spectrum becomes available, the "Down from 51" plan is of greater value since it will provide less interference between mobile broadband spectrum and TV band spectrum. This enables a nationwide footprint of common unlicensed spectrum that can be used by consumers, as well as licensed mobile broadband offload.

The number of filters required for the "Down from 51" spectrum plan is no more onerous than the primary proposal in the NPRM. Bandpass filters in the 600 megahertz band can reasonably be built assuming a 20 MHz bandwidth. In this band, it is safe to assume that 5 to 6 MHz will be required as a guard band for adjacent channel rejection. These values are approximate and represent what is technically feasible for a rational and sustainable bill of material cost. Given these values, the "Down from 51" plan as we have outlined here would not change filtering costs or increase the number of filters required in a device. Filter costs, as well as most component costs, will decrease with volume manufacturing. A healthy unlicensed market within the 600 megahertz band will provide a market driven reduction in component costs for both licensed and unlicensed devices in this band. This further adds to the value of licensed spectrum.

If one assumes the existing TV Band Device transmit power rules as a guide to any services within the recovered 600 megahertz spectrum, it becomes clear that no unlicensed transmission at higher power likely in the guard bands set aside by the NPRM proposal. This is because transmission at the higher levels requires an available bandwidth of 18 MHz under the existing rules. However, unlicensed bandwidth in the guard bands of the FCC's lead proposal are likely to be only 6 MHz wide, and no wider than 10 MHz. This limits the number of locations where such higher power devices can be used, and they would likely be confined to rural or remote areas. Under our "Down from 51" approach, higher power unlicensed devices could operate across markets without conflicting with Digital TV.

A larger unlicensed band also provides the opportunity to implement OFDM power shaping at the band edges. Techniques for managing out of band emissions across the OFDM bandwidth are being implemented in such broadband standards as LTE where it is referred to as Additional Maximum Power Reduction (A-MPR). A-MPR provides the ability to manipulate the OFDM spectral emission mask from a network entity. This functionality exists in the standard to enable a device to meet additional ACLR (adjacent channel leakage ratio) and spectrum emission requirements, and is signaled by the network to the user equipment device. This enables devices to meet additional spectral requirements in specific deployment scenarios.[41] The "Down from 51" band plan can utilize these capabilities in both the licensed and unlicensed portions for improved adjacent channel performance with each other and with incumbent TV band devices.

4.2 A Family of "Down from 51" Band Plans

Our proposed "Down from 51" plan meets the FCC's goal to accommodate cross-market supply variability, and can be adapted to "families" for this purpose. We maintain the licensed uplink adjacent to the already allocated lower 700 megahertz

[41] This is one of the many benefits of OFDM modulation, the ability to tailor the band profile by controlling the power in subcarriers. Most, if not all, modern mobile broadband over the air waveforms have adopted OFDM for current and future generation services. The availability of spectral shaping through features similar to A-MPR should be considered available for all future mobile broadband services.

mobile broadband uplink spectrum allocated above TV 51. We propose to maintain a consistent guard band between the mobile broadband downlink services and incumbent TV band services. This is shown in Figure 7 as "GB" in TV 31.

Uplink and downlink licensed mobile broadband spectrum can be allocated in 5 MHz blocks, consistent with previous allocations in the 700 megahertz band and LTE technology. Depending on the amount of recovered spectrum, TV channel 37 can also act as a *de facto* guard band in a fashion similar to the NPRM proposal. Yet this band plan allocation is not dependent on this assignment for TV 37 should it ever be desired to reallocate TV 37. In all ways, this band plan is technically reasonable to protect licensed services while promoting the greatest value to consumers, licensed mobile broadband services, and digital TV broadcast.

5 Benefits of "Down from 51"

The band plan proposed in this analysis will have benefits to all stakeholders. Consumers will gain benefits associated with useful low-band WiFi-like services. Mobile operators will benefit from the attendant complementarities of licensed and unlicensed networks. All users of the band will enjoy greater interference protection, providing greater certainty for investment. These widespread benefits enhance the economic payoff of the incentive auction, both to the broader economy and to the revenue raised in the auction.

5.1 "Down from 51": Benefits to Unlicensed

A healthy unlicensed band adds value to the entire ecosystem surrounding the incentive auctions and mobile broadband services. With a sufficient duplex gap to enable unlicensed use, throughput is increased and complexity reduced as a result of contiguous spectrum. There will be less interference to or from unlicensed services in our proposed band plan than with the Commission's lead proposal. This benefits the service throughput potential for unlicensed and licensed users. As these services become more viable and easy to deploy, the uptake of these WiFi-like devices will increase. This increase in volume will drive down the costs for both licensed and unlicensed services alike. This increases value of the licensed spectrum and, as explored later in this paper, alternate economic methods can still result in post-auction revenue for unlicensed spectrum.

Viable unlicensed services add value to licensed mobile broadband through the availability of coverage-oriented offload. This offload can complement solutions used by licensed mobile broadband on 2.4 GHz WiFi, with the added benefit of additional spectrum and enhanced coverage and in-building penetration. With contiguous unlicensed spectrum there is greater capacity at lower cost. If the size of the unlicensed duplex gap is on the order of 20 MHz or greater, all TV band device power categories should be enabled across all markets, even under current TVWS

rules. This will enable coverage at low cost and a service that is attractive to consumers and industry alike. Our estimate is that a 20 MHz block will enable high-speed data throughputs on the order of 40-70 Mbps. These throughputs would increase with MIMO spatial multiplexing gains, which are becoming common with mobile broadband services and are already part of the 802.11af specification for WiFi like services in the TV bands.

The nationwide contiguous licensed spectrum will remove the need for onerous TVWS protocols and reduce costs. In concert with new nationwide spectrum availability, this provides a significant boost to TV band device scale economics. In turn, use cases are likely to extend well beyond mobile offload.

As noted by Milgrom et al, one of the primary benefits of unlicensed spectrum is its low barrier to entry.[42] This feature enables widespread innovation, which is difficult to predict. However, one can envision a range of possible innovations that would be enabled by newfound access to unlicensed spectrum that is suitable for wide-area coverage and in-building propagation at economic scale.

Use cases may include wide-area wireless Internet, home and enterprise wireless networking, and smart city networks such as traffic monitoring, surveillance cameras and utility management. Machine-to-machine communications, including medical systems, along with voice and short message services are also viable use cases in the 600 megahertz band. Many of these services can have profound consumer benefits, and will become more quickly realized through unlicensed spectrum that is of sufficient bandwidth to enable meaningful data rates. Such services would not be sustainable in the narrow and fragmented guard bands that predominate in the FCC's lead band plan proposal, but would become viable under the band plan framework proposed in this paper.

[42] Milgrom, Levin, and Eilat, "The Case for Unlicensed Spectrum", October 2011.

5.2 "Down from 51": Benefits to Licensed Mobile Broadband

The licensed mobile broadband industry has come to rely on the ability to offload data traffic to unlicensed services such as WiFi. This ability has enabled the success of licensed mobile as it permits new and better services to take hold within the consumer market place even though the licensed network infrastructure may not be in place to support it. The cost of the needed licensed network infrastructure would change the economics of the mobile broadband market place. One estimate pegs the value of this offload at $93B in 2012 alone.[43]

This offload capability is not just beneficial to licensed mobile operators. In reality, the entire ecosystem has benefited since the success of the mobile operators extends to the success of the industry vendors and the public that uses wireless services. The uptake of mobile broadband has been aided by the reduction in infrastructure costs, and the consumer wins through reduced equipment costs and the ubiquity of wireless services.

As explored in Section 2, the benefits of WiFi to the wireless ecosystem as a whole can be extended through new availability of 600 MHz unlicensed spectrum, given favorable physical characteristics that can help increase the ubiquity of WiFi networks.

The "Down from 51" approach also benefits licensed mobile broadband operating in the reclaimed 600 MHz spectrum by mitigating interference risk. In contrast, the FCC's lead band plan proposal entails a greater risk of interference due to the mixing of DTV and licensed services. The current TV channel 51 case illustrates some of the risk to licensed mobile broadband from DTV.[44] Our "Down from 51" proposal will reduce this interference risk to licensed mobile service.

[43] Thanki, 2012.

[44] See, for example, Maisle Ramsey, "FCC Moves on 700 MHz interference with Channel 51 freeze", Wireless Week, August 23, 2011.

5.3 "Down from 51": Benefits to TV Broadcast

Digital TV broadcasters benefit from being further separated from any licensed downlink transmitters. The FCC proposal does not adequately consider that modern mobile broadband networks will include small-cells, both in-home base stations (femtocells) as well as outdoor picocells below rooftop height. The interlacing of DTV service bands with Mobile Broadband service bands, as the FCC has proposed, will heighten the interference potential between these services, to the detriment of DTV. The "Down from 51" approach greatly reduces this risk to broadcasters.

5.4 Economic and Revenue Benefits

The "Down from 51" band plan optimizes spectrum utility, and thereby maximizes the economic value of the incentive auction.

We have noted in this paper that unlicensed networks complement licensed networks through data traffic offload that reduces mobile network costs. In so doing, the present value of profits realized from licensed spectrum (i.e., spectrum value) is higher than would be the case without WiFi offload.

We have also noted that the greater interference protection provided to mobile in "Down from 51" enables greater certainty around license usage rights and investment, which also has a salutary effect on licensed spectrum value.

Further, preeminent auction experts Bulow, Levin, and Milgrom note that gross revenue is often determined by the budgets of participants.[45] This suggests that marginal changes to the quantity of licensed spectrum sold at auction will not greatly impact total revenues, and that overall predictability around license usage rights and inherent spectrum characteristics, among other things, are more important to revenue. This finding is supported by recent research by Wallsten, who finds that, all else being equal in FCC auctions, making more bandwidth available is

[45] Jeremy Bulow, Jonathan Levin, and Paul Milgrom, "Winning Play in Spectrum Auctions", Stanford University, February 2009. The authors note that, *"…it is bidders budgets, as opposed to their license values, that determine average prices in a spectrum auction*."

correlated with lower valuations,[46] and by Bazelon, who estimates the price elasticity of demand for spectrum at -1.2, meaning that increasing the quantity of spectrum supplied reduces values.[47]

It is generally accepted that the broader economic benefits to society resulting from spectrum are multiples higher than the revenue that accrues to the government, suggesting that such broad benefits should be the primary consideration of spectrum policymakers. Nevertheless, it may be appropriate to explore new economic tools in the context of unlicensed spectrum use that address revenue-based concerns, provided that their implementation does not substantially reduce the substantial social welfare that has and will continue to accrue from WiFi-like services. This paper does not endeavor a holistic economic policy proposal. However, such an approach may seek to increase the utility of the spectrum for unlicensed networking by reducing noise from competing, less-valuable services and devices, while calibrating prices in a manner that encourages productive uses.

[46] Scott Wallsten, "Is There Really A Spectrum Crisis? Quantifying the Factors that Affect Spectrum License Value", Technology Policy Institute, January 23, 2013.

[47] Coleman Bazelon, "The Expected Receipts from Proposed Spectrum Auctions", The Brattle Group, July 28, 2011.

6 Summary

This paper has explored how best to maximize the utility of the spectrum repurposed to wireless broadband use through the FCC's upcoming incentive auction of broadcast spectrum. In particular, we have explored the shortcomings of the FCC's lead band plan proposal in this regard, and revealed how an approach based on an alternative known as "Down from 51" is more suited to maximizing consumer benefits in mobile, TV, and unlicensed uses.

As the FCC moves forward with the incentive auction initiative, it should take note of the complementary nature of WiFi and mobile access, which has led to the growth of wireless broadband seen today. Spectrum policy must be responsive to this market dynamic and preserve this mutually beneficial relationship for the future. This entails adopting a band plan that includes a useful, contiguous, nationwide block of unlicensed spectrum. The "Down from 51" band plan meets this need, provides greater interference protection for TV and mobile services, and enhances the value of the spectrum that is licensed and sold at auction.

The FCC's incentive auction represents a unique opportunity to further the goal of the National Broadband Plan to facilitate the continued growth of wireless broadband through balanced policy. For the sake of the mobile / WiFi ecosystem, the innovators of tomorrow and consumers everywhere, we hope they get it right.