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

In the Matter of 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

COMMENTS OF THE NATIONAL CABLE & TELECOMMUNICATIONS ASSOCIATION

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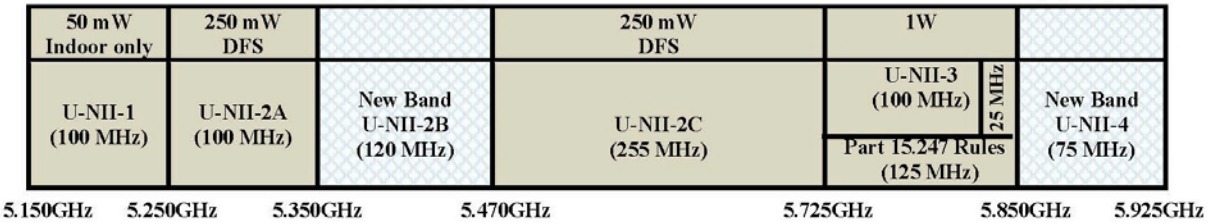
I. INTRODUCTION AND SUMMARY.

The cable industry has invested heavily in the development of expansive Wi-Fi networks across the country. These networks allow subscribers to access fast and reliable Internet connections indoors and outdoors even when away from their home or office, advancing the Commission's broadband access goals. Cable operators' Wi-Fi access points, as well as the Wi-Fi hotspots many cable broadband Internet customers use in their homes today, rely exclusively on unlicensed spectrum. But the remarkable growth of Wi-Fi consumer demand is beginning to overwhelm existing unlicensed spectrum designations—the 2.4 GHz band is already saturated in many locations. Additionally, the next-generation 802.11ac standard can deliver "gigabit Wi-Fi" services to American consumers. But gigabit Wi-Fi needs channel sizes that are not possible for use in networks like those operated by cable companies because of the rules the Commission imposes on the 5 GHz band. This means that the Commission must act now to address an unlicensed spectrum challenge that grows every day.

NCTA therefore strongly supports the Commission's *NPRM*, which proposes to designate two additional unlicensed spectrum bands and to adjust the technical rules in the

existing 5 GHz Unlicensed National Information Infrastructure (U-NII) bands.[1] We agree that "[w]ireless broadband services are in high demand by the public"[2] and "that an increase in capacity gained from 195 megahertz of additional spectrum [in the 5 GHz band] . . . would continue to foster the development of new and innovative unlicensed devices, and increase wireless broadband access and investment."[3]



NCTA recommends that the Commission use this proceeding to promote wireless broadband in the 5 GHz band in four ways. *First*, the Commission should harmonize the rules for the U-NII-1 band with the rules for the U-NII-3 band by adopting a maximum transmit power limit of 1 W and eliminating the indoor-only use restriction for U-NII-1. *Second*, the Commission should apply the U-NII-3 rules to the new U-NII-4 band. *Third*, the Commission should revise Dynamic Frequency Selection (DFS) requirements in the U-NII-2 bands as necessary to protect incumbent government users, but should not expand DFS to any additional bands because of the high cost and significant operational restrictions this requirement imposes on consumers and networks. *Fourth*, the Commission should protect incumbent government operations by adopting reasonable equipment certification rules to prevent unauthorized changes

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1 *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, 28 FCC Rcd 1769, 1770, ¶¶ 1-2 (2013) (*NPRM*).

2 *Id.* at 1774, ¶ 15.

3 *Id.* at 1770, ¶ 2.

to the certified operating parameters for U-NII devices, and by providing manufacturers with a reasonable time period to comply.

By making these changes, the Commission can best advance its goal of ensuring that the U-NII bands realize their "significant promise for helping to accommodate the needs of businesses and consumers for fixed and mobile broadband communications."[4] But there is no time to waste—delay will lead to real and sustained consumer disruption in light of accelerating 2.4 GHz band exhaustion. Furthermore, the Commission must act before formal adoption of the 802.11ac standard next year so that the United States has a band plan in place that allows it to remain a world leader in deploying cutting edge Wi-Fi technologies for businesses and consumers.

II. CABLE WI-FI NETWORKS ARE AN IMPORTANT NEW CONTRIBUTION TO THE NATIONAL ECONOMY AND DEPEND ON ACCESS TO UNLICENSED SPECTRUM RESOURCES.

The unlicensed wireless sector is central to U.S. economic growth and innovation. Recent studies calculate the annual contribution of the unlicensed wireless sector to be between $50 and $100 billion per year.[5] A new and growing contribution to this robust unlicensed sector comes from the cable industry, which is now investing heavily in Wi-Fi network deployments. In less than two years, cable operators have deployed more than 150,000 Wi-Fi access points throughout the country in both urban and rural areas, and more access points are being deployed every day.

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[4] *Id.* at 1774, ¶ 15.

[5] *See* Mark Cooper, *Efficiency Gains and Consumer Benefits of Unlicensed Access to the Public Airwaves* at 21-24 & Ex. IV-2 (Jan. 2012). Other studies have estimated the global economic impact from connected devices (the majority of which will use unlicensed spectrum) will reach $4.5 trillion by 2020. *See generally* GSMA, *The Connected Life: A USD 4.5 Trillion Global Impact in 2020* (Feb. 2012), *available at* http://connectedlife.gsma.com/wp-content/uploads/2012/02/Global_Impact_2012.pdf.

Cable operators have devoted hundreds of millions of dollars to develop Wi-Fi metropolitan networks (metronets). Metronets provide subscribers with broadband access not only inside the home, but also outside the home and while traveling.[6] Metronets use thousands of deployed wireless access points to provide substantial coverage throughout a metropolitan area. These network deployments rely exclusively on unlicensed spectrum bands, including, increasingly, the 5 GHz band.[7] Given access to sufficient unlicensed spectrum resources, these important new Wi-Fi networks promise several significant public interest benefits: (1) providing millions of consumers with fast, reliable Internet access, inside and outside the home; (2) permitting consumers to manage their wireless 3G/4G data plan usage by relying on Wi-Fi as a supplement to licensed networks; and (3) helping to alleviate overburdened cellular networks as consumers elect to offload more and more of their traffic to Wi-Fi.[8]

Several cable companies have made large investments in bringing these new networks to consumers. For example, Cablevision has deployed 80,000 unlicensed access points in retail and commercial establishments, convention centers, along the streets, and in areas where the public gathers outdoors in its New York, New Jersey, and Connecticut footprint, and makes its Wi-Fi

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[6] Comments of Robert Cerbone, Vice President, Wireless Products, Time Warner Cable, at Center for Internet and Society at Stanford Law School, "The Power and Potential of the Unlicensed Economy" (July 11, 2012), *available at* http://stanfordvideo.stanford.edu/stream/saapanel.html (Stanford Unlicensed Economy Conference).

[7] *Id.*

[8] *NPRM*, 28 FCC Rcd at 1773, ¶ 11, n.18; *Visual Networking Index Mobile Forecast Highlights, 2012-2017*, United States – Network Connections, CISCO SYSTEMS, http://www.cisco.com/web/solutions/sp/vni/vni_mobile_forecast_highlight/index.html (last visited Apr. 23, 2013) (filter by country to obtain information for the United States and select Network Connections, Offload Traffic). Cisco's VNI Mobile Forecast states that 47 percent of U.S. mobile traffic was offloaded to fixed networks through Wi-Fi and other technologies in 2012. Cisco predicts that this number will only continue to grow, reaching 66 percent by 2017.

service available to subscribers for no extra charge.[9] Comcast currently makes its Xfinity WiFi service available to qualifying high-speed Internet subscribers for no extra charge at more than 50,000 access points in Atlanta, Baltimore, Boston, Chicago, Philadelphia, Pittsburgh, San Francisco, and Washington, D.C., and has plans to expand throughout its footprint in 2013.[10] Time Warner Cable has deployed more than 15,000 access points in several of its markets, a substantial number of which comprise a very large and growing unlicensed Wi-Fi network in Los Angeles, and it has plans to more than double its Wi-Fi network coverage in 2013.[11] Bright House Networks has made more than 16,000 Wi-Fi access points available to Internet users throughout its footprint, primarily in central Florida.[12] Cox Communications recently launched a network of more than 1,400 Wi-Fi access points for its Northern Virginia and Connecticut customers.[13] Finally, smaller cable operators like BendBroadband in central Oregon have begun to deploy Wi-Fi access points in more rural areas.

In addition to individual cable companies' Wi-Fi platforms, five cable providers have teamed up to provide reciprocal wireless broadband access for each other's subscribers. In May 2012, Bright House Networks, Cablevision, Comcast, Cox, and Time Warner Cable announced a

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[9] *See* Free WiFi, OPTIMUM ONLINE, http://www.optimum.com/home-internet-service/wifi-service.jsp (last visited Apr. 30, 2013).

[10] *See* Find a Hotspot, XFINITY, http://hotspots.wifi.comcast.com/ (last visited Apr. 30, 2013).

[11] Jeff Baumgartner, *TW Cable to Double Down on Wi-Fi in 2013*, LIGHT READING (Feb. 1, 2013), *available at* www.lightreading.com/carrier-wifi/tw-cable-to-double-down-on--wifi-in-2013/240147626.

[12] *Cf. WiFi Available: Stay Connected at Work and Play!*, HOUSE 2 HOUSE BLOG (Jan. 12, 2012), http://house2house.brighthouse.com/wifi-available-stay-connected-at-work-and-play/; Bright House Networks Wi-Fi, *Take your High Speed Internet With You*, BRIGHT HOUSE NETWORKS, http://brighthouse.com/central-florida/shop/internet/wifi (last visited Apr. 23, 2013).

[13] *Cox WiFi Launches in Northern Virginia and Connecticut*, COX COMMUNICATIONS (Jan. 31, 2013), *available at* http://cox.mediaroom.com/index.php?s=43&item=649.

platform called CableWiFi®[14] that enables any of the five companies' qualified subscribers to connect to the other providers' Wi-Fi networks for no additional charge. CableWiFi© is now available in many major metropolitan areas, including Atlanta, Baltimore, Boston, Charlotte, Chicago, Kansas City, Los Angeles, New York City, Orlando, Philadelphia, Pittsburgh, San Francisco, Tampa, and Washington, D.C. To use CableWiFi®, subscribers connect to the CableWiFi® Service Set Identifier (SSID), select their home service provider, and sign in with their home service provider credentials. The service then functions just as though customers were connecting in their home market. In addition, non-subscribers can currently use the CableWiFi® service for a fee. Collectively, the cable industry provides connections to over 150,000 access points nationwide, with more deployments planned over the coming months, making CableWiFi® one of the largest Wi-Fi networks in the world.[15]

Americans rely on cable companies' Wi-Fi networks not only for everyday business, education, and entertainment purposes, but also in emergencies, where Wi-Fi networks play an increasingly important role. Natural disasters can have a devastating impact on communications networks at a time when communications are critical. Wi-Fi networks have become a powerful tool in recovery efforts because of their survivability and interoperability. These networks rely on widely distributed small cells which can each operate independently, making them resilient in the face of natural disasters. In addition, Wi-Fi allows exceptional interoperability, permitting any user with a Wi-Fi capable device to connect to any access point on a carrier-agnostic basis.

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[14] CABLE WI-FI®, http://www.cablewifi.com/ (last visited May 9, 2013); Comments of Robert Cerbone, Vice President, Wireless Products, Time Warner Cable, at Stanford Unlicensed Economy Conference; Chenda Ngak, *Time Warner, Comcast, Cablevision to Offer Free Wi-Fi Hotspots*, CBSNEWS.COM (May 22, 2012), *available at* http://www.cbsnews.com/8301-501465_162-57439268-501465/time-warner comcastcablevision-to-offer-free-wi-fi-hotspots/.

[15] *See* CABLE WI-FI®, http://www.cablewifi.com/, *supra* note 14.

After Hurricane Sandy, these characteristics enabled hundreds of Wi-Fi hotspots to remain operational and provide critical communications access while carriers worked to repair cellular systems.

III. SPECTRUM IN THE 5 GHZ BAND IS CRITICAL TO UNLICENSED USERS.

As Wi-Fi-enabled devices such as smartphones, tablets, laptops, and portable media players become ubiquitous, providers of Wi-Fi networks such as the cable networks described above need more unlicensed spectrum to accommodate the traffic that results from growing demand. Although the Wi-Fi industry primarily has used the 2.4 GHz band in the past, many device manufacturers and service providers are turning to the 5 GHz band to meet growing demand as the 2.4 GHz band reaches exhaustion. The 5 GHz band is particularly attractive for new Wi-Fi deployments because it provides a large amount of unlicensed spectrum, is compatible with existing Wi-Fi standards, and because 5 GHz capability is already built into many consumer devices used worldwide. In addition, the next-generation Wi-Fi standard—IEEE 802.11ac—is built exclusively for the 5 GHz band and will rely on wide channels that can only be achieved in the 5 GHz band to deliver gigabit Wi-Fi.

A. Use of Unlicensed Technologies Is Growing Rapidly and the Core 2.4 GHz Band Is Quickly Becoming Saturated.

The Commission's forward-looking decisions to create unlicensed designations produced today's unlicensed success story. Innovators today develop and deploy thousands of new unlicensed devices every year. Consumer demand for these new devices has skyrocketed, with Wi-Fi-enabled devices at the forefront of the market. Growth of Wi-Fi device sales has

increased by double digits in recent years, with growth in 2011 estimated to be between 25 and 30 percent—exceptional performance in an otherwise difficult economy.[16]

This increase in Wi-Fi device deployment creates a corresponding increase in Wi-Fi traffic. Wi-Fi today accounts for an estimated 80 percent of all traffic from smartphones, tablets, and other consumer electronics.[17] In the United States, more data is carried over Wi-Fi than any other Internet source,[18] and Cisco's Visual Networking Index estimates that today's already enormous Wi-Fi traffic figures will grow by approximately 2.5 times between 2011 and 2015.[19] Wi-Fi has been so successful, in fact, that existing spectrum designated for unlicensed use is becoming increasingly congested—a trend that will only continue. Indeed, the 2.4 GHz band, the primary band used for Wi-Fi, is already reaching exhaustion in larger, high-penetration markets.[20] Assuming a Wi-Fi penetration rate of 60 percent in 2011, and a growth rate of 165 percent (adjusted downward for efficiency gains), a recent study suggests that Wi-Fi spectrum at 2.4 GHz will be exhausted by the end of 2014.[21] Spectrum exhaust will mean reduced Wi-Fi

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[16] Comments of Edgar Figueroa, CEO, Wi-Fi Alliance, at Stanford Unlicensed Economy Conference.

[17] Cooper, *supra* note 5, at 13.

[18] John Solit, *How Much Traffic Does Wi-Fi Carry in America?*, NTCA CABLETECHTALK (Feb. 8, 2013), *available at* http://www.cabletechtalk.com/broadband-internet/broadband/question-how-much-data-is-carried-over-wi-fi/.

[19] Rob Alderfer, *WiFi Spectrum: Exhaust Looms*, CABLELABS at 7 (May 2013) (citing *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011-2016*, CISCO) (included as Attachment A).

[20] *See id.* at 12, 15-16. Several FCC Commissioners have also recognized the Wi-Fi spectrum overload problem. *See NPRM*, 28 FCC Rcd at 1818 (Statement of Chairman Julius Genachowski),1820-21 (Statement of Commissioner Robert McDowell), 1822 (Statement of Commissioner Mignon Clyburn), 1823 (Statement of Commissioner Jessica Rosenworcel).

[21] Alderfer, *supra* note 19 at 9, 11-12.

performance for consumers in terms of coverage and speed.[22] As former Chairman Genachowski has recognized, everyone experiences the detrimental effects of spectrum exhaust in crowded areas of dense use.[23]

Anticipating the looming exhaustion of the 2.4 GHz band, Wi-Fi network providers have turned to the 5 GHz band, particularly in areas of high user density. The 5 GHz band will continue to grow in importance as end users and network operators suffer the effects of 2.4 GHz exhaust.

B. The 5 GHz Band Holds Great Promise for the Continued Deployment of Cable Wi-Fi.

Cable companies have reacted to congestion at 2.4 GHz by turning to the 5 GHz band because in many respects the 5 GHz band is well suited for Wi-Fi network deployment.

First, Wi-Fi operations in the 5 GHz band use existing IEEE 802.11 standards (802.11a, 802.11n).[24] As a result, the band is already well-positioned to accommodate the development of Wi-Fi networks and already uses current standards that will allow easy implementation.

Second, manufacturers build 5 GHz Wi-Fi capability into base stations, laptops, smartphones, tablets, and other unlicensed devices today.[25] Millions of consumers worldwide are able to access 5 GHz Wi-Fi networks using equipment they already own. This will empower manufacturers to quickly implement rule changes so that consumers benefit from additional 5 GHz spectrum rapidly after the Commission makes it available.

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[22] *Id.* at 12.

[23] *FCC Chairman Julius Genachowski Announces Major Effort to Increase Wi-Fi Speeds and Alleviate Wi-Fi Congestion at Airports, Convention Centers, and in Homes with Multiple Devices and Users*, FCC Press Release (Jan. 9, 2013); *NPRM*, 28 FCC Rcd at 1818 (Statement of Chairman Julius Genachowski).

[24] *NPRM*, 28 FCC Rcd at 1775, ¶ 18.

[25] *See, e.g.*, Alderfer, *supra* note 19, at 6-7.

Third, much of the 5 GHz band is harmonized internationally, with many countries permitting unlicensed use in the band.[26] This allows equipment makers and network operators to take advantage of economies of scale and scope as they produce and market their products worldwide.[27] Indeed, European regulators are similarly considering making additional spectrum available for Wi-Fi in the 5 GHz band.[28]

Fourth, the 5 GHz band provides a substantial amount of spectrum for unlicensed use. As a point of comparison, the 2.4 GHz band offers 83.5 megahertz of unlicensed spectrum, while the portion of the 5 GHz band that is currently available and practically usable for cable Wi-Fi networks is 100 megahertz (the U-NII-3 band).[29] Another 200 megahertz in the 5 GHz band would become available for cable Wi-Fi networks if the Commission adopted the rule changes proposed in the *NPRM* that are discussed below. In order for the 5 GHz band to continue to promote innovation and to accommodate increased demand, Wi-Fi network providers need

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[26] *See* Cisco High Density Wireless LAN Design Guide, CISCO at App'x A, *available at* http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps10981/design_guide_c07-693245_ps11983_Products_White_Paper.html#wp9001467 (showing countries where various 5 GHz frequencies are available for Wi-Fi use).

[27] *NPRM*, 28 FCC Rcd at 1770-71, ¶ 4.

[28] *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Promoting the Shared Use of Radio Spectrum Resources in the Internal Market*, 52012DC0478 (Sept. 3, 2012), *available at* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52012DC0478:EN:NOT (proposing, "[d]epending on the outcome of technical sharing studies and of the impact in the market, considering the designation of additional harmonised licence-exempt spectrum for RLAN services (Wi-Fi) at 5 GHz through a revision of Decision 2005/513/EC").

[29] Currently, cable operators predominantly use 100 megahertz of the band for Wi-Fi because of the Commission's rules, which create a patchwork of indoor-only restrictions, low power levels, and DFS requirements in different portions of the band. *See* 47 C.F.R. §§ 15.401-07. This makes deployments in those other portions of the band highly impractical. *See* Alderfer, *supra* note 19 at 16-17.

access not just to more unlicensed spectrum, but to more spectrum governed by operating rules that will accommodate efficient and effective wireless broadband deployments.

C. The 5 GHz Band Has Become Even More Important for Cable Wi-Fi with the Adoption of the New IEEE 802.11ac "Gigabit Wi-Fi" Standard.

As the Commission recognized in the *NPRM*, the new IEEE 802.11ac standard for Wi-Fi is now being developed worldwide, and will be finalized by February 2014.[30] This next-generation standard will "allow for a significant increase in bandwidth and data rates in the 5 GHz band."[31] Cable companies would like to make new 802.11ac technologies broadly available to bring gigabit Wi-Fi to businesses and consumers soon after the new standard is finalized.

The 802.11ac standard will enable providers to deploy networks using more advanced modulation and coding schemes, which will permit devices to operate more efficiently.[32] In addition, the 802.11ac standard enables use of wider channels than older Wi-Fi standards,[33] which will mean an increase in raw throughput capacity. The higher throughput capacity, in turn, should lead to shorter transmission times (and therefore higher Wi-Fi air interface capacity), lower battery consumption on Wi-Fi devices, and better overall customer experiences.[34]

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[30] *NPRM*, 28 FCC Rcd. at 1775, ¶ 18 (citing OFFICIAL IEEE 802.11 WORKING GROUP PROJECT TIMELINES – 2013-03-22, http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm (IEEE 802.11 Project Timelines)).

[31] *Id.*

[32] *802.11ac: The Fifth Generation of Wi-Fi*, Technical White Paper, CISCO at 3 (Aug. 2012), *available at* http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.pdf (Cisco 802.11ac Paper).

[33] *Id.*

[34] *Id.*

The new standard will be particularly useful for enabling high-bandwidth applications like HD video streaming and real-time data backup, and will be very effective for Wi-Fi network deployments in outdoor, user-dense environments, including stadiums and arenas, as it will support larger numbers of users at higher speeds.[35] As discussed below, however, many of the key benefits of the 802.11ac standard depend on access to 80 or 160 megahertz channels, and delivery of gigabit throughput is possible only with 160 megahertz channels. Under the Commission's rules as they stand today, existing unlicensed designations do not provide cable operators a practical option to use channels of this size, particularly because of rules that limit outdoor operation and mandate unreasonably low power levels. The Commission therefore can facilitate the utility of the 5 GHz band for these types of applications by: (1) increasing the power limits and removing the indoor use restriction in U-NII-1, which will produce at least one additional 80 megahertz 802.11ac channel that can be used for outdoor access points as well as for more challenging indoor environments; and (2) adding a new U-NII-4 band with rules that match the U-NII-3 band, thereby producing a full 160 megahertz contiguous 802.11ac channel.

IV. THE COMMISSION SHOULD ADOPT NEW RULES FOR THE 5 GHZ BAND THAT ADVANCE INNOVATION AND PROMOTE BROADBAND AVAILABILITY BY OPTIMIZING THE BAND FOR UNLICENSED USE.

The Commission has a historic opportunity in this proceeding to more than ***triple*** the amount of usable spectrum for Wi-Fi in the 5 GHz band.[36] In order to promote the broadest possible opportunities for innovation and maximize the availability of broadband in this

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[35] *Id.* at 4.

[36] The Commission states that this proceeding could provide up to 35 percent more 5 GHz spectrum for unlicensed use. *NPRM*, 28 FCC Rcd at 1770, ¶ 2. However, because much of the 555 MHz of spectrum currently labeled as available for unlicensed use is, in fact, not suitable for most Wi-Fi deployments, NCTA estimates that favorable changes to the U-NII-1 rules and the addition of U-NII-4 could triple the amount of usable unlicensed spectrum currently available to Wi-Fi network providers in the 5 GHz band at U-NII-3.

proceeding, the Commission should: (1) harmonize the rules for the U-NII-1 band with the rules for the U-NII-3 band by increasing the maximum allowed power to 1 W, removing the indoor-use restriction, and declining to impose a DFS requirement; (2) harmonize the rules for the new U-NII-4 band with the rules for U-NII-3; (3) limit the use of DFS to the U-NII-2 bands, making changes to DFS in the U-NII-2 bands where necessary to protect government incumbents; and (4) adopt reasonable changes to the equipment certification rules to protect government incumbents and allow a reasonable period of time for manufacturers to adapt to those rules.

The Commission should move forward expeditiously to adopt these recommendations and make more unlicensed spectrum available for wireless broadband use, including, if necessary, by adopting rules for some portions of the band while continuing to work on more challenging segments. The Commission should also ensure that the U.S. positions adopted for World Radiocommunications Conference 2015 promote robust unlicensed operations in the 5 GHz band.

A. The Commission Should Coordinate U-NII-1 and U-NII-3 Rules.

As mentioned above, cable companies overwhelmingly use the U-NII-3 band for Wi-Fi network deployment at 5 GHz. The current low (50 mW) power limit and indoor-use restriction in the U-NII-1 band renders it all but unusable for many Wi-Fi operations and entirely unsuitable for outdoor deployments. These rules force cable companies to disregard the entire U-NII-1 band. Accordingly, NCTA welcomes the Commission's proposal to modify the rules for the U-NII-1 band to harmonize them with the rules for the U-NII-3 band.[37]

Harmonizing the rules for the U-NII-1 and U-NII-3 bands will provide several important benefits for consumers. First, doing so will enable service providers to offer 160 megahertz

[37] *Id.* at 1781-82, ¶ 39.

802.11ac Wi-Fi channels (80+80 megahertz) through a process known as channel bonding. Specifically, operators could use a new non-contiguous 160 megahertz channel comprising 80 megahertz of spectrum at U-NII-1 and 80 megahertz of spectrum at U-NII-3. Non-contiguous bonded 801.11ac channels are not as efficient as a single 160 megahertz contiguous channel,[38] but this bonded-channel strategy would better benefit consumers by increasing broadband capacity beyond that available under the current 5 GHz options. Adopting higher power and enabling outdoor use of U-NII-1 conceivably would also allow providers to use a contiguous 160 megahertz channel spanning U-NII-1 and U-NII-2A. However, Commission rules would require operators to limit operations on such a channel to U-NII-2A's 250 mW power level and to use DFS,[39] making this channel useful for only a subset of applications.

Second, increasing the transmit power limit in U-NII-1 is very important for unlicensed operations because higher power results in improved range, coverage, and/or better throughput. Wi-Fi operations at 5 GHz are already difficult indoors because of the relatively poor propagation characteristics of the band. The higher frequencies at 5 GHz, as compared with 2.4 GHz, mean less range and increased signal loss attributable to walls and other building materials.[40] This is one of the primary reasons that most cable operators use the U-NII-3 band,

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[38] Cisco 802.11ac Paper at 14.

[39] FCC, Office of Engineering and Tech. Laboratory Division, *Guidance for IEEE 802.11ac and Pre-ac Device Emissions Testing* at 3 (Apr. 8, 2013) (*OET Guidance*) (noting that "[a]ll operational requirements for each band of operation must be satisfied"); *NPRM*, 28 FCC Rcd at 1784, ¶ 46 ("When devices are designed to operate across multiple frequency bands, the Commission's rules require that applicants demonstrate compliance with the rules for each of the individual frequency bands in which they intend to operate in order to be certified for operation in each band.").

[40] *See Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range*, ET Docket No. 96-102, RM-8648, RM-8653, Report and Order, 12 FCC Rcd 1576, 1590, ¶ 31 (1997) (*1997 U-NII Order*) (stating that signals at higher frequencies "have propagation constraints that will reduce the communication

which permits a maximum allowed power level of 1 W. A higher power limit would make the U-NII-1 band much more useful for both indoor and outdoor operations. It would enable whole-home indoor usage of the band because it would permit better penetration of building materials.[41] In addition, because higher power provides for operation at greater distances and in more locations, network providers can deploy fewer access points to cover indoor or outdoor areas, resulting in better coverage and the promotion of investment by reducing the cost of network builds.

Although many handheld devices transmit at power levels lower than 1 W because of power management and RF exposure considerations, users still greatly benefit from higher power base stations. A higher powered transmit signal improves signal quality, particularly in noisy and interference-laden environments, even when the user has a lower power client device. Importantly, most handheld device data use occurs in the downlink. In other words, users generally download much more information than they upload. Therefore, increasing transmit power results in higher throughput and a better user experience even in cases when the user's device does not transmit at the band's maximum power limit.

Third, the Commission should remove the U-NII-1 indoor use restriction. Doing so will facilitate the development of the outdoor access points critical to the success of cable Wi-Fi

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distances of devices operating at equal powers"); *cf. Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, Notice of Proposed Rulemaking and Order, 27 FCC Rcd 15594, 15601-02, ¶ 19 (2012) (noting with respect to the 3.5 GHz band that "[a]ll other things being equal under the free space line of sight condition, a signal propagating at 3.5 GHz would be expected to decay faster than a signal in lower frequency bands" and that "range limitations would be even greater in attenuated environments, where higher frequency signals are less prone to penetrate building materials").

[41] *1997 U-NII Order*, 12 FCC Rcd at 1594-95, ¶ 42 (noting that increasing U-NII device power limits above 100 mW will enable a larger variety of operations).

networks. NCTA agrees with the Commission that the "wireless device market has changed dramatically" since it established the rules for the U-NII-1 band in 1997, and that assumptions about wireless use, including that devices operate exclusively "within localized indoor settings[,] . . . . may not be valid for today's market."[42] Today, "devices . . . are increasingly mobile or portable in nature, not easily limited to indoor locations, and often need[] more power to link with other networks at farther locations."[43] The U-NII-1 band rules should reflect these realities.

The Commission should move forward expeditiously with these changes—adopting U-NII-1 rules that promote growth and investment will help to address the growing unlicensed spectrum challenge almost instantly because consumer devices can already use the U-NII-1 band today. In February, NTIA sent a letter to the Commission suggesting that the U-NII-1 band might eventually be used to relocate federal aeronautical mobile telemetry (AMT) systems from the 1755-1850 MHz band. NTIA "recommend[ed] that the FCC refrain from proposing to change the U-NII rules in the [U-NII-1] band until NTIA and the FCC conclude how they will address the accommodation of the AMT operations currently using the 1755-1850 MHz band."[44] While NTIA and the Commission should continue to coordinate use of the 5 GHz band to ensure protection of incumbent government users, it is unreasonable to delay rule changes that would benefit millions of consumers and enable next-generation Wi-Fi services because of the possibility that a new group of government users may or may not ask Congress for funds to migrate to the U-NII-1 band at some unspecified point in the future.

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[42] *NPRM*, 28 FCC Rcd at 1781, ¶ 37.

[43] *Id*.

[44] Letter from Lawrence E. Strickling, Administrator, NTIA, to Julius Genachowski, Chairman, FCC, at 4 (filed Feb. 19, 2013).

And, in any event, as the Commission is well aware, very few portions of the 5 GHz band are currently free from substantial government operations. This fact alone should make Congress, the Administration, and the Commission reluctant to relocate *additional* government users to a portion of the 5 GHz band that is otherwise well-suited to accommodate robust wireless broadband operations in the near future. As noted above, unlicensed operations are immensely valuable to the U.S. economy, contributing between $50 and $100 billion per year, and the core 2.4 GHz band is rapidly approaching exhaustion. The Commission should not stymie further growth and innovation by deferring important rule changes because of highly uncertain future events, particularly as NTIA has determined that it will take 10 years to repurpose the 1755-1850 MHz band.[45]

B. The Commission Should Coordinate U-NII-3 and U-NII-4 Rules.

NCTA also supports the Commission's proposal to open U-NII-4 for unlicensed use. An additional 75 megahertz of unlicensed spectrum will make an enormous contribution to meeting the growing demand for unlicensed spectrum. Furthermore, cable companies support the Commission's proposal to add the 5.825-5.85 GHz segment to U-NII-3.[46] This action is important both because the 25 megahertz will create additional Wi-Fi spectrum resources for consumers, and because connecting the U-NII-3 and U-NII-4 bands in this way will allow for a contiguous 802.11ac channel that can achieve speeds of up to 1 Gbps.

To ensure that the new U-NII-4 band is as useful for Wi-Fi as the current U-NII-3 band, the Commission should harmonize its technical rules across U-NII-3 and U-NII-4. Accordingly,

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[45] NTIA, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band* at iii (Mar. 2012), *available at* http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.

[46] *NPRM*, 28 FCC Rcd at 1778, ¶ 27.

NCTA supports the Commission's conclusion that "the same framework and technical requirements . . . should apply across the expanded U-NII-3 and U-NII-4 bands."[47] As previously noted, the existing rules for the U-NII-3 band make the band very attractive for Wi-Fi. As a result, cable Wi-Fi networks utilize this portion of the band almost exclusively.

Applying the U-NII-3 rules, including a 1 W maximum allowed power limit for indoor and outdoor operations, to U-NII-4 will make U-NII-4 equally attractive for unlicensed broadband operations. In addition, harmonizing the rules governing the 200 megahertz of spectrum spanning U-NII-3 and U-NII-4 would facilitate the use of contiguous 160 megahertz channels under the new 802.11ac standard. Not only would this open up the possibility for a contiguous 160 megahertz channel spanning U-NII-3 and U-NII-4, but it would also facilitate two new non-contiguous 80+80 megahertz channels—one spanning U-NII-1 and U-NII-3 and one spanning U-NII-1 and U-NII-4—if the Commission also adopts the rule changes that NCTA proposes for U-NII-1.

Importantly, use of the U-NII-3 technical rules in the U-NII-4 band will allow Wi-Fi to co-exist with potential future uses of Intelligent Transportation Systems (ITS) in this band. As NTIA has recognized, there exist a variety of sharing mechanisms that could likely be adopted to address the risk of interference to ITS users in U-NII-4.[48] Cable companies are committed to working to determine the best approach to sharing and stand ready to complete the needed technical work directly with ITS licensees and at IEEE.

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[47] *Id*. at 1798, ¶ 97.

[48] NTIA, *Evaluation of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6406(b) of the Middle Class Tax Relief and Job Creation Act of 2012* at 5-10 to 5-11 (Jan. 2013), *available at* http://www.ntia.doc.gov/files/ntia/publications/ntia_5_ghz_report_01-25-2013.pdf (*NTIA 5 GHz Report*).

It is critical to note, however, that there will never be a better moment to put a sharing mechanism in place—we must not delay. This is the case because today there are no deployed incumbent 5 GHz ITS operations. Although fourteen years have passed since the Commission authorized ITS to use U-NII-4, there is not one commercially available ITS network deployed in the 5 GHz band. In fact, the ITS industry has only recently begun to coalesce around the 802.11p standard, and testing of the technology in a small number of experimental vehicles is still underway. Other bands where the Commission is considering sharing will be far more challenging because they include well-established incumbents with a large embedded base of users and widely deployed technology. Devising sharing mechanisms once an incumbent system is in place is considerably more difficult than will be the case in U-NII-4, where all parties can design and deploy systems with sharing built in from the beginning. This is a perfect band and the perfect time to make the Administration's and Commission's vision of spectrum sharing into a reality.

The Commission should therefore recognize this unique opportunity and act now to permit unlicensed use in the U-NII-4 band with a requirement that unlicensed devices not create harmful interference to ITS devices, just as it has successfully done for incumbents in other unlicensed bands. It is clear that it will be many years before the first ITS-capable commercial vehicles begin to appear on the market, and it will be decades before we know if ITS will ever be widely deployed.[49] Because of the well-recognized need for additional spectrum to support

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[49] *See The Road Ahead: Advanced Vehicle Technology and its Implications: Hearing Before the S. Comm. on Commerce, Science, and Transportation*, 113th Cong. (2013) (statement of the Honorable David L. Strickland, Adm'r, Nat'l Highway Traffic Safety Admin.), *available at* http://www.commerce.senate.gov/public/?a=Files.Serve&File_id=566d5c52-be38-4245-ab44-1ccbf2f198db; Doug Newcomb, *Why Your Next Car Should – and Shouldn't – be a Wi-Fi Hotspot*, POPULAR MECHANICS (Oct. 18, 2012), *available at*

broadband services, the Commission simply cannot allow U-NII-4 to lie fallow for this extended period of time. And even once ITS technology does reach the market, the Commission's commitment to promoting more efficient use of scarce spectrum resources should lead it to permit sharing. Sharing will result in a far more efficient and intensive use of U-NII-4 than could ever be achieved by reserving 75 megahertz for a single specialized service.

C. The Commission Should Not Impose DFS Obligations Outside of the U-NII-2 Bands.

Wi-Fi operators use the U-NII-3 band extensively not only because of its 1 W transmit power, but also because of the absence of a DFS requirement. This is because, as described in greater detail below, DFS imposes three substantial costs on consumers and service providers: (1) "listen-and-avoid" network operations are substantially more complex than traditional operations; (2) the DFS process causes delays and service gaps that undermine consumer broadband use; and (3) consumer devices and network equipment with DFS are more expensive.

First, DFS requires network providers to design and operate far more complicated networks. Network operators must implement mechanisms designed to permit devices to detect and recover from service interruptions that occur when DFS requires a device to vacate a channel. This approach to service monitoring usually requires dedicated hardware. In addition, network operators must closely monitor the rate of DFS false alarms where a device vacates a channel not in use by a protected incumbent because it is unable to distinguish certain types of

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http://www.popularmechanics.com/cars/news/industry/why-your-next-car-should-and-shouldnt-be-a-wi-fi-hotspot-13852868 (quoting an industry analyst explaining that "[t]he reality is that adoption of DSRC technology is at least 10 years away and will require investments that federal and local governments may be unwilling to make, while the resistance of carmakers will also be strong").

interference in the band from protected radar signals. A high rate of DFS false alarms can cause substantial delays for a device to reacquire service.

Second, DFS causes network-acquisition delays and service interruptions for consumers that undermine their ability to use the band for broadband access. Network-acquisition delays occur when a master device with DFS capability denies a consumer access to a band as it works to determine which channels are available. This delay can extend longer than one minute, often causing consumers to abandon their effort to connect because they conclude that there is no available Wi-Fi network. Service interruptions occur in the middle of a consumer broadband session, when a DFS device senses a protected user and acts to vacate the channel. When the device senses a protected user, vacates the channel, and selects a new channel, DFS delays again extend to more than one minute as the device scans for an unoccupied frequency. Such delays are acutely noticeable to the end user—particularly if the user is downloading or streaming content, sending messages or engaging in activities that require near real-time communication, including in an emergency context as described in Part II of these comments, or connecting to corporate networks. As a result, users may simply abandon an attempt to connect to a particular DFS-capable access point.

Third, consumer equipment that incorporates DFS is difficult to bring to market in a timely and affordable way. This is the case because successfully testing and certifying DFS-capable devices entails a more complex process than certifying normal Wi-Fi equipment, requiring manufacturers to expend more resources for design, internal testing, and certification. Manufacturers pass along these costs to their customers, including cable companies that purchase hundreds of thousands of Wi-Fi access points.

For the above reasons, the Commission should limit DFS requirements to the U-NII-2 bands where DFS already exists, and then only in cases where the Commission, working with NTIA, determines that DFS is the only way to protect existing government incumbents using these frequencies intensively. In any event, the Commission should not expand DFS regulations outside of the U-NII-2 band because doing so would render any bands where DFS is imposed unsuitable for the development of widespread consumer Wi-Fi networks like those built by cable companies.

Furthermore, because the 802.11ac standard accommodates 80 and 160 megahertz channels, changes to DFS in one U-NII band will significantly impact the utility of adjacent portions of the band for unlicensed broadband use. For example, unlicensed devices using a 160 megahertz 802.11ac channel that spans U-NII-1 and U-NII-2A will be forced to abide by the "lowest common denominator" of all of the applicable rules, including DFS.[50] This means that an unlicensed device using a 160 megahertz channel spanning U-NII-1 and U-NII-2A would need to abide by DFS requirements although the device would not be required to implement DFS if it operated only in the U-NII-1 band. As the Commission recognizes, it "should strive to provide as much consistency in [its] rules as possible so that wide bandwidth U-NII devices operating across multiple bands are not driven to comply with the most restrictive requirements for any one band and forfeit opportunities for new broadband applications that may be permitted in other bands."[51]

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[50] *OET Guidance* at 3; *NPRM*, 28 FCC Rcd at 1784, ¶ 46.

[51] *NPRM*, 28 FCC Rcd at 1775-76, ¶ 19.

D. The Commission Should Adopt Reasonable Equipment Certification Rules to Prevent Unauthorized Modifications.

The Commission also proposes changes to the U-NII equipment certification rules that would help prevent unauthorized U-NII device modifications.[52] NCTA supports reasonable changes to the rules for equipment certification, but urges the Commission to adopt rules that identify the capabilities the device must have rather than mandating specific technical requirements for those devices. Mandating specific technical requirements can increase the cost to manufacturers to design and build devices, which in turn increases the cost for cable companies that rely on such devices to build out their cable Wi-Fi networks.

NCTA agrees that manufacturers can take measures to prevent DFS from being disabled for devices operating in the U-NII-2 bands, including implementing security features in unlicensed devices that would prevent third parties from reprogramming the device to operate outside the parameters for which the device was certified. In addition, the Commission's rules could restrict end-user access to a device's country codes, because switching to another country code can permit devices to access bands in which they are not certified to operate in the United States. Although many of these measures could be implemented in hardware or software, hardware changes substantially increase the cost to network providers. Software controls, on the other hand, are more cost effective, and Commission rules could require manufacturers to design such an approach to prevent manipulation.

Whether the Commission ultimately adopts a hardware- or software-based approach to resolving the issue of unauthorized modifications, NCTA requests that the Commission's rules specify only the desired end result rather than mandating the specific manner in which these

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[52] *Id*. at 1785, ¶ 51.

features must be incorporated into devices. Manufacturers may wish to incorporate security features in different ways for different devices or may arrive at a particular implementation solution that the Commission has not yet envisioned. The rules ultimately adopted should allow innovation in how best to incorporate the security features necessary to prevent the unauthorized operation of U-NII equipment.

The Commission has also proposed a twelve-month transition period for manufacturers to produce devices that comply with new or modified rules and to obtain equipment certification, with a grandfathering provision to permit the continued operation of U-NII devices already installed or in use.[53] So long as the Commission adopts its proposal to grandfather in existing U-NII devices and does not require the exchange of existing units, twelve months should provide sufficient time for manufacturers to design and build new equipment. This short transition period, however, would not provide sufficient time to obtain certification for the new equipment as well. NCTA therefore recommends extending the transition period to eighteen months if the transition period will include certification. In addition, if the Commission does not permit the continued operation of U-NII devices currently in use and requires manufacturers to provide replacements for these devices, the Commission should provide a three-year transition period.

V. THE COMMISSION SHOULD MOVE FORWARD AS QUICKLY AS POSSIBLE TO MAKE MORE UNLICENSED SPECTRUM AVAILABLE IN THE 5 GHZ BAND.

The Commission can best address the unlicensed spectrum challenge and promote innovative investments like cable Wi-Fi networks by moving expeditiously to adopt final rules in this proceeding. Wi-Fi network providers need access to more spectrum and updated technical

[53] *Id*. at 1803, ¶¶ 114-15.

rules as soon as possible to help ease congestion on already busy networks and to encourage the deployment of 802.11ac-ready devices.

NTIA's *5 GHz Report* suggests that it will take almost two years for NTIA to conduct its analysis of how commercial users can share the 5 GHz band with federal users.[54] The Commission and NTIA should accelerate this process. Within two years the 2.4 GHz band will be exhausted in many parts of the country.[55] The Commission must find a viable alternative to the 2.4 GHz band before this occurs. Furthermore, by early 2014, the IEEE Standards Committee anticipates that the 802.11ac standard will be ready for use and manufacturers anticipate that they will be offering equipment to enable its rapid adoption.[56] These devices will need access to the additional spectrum the Commission proposes to provide in the 5 GHz band to fully realize the benefits of 802.11ac's wider channels. Moreover, manufacturers and network operators need final rules for the 5 GHz band as quickly as possible to design, develop, and obtain equipment authorization for these new devices. The Commission should encourage investment in and development of 802.11ac-capable equipment by moving rapidly to provide more unlicensed spectrum in the 5 GHz band. If the Commission delays action in this proceeding by two years the United States will not have a single 160 megahertz 802.11ac channel available for outdoor use, a result that is clearly unacceptable.

Therefore, if the Commission determines that it can resolve questions with respect to some portions of the band more quickly, it should move forward with new rules for those portions while it continues to work on more challenging areas of the band. The Commission

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[54] *NTIA 5 GHz Report* at 6-4.

[55] Alderfer, *supra* note 19, at 12, 16.

[56] *See* IEEE 802.11 Project Timelines.

need not resolve every spectrum-sharing question with respect to every portion of the band before making certain portions available for unlicensed use. The Commission should approve rule changes in U-NII-1, and/or open U-NII-4 for unlicensed use, while it works with NTIA on the complex question of updating DFS. This would provide important additional spectrum to consumers and network operators struggling with congestion in the 2.4 GHz band.[57]

VI. CONCLUSION.

Wi-Fi has become the single most important tool for consumer broadband access. Usage is skyrocketing and innovators produce thousands of new Wi-Fi-enabled technologies each year. Cable companies are working hard to meet customer demand by investing in large Wi-Fi networks across the country. But with the core 2.4 GHz band at its saturation point in many communities, and the emergence of a new gigabit Wi-Fi standard that requires larger channels than those available today, we are facing an unlicensed spectrum challenge.

The Commission's proposal to designate two new 5 GHz bands and to update its rules for existing 5 GHz bands is the best hope for meeting this challenge. NCTA therefore recommends that the Commission adopt rules to: (1) harmonize the U-NII-1 and U-NII-3 bands; (2) harmonize the U-NII-3 and new U-NII-4 bands; (3) limit DFS requirements to the U-NII-2 bands; and (4) protect government operations by adopting stricter equipment certification rules that prevent unauthorized changes to the certified operating parameters for U-NII devices. But there is no time to delay. If the Commission does not act quickly, the unlicensed spectrum challenge will become a crisis.

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[57] *See* Alderfer, *supra* note 19, at 17.

Respectfully submitted,

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Attachment A

WiFi Spectrum: Exhaust Looms

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May 28, 2013

Abstract

The release of additional wireless spectrum for WiFi use is currently being debated at the FCC and in Congress. Economic literature supports substantial benefits associated with WiFi spectrum. This paper investigates the need for additional WiFi spectrum by modeling key technology trends over a five year period, with a primary focus on the 2.4 GHz band. In so doing, the analysis reveals a looming WiFi spectrum shortage. This finding adds urgency to the current policy discussion.

About the Author

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1 Executive Summary

This paper adds context to the current spectrum policy debate by providing a quantitative forecast of WiFi capacity and spectrum needs. The goal is not to provide a specific, determinative WiFi capacity estimate, but rather to provide a directional indication of how technology development and growing usage impacts WiFi spectrum needs.

Using known trends, we find that WiFi spectrum is likely to be exhausted in the near-term, and that this will negatively impact WiFi performance for consumers. Given that WiFi is nearly ubiquitous in connected devices, and that the wireless broadband ecosystem as a whole is dependent on WiFi connectivity, this result would hinder the nation's broadband goals.

We develop our forecast through a growth multiple methodology, using a limited number of factors that influence WiFi capacity, thus enhancing transparency and avoiding arbitrary precision. By using conservative values for each factor, we are careful not to overstate the risk of WiFi spectrum exhaust.

Our primary model focuses on the 2.4 GHz WiFi spectrum band, as it is the band used by most devices today. Accounting for WiFi data traffic growth, as well as growth of network density and gains in technology efficiency, we estimate that WiFi capacity needs in 2015 will be approximately 1.65 times the 2011 level, which serves as the baseline year of our forecast. Applying this multiple to the estimated baseline amount of spectrum in use enables us to forecast the spectrum needed by the end of our forecast period. We use a baseline spectrum utilization assumption based on WiFi penetration, which leads us to conclude that the 2.4 GHz band will likely reach exhaustion by 2014.

We recognize that alternative assumption sets may be valid, and we explore their effect. For example, the data we use represents national averages, but in some markets spectrum utilization may be higher or lower. Limited testing of WiFi performance in Manhattan indicates that current spectrum utilization is higher than assumed in our primary model, and that spectrum exhaust can be observed today in dense markets.

In addition, we explore how the 5 GHz WiFi band may impact capacity, and observe that it is different from 2.4 GHz in many material respects. Poorer propagation and greater regulatory limitations, among other things, complicate its use and its inclusion in our model. For completeness, however, we incorporate the 5.8 GHz portion of the band into our view of spectrum exhaust, and account for technology differences that are likely to accelerate spectrum consumption, as well as propagation limitations that may affect utility, relative to 2.4 GHz.

While these and other adjustments may impact the specific numerical estimates of WiFi spectrum capacity, any reasonable forecast will lead to the conclusion that the need for additional WiFi spectrum is not a matter of "if", but "when". Given the substantial time typically required to make new spectrum available, this finding adds urgency to the current spectrum policy debate.

2 Introduction

"The focus has been on the mobile spectrum crunch. But there is also a WiFi traffic jam. When you see what is going on on the CES exhibit floor, you realize we have to do something about this. WiFi is such an integral part of the ecosystem."[1]

- FCC Chairman Julius Genachowski, 2013 International CES

"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."[2]

- FCC Commissioner Robert McDowell, February 2013

Much has been made of late of the need to free additional spectrum for unlicensed WiFi use. Research shows that such a policy approach will indeed entail significant economic benefits.[3] But how do we know that we *need* additional spectrum for WiFi? After all, a robust ecosystem has flourished in the 2.4 GHz band, and has proven crucial to the rise of wireless broadband in the United States and globally. Isn't it possible that 2.4 GHz will prove sufficient to enable continued growth for some time?

This paper endeavors to examine the technology trends underlying WiFi use to determine the extent of spectrum exhaust, now and in the future. With knowledge of developments in data traffic growth, devices and hotspots, and the effect of new standards, we can quantify WiFi spectrum capacity.

By modeling these factors, the need for additional WiFi spectrum becomes clear. Reasonable debate may exist about the specific inputs to the model described in this paper. However, it is also the case that any reasonable extrapolation of known trends leads to the conclusion that WiFi spectrum exhaust is a matter of "when", not "if". In light of the substantial time typically required to release new spectrum, this finding serves as a guidepost for spectrum policy. In the absence of new WiFi spectrum, it is likely that wireless broadband consumers will experience reduced performance. This poses a risk to continued growth of the wireless broadband ecosystem, a central element of technology and economic policy in the United States.[4]

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[1] Katy Bachman, "FCC to Free Up More WiFi Spectrum", *AdWeek*, January 9, 2013.
[2] "FCC Acts to Significantly Increase Spectrum Available for Unlicensed Devices in the 5 GHz Band", Statement of Commissioner McDowell, February 20, 2013.
[3] See, for example, Milgrom, Levin, and Eliat, "The Case for Unlicensed Spectrum", October 2011; and, Richard Thanki, "The Economic Significance of License-Exempt Spectrum to the Future of the Internet", June 2012.
[4] *Presidential Memorandum: Unleashing the Wireless Broadband Revolution*, June 28, 2010, Office of the Press Secretary, The White House.

3 Method

This paper seeks to quantify the need for additional WiFi spectrum in the United States by modeling known technology trends over a five year period, with a primary focus on the 2.4 GHz band.

To avoid arbitrary precision and enhance transparency, a limited number of factors will inform our model, each known to have a significant impact on wireless capacity. Growth of WiFi traffic is a crucial element of the model, and serves as the basis for the development of a growth multiple over the forecast period. Network density and gains in wireless efficiency will enable us to adjust our "nominal" traffic growth multiple for its "real" effect on WiFi network capacity.

This adjusted growth multiple will then be applied to the amount of spectrum in use today for WiFi. In this manner we can understand the amount of WiFi spectrum that will be required over the forecast period, and compare that to the amount of spectrum available to determine the likely "spectrum deficit". This deficit signals WiFi spectrum exhaust and reduced wireless performance.

Since the amount of spectrum in use today will vary in different areas, the precise timing and effect of the spectrum deficit will also vary. We will approximate a nationwide average, and explore the circumstances in dense markets that can be thought of as on the leading edge of WiFi spectrum exhaust. Due to the availability of data, we will use 2011 as our baseline year for modeling purposes, with forecasts through 2015.

We focus our primary analysis on the 2.4 GHz Industrial Scientific Medical (ISM) band, which serves as the primary band for WiFi services. Other bands are also available for WiFi – most notably the 5 GHz Unlicensed National Information Infrastructure (U-NII) band – but are categorically different in utility, technology, and inherent physical characteristics. Approximately 555 megahertz of spectrum is allocated to WiFi (U-NII) service in the 5 GHz band; however, only 100 megahertz is available on comparable terms to the 2.4 GHz band. New WiFi standards for the 5 GHz band use channel bandwidths that are two to eight times greater than current standards, and 5 GHz propagates approximately one quarter as well as the 2.4 GHz band. We will explore these and other circumstances surrounding 5 GHz in more detail, which add important context to the findings in our primary model of the 2.4 GHz band.

As in any model, outputs are dependent on inputs. One may reasonably debate the specific quantitative values of the inputs in this model of WiFi spectrum exhaust; however, any reasonable set of data will lead to the conclusion that additional WiFi spectrum is required to enable continued growth of wireless broadband.

4 WiFi Traffic Growth

WiFi has proven to be an essential element of the wireless broadband ecosystem. ABI Research estimates that over 1.5 billion WiFi chipsets were shipped in 2012, and WiFi will continue to be one of the fastest growing elements of the wireless market.[5] This is in part a function of integration with smartphones, which now make up

[5] ABI Research, 2011, "Wireless Connectivity Chipsets Revenues to Exceed $10 Billion in 2012, Wi-Fi Chipsets Account for 40% of the Market", September 18, 2012.

more than half of wireless phones in the US[6], nearly all of which come with WiFi capability.[7] But WiFi growth will also come from a much broader product segment, including laptops, tablets, televisions, gaming consoles, cameras, and more.[8] Gartner Research predicts sales of tablets to triple between 2012 and 2016,[9] for example, and nearly 90% of tablet owners opt for WiFi connectivity over mobile.[10]

In light of the substantial growth of WiFi-enabled devices, it is not surprising that the amount of data carried over WiFi networks is also growing. One of the leading forecasts of data traffic is Cisco's Visual Networking Index (VNI). The most recent VNI notes that average data consumption over WiFi is nearly four times that of mobile.[11] Examining the 2011 to 2015 forecast period of our model, Cisco estimates WiFi traffic to grow by approximately 2.5 times[12], as shown in Figure 1.

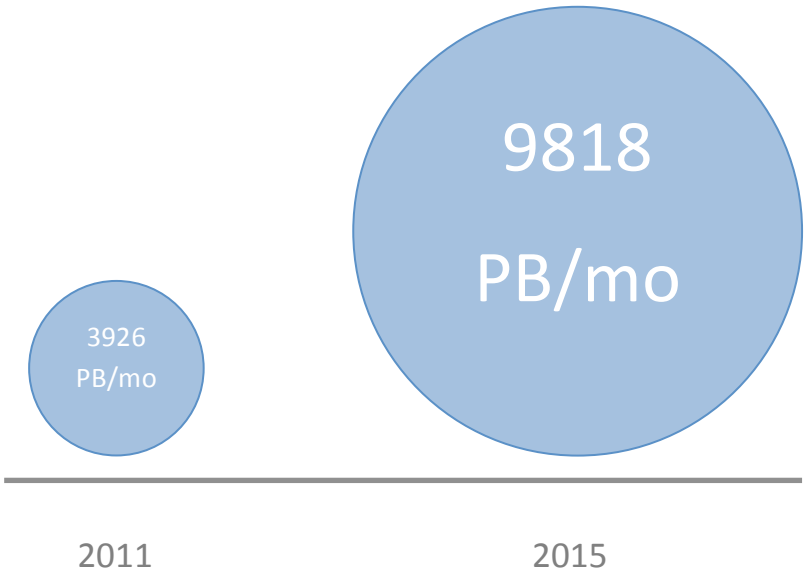

Figure 1: Cisco VNI Forecast of North American WiFi Data Traffic Growth, 2011-2015, in Petabytes per month

Other data points suggest that a 2.5X growth multiple over the 2011-2015 period is within reason. For example, Cisco's 2011 VNI (the year prior to the report used for our model) forecasted global WiFi traffic to grow roughly 3X growth between 2011 and 2015.[13]

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[6] comScore, February 6, 2013 press release, "comScore Reports December 2012 U.S. Smartphone Subscriber Market Share"
[7] Marguerite Reardon, "Can you ditch your smartphone data plan for WiFi?", CNET, November 28, 2012.
[8] ABI Research, 2012.
[9] Gartner Research, 2012, as reported by Matt Hambien, "Smartphones and tablets growth exploding, especially in business, Gartner says", Computerworld, November 6, 2012.
[10] Chetan Sharma Consulting, "US Wireless Market Update, Q42011 and Full Year 2011". Note that mobile-enabled tablets generally also come equipped with WiFi.
[11] Cisco, "Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017", average daily Wi-Fi and mobile data consumption, global figures.
[12] Cisco, "Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011-2016", North American WiFi traffic, offload and fixed. Global WiFi traffic is forecasted by Cisco to grow from 11.5 exabytes per month in 2011 to 37.2 exabytes per month in 2015 (offload and fixed). Similar data cannot be gleaned from Cisco's 2013 VNI data release.
[13] Cisco, "Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015", Global WiFi IP traffic. This forecast implies annual global WiFi traffic growth of approximately 16 Exabytes (average per month) to 48 Exabytes

As usage of data-intensive applications grows, particularly video-based content, it is no surprise that data traffic is poised to more than double in the coming years. This estimate may in fact prove conservative, as mobile services move away from unlimited packages and users increasingly rely on WiFi to serve their online needs while managing their mobile bills.[14]

5 Translating Traffic Growth to WiFi Network Capacity

The amount of data traffic is a key factor in WiFi network capacity, but it is not the only factor. Network density (spectrum re-use) and technology efficiency are also important to understand in judging the ability of WiFi to keep up with robust traffic growth. Our model therefore must account for trends in density and efficiency. In effect, we must quantify how 'nominal' growth in WiFi data traffic translates to 'real' growth, in terms of its effect on WiFi networks. Once this is adjustment is made, we can consider the final crucial element to network capacity: spectrum.

One step that can be taken to mitigate growth in wireless traffic is to grow the density of the network and "re-use" available frequencies. In mobile, this is known as cell splitting, and is an important principle in the development of heterogeneous networks and small cells.[15] The benefit of this approach is to have fewer users on the same frequencies within a single cell, thus enabling better network performance.

Similarly, it is possible to add more WiFi access points to re-use the 2.4 GHz band on a spatial basis. In fact, the Wireless Broadband Alliance forecasts that hotspots will nearly double by 2015.[16] However, ABI Research forecasts that the number of WiFi-capable devices will double over that same period.[17] Therefore, network density (WiFi frequency re-use) is growing at roughly the same rate as new devices are joining the network. On average, these trends offset and have little net impact on WiFi network capacity. In other words, growth of network density through the addition of hotspots will not serve to mitigate quickly growing WiFi traffic, on average over the forecast period.[18]

Another factor that may serve to mitigate WiFi data traffic growth is ongoing improvement in wireless efficiency as new technology takes hold in the market. Efficiency can be quantified by the amount of data transmitted within a given unit of time within a given bandwidth, or bits per second per hertz (b/s/Hz). WiFi standards specifying efficiency are designed by the Institute of Electrical and Electronics Engineers (IEEE) as part of the 802.11 family of standards. In 2011, two WiFi standards enjoyed significant market share – 802.11a/g and the

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between 2011 and 2015 - a 3X multiple. Note that these are global figures, so are larger than the North American breakout in Figure 1.

[14] Cisco's 2013 VNI (covering the 2012-2017 forecast period) cites the introduction of tiered mobile plans as a reason for slower mobile data growth.

[15] See, for example, "Neighborhood Small Cells for Hyper-Dense Deployments: Taking HetNets to the Next Level", Qualcomm Research, February 2013.

[16] Wireless Broadband Alliance Industry Report, 2011. Global figures, public and private hotspots.

[17] ABI Research, 2012, as reported by the WiFi Alliance, "Wi-Fi Certified Passpoint: Secure, easy-to-use hotspots", June 26, 2012. ABI forecasts WiFi devices to grow from 1.1 billion in 2011 to 2.2 billion in 2015, globally.

[18] In fact, the 2015 device to hotspot ratio is slightly larger than the equivalent 2011 ratio, which slightly exacerbates WiFi traffic growth.

newer 802.11n. Maximum theoretical efficiency in 802.11n is higher than a/g, by approximately 2.67 times.[19] While actual efficiency realized by users is likely to be lower than the maximum theoretical levels, relative efficiency levels in the standards provide an indication of how WiFi may improve as more devices use the 'n' standard over time. 802.11ac, the latest mass-market IEEE WiFi standard, is not factored into this efficiency evolution because it uses only 5 GHz spectrum. We will explore additional considerations relating to 5 GHz in a later section of this paper.

So, with knowledge of the relative efficiency levels of WiFi technologies, we need to know how their market share may change during our forecast period in order to determine the effect on WiFi network capacity. According to Infonetics Research, 802.11n technology began gaining significant North American market share in 2009, and has gained share every year. Assuming a 3-year device replacement cycle, 802.11n had 55% of the WiFi market in 2011, and would grow to nearly all of the market by 2015.[20] That translates to approximately 38% gain in average efficiency of WiFi technology over the period, as shown in Figure 2.

	2011	2015	
Market Penetration			
802.11a/g	45%	1%	
802.11n	55%	99%	
Relative Spectral Efficiency (b/s/Hz, relative to 802.11a/g)			
802.11a/g	1	1	
802.11n	2.67	2.67	
Average Relative Spectral Efficiency			
	1.92	2.65	***= 38% boost***

Figure 2: Model of Growth in Average WiFi Technology Efficiency, 2.4 GHz Band[21]

Expected 38% growth of WiFi efficiency over the forecast period will help to mitigate some of the growth in WiFi traffic, in terms of its real effect on network capacity. The net effect will be to move the 'nominal' traffic growth multiplier of 2.5X over the forecast period to a 'real', adjusted multiplier of approximately 1.65X. Figure 3 below details the effect on WiFi network capacity of traffic growth, network density, and gains in technology efficiency.

[19] 802.11a/g is designed for maximum efficiency of 2.7 b/s/Hz, while 802.11n maxes out at 7.2 b/s/Hz, though real-world efficiency levels will be lower. For our model, these numbers are adjusted to a basis relative to 802.11a/g, so that a/g efficiency is equal to one, and n efficiency is equal to 2.67. Relative efficiency is important because our model is built to forecast growth of capacity needs over the near future from a baseline.

[20] These assumptions would lead to a forecasted 100% market share of 802.11n by 2015; however, we retain a 1% share for 802.11a/g in our model for lagging replacement.

[21] Market share data from Infonetics Research, *Wireless LAN Equipment and WiFi Phones*, 3Q2012. Data used represents access points.

Factor	2011	2015	Source / Notes
1) WiFi Traffic Growth Multiplier ("Nominal")	100%	250%	Cisco VNI, 2012
2) Network Density (Device:Hotspot ratio)	100%	106%	From WBA and WFA. Higher ratio exacerbates effect of traffic growth.
Traffic Growth Multiplier, Adjusted for Density	*100%*	*266%*	*6% increase in 'real' traffic due to higher device density ratio.*
3) Average Wireless Efficiency	100%	138%	Infonetics, IEEE data. Higher efficiency mitigates effect of traffic growth.
"Real" WiFi Network Capacity Multiplier	*100%*	***165%***	*Capacity multiplier. (266% adjusted for 38% efficiency growth.)*

Figure 3: From Nominal Traffic Growth to Real Capacity Effects

6 Spectrum Needs

The final element of our WiFi capacity model is spectrum. To understand the need for additional WiFi spectrum, we can apply our 1.65X capacity multiplier – our estimate of how much additional capacity will be needed by 2015 – to the amount of spectrum in use today. Doing so will allow us to estimate spectrum needs in 2015.

It is difficult to know with precision how much WiFi spectrum is in use today. The FCC performs no regular measurement of spectrum utilization. Since the 2.4 GHz band is unlicensed and open to anyone to use, there is no central repository of network data. So, in estimating the amount of spectrum in use today, we must necessarily make proxy estimates. One relevant proxy is WiFi penetration.

SNL Kagan estimates that in 2011, 60% of all US households had WiFi.[22] This is one basis for approximation of nationwide spectrum utilization, though admittedly an imperfect one – some areas may have higher utilization, others lower. A later section of this paper shows real-world WiFi congestion in dense markets. However, even within households, the growing number of connected devices, neighboring access points, and contention from other 2.4 GHz devices like microwave ovens, suggest that a 60% WiFi spectrum utilization assumption may be conservative. The below graphic from the Wall Street Journal provides one perspective on in-home WiFi spectrum utilization.

[22] SNL Kagan, 2012.

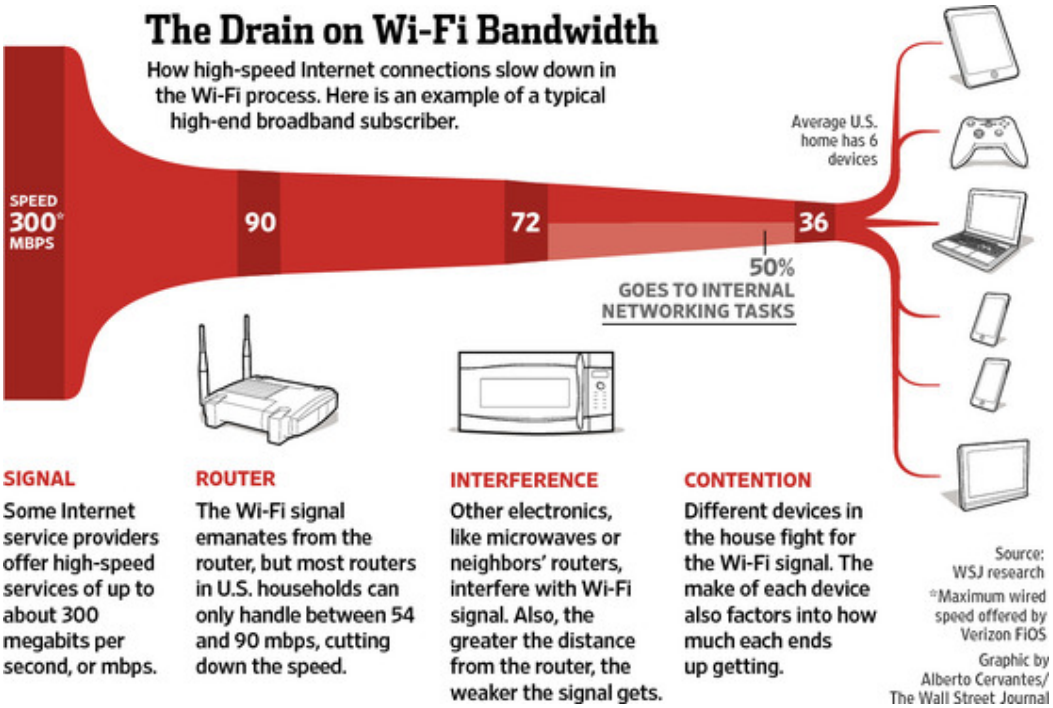

Figure 4: In-Home WiFi Utilization (Wall Street Journal)[23]

Approximately 80 MHz of spectrum is available for WiFi in the 2.4 GHz band.[24] Our 60% utilization assumption therefore translates to about 48 MHz in use in 2011. From this baseline, we can apply our 1.65X capacity multiplier to understand 2015 spectrum needs. On this basis, we can estimate that approximately 90 MHz of WiFi spectrum will be needed by 2015. In other words, it is likely that there will be a WiFi spectrum deficit of approximately 10 megahertz, on average, in the next several years.

[23] Shalini Ramachandran, "Why Wi-Fi Is Often So Slow", *Wall Street Journal*, September 18, 2012. Note that this graphic assumes the use of an 802.11g router, which has slower maximum speed than newer 802.11n routers.

[24] There are only three 22 MHz-wide non-overlapping WiFi channels in 2.4 GHz; however, to avoid overstating the need for new WiFi spectrum, we will use 80 MHz as the amount of WiFi spectrum available. Note that this forecast pertains only to the 2.4 GHz band; 5 GHz is discussed in a later section of this paper.

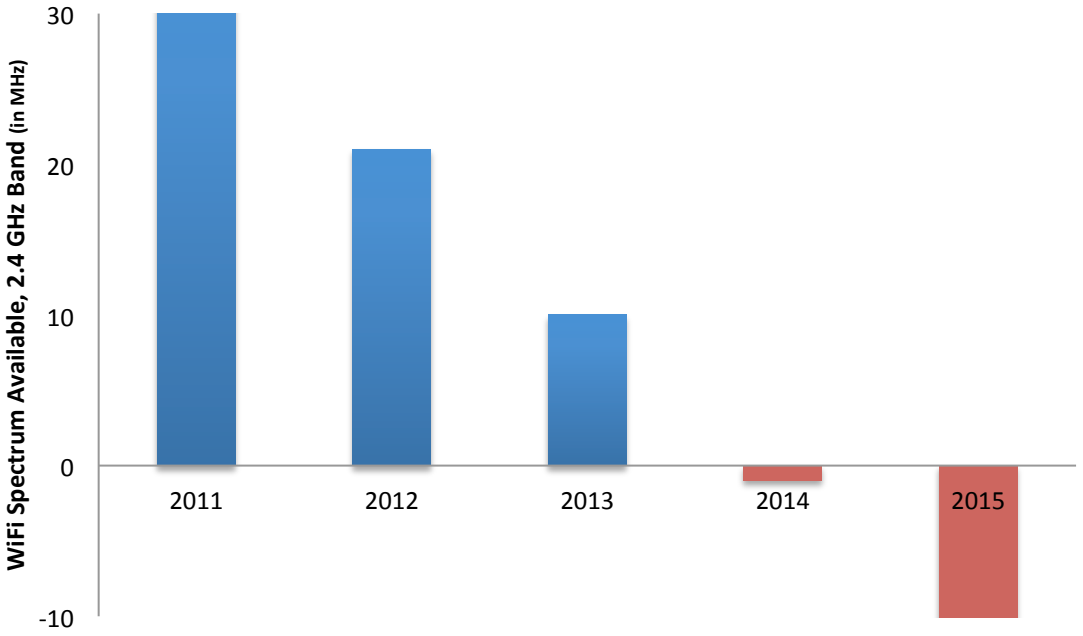

Figure 5: 2.4 GHz WiFi Spectrum Deficit Over Time, in Megahertz, Assuming 60% Baseline Utilization

It is worth noting that our model of WiFi capacity is inherently an average. The national-level data used implies a national average of relevant trends. This is important for policymaking, but also masks location-specific variability. In larger, denser markets, the factors explored in this paper are likely to point to higher capacity multiples and a more urgent need for spectrum; in smaller rural markets, the opposite is likely to be true.

WiFi spectrum exhaust will translate to reduced wireless performance. Consumers are likely to experience reduced coverage and throughput. This is known in networking as the contention ratio – the potential maximum demand on the available bandwidth. The higher the ratio, the more devices there are sharing bandwidth, the lower throughput each device enjoys. The precise impact of WiFi spectrum exhaust will vary by local circumstances, but in general, without additional spectrum, WiFi will become less useful, particularly for high bandwidth services like video. This is likely to affect wireless users that manage their mobile data bills through reliance on WiFi for bandwidth-intensive applications.

Spectrum exhaust is a particular concern in WiFi, since it uses unlicensed spectrum with no central network operator to guarantee consistent user experiences. In mobile, which uses licensed spectrum, network operators can plan network architectures to optimally serve users; in WiFi, networking is mostly ad-hoc. Further, mobile operators can use pricing and usage controls to manage bandwidth on their networks; such options are limited in unlicensed networking. In addition, the 2.4 GHz band is home to a variety of technologies, many of which can serve as sources of interference to WiFi systems, further degrading user experiences.[25]

[25] Mass Consultants, final report for OfCom, *Estimating the Utilisation of Key License-Exempt Spectrum Bands*, Issue 3, April 2009.

Given the substantial economic benefits provided through WiFi to date, [26] the threat of spectrum exhaust and its impact, and the typically lengthy process to release new spectrum for commercial use,[27] urgency is appropriate in addressing the need for WiFi spectrum.

7 WiFi Exhaust in the Real World

No model can perfectly predict the future, but reasonable observations of WiFi trends lead to the conclusion that spectrum exhaust looms, along with attendant WiFi performance impacts. As described, our model consists of national trends, and specific circumstances will vary by location. Understanding some of these location-specific dynamics provides another window into WiFi spectrum exhaust.

Midtown Manhattan is perhaps the most interesting location-specific case study, as it is the densest area of the country,[28] and represents a true proving ground for WiFi performance. Greater population and housing density is likely to translate in our model to a higher baseline of WiFi spectrum utilization. In our primary model, we took a nationwide average proxy of 60% utilization, with spectrum exhaust likely within a few years. In the case of Midtown, we might expect much higher utilization, perhaps close to 100%. High utilization is likely to translate to reduced WiFi performance, as described previously, so Midtown WiFi use represents an opportunity to examine the effects of spectrum exhaust.

Informal site surveys taken in Midtown yield some insight into the dynamic of WiFi spectrum exhaust. Running an application called Netspot on a 2012 MacBook Air with 802.11n WiFi technology,[29] several measurements were taken on a recent weekday mid-morning in Midtown. These measurements reflect an uncontrolled environment, with performance likely to be impacted by many factors, such as the number of access points, client devices, and interfering transmitters in range, which may be relevant to spectrum utilization, as well as factors such as backhaul limitations, distance, and client device performance, which are less related to spectrum utilization. Nonetheless, such an environment provides insight into WiFi performance experience in the real world.

In our testing inside a Starbucks near Columbus Circle, Netspot detected 20 unique networks, as seen in Figure 6 below. It is worth noting that all of these networks were transmitting on the 2.4 GHz band; therefore, all networks were competing for the three non-overlapping channels in the band. As a result, the signal to noise ratio, which measures signal strength relative to background noise, is very low.

[26] See, for example, Thanki, 2012.
[27] The FCC's National Broadband Plan notes that it typically takes between 6 and 13 years to release new spectrum. See *National Broadband Plan*, Exhibit 5-C.
[28] For analysis of urban population density, see Dan Malouff, "Compare the neighborhood density of US urban areas", GreaterGreaterWashingon, March 27, 2013.
[29] This device can use the 2.4 GHz and 5 GHz WiFi bands, and is backward compatible with 802.11a/b/g.

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SSID	BSSID	Ch...	Band	Security	Vendor	Mode	Level (SNR)	Signal	Signal %	Avg	Max	Min	Noise	Noi...	Last seen
guest	00:16:9C:B9:97:E0	6	2.4GHz	Open	Cisco	802.11g		-84	16%	-83	-79	-	-92	8%	now
11FX01026690	0C:D5:02:6A:D3:0B	6	2.4GHz	WEP	Westell	802.11g		-83	17%	-88	-73	-	-92	8%	now
4CC - NHFC	68:7F:74:64:AE:66	6	2.4GHz	WEP	Cisco-Linksys	802.11n		-88	12%	-92	-85	-	-92	8%	now
james was her...	00:26:B0:FE:6E:79	1	2.4GHz	WPA2 Personal	Apple	802.11n		-89	11%	-92	-79	-	-92	8%	now
guest	00:16:9C:B9:B3:60	1	2.4GHz	Open	Cisco	802.11g		-86	14%	-86	-79	-90	-92	8%	now
user	00:16:9C:B9:D1:81	11	2.4GHz	WPA2 Enterprise	Cisco	802.11g		-81	19%	-82	-54	-87	-92	8%	now
ZyXEL	B0:B2:DC:33:5E:33	6	2.4GHz	Open	Zyxel	802.11g		-87	13%	-83	-80	-	-92	8%	now
user	00:16:9C:B9:97:E1	6	2.4GHz	WPA2 Enterprise	Cisco	802.11g		-84	16%	-82	-79	-87	-92	8%	now
marc	C8:3A:35:F3:17:50	11	2.4GHz	WEP	Tenda	802.11g		-82	18%	-78	-59	-	-92	8%	now
ZyXEL	50:67:F0:65:11:62	6	2.4GHz	Open	ZyXEL	802.11g		-	0%	-97	-87	-	-92	8%	2min 5s ago
guest	00:16:9C:B9:D1:80	11	2.4GHz	Open	Cisco	802.11g		-80	20%	-82	-44	-85	-92	8%	now
attwifi	00:21:55:B3:93:F0	1	2.4GHz	Open	Cisco	802.11g		-53	47%	-55	-48	-64	-92	8%	now
user	00:16:9C:B9:B3:61	1	2.4GHz	WPA2 Enterprise	Cisco	802.11g		-90	10%	-89	-68	-90	-92	8%	now
secap1	C8:3A:35:F5:F6:D8	6	2.4GHz	WPA2 Personal	Tenda	802.11n		-	0%	-89	-87	-	-92	8%	17min 8s ago
nyt40da76	00:19:CB:40:DA:76	11	2.4GHz	WPA Personal	ZyXEL	802.11g		-	0%	-90	-89	-	-92	8%	16min 35s ago
878MG	00:7F:28:87:E9:AF	6	2.4GHz	WPA2 Personal	Actiontec	802.11n		-	0%	-91	-91	-	-92	8%	16min 14s ago
MTA3824	00:A0:0A:AF:93:8D	1	2.4GHz	WPA2 Personal	Airspan	802.11g		-	0%	-91	-91	-	-92	8%	12min 7s ago
NETGEAR59	2C:B0:5D:25:3C:1A	6	2.4GHz	WPA2 Personal	NETGEAR	802.11n		-	0%	-90	-89	-	-92	8%	9min 38s ago
SBG65808F	20:10:7A:84:B7:B6	1	2.4GHz	WPA2 Personal	Gemtek	802.11n		-	0%	-90	-89	-	-92	8%	3min 12s ago
EVO 4G LTE 8...	1C:B0:94:86:D2:52	1	2.4GHz	WPA Personal	HTC	802.11n		-	0%	-90	-90	-	-92	8%	33s ago

Figure 6: WiFi Network Measurement Inside Columbus Circle Starbucks, NYC

Low signal-to-noise is likely to be influenced by high spectrum utilization, and is likely to be associated with low throughput. This was confirmed through a performance test run shortly after the Netspot scan, which showed downlink throughput of 0.06 Mbps,[30] which is less than 1% of theoretically possible performance.[31] With a single sample of performance, these results should not be interpreted as representative or conclusive; however, they do provide a real world anecdote consistent with spectrum exhaust.

Another Midtown example provides further insight. Outside of the Apple store in a public plaza, Netspot detected 100 unique networks, using both 2.4 GHz and 5 GHz, as seen in Figure 7.[32] While access point utilization of 5 GHz spectrum should, in theory, provide higher signal-to-noise as a result of greater channel availability and a cleaner operating environment, in fact the signal strength was low, likely influenced by the greater number of competing networks. Throughput was measured at 3.6 Mbps[33] -- approximately 2% of maximum performance.[34] 5 GHz spectrum is different from 2.4 GHz in many material respects that are likely to have influenced this result; these differences will be explored in the next section of this paper.

[30] Using ZDNet broadband speed test.

[31] Theoretical maximum performance of 802.11n is 150 Mbps for a single spatial stream. Theoretical maximum for 802.11g is 54 Mbps. 0.06 Mbps is less than one percent of either standard.

[32] Not all detected networks are shown in the screen shot that is Figure 7.

[33] Using speedtest.net. Figure 7 shows only a small number of the total detected networks due to space on the page.

[34] 5 GHz channel 149 was selected for connection and testing, using the ApplePlazaWiFi network SSID while sitting in the Apple plaza. Signal-to-noise was low despite geographic proximity to the intended service area, influencing low throughput.

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SSID	BSSID	Ch...	Band	Security	Vendor	Mode	Level (SNR)	Signal	Signal %	Avg	Max	Min	Noise	Noi...	Last seen
ApplePlazaWIFI	A4:56:30:01:DA:2F	149	5GHz	Open	Cisco	802.11n		-85	15%	-85	-82	-	-92	8%	now
ROBIN	20:C9:D0:1B:D2:9B	11	2.4GHz	WPA2 Personal	Apple	802.11n		-75	25%	-77	-74	-	-92	8%	now
1907	00:0B:86:7B:E7:28	48	5GHz	WPA2 Enterprise	Aruba	802.11n		-83	17%	-88	-83	-	-92	8%	now
CBALJ-TC	C8:BC:C8:FE:5C:BD	7	2.4GHz	WPA2 Personal	Apple	802.11n		-69	31%	-73	-67	-	-92	8%	now
rsia1578	24:01:C7:18:5D:90	8	2.4GHz	WPA Personal	24:01:C7	802.11g		-77	23%	-78	-74	-	-92	8%	now
Mercer-Guest	D4:A0:2A:49:5D:51	7	2.4GHz	WPA Personal	Cisco	802.11g		-	0%	-77	-72	-	-92	8%	3s ago
NETGEAR93-5G	74:44:01:45:63:56	149	5GHz	WPA2 Personal	NETGEAR	802.11n		-79	21%	-84	-79	-	-92	8%	now
1907	00:0B:86:7B:FC:C8	157	5GHz	WPA2 Enterprise	Aruba	802.11n		-	0%	-91	-87	-	-92	8%	44s ago
FLH_GUEST	64:A0:E7:26:59:FE	149	5GHz	WPA2 Personal	Cisco	802.11n		-	0%	-90	-87	-	-92	8%	25s ago
650Madison	00:3A:98:7C:D8:B0	1	2.4GHz	WPA2 Personal	Cisco	802.11g		-	0%	-84	-74	-	-92	8%	25s ago
Guest	00:18:74:49:F4:A1	11	2.4GHz	Open	Cisco	802.11g		-66	34%	-72	-64	-	-92	8%	now
MOON	00:3A:98:C6:7C:B1	11	2.4GHz	WPA2 Personal	Cisco	802.11g		-	0%	-87	-78	-	-92	8%	25s ago
La Jolla Guest...	06:24:36:AB:69:31	10	2.4GHz	WPA2 Personal	06:24:36	802.11n		-74	26%	-75	-70	-	-92	8%	now
686C	00:13:F7:B6:68:6E	1	2.4GHz	WEP	SMC	802.11g		-	0%	-87	-76	-	-92	8%	44s ago
Coastal_Wireless	00:25:84:03:CC:D0	1	2.4GHz	WEP	Cisco	802.11g		-61	39%	-65	-57	-	-92	8%	now
BG_Welcome	00:0B:86:7B:E7:29	48	5GHz	Open	Aruba	802.11n		-83	17%	-87	-83	-	-92	8%	now
Cisco20527	C0:C1:C0:64:30:62	2	2.4GHz	WPA2 Personal	Cisco-Linksys	802.11n		-	0%	-88	-78	-	-92	8%	44s ago
1907	00:0B:86:7B:96:58	161	5GHz	WPA2 Enterprise	Aruba	802.11n		-86	14%	-87	-84	-	-92	8%	now
CMNet (5GHz)	DC:9F:DB:1B:63:8E	44	5GHz	WPA2 Personal	Ubiquiti	802.11n		-86	14%	-87	-85	-	-92	8%	now
Cisco08152	98:FC:11:62:45:B8	6	2.4GHz	Open	Cisco-Linksys	802.11n		-	0%	-81	-71	-	-92	8%	25s ago
Mercer-Guest	D4:A0:2A:76:43:F1	64	5GHz	WPA Personal	Cisco	802.11a		-86	14%	-89	-85	-89	-92	8%	now
nyit-g	00:1C:0F:4C:29:5D	56	5GHz	Open	Cisco	802.11a		-81	19%	-82	-81	-84	-92	8%	now
Mercer-Corpo...	D4:A0:2A:76:43:F0	64	5GHz	WPA Personal	Cisco	802.11a		-87	13%	-88	-85	-88	-92	8%	now
ApplePlazaWIFI	0C:85:25:AA:A1:AF	56	5GHz	Open	Cisco	802.11n		-76	24%	-77	-76	-81	-92	8%	now
CW-Inside	24:01:C7:15:10:30	6	2.4GHz	WPA2 Personal	24:01:C7	802.11n		-	0%	-81	-72	-	-92	8%	22s ago
CW-Inside	24:01:C7:15:10:3F	161	5GHz	WPA2 Personal	24:01:C7	802.11n		-	0%	-90	-88	-	-92	8%	19s ago
TG862GF2	00:1D:D3:A5:5E:F0	6	2.4GHz	WPA2 Personal	ARRIS	802.11n		-	0%	-78	-73	-	-92	8%	9s ago
JNYC-AP	00:1D:70:92:7B:90	1	2.4GHz	WPA2 Personal	Cisco	802.11n		-73	27%	-74	-72	-	-92	8%	now
1907	00:0B:86:7B:E7:20	1	2.4GHz	WPA2 Enterprise	Aruba	802.11n		-71	29%	-76	-71	-	-92	8%	now
JBSGuest	B4:A4:E3:1F:A8:30	8	2.4GHz	Open	Cisco	802.11n		-78	22%	-78	-72	-	-92	8%	now
nyit-g	00:1C:0F:4C:29:52	1	2.4GHz	Open	Cisco	802.11g		-76	24%	-74	-70	-	-92	8%	now
WNYC	B8:8D:12:5F:A8:51	10	2.4GHz	WPA2 Personal	Apple	802.11n		-72	28%	-78	-72	-	-92	8%	now
JNYC-GUEST	00:1D:70:92:80:D1	1	2.4GHz	WPA2 Personal	Cisco	802.11n		-73	27%	-76	-73	-	-92	8%	now
CW-Client	24:01:C7:15:10:3D	161	5GHz	WPA2 Personal	24:01:C7	802.11n		-87	13%	-89	-87	-	-92	8%	now
Mercer-Corpo...	D4:A0:2A:49:5D:50	7	2.4GHz	WPA Personal	Cisco	802.11g		-74	26%	-77	-74	-	-92	8%	now
STARS	00:3A:98:C6:9C:72	1	2.4GHz	WPA2 Personal	Cisco	802.11g		-81	19%	-84	-81	-	-92	8%	now
JBSOffice	B4:A4:E3:1F:C6:51	2	2.4GHz	WPA2 Personal	Cisco	802.11n		-75	25%	-78	-74	-	-92	8%	now
Sherry_WiFi	C0:8A:DE:36:21:C8	6	2.4GHz	Open	Ruckus	802.11n		-76	24%	-79	-76	-	-92	8%	now
IMI_CREST_34	00:1E:E5:23:89:42	6	2.4GHz	Open	Cisco-Linksys	802.11g		-73	27%	-77	-73	-	-92	8%	now
AnnaN	20:AA:4B:78:ED:C2	149	5GHz	WPA2 Personal	Cisco-Linksys	802.11n		-88	12%	-87	-87	-89	-92	8%	now
Guest	00:18:74:49:FD:B1	11	2.4GHz	Open	Cisco	802.11g		-74	26%	-74	-74	-74	-92	8%	now
BG_Welcome	00:0B:86:7B:E2:59	44	5GHz	Open	Aruba	802.11n		-88	12%	-88	-88	-88	-92	8%	now
SYNC_00000000	00:26:84:2A:27:16	1	2.4GHz	WPA2 Personal	Ford	802.11g		-71	29%	-70	-68	-71	-92	8%	now

Figure 7: WiFi Network Measurement In Apple Plaza, NYC

The two informal Midtown Manhattan site surveys noted here do not represent a scientific approach to spectrum utilization estimation or WiFi performance measurement. They do however provide anecdotal evidence supporting high WiFi spectrum utilization in a dense market. Our model of WiFi spectrum exhaust attempted a nationwide approximation, which masks location-specific variability. One would expect to see much higher utilization than our average in dense markets such as Manhattan. Indeed, this is the implied result of our limited testing. The low throughputs achieved characterize WiFi spectrum congestion in the real world, visible today.

Adapting our spectrum exhaust model for these dense-market observations would provide the view of WiFi capacity seen in Figure 8. Beginning from a baseline of higher utilization than assumed previously, the WiFi capacity deficit is seen as more urgent.

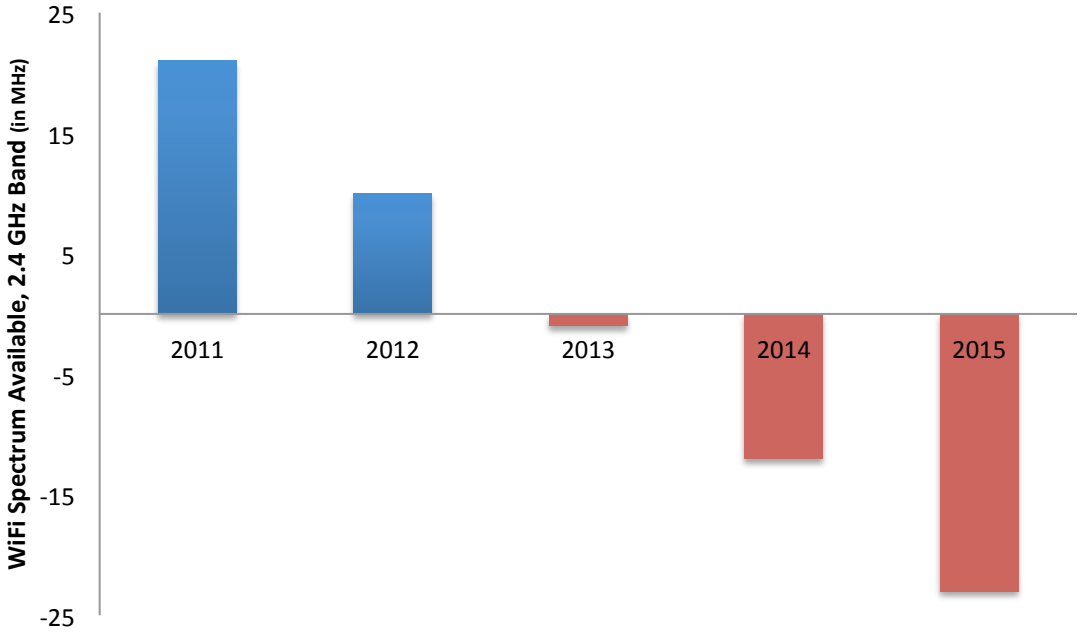

Figure 8: 2.4 GHz WiFi Spectrum Deficit Over Time, in Megahertz, Dense Markets With High Utilization

In this perspective, our 2013 spectrum utilization assumption is 100%, based on our observations in Manhattan. Our 1.65X multiple of WiFi capacity needs over the forecast period is consistent with our primary model. The result of this adjustment to our model is that WiFi capacity becomes even more strained, as suggested by the low throughputs observed in our testing. The real-world implication is that WiFi spectrum needs are even more urgent in dense markets than national averages would suggest.

8 5 GHz

This paper seeks to explore technology trends affecting WiFi capacity in the 2.4 GHz band, which is the main band used by WiFi services. A WiFi ecosystem is developing at 5 GHz as well. However, the role that 5 GHz will play is as yet unclear due to of divergent regulatory regimes, technology differences, and inherent physical characteristics.

The 5 GHz WiFi band, allocated as the Unlicensed National Information Infrastructure (UNII) band by the FCC, notionally enjoys approximately 555 MHz of bandwidth. However, different rules designed to protect other services span this bandwidth, inherently reducing utility for WiFi. Figure 9 shows some of this regulatory complexity. Only 100 MHz of the 5 GHz band, known as the UNII-3 sub-band, has comparable rules to the 2.4

GHz band, allowing for 1 Watt transmission power and free of other interference avoidance requirements like indoor-only use restrictions or dynamic frequency selection.[35]

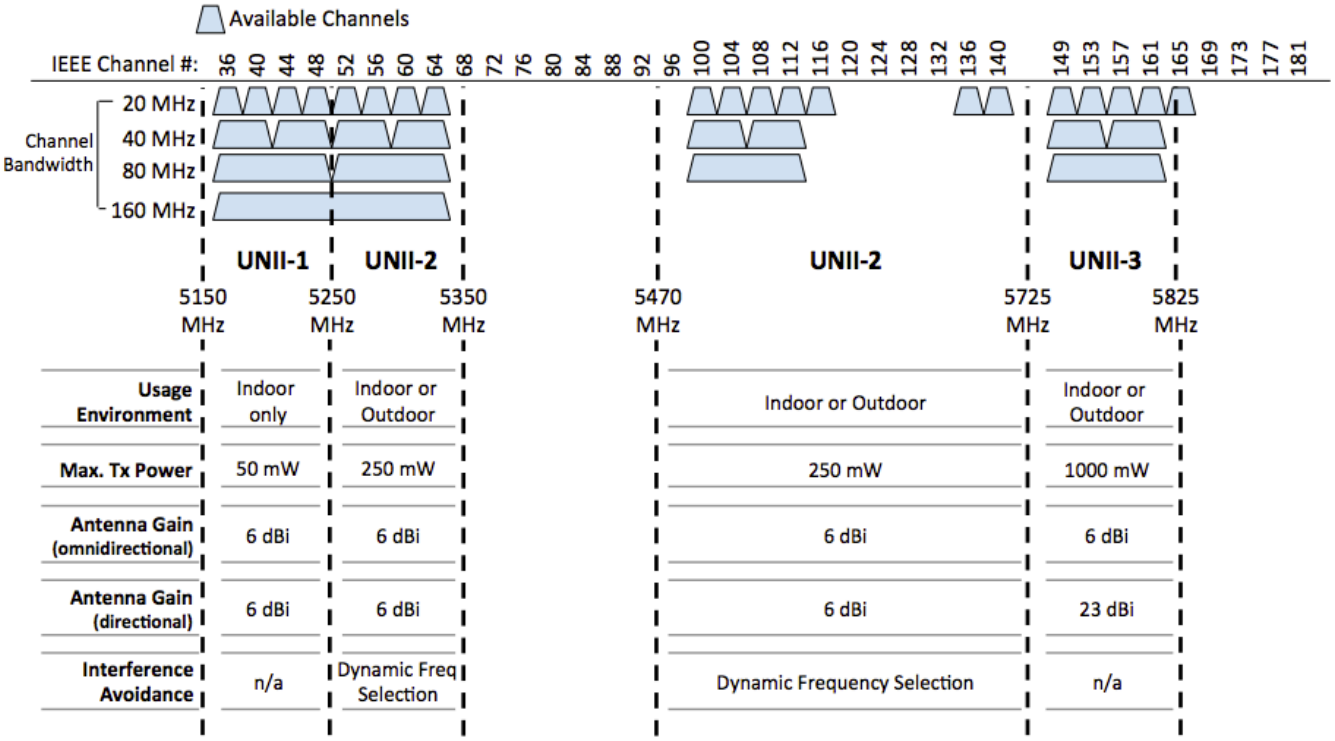

Figure 9: 5 GHz U-NII Band Plan Showing Regulatory Complexity

The latest generation of smartphones – such as the iPhone5, HTC One X, and Samsung Galaxy S III – now support 5 GHz WiFi, signaling some use of the band despite the regulatory complexity seen above.[36] Most 5 GHz use is likely to come in the UNII-3 portion of the band because of the relative simplicity of access terms. Dynamic frequency selection technology is not widely deployed or supported,[37] and some experiences to date suggest that implementation has not enabled seamless connectivity.[38]

The FCC has proposed several modifications to 5 GHz rules in an effort to simplify regulations and enable greater commercial use.[39] These efforts are encouraging, and could ultimately foster future WiFi capacity. At this stage, however, it appears too early to presume that favorable FCC rule changes will proceed, and to incorporate the

[35] Dynamic frequency selection rules in the 5 GHz band require certain portions of the band to scan for radar signals, and if detected, to cease operation or move channels. 47 CFR 15.407

[36] We do not break out WiFi traffic by band in our capacity model due to the lack of reliable segmented data.

[37] Based on informal discussions with vendors and clients.

[38] See, for example, Brett Glass, "Shared Spectrum, Sunspots, and the Birthday Paradox: Lessons Learned from Sharing of the 5.4-5.7 GHz (UNII-2) Frequency Band", 2012 Telecom Policy Research Conference.

[39] FCC 13-22, "Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band", *Notice of Proposed Rulemaking*, adopted February 20, 2013.

full 5 GHz band into our core model of WiFi spectrum availability. FCC proceedings can take years to complete,[40] and other 5 GHz spectrum users have raised a number of concerns with expanding WiFi use of the band.[41]

In addition, the physical characteristics of the 5 GHz band are different from the 2.4 GHz band. In general, higher radio frequency bands experience greater propagation loss and path loss than lower radio frequencies. Propagation loss involves signal attenuation over shorter distances at higher frequencies, holding all else constant. In our present context, the 2.4 GHz band involves better propagation than the 5 GHz band by a factor of 4.3X. That is, holding all else equal, WiFi signals at 2.4 GHz will travel 4.3 times farther than signals at 5 GHz. Path loss also involves signal attenuation through objects such as buildings and trees, and is also greater at higher frequencies.[42]

Path and propagation loss may be beneficial in some circumstances. For example, high signal attenuation may be a virtue in networking dense residential environments, such as apartment buildings, since signals are less likely to interfere with each other. However, networking with 'high loss' spectrum across wide areas is problematic and costly. As Internet service providers seek to expand their WiFi footprints, 5 GHz may suit some, but not all, of their needs. Namely, if suitable rules are established 5 GHz may provide substantial capacity, but not coverage.[43]

It is therefore clear that the 5 GHz band differs from 2.4 GHz in many material respects; these differences are one reason why the vast majority of installed WiFi devices and equipment rely on the 2.4 GHz band, rather than 5 GHz. This is also why our primary analysis of WiFi spectrum exhaust examines the 2.4 GHz band.

However, if one were to model 5 GHz WiFi capacity, the 100 MHz of the UNII-3 sub-band would be the most appropriate to include because access rules are similar to 2.4 GHz.[44] Doing so could delay spectrum exhaust in smaller markets. In large, dense markets, however, the additional 'cushion' of spectrum is likely to be more quickly exhausted.

The temporary nature of any likely spectrum cushion provided by 5 GHz is driven in part by the emergence of 802.11ac, the newest mass-market IEEE WiFi standard. 802.11ac promises at least a 3X improvement in performance over 802.11n through improvements in efficiency and leveraging larger channels of 80 or 160 MHz, compared to the 20 to 40 MHz channels in 802.11n.[45] With multiple-input, multiple-output (MIMO) spatial

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[40] See, for example, remarks of FCC Commissioner Ajit Pai at the Federal Communications Bar Association, February 21. 2013.

[41] See, "Evaluation of the 5350-5470 MHz and 5850-5925 MHz Bands Pursuant to Section 6404(b) of the Middle Class Job Creation and Tax Relief Act of 2012", NTIA Report, Department of Commerce, January 2013. Also see, *Letter of NTIA Administrator Lawrence Strickling to FCC Chairman Julius Genachowski*, February 19, 2013. Also see, *Letter of the Intelligent Transportation Society of America to FCC Chairman Julius Genachowsk*i, February 12, 2013.

[42] Dirk Grunwald and Kenneth Baker, "FCC Broadcast Incentive Auction: A Band Plan Framework for Maximizing Spectrum Utility", 2013.

[43] Coverage is likely to become increasingly important in WiFi networks, as home WiFi penetration reaches saturation and customers seek to utilize their fixed broadband subscriptions outside of the home. The CableWiFi initiative, for example, is designed to enable WiFi access for cable customers not only outside of the home, but outside of the home territories of their cable providers.

[44] Both 2.4 GHz and UNII-3 have maximum transmit power of 1 watt, are free of dynamic frequency selection requirements, and are permitted for outdoor use. Other portions of the 5 GHz band are limited to lower power (in some cases, as little as 5% of 2.4 GHz and UNII-3), are limited to indoor use, or are required to use dynamic frequency selection technology.

[45] Greater efficiency is also enabled in 802.11ac through higher-order modulation techniques. For a review of 802.11ac features, see the Cisco Technical White Paper, "802.11ac: The Next Generation of Wi-Fi".

streaming technology, speeds over 1 Gbps are possible in optimal use environments. High-bandwidth applications will benefit from this new standard, which only uses the 5 GHz band. However, performance improvements come with the use of wider channels and more spectrum. This fundamental technology difference adds further complexity to the inclusion of 5 GHz in our WiFi capacity model, since wider channelization will increase the rate of spectrum consumption relative to prior WiFi standards.

One means of accounting for 5 GHz UNII-3 bandwidth in our WiFi capacity model is to normalize for channel bandwidths used by 802.11ac as that technology gains market share. Doing so helps to rectify one of the key technology differences between 2.4 GHz and 5 GHz over time – greater spectrum use enabled by differing IEEE standards. Because 802.11ac uses channel bandwidths that are between two and eight times 802.11n,[46] we can use 3X as a rough, and conservative, normalizing factor. We will use 3X rather than a higher number (such as 5X, which would be the mean step-up in channel bandwidth between 802.11n and 802.11ac), to avoid overstating the increased rate of spectrum consumption as a function of standards evolution. For example, use of 160 MHz channels in 802.11ac is made very difficult by current FCC rules, as explained further below, so by using a 3X normalizing factor we discount the high-end of increased spectrum consumption in new standards.

According to ABI Research, 802.11ac WiFi equipment sales will accelerate over the coming years, reaching over 90% of all WiFi devices by 2015, the last year of our forecast period.[47] Figure 10 below shows the significant forecasted growth of 802.11ac capable WiFi devices, which reach nearly 2 billion by 2015.

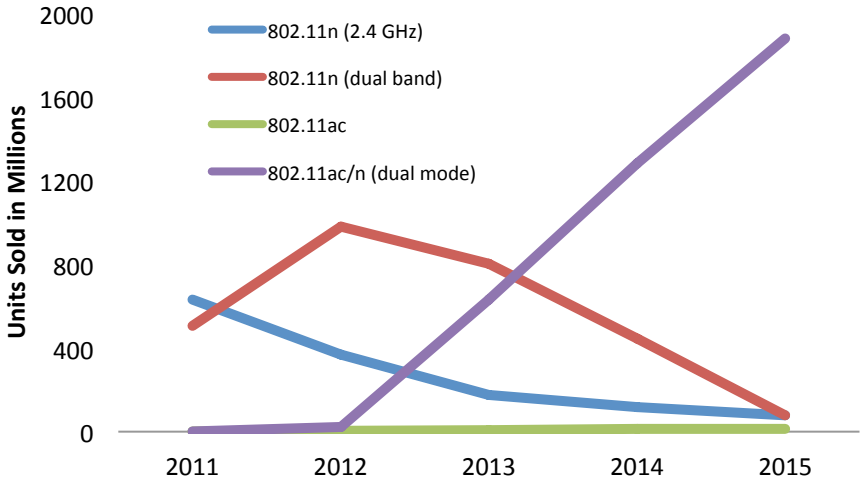

Figure 10: Forecasted Sales Growth of 802.11ac (ABI Research)

To estimate the impact of expected rapid growth of 802.11ac on 5 GHz spectrum capacity, we need to translate sales velocity shown in Figure 10 to market share. To do so, we will assume the same 3 year replacement rate as in our primary model. Doing so translates to approximately 70% 802.11ac market share by 2015. Therefore, 70% of WiFi devices in 2015 may be utilizing the larger bandwidths offered by 802.11ac, consuming more spectrum

[46] 802.11n uses channels of 20 or 40 MHz. 802.11ac also uses channel bandwidths of 80 or 160 MHz. Using a 3X normalizing factor may therefore understate the accelerated 'burn rate' of spectrum under 802.11ac.

[47] ABI Research, *Wireless Connectivity Research Service*, August 2011. Includes all product categories: mobiles, televisions, gaming, laptops, etc.

than previous WiFi standards. To account for this in our model, we will use the 3X factor described above, and apply it to the 70% share of 802.11ac in order to account for the effect of greater spectrum consumption on WiFi spectrum capacity.

The effect is seen Figure 11, where the solid blue line represents the simple addition of the 100 MHz of UNII-3 to our primary 2.4 GHz capacity model, and the dashed line shows the accelerated spectrum 'burn rate' as 802.11ac gains share. The effect of this accelerated UNII-3 consumption becomes significant by 2015, the last year of our forecast period,[48] increasing average spectrum consumption by more than 20 megahertz relative to 802.11n. This trend of greater 'spectrum burn' will continue over time as 802.11ac continues to grow.

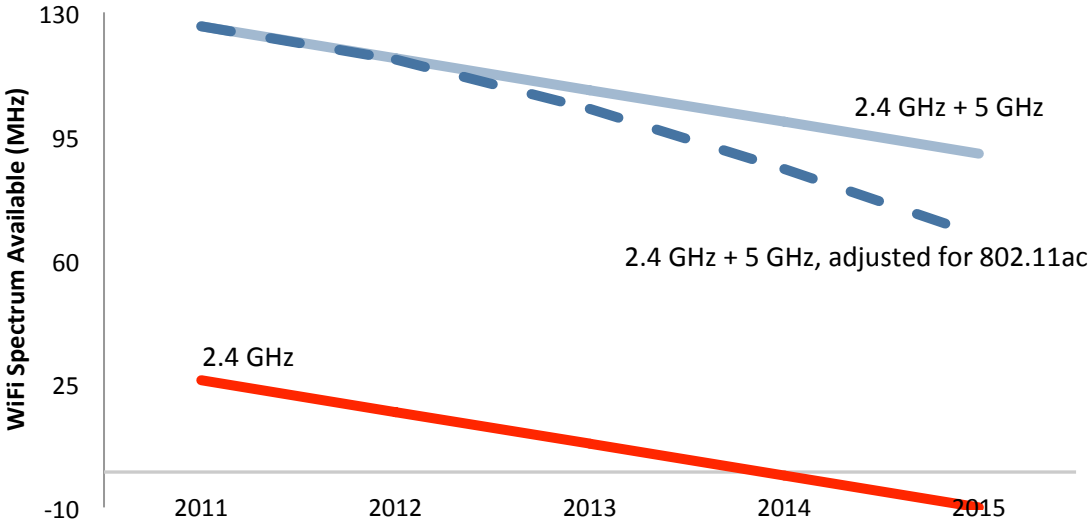

Figure 11: WiFi Spectrum Deficit Over Time if 5 GHz UNII-3 Band is Included[49]

Further adjustments could be made to this projection to account for other differences between 5 GHz and 2.4 GHz. For example, one of the most fundamental differences between the two bands is propagation. As noted above, 2.4 GHz spectrum travels over four times farther than 5 GHz, holding all else constant. This difference will result in reduced coverage for 5 GHz access points, in turn reducing the likelihood of accessibility for WiFi users. Actual real-world coverage differences between the two bands will vary based on a number of factors; however, a simple adjustment of spectrum availability for propagation characteristics provides another perspective on

[48] 2015 remains the last year of our forecast period due to data limitations. Cisco has not made public their estimates of WiFi traffic in their 2013 VNI forecast. However, the information released does indicate that WiFi traffic may be higher than previous forecasts due to greater mobile offload, which is being driven by the proliferation of tiered mobile data pricing plans.

[49] Figures 11 and 12 provide multiple views of WiFi spectrum capacity for a rounded perspective, beyond our primary 2.4 GHz capacity model, despite the differences between 2.4 GHz and 5 GHz described in Section 8 of this paper. Note that our model does not consider 'dynamic' traffic effects; for example, it is possible that as 802.11ac gains share, some WiFi traffic will move from 2.4 GHz to 5 GHz.

how 5 GHz may impact the overall WiFi spectrum deficit. Figure 12 depicts this view, showing 5 GHz spectrum accessibility reduced by 4.3X, which is the theoretical signal attenuation difference between 2.4 GHz and 5 GHz.

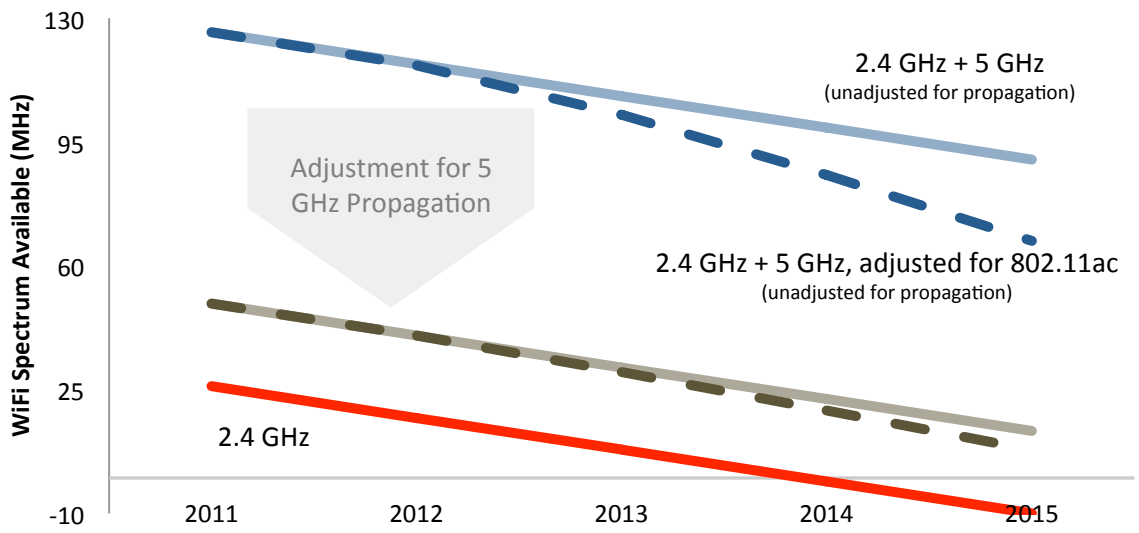

Figure 12: WiFi Spectrum Deficit Over Time if 5 GHz UNII-3 Band is Adjusted for Propagation

It is also worth noting that the full benefit of 802.11ac cannot be realized under the current terms of access to 5 GHz. As seen in Figure 9, only one 160 MHz-wide channel is feasible under the current rules, spanning from UNII-1 to UNII-2. However, both of these sub-bands entail restrictions on commercial use not seen in 2.4 GHz, such as indoor-only use requirements and power limited to just 5% of the 2.4 GHz band limits, in the case of UNII-1. In addition, since UNII-2 has different access rules, which include dynamic frequency selection technology, it is unclear how a full 802.11ac channel would be implemented across divergent regulatory regimes. Only UNII-3 has terms of access similar to the 2.4 GHz band, though bandwidth is insufficient to enable a 160 MHz channel. The FCC has recognized these and other impediments to 802.11ac implementation in its recent Notice of Proposed Rulemaking.[50] American consumers will not realize the full benefits of new WiFi technology without additional action to make spectrum available.

9 Conclusion

This paper has analyzed several key trends in WiFi technology and usage in an attempt to quantify the need for additional WiFi spectrum. In so doing, we have found that reasonable forecasts of WiFi traffic growth, network density, and technology efficiency gains collectively point to a clear need for more spectrum. These trends were modeled using national data; local circumstances vary, and dense markets are likely to find an even more urgent need for spectrum than projected here, as seen in limited testing in Manhattan.

[50] FCC 13-22

As with any model of the future, conclusions are dependent on inputs. The elements of our model intentionally use a limited number of known trends, and quantify these trends in conservative terms. While values of specific factors may be debated, it appears that WiFi spectrum exhaust is a matter of “when”, not “if”.

This conclusion adds urgency to the current policy debate surrounding the release of additional WiFi spectrum. WiFi spectrum exhaust will mean reduced performance for consumers. Since WiFi is central to the broadband ecosystem, WiFi spectrum exhaust therefore also means reduced broadband utility. Expansion of broadband access has become a central goal of technology and economic policy in the United States. New WiFi spectrum is therefore a critical element of this important national goal.