

**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
)	
)	
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands)	IB Docket No. 15-256
)	
)	
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band)	RM-11664
)	
)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services)	WT Docket No. 10-112
)	
)	
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
)	

REPLY COMMENTS OF CTIA®

Thomas C. Power
Senior Vice President, General Counsel

Scott K. Bergmann
Vice President, Regulatory Affairs

Paul Anuskiewicz
Vice President, Spectrum Planning

Brian M. Josef
Assistant Vice President, Regulatory Affairs

CTIA®
1400 Sixteenth Street, NW, Suite 600
Washington, DC 20036
(202) 785-0081

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REPLY COMMENTS OF CTIA®

I. INTRODUCTION AND SUMMARY.

CTIA® hereby files these reply comments in response to the Commission’s *Notice of Proposed Rulemaking* (“*NPRM*”) seeking comment on a regulatory regime for mobile operations

in various spectrum bands above 24 GHz.¹ The record developed in this proceeding makes clear that 5G services will bring significant benefits to mobile consumers, and that frequency bands above 24 GHz will play an essential role in enabling next-generation wireless innovation.

Opening comments also demonstrate widespread agreement with CTIA's vision for a robust 5G ecosystem. By adopting licensing and service rules that provide certainty and clarity to prospective spectrum users, while leveraging the unique technical characteristics of millimeter wave spectrum, the Commission will help to ensure that the U.S. remains a leader in mobile. In addition, the Commission should take the following steps:

- The Commission should allocate the spectrum bands identified in the proposed rulemaking for mobile broadband services, but should also continue to work to identify and allocate additional spectrum for 5G in the low, medium, and high frequency ranges.
- The Commission should adopt a licensing and service rules framework grounded in the Commission's long-standing, highly successful principles of exclusive spectrum use, flexible technical and service rules, and certainty for licensees.
- The Commission should not adopt a sharing-intensive framework in the millimeter wave bands. While troubling as a general matter, a "use-it-or-share-it" framework would have a particularly negative impact on the deployment and provision of 5G services. And the Commission should not adopt rules based on a Spectrum Access System before such a system has been tested and proven to be an effective means of overseeing spectrum use.
- The Commission should not complicate an already-challenging 5G environment by granting new rights to secondary users outside of the Commission's auction framework or the secondary market. CTIA strongly supports protecting primary incumbents in the bands under consideration by the Commission, but the Commission should not create additional impediments that will complicate and potentially delay deployment of service.

¹ *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, Notice of Proposed Rulemaking, 30 FCC Rcd 11878 (2015) ("*NPRM*").

II. THE SPECTRUM BANDS IDENTIFIED BY THE COMMISSION WILL PLAY A CRITICAL ROLE IN FACILITATING NEXT-GENERATION MOBILE BROADBAND SERVICES.

CTIA strongly supports the efforts by the Commission in this proceeding to explore previously untapped spectrum bands and to develop a regulatory regime that will leverage these bands' unique properties for the benefit of wireless consumers. While wireless connectivity is already an essential element of daily life in the United States, next-generation services have the potential to be truly transformative. Efforts to develop 5G technologies and services are already well underway, and it is essential that the Commission continue its efforts to make additional spectrum available at low, medium, and high frequencies. CTIA commends the work of the Commission thus far, believes that the bands proposed by the Commission in the *NPRM* should be made available as quickly as possible, and asks that the Commission quickly turn its efforts to additional frequency bands.

The next generation of mobile broadband will benefit wireless consumers in three key ways: by bringing much higher speeds, by connecting a multitude of new devices to broadband, and by providing real-time performance that will enable new services and applications. Leading technology companies such as Samsung,² Ericsson,³ Nokia,⁴ Intel,⁵ and Qualcomm,⁶ and

² James Geddes, *Samsung Testing 5G Network With Lightning Speed Standards Of 20 GB Per Second*, TECHTIMES (Jul. 14 2015), <http://www.techtimes.com/articles/68237/20150714/samsung-testing-5gnetwork-with-lightning-speed-standards-of-20-gb-per-second.htm>.

³ Joe Lorrio, *Volvo and Ericsson Partner on the Real Killer App for Autonomous Cars: Streaming HD Video*, CAR AND DRIVER (Jan 4, 2016), <http://blog.caranddriver.com/volvoand-ericsson-partner-on-the-real-killer-appfor-autonomous-cars-streaming-hd-video/>.

⁴ Nokia Press Release, *Nokia Networks showcases 5G speed of 10 Gbps with NI at the Brooklyn 5G Summit* (Apr. 8, 2015), <http://networks.nokia.com/news-events/press-room/press-releases/nokia-networksshowcases-5g-speed-of-10gbps-with-ni-atthe-brooklyn-5g-summit>.

Verizon⁷ are demonstrating and testing 5G speeds in excess, sometimes well in excess, of one gigabit per second. These speeds, in turn, will enable a variety of new applications, particularly mobile video and gaming applications. Commensurate network capacity gains will enable consumers to experience a higher level of performance without decreases in speed or quality. 5G also will provide the scale needed for wireless networks to support billions of devices and unlock the potential of the Internet of Things. Industries such as healthcare, the wearables market, and the automotive industry will be able to leverage 5G technologies to create an unprecedented degree of connectivity for American consumers. And finally, the reduction in latency made possible by 5G will enable numerous benefits and applications not available today. For example, it is estimated that a 5G-enabled self-driving car traveling at 60 miles per hour will move just over one inch from the time it identifies an obstacle to the time when the braking command is executed.⁸ By contrast, the same car, using 4G technology under the same conditions, would move 4.6 feet before braking commences.⁹ This is just one example of the numerous use cases made possible by the significantly lower latency of 5G networks.

⁵ Deb Miller Landau, *How 5G Will Power the Future Internet of Things*, IQ BY INTEL, <http://iq.intel.com/how-5g-will-power-the-future-internet-of-things/> (last visited Feb. 22, 2016).

⁶ QUALCOMM, *Qualcomm's 5G Vision* (Nov. 2015), <https://www.qualcomm.com/media/documents/files/qualcomm-5g-vision-presentation.pdf>.

⁷ Verizon 5G Trials Driving Ecosystem Towards Rapid Commercialization (Feb. 22, 2016), <http://www.verizon.com/about/news/verizon-5g-trials-driving-ecosystem-towards-rapid-commercialization>.

⁸ Thomas K. Sawanobori, *The Next Generation of Wireless: 5G Leadership in the U.S.*, CTIA, at 11 (Feb. 9, 2016), <http://www.ctia.org/docs/default-source/default-document-library/5g-white-paper.pdf>, attached hereto as Attachment A

⁹ *Id.*

Opening comments demonstrate that efforts to develop 5G networks and products are well underway, and CTIA commends the Commission for exploring new and innovative ways to bring to market the spectrum necessary to support these services. While the *NPRM* focuses on spectrum above 24 GHz, the wireless industry will require access to high-, mid-, and low-frequency spectrum to deliver the next generation of mobile broadband. The high-frequency bands highlighted by the Commission in the *NPRM* will provide significant bandwidth and capacity to 5G services. Meanwhile, lower-frequency bands have better propagation characteristics and will be more advantageous for macro network coverage and capacity. CTIA therefore urges the Commission to maintain its focus on clearing spectrum in all three frequency ranges.

CTIA applauds the Commission for staying ahead of the need for 5G spectrum and urges the Commission not to slow its efforts to make this additional spectrum available for 5G services. By initiating the *Notice of Inquiry* process last year, and now by seeking comment on proposed licensing and service rules for the millimeter wave bands, the Commission has taken important steps. CTIA and its members also appreciate the efforts by the Commission to make allocation of additional mobile broadband spectrum, and millimeter wave spectrum in particular, a top priority at the recent WRC-15. It is essential that the Commission continue this momentum. As explained further below, the record developed by the Commission with respect to the 28 GHz, 37 GHz, 39 GHz, and 64-71 GHz bands presents no insurmountable challenges and provides the Commission with more than a sufficient basis to expeditiously adopt rules for these bands. The Commission should therefore act quickly to make these bands available for mobile broadband services. Once the Commission has addressed the spectrum bands that are the focus of this proceeding, it should turn its efforts to the other bands briefly discussed in the

NPRM and discussed in detail in the *Notice of Inquiry*, and continue its practice of prompt action by proceeding to a *NPRM* on those bands as well.

III. COMMENTERS SHARE CTIA’S VISION FOR A ROBUST 5G ECOSYSTEM.

In its opening comments, CTIA laid out its vision for a robust 5G ecosystem, noting that adoption of CTIA’s proposed framework would promote the rapid deployment of 5G services and promote innovation, investment, and competition.¹⁰ The record developed in opening comments makes clear that the wireless industry generally shares CTIA’s vision for a robust 5G ecosystem and that the Commission can enable significant public interest benefits by following the 5G blueprint laid out by CTIA and others. Specifically, the Commission should (1) apply its flexible-use, exclusive licensing framework to the 28, 37, and 39 GHz bands; (2) allocate at least a portion of the 64-71 GHz band for licensed use; (3) license large, contiguous blocks of spectrum in the millimeter wave bands; (4) adopt long license terms with renewal expectancies; (5) adopt reasonable, “substantial service”-based performance requirements; and (6) heed the efforts of national and international standards-setting groups when adopting rules for this spectrum.

A. The Commission Should Apply its Flexible-Use, Exclusive Licensing Framework to the 28, 37, and 39 GHz Bands.

In adopting service rules for the 28 GHz, 37 GHz, and 39 GHz bands, commenters agree that the Commission can best promote innovation and rapid deployment by extending its flexible-use, exclusive-licensing framework to these bands. In so doing, the Commission should grant flexible use rights to incumbent licensees in the 28 and 39 GHz bands, as they have expressed an interest in providing 5G mobile services and can promptly leverage their existing

¹⁰ Comments of CTIA, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664 (filed Jan. 28, 2016) (“CTIA Comments”).

spectrum assets. The Commission should also heed commenters' calls to abandon the proposed "hybrid" licensing approach for the 37 GHz band in favor of a regime consistent with that adopted for the adjacent 39 GHz band.

The record in this proceeding makes clear that the Commission's longstanding, flexible-use, exclusive-licensing framework should be applied to the 28, 37, and 39 GHz bands.

Commenters note that this framework will promote innovation and investment and lead to a more rapid deployment of 5G services.¹¹ CTIA agrees with Verizon that "[t]o trigger robust investment and innovation in the [millimeter wave] bands in the near term, the Commission's licensing approach in this proceeding should primarily mirror the approach that propelled the United States to global leadership in 4G technology."¹² And it is clear that the economic and innovation benefits of exclusively licensed spectrum are considerable. It was on exclusively licensed spectrum that the U.S. wireless industry migrated through four generations of technology, becoming a global leader in the provision of 4G service. While wireless providers increasingly use unlicensed spectrum, exclusively licensed spectrum remains critically important, as exclusively licensed spectrum generates \$400 billion in economic activity

¹¹ See, e.g., Comments of 4G Americas, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 14 (filed Jan. 26, 2016) ("4G Americas Comments") ("4G Americas reiterates the importance of licensing spectrum on an exclusive basis to provide certainty for investment in 5G network deployment."); Comments of Ericsson, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at iii (filed Jan. 28, 2016) ("Ericsson Comments"); Comments of Samsung Electronics America, Inc. and Samsung Research America, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 13 (filed Jan. 28, 2016) ("Samsung Comments") ("A consistent licensing approach, allowing spectrum to be used on an exclusive basis, with full flexibility to deploy service will permit 5G services to be deployed in a robust fashion.").

¹² Comments of Verizon, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 5 (filed Jan. 28, 2016) ("Verizon Comments").

annually.¹³ The Commission should build on the long-standing success of the wireless industry and continue to follow its approach of exclusive licensing and flexible use rights.

As part of its licensing framework, the Commission should grant flexible use rights to incumbent licensees in the 28 and 39 GHz bands. Specifically, incumbent licensees should be granted new licenses providing flexible rights to operate in their existing spectrum and geographic service area. This is appropriate in light of the fact that the Commission contemplated such rights when these initial licenses were auctioned, but technological development did not yet support such operation.¹⁴ Today, however, incumbent licensees have expressed a willingness and ability to offer these services using their existing spectrum rights, and have asked that their existing rights be preserved and enhanced.¹⁵ The mobile services envisioned by these incumbents are in line with the Commission's 5G vision, and these incumbents should be accommodated under the new licensing framework.

¹³ *Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy*, THE BRATTLE GROUP, at 23 (May 11, 2015).

¹⁴ *NPRM* ¶ 96.

¹⁵ Comments of Straight Path Communications Inc., GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 14-15 (filed Jan. 27, 2016) (“Straight Path has invested in developing a point-to-multipoint system at 39 GHz and expects to bring that system to the U.S. market in 2016. It is also developing its own 5G transceiver at 39 GHz, which it expects to initially deploy for point-to-multipoint fixed service. These systems generally have a coverage area comparable to a 5G mobile system, and each site has similar characteristics of a 5G cell.”); Comments of T-Mobile USA, Inc., GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 9-12 (filed Jan. 27, 2016) (“T-Mobile Comments”); Comments of XO Communications, LLC, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 8-11 (filed Jan. 28, 2016) (“As an existing licensee in the LMDS and 39 GHz bands, XO has extensive experience and expertise in the upper microwave bands and will be able to deploy and coordinate 5G facilities in a manner that enables those systems to coexist efficiently with existing backhaul and other fixed wireless deployments.”).

Finally, commenters note that by adopting a “hybrid” licensing approach for the 37 GHz band, the Commission would limit the utility of the band and squander the opportunity to leverage the contiguity of the 37 and 39 GHz bands. By adopting a “hybrid” licensing approach in the 37 GHz band, the Commission would undermine the 37 GHz band on a stand-alone basis. The Commission’s proposal would create a complex “Swiss cheese” licensing scheme that would greatly hinder deployment of equipment and services. Put simply, “a hybrid licensing proposal would add complexity where none is needed.”¹⁶ In addition, the “hybrid” approach would undermine operators’ ability to make a viable business case justifying the substantial network investment in the 37 GHz band, as they may lack a clear opportunity for indoor deployments. Verizon recognizes the difficulties with this framework, noting that “... licensees whose business plans involve providing both outdoor and indoor coverage would need to negotiate a patchwork of agreements with various building owners and tenants within their service territories.”¹⁷

Moreover, considerable benefits can be achieved if the Commission adopts the same licensing regime for the 37 and 39 GHz bands. As AT&T notes, “[b]ecause the 37 GHz band is

¹⁶ Ericsson Comments at 8.

¹⁷ *See, e.g.*, Verizon Comments at 8 (“With no terrestrial licensees, this band offers an excellent opportunity for a variety of next generation technologies. Holders of flexible-use licenses in the 37 GHz band would thus have a clean slate on which to rapidly deploy next generation technologies in a band harmonized globally for mobile operations. By contrast, the hybrid proposal would limit the utility of the 37 GHz band. The NPRM assumes that operators will predominantly be interested in outdoor deployments, but that is not so. The mmW spectrum will likely be used heavily in more populated, urban environments where indoor coverage is critical. As the Commission has pointed out, the vast majority of current wireless use is indoors. Operators may not be able to make a business case for developing the 37 GHz band without the opportunity for indoor deployments. And licensees whose business plans involve providing both outdoor and indoor coverage would need to negotiate a patchwork of agreements with various building owners and tenants within their service territories. Just the first step of that process—identifying whom to contact for every indoor location—would be costly and time consuming.”).

adjacent to the 39 GHz band, a large block of contiguous spectrum could be created by combining the bands under a single licensing framework. . . . By adopting the same licensing regime for both the 37 GHz and 39 GHz bands, the Commission will ensure that 5G systems have access to the contiguous spectrum they need to thrive.”¹⁸ This would also enable equipment manufacturers to achieve economies of scale and develop applications designed to harness the contiguity of the 37 GHz and 39 GHz bands.¹⁹ Thus, in light of the widespread record opposition to the “hybrid” approach, CTIA urges the Commission to reject this proposal and extend the same licensing framework to both the 37 GHz and 39 GHz bands.

B. The Commission Should Allocate a Portion of the 64-71 GHz Band for Licensed Use.

The record in this proceeding echoes CTIA’s support for both licensed and unlicensed allocations in the millimeter wave bands, but also makes clear that the Commission should reconsider its decision to designate the entirety of the 64-71 GHz band for unlicensed use. In particular, the 66-71 GHz portion of this band has characteristics that make it ideally suited for

¹⁸ Comments of AT&T, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 15-16 (filed Jan. 28, 2016) (“AT&T Comments”).

¹⁹ Verizon Comments at 7 (“Equipment manufacturers could achieve economies of scale producing equipment that operates on standardized channels across the entire band. And the band could host a large pool of very wide-bandwidth channels that would facilitate major efficiencies for operators and would be ideal for future high bandwidth applications such as video distribution. Achieving those benefits requires the Commission to apply the same rules to both 37 GHz and the 39 GHz bands, and establish a single channelization scheme for the new band.”). *See also* T-Mobile Comments at 13 (“Having that much contiguous spectrum will help drive innovation and significant economies of scale and scope for infrastructure across the combined bands, ultimately benefitting providers and consumers. In addition, 3 gigahertz of continuous bandwidth could support multiple large bandwidth licenses, such as six, 500 megahertz licenses, satisfying the twin goals of creating large spectrum blocks and multiple licensees in the combined band. The Commission should therefore harmonize the rules in these bands – including licensing the 37 GHz band with the same geographic license scheme as 39 GHz – to allow industry to develop use cases, deployment plans, and an equipment ecosystem for 5G that is interoperable across the entire 3 gigahertz.”).

licensed use, and the Commission can take advantage of these properties while at the same time meeting its unlicensed spectrum allocation goals.

Several commenters support a bifurcation of the 64-71 GHz band into unlicensed and licensed portions to capitalize on the international harmonization potential of the 66-71 GHz band. As Nokia observes, “[t]he 66-71 GHz band is among the bands to be studied in ITU towards WRC-19, and has the potential to become a true globally harmonized licensed band,” which in turn “promotes economies of scale and enables global roaming, which reduces equipment design complexity and. . . improves spectrum efficiency.”²⁰ Commenters also note that if the 66-71 GHz band is allocated for licensed use, the 64-66 GHz band can be combined with the 57-64 GHz band to create a nine-gigahertz block of unlicensed spectrum, a considerable allocation that can be used to enable a variety of services and technologies.²¹

Commenters also note that bifurcating the 64-71 GHz band into licensed and unlicensed portions would maintain an equitable division between licensed and unlicensed services in this proceeding. Given the nascent nature of 5G and deployment of wireless broadband in the millimeter wave bands, it makes sense to provide a relatively equal allocation of unlicensed and licensed spectrum. As T-Mobile observes, licensed spectrum “grants providers the stable environment needed to encourage greater investment and technical innovation. Therefore, the

²⁰ Comments of Nokia, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 17 (Jan. 27, 2016) (“Nokia Comments”). *See also* AT&T Comments at 17 (“AT&T is concerned that expanding unlicensed uses in the entire block of spectrum would be contrary to the important principle of promoting international harmonization. Licensing a portion of this band would be consistent with global allocations, promoting economies of scale and globally accessible services.”).

²¹ T-Mobile Comments at 15 (“In particular, the Commission should designate the 64-66 GHz band for unlicensed operations, creating a 9 gigahertz block of spectrum with the existing 57-64 GHz band, and license the 66-71 GHz band. Such an approach would be consistent with the outcome of WRC-15.”).

Commission should evaluate the amount of spectrum that it is creating for unlicensed and licensed use, respectively, in this proceeding.”²² This more balanced approach in this instance will enable the Commission to achieve its policy goals with respect to unlicensed spectrum, while preserving a highly valued and internationally harmonized swath of spectrum for licensed use.

C. The Commission Should License Large, Contiguous Blocks of Spectrum in the Millimeter Wave Service.

The record affirms that the Commission should take advantage of this rare opportunity to license large, contiguous blocks of spectrum in the millimeter wave bands. As commenters observe, 5G services will require significant blocks of spectrum to achieve the level of performance desired by consumers, the Commission, and players in the wireless ecosystem. The millimeter wave bands under consideration in this proceeding are well-positioned to provide these benefits. The Commission should not squander this opportunity by adopting a band plan that divides the millimeter wave spectrum into small channels, forcing operators to aggregate adjacent blocks to achieve the benefits this proceeding is designed to produce. The Commission has proposed to license the 28 GHz band as a single 850-megahertz block, and to divide the 39 GHz band into 50-megahertz channels.²³ As opening comments make clear, the Commission can best deliver on the promise of these bands by instead adopting channels of approximately 200 megahertz each.

Commenters note particular concern with the Commission’s proposed 39 GHz band plan. This proceeding makes clear that large blocks of spectrum will be needed to deliver on the promise of 5G, and that it will be far easier to achieve these benefits if the millimeter wave bands

²² *Id.* at 14.

²³ *NPRM* ¶¶ 116-117.

are not overly segmented. CTIA agrees with Samsung that “[u]se of the existing channelization for the 39 GHz band would inhibit the ability of license holders to effectively use the spectrum in the most efficient manner as well as make interoperability with the 37 GHz band difficult.”²⁴ Further, “multiple 200 MHz blocks will be needed to attain the data speeds and meet the capacity needs of wireless providers using 5G.”²⁵ The Commission’s proposal for the 39 GHz band appears to contravene the central goals of this proceeding – as T-Mobile observes, “the Commission’s proposed 39 GHz band plan does not take advantage of the potential use of wider bandwidths – the very criterion the Commission found useful in selecting bands for consideration in this proceeding.”²⁶ While carrier aggregation can be used to overcome some of these limitations, it does not serve as a substitute for large, naturally contiguous blocks of spectrum – and this proceeding represents a rare opportunity for the Commission to license such blocks.²⁷

While commenters vary in their band plan proposals, the record generally supports CTIA’s proposal to divide the 28 GHz, 37 GHz, and 39 GHz bands into blocks of approximately 200 megahertz each. By following this approach, the Commission will balance its objectives of promoting competition, enabling advanced technologies, and maintaining regulatory simplicity. AT&T believes that “200 MHz channels in particular will help optimize traffic management and

²⁴ Samsung Comments at 14.

²⁵ *Id.*

²⁶ T-Mobile Comments at 12.

²⁷ Comments of the Telecommunications Industry Association, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 29 (filed Jan. 27, 2016) (“TIA Comments”) (“While some spectrum fragmentation can be overcome through the use of carrier aggregation technologies, those technologies do not yet provide the same level of spectrum efficiency as is achieved when wide blocks of contiguous spectrum are used.”).

system performance.”²⁸ Numerous other commenters have voiced their support for blocks of 200 megahertz (at a minimum).²⁹ Further, by adopting a consistent block size, the Commission will enable equipment manufacturers to develop equipment in the most efficient and effective manner possible, promote interoperability, and enable multiple licensees in each market to offer millimeter wave services. Thus, CTIA reiterates its request to divide the 37/39 GHz bands into unpaired 200-megahertz blocks and to divide the 28 GHz band into three 200-megahertz blocks and one 250-megahertz block.

D. Ten-Year License Terms and Renewal Expectancies Will Promote Investment.

In adopting licensing and service rules for the millimeter wave bands, the Commission is laying the groundwork for a truly nascent mobile ecosystem. Under such conditions, and as a general matter, commenters agree that the Commission can best promote investment and innovation by granting millimeter wave licensees significant license terms and renewal expectancies. In particular, a ten-year initial license term with a renewal expectancy is in line with other mobile broadband spectrum bands and will provide the wireless industry with the certainty needed to develop equipment and design and deploy networks.

Commenters agree that a significant license term is warranted in light of the fact that 5G technologies are in a very early stage of development. As AT&T observes, “license terms should afford licensees the flexibility to employ ‘innovative technologies which may not be available immediately upon licensing.’”³⁰ CTIA agrees with Intel that the license term “should

²⁸ AT&T Comments at 14.

²⁹ See, e.g., Comments of QUALCOMM Incorporated, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 11 (filed Jan. 27, 2016) (“Qualcomm Comments”); Samsung Comments at 14; Ericsson Comments at 9.

³⁰ AT&T Comments at 19-20, quoting *NPRM* ¶ 119.

reasonably accommodate the development, deployment, and adoption of new, innovative services,” which is challenging because there is “no current market history for judging the expected timelines.”³¹ However, commenters generally agree that a ten-year license term is sufficient to promote the needed investment and product/network development in these bands.³² The record also contains support for extending this initial license term if conditions warrant.³³ Finally, CTIA agrees with those commenters who call for a renewal expectancy for millimeter wave licensees who meet applicable performance requirements for their licenses.³⁴

E. Performance Requirements for the Millimeter Wave Bands Should Reflect the Bands’ Unique Characteristics and Use Cases.

Just as ten-year license terms are necessary to permit sufficient time to develop standards and equipment and deploy networks, performance requirements should also be tailored to reflect

³¹ Comments of Intel Corporation, GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95, WT Docket No. 10-112, and RM-11664, at 23 (filed Jan. 27, 2016) (“Intel Comments”).

³² *See, e.g.*, AT&T Comments at 20; Nokia Comments at 19; Intel Comments at 23; Verizon Comments at 10; Qualcomm Comments at 11-12.

³³ *See, e.g.*, Intel Comments at 23 (“Depending on how the 5G standards process progresses, it may be appropriate to consider extending the initial license term beyond ten years. If, for example, the standards process is delayed, longer initial license terms may be necessary to allow licensees sufficient time to develop the spectrum and realize a return on investment.”); Verizon Comments at 10 (“Initial license terms should be at least the 10 years proposed in the Notice and potentially longer given the need for certainty and the costs of network densification.”).

³⁴ *See, e.g.*, Intel Comments at 23 (“Linked to that, licensees should be given the certainty of renewal expectancy so long as they meet the performance requirements.”); Nokia Comments at 19; Verizon Comments at 10 (“The Commission should assign licenses that have reasonably long terms and renewal expectancies. That will encourage investment and innovation by improving the expectations of returns on capital expenditures to build out the spectrum and maintain current accounting and tax rules that come with renewal expectancy.”); AT&T Comments at 20 (“Consistent with the important principle of maximizing new technologies and services throughout 5G systems, ten year renewal terms and license expectancies will promote capital investments in the mmW bands. Concrete renewal terms are important for bolstering confidence that the investment needed to deploy complex 5G technology and infrastructure will not be stranded.”).

the nascent state of the market for 5G and to permit licensees the flexibility needed to deploy innovative services. The record in this proceeding makes clear that the characteristics of millimeter wave spectrum and of 5G compel the development of performance requirements that adequately reflect the bands themselves and the services deployed therein. CTIA joins those commenters who call for a “substantial service” framework in the millimeter wave bands, with clear safe harbors for licensees. At a minimum, however, the Commission’s performance requirements should be highly flexible and reflect the unique use cases envisioned for millimeter wave bands.

Opening comments make clear that the characteristics of 5G and of the millimeter wave bands compel use of performance requirements that are flexible. As TIA notes, “where (as here) the Commission is developing service rules long before technologies and use cases have been determined, the Commission should make sure that performance requirements do not skew the market and chill innovation.”³⁵ For this reason, observes, T-Mobile, “the performance requirements that traditionally apply to lower mobile wireless band licenses may not logically apply here.”³⁶ The Commission should be mindful of this fact in adopting performance requirements, and any performance requirements should be highly flexible. Further, the Commission may find that the still-developing 5G technologies will dictate the adoption of performance requirements that allow for the evolution of networks and systems to be deployed in these spectrum bands.³⁷

³⁵ TIA Comments at 26.

³⁶ T-Mobile Comments at 19.

³⁷ AT&T Comments at 23 (“As time progresses and with a clearer understanding of how 5G networks and systems will operate, the Commission’s evaluation of substantial service showings can evolve accordingly.”); Nokia Comments at 20 (“We encourage the Commission to consider alternative approaches while recognizing that they may need to revisit the metric in the future

Fortunately, as CTIA noted in its initial comments,³⁸ there is a framework that has been used by the Commission – “substantial service” – that would be a logical approach for performance requirements. Other commenters agree and support the adoption of a “substantial service” framework in the millimeter wave bands with clear safe harbors set forth for licensees. While population or geographic-area coverage benchmarks may be appropriate for other frequency bands, the use cases associated with millimeter wave spectrum are more closely aligned with bands subject to “substantial service” requirements. A “substantial service” framework has the added benefit of accommodating a variety of network architectures. AT&T believes “that the flexibility inherent in a ‘substantial service’ approach may be appropriate – especially coupled with safe harbors recognizing the state of overall 5G progress.”³⁹ Nokia adds that “performance metrics need to be flexible” and that “a more appropriate performance metric might be the number of transmitters in service, number of connected devices, carried traffic, etc.”⁴⁰ Numerous other commenters have voiced their support for a flexible “substantial service” framework and have stressed the need for flexibility in this area.⁴¹ In addition, the safe harbors

based on lessons learned from deployments.”); Ericsson Comments at 11 (“The Commission can make clear that it may reexamine the performance requirements in the future, should the approach warrant adjustment or prove to be inappropriate or invalid.”).

³⁸ CTIA Comments at 23-26.

³⁹ AT&T Comments at 22.

⁴⁰ Nokia Comments at 20.

⁴¹ *See, e.g.*, Verizon Comments at 19 (“The Commission should apply the ‘substantial service’ requirement flexibly, given that future technologies and deployment paradigms may be different than past ones. That is particularly important in the context of mmW technologies because no one can know what use cases will emerge, let alone how to measure the scope of operators’ deployments of new technologies in these bands.”); 4G Americas Comments at 10 (“We believe that it is more appropriate to base performance metrics on usage and/or service levels, rather than census data. The chosen metrics need to be flexible, reflecting the considerable diversity of 5G applications presently being discussed in the relevant standards

adopted by the Commission should provide examples of potential deployment scenarios that would meet the Commission’s “substantial service” requirement, thus providing further certainty to licensees. Regardless of the specific performance metrics adopted, the Commission’s requirements should be highly flexible, reflect the unique use cases for the millimeter wave band, and be realistic and achievable in light of the current state of technology.

F. A Successful 5G Ecosystem Will Reflect Industry Collaboration and Standards Efforts.

Finally, CTIA notes that numerous standards organizations and other industry groups are working to develop 5G technologies and services. This work is ongoing at both a national and international level, and it is essential that the Commission’s actions in this proceeding reflect these efforts. If the Commission develops a band plan and service rules that are consistent with the work of standards setting entities, the United States can take a leading role in 5G, just as it has with 4G. CTIA therefore echoes T-Mobile’s call for the Commission to consider the efforts of groups such as the 3rd Generation Partnership Project and, among other things, “ensure that its proposed band plans are consistent with those developed by international standards setting entities.”⁴²

IV. THE COMMISSION SHOULD REJECT PROPOSALS THAT WOULD UNDERMINE INNOVATION IN THESE BANDS.

A. The Commission Should Not Adopt a Sharing-Intensive Framework in the Millimeter Wave Bands.

Both because the Commission needs to promote investment in the 5G ecosystem, and because there remain many questions regarding future 5G deployments, the Commission should

bodies and industry for a.”); Qualcomm Comments at 13 (“Qualcomm believes that any new performance metrics should be as flexible as the underlying service rules to account for the broad range of 5G services, usage models, and applications.”).

⁴² T-Mobile Comments at 13.

refrain from adopting a sharing-intensive framework in the millimeter wave bands. Instead, and as explained above, the Commission’s actions should be governed by the principles of exclusive rights and technological flexibility that have allowed mobile broadband services to flourish. CTIA therefore opposes the adoption of “use it or share it” requirements and the adoption of the Spectrum Access System (“SAS”) model in the millimeter wave bands.

Numerous commenters highlighted the threat to innovation and licensee rights presented by the Commission’s proposed “use it or share it” requirement. As Verizon notes, “use it or share it” is a “regulatory experiment that, until tested and proven to work, would introduce risk that licensees may not be able to use their spectrum when and where they need it.”⁴³ Further, such a requirement is entirely unsuitable given the nascent nature of technology in this band. CTIA agrees with Qualcomm that “[s]uch an obligation would introduce uncertainty at this critical stage and could deter the investments necessary to make millimeter wave mobile deployments successful.”⁴⁴ As AT&T states, the Commission’s proposal would redistribute “unused” millimeter wave spectrum just five years into a license term, despite the fact that deployment timetables for millimeter wave services are unknown.⁴⁵ As a result, a licensee may be forced to deploy a network in a rushed, inefficient manner simply to ensure that it retains its license rights. The dynamic nature of millimeter wave use also makes a “use it or share it”

⁴³ Verizon Comments at 20.

⁴⁴ Qualcomm Comments at 13.

⁴⁵ AT&T Comments at 21 (“Second, it would be premature to redistribute ‘unused’ spectrum for shared uses a mere five years into a license term. As the record in this proceeding already highlights, it will still require additional research and development to leverage mmW bands to support 5G systems in the first place. At the same time, 5G use cases and services are still being developed. The Commission’s regulatory approach should reflect these practical realities and grant prospective licensees sufficient time to deploy complex 5G networks and services before redistributing the spectrum.”).

requirement highly impractical. Simply defining whether spectrum is in “use” would be challenging, and the Commission’s chosen definition has the potential to preclude highly beneficial use cases in the millimeter wave bands.⁴⁶ For the reasons highlighted in this proceeding and by CTIA in its opening comments, a “use it or share it” requirement is premature, highly impractical, and has the potential to thwart the very objectives of this proceeding.

For similar reasons, the Commission should reject calls to apply the SAS framework to the millimeter wave bands. The SAS, first adopted for the 3.5 GHz band, has yet to be tested in any real-world environment, let alone deployed on a wide-spread basis. There is no basis for extending the SAS to additional frequency bands before it has been proven successful in any frequency band.⁴⁷ CTIA therefore agrees with Samsung that “the Commission should limit the experiment of this new methodology to that band until it demonstrates its feasibility.”⁴⁸ The use of a SAS framework to govern the 3.5 GHz band necessarily will evolve, subject to incremental (and even substantial) modifications, as the Commission and stakeholders learn lessons from the initial implementation. Even when SAS proves to be fully matured in the 3.5 GHz band, “scaling [a SAS] framework from a fully-proven concept in the 3.5 GHz band and all the

⁴⁶ AT&T Comments at 20-21 (“[I]mposing a ‘use-it-or-share-it’ obligation on licensees would inject unnecessary complexity into the already arduous task of deploying 5G networks. Indeed, even defining ‘unused spectrum’ would be challenging. In some instances, managing a very high quality of service requirement may cause spectrum ‘use’ to appear very low in certain intervals when capacity is actually being held in reserve for peak demand periods.”).

⁴⁷ *See, e.g.*, T-Mobile Comments at 17 (“SAS remains an untested concept. While there are rules that permit its use in the 3.5 GHz band, there are no current SAS or similar database-driven operations. Moreover, coordination between terrestrial and satellite uses will be difficult – for example, the Commission has assumed that millimeter wave base stations will have omnidirectional antennas, which is not likely accurate – and an SAS will be unable to predict interference without knowing beamforming algorithms.”).

⁴⁸ Samsung Comments at 23.

idiosyncratic risks associated with that band, to another band and its different collection of risks and requirements, would not likely be a simple undertaking.”⁴⁹ For these reasons, CTIA agrees with Intel that adopting a SAS framework in the millimeter wave bands “would be an unnecessary burden layered onto all the more directly pertinent mmW efforts.”⁵⁰ The Commission should therefore reject this proposal.

B. The Commission Should Not Grant New Rights to Secondary Users Outside a Market-Based Mechanism.

The millimeter wave frequency environment will be a complex one, with diverse uses of spectrum occupying the same bandwidth. CTIA applauds the efforts by the Commission in this proceeding to protect primary incumbents from interference, but opposes any proposal to elevate the interference protection rights of any non-primary incumbent. To this end, the Commission should reject calls by secondary satellite licensees to elevate their operations to primary status outside of market-based forces. To the extent these licensees wish to obtain primary status, they are welcome to purchase spectrum rights at auction or on the secondary market. Such action is the most equitable and efficient means of balancing competing spectrum uses.

First, it is entirely fair for the Commission to maintain secondary status for 28 GHz satellite incumbents, as they were on notice of this status and the potential future occupation of their spectrum by mobile operations. As Samsung notes, these incumbents “invested at their own risk with these facts disclosed prior to their commencement of operations.”⁵¹ In fact, studies indicate that these satellite incumbents will be adequately protected from interference

⁴⁹ Intel Comments at 22.

⁵⁰ *Id.*

⁵¹ Samsung Comments at 22.

notwithstanding their secondary status.⁵² However, to the extent satellite operators believe that new millimeter wave uses will interfere with their uses, they have long been aware of the potential for such interference and should not be permitted to simply elect primary status. Indeed, permitting such self-election risks undermining terrestrial deployment in the 28 GHz band.⁵³

Second, requiring 28 GHz satellite licensees to participate in an auction or the secondary market is an equitable way of addressing satellite licensees' concerns. CTIA sees no reason why a Fixed-Satellite Service ("FSS") licensee, if it follows the same processes as a wireless licensee to obtain spectrum access, should not be permitted to purchase co-primary rights. What CTIA does not support is simply giving these rights to FSS licensees while requiring prospective terrestrial licensees to invest substantial sums at auction. The record in this proceeding supports such a finding. T-Mobile, for example, states that "[t]here is no basis for the Commission to permit current 28 GHz earth station operators – that have only secondary status today – to simply elect primary status."⁵⁴ CTIA therefore supports the Commission's proposal to permit FSS incumbents to participate in the millimeter wave spectrum auction and take whatever *market-based* steps they deem necessary to protect their operations.

⁵² *Id.* ("Satellite users have been able to find sharing solutions feasible based on use of the band for uplink feeder link stations that have generally high gain antenna and sufficient link margin for communications. Samsung undertook a preliminary compatibility study to examine the coexistence of 5G millimeter wave services with Federal fixed and mobile satellite services in the bands adjacent to LMDS, including the 30-31 GHz band and the 31-31.3 GHz band. The study found that, under the existing parameters and licensing rights, although a single beam spot of an FSS receiver covers the land area of 711 major cities, a mobile base station in the adjacent channel does not cause significant interference to space station FSS. FSS systems are adequately protected under the current rules and further protection is not warranted.").

⁵³ Ericsson Comments at 21-22.

⁵⁴ T-Mobile Comments at 16.

Finally, CTIA submits that the Commission should not authorize FSS operations in other bands under consideration for mobile broadband, such as the 40 GHz band, until the ramifications of such use and the potential for sharing with mobile services is fully studied and considered by all affected stakeholders. The record in this proceeding makes clear that balancing the needs of satellite and terrestrial users of millimeter wave spectrum is a delicate process. The Commission should not unduly burden future efforts by creating new incumbents that will complicate 5G deployment in the near to medium term.

V. CONCLUSION.

As this proceeding demonstrates, a shared vision for 5G in the United States is rapidly taking shape. CTIA and its members are extremely excited about the potential for millimeter wave bands to host game-changing and highly beneficial mobile services. CTIA encourages the Commission to adopt licensing and service rules for the millimeter wave bands consistent with CTIA's submissions in this proceeding. By providing stability and flexibility to future millimeter wave spectrum licensees, the Commission will help spur innovation and promote future U.S. leadership in mobile.

Respectfully submitted,

By: /s/ Brian M. Josef

Brian M. Josef
Assistant Vice President, Regulatory Affairs

Thomas C. Power
Senior Vice President, General Counsel

Scott K. Bergmann
Vice President, Regulatory Affairs

Paul Anuszkiewicz
Vice President, Spectrum Planning

CTIA[®]
1400 16th Street, NW, Suite 600
Washington, D.C. 20036
(202) 785-0081

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ATTACHMENT A



The Next Generation of Wireless: 5G Leadership in the U.S.

Thomas K. Sawanobori

SVP and Chief Technology Officer, CTIA

February 9, 2016



Source: Volvo Cars



Entire industries, from agriculture to transportation, will be transformed to be more capable, efficient, and intelligent. That's the promise of the next-generation of wireless technology, known as 5G.

Wireless connectivity touches every aspect of our daily lives today, but we are just scratching the surface of its consumer benefits. Imagine a future where nearly everything is connected to ubiquitous, very high-speed wireless networks. Imagine enjoying enriched entertainment while riding to work in a self-driving car, doctors that monitor patients' vital signs remotely in real-time, and communities that are smarter and more connected.

Entire industries, from agriculture to transportation, will be transformed to be more capable, efficient, and intelligent. That's the promise of the next-generation of wireless technology, known as 5G.

United States leadership in this next-generation of wireless is critical. We are a global leader in 4G LTE. 99.6% of Americans now have access to a 4G LTE network, thanks to nearly \$150 billion invested since 2010 by wireless operators large and small.

That means nearly every American can access mobile broadband at speeds up to tens of Mbs a second.

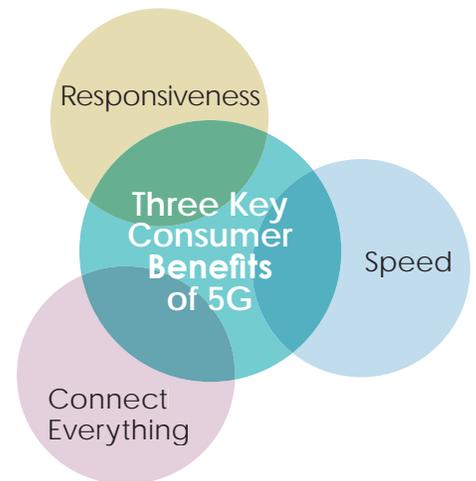
This 4G LTE leadership has paid dividends throughout the U.S. economy and our mobile ecosystem. Licensed wireless service generates over \$400 billion in annual economic activity and every wireless industry job results in another 6.5 people finding employment. American entrepreneurs capture 91% of the world's mobile app downloads, and U.S. companies run the operating systems on 9 out of 10 smartphones worldwide.

Other countries have seen our 4G LTE success and want to seize the mantle of 5G leadership. South Korean carriers have announced trials at the Winter Olympics in 2018, and Japanese operators plan to demonstrate 5G in 2020 at the Summer Olympics in Tokyo. The EU has committed 700M Euro to 5G R&D.

The U.S. wireless industry is committed to maintaining our global leadership as

the wireless ecosystem evolves from 4G LTE to 5G. U.S. carriers including AT&T, T-Mobile, Verizon, Sprint, US Cellular, and suppliers, including Ericsson, Nokia, Intel, QUALCOMM, Samsung, Cisco, Microsoft, Motorola, CommScope, HP, and others are partnering to drive foundational 5G activities on technology and global standards-setting fronts. One U.S. operator has announced trials of 5G networks; others are working hard on technical requirements and standards.

The advanced US trials, the standards process commitment, and the science and engineering are critical to 5G efforts. The technical development of 5G is evidenced by the significant amount of literature and papers produced by Next Generation Mobile Networks, 4G Americas, Ericsson, Nokia, Samsung, QUALCOMM, Intel, and others. Leading operators have been very active in 4G Americas defining requirements for 5G including AT&T, T-Mobile, and Sprint. Next Generation Mobile Networks has key representatives from around the globe including AT&T, Sprint, T-Mobile, Verizon, and US Cellular. Signals Ahead has published a paper "Understanding the Ins and Outs of the 5G Use Cases" examining 72 use cases possible with 5G. CTIA's focus is on what 5G will mean for consumers, the benefits consumers will experience with 5G networks, and how public policy can advance these consumer interests.



Specifically, this paper explores three key aspects – speed, connection ubiquity, and immediacy – of 5G networks that will transform consumers' wireless experience and enable a fully-connected mobile life. We also provide clear steps policymakers can take to help maintain U.S. wireless leadership and support future 5G investment.

In particular, current spectrum planning by the Federal government needs to account for the increased demand that is projected for mobile broadband services; working with stakeholders, the Administration and the FCC must not only keep on track with respect to current efforts, but must also identify new bands capable of being auctioned and develop a timetable for those auctions. Along with smart infrastructure and siting policies, as well as wise R&D investments, more focused spectrum re-allocation planning will be vital to robust development and deployment of 5G in the U.S.



"5G is about more than faster mobile services – it will enable new use cases related to the Internet of Things." • Rima Qureshi, SVP and Chief Strategy Officer, Ericsson

The Evolution Of Wireless Networks

Wireless has evolved significantly over the last thirty years. With every generation of technology new consumer benefits are unleashed and we become one step closer to our connected life future.

In 1981, the first generation of wireless (1G) gave us analog wireless voice, connecting Americans on the go for the first time. 2G enabled digital voice, increased capacity, and introduced text messaging in the 1990s.

3G brought us the first true wireless data in the 2000s, giving consumers access to the Internet everywhere they go. And 4G LTE, first deployed in 2010, has delivered the ubiquitous high-speed wireless broadband we enjoy today, unlocking the potential of mobile video and so much more innovation.

Today's 4G LTE networks offer consumer speeds of 10-20 Mb/s on average, with network latency – the time it takes between a consumer's request for data and when that data arrives back at their device – is approximately 50 milliseconds end-to-end (including 10 millisecond air link). 4G LTE networks offer a device density of approximately 2000 active devices per square kilometer, which has helped support the introduction of the Internet of Things.

Thanks to these advances, and the mobile innovation that rides on those networks, consumers have embraced 4G LTE wireless service. Mobile data use keeps growing, and the trend lines are daunting, with a six-fold growth in traffic expected by the end of the decade.

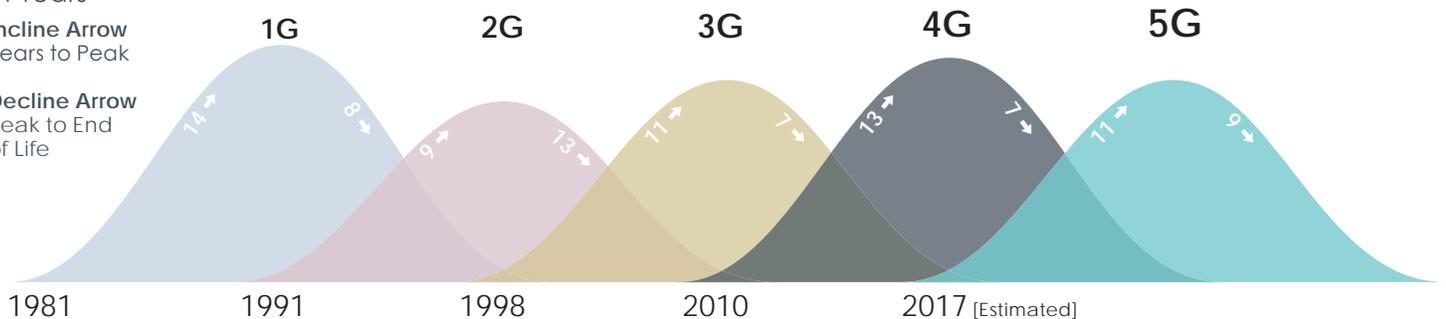
While we are focused here on longer-term developments, the 4G LTE platform will continue to evolve and carriers will continue to innovate at break-neck speed with network capabilities like carrier aggregation to provide more capacity and increased download speeds, voice over LTE (VoLTE) for a higher quality voice experience, and Rich Communications Services (RCS) for video chatting and enriched messaging. Operators throughout the U.S. including AT&T, Sprint, T-Mobile, Verizon, US Cellular and others are aggressively working to implement new capabilities. Carriers in the US are laying the strong foundation for 5G today with 4G LTE. Leading U.S. operators have been deploying wide band carriers and two carrier aggregation for the last couple of years. Beyond that operators are doing more. For example, T-Mobile is employing new spectrum, 3 carrier aggregation, and new

North American Mobile Network Life Cycles

In Years

Incline Arrow
Years to Peak

Decline Arrow
Peak to End of Life



service capabilities to make 4G LTE a great platform for serving usage and meeting consumer needs. Sprint is upgrading its network to LTE Plus with 3 carrier aggregation and believes 4G LTE will be the 'foundational layer' for what 5G becomes. Wireless carriers are also leveraging new capabilities in low power, less expensive 4G LTE chipsets to foster greater growth in the IoT. Thanks to these advances in 4G LTE technology, consumers' wireless experience will continue to improve significantly even before the rollout of next generation technology and services.

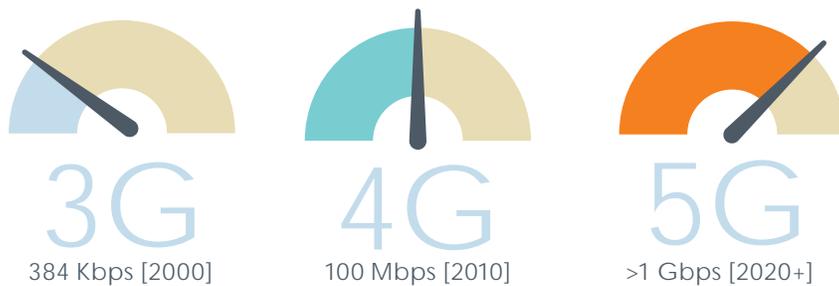
Yet we stand on the cusp of a significant new development in the wireless industry: 5G. Standards will be developed by 2018, and the U.S. wireless industry expects to rollout 5G services the following few years. Some have suggested commercial rollout will start before 2020 with early versions of the standards.

5G is not just another evolution in wireless technology, 5G will be a game-changer for consumers. Here's why.

Key Consumer Benefits

5G will benefit wireless consumers in three key ways:

- **5G will be very fast**, even in densely populated areas.
- **5G will connect everything**, supporting the Internet of Things.
- **5G will be real-time**, minimizing delays in network response and enabling entirely new services and applications.



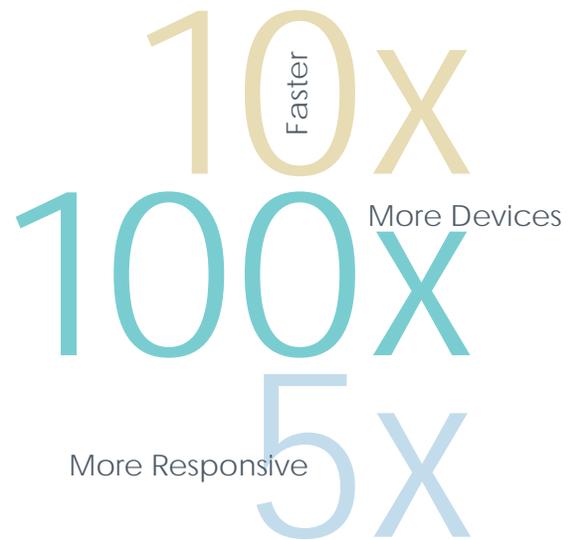
5G: Very Fast

Each generation of wireless technologies leapfrogs the capabilities of the prior generation, and the most tangible change is a significant increase in network speed. 5G will be no exception.

Our 4G LTE networks are fast, with speeds that can approach ~100 Mb/s peak rates. But thanks to innovations like millimeter (mm) wave technology, 5G networks will be extremely fast – generating a throughput more than 10 times faster, potentially over 1 Gb/s – particularly in dense urban locations and initially likely in localized “hot spots.” Indeed, technology leaders such as Samsung, Ericsson, Nokia, Intel, QUALCOMM, and others are demonstrating and testing 5G speeds in excess of 1 Gb/s in initial testing and collaboration with industry players.

Consumer Benefits of 5G

By the Numbers





"5G will really change the game, and I think it will be another spike of growth in the wireless industry." • Lowell McAdam, Chairman and CEO, Verizon

The 5G revolution in data speeds will unleash a host of consumer benefits, including:

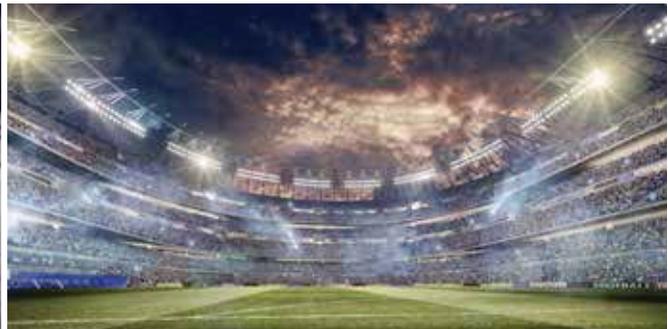
Very high speed broadband to businesses, train stations, airports, campuses, public venues, stadiums, shopping malls, or other locations

It is envisioned that 5G will be best suited to handle traffic where there is considerable demand and a high concentration of users.

All consumers have experienced the challenge of posting a photo or making a phone call from a crowded stadium or event. 5G will not only provide faster peak speeds, it is designed to handle highly dense environments and will provide a consistent very fast speed consumer experience.

Specifically with the capacity gains from 5G, consumers will be able to experience 5G without a diminution in speed or quality. For businesses in particular, this high speed connectivity can improve connectedness with employees who work remotely or travel frequently and reduce operating costs.

Beyond these venues, 5G is suitable for fixed wireless connectivity. It can provide businesses and residences with very high speed wireless broadband. 5G can provide these capabilities indoors and outdoors.



Movies, video, and other media

The average consumer usage patterns have changed dramatically with 4G LTE. Internet browsing, social media, and video drive the majority of consumer usage on smartphones. Consumers now spend an average of 2.8 hours per day with mobile content thanks to LTE speeds and functionalities.

Downloading a movie or large file can still take minutes if not longer.

Very high speed hotspots can enable rapid downloads of movies and video, or streaming to a smart device, tablet, or laptop, faster than ever before. Nokia, for example, promises speeds fast enough to download a 3-D movie in seconds, compared to several minutes over 4G LTE, or more than an hour on 3G.

New video applications

5G will enable fast access to ultra HD content including 4K and 8K video. The benefits of Ultra HD will be especially compelling on tablets, laptops, and other larger screen devices.

High speed wireless connections will also revolutionize gaming and entertainment, providing an immersive experience that allows users to actively interact with simulated

elements.

For example, attending a football game in the future could be enriched by having access to ultra HD content from a variety of perspectives – quarterback, defensive player, or coach, among others. These could be provided to enhance the stadium experience for viewers with equipped devices.

5G: Connecting Everything

●●●●●●●● 5G will be much more than faster speeds. 5G promises consumers a more connected wireless network with much higher device density, enabling the connectivity of virtually all of our physical world. 5G will provide the scale for wireless networks to support billions of sensors, wearables, and devices that will unlock new innovations and functionalities.

While 4G LTE provides a solid foundation for IoT where advancements are being made to 4G LTE with lower cost, lower power chipsets to support IoT, the wireless network of today ultimately has a connection density limitation that needs to be addressed to support the massive number of active sensors, wearables, and connected devices.

Specifically, the massive number of new wireless Internet of Things (IoT) devices – nearly 28 billion in total and roughly 1.5B M2M and consumer connected wireless (cellular) devices by 2021, will ultimately need a technology upgrade. The limitations in today's technology could impact the responsiveness a consumer perceives in accessing the network. 5G will be able to support massive connection density, possibly on the order of 100 times greater than 4G LTE.

Consumers can expect an array of connected devices with 5G networks, including:

Smart Cities

Cities are looking to use wireless technology and the IoT to create impactful solutions for their citizens.

Many consumers today rely on applications like Waze that provide real-time information. Imagine sensors that provide automatic real-time information on parking, traffic, and every other facet of your daily life. Intelligent systems can help route you optimally to your destination and direct you to the most convenient parking location.

To make smart cities a reality for consumers, operators are forming alliances with technology companies, industry leaders, and universities to create a framework for smart cities and more connected communities.

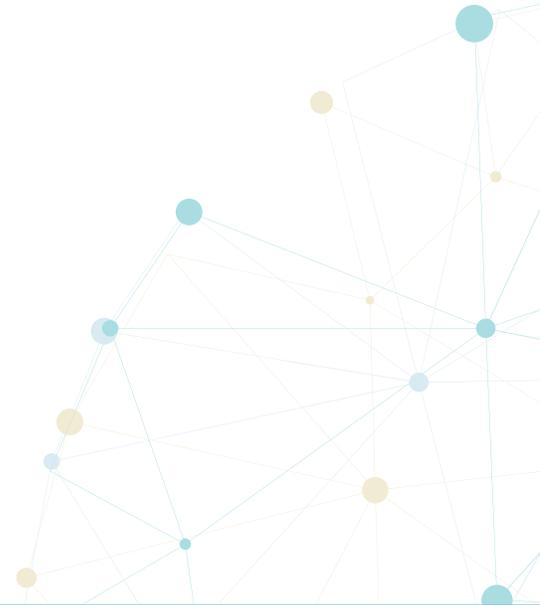
For example, AT&T is partnering with Cisco, Deloitte, Ericsson, GE, IBM, Intel, and Qualcomm in cities such as Atlanta. In addition to enabling wireless connectivity to things like utility meters, street lights, and water systems. The new framework will enable new categories such as:

AT&T is also developing a new digital dashboard—the Smart City Network Operation Center—which will provide a comprehensive overview of public infrastructure and conditions. This will offer cities a dashboard view of how assets are performing in near-real time. City officials also will be able to keep tabs on power outages, water leaks, traffic issues, and more – all from one location.

5G's higher throughput and lower latency is expected to enable such

- **Infrastructure** – remote monitoring of roads, bridges, buildings, parks, and venues
- **Citizen convenience** – real-time traffic information including consideration of traffic lights and smart parking, in which you can find a spot and reserve one
- **Public transportation** – digital signage to let commuters know when the next bus or train will arrive
- **Public safety** – manage traffic patterns of pedestrians at stadiums, parks, and busy intersections. Alerts of incidents such as a shooting could enable better response and improved safety.

While sensor networks are already starting to enable smart cities, 5G will also greatly expand the number of sensor devices, optimizing traffic and parking. As just one example, 5G will make flexible bus management possible, allowing bus stops and people to tell buses when people are waiting, and bus drivers to skip empty stops or send more buses when demand is high.



5G

Case Study

Using 5G to Improve Urban Transportation



Ericsson's Connected Mobility Arena project, designs prototype 5G-enabled solutions addressing mass transportation impacts. Initial use cases will focus on improving the transport of people and goods through Driver Assistance (providing real-time recommendations for drivers to improve travel efficiency) and Semi- and Fully Automated vehicles.

With Driver Assistance, bus drivers will be instructed in real time how long to wait to pick up passengers, and passengers can be instructed which bus to take and when. The resulting efficiencies will lower costs for consumers and reduce environmental impacts. Likewise, Semi- and Fully Automated vehicles will be able to use "vehicle platooning" to have vehicles coordinate braking and acceleration, which will increase road capacity and reduce traffic congestion.

While these 5G solutions will evolve from existing technologies, they will include Quality of Service requirements that specify the maximum network delay and/or minimum guaranteed throughput.

solutions. Capabilities like these can enable cleaner, more efficient cities with better use of city resources. Global smart city economic benefits are estimated to range from \$644B-1.2T by 2025.

Wearables and Tag Devices

With 5G, wearables and tag devices are expected to become more prevalent. Wearables remain in their infancy – just 21% of adults have a fitness device today – but the opportunities are vast. The projected annual value of wearables is \$600B globally by 2025.

Unlike today's devices, however, future 5G wearables will be fully connected devices – in other words, devices that do not need to be tied to a smartphone to connect to the Internet.

Samsung, for example, is developing connected healthcare and fitness

devices that not only record exercise performance and make recommendations, but also can send real-time vital health statistics (like brain function, heartbeat, and blood pressure) to healthcare experts to prevent emergencies before they happen.

Tag devices (which allow individuals to stay in constant connection with valuable items or loved ones) present a host of potential consumer uses: tracking and monitoring bicycles, motorcycles, pets, briefcases, handbags, keys, and even children.

Automotive

The auto industry has already leveraged 4G LTE for entertainment, information, and safety in vehicles across the country. But even as in-car 4G LTE use continues, 5G promises real-time vehicle solutions with richer information and safety options.

For instance, vehicle broadband access can enable maintenance-type notifications for vehicle servicing needs. Instead of a simple 'check engine' light, a sensor could

alert the driver that engine cleaning is recommended and allow the driver to schedule an appointment. More serious concerns such as low tire pressure could direct the driver to the nearest service station.

Vehicle broadband access could also include video streaming, video downloads, music and audio, broadband Internet access, and new emerging applications such as virtual or augmented reality.

Smart Homes

With 5G, our homes will continue to grow smarter through enhanced home security (remote video security monitoring and controls; wireless-controlled door locks), and smart appliances (refrigerators that notify you when low on certain products). New technology will enable much higher throughputs which can enable multiple high resolution cameras and other sensors to be connected and remotely monitored.



“[W]e see 5G as a big step forward ... You can call it a revolution, it's definitely not incremental change.” • Matt Grob, CTO, Qualcomm

M-Health and Telemedicine

The next generation of wireless technology will unlock the potential of mHealth and telemedicine. Already today, remote diagnostic vital signs are being trialed and utilized, but with a wireless network that can connect consumers' body sensors with health care facilities, consumers will see improvements in health care outcomes and efficiency gains.

For instance, sensors for health monitoring are going to be more prevalent, with automated reporting to a doctor's office or nurses' station. These advances will improve safety, health, and efficiency.

In the area of health monitoring, there are many opportunities for improved,

remote monitoring. For instance, researchers at the University of Virginia are working to transform type 1 diabetes management by introducing an “artificial pancreas” solution, which will automatically monitor patients' blood-sugar levels and deliver insulin as needed. The system will use a body sensor to report insulin levels to a smartphone app, which will then analyze the data and wirelessly control a wearable insulin pump. In the future, high resolution images and video can be used by doctors to rapidly and cost-effectively diagnose problems and affect quicker medical outcomes. Emergency medical teams may transmit high resolution images to doctors in



hospitals for diagnosis and treatment en route. The potential global benefits are considerable, including longer lives and the improved quality of those lives, estimated to reach somewhere between \$700B and \$1.2 T globally by 2025.

Smart Grid

The energy area will expand from meter reading and collecting to the smart grid opportunity. Projections indicate that smart grid modernization investments could total \$1.3T over the next 15 years. Wireless connections will enable monitoring of the grid, particularly in the distribution network. Substations will require wired connections, but sensors deployed throughout the distribution network and on remote meters will enable the utilities to better serve customers. Companies such as Sprint are already deploying solutions for smart grid for companies such as Tollgrade Communications, a global leader of Smart Grid Sensors with Predictive Grid® Analytics.

Smart grid technology provides three main consumer benefits:

- 1 keeps the lights on by enabling overhaul of the grid system; ensuring the grid grows to meet expected increases; and limiting brownouts / blackouts / surges;
- 2 lowers energy costs by giving consumers' control over their usage and facilitating troubleshooting; and
- 3 helps secure energy independence by enabling full scale vehicle charging, focusing on renewable energy.

Industrial and Other IoT Examples

Agriculture is another area where IoT has great potential. Sensors with wireless connectivity for crop fields can help optimize growing and minimize use of water and fertilizers through more targeted application. Livestock can be monitored remotely, as can tanks and other farm equipment, making farming more efficient.

Consumers will benefit from fresher

produce and products that are produced using more efficient farming methods. All told, economic benefits in agriculture are estimated in the \$53-341B range annually.

Public safety is a key area where IoT can deliver benefits in terms of improved disaster and emergency services and improved crime detection and monitoring. Wireless connections

will inform public safety personnel of the status of threats and help coordinate response tactics.

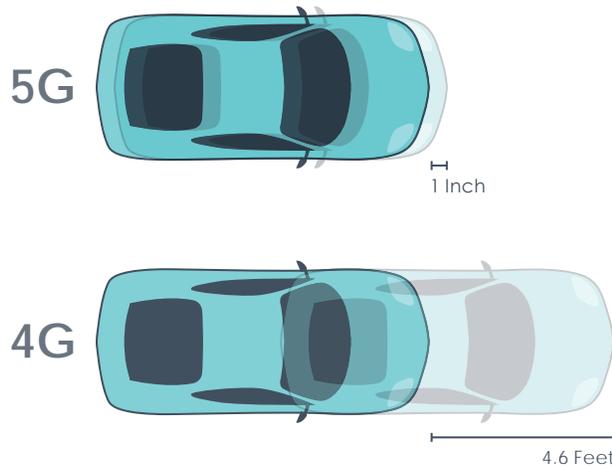
Hardened wireless cameras may be used to provide video of fire status around walls and inside buildings. 5G will help public safety save lives through better responses to emergencies, and economic benefits range from \$38-72B annually.



Source: Volvo Cars

Reduced latency has significant real-world implications.

For instance, it would take about 4.5 feet for a 4G car to apply its brakes. Just an inch for a 5G car to do so, helping avoid collisions and accidents.



5G: Real-Time

●●●●●●● 5G also promises a marked improvement in wireless network lag time – enabling faster communications.

4G LTE latency rates – the technical term for the delay between your request for data and when your mobile device receives it – are low, roughly 10 milliseconds over-the-air; 50 milliseconds end-to-end. This enables consumers to have good quality voice over IP (VoIP) calls and video calls with little delay or jitter. 5G latency rates will be even lower – targeted to be five to ten times lower.

This reduction in latency may seem inconsequential, but a near real-time consumer wireless experience will enable a host of benefits and applications not possible today.

The real-time abilities of 5G will unlock:

Vehicle Safety and Collision Avoidance

Automobiles will increasingly use sensors and collision avoidance capabilities to alert the drivers to stay in lanes, avoid collisions, and to contact emergency services in the event of an accident.

Sensing with vehicles at speed requires very low latency and the real-time nature of 5G should provide such capabilities. With the reduced latency of a fully optimized ideal 5G network, a self-driving car travelling at roughly 60 mph will move just over one inch from the time it identifies an obstacle to the time when the braking command is executed. This performance is comparable to a standard anti-lock braking system.

By contrast, with the latency on a 4G LTE network, the car would move 4.6 feet under the same conditions.

There are some unique applications of Vehicle-to-Vehicle (V2V) communications, including: intersection movement assistance, left hand turn assist, and emergency electronic brake lights (for poor visibility). In addition, V2V communications can enhance forward collision warnings, blind spot and collision warnings, and do-not-pass warnings. While there are some Direct Short Range Communications (DSRC) technologies being evaluated, 5G may play a role in the future.

V2V safety applications have the potential to prevent or reduce the severity of up to 80% of non-alcohol-related crashes. 5G, with its device density and real-time capabilities, has the potential to advance V2V features.



Source: Volvo Cars

Augmented and Virtual Reality

5G has the potential to dramatically change consumer uses and experiences with respect to enriched medical training, education, entertainment, and retail by enabling real-time interactions that take place wirelessly, without visual delay. Virtual reality is becoming available to consumers today with the launch of products such as Samsung's Gear VR,

5G

Case Study

Verizon VGo Robotic Telepresence

Several companies have established innovation centers to enable wireless companies to develop and test innovative wireless technology solutions. One of the early examples is the VGo Robotic Telepresence, a wireless, robotic telepresence unit. The unit is mobile and can be used to provide video conference capabilities for education, health, and other situations where a robot is useful. It can be used to allow a sick child to attend class real-time or for a home-bound person to communicate live with a medical practitioner.



Verizon recently established a 5G Technology Forum with key leaders/partners in the industry: Alcatel Lucent, Cisco, Ericsson, Nokia, Samsung, and Qualcomm as well as several East and West Coast venture capitalists. The collective companies represent billions of dollars in R&D investment and are the innovative leaders collaborating to develop the 5G standards. This will help bring the reality of 5G in the U.S., enabling a vision of a more fully connected world.

Microsoft HoloLens , Oculus Rift, Sony Playstation VR, and HTC Vive Pre.

These virtual and augmented reality applications will be enabled by the real-time communications made possible with the extremely low latency rates possible with 5G.

For instance, virtual reality is being used to provide medical training, job training astronauts, medics, police officers and for skilled trades such as welders, as well as in automotive product development and in a wide range of advertising applications – from promoting movies to tourism in British Columbia.

5G's low latency will play a pivotal role in the evolution of virtual reality applications like these, affording users life-like experiences on the move.

In the health sector, medical facilities are using the wireless Oculus Rift, which provides a 360 degree immersive experience on the go, as a training tool that allows medical students to experience a procedure from a surgeon's perspective.

Western University of Health Sciences in Pomona, California, for example, is using the Oculus Rift at its first-of-its-kind virtual reality learning center, which allows students from every program—dentistry, osteopathic medicine, veterinary medicine, physical therapy, and nursing—to learn through virtual reality technologies.

In education, Google is piloting a field a trip simulation system called Expeditions, providing students a 3D-rich experience that simulates going on a field trip to far-off places. Imagine schools with limited resources being able to bring the Colosseum in Rome or the Parthenon in Greece to students.

Virtual reality and augmented reality can also provide absorbing educational opportunities such as visiting virtual museums that assemble lost artworks or provide the context for an artist like Van Gogh's life's work. This can deliver benefits in the form of sustainability, by eliminating costly travel, as well as environmental preservation in touring sensitive areas.

Virtual reality will dramatically change the world of entertainment including movies, concerts, and other immersive experiences. Imagine being able to experience your favorite band or artist in a virtual concert in 3D in the comfort of your own home. Virtual reality can even be used for retail. Tommy Hilfiger just announced the use of Virtual Reality in their stores where consumers can experience a fashion show in 3D. Virtual reality holds out the promise of more customized experiences, which can be updated and enabled wirelessly, and the prospect of cost savings and increased demand for actual as well as virtual goods.

Real-time Video Conferencing

With enhanced real-time capabilities from 5G networks, video conferencing will become more pervasive, which enables telecommuting, richer meetings, and energy savings.



“5G represents a once-in-a-generation opportunity to transform our homes, our cities, and our society. But that means working together on the right framework for wireless innovation and investment.” • Meredith Attwell Baker, President and CEO, CTIA

What We Need From Policymakers

●●●●●● Policymakers play an important role in advancing 5G technology with a focus on three key issues: more spectrum, streamlined infrastructure deployment, and support for research and development. If consumers are to benefit from 5G services by 2020, we need a committed effort to provide operators with the tools they need to invest in another generation of networks.

Beyond a light-touch, investment friendly regulatory approach, we need to:

Find more spectrum

America’s global leadership in mobile depends on spectrum. Countries around the world are looking to 5G not merely as a wireless technology, but as a key input for economic growth. We must do the same or risk innovation and investment being exported overseas. Because wireless fosters innovation across nearly every industry sector, the potential consequences of falling behind are stark.

The cornerstone for wireless growth and innovation will be clearing additional spectrum for 5G. Very large swaths of high band spectrum are required to support localized 5G “hotspots.” Additional low and mid band spectrum will enable 5G

technology to support much higher device density throughout wide coverage areas.

The FCC should act on the Spectrum Frontiers High Band docket this year in order to make spectrum available for 5G in a timely manner. It is important that spectrum be available to allow operators to deploy as early as they choose for business and technical reasons.

Furthermore, Congress and the Administration should act to identify additional spectrum to be auctioned as soon as practicable. This will provide the low and mid band spectrum to keep up with growth and to enable deployment of the latest technology.

Streamline infrastructure deployment

Sound infrastructure policy is a necessary complement to sound spectrum policy. When and how we introduce 5G depends, in part, upon removing barriers to the deployment of cell sites and antennas.

Ultra-dense network configurations, particularly in metro areas heavy with users, will be a major component of 5G. Small cells are

key to creating these ultra-dense networks. Moreover, because the propagation of higher frequencies is limited in range and building penetration, wireless deployments will be needed for both indoor and outdoor environments. Towers also will have to be constructed to provide 5G coverage across the nation.

Urban small cells



Source: Nokia



To enable these deployments, policymakers should continue to adopt reasonable, predictable siting processes. Such steps include imposing a deadline on federal agencies to act on wireless siting applications and further streamlining by the FCC of small cell and DAS environmental processing.

In addition, cities and municipalities should look for ways to facilitate new deployments using existing and new facilities.

Increase support for 5G R&D

The U.S. needs a robust ecosystem of research and development (R&D) in wireless technologies, infrastructure, chipsets, devices, and applications. Focused R&D is needed to realize the full innovation potential of spectrum made available for 5G services. Policymakers should continue efforts to increase support for R&D; last year's decision to make permanent the R&D tax credit is a good first step.

Many technology companies including QUALCOMM, Samsung, Intel, Cisco, Ericsson, Motorola, and others are investing in R&D and funding research internally and with universities. Nokia, which recently acquired Alcatel-Lucent (Bell Labs), has been investing in 5G R&D and has funded NYU Poly, one of the leading U.S. universities in millimeter wave technology, to develop

and demonstrate 5G technology capabilities.

Furthermore, the government should continue to make direct investments in 5G, such as through the National Science Foundation (NSF). NSF is funding several research programs using their various research programs, testbed infrastructure programs, and testbeds. Partnering with other government agencies including the White House Office of Science and Technology (OSTP), NTIA, DARPA, and others, the NSF can be an important tool to advance 5G research and strengthen the partnership between industry and universities.

Together, with appropriate new spectrum, streamlined infrastructure deployment, and favorable R&D, the ecosystem will help ensure the U.S. is a leader in 5G.

Smart Cities

Operators and technology companies are partnering with cities to provide sensors, connectivity, platforms and solutions to enable consumer benefits, efficiency and energy savings.

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