

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

In the Matter of)	
)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services)	GN Docket No. 14-177
)	
Amendment of the Commission’s Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands)	ET Docket No. 95-183 (Terminated)
)	
Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands)	PP Docket No. 93-253 (Terminated)
)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band)	RM-11664
)	
)	

NOTICE OF INQUIRY

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By the Commission: Chairman Wheeler and Commissioners Clyburn, Rosenworcel, Pai, and O’Rielly
issuing separate statements.

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I. INTRODUCTION

1. In this *Notice of Inquiry*, we begin a proceeding to examine the potential for the provision of mobile radio services in bands above 24 GHz. As technologies continue to evolve, innovators are working to tap into the potential of using high-band spectrum for mobile services. In particular, industry and technical groups are beginning to examine the use of higher frequencies sometimes known as millimeter wave (mmW) bands for mobile use.¹ This examination of the possible uses of the mmW bands for mobile use takes place within the context of broader efforts to develop technical standards for so-called Fifth Generation (5G) mobile services. In view of the technological and marketplace developments outlined in this item, we seek to discern what frequency bands above 24 GHz would be most suitable for mobile services, and to begin developing a record on mobile service rules and a licensing framework for mobile services in those bands.

2. This *Notice of Inquiry* builds on work done by the Commission's Technological Advisory Council (TAC) and fulfills a TAC recommendation. This proceeding is not a substitute for our efforts to make additional lower frequency spectrum available for mobile services, but rather is a supplement to those efforts. As innovation and development focuses on using higher bands to help support mobile broadband, we aim to help foster a regulatory environment that is responsive to these technological changes. We also seek to advance our understanding of the means by which mobile services can avoid interfering with each other and with incumbent services and users that may share the same frequency bands as well as the impact on adjacent band radio services. We expect our inquiries in this proceeding to lay the foundation for more detailed proposals to be developed in subsequent rulemaking proceedings.

3. The Commission has a longstanding practice of adopting flexible service rules for mobile wireless services, and has generally eschewed mandating the use of specific technologies or standards, preferring instead to let innovation and market competition drive the direction of technological development, and to put in place regulations that can accommodate future technological advances. We do not anticipate deviating from these principles as we examine the suitability of bands above 24 GHz for mobile services. While our inquiry is informed by the work of many different stakeholders to develop and define the next generation of mobile wireless services and technologies, in this proceeding we are not attempting to define, standardize, or specify the characteristics of 5G service. Nor do we anticipate ultimately adopting rules that will incorporate a specific 5G standard. Our use of the term "5G" in this item, therefore, is intended as a convenient shorthand rather than a circumscription.

II. BACKGROUND

4. Today, mobile broadband networks generally use spectrum bands below 3 GHz, primarily due to the favorable propagation characteristics of that spectrum and the ready availability of components.² Over time, as technology has advanced, operators have used progressively higher frequencies for mobile wireless use. The first band used for mobile wireless use was 845-890 MHz (the Cellular Radiotelephone Service).³ Today, the Personal Communications Service and Advanced Wireless

¹ See John Thompson *et al.*, *5G Wireless Communications Systems: Prospects and Challenges*, IEEE Communications Feb. 2014 ("5G Wireless") at 62.

² Naga Bhushan *et al.*, *Network Densification: The Dominant Theme for Wireless Evolution into 5G*, IEEE Communications, Feb. 2014 ("Network Densification") at 82, 87.

³ See generally 47 C.F.R. Part 22, Subpart H.

Services bands, which are generally in the 1.7-2.1 GHz range, are used extensively for mobile wireless service.⁴ The Broadband Radio Service and Educational Broadband Service in the 2496-2690 MHz band have been used more recently for mobile broadband service.⁵ Recently, we sought comment on a detailed proposal for establishing a new Citizens Broadband Radio Service in the 3550-3650 MHz band that could leverage new methods of spectrum sharing and promote a diverse array of network technologies, with a focus on relatively low-powered applications.⁶

5. Until recently, the prevailing assumption was that mobile service in higher frequency bands, such as bands above 24 GHz, was infeasible because radio waves at those frequencies travel in straight lines and could provide only line-of-sight service. Also, the propagation and atmospheric absorption characteristics of higher frequency bands significantly reduce the coverage of individual base stations and require a very expensive network to achieve a reasonable extent of aggregate coverage. As discussed further below, however, some of the leading wireless equipment manufacturers are now developing ways to provide non-line-of-sight services in higher frequency bands with increased range.⁷ The National Science Foundation has also funded basic research in 5G, including making mmW propagation measurements.⁸ In addition, in 2014 the National Institutes of Science and Technology created a new Communications Technology Laboratory (CTL) that will, among other things, “promote interdisciplinary research, development and testing in areas related to advanced communications such as radio frequency technology, digital information processing, cybersecurity, interoperability and usability.”⁹ The CTL is also a joint partner with NTIA in the Center for Advanced Communications (CAC), which will “provide opportunities for collaborate R&D and access to test-bed resources.”¹⁰

6. As they have developed, mobile wireless communications technologies have progressed through several “generations,” each of which has advanced the nature of mobile wireless services. The first generation of wireless technical standards, or 1G, originated in the 1980s and was based on analog technology. The first digital wireless systems were known as 2G technologies. While there are a variety of different definitions used for 3G and 4G wireless technologies, the International Telecommunications Union (ITU) adopted standards that are often cited as definitions of 3G (IMT-2000) and 4G (IMT-Advanced) standards.¹¹

⁴ See generally 47 C.F.R. Parts 24 and 27.

⁵ See generally 47 C.F.R. Part 27, Subpart M.

⁶ See Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, *Further Notice of Proposed Rulemaking*, 29 FCC Rcd 4273 (2014) (“3.5 GHz FNPRM”).

⁷ See, e.g., Wonil Roh *et al.*, *Networks and Devices for the 5G Era*, IEEE Communications, Feb. 2014, 106 (“Roh *Networks and Devices*”) at 111.

⁸ In October 2013, the National Science Foundation awarded \$500,000 to two researchers at the Polytechnic Institute of New York University (NYU-Poly) and Auburn University to gain a deep understanding of radio communication in the 60GHz band. See <http://www.fiercewireless.com/tech/story/nsn-joins-5g-research-nyu-wireless/2013-12-04>. The NSF has also funded \$800,000 to the NYU-Poly in 2012 to develop 5G cellular networks. See <http://nyconvergence.com/2012/07/nyu-poly-given-2-mill-grant-to-develop-5g-network.html>.

⁹ See CTL press release: <http://www.nist.gov/ctl/rochford-032514.cfm>.

¹⁰ See CTL website: <http://www.nist.gov/ctl/>; CAC press release http://www.nist.gov/public_affairs/releases/nist-ntia-mou-061413.cfm. In September 2014, Kent Rochford, co-Director of the Center for Advanced Communications, participated in a 5G conference in London to discuss standardization and regulatory challenges of 5G network as a panelist. See http://eu-ems.com/agenda.asp?event_id=219&page_id=1889.

¹¹ See ITU global standard for international mobile telecommunications ‘IMT-Advanced’, *available at* <http://www.itu.int/ITU-R/index.asp?category=information&rlink=imt-advanced&lang=en>.

7. During the past year, significant momentum has started to build around the idea of a “Fifth Generation” that will substantially exceed the capacity of existing mobile technologies.¹² There is as yet no consensus definition of 5G, but some believe it should accommodate an eventual 1000-fold increase in traffic demand,¹³ supporting high-bandwidth content with speeds in excess of 10 gigabits per second (Gb/s); end-to-end transmission delays (latency) of less than one-thousandth of a second; and, in the same networks, sporadic, low-data-rate transmissions among an “Internet of things”¹⁴ — all of this to be accomplished with substantially improved spectral and energy efficiency.¹⁵ Achieving these objectives will likely require the development of new system architectures to include heterogeneous networks that will deliver service through multiple, widely-spaced frequency bands and diverse types of radio access technologies, including macrocells, microcells, device-to-device communications, new component technologies, and unlicensed as well as licensed transceivers.¹⁶ In this context, bands above 24 GHz are typically considered not for stand-alone mobile services but as supplementary channels to deliver ultra-high data rates in specific places, as one component of service packages that will likely include continued use of lower bands to ensure ubiquitous coverage and continuous system-wide coordination.¹⁷

8. In connection with these developments, standards bodies and industry groups are working to complete the preparation of 5G technical standards in 2016-2018, with initial deployment of services using these technologies expected around 2020.¹⁸ The International Telecommunication Union Radiocommunication Sector (ITU-R), through its Working Party 5D, has begun a detailed investigation of the key elements of 5G.¹⁹

9. Organizations representing diverse countries and regions have already launched programs oriented toward research and development of so-called 5G services. The European Telecommunications Standards Institute (ETSI) is providing a framework for two initiatives, 5GNOW and METIS (Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society) to study new waveforms and technical capabilities to meet traffic requirements in 2020; the 5G Research Center in the United Kingdom is developing a test bed for 5G technologies, and China’s IMT-2020 Forum is studying user demands, spectrum characteristics, and technology trends that will underpin 5G developments.²⁰

¹² *5G Wireless* at 62.

¹³ *Network Densification* at 82.

¹⁴ *5G Wireless* at 63-64. See also Rakesh Taori, Samsung Research America, *On Feasibility of mmWave Bands for 5G Cellular Access*, slide presentation to Telecommunications Industry Assn. Workshop, *Beyond 2020: A Vision of 5G Networks*, Nov. 21, 2013 (“*Beyond 2020*”).

¹⁵ Chih-Lin I *et al.*, *Toward Green and Soft: A 5G Perspective*, IEEE Communications, Feb. 2014 (“*Green and Soft*”) at 66.

¹⁶ Boyd Bangerter *et al.*, *Networks and Devices for the 5G Era*, IEEE Communications, Feb. 2014 (“*Bangerter Networks and Devices*”) at 90.

¹⁷ *Bangerter Networks and Devices* at 90-91.

¹⁸ *5G Wireless* at 62.

¹⁹ *ITU Towards IMT for 2020 and Beyond*, ITU web site at <http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/default.aspx>. See also ITU-R Working Party 5D Workshop Agenda, *Research Views on IMT Beyond 2020*, Ho Chi Minh City, Vietnam, February 12, 2014 (accessible via ITU web site link at <http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rwp5d&lang=en>); Intel Corp., AT&T Inc., Samsung Electronics Co. Ltd., Telefon AB-LM Ericsson, Nokia Solutions and Networks Oy and Nokia Corp., *Proposal for Development of a Draft New Report on Technical Feasibility of IMT in the Bands Above 6 GHz*, Joint Submission to ITU Radiocommunication Study Group WP 5D, October 2, 2013. (proposing report to be completed by WP 5D meeting in June 2015).

²⁰ *Green and Soft* at 66. Led by Ericsson and funded by the European Commission, METIS is a consortium of 29 organizations that aims to replicate Europe’s worldwide success with GSM and subsequent technologies. The majority of participants are universities and mobile network operators, with industry partners including Alcatel-
(continued....)

Other 5G initiatives include the China Ministry of Science and Technology's National 863 Key Project in 5G, Korea's 5G Forum, Japan's 2020 and Beyond program,²¹ and the European Commission's 5G Public-Private Partnership Association (5GPPP).²² In the U.S., major research efforts are underway at a number of academic institutions, including the Polytechnic Institute of New York University,²³ Virginia Polytechnic Institute and State University (Virginia Tech), and several universities that are being funded by Intel through the Intel Strategic Research Alliance (ISRA).²⁴

10. Several private companies are investing substantial resources in the development of advanced mobile service technologies, including (in addition to Intel) Alcatel-Lucent, Ericsson, Huawei, InterDigital, Nokia, Qualcomm, Samsung, and others.²⁵ While some companies involved in these efforts acknowledge that there is room for further efficiency gains in bands that are already licensed to mobile wireless providers, they generally believe that provision of 5G-level service will require use of higher frequency bands in at least some places where traffic demands will exceed available capacity, particularly in urban areas, event venues, and other locations experiencing congestion due to high density use.²⁶

11. Some of the most widely publicized field trials of millimeter-wave mobile service have been conducted at New York University and the University of Texas with funding from the U.S. Army and Samsung. Those trials found that 39 GHz mobile base stations can sustain 100 percent coverage in cells with a 200-meter radius in high-density urban areas.²⁷ Receivers equipped with highly directional, steerable antennas were able to capture and combine as many as 14 links with rooftop-mounted transmitters despite obstructions in propagation paths, i.e., the receivers were able to "see" multiple

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Lucent, BMW, Huawei, Nokia, and Nokia Solutions and Networks (NSN). Agilent Technologies, *White Paper: Current Activity in 5G* (<http://www.home.agilent.com/agilent/editorial.jsp?ckey=2311424&id=2311424&nid=-34869.0&lc=fr&cc=CA>). For further information on METIS, see Kumar Balachandran and Afif Osseiran, Ericsson Research, *Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society: Paving the Way for 5G*, slide presentation to Telecommunications Industry Assn. Workshop, *Beyond 2020: A Vision of 5G Networks*, Nov. 21, 2013.

²¹ Francis O'Brien, Jr., *The Basics of 5G: What, When and Why*, slide presentation to Telecommunications Industry Assn. Workshop, *Beyond 2020: A Vision of 5G Networks*, Nov. 21, 2013 ("Basics of 5G").

²² Rick Merritt, *5G Work Officially Begins in Europe*, EE Times, Dec. 18, 2013 (online at http://www.eetimes.com/document.asp?doc_id=1320437). See also Cheng-Xiang Wang, *Cellular Architecture and Key Technologies for 5G Wireless Communications Networks*, IEEE Communications, Feb. 2014, 122 at 123.

²³ The National Science Foundation grants from the Networking Technology and systems program for 5G wireless.

²⁴ Participants in ISRA as of the summer of 2013 included the University of Southern California, New York University, Princeton, Stanford, University of Illinois at Urbana-Champaign, University of Texas at Austin, University Fabra Pompeu, Purdue University, Cornell, IIT Delhi, University of California at Los Angeles, Rice University, and Macquarie University. See Shilpa Talwar, *Next Generation Wireless Communication (5G): Transforming the Wireless User Experience*, Intel Labs, July 15, 2013, accessible online at <http://blogs.intel.com/intellabs/2013/07/15/next-generation-wireless-communication-5g-transforming-the-wireless-user-experience/>.

²⁵ See *Basics of 5G*. Nokia is conducting 5G-oriented research and development through its wholly-owned subsidiary, Nokia Solutions and Networks ("NSN").

²⁶ See *5G Wireless at 63; Roh Networks and Devices at 111-112*. Uniquely among these companies, Qualcomm representatives have expressed the view that bands below 3 GHz have sufficient unexploited capacity to support the traffic volumes that 5G services will generate over the next decade, even though Qualcomm projects a 1000-fold increase in mobile traffic demand during that period. *Network Densification at 82 and 88*.

²⁷ Theodore S. Rappaport et al., *Broadband Millimeter Wave Propagation Measurements and Models Using Adaptive Beam Antennas for Outdoor Urban Cellular Communications* (Pre-publication IEEE Paper No. AP1204-0493, manuscript revised August 2012).

reflected signals from places where lines of sight to base stations were blocked.²⁸ Samsung has conducted similar trials at 28 and 38 GHz, respectively, in Suwon, Korea, and Austin, Texas.²⁹

12. Other companies are working to overcome line-of-sight limitations in frequency bands ranging from 5.8 GHz to as high as 72 GHz. Ericsson has demonstrated the ability to establish reliable wireless links at 5.8 GHz and at 28 GHz by combining multiple reflected signals.³⁰ Intel is exploring the possibility of developing chipsets capable of supporting mobile access in the 39 GHz band and Wi-Fi-like “WiGig” operations in the 60 GHz band.³¹ Nokia has conducted ray-tracing computer simulations to demonstrate that mobile service would be feasible at 72 GHz.³² While the details of additional proprietary research are not publicly known at this time, it is a matter of public record that AT&T, Huawei, and Qualcomm, as well as Samsung, Ericsson, Intel, and Nokia are providing substantial funding to academic centers investigating millimeter-wave wireless mobile.³³

13. The overall picture that emerges from these developments is a potential coalescence of technologies that could lead to the emergence of a new and radically more capable generation of wireless mobile service that can capitalize on use of the millimeter wave region of the spectrum around the year 2020. Before those technologies can be deployed, however, additional work is required to complete the necessary research and development; negotiate mutually harmonized standards, consider frequency allocations³⁴ and regulatory frameworks; and build or modify manufacturing facilities and processes required to supply necessary system components. Those tasks are already underway among governments, companies, and institutions around the world.

14. The purposes of this proceeding include learning about the development status of enabling technologies that are essential to build mobile broadband networks in frequencies above 24 GHz, identifying mmW bands that could be suitable for the provision of so-called 5G mobile services, and exploring the technical challenges that deployment of a new generation of mobile technology will present. Our efforts have been greatly facilitated by the Commission’s TAC, a diverse array of leading experts whose mission is to help the FCC identify important areas of innovation and develop informed

²⁸ Theodore S. Rappaport et al., *Cellular Broadband Millimeter Wave Propagation and Angle of Arrival for Adaptive Beam Steering Systems* (IEEE Paper No. 978-1-4577-1155-8/12, © 2012).

²⁹ *Roh Networks and Devices* at 107.

³⁰ Jonas Hansryd et al., *Non-line-of-sight Microwave Backhaul for Small Cells*, Ericsson Review, Feb. 22, 2013, at 2 et seq.

³¹ Ali Sadri, *mmWave Technology Evolution from WiGig to 5G Small Cells*, June 28, 2013 (slide presentation to Commission staff by Intel Director of mmWave Standards & Advanced Technology and CEO and Chairman of WiGig Alliance). The Commission has approved several devices in the 60 GHz band pursuant to Section 15.255 of our rules. See, for example, grants of certification for FCC ID: PPD-QCA9005 and PJ8-WIL6110 at www.fcc.gov/oet/ea/fccid.

³² Stephen G. Larew et al., *Air Interface Design and Ray Tracing Study for 5G Millimeter Wave Communications*, paper presented at IEEE International Workshop on Emerging Technologies for LTE-Advanced and Beyond-4G, Dec. 13, 2013.

³³ See, e.g., *NYU Wireless Pulse*, Feb. 2014, at 3 (<http://nyuwireless.com/wp-content/uploads/2014/03/Feb2014x.pdf>); Shilpa Talwar, *Next Generation Wireless Communication (5G): Transforming the Wireless User Experience*, Intel Labs, July 15, 2013 (<http://blogs.intel.com/intellabs/2013/07/15/next-generation-wireless-communication-5g-transforming-the-wireless-user-experience/>).

³⁴ While additional spectrum allocations may be appropriate, we would continue to permit flexible deployment of new technologies, including, but not limited to, mobile wireless technologies, in spectrum that is already allocated for wireless services.

technology policies supporting America's competitiveness and job creation in the global economy.³⁵ In light of the developments described above, and following a series of presentations by invited guests to its Spectrum Frontiers working group, the TAC recommended that we issue a notice of inquiry to evaluate mobile broadband feasibility in bands above 30 GHz.³⁶

15. Another important purpose of this proceeding is to begin the process of revisiting allocations and service rules for the mmW bands where it makes sense to accommodate the future deployment of mobile services. In reviewing proposals to change service rules in the mmW bands, our main goal will continue to be to develop flexible rules that accommodate as wide a variety of services as possible.³⁷ As advanced mobile service technologies suitable for these bands are still in the early stages of development, and alternative uses of the bands may also emerge, we aim to develop a framework that will accommodate as wide a variety of services and uses as possible, and that will promote coexistence between different services in these bands. Our inquiry is consistent with the Presidential Memorandum encouraging the Commission, in collaboration with NTIA, where appropriate, to expedite the repurposing of spectrum and otherwise enable innovative and flexible commercial uses of spectrum, including broadband, to be deployed as rapidly as possible.³⁸

III. DISCUSSION

16. In the sections below, we begin by seeking comment on the technologies underlying the development of mmW mobile services using bands above 24 GHz.³⁹ We seek comment on a wide array of issues in order to understand better the state of the art and potential future technological developments. Next, we invite comment on frequency bands that would be suitable for advanced mobile services and the best ways to manage interference among operators and other licensees operating in the same or adjacent bands. Finally, we seek comment on licensing and authorization schemes for mobile operations above 24 GHz. Our inquiries on technology, spectrum bands, and licensing mechanisms are related. The inquiries will help inform our approach to enable short and long term solutions to meet the needs of those who seek

³⁵ The current TAC was formed in October 2010, under the authority of the Federal Advisory Committee Act, 5 U.S.C. App. 2 (1988).

³⁶ See Meeting Presentation, September 23, 2013 Meeting of the Technological Advisory Council, available at <http://www.fcc.gov/encyclopedia/technological-advisory-council>. While 30 GHz is the normal cut off for what is defined as millimeter wave spectrum, as discussed below, we are also considering the suitability of bands between 24 GHz and 30 GHz for 5G mobile services.

³⁷ See, e.g., Amendments to Parts 1, 2, 87 and 101 of the Commission's Rules to License Fixed Services at 24 GHz, WT Docket No. 99-327, *Report and Order*, 15 FCC Rcd 16934, 16936 ¶ 1 (2000) ("The rule changes we adopt today establish a flexible regulatory and licensing framework."); Amendment of the Commission's Rules Regarding the 37.0 - 38.6 GHz and 38.6 - 40 GHz Bands, *Report and Order and Second Notice of Proposed Rulemaking*, ET Docket No. 95-183, 12 FCC Rcd 18600, 18603 ¶ 1 (1997) ("*39 GHz R&O*") ("[W]e also are interested in providing sufficient flexibility for terrestrial-based licensees to provide the public with innovative services. We believe that the public interest would be served by permitting the market to decide which entrepreneurial efforts will succeed."); See Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies For Local Multipoint Distribution Service and For Fixed Satellite Services, CC Docket No. 92-297, *Second Report and Order, Order on Reconsideration and Fifth Notice of Proposed Rulemaking*, 12 FCC Rcd 12545, 12637 ¶ 207 (1997) ("*Second LMDS Report and Order*") ("We conclude that, for now, our significant allocation of spectrum under such a broad and flexible service definition should permit licensees to satisfy a broad array of their customers' communications needs, whether through one or multiple service offerings.").

³⁸ See Expanding America's Leadership in Wireless Innovation, *Presidential Memorandum*, 78 Fed. Reg. 37431 (June 14, 2013) at § 7.

³⁹ Although the millimeter wave region of the spectrum technically begins at 30 GHz, based on some of the studies referenced above it is appropriate to consider bands above 24 GHz because the 24 GHz and LMDS bands appear to be appropriate bands to include in this *Notice of Inquiry*.

to use bands above 24 GHz for mobile services. The record we develop concerning technology will help us identify the mmW bands that can best accommodate mobile services without displacing or impairing existing uses. This record will also enable the National Telecommunication and Information Administration (NTIA) in conjunction with the federal agencies to begin assessing the impact on and protection of authorized incumbent operations in the same band or in adjacent bands that may be determined to be suitable. We also anticipate that the choices of the best licensing mechanisms could vary in different bands, based in part on the available technology and the types of other services present in each band.

A. Technology Developments

17. We seek to develop a record on technological developments relevant to the use of bands above 24 GHz for mobile services and what service rules would be necessary to facilitate mobile use of those bands. We seek comment on the following general questions and later in this inquiry invite comment on specific frequency bands:

- (1) Will it be feasible to provide mobile services in bands above 24 GHz?
- (2) To what extent will the viability of mobile service above 24 GHz be dependent on having complementary access to mobile services in lower frequency bands?
- (3) What characteristics of the anticipated technology will be relevant to the choices of frequency bands above 24 GHz such as required bandwidth, propagation, availability of electronic components, antenna designs and costs of deployment?
- (4) What characteristics of the anticipated technology are likely to inform the agency's determination of what regulatory framework (or frameworks) for mobile services in the mmW bands will best serve the public interest?
- (5) What characteristics of the technology are relevant to the manner in which mobile services in the mmW bands might coexist without impact on incumbent services that occupy the relevant frequency bands?
- (6) Are there frequency bands contemplated for mobile use that are being considered for alternative uses and, if so, what might those alternative uses be? To what extent are such uses compatible or incompatible with the kinds of mobile wireless technologies being explored in this NOI?
- (7) What technical and operational characteristics as well as interference mitigation techniques of the anticipated technologies for these bands need to be considered in assessing sharing and compatibility with in-band and adjacent band incumbent services? Are there other technical considerations the Commission should examine in enabling deployment of mobile services in bands above 24 GHz?

Additionally, in the discussion that follows, we ask a number of specific questions about technology enablers of mobile services in high-frequency bands, including so-called 5G technologies. Our aim in asking these questions is to understand the nature of the contemplated technologies to assist us in developing flexible service rules in the mmW bands (which we define for these purposes as bands above 24 GHz) that will accommodate the widest possible range of technologies and uses, including compatibility with incumbent services. We do not believe it would be in the public interest to design rules that mandate the use of specific technologies, because such rules would rapidly become outdated. In addition to seeking comment on mobile use of the mmW bands, we also seek comment on alternative uses of the mmW bands.

1. Antenna Technology

18. The use of higher frequency bands for advanced mobile services, as well as other new service applications, will likely be dependent upon new advanced antenna technologies. The narrow beamwidths typically associated with antennas at higher frequencies has led to the study of using

advanced multiple-input multiple-output (MIMO) and adaptive beam-forming. These antenna technologies may be among the key factors for overcoming some of the challenging propagation characteristics of mmW bands and could increase efficiency, allow for higher data rates, and provide reasonable coverage for mobile broadband services. In the section that follows, we seek comment on the current development of antenna technology in the mmW bands. What advanced antenna technologies are anticipated to be feasible in the mmW bands? What is the potential timeframe for commercial implementation of these technologies in mobile broadband services in the mmW bands?

a. Base Station Antennas

19. New antenna technologies being developed for advanced mobile services in the mmW bands could change the way base stations are deployed and how networks will operate. For example, base stations may have a complex antenna array with numerous elements and multiple configurations capable of serving a variety of mobile devices. We seek comment on the types of antenna arrays that may be available for base stations supporting advanced mobile services. What do commenters anticipate the size and configuration of the antenna arrays will be, including the orientation of the vertical and horizontal elements and the predicted number of beams? With respect to antennas located at base stations, what factors are likely to affect the physical size of and space needed for the antenna arrays?

20. In today's 3G and 4G systems, while macro-base stations typically utilize high-gain antennas on outdoor tower structures, there are also a wide range of base stations with smaller antenna configurations, including femto-cells and pico-cells. We seek comment on the types of base station configurations that may be used to support advanced mobile services in the mmW bands, including whether there will be a similar range and mix of higher and lower power base stations. What types of Power Amplifiers (PAs) and how many PAs will be needed to support the various antenna array systems? Does each antenna element require a dedicated PA? Are there potential configurations in which the PA(s) and the array antennas are separated? If so, what are the options for physically connecting the PA(s) and array antennas? How many users can simultaneously connect to the base station and what are the limiting factors?

21. Traditional wireless systems below 3 GHz generally utilize a fixed antenna pattern. The use of adaptive beam-forming with multiple antenna arrays in a base station using mmW bands within an advanced mobile service network may be one of the key factors in overcoming the propagation challenges in the mmW bands. We also recognize that the use of advanced antenna technologies may require the Commission to consider a different framework for technical rules that are suitable for advanced mobile wireless services in mmW bands. Therefore, we encourage the commenters to provide detailed responses for the follow questions. How will the base stations manage the transmitted effective isotropic radiated power (EIRP) of each antenna beam to generate the desired gain? What will the typical gain be for an individual element of the array? Will each element in the antenna array have a variable power that can be managed depending on the demand placed on the base station? Will the aggregate transmitter power for the base station increase as more elements of the array are used for operation? What are the vertical and horizontal beamwidths that the antenna array could cover? What type of sectorization is being considered for a base station array? What is the desired PA output power and EIRP of the base station?

22. The antenna arrays used in advanced mobile service base stations may need to be tailored to the specific environments in which they are deployed. For example, the configuration of the antenna array and its elements may be omnidirectional or confined to a particular area. How will antenna arrays be configured to deal with varying deployment scenarios while still providing the desired level of connectivity to the user? What potential challenges may be encountered with an indoor deployment versus an outdoor deployment? How will the orientation of the handset affect the connectivity? How will such factors as "head loss" affect connectivity?

b. Mobile Station Antennas

23. We ask commenters to provide information on how the technologies underlying mmW mobile wireless systems will be incorporated into mobile stations (i.e., user devices, including handsets).

The form factor of mobile stations may limit the size and number of antenna elements that may be included on the device. We seek comment on how these limitations may influence the design of advanced mobile systems. What size antenna arrays do commenters expect, and how much physical space will they likely occupy in handsets? Do commenters anticipate that the limited number of elements within an array will present connectivity issues? What kind of architecture may be needed to allow the antenna array to operate in conjunction with normal handset use?

24. What is the likely gain of the array elements in the handset? How many beams should a handset be capable of creating, and what types of beam pattern could be used? Can handsets be designed to overcome obstacles that block their lines of sight to base stations? How long will it take a handset to recognize connectivity impairments and switch connections? What are the other RF components that need further development in order to support the beam-forming techniques that may be utilized to support advanced mobile services in the mmW bands?

25. We ask commenters whether the added complexity of an advanced wireless network incorporating mmW bands for mobile service will require different handset architecture than that of current-generation technologies, such as Long Term Evolution (LTE). For example, how does the MIMO implementation for LTE handsets compare with the beam-forming implementation in 5G handsets, in terms of baseband signal processing and RF layer signal processing? How do commenters anticipate a transition from current LTE designs will occur? As LTE networks are redesigned for a 5G environment, will 5G architectures be integrated into current LTE designs, or added as a separate system or module, requiring, for example, use of a dual handset capable of operating on both LTE and 5G networks? Alternatively, will another approach be used?

26. We also seek comment on likely advances in the design of integrated circuits (ICs) to be used in radio frequency equipment for higher frequencies. Developers of 5G technology are investigating complementary metal-oxide-semiconductor (CMOS) and silicon-germanium (SiGe) chips. Many factors impact the design of the ICs, including size and power consumption. What does industry see as the leading design for ICs that should be used in equipment for frequencies above 24 GHz? Will developments in design produce ICs that are of a suitable size for handheld devices? Will their power consumption be supportable by current handheld batteries? Are these developments likely to lead to mobile devices that are capable of utilizing bands above 24 GHz? What is the potential for using CMOS above 70 GHz?

c. Operation

27. As mentioned earlier, it seems possible that mmW band technologies within a cellular network will be a supplementary component within an architecture that will continue to use lower frequencies. Considering such a multi-layer architecture, how would a user connect to the network and how will base stations detect and transmit to a mobile user in their coverage areas, particularly given the high directivity of mmW band antenna technology? How would handoffs between cells be coordinated? In this multi-layer architecture, does a mmW band network rely on the overlay network for any type of assistance in order to provide a seamless service? Do commenters anticipate any special challenges involved in handoffs between indoor and outdoor environments? How would the network handle multipath and diffraction interference that can arise in a dense urban environment?

28. The configurations of multiple antenna arrays pointing at varying angles and covering different parts of the base station coverage area could lead to aggregate interference. If so, how will base stations manage power and directional coverage to avoid harmful interference among licensees?

29. Considering the potential use of advanced antenna technologies that include dynamic beam-forming, how will 5G mobile stations in the mmW bands identify themselves to a base station and establish an initial connection? The limited coverage areas of mmW mobile service base stations may also require more frequent hand-offs as the handset moves between cells. If so, which would be more likely to handle the processing - the network or the handset - and to what extent? How will adequate continuity of coverage be achieved?

2. Bandwidth, Duplexing, Modulation, and Multiple Access

30. We seek comment on how much contiguous spectrum will be needed to support advanced mobile services and other contemplated services in bands above 24 GHz. Nokia's studies suggest the need for 2 gigahertz of contiguous spectrum to achieve maximum data throughputs of 10 Gbps and at least 100 Mbps at the cell edge with a maximum latency of no more than 1 millisecond.⁴⁰ Samsung has demonstrated 500 megahertz systems in the 28 GHz band with data rates ranging from 260 Mbps to 1 Gbps.⁴¹ We also seek comment on whether technology will allow licensees to effectively aggregate smaller, non-contiguous blocks of spectrum for use in providing mobile services, possibly reducing the need for large blocks of contiguous spectrum.⁴²

31. Most 5G proposals or demonstrations using spectrum above 24 GHz are based on Time-Division Duplexing (TDD), whereas most 3G/4G systems are currently designed based on Frequency-Division Duplexing (FDD).⁴³ Are there any inherent advantages of using TDD in higher frequency bands as compared to FDD? We seek comment on whether developers of 5G services are considering new technologies such as "Any Division Duplexing" (ADD), which proposes the possibility of using self-interference cancellation techniques.⁴⁴ In light of the advantages of a flexible use policy, it would appear to be appropriate to allow licensees to choose their methods of duplexing for mobile wireless use in higher frequency bands. We seek comment on this issue.

32. Early 2G systems were based on narrowband, single carriers with various coding and modulation techniques. Subsequently, 3G systems widely used spread-spectrum technology, utilizing 1.25 megahertz to 5 megahertz channel bandwidths, which provided higher capacity than 2G systems. The recent deployment of LTE is based on Orthogonal-Frequency-Division Multiplexing (OFDM), which provides the capability to use a variety of channel bandwidths up to 20 megahertz or more for downlinks and uplinks.⁴⁵ It appears that the current 5G demonstration systems in bands above 24 GHz are built with single carrier modulation. We note that in system development there are tradeoffs between using complex coding and modulation schemes that promote spectral efficiency versus simpler schemes that can be developed quickly and with less expense. Do commenters anticipate that systems incorporating mmW bands for mobile use will initially use simpler modulation and coding schemes? What would be the difference in the cost and timeline to develop more complex systems initially? How should the tradeoffs between simplicity and efficiency be taken into account as advanced mobile service technologies are developed in the mmW bands, and how should the Commission's future consideration of these bands take account of these tradeoffs?

33. Multiple Access schemes would allow simultaneous connections of many users to the network. Time-Division-Multiple-Access (TDMA), Frequency-Division-Multiple-Access (FDMA),

⁴⁰ See Amitabha Ghosh, *Can Mwave Wireless Technology Meet the Future Capacity Crunch*, Nokia Siemens Networks, Inc., June 11, 2013, available at http://icc2013.ieee-icc.org/Mmwave_Spring_ICC2013_Ghosh.pdf.

⁴¹ See Wonil Roh, Communications Research Team, Samsung Electronics Corp., *Performances and Feasibility of mmWave Beamforming Prototype for 5G Cellular Communications*, Presentation to IEEE ICC 2013, June 11, 2013.

⁴² See, e.g., *Applications of Self Interference Cancellation in 5G and Beyond*, IEEE Communications Magazine, February 2014 at 114 ("Applications of Self Interference Cancellation") (raising the idea of a software controlled duplexer to simplify and reduce the cost of supporting multiple fragmented frequencies).

⁴³ Although Clearwire has deployed a TDD version of WiMAX system in the 2.5GHz BRS band, most of 2G/3G/4G systems are based on FDD.

⁴⁴ See *Applications of Self Interference Cancellation* at 115.

⁴⁵ There have been proposals to expand CDMA systems beyond 5 megahertz at a cost of higher complexity due to faster clock speed. The tonal structure of OFDM substantially reduced the implementation complexity and LTE Advanced can aggregate up to five carriers (up to 100 megahertz) to increase user data rates. See <https://www.qualcomm.com/products/lte/advanced>.

Code-Division-Multiple-Access (CDMA), and Orthogonal-Frequency-Division-Multiple-Access (OFDMA) have been implemented in 2G/3G/4G systems. We seek comments on the multiple access schemes for mmW mobile systems. What are the limiting factors or considerations for determining the best multiple access schemes for those bands? Again, we do not contemplate mandating the use of specific access schemes but, rather, seek to develop a better understanding of emerging technologies.

3. Performance and Coverage

34. We also seek comment on the specifications for data throughput, latency and other performance metrics that would be associated with advanced mobile services in the mmW bands. At least one source suggests that 5G would provide data rates up to 10 Gbps maximum and at least 100 Mbps at cell edges, with latencies of less than 1 millisecond.⁴⁶ We ask whether these are reasonable expectations for the performance of advanced mobile services in these bands. If so, how will access to these types of data rates affect businesses and consumers? Would such capabilities create opportunities for new applications that do not exist today or ameliorate network congestion that would otherwise occur due to anticipated growth in traffic?

35. In addition, we note that, by their nature, radio signals in bands above 24 GHz propagate over short distances, and the atmospheric absorption characteristics of those bands further restricts coverage. The Commission recognizes that 5G system designs are not fully developed, and that there are many undetermined technical specifications that will impact their potential coverage. However, we encourage commenters to describe how to characterize coverage in comparison with today's networks that typically provide coverage over wide areas. What are the likely or possible coverage areas of individual mmW base stations that enable mobile service as part of a 5G network? How do the coverage areas scale as the number of base stations increases? Are the coverage areas sufficient to provide service outside of dense urban areas? For a given coverage claim, the Commission invites commenters to explain the relevant assumptions, such as frequency band, cell-edge throughput, RF environment (urban/suburban/rural, LOS/NLOS, etc.), antenna complexity (size of array for beam-forming) for access points, and end-user equipment and the interference environment from other access points and users.

4. Network Architecture

36. We note that there are two predominant models of wireless network deployments. One is the service provider model, usually with licensed spectrum, where a single operator deploys and manages a network. In this model, service providers deploy a network composed of a radio access network and core network to provide wireless coverage and capacity to subscribers of the service. Service provider deployments increasingly support various levels of heterogeneity among kinds of base stations, allowing the operators to manage their resources effectively and maintain service quality.

37. The other model is decentralized Wi-Fi-like deployment, in which network elements are mostly deployed by end users. This model offers service with limited coverage utilizing low-power access points. Under this model, the network architecture tends to be flatter, because each access point is not as tightly interconnected or managed by a centralized authority. One of the advantages of this model is support for millions of access points deployed by a multitude of service providers, organizations and individual users.

38. According to CTIA, wireless operators had deployed 304,360 cell sites in the United States providing wireless connections to more than 335 million devices as of December 2013.⁴⁷ Operators are increasingly using small cells to enhance coverage and add capacity. By one estimate, over

⁴⁶ See Mark Cudak, *et al.*, *Moving Towards MMWave-Based Beyond-4G (B-4G) Technology*, Vehicular Technology Conference (VTC Spring), 2013 IEEE 77th.

⁴⁷ See <http://www.ctia.org/your-wireless-life/how-wireless-works/annual-wireless-industry-survey>.

six million small cells were deployed worldwide by late 2012.⁴⁸ Similarly, ABI Research reported 4.2 million Wi-Fi hotspots in 2013 deployed by mobile and fixed-line operators,⁴⁹ and the Wireless Broadband Alliance has reported 416 million private hotspots in 2012 globally.⁵⁰ In the United States, Comcast announced that Xfinity's Wi-Fi network will reach 8 million hot spots by the end of 2014.⁵¹

39. We recognize the consumer benefits of both deployment models. We also recognize the difference in the potential scale of access point deployments under the two models. What type of deployment model – operator-driven, user-driven, or a new model or models – do commenters envision for mmW mobile services, and what network architectures could support the anticipated scale of deployment? How would mmW mobile network architecture compare with the current 3G/4G architecture or Wi-Fi-like hotspot architecture? Would there be a hybrid model that can support various types of deployment, and what are the enabling technologies to achieve such goals? Note that we discuss the benefits and costs of different licensing mechanisms, which roughly correspond to some of these architectural distinctions, in Section C, below.

5. Technical Rules

40. The Commission has applied various approaches to establishing technical rules for services operating above 24 GHz. There are two approaches that are particularly relevant here. For point-to-point services, the Commission's rules specify detailed technical requirements including specific channel plans, bandwidth limits, tolerance, emission limits, out-of-band emission (OOBE) limits, maximum transmitter power and/or EIRP, minimum antenna gains, and requirements for channel loading.⁵² In contrast, in services such as LMDS and 39 GHz, which have been licensed, by auction, on a geographic area basis, licensees have a great deal of flexibility in deciding how to deploy their equipment and services, subject to basic limits on power or requirements to coordinate with other licensees near the borders of their service areas. Given that the technology is still in the early stage of development, we recognize that it is premature to seek comment on detailed technical rules at this time. We believe that certain technical parameters are more universally applicable regardless of the technologies and regulatory environment. We therefore seek comment on certain technical parameters, which will help us develop the general outlines of technical rules that we could adopt for mobile and other services in the bands above 24 GHz. In addition to the specific issues discussed below, we seek general comment on any other technical requirements we should consider within our rules, including any information about new technologies that will facilitate the assessment of protection for incumbent services in the bands above 24 GHz that are proposed as suitable.

41. What maximum transmit power and/or EIRP limits would be appropriate for mobile services in the mmW bands? Is the +55 dBW EIRP limit currently applicable in the 27.5-28.35 GHz band and 39 GHz band appropriate?⁵³ Given the probability of these systems using small cell

⁴⁸ See *Small Cells Outnumber Traditional Mobile Base Stations*, Small Cell Forum, Press Release (Oct. 31, 2012) (available at <http://www.smallcellforum.org/newsstory-small-cells-outnumber-traditional-mobile-base-stations>).

⁴⁹ See *Global Wi-Fi Hotspots Will Grow to 7.1 Million in 2015 as a Method to Offload Traffic*, Press Release, ABI Research (May 8, 2014), available at <http://www.directionsmag.com/pressreleases/global-wi-fi-hotspots-will-grow-to-7.1-million-in-2015-as-a-method-to-offload/398302>.

⁵⁰ See *Global Developments in Public Wi-Fi*, Wireless Broadband Alliance, at 6, available at http://www.wballiance.com/wba/wp-content/uploads/downloads/2012/07/16_WBA-Industry-Report-2011-Global-Developments-in-Public-Wi-Fi-1.00.pdf.

⁵¹ See *Comcast to Reach Eight Million Xfinity WiFi Hotspots in 2014*, Apr. 30, 2014), available at <http://corporate.comcast.com/news-information/news-feed/comcast-to-reach-8-million-xfinity-wifi-hotspots-in-2014>.

⁵² See generally 47 C.F.R. Part 101.

⁵³ See 47 C.F.R. § 101.113(a).

architecture, are lower power limits more appropriate? What are the tradeoffs? Would a power spectral density or power flux density limit be more appropriate, and, if so, at what minimum unit of bandwidth?⁵⁴ Considering the potential for complex antenna arrays and multiple simultaneous beams, should the limits be set for each antenna beam, or should our requirements be applied to the aggregate of all beams? What should the appropriate limits be for mobile units? What other factors should be considered in the assessment of incumbent service protection?

42. We also seek comment on appropriate OOB limits. Would an attenuation of $43 + 10\log(P)$ for out-of-band emissions be appropriate? If not what OOB limits or range of limits would be appropriate for the mmW bands above 24 GHz? Again, considering the possibility of large antenna arrays and multiple simultaneous beams, would OOB limits need to be specified for each antenna element, or do they need to take into account the aggregate signals from all beams?

43. The addition of mobile services in the mmW bands may also change the way licensees interact in adjacent market areas. We seek comment on the rules that will be necessary to prevent harmful interference between licensees in adjacent geographic areas using the same frequency bands. Will interference management issues be different for wireless networks using so-called 5G technologies? In the 39 GHz and LMDS bands, licensees are required to coordinate with other licensees if they propose to operate near the license area of another licensee, but the rules do not contain any PFD limits at the boundaries of license areas.⁵⁵ Will we need to establish PFD limits to prevent harmful interference? Alternatively, would it be appropriate to establish field strength limits at the borders of license areas, as we currently do in certain Part 27 services? Given the dynamic characteristics and robustness anticipated for new mobile technologies in the mmW bands, what would constitute appropriate protections against harmful interference?

6. Alternative Uses, Including Backhaul

44. We recognize that some parties may contemplate uses other than mobile services for the mmW bands. In some of these bands, incumbent licensees currently offer fixed (including point-to-multipoint) services. In addition, other parties may contemplate that the mmW bands would be used for non-mobile services. We invite those parties to explain their current and proposed uses of the mmW bands. Those parties should explain whether their uses would be compatible with mobile services as well as existing incumbent operations. We also ask parties proposing service rules for mobile use to offer rules that would accommodate as wide a variety of services and uses as possible.

45. We specifically inquire about the utility of the mmW bands for backhaul. The Commission also recognizes that availability of economical backhaul solutions for small cell deployment is a challenge in today's environment and expects it to continue to be a challenge for access point deployment in the future. We seek comment on the extent to which it is feasible to use bands above 24 GHz for backhaul, particularly non-line-of-sight (NLOS) backhaul, which may be necessary for dense cell deployments. Are there enabling technologies that will facilitate the shared use of bands for different types of uses? Could the 5G technologies discussed above also provide backhaul capabilities? Would it be possible to use "in band" service in which backhaul reuses frequencies that are also used for access? Given the short ranges of developing 5G technologies, would mesh or multi-hop architectures be viable?

⁵⁴ Power flux density is the amount of power flow through a unit area within a unit bandwidth. See 47 C.F.R. § 25.103. The units of power flux density are those of power spectral density per unit area, namely watts per hertz per square meter. *Id.* Power spectral density is the amount of an emission's transmitted carrier power applied at the antenna input falling within the stated bandwidth. *Id.* The units of power spectral density are watts per hertz. *Id.*

⁵⁵ See Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies For Local Multipoint Distribution Service and For Fixed Satellite Services, CC Docket No. 92-297, *Second Report and Order, Order on Reconsideration and Fifth Notice of Proposed Rulemaking*, 12 FCC Rcd 12545, 12663-12664 ¶¶ 277-281 (1997) ("*Second LMDS Report and Order*"); *39 GHz R&O*, 12 FCC Rcd at 18614-18615 ¶¶ 21-25.

To what extent could mmW band-based backhaul address gaps or high costs to extend fiber optic networks?

B. Frequency Bands Above 24 GHz for Mobile Services

46. Since most of the candidate bands above 24 GHz are already shared and, most likely, will continue to be shared by other services, it is important to determine whether or not those services are compatible with advanced mobile service in the mmW bands. Similarly, in selecting the most suitable bands above 24 GHz for mobile services, we must determine whether advanced mobile operations in a given band are consistent with our country's goals of encouraging highly efficient use of spectrum, as well as promoting innovation, investment, and America's global competitiveness.⁵⁶ The following discussion seeks comment on various aspects of the band selection issues we have introduced in this paragraph.

47. In the context of which bands above 24 GHz are most suitable for advanced mobile services, we seek comment on the extent to which we should consider international allocations and service rules in other countries in order to foster global harmonization. Various international organizations and standards bodies, including 3GPP, 5GNow, and METIS have launched 5G-oriented research and development programs.⁵⁷ These organizations are made up of various different vendors, operators, and academic organizations.⁵⁸ We recognize that these entities will play a significant role in determining the technical requirements and standards for 5G systems and technologies, including the use of mmW bands for mobile wireless services. A common goal cited by these organizations is to build consensus and contribute to standardization of future mobile and wireless communications.⁵⁹ Several entities have projects that will be ongoing at least through the spring of 2015, including the METIS 2020 project,⁶⁰ and the 5GNow project.⁶¹ We anticipate that the activities of these organizations, and others, will help to inform this proceeding, so we invite parties that are involved in or familiar with these ongoing activities to comment on the global technical and regulatory requirements that are being considered and/or proposed in these bands for 5G services.

48. We note that most of the bands that we explore in the context of this *Notice of Inquiry* are allocated internationally for fixed and mobile services.⁶² We recognize that in a global economy there will often be a need for single devices to operate seamlessly throughout more than one, or perhaps even throughout many different countries. Further, global harmonization of regulatory and technical requirements will promote global economies of scale in equipment manufacturing. To that end, how essential is global harmonization of technical and regulatory requirements to the success of advanced mobile services? What are the economic benefits of global harmonization within the bands above 24

⁵⁶ See Federal Communications Commission Strategic Plan 2012-2016, Goals 2 and 4.

⁵⁷ See Paragraph 9, *supra*.

⁵⁸ See 3GPP's website at <http://www.3gpp.org/about-3gpp/about-3gpp>; METIS website at <https://www.metis2020.com/about-metis/partners/>; and 5GNow website at <http://www.5gnow.eu/node/6>.

⁵⁹ See 5GNow's website at <http://www.5gnow.eu/node/1>; see also METIS web site at <https://www.metis2020.com/about-metis/project-objectives/>.

⁶⁰ See METIS 2020 project website at https://www.metis2020.com/documents/deliverables/?doing_wp_cron=1399302874.2642769813537597656250, referencing a final project report deliverable of April 30, 2015.

⁶¹ See 5GNow project website at <http://www.5gnow.eu/node/1> referencing a start date of September 1, 2012 and end date of February 28, 2015.

⁶² See international table of allocations. 27.5 – 28.35 GHz, 29.1 – 29.25 GHz, 31 – 31.3 GHz, 37 – 38.6 GHz, 38.6 – 40 GHz, 42 – 42.5 GHz, 57 – 64 GHz, 71 – 76 GHz, 81 – 86 GHz and 92 – 94 GHz all have fixed and mobile allocations in Region 1, Region 2, and Region 3.

GHz for these services? Do certain bands suit these services better because of existing global allocations and/or regulatory frameworks in various countries?

49. We also note that research and development efforts underway for 5G envision devices that will use adaptive software-defined air interfaces and software-defined networking techniques. These types of interfaces may provide intelligence and flexibility that can enable handsets and user equipment to operate seamlessly across different networks, different technologies, and different frequency bands.⁶³ What effect would the use of such technology have on the suitability of certain bands for mobile mmW services? Would the use of such technology reduce the need for large blocks of contiguous spectrum? Would the use of such technology allow for different network architectures that would enable devices to work seamlessly across different frequency bands? What effect would the capability of operating across different frequency bands have on the appropriate regulatory licensing framework?

50. In the discussion below, we invite comment on the suitability of the Local Multipoint Distribution Service (LMDS) bands, the 39 GHz band, the 37/42 GHz bands, the 60 GHz band, the 70/80 GHz bands, and the 24 GHz band for advanced mobile services. We also invite comment on any other bands above 24 GHz that are not included in this list but might be appropriate. We seek comment and discussion on bands above 95 GHz that commenters believe would be suitable candidates for mobile services. As with other bands, we encourage commenters to explain the characteristics that enable mobile services, the nature and extent of incumbent services, and steps that can be taken to ensure incumbent uses are protected.⁶⁴ Our intent is to examine any mmW bands that could be suitable for advanced mobile services, whether or not the band is part of a global and organized standards effort for 5G. The following is a brief summary of the most salient characteristics of the relevant bands.

1. LMDS Band (27.5-28.35 GHz, 29.1-29.25 GHz, and 31-31.3 GHz)

51. *Bandwidth:* 1,300 megahertz. In 1997, the Commission allotted 1,300 megahertz of LMDS spectrum in each basic trading area (BTA) across the United States.⁶⁵ Specifically, the

⁶³ See presentation “Mobile and Wireless Communications system for 2020 and beyond(5G) by Dr. Afif Osseiran, Ericsson - <https://www.metis2020.com/wp-content/uploads/presentations/ITU-R-2020-VisionWS.pdf>. See also An efficient RAT selection mechanism for 5G cellular networks by Alexandros Kaloxylos *Senior Member, IEEE*, Sokratis Barmounakis, Panagiotis Spapis, Nancy Alonistioti - https://www.metis2020.com/wp-content/uploads/publications/IWCMC_2014_Kaloxyls_et_al_RATSelectionMechanismFor5G.pdf.

⁶⁴ We recognize that there are also pending proposals relating to fixed use of bands above 24 GHz. See, e.g., Comments of the Fixed Wireless Communications Coalition in Response to Notice of Inquiry, WT Docket No. 10-153 (filed Oct. 5, 2012) (proposing changes to antenna standards for 71-76 and 81-86 GHz bands); Petition for Rulemaking, Battelle Memorial Institute, RM-11713 (filed Feb. 6, 2014) (requesting commencement of proceeding to establish fixed service rules for the 102-109.5 GHz band). For the most part, proposals relating to fixed operation in these bands will be addressed separately. We will discuss in this *Notice of Inquiry* FWCC’s petition for rulemaking seeking commencement of a proceeding to establish fixed service rules in the 42-43.5 GHz band because that proposal raises the question of what uses would be appropriate in that band. We note that the TAC examined the use of bands above 95 GHz, and, unlike other mmW bands where it suggested issuing this *Notice of Inquiry*, suggested instead that the Commission should carefully balance the benefits and risks of adopting service rules in these bands and take an active role to establish a framework for coexistence with passive services. See *TAC September 23, 2013 Meeting Presentation*.

⁶⁵ See *Second LMDS Report and Order*, 12 FCC Rcd at 12605 ¶ 136 (1997); see also Rand McNally Commercial Atlas & Marketing Guide 36-39 (123rd ed. 1992). Rand McNally is the copyright owner of the Major Trading Area (MTA) and BTA Listings, which list the BTAs contained in each MTA and the counties within each BTA, as embodied in Rand McNally’s Trading Area System MTA/BTA Diskette, and geographically represented in the map contained in Rand McNally’s Commercial Atlas & Marketing Guide. The conditional use of Rand McNally copyrighted material by interested persons is authorized under a blanket license agreement dated February 10, 1994 and covers use by LMDS applicants. This agreement requires authorized users of the material to include a legend on reproductions (as specified in the license agreement) indicating Rand McNally ownership. The Commission has allocated the LMDS for operations in a total of 493 BTAs throughout the nation.

Commission allocated two LMDS licenses per BTA – an “A Block” and a “B Block” in each.⁶⁶ The A Block license is comprised of 1,150 megahertz of total bandwidth, and the B Block license is comprised of 150 megahertz of total bandwidth.⁶⁷ The A Block consists of the sub bands 27.50-28.35 GHz (the A1 Band); 29.10-29.25 GHz (the A2 Band); and 31.075-31.225 GHz (the A3 Band).⁶⁸ The B Block consists of the sub bands 31.00-31.075 (the B1 Band) and 31.225-31.30 GHz (the B2 Band).⁶⁹

52. *Licensing Status:* Of the 986 designated license areas (493 BTAs times two licenses per BTA), 416 areas have active licenses, which cover about 75 percent of the U.S. population.

53. *Status of Mobile Allocation and Rights:* LMDS occupies portions of two spectrum bands that the Commission has allocated on a co-primary basis for Fixed and Mobile services, as reflected in the U.S. Table of Frequency Allocations.⁷⁰ While the Commission has not, to date, authorized any specific service (including LMDS) to provide mobile service in those bands, it did express an expectation that it would expand the LMDS authorization for Fixed service to include Mobile service if proposed and supported by the resulting record. In the *LMDS Second Report & Order*, the Commission stated:

To ensure the flexibility in LMDS service offerings that commenters seek and we proposed, we will permit any fixed terrestrial uses that can be provided within the technical parameters for LMDS. We conclude that, for now, our significant allocation of spectrum under such a broad and flexible service definition should permit licensees to satisfy a broad array of their customers' communications needs, whether through one or multiple service offerings. Although LMDS is allocated as a fixed service, we know of no reason why we would not allow mobile operations if they are proposed and we obtain a record in support of such an allocation. We believe this would be consistent with our goal of providing LMDS licensees with maximum flexibility in designing their systems. We have authorized other wireless services to include mobile and fixed services, depending on whether developments in the service and related equipment demonstrate a need for changing the rules and a capability for mobile and fixed services to coexist in these bands.⁷¹

54. *Other Authorized Services:* There are no primary federal allocations in the LMDS band. For the 27.5-28.35 GHz band segment, the U.S. Table of Frequency Allocations includes a co-primary Fixed-Satellite Service (FSS) Earth-to-space allocation,⁷² but Section 25.202 of the Commission's rules provides that the FSS is secondary to LMDS in that band.⁷³ Twenty stations are licensed for Earth-to-space transmissions on a secondary basis in the 27.5-28.35 GHz band.⁷⁴ For the 29.1-29.25 GHz band segment, Section 25.202 of the Commission's rules provides that 29.1-29.25 GHz is co-primary for Mobile-Satellite Service (MSS) feeder links and LMDS,⁷⁵ and Section 101.1001 of the Commission's rules limits LMDS to hub-to-subscriber transmissions in this band segment.⁷⁶ Section 25.257 of the

⁶⁶ See *Second LMDS Report and Order*, 12 FCC Rcd at 12556 ¶ 12.

⁶⁷ See *id.*

⁶⁸ See 47 C.F.R. § 101.1005.

⁶⁹ See *id.*

⁷⁰ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁷¹ *LMDS Second Report & Order*, 12 FCC Rcd at 12637 ¶ 207.

⁷² See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁷³ 47 C.F.R. § 25.202(a)(1) n.2.

⁷⁴ On May 13, 2014, the Commission's IBFS database listed 20 FSS Earth-to-space licenses for the 27.5-28.35 GHz band.

⁷⁵ 47 C.F.R. § 25.202(a)(1), n.6. Pursuant to 47 C.F.R. § 25.202(g), the edges of the band are also used for telemetry, tracking, and command functions.

⁷⁶ 47 C.F.R. § 101.1001(b)(2).

Commission's rules allows as many as ten MSS feeder link earth station complexes to be deployed in the 29.1-29.25 GHz band segment,⁷⁷ but there are currently only five active licenses for feeder link and telemetry, tracking, and command earth stations in those frequencies.⁷⁸ The 31-31.3 GHz band segment has co-primary allocations for terrestrial Fixed and Mobile services, with a secondary federal and non-federal allocation for space-to-Earth standard frequency and time signal operations.⁷⁹

55. We seek comment on the suitability of the LMDS band for advanced mobile services of the kind discussed above. With respect to the 27.5-28.35 GHz band, we note that satellite operations are secondary to LMDS, but there appears to be considerable satellite use of that band. Does the 29.1-29.25 GHz band contain sufficient spectrum to make it useful for advanced mobile services, and is there any way to authorize mobile use while protecting co-primary MSS feeder links? With respect to the 31-31.3 GHz band, we ask commenters whether that band contains sufficient spectrum to be useful for advanced mobile services. LMDS operators are presently required to follow Part 101 Fixed Service rules to coordinate frequency use with LMDS operators in adjacent license areas, but the last time the Commission addressed the issue of using, as an alternative mechanism of preventing co-channel interference, power flux density (PFD) or other limits at boundaries between geographic service areas (GSAs), it did not have a sufficient record to develop such limits.⁸⁰ In general, we have found it necessary to establish such specified limits whenever we have authorized the provision of mobile services by licensees holding exclusive service rights for GSAs.⁸¹ We invite comments on PFD limits and any additional requirements that might be necessary to prevent harmful interference between adjacent LMDS operators if we authorize them to begin providing mobile services. In addition, commenters are requested to address any adjacent band protection requirements related to federal FSS and MSS (Earth-to-space) in the 30-31 GHz band if the 31-31.3 GHz band is proposed to be suitable for advanced mobile services.

2. 39 GHz Band (38.6-40 GHz)

56. *Bandwidth and Channelization:* 1,400 megahertz. The band is licensed by Economic Area (EAs) (there are 176 EAs).⁸² There are fourteen paired blocks of 50 by 50 megahertz channels.⁸³ In addition, there are currently 229 active Rectangular Service Area (RSA) licenses that predate the creation of the EA licenses and where the licensees self-defined their service area. Those RSA licensees retain the exclusive right to operate within their RSAs.⁸⁴

57. *Licensing Status:* Out of 2,464 possible EA licenses (14 channel pairs for each of 176 EAs), 859 are currently licensed. Other licenses were voluntarily cancelled or terminated for failure to meet substantial service requirements.⁸⁵ The populations in licensed areas (both EA and RSA licenses) vary by channel, but in aggregate they cover about 49 percent of the U.S. population.

⁷⁷ 47 C.F.R. § 25.257(c). There is only one NGSO MSS operator licensed to use the 29.1-29.25 GHz band, but that operator may have up to eight feeder link earth station complexes transmitting in the band.

⁷⁸ On June 10, 2014, the Commission's IBFS database listed five MSS Earth-to-space licenses for Iridium for the 29.1-29.25 GHz band, under call signs E960131, E960244, E960272, E050282, and E060300.

⁷⁹ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁸⁰ *LMDS Second Report & Order*, 12 FCC Rcd at 12663-12664 ¶¶ 277-281. See also 47 C.F.R. § 101.103(g).

⁸¹ See, e.g., 47 C.F.R. § 27.55.

⁸² See 47 C.F.R. § 101.147(v)(2).

⁸³ See 47 C.F.R. § 101.147(v)(1).

⁸⁴ See *39 GHz R&O*, 12 FCC Rcd at 18637 ¶ 79.

⁸⁵ See 47 C.F.R. § 101.17.

58. *Status of Mobile Allocation and Rights:* This band has a co-primary allocation for fixed and mobile services.⁸⁶ The Commission provided licensees the flexibility to provide mobile services and stated the belief that “the issue of technical compatibility of fixed and mobile operations within a service area is one that can and should be resolved by the licensee.”⁸⁷ The Commission declined to permit mobile operations, however, until it conducted a separate proceeding to resolve inter-licensee and inter-service interference issues.⁸⁸

59. *Other Authorized Services:* There are no Federal allocations in the 38.6-39.5 GHz band.⁸⁹ There is a Federal allocation for FSS (space-to-Earth) and MSS (space-to-Earth) in the 39.5-40 GHz band. Federal government earth stations in the MSS in the 39.5-40 GHz band are prohibited from claiming protection from non-Federal stations in the fixed and mobile services in this band, but are not required to protect non-federal fixed and mobile services in the band (i.e., 5.43A of the ITU Radio regulations does not apply).⁹⁰ This prohibition does not apply to Federal government earth stations in the FSS. When the *39 GHz Order* was adopted, Federal government use of the band was limited to military systems in the 39.5-40 GHz band segment, but the Department of Defense stated that it had plans to implement satellite downlinks at 39.5-40 GHz in the future, and the National Aeronautics and Space Administration (NASA) identified 39.5-40 GHz as a possible space research band to accommodate future Earth-to-space wideband data requirements.⁹¹ The *39 GHz Report and Order* expressed optimism that such plans would not affect the continued development of the 39 GHz band for non-Government use, but the Commission said that it intended to address those interference issues in a future, separate proceeding that would focus on developing inter-licensee and inter-service standards and criteria.⁹² At present, the U.S. Table of Frequency Allocations provides that Federal satellite services in the 39.5-40 GHz band are limited to military systems.⁹³

60. Non-Federal government FSS (space-to-Earth) is co-primary throughout the entire 39 GHz band,⁹⁴ but, under a “soft segmentation” band plan adopted by the Commission in 2003, FSS is subject to lower power flux density limits in the 37.5-40 GHz band to accommodate high-density fixed terrestrial systems.⁹⁵ Hughes Network Systems, LLC holds the only non-Federal FSS authorization to

⁸⁶ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁸⁷ See *39 GHz R&O*, 12 FCC Rcd at 18615 ¶ 24.

⁸⁸ See *39 GHz R&O*, 12 FCC Rcd at 18615 ¶ 25.

⁸⁹ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁹⁰ See Table of Frequency Allocations, 47 C.F.R. § 2.106, footnote US382.

⁹¹ *39 GHz Order*, 12 FCC Rcd at 18615 ¶ 25.

⁹² *39 GHz Order*, 12 FCC Rcd at 18615 ¶ 25.

⁹³ 47 C.F.R. § 2.106, Table of Frequency Allocations, Federal Government Footnote G117.

⁹⁴ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

⁹⁵ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106; Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, IB Docket No. 97-95, *Second Report and Order*, 18 FCC Rcd 25428, 25438 ¶ 24 (2003) (“*V-Band Second Report and Order*”). See also 47 C.F.R. § 25.208(r). The Commission has pending a proposal to establish procedures pursuant to which FSS licensees may raise their power flux density levels if necessary to compensate for “rain fade.” See Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, *Third Further Notice of Proposed Rulemaking*, 25 FCC Rcd 15663 (2010) (“*V-Band Third Further FNPRM*”).

provide space-to-Earth transmissions in this band (at 39-40 GHz); the IBFS database shows no pending applications.⁹⁶

61. We seek comment on the suitability of the 39 GHz band for advanced mobile services. As noted above, the Commission assumed that geographic area licensees would be in the best position to coordinate fixed and mobile uses in that band. Is that assumption still accurate, or are additional procedures or rules necessary? Also, in the *39 GHz Order*, the Commission required that 39 GHz operators follow Part 101 Fixed Service rules to coordinate frequency use with operators in adjacent license areas, but it did not establish power-flux-density limits or other rules to govern interference between geographically adjacent licensees.⁹⁷ As mentioned above, we generally find it necessary to establish such specified limits whenever we authorize the provision of mobile services by licensees holding exclusive GSA service rights.⁹⁸ We invite comments on the need for such a requirement to accommodate the provision of advanced mobile services in the 39 GHz band. With respect to the FSS, do the existing limitations on satellite power flux density make such operations compatible with mobile operations? What other technology characteristics should be taken into account to assess compatibility between potential commercial mobile broadband service with existing incumbent operations including federal MSS and FSS? Are there any additional measures needed in terms of OOB limits that are needed to protect federal MSS and FSS downlink operations in the adjacent 40-40.5 GHz band? We also seek comment on whether any limitations or special rules on mobile use would be necessary in order to protect Federal military FSS use of the 39.5-40 GHz band.

3. 37/42 GHz Bands (37.0-38.6 GHz and 42.0-42.5 GHz)

62. *Bandwidth and Channelization:* 1600 and 500 megahertz, respectively. Because there are currently no terrestrial service rules in place for these bands, there is no channelization plan for the allocated terrestrial services.

63. *Licensing Status:* In 2004, the Commission sought comment on establishing fixed and point-to-point multipoint service rules in the 37 GHz and 42 GHz bands, as well as allowing “mobile use in the future, if and when the technology develops.”⁹⁹ In early 2005, commenters, including First Avenue Networks, Inc., Winstar Communications, LLC, and the Fixed Wireless Communications Coalition (FWCC), believed that it was not in the public interest to license the 37 GHz and 42 GHz bands at that time because the supply of millimeter wave spectrum exceeded the demand for such spectrum.¹⁰⁰ The Commission has not issued final rules in response to the *37/42 GHz NPRM*.

64. On May 9, 2012, FWCC filed a petition for rulemaking seeking the establishment of service rules for fixed point-to-point use of the 42-43.5 GHz band under Part 101 of the Commission’s

⁹⁶ Hughes Network Systems, LLC, license file SAT-LOA-20111223-00248. See Policy Branch Information Actions Taken, Report No. SAT-00889, *Public Notice*, 27 FCC Rcd 9293 (IB Pol. 2012).

⁹⁷ *39 GHz Order*, 12 FCC Rcd at 18613-186125 ¶¶ 21-25.

⁹⁸ See, e.g., 47 C.F.R. § 27.55.

⁹⁹ See Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands; Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 and PP Docket No. 93-253, *Third Notice of Proposed Rulemaking*, 19 FCC Rcd 8232, 8242 ¶ 25 (2004) (“*37/42 GHz Third NPRM*”).

¹⁰⁰ See Reply Comments of the Fixed Wireless Communications Coalition, ET Docket No. 95-183 and PP Docket No. 93-253 (filed Jan. 3, 2005); Reply Comments of Winstar Communications LLC, ET Docket No. 95-183 and PP Docket No. 93-253 (filed Jan. 3, 2005); Comments of First Avenue Networks, Inc., ET Docket No. 95-183 and PP Docket No. 93-253 (filed Dec. 2, 2004).

rules.¹⁰¹ The Commission continues its evaluation of FWCC's petition for rulemaking. Accordingly, there are no service rules or licenses for terrestrial operation in these bands.

65. *Status of Mobile Allocation and Rights:* There are co-primary allocations for terrestrial mobile service in these bands, but the Commission has not yet adopted service rules to authorize such services.¹⁰² All operations in the 42-42.5 GHz band are urged to take all practicable steps to protect radio astronomy observations in the 42.5-43.5 GHz band from interference.¹⁰³

66. *Other Authorized Services:* In 2004, NTIA sent a letter to the Commission identifying the following NASA receiving earth stations in the space research service in the band 37-38 GHz band: Goldstone, California; Guam, Pacific Ocean; Merritt Island, Florida; Wallops Island, Virginia; and White Sands, New Mexico.¹⁰⁴ NTIA also identified Green Bank, Virginia; and Socorro, New Mexico NSF sites to support their Very Long Baseline Interferometry (VLBI) earth station operations. NTIA noted the importance of the band 37-38 GHz to support U. S. goals to provide a permanent manned presence in Earth orbit (on or near the moon) and to initiate manned exploration of the planet Mars, and to support VLBI by satellite. There is also an allocation for federal space research, fixed, and mobile service operations in the band 37-38.6 GHz. NTIA identified 14 military sites in the band 37-38.6 GHz that required protection. NTIA recommended that coordination with the federal operations be performed within the Interdepartment Radio Advisory Committee (IRAC) process. In 2006, NTIA sent a follow-up letter to the FCC reaffirming the need to protect NASA, NSF, and military operations from non-federal terrestrial and fixed-satellite service operations in the band 37-38 GHz.¹⁰⁵ NTIA requested that the protection of federal operations be accomplished by establishing a U.S. footnote to the table of frequency allocations specifying the federal sites and the coordination areas. NTIA also recommended that because of the potential interference from airborne systems, the aeronautical mobile service allocation should be deleted from the band 37-38 GHz.

67. In addition to Fixed and Mobile allocations, there is a co-primary FSS (space-to-Earth) allocation for the 37.5-38.6 GHz band segment, and Broadcasting and Broadcasting-Satellite Service (BSS) allocations for the 42-42.5 GHz band segment.¹⁰⁶ The Commission has proposed eliminating the BSS allocations in the 42-42.5 GHz band and adding a FSS (space-to-Earth) allocation in order to protect adjacent channel radio astronomy in the 42.5-43.5 GHz band.¹⁰⁷ As described above, the soft segmentation plan adopted in the *V-Band Second Report and Order* favors terrestrial services in the 37.0-38.6 GHz band.¹⁰⁸

68. *Termination of ET Docket No. 95-183 and PP Docket No. 93-253.* We will terminate ET Docket No. 95-183 and PP Docket No. 93-253 – dockets in which the record has become stale – and

¹⁰¹ Petition for Rulemaking, Fixed Wireless Communications Coalition, RM-11664 (filed May 9, 2012). FWCC originally sought the establishment of service rules for the 41-42.5 GHz band. In light of opposition from satellite licensees, FWCC revised its proposal to specify the 42-43.5 GHz band. See Letter from Mitchell Lazarus, Esq., counsel for the Fixed Wireless Communications Coalition to Marlene H. Dortch, Secretary, Federal Communications Commission, RM-11664 (filed Feb. 11, 2013).

¹⁰² See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹⁰³ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, note US211.

¹⁰⁴ See letter from Fredrick R. Wentland, Associate Administrator, Office of Spectrum Management, NTIA, dated March 24, 2004, to Mr. Edmond J. Thomas, Chief, Office of Engineering and Technology, FCC.

¹⁰⁵ See letter from Fredrick R. Wentland, Associate Administrator, Office of Spectrum Management, NTIA, dated Sept. 13, 2006, to Mr. Julius Knapp, Chief, Office of Engineering and Technology, FCC.

¹⁰⁶ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹⁰⁷ See *V-Band Third Further NPRM*, 25 FCC Rcd at 15668-15670 ¶¶ 12-19.

¹⁰⁸ See *V-Band Second Report & Order*, 18 FCC Rcd at 25438 ¶¶ 23-24.

resume consideration of potential uses of the 37 GHz and 42 GHz bands in this proceeding (GN Docket No. 14-177). Much has changed since 2005 when comments were filed in those proceedings. We believe it is appropriate to create a new record regarding the potential use of this band for both fixed and mobile services. We will work together with NTIA to ensure that federal operations are protected while maximizing the use of the 37-38.6 GHz band for commercial operations. In addition, it would be appropriate to give NTIA and other federal agencies an opportunity to refresh the record on federal deployments and plans in the 37-38.6 GHz band.

69. We seek comment on the suitability of the 37 GHz and 42 GHz bands for advanced mobile services. Through the IRAC process, we will work with NTIA and the Federal agencies, to update the information on current and future Federal use of the 37 GHz band and establish sharing arrangements to promote the development of innovative commercial wireless services. Since we have not developed any terrestrial service rules for these bands, we seek comment on the appropriate licensing mechanism for those bands, as discussed below. With respect to the 42 GHz band, would authorizing mobile operations be consistent with protecting radio astronomy observations in the 42.5-43.5 GHz band? As an alternative, we seek comment on FWCC's proposal to authorize fixed point-to-point use of the 42-43.5 GHz band. Would fixed point-to-point use be more consistent with other uses in that band?

4. 60 GHz Bands (57-64 GHz and 64-71 GHz)

70. *Bandwidth:* 7 gigahertz and 7 gigahertz, respectively.

71. *Licensing Status:* There are no licensed operations in any of these bands. Unlicensed operation within the 57-64 GHz band is permitted under Part 15 of our rules.¹⁰⁹ Non-Federal government operators of outdoor radio equipment in the 57-64 GHz band segment are not required to obtain individual licenses or seek coordination with NTIA if they limit average EIRP to 82 dBm minus 2 dB for every dB that their antenna gain is less than 51 dBi.¹¹⁰ Last year, the Commission expanded the use of Part 15 devices in the 57-64 GHz band in order to “help the Commission fulfill its objectives to bring broadband access to every American by providing additional competition in the broadband market, lowering costs for small business owners accessing broadband services, and supporting the deployment of 4th generation (4G) and other wireless services in densely populated areas.”¹¹¹ Specifically, the Commission allowed longer communication distances for outdoor point-to-point systems in the 57-64 GHz band by allowing higher powers, specified emission limits as an EIRP power level to provide uniformity and consistency in the rules, and eliminated the requirement for certain devices in the 57-64 GHz band to transmit identification information.¹¹² Frequencies from 64-71 GHz are not among those listed in our rules as available for licenses issued in the terrestrial Fixed Service¹¹³ or for any satellite services except for inter-satellite service.¹¹⁴ Our rules list 65-71 GHz as available for Inter-Satellite (ISS) licenses,¹¹⁵ but there are no current ISS licenses.¹¹⁶

¹⁰⁹ See 47 C.F.R. §§ 15.15 and 15.255.

¹¹⁰ 47 C.F.R. § 15.255(b)(1)(ii).

¹¹¹ Revision of Part 15 of the Commission's Rules Regarding Operation in the 57-64 GHz Band, ET Docket No. 07-113, *Report and Order*, 28 FCC Rcd 12517 ¶ 1 (2013).

¹¹² *Id.*

¹¹³ See 47 C.F.R. § 101.101.

¹¹⁴ See 47 C.F.R. §§ 25.202(a)(1) and (5).

¹¹⁵ See 47 C.F.R. §§ 25.202(a) (5).

¹¹⁶ The Commission's IBFS database indicates that four inter-satellite service licenses or authorizations in the 65-71 GHz band have been revoked, and 15 such authorizations have been surrendered.

72. *Status of Mobile Allocation and Rights:* Each of the 60 GHz bands has co-primary mobile allocations.¹¹⁷ In the 64-66 GHz band, aeronautical mobile operation is prohibited.¹¹⁸ As noted above, the only operations in those bands are in the 57-64 GHz band pursuant to Part 15 of the rules.

73. *Other Authorized Services:* The 65-71 GHz band is authorized for ISS links.¹¹⁹ There are currently no active satellite licenses in that band. There is also a series of allocations for Federal and non-Federal Fixed, Radiolocation, Radionavigation-Satellite, Earth Exploration-Satellite, and ISS operations throughout these bands.¹²⁰ International and domestic rules also indicate that any use of the 66-71 GHz band by the land mobile service is subject to not causing interference to, and accepting interference from, the space radiocommunication services in this band.¹²¹

74. We seek comment on the advisability of amending our rules to allow unlicensed Part 15 operations in the 64-71 GHz band segment. As an alternative, we seek comment on the possibility of authorizing licensed operations in that band. We request commenters to provide supporting information on existing or in development viable technology that would be envisioned for this band. We also seek comments on any interference that either licensed or unlicensed advanced mobile operations in the 65-71 GHz band segment could cause to any inter-satellite operations that might eventually develop in the 65-71 GHz band.

5. 70/80 GHz Bands (71-76 GHz, 81-86 GHz)

75. *Bandwidth and Channelization:* 5 gigahertz and 5 gigahertz, respectively. Currently, there is no channelization plan for these bands.

76. *Licensing Status:* As of June 6, 2014, there were 270 active non-exclusive nationwide licenses covering the 70 GHz, 80 GHz, and 90 GHz bands. Based upon information available from the third-party database managers who are responsible for registering links in those bands, as of June 6, 2014, there were approximately 10,240 registered fixed links in the 70 GHz band, and 8,620 registered fixed links in the 80 GHz band.¹²²

77. *Status of Mobile Allocation and Rights:* There are co-primary mobile allocations in all three bands, subject to the requirement that non-Federal operations may not cause harmful interference to, nor claim protection from, Federal Fixed Satellite Service operations located at 28 military bases.¹²³ Operators in the 80 GHz bands must also avoid interfering with 18 radio astronomy observatories.¹²⁴ There are no mobile service rules in place for these bands.

78. *Other Authorized Services.* In 2003, the Commission established service rules to promote non-Federal fixed development and use of spectrum in the 71-76 GHz, 81-86 GHz, and 92-95 GHz bands.¹²⁵ Based on its determination that systems in these bands can readily be engineered to produce highly directional, “pencil-beam” signals that can co-exist in the same vicinity without causing interference to one another, the Commission adopted a flexible and innovative regulatory framework for

¹¹⁷ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹¹⁸ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹¹⁹ See 47 C.F.R. § 25.202(a)(5).

¹²⁰ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹²¹ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106 n.5.553.

¹²² These statistics are based on a review of the Universal Licensing System.

¹²³ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, note US389.

¹²⁴ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, note US388.

¹²⁵ See generally Allocations and Service Rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands, WT Docket No. 02-146, *Report and Order*, 18 FCC Rcd 23318 (2003) (70-80-90 GHz R&O); 47 C.F.R. § 101.1523.

the bands.¹²⁶ Specifically, the *Report and Order* permits the issuance of an unlimited number of non-exclusive, nationwide licenses to non-Federal Government entities for all of these bands. Under this licensing scheme, a license serves as a prerequisite for registering individual point-to-point links; licensees may operate a link only after the link is registered with a third-party database.¹²⁷

79. As noted above, non-Federal operations in all of these bands must protect Federal FSS operations located at 28 military bases. In addition, in the 80 and 90 GHz bands, licensees who propose to register links located near 18 radio astronomy observatories must coordinate their proposed links with those observatories.¹²⁸ Third-party database managers are responsible for recording each proposed non-Federal link in the third-party database link system and coordinating with NTIA's automated "green light/yellow light" mechanism to determine the potential for harmful interference with Federal operations and radio observatories.¹²⁹

80. The 71-74 GHz band segment also has co-primary allocations for Federal and non-Federal Fixed, FSS, Mobile, and MSS (space-to-Earth) operations.¹³⁰ The 74-76 GHz band segment has co-primary allocations for Federal and non-Federal government Fixed, FSS (space-to-Earth), Mobile, and Space Research Service operations.¹³¹ In addition, there are non-Federal allocations in that band segment for Broadcasting and BSS operations.¹³² The 81-86 GHz band has co-primary allocations for Federal and non-Federal government Fixed, FSS (Earth-to-space), and Mobile, and within that band the 81-84 GHz band segment also has a Federal and non-Federal government allocation for MSS (Earth-to-space).¹³³

81. We seek comment on whether mobile operations in the 70 GHz and 80 GHz bands could coexist with existing Federal and non-Federal fixed operations. Could elements of the licensing model that presently applies to the 70/80 GHz bands be adapted to facilitate coordination with advanced mobile service if it were to be authorized in those bands? Could the automated coordination and registration system that applies to fixed stations in this band be applied to advanced mobile service base stations, and, if so, would that adequately protect Federal government operations and other non-Federal government operators from interference from commercial base stations? Alternatively, we seek comment on the advisability of allowing unlicensed Part 15 operations in the 70/80 GHz band segments.

82. We also seek comment on what rules would be needed to authorize mobile subscriber units while avoiding harmful interference to other authorized operations. Could the potential for interference be limited if the mobile subscribers were required to refrain from transmitting except when operating under the control of a nearby base station? If such precautionary measures would not be

¹²⁶ See *70-80-90 GHz R&O*, 18 FCC Rcd at 23337-23339 ¶¶ 44-47.

¹²⁷ See *70-80-90 GHz R&O*, 18 FCC Rcd at 23340-23341 ¶¶ 50-51.

¹²⁸ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, note US388.

¹²⁹ See Wireless Telecommunications Bureau Announces Permanent Process for Registering Links in the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands, *Public Notice*, 20 FCC Rcd 2261 (WTB BD 2005). A "green light" response indicates that the link is coordinated with the Federal Government; a "yellow light" response indicates a potential for interference to Federal Government or certain other operations. See generally 47 C.F.R. § 2.106 (US388, US389). In the case of a "yellow light," the licensee must file an application for the requested link with the Commission, which in turn will submit the application to the IRAC for individual coordination. See *70-80-90 GHz R&O*, 18 FCC Rcd at 23341-43 ¶¶ 52, 54, 58. This automated process is designed to streamline the administrative process for non-Federal users in the bands. We noted that the classified nature of some Federal Government operations precludes the use of a public database containing both Federal Government and non-Federal Government links. See *70-80-90 GHz R&O*, 18 FCC Rcd at 23340 ¶ 48.

¹³⁰ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹³¹ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹³² See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹³³ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

sufficient by themselves, should we consider adopting a system of dynamic access control using databases similar to those used to control access to TV White Spaces, in this case to enforce exclusion zones around important Federal and radio astronomy sites? We invite commenters to evaluate the extent to which such measures could prevent non-Federal subscriber units from causing interference to Federal government operations or to other non-Government operators in the 70 GHz and 80 GHz bands.

6. 24 GHz Bands (24.25-24.45 GHz and 25.05-25.25 GHz)

83. *Bandwidth and Channelization Plan:* 400 megahertz, divided into paired 40 megahertz channels.¹³⁴

84. *Licensing Status:* There are two types of fixed licenses in this band. 24 GHz Service licenses have a total of 176 EA or EA-like service areas.¹³⁵ In 2004, the Commission held Auction No. 56, in which it made 890 24 GHz licenses available. Only seven of the 890 licenses were sold.¹³⁶ In addition, FiberTower Spectrum Holdings LLC and Puerto Rico Telephone Company hold a total of seven pre-auction Digital Electronic Messaging Service licenses in this band.

85. *Status of Mobile Allocation and Rights:* There is no mobile allocation in either of the 24 GHz band segments.¹³⁷ In the *24 GHz Report & Order*, the Commission found that it would be premature to allow mobile operations in the 24 GHz bands but reserved the discretion to revisit that issue if it is presented with technical information demonstrating that such operations would be technically feasible without generating interference to fixed operations and BSS feeder links in 24 GHz band segments.¹³⁸

86. *Other Authorized Services.* Neither the 24.25-24.45 GHz nor the 25.05-25.25 GHz band segment has any allocation for the Federal government.¹³⁹ The 25.05-25.25 GHz band segment has co-primary allocations for non-Federal government Fixed Service and FSS (Earth-to-space) services, and a footnote to the U.S. Table of Frequency Allocations provides that the use of the 25.05-25.25 GHz band by the FSS (Earth-to-space) is limited to feeder links for the BSS.¹⁴⁰ Section 25.203(l) of the Commission's rules provides that applicants for feeder link earth station facilities operating in the 25.05-25.25 GHz band may be licensed only in EAs where no existing FS licensee has been authorized, and shall coordinate their operations with 24 GHz FS operations if the power flux density of their transmitted signal at the boundary of the FS license area is equal to or greater than -114 dBW/m² in any 1 MHz.¹⁴¹ The *17/24 GHz Broadcasting-Satellite Service Report and Order* determined that future FS systems locating near an authorized 17/24 GHz BSS feeder link earth station may not claim protection from interference from the feeder link earth station's transmissions, provided that those transmissions are compliant with the Commission's rules, and that future 24 GHz FS applicants would be required to take into account the transmissions from the previously authorized earth station when considering system designs, including

¹³⁴ See 47 C.F.R. § 101.147(r)(13).

¹³⁵ See 47 C.F.R. § 101.5233.

¹³⁶ See 24 GHz Service Spectrum Auction Closes, Winning Bidders Announced, *Public Notice*, 19 FCC Rcd 14738 (WTB 2004).

¹³⁷ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹³⁸ See *24 GHz Report and Order*, 15 FCC Rcd 16934 at 16938 ¶ 7.

¹³⁹ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106.

¹⁴⁰ See U.S. Table of Frequency Allocations, 47 C.F.R. § 2.106, note NG 167. Pursuant to 47 C.F.R. § 25.202(g), 17/24 GHz BSS satellite telemetry, tracking, and command functions may also be authorized at the upper edge of the 25.05-25.25 GHz band.

¹⁴¹ 47 C.F.R. § 25.203(l).

their choices of locations for their license areas.¹⁴² There are three active licenses for feeder link earth stations in the 25.05-25.25 GHz band segment, all of them held by DirecTV.¹⁴³

87. We seek comment on the advisability of adding a mobile allocation and developing advanced mobile service rules in the 24 GHz band. Is there sufficient spectrum available in the band to make it useful for this purpose? Is it possible to allow mobile operations while protecting Earth-to-space satellite services in the 25.05-25.25 GHz band segment? Should we establish exclusion zones around the 17/24 GHz BSS feeder links that operate in that band segment? In light of the small number of existing terrestrial licenses in this band, if we decide to authorize mobile service, should we adopt a new licensing framework for this band? What other technology characteristics should be taken into account to assess compatibility with and ensure protection of federal radar operations in the adjacent 24.05-24.25 GHz band?

C. Licensing Mechanisms

88. All but one of the candidate bands for advanced mobile wireless services at or above 24 GHz discussed above have existing mobile allocations. We seek comment here on the appropriate authorization and/or assignment mechanisms that will ensure flexibility of technology and use as well as compatibility with incumbent federal and non-federal operations. Specifically, we seek comment on whether, and if so how, we should authorize incumbent licensees that are currently licensed to provide fixed service, to begin mobile operations in these bands, as well as the means by which we should assign any new (or unassigned) rights for mobile use in these bands. In the LMDS, 39 GHz, and 24 GHz bands, the Commission has already established geographic area licenses based either on Basic Trading Areas or EAs. In the 57-64 GHz band, the Commission has chosen to allow unlicensed operation pursuant to Part 15 of our rules. The viability of mobile wireless services in bands above 24 GHz will be materially affected by the frameworks that we adopt for assigning new licenses. We must seek to strike the right balance between the benefits of competition, on the one hand, and the efficiencies of scale and scope that justify investments of capital and expertise.

89. The unique characteristics of bands above 24 GHz raise several additional issues that are specific to that spectrum. Mobile operations will most likely be integrated into networks that provide ubiquitous coverage and network coordination in lower bands. They may also be provided in the same area, at the same time, and on the same spectrum as fixed point-to-point or point-to-multipoint operations. Individual base stations in bands above 24 GHz will likely have very small coverage areas and, even in the aggregate, will likely have limited geographic coverage. The licensing scheme must assign rights in a way that maximizes the utility of the spectrum, minimizes the potential for interference among co- and adjacent-channel users, and allows flexibility for licensees to meet the needs of their end users.

90. Finally, whatever licensing regimes we adopt should take into account the fact that signals from carriers' outdoor base stations will rarely be able to penetrate into the interiors of buildings, where around 75 percent of cellular data usage occurs today.¹⁴⁴ Reaching such spaces will almost certainly require the deployment of indoor base stations.

¹⁴² In the Matter of the Establishment of Policies and Service Rules for the Broadcasting-Satellite Service at the 17.3-17.7 Frequency Band and at the 17.7-17.8 GHz Frequency Band Internationally, and at the 24.75-25.25 GHz Frequency Band for Fixed Satellite Services Providing Feeder Links to the Broadcasting-Satellite Service, *Report and Order and Further Notice of Proposed Rulemaking*, 22 FCC Rcd 8842, 8895 ¶ 128 (2007) (“17/24 GHz Broadcasting-Satellite Service Report and Order”).

¹⁴³ See DirecTV Enterprises, LLC, call signs E070027, E090173, and E130081.

¹⁴⁴ Real Wireless Ltd, *The Business Case for Urban Small Cells*, at 33 (Feb. 4, 2014) (analysis commissioned by Small Cell Forum) (<http://www.scf.io/en/documents/087 - Business case for urban small cells.php>), citing Ofcom, *Mobile Data Strategy* (November 2013) (http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/summary/MDS_Condoc.pdf).

91. With the above considerations in mind, we seek comment on the licensing options discussed below and invite suggestions for additional alternatives. We acknowledge that some of these options will be more appropriate for certain frequency bands than for others, and that the most reasonable outcome could involve a diversity of options applied to different bands. To the extent that commenters suggest modifying licensing mechanisms that currently exist in given bands, they should address how such changes would affect the incumbent licensees, if at all, and the relative costs.

92. *Option 1: License vacant spectrum by auctioning exclusive rights to geographic service areas.* This option would extend to mobile services the status quo for the 24 GHz, LMDS, and 39 GHz bands, and it would be the most familiar option for carriers that are presently providing mobile wireless services in the bands below 3 GHz under similarly extensive geographic area licenses. One upside of this option, for licensees seeking to deploy advanced mobile services, is that it would provide maximum flexibility within a geographic license area to deploy base stations as demand grows. This option would also offer the simplest way to prevent harmful interference to other providers of mobile service operating on the same channels, because such interference would need to be managed only along the perimeters of large service areas.

93. One potential concern with geographic area licensing is that portions of license areas outside of high-traffic areas could end up lying fallow. We seek comment on the following three ways that might successfully address this problem, and we invite suggestions for any alternatives. First, we could rely on secondary market leasing. Licensees with excess capacity could enter into leasing arrangements with other providers that need capacity. To date, there has been limited leasing in bands above 24 GHz. However, if mobile capacity exists in these bands in the future, particularly in dense urban areas, the demand for excess capacity (to the extent excess capacity exists) may significantly increase.

94. Second, we could establish smaller licensing areas to minimize the amount of unserved area in any given license. For example, in the *Incentive Auction Report and Order* the Commission adopted a new geographic area, the Partial Economic Area (PEA). PEAs are subparts of EAs.¹⁴⁵ In the *3.5 GHz FNPRM*, the Commission proposes licensing Priority Access rights on a census tract basis.¹⁴⁶ These smaller license areas may be appropriate for mobile operations above 24 GHz, and could be a tool to help ensure intensive mobile use of the spectrum.

95. Third, we could adjust performance requirements to ensure maximum utilization of spectrum. Currently, the 24 GHz, LMDS, and 39 GHz licensees must demonstrate substantial service at renewal, and a license automatically terminates if the licensee fails to demonstrate substantial service.¹⁴⁷ One option would be to use a more objective build-out requirement for mobile services. Another option would be to adopt an alternative remedy for failure to meet the build-out requirement. For example, in lieu of license termination, a licensee could be allowed to keep the portion of the license area it has built out (keep-what-you-use), but be required to share the rest of the license area with other interested parties, or to relinquish the remainder for licensing to other parties. Or, an analog to keep what you use, we could allow licensed opportunistic non-interfering use of the license area on a secondary basis outside of the licensees' constructed areas of operations.

96. We seek comment on ways in which geographic area licensing could be tailored most effectively for mobile services in the bands above 24 GHz to ensure greater utilization of spectrum. What is the optimal geographic area size? At some size, construction requirements become difficult to generalize across different licenses in different areas. What kind of construction requirement is best? We

¹⁴⁵ See *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, GN Docket No. 12-268, *Report and Order*, FCC 14-50 (rel. June 2, 2014) at ¶¶ 70-76.

¹⁴⁶ See *3.5 GHz FNPRM*, 29 FCC Red at 4286-4287 ¶¶ 44-46.

¹⁴⁷ See 47 C.F.R. §§ 101.17, 101.527, 101.1011.

also note that as the geographic license area shrinks, the burden of administering the licensing scheme, including verifying build out, increases. How can we accommodate these issues?

97. *Option 2: Adopt nonexclusive licensing rules using automated frequency coordination.* The technologies being developed for advanced mobile applications in frequencies above 24 GHz could allow opportunities for reuse of spectrum and for spectrum sharing that are not possible at lower frequencies with current technology. In principle, tightly packed base stations with dynamic beam-forming capabilities should be able to share the same channels without causing mutual interference by pointing their beams in non-interfering directions. Variants of this option would arguably require the use of dynamic spectrum databases that would monitor the activities of mobile base stations continuously and direct their activities in real-time, with minimal latencies in response times. To the extent that such base stations are under common ownership, carriers will likely utilize such coordination and control in order to avoid interference within their own networks. Academic researchers have published proposals to extend such coordination to third-party database administrators, in order to facilitate spectrum sharing among diverse licensees equipped with dynamic beam-forming technologies.¹⁴⁸

98. We have recently proposed to apply real-time spectrum database management to shared tiers of service to be managed by a dynamic spectrum access system (SAS), which in turn is conceptually similar to but more advanced than the databases used to manage Television White Spaces (TVWS) devices.¹⁴⁹ In connection with that proposed system, we have also proposed to issue licenses for single census tracts, limited in duration to one year but with applicants allowed to aggregate multiple years of licenses in advance, through competitive bidding.¹⁵⁰ Could such an approach be adapted to advanced mobile services in higher frequency bands? This licensing scheme has the benefit of low regulatory barriers to entry.

99. How would this scheme work for mobile operations above 24 GHz? How would licensees effectively coordinate to avoid interference along the borders of their areas of operations? How would we encourage the use of the spectrum while minimizing potentially inefficient “land rush” behavior? Can some of the burden of coordination be handled through a centralized database or databases, as used for TVWS devices?

100. *Option 3: Authorize Mobile Operations pursuant to Part 15 of our rules.* Part 15 already applies to one of the bands under consideration in this proceeding, namely the 57-64 GHz band. Carriers are already off-loading some of their traffic onto Wi-Fi operations in the lower unlicensed bands, including Wi-Fi stations that are not owned or otherwise subject to direct control by the carriers.¹⁵¹ For purposes of this proceeding, it appears that the most obvious candidate bands for Wi-Fi-type authorization would be the 57-64 gigahertz band, where it already exists, and higher bands with similarly short transmission ranges. We seek comment on authorizing mobile operations in bands above 24 GHz pursuant to Part 15 of our rules. We seek comment on any special rules or protocols that would be needed to allow Wi-Fi type wireless uses in bands above 24 GHz. For example, would Wi-Fi operations be less likely to lead to congestion if we restricted Wi-Fi operations in these bands to dynamically pointed

¹⁴⁸ See, e.g., Muhammed Zeeshan and Salman Ali, *A Spectrum Exploitation Scheme with Channel Assignment for Genetic Algorithm based Adaptive-Array Smart Antennas in Cognitive Radio Networks*, IEEE ICC 2012 Cognitive Radio and Networks Symposium, June 12, 2012 (IEEE article number 978-1-4577-2053).

¹⁴⁹ See Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, *Further Notice of Proposed Rulemaking*, 29 FCC Rcd 4273 (2014) (“3.5 GHz FNPRM”).

¹⁵⁰ See 3.5 GHz FNPRM, 29 FCC Rcd at 4286-4287 ¶ 44.

¹⁵¹ According to a Maravedis-Rethink survey of mobile network operators commissioned by the Wireless Broadband Alliance, Wi-Fi hotspots owned by third parties will still account for 45 percent of the locations available to mobile subscribers in 2018. Wireless Broadband Alliance, *Wireless Broadband Alliance Industry Report 2013: Global Trends in Public Wi-Fi* (November 18, 2013) at 26.

“pencil” beams, with omnidirectional pilot signals restricted to lower bands? What are the costs and benefits of a system with flat hierarchical and distributed control?

101. *Option 4: Hybrid Licensing Involving Sharing Between Licensed Operations and Either Unlicensed Operations or Secondary Licensed Operations.* In addition to the use of automated frequency coordination, there are other possible sharing options available. As noted above, we could adjust performance requirements for primary licensees to be required to share the unbuilt portions of their license areas with other interested parties, or to relinquish the remainder for licensing to other parties. Alternatively, we could allow licensed opportunistic non-interfering use of the license area on a secondary basis outside of the licensees’ operations. Lower priority users could be authorized to deploy fixed, point-to-point links in areas where licensed carriers have not yet deployed mobile base stations. Consistent with the Commission’s recent action authorizing consumer signal boosters,¹⁵² we could authorize consumers to deploy Wi-Fi-like access points, subject to the requirement that they cease operations or otherwise operate on a secondary, non-interfering basis if carriers expand their deployment of mobile base stations. Would it be possible and appropriate to grant owners and tenants the right to deploy base stations or access points indoors because mmW signals will be less able to penetrate into the interiors of buildings? Should such lower priority rights be granted on a licensed or unlicensed basis?

102. *Other options.* This discussion of licensing scenarios is not meant to be exhaustive. We invite commenters to present alternative licensing mechanisms not discussed here, including the costs and benefits of such options.

IV. PROCEDURAL MATTERS

103. Pursuant to sections 1.415 and 1.419 of the Commission’s rules, 47 CFR §§ 1.415, 1.419, interested parties may file comments and reply comments on or before the dates indicated on the first page of this document. Comments may be filed using the Commission’s Electronic Comment Filing System (ECFS). See *Electronic Filing of Documents in Rulemaking Proceedings*, 63 FR 24121 (1998).

- Electronic Filers: Comments may be filed electronically using the Internet by accessing the ECFS: <http://fjallfoss.fcc.gov/ecfs2/>.
- Paper Filers: Parties who choose to file by paper must file an original and one copy of each filing. If more than one docket or rulemaking number appears in the caption of this proceeding, filers must submit two additional copies for each additional docket or rulemaking number.

Filings can be sent by hand or messenger delivery, by commercial overnight courier, or by first-class or overnight U.S. Postal Service mail. All filings must be addressed to the Commission’s Secretary, Office of the Secretary, Federal Communications Commission.

- All hand-delivered or messenger-delivered paper filings for the Commission’s Secretary must be delivered to FCC Headquarters at 445 12th St., SW, Room TW-A325, Washington, DC 20554. The filing hours are 8:00 a.m. to 7:00 p.m. All hand deliveries must be held together with rubber bands or fasteners. Any envelopes and boxes must be disposed of before entering the building.
- Commercial overnight mail (other than U.S. Postal Service Express Mail and Priority Mail) must be sent to 9300 East Hampton Drive, Capitol Heights, MD 20743.
- U.S. Postal Service first-class, Express, and Priority mail must be addressed to 445 12th Street, SW, Washington DC 20554.

¹⁵² See Amendment of Parts 1, 2, 22, 24, 27, 90 and 95 of the Commission’s Rules to Improve Wireless Coverage Through the Use of Signal Boosters, WT Docket No. 10-4, *Report and Order*, 28 FCC Rcd 1663 (2013).

104. People with Disabilities: To request materials in accessible formats for people with disabilities (braille, large print, electronic files, audio format), send an e-mail to fcc504@fcc.gov or call the Consumer & Governmental Affairs Bureau at 202-418-0530 (voice), 202-418-0432 (tty).

V. ORDERING CLAUSES

105. Accordingly, IT IS ORDERED, pursuant to Sections 1, 303(g), and 403 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 151, 303(g), and 403, and Section 1.430 of the Commission's rules, 47 C.F.R. § 1.430, that this NOTICE OF INQUIRY IS ADOPTED.

106. IT IS FURTHER ORDERED that ET Docket No. 95-183 and PP Docket No. 93-253 ARE TERMINATED.

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

**STATEMENT OF
CHAIRMAN TOM WHEELER**

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177; Amendment of the Commission’s Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 (Terminated); Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, PP Docket No. 93-253 (Terminated); Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, Notice of Inquiry*

An effective spectrum strategy requires an all-of-the-above approach. This means making more spectrum available for not only licensed but unlicensed uses; for both exclusive use and sharing. It also means exploring entirely new spectrum opportunities.

This Notice of Inquiry we adopt today explores the possibility of facilitating the use of a huge amount of spectrum that could be used strategically to help meet the growing demand for wireless broadband.

Years ago, engineers and policymakers debated the feasibility and practicality of using spectrum above 2 GHz for mobile wireless services. More recently, industry representatives have talked about 3 GHz as the upward cap on spectrum usable for mobile; yet, our 3.5 GHz proceeding is quickly challenging that presumption too.

It’s been long assumed that frequencies even higher up on the spectrum chart could not support mobile applications due to physical and technical limitations. But smart thinkers, innovators, and technologists are devising solutions to this previous perceived limitation.

By using innovative technologies that can simultaneously track and acquire multiple signals reflecting and ricocheting off obstacles in the physical environment, future devices might be able to leverage much higher frequency bands, those above 24 GHz, for mobile applications. This technology could theoretically dramatically increase wireless broadband speeds and throughput – up to 10 gigabits per second.

Some in the industry are referring to the use of these bands in the context of so-called “5G.” What 5G is, or what it’s not, is not the issue at this point. What *is* the issue is the encouragement of further development of next generation wireless service.

The Commission’s Technological Advisory Council looked into this possibility and suggested the Commission initiate a Notice of Inquiry to begin to better understand the state of the art.

Today’s NOI begins our formal inquiry into this technology – asking many detailed questions about how it works, and how it is different from current technology. The NOI also is designed to develop a record about how these technologies fit into our existing regulatory structures, including how they can be authorized, to make sure we are facilitating and not unduly burdening their further development.

The possibilities of 5G are very intriguing. The technology is certainly intriguing, but even more intriguing is what it means for the future of communications. It promises new user experiences, new deployment models, potentially even new industries. 5G will not be just better, faster, and cheaper; it likely will be something fundamentally different from what is possible today. And these possibilities may extend beyond 5G to other technologies and communications applications, such as satellite or airborne communications, or spark new applications yet to be imagined.

At this stage of the process, we should all be open to possibility. I expect all stakeholders to take a fresh look and a fresh approach: one focused on solutions to the benefit of the American people, and not just parochial interests. Those parties that engage in a productive manner will ensure they are part of this conversation, and other solution-driven conversations.

To those who may not be comfortable with expanding our horizons in this way, I challenge you not to say “no” even before we start down this road. Be a part of the community that makes this happen, the community that says “yes” to new frontiers of spectrum use.

Thank you to the Wireless Telecommunications Bureau and the Office of Engineering and Technology for your creative and forward-looking thinking on this item.

**STATEMENT OF
COMMISSIONER MIGNON L. CLYBURN**

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177; Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 (Terminated); Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, PP Docket No. 93-253 (Terminated); Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, Notice of Inquiry*

All trends point to an ever increasing demand for advanced wireless services, which means that we need to both promote efficient uses, and reallocate more spectrum, for commercial benefits. Since reallocating sufficient spectrum, to meet the needs of wireless consumers is a multi-year process, the time to start planning our mobile future, is now.

While many wireless carriers are in the midst of deploying 4G networks, the industry is already calling for a Fifth Generation that will substantially exceed the capacity of existing mobile technologies. While there is no consensus on the definition of 5G, some believe it could accommodate an eventual 1000-fold increase in traffic demand and support high-bandwidth content with speeds in excess of 10 gigabits per second. Achieving these objectives will likely require the development of new networks that will deliver service through multiple, widely-spaced frequency bands, using macrocells, microcells, unlicensed as well as licensed transceivers. While some companies agree there is room for further efficiency gains in the bands below 3 GHz, they generally believe that provision of 5G-level service will require use of higher frequency bands, such as those above 24 GHz.

In planning for the future use of bands above 24 GHz, we need a better understanding of those state of the art and potential future developments in technology, for it will require us to study the best ways to manage interference among operators and other licensees that operate in the same or adjacent bands. And of course, we want to spur creative ideas for the best licensing and authorization blueprints on mobile operations above 24 GHz.

So I commend the Chairman for starting the process with this Notice of Inquiry and thank Roger Sherman, Julie Knapp and their staffs at the Wireless Telecommunications Bureau and Office of Engineering and Technology for presenting this thoughtful item.

**STATEMENT OF
COMMISSIONER JESSICA ROSENWORCEL**

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177; Amendment of the Commission’s Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 (Terminated); Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, PP Docket No. 93-253 (Terminated); Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, Notice of Inquiry*

The United States leads the world in 4G LTE wireless deployments. While we are home to less than five percent of the globe’s population, we have nearly half of all LTE subscriptions worldwide.

The world has taken note. I can say this with confidence, because just last week I was in Austria, where I represented the United States at the annual gathering of the International Institute of Communications. So I was able to sit down in Vienna with colleagues from around the world and talk—over some spectacularly strong coffee—about what we have accomplished here on our shores.

We can be proud. But we also have more work to do. Because laurels, are not, in fact, good resting places. Because we need to think beyond our success with 4G service. Because the race to 5G is on.

Look around, because the evidence is there. Slowly but surely, the world’s wireless economies are planning for 5G. Last year, South Korea announced plans to run its first 5G trials by the time it hosts the Winter Olympics. That’s just three years away. Not to be outdone, Japan’s Ministry of Internal Affairs and Communications announced that it hopes to roll out 5G service in a number of cities by 2020—the year that Tokyo hosts the Summer Olympics.

Other parts of the world have stepped up their efforts, too. Earlier this year, the European Commission entered into a cooperative agreement with South Korea. They plan to work together on a global definition of 5G service and cooperate on 5G research. Meanwhile, last year in China three of the nation’s ministries jointly established a group to promote the development of 5G technologies.

So we have signs that the rest of the world is on the road to 5G. There is no reason for the United States to stay in the starting gate. We need to build on our 4G success—and get going right now.

The good news is that today’s Notice of Inquiry combined with our Report and Order on wireless facilities siting represents a starting gun. We are off. We are thinking about the spectrum and infrastructure policies that best support next-generation wireless networks.

In our current generation of wireless networks, we focus on spectrum from 600 MHz to 3 GHz. That represents today’s sweet spot for mobile broadband. But the future could look different—very different. That’s because we are moving from networks designed for analog voice to networks designed for high-speed digital data. To keep up with escalating data demand, our next generation networks are going to have to do some heavy lifting. They will need to accommodate more traffic coming from more devices at higher data rates. At the same time, they will need to lower latency and conserve power to extend battery life. Well, that sounds easy, right?

So how do we meet these demands? We look up. Way, way, up. To infinity and beyond. We need to bust through our old 3 GHz ceiling. Let’s take a look at spectrum all the way up in the 60 GHz range—and maybe all the way to 90 GHz. At these ranges we can aggregate spectrum and allow data intensive applications to ride across hundreds of megahertz at a time.

But these stratospheric frequencies can mean more than just wide channels. The physics here are different. That means real propagation challenges, but also new opportunities to think about 5G network topology. Because if you mix those wide channels with small cells packed close together, you can densify networks at lower cost. This, in turn, can mean service that reaches further into buildings at faster speeds than ever before, especially in fast-growing areas with the greatest traffic demands.

To take advantage of these millimeter waves will require thinking through some novel technical and policy issues. At the same time, we will need to continue to work to secure spectrum for new commercial use below 3 GHz. But if we do both right, we will take our leadership in 4G service and leverage it into the emerging world of 5G service. So let's get out of the gate, get going, and make it happen.

**STATEMENT OF
COMMISSIONER AJIT PAI**

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177; Amendment of the Commission’s Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 (Terminated); Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, PP Docket No. 93-253 (Terminated); Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, Notice of Inquiry*

Today’s Notice of Inquiry examines something that many people thought impossible not long ago—and no, I’m not referring to my Kansas City Royals ending their 29-year playoff drought and making it to the World Series. I’m talking about something even more impressive: using spectrum above 24 GHz for mobile broadband. To put this in perspective, consider that existing mobile technologies rely almost exclusively on spectrum below 3 GHz.

But over the past year, organizations around the world have been exploring the use of bands above 24 GHz as part of a broader effort to develop 5G mobile technologies. Commercial deployment of 5G offerings could begin in just six years. And while there is no consensus definition of 5G today, many expect that it will provide speeds ranging from one to 10 gigabits per second. To support those speeds, we will need to find wide, contiguous channels. A prime location could be in bands above 24 GHz.

By seeking comment now on the potential use of these bands, we will help ensure that our nation continues to lead the world in mobile wireless when the time comes to transition to 5G technologies. Hopefully, today’s NOI will also encourage companies to continue to research and develop options for deploying 5G offerings here in the United States. Next week, I will have the chance to see some of those efforts firsthand when I visit one of Samsung’s labs in Texas. There, researchers are developing 5G base and mobile technologies that use spectrum above 24 GHz.

Finally, I would like to thank my colleagues for agreeing to expand today’s notice to include a number of additional bands, including those above 86 GHz. It is important that we consider all bands that might be used for mobile broadband technologies. This item has my full support, and I will be voting to approve.

STATEMENT OF
COMMISSIONER MICHAEL O'RIELLY

Re: *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177; Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 (Terminated); Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, PP Docket No. 93-253 (Terminated); Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, Notice of Inquiry*

The beauty of today's Notice of Inquiry is that no one in this room knows where it will eventually take us. Which spectrum bands above 24 GHz can be effectively used in the short-term, over the long-term? Will the technologies be mobile or fixed, unlicensed or licensed? What equipment will be necessary to utilize these bands? Only research, testing and time will tell.

Commercial use of high band, or millimeter wave, spectrum provides a host of opportunities and challenges to our technology developers, including technical hurdles and the constraints of physics. I look forward to exploring with interested stakeholders the potential for these bands, while also recognizing the incumbents already using these frequencies.

At its heart, this item expands our search for additional spectrum to meet America's mobile needs, especially wireless broadband technologies. Two important data points highlight this: the growth in monthly mobile data,¹ and the growth of mobile connected devices.² Consumer demand for faster wireless speeds is also exceptionally clear.

My colleague, Commissioner Rosenworcel, has been outspoken in the last few weeks on the need to open these frequencies to additional commercial wireless uses, and she is correct. The bands in the higher giga-sphere represent an untapped ocean of possibility for wireless usage. The Commission cannot sit idly by and start our search for future commercial bands only when the need arises. That is too late. We must be forward looking to figure out what is next in the spectrum pipeline.

If I had one pause, it is that some refer to these bands as 5G. The truth is that 5G wireless technologies are likely to use many spectrum bands, and may or may not include these millimeter wave frequencies. As the item recognizes, there is no consensus definition of 5G. It would be wise to sharpen our lexicon ever so slightly going forward.

¹ In 2013, Americans consumed 360 Petabytes – the equivalent of 90 million DVDs – of mobile data per month. It is estimated that by 2018 this number will grow to approximately 2.7 Exabytes – or 677 million DVDs. See Cisco, *VNI Mobile Forecast Highlights, 2013-2018, United States – 2013 Year in Review*, http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country (filtering by United States and 2013 Year in Review) (last visited Oct. 16, 2014); Cisco, *VNI Mobile Forecast Highlights, 2013-2018, United States – 2018 Forecast Highlights*, http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country (filtering by United States and 2018 Forecast Highlights) (last visited Oct. 16, 2014).

² It is expected that between 2013 and 2018, the number of mobile-connected devices will increase from 390 million to 673 million and that machine-to-machine traffic will increase 68 fold. See Cisco, *VNI Mobile Forecast Highlights, 2013-2018, United States – Network Connections*, http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country (filtering by United States and Network Connections) (last visited Oct. 16, 2014); Cisco, *VNI Mobile Forecast Highlights, 2013-2018, United States – M2M*, http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country (filtering by United States and Potential M2M Connections) (last visited Oct. 16, 2014).

I thank the Chairman for initiating this proceeding and the Wireless Telecommunications Bureau and Office of Engineering and Technology for their work on this item.