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
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	RM-11664

COMMENTS OF QUALCOMM INCORPORATED

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SUMMARY

Qualcomm applauds the Commission for its timely release of this *Notice of Inquiry* seeking input on the use of spectrum bands above 24 GHz for 5G mobile broadband services. These millimeter wave bands can be used as part of the 5G solution, but 5G services will encompass much more than just operations in these bands. Qualcomm envisions 5G services using low-band, mid-band, and high-band spectrum, all in concert with one another to deliver unparalled forms of connectivity, not just in terms of capacity, data rates, and latency, but also in terms of the mode of connectivity (*i.e.*, device to device, mesh, etc.), and the support of new device types, including drones, robots, and other industrial machines. 5G services will enable use cases that are not even imaginable today as supportable by traditional cellular technology.

The millimeter wave bands present an important opportunity to open up large contiguous blocks of spectrum to help meet today's surging mobile broadband data demands, particularly in major metropolitan areas and event venues where large populations of mobile users are concentrated. 5G services, however, will need to use more than just these millimeter wave bands to support a superior and more uniform quality of user experience ("QoE") with ultra-low latency and ultra-high throughput across all locations and to all devices. Additional sub-5GHz spectrum will also be needed.

Therefore, while Qualcomm applauds the FCC's initiative to free up the millimeter wave bands for mobile broadband use, it is equally important that the agency redouble its efforts to work with NTIA, other federal agencies who rely upon spectrum, Congress, and the wireless industry to repurpose much more spectrum below 5 GHz for mobile broadband. The remarkable success of the AWS-3 auction demonstrates firsthand the value of sub-5 GHz spectrum, which will be an important building block for 5G. The amount of low-band spectrum available for 5G

services needs to be great enough so that the 5G QoE is much better than 4G (which is already excellent) in all areas including areas where there is no millimeter wave coverage.

To be clear, support of bands above 24 GHz will require additional research and development, which Qualcomm and many others in the industry are busily working on. Qualcomm believes that this higher band spectrum will generate a significant return in terms of providing high levels of throughput in areas where it is needed most, and agrees with the Commission's decision to follow its longstanding practice of adopting flexible service rules, and not mandating specific technologies, for it has helped to provide increasing levels of competition and drive continued innovation in the mobile ecosystem. This successful regulatory approach has enabled the U.S. to lead the world in the deployment of 4G LTE services, and continuing that approach will drive the success of 5G and future generations of services.

Accordingly, Qualcomm encourages the FCC to promptly issue band-specific *Notices of Proposed Rulemaking* proposing to exclusively license for mobile broadband services large blocks of spectrum currently assigned to the LMDS, 39 GHz and 37/42 GHz services. The Commission should also take the necessary steps to extend the current 60 GHz unlicensed band to include the 64 to 71 GHz swath of spectrum identified in the *NOI*. Each of these bands that are targeted for mobile broadband use should be permitted to also support backhaul operations, as it would provide a range of deployment options and enable the timely deployment of 5G services in these millimeter wave bands.

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QUALCOMM Incorporated respectfully submits these comments in response to the Commission's *Notice of Inquiry* into the use of spectrum bands above 24 GHz for Fifth Generation ("5G") mobile broadband services.[1] Qualcomm is pleased to share its vision for 5G wireless communications services that will further enrich existing use models and applications, connect new industries and device types, and enable completely new user experiences. It is critically important that the FCC continue its important work to free up additional spectrum below 5 GHz for mobile broadband services while it explores, via this *NOI*, 5G opportunities in bands above 24 GHz because the lower band spectrum, in the range currently used for 3G and 4G mobile broadband services, will continue to play an essential role in the successful delivery of 4G and 5G services coast-to-coast. In these comments, Qualcomm provides its current thinking on how to best enable mobile operations above 24 GHz, recognizing that our view may be refined, and perhaps even rethought, as our research and development work progresses.

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[1] *See* Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177, *Notice of Inquiry*, FCC 14-154 (rel. Oct. 17, 2014) ("*NOI*").

INTRODUCTION

Qualcomm is pleased that the FCC is looking to open up bands above 24 GHz for 5G mobile broadband services. This higher band spectrum can be an important part of a 5G solution by supplementing the longer range capabilities of spectrum below 5 GHz. These millimeter wave bands are not the 5G solution. Rather, these bands will support one aspect of an overall 5G system, which will involve lower spectrum bands as well. Thus, it is equally important that additional sub-5 GHz spectrum be repurposed for mobile broadband use in order to satisfy the 1000x increase in mobile data demand we are currently experiencing.

Qualcomm believes that 5G mobile services will transform societies and industries to an even greater extent than previous service generations. Wireless services make a leap approximately every 10 years with a new generation of services. 1G, which was introduced in the 1980s, brought mobility to analog voice. 2G introduced the benefits of digital voice globally and laid the foundation for mass communication in the 1990s. 3G provided improved data capabilities around the turn of the century and introduced true mobile broadband connectivity, which exploded with the introduction of the smartphone. In 2010, 4G services expanded mobile broadband connectivity with higher data rates and more capacity. In the smartphone era of today, mobile is driving new experiences like wireless 4K Ultra HD video, and brand new mobile data services are being introduced each week. Thus, it is not surprising that mobile device sales have overtaken personal computer sales, and mobile computing is expanding well beyond smartphone applications into the Internet of Everything ("IoE").

5G mobile services will provide more than much higher data rates. 5G connectivity will create new services, new industries and devices, and empower brand new user experiences via support of ultra-low latency, ultra-low power, ultra-high reliability and ultra-high security devices with flawless connectivity. Over the next ten years during which 5G services begin to be

released, devices will be transformed into a wider variety of form factors and capabilities at a much quicker pace. As a result, when compared to 4G services, 5G services will introduce much broader dimensions of improvements to meet our growing connectivity needs.

To provide these new capabilities and communications needs, it is important to begin work today on defining the scope and capabilities of 5G services, which is what Qualcomm and its wireless industry partners are doing. Thus, the Commission's release of this *NOI* is timely indeed. While 4G LTE and LTE Advanced will continue to evolve to their full potential and be deployed well past 2020, it is important for the industry and regulators alike to start moving forward with 5G efforts so that 5G services can begin to be deployed around 2020.

As explained herein, 5G services will use high-band, mid-band, and low-band spectrum to support and seamlessly unify the technologies that today are part of the 4G ecosystem, such as LTE Broadcast, device to device discovery via LTE Direct, and LTE in unlicensed spectrum, while providing significant performance improvements over 4G across all geographies. To achieve this vision, 5G services need scalability and adaptability across a wide variation of use cases — from mission-critical applications like remote controlled vehicles and medical procedures to less time-critical communications from miniaturized sensors and other M2M devices.

Qualcomm expects that 5G services will be supported by a unified air interface and enable low-cost and highly energy efficient operation across all spectrum bands including the bands above 24 GHz explored in this *NOI*. At the same time, there is no question that spectrum bands below 5 GHz will continue to be valued most highly and provide the foundation for tomorrow's 5G mobile broadband ecosystem.

DISCUSSION

I. The FCC Should Enable Mobile Use Of Bands Above 24 GHz While The Agency And Other Parts Of The Federal Government Redouble Their Efforts To Free Additional Mobile Spectrum Below 5 GHz

The Commission's important work to open up additional spectrum bands above 24 GHz for mobile broadband use should proceed in parallel with intensified efforts to clear additional spectrum below 5 GHz for mobile use by working with Congress, NTIA and other federal agencies that can operate more efficiently in less spectrum through, *inter alia*, using more efficient spectrum techniques and sharing spectrum resources among a greater population of federal users. Qualcomm wholeheartedly agrees with the FCC that this *NOI* "is not a substitute for … efforts to make additional lower frequency spectrum available for mobile services, but rather is a supplement to those efforts."[2]

Indeed, it is critically important for the FCC to continue its work with the wireless industry, NTIA, other federal agencies, and Congress, to consider all reasonable approaches to providing additional — and much-needed — exclusively licensed sub-5 GHz spectrum for mobile broadband. The highly successful AWS-3 auction demonstrates the supremely high value of exclusively licensed spectrum. Much more exclusively licensed mobile broadband spectrum is needed to successfully support the expected 1000x increase in mobile broadband data demand over the coming decade.[3]

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[2] *NOI* at ¶ 2.

[3] *See* Qualcomm website, "1000x Data Challenge," *available at* https://www.qualcomm.com/invention/technologies/1000x (*last accessed* Jan. 15, 2015). *See also* Qualcomm Presentation, "The 1000x Mobile Data Challenge — More Small Cells, More Spectrum, Higher Efficiency" *available at* https://www.qualcomm.com/media/documents/files/1000x-mobile-data-challenge.pdf (*last accessed* Jan. 15, 2015).

Federal agencies that use or manage spectrum below 5 GHz need should expedite their efforts with the U.S. Congress and wireless industry to free up additional spectrum for mobile broadband, particularly bands below 5 GHz. Specific means of freeing up more spectrum for exclusive commercial use may involve more intensive sharing among federal users in less spectrum by using wireless technologies that support greater spectral efficiency.

II. Qualcomm Agrees That The Commission Should Follow The Same Regulatory Path For 5G Services That Has Enabled 3G And 4G Services To Flourish

Qualcomm applauds the FCC's stated approach to apply to 5G services the same highly successful regulatory principles it has applied to mobile broadband services previously. Flexible service rules and technology-neutral regulations have let innovation and market competition drive rapid technology advances for previous generations of wireless interfaces.[4] As the Commission rightly recognizes, designing service rules specific to a given technology would constrain innovation because rules that are locked in to a particular standard would soon become outdated.[5]

A. 5G Services In Bands Above 24 GHz Will Supplement 5G Operations In Lower Bands To Provide Ultra-High-Speed Broadband Where Data Demands Are High

5G operations in spectrum bands above 24 GHz will be used to provide ultra-high-speed services in specific areas, supplementing 5G services that use sub-5 GHz spectrum to provide coast-to-coast connectivity.[6] Qualcomm and others in the wireless industry are investing heavily in the development of advanced mobile technologies, and they believe that wide channels available in these higher spectrum bands will be needed to support growing traffic demands,

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4 *See NOI* at ¶ 3.

5 *See id.* at ¶ 17.

6 *See id.* at ¶ 7.

particularly in dense urban areas and many event venues, both indoors and outdoors.[7] These efforts include significant funding of universities investigating millimeter-wave wireless mobile service solutions.[8]

Each new wireless generation must provide significant improvements over the previous generation, so 5G services need to look beyond today's trends and device capabilities to define new services and use models to drive requirements beyond what 4G technologies can do. 5G must support communications among a massive number of connected things — perhaps in the trillions — that we expect to be online in the 2020 to 2030 timeframe.

5G services need to be able to scale up as needed to provide much higher data rates and support much greater capacity to provide a high quality of user experience ("QoE") to the multiple devices that each user will rely upon in the day-to-day lives. Indeed, the addition of proximal and contextual awareness to wireless devices will create additional value to the mobile broadband user experience. When considering operations in the bands above 24 GHz, there are multiple dimensions to introduce more capacity and further densify networks, such as advanced receiver designs coupled with spatial multiplexing techniques that can leverage the wide swaths of spectrum available in the millimeter wave bands.

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[7] *See id.* at ¶¶ 10, 19. The statement in the *NOI* that "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," *NOI* at ¶ 10 n.26, is not accurate. The Qualcomm "Network Densification" paper, which the *NOI* cites for this claim, makes clear that given "reasonable projections on additional spectrum availability, expansion of small-cell deployments, and growth in backhaul infrastructure, we believe that the cellular communication industry is well positioned to meet the 1000x demand over the next decade." *See* Naga Bhushan et al., "Network Densification: The Dominant Theme for Wireless Evolution into 5G," IEEE COMMUNICATIONS (Feb. 2014) at 88. No claims are made about whether bands below 3 GHz have sufficient unexploited capacity to meet expected traffic demands over the next decade. As Qualcomm explains herein and has explained in many FCC filings, much more low band spectrum is needed to meet the 1000x growth in data demand over the coming decade.

[8] *NOI* at ¶ 12.

5G technology will enable new mission-critical services and thus will need to expand well beyond human communication requirements, particularly in areas such as latency, security, and reliability. Mission critical communications services — where failure is not an option — include the control of critical infrastructure, such as the power grid, and remote control of vehicles, aerial drones, and even medical procedures.

As 5G technology will need to scale up to support a massive number of connected things, such as tiny battery-powered sensors, it also will be important to scale down in cost, data rates, power and mobility to provide extremely low-power, low complexity protocols to support these sensors and many other types of highly useful applications and services. Deeper contextual and service awareness with both 5G devices and network equipment, in many cases enabled by tiny sensors, will empower new user experiences and refined network optimization. Device to device discovery, currently emerging in 4G via LTE-Direct, will need to be an integral part of 5G for proximal services where devices sense relevant value in the proximity to other devices and users. Devices that sense their surroundings can use these connectivity senses both to connect to desired things and avoid unwanted things.

In order to support these innovative 5G services and applications, wireless connectivity in spectrum bands above 24 GHz will work alongside operations in bands below 5 GHz to provide highly reliable and secure, ultra-low latency, ultra-low power, low cost devices.

B. Clearing Millimeter Wave Bands For Mobile Use Will More Likely Spur The Introduction Of Innovative Services Than Will Requiring Spectrum Sharing

Qualcomm believes that the Commission should consider clearing bands above 24 GHz for mobile use, to the greatest extent possible, because it may be too restrictive to require new mobile use of these bands to protect current incumbent users. While the FCC states that it is looking for information from the industry on how to "accommodate mobile services without

displacing or impairing existing uses,"[9] Qualcomm is concerned that imposing such a restrictive requirement at the outset could well impede the success of efforts to open up some (or all) of these bands for mobile broadband.

Given that many of the bands identified in the *NOI* have not been considered for mobile operations before, requiring new mobile operations to work around the current incumbent users in a given band could limit the feasibility of supporting mobile services in these millimeter frequency bands. As a matter of fact, many LMDS and 39 GHz service licenses have been cancelled or forfeited due to the respective licensees' failure to meet the construction requirements, so there are large areas of this country where mobile deployments won't need to contend with interference from or to these other services. In the limited areas of the country where these licenses, which comprise a limited number of point-to-point microwave links, remain active, the Commission should explore moving those links to other bands.

At the same time, Qualcomm believes that it is worth exploring technical and regulatory tools that may be used to protect current incumbent users. For example, due to the narrower beams that are possible in the bands above 24 GHz, the interference to incumbent users can potentially be more easily controlled and thus support new sharing scenarios. Additionally, a licensed spectrum sharing framework called Authorized Shared Access ("ASA") allows a mobile user to operate within a given frequency band or channel when an incumbent user is not operating.[10] Qualcomm and others have proposed the use of ASA in the 3.5 GHz "small cell" band to enable sharing with incumbent federal radar systems. For those bands above 24 GHz

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9 *NOI* at ¶ 16.

10 *See, e.g.*, Qualcomm Comments on 3.5 GHz Licensing Public Notice in GN Docket No. 12-354 (filed Dec. 5, 2013).

that require a federal incumbent use to be completely protected from interference from mobile users, ASA could play a useful role to free up spectrum for mobile use.

III. 5G Mobile Operations Can Be Successfully Deployed In Bands Above 24 GHz

Qualcomm's technical analyses of the spectrum bands above 24 GHz show that it is feasible to deploy mobile services in these bands.[11] At the same time, 5G operations in these bands will need to access lower band spectrum (*i.e.*, below 5 GHz) to provide ubiquitous coverage in a cost effective manner.

Coverage using the millimeter wave bands may have regions of outage due to the geometric nature of signal propagation, and access to lower frequency bands will be essential to making overall system operations more robust and reliable. Moreover, the wireless technology tools and deployment models used to support these millimeter wave bands will be quite different than what are currently used today to provide mobile broadband in sub-3 GHz spectrum, and these tools and models will take advantage of the different propagation characteristics on millimeter wave spectrum, as explained below.

A. Advanced Antenna Designs Coupled With The Directional Nature Of Transmissions In These Bands Can Facilitate Coexistence With Incumbents

The narrower beams that can be generated in bands above 24 GHz could help limit interference to incumbent users of the band. Antennas that operate in millimeter wave spectrum can use beamforming to generate thin beams, and may be steerable in both azimuth and elevation. These antennas can reject interference from all directions other than the desired

[11] *NOI* at ¶ 17.

direction, allowing for much more intensive frequency reuse than is possible with lower band spectrum.[12]

Qualcomm has found that base station antenna arrays with many elements, *e.g.*, from 16 elements to 256 elements, are possible in these bands, with each individual element having some gain.[13] Patch antennas can have 5-6 dB gain per element, and column antennas with fixed elevation can have 15 dB gain per element. However, each antenna element that needs to be individually controllable would require its own Power Amplifier ("PA"). In order to provide a desired level of connectivity to a mobile device, antenna arrays may use varying beamwidths and have multiple antenna subarrays that can be turned on and off as needed.[14]

Like today's macrocellular base stations that operate in sub-3 GHz spectrum, millimeter wave band operations also would use a mix of higher power and lower power base stations mounted at different elevations as well as indoors and on the exterior of buildings.[15] Wireless propagation properties of millimeter band spectrum in an indoor environment may be very different than outdoor propagation properties. For example, non-Line-of-Sight ("LoS") propagation, shadowing from walls and partitions and even individuals, particularly in dense user environments, will need to be accounted for.[16] The number of users in the millimeter bands that can simultaneously connect to a single base station will depend on various characteristics of the

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12 *See id.* at ¶¶ 18-22.

13 *See id*. at ¶ 19.

14 *See id.* at ¶ 22.

15 *See id*. at ¶ 20.

16 *See id*. at ¶ 22. In addition to understanding the impact of handset orientation on millimeter wave band signal propagation, it will be important to characterize the effect of the human body given the expected deployment scenarios and use cases.

system such as the operating bandwidth, transmit power levels, resource granularity, and modulation schemes, among other technical factors.

In addition, the limited real estate within end user devices may limit the number of antennas, but, at the same time, operating in higher frequency bands allows many more antenna elements to be packed into the same area. And, to overcome potential link budget issues, larger PAs and more extensive antenna arrays at the base station and advanced modulation schemes can be used.[17] Handsets also may be able to overcome obstacles that impede LoS to base stations because non-LoS paths can offer significant energy; they can use multiple subarrays to cover more angular space and improve signal reception.[18] At the same time, due to user device size constraints, the RF beamwidth from devices may not be as narrow as base station beamwidths.

B. Systems That Operate In Millimeter Wave Spectrum Will Need To Simultaneously Access Lower Band Spectrum To Provide Ubiquitous Service

As noted in Section II.A above, Qualcomm believes that cellular networks will use millimeter band spectrum as a supplementary component within an architecture that is anchored in lower-band spectrum because of the highly favorable propagation characteristics of sub-5 GHz spectrum.[19] Users in many cases will connect to the network through lower band spectrum and then access the millimeter bands as needed where those bands are available. It also will be possible, however, to directly access the network via millimeter wave network infrastructure. Given the wide bandwidths that are available at 24 GHz and above, user devices and base

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17 While there may be some benefit to using simpler modulation schemes, more advanced schemes will allow improved operation in the face on non-LoS and low Signal-to-Noise ("SNR") ratio communications scenarios. *See id.* at ¶ 32.

18 *See NOI* at ¶ 24.

19 *See id.* at ¶ 26.

stations can use highly redundant transmissions (or directed identification signals) for device discovery to overcome higher path loss.[20]

Handoffs between sites operating in millimeter wave band spectrum would rely on measurement procedures, similar to what is used in cellular networks today, except that the directional nature of this higher band spectrum will need to be accounted for. Handoffs between indoor and outdoor base stations present challenges because indoor-outdoor penetration losses are generally higher at higher frequencies.[21] Also, broadcast type operations will continue to be best supported by lower band spectrum due to its inherent omnidirectional transmission capabilities.

C. The Wide Bandwidths Available Above 24 GHz Offer Compelling Mobile Broadband Delivery Opportunities

A number of the bands identified in the *NOI* have 500 MHz or greater channel bandwidth, which can be used to provide compelling mobile service throughputs. To some extent, the dynamic variations in link quality to be expected in non-LOS operation that results from mobile operations in the millimeter wave bands can be compensated for by using higher burst rates that can support a high quality user experience.[22]

Qualcomm believes that it will continue to be important to provide large contiguous blocks of spectrum in the millimeter wave bands. Depending on the situation and the type of beamforming employed, aggregating small chunks of disparate spectrum could make RF transceiver complexity quite challenging. Also, Qualcomm anticipates that the types of services supported in these bands may be asymmetric, such as user streaming and downloading of

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20 *See id*.

21 *See id*.

22 *See id*. at ¶ 30.

audiovisual content, and thus benefit from the flexibility that Time Division Duplex ("TDD") operation provides. Additional potential benefits of TDD include exploiting reciprocity for beamforming and supporting dynamic resource matching to traffic.[23]

D. Hybrid Architectures Comprised Of Both Operator-Driven and User-Driven Models May Be Deployed In These Bands

Qualcomm believes that both wireless operator-driven models and user-driven models can be successfully deployed in the millimeter wave bands. Moreover, it will be important for spectrum to be licensed on an exclusive basis in order to support an acceptable quality of service and quality of user experience.[24] While macrocells can use beam steering to generate narrow, highly-focused millimeter wave beams in high dense environments, Qualcomm expects that most mobile deployments in bands above 24 GHz are likely to be comprised of densified collections of small cells each with defined areas of service. Relaying between small cells and deployment of mesh-like architectures will be valuable for both data and control planes. Qualcomm also expects device-to-device connectivity to expand coverage and support sharing of cached content among nearby users. Designing networks with these capabilities built in will improve robustness and lower the cost of network equipment and user devices.

Also, just because small cells may be deployed in these bands does not mean that the transmit EIRP would necessarily be lower.[25] Signal propagation losses are much higher in these bands and has to be compensated for by using higher EIRP; diffraction, foliage, rain, and body shadowing losses, among other conditions, take on increasing important when one looks to

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[23] *See id.* at ¶ 31.

[24] *See id*. at ¶ 39.

[25] *See id.* at ¶ 41.

support mobile operations in the millimeter wave bands. The specific power levels needed to provide mobile service in a given band must be determined through careful link-budget analysis.

E. Protection Criteria For Co-Channel And Adjacent Channel Incumbent Users Should Be Defined For Each Band At The NPRM Stage

More information will be required from federal users of the bands identified for mobile operations as well as federal users of adjacent bands in order to propose appropriate protection criteria. Qualcomm believes that the protection criteria of potentially affected services will be an important part of the follow-on rulemakings that will be used to set operational criteria for mobile operations in the specific bands,[26] and the Commission should collect this information prior to issuing an NPRM proposing to allow mobile operations in a given band.

F. Backhaul Operations Should Also Be Supported In These Bands

The millimeter wave bands identified in the *NOI* could be very well suited for backhaul. In fact, a number of these bands already support point-to-point microwave links. 5G operations in these bands may be able to seamlessly integrate and dynamically share spectral resources in a single band between mobile access links and backhaul links.[27] This deployment scenario would be particularly useful for mesh-relaying due to the shorter transmission ranges that the millimeter wave band spectrum supports. While millimeter wave band spectrum can be used to backhaul small cells that provide mobile connectivity using sub-5 GHz band spectrum, networks deployed with integrated access and backhaul can lower deployment costs and operating costs of maintaining backhaul and access networks that use different technologies.

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[26] *See NOI* at ¶¶ 41-43.

[27] Techniques such as SDMA and full-duplexing, in addition to inter-cell co-ordination and scheduling can support for flexible use between mobile access and backhaul.

Indeed, the ability to use high-gain antennas at both ends of the fixed link make these bands attractive for backhaul use for it provides a transport network that is convenient to deploy and has higher capacity than the access network.[28] However, in contrast to using these bands for access, where link failover to lower bands may be tolerable from the end-user perspective, backhaul use needs to be substantially more tolerant to link failures due to propagation and misalignment issues, among other technical challenges. Support of such robustness can be addressed through flexible regulations and technology innovation.

G. Millimeter Wave Mobile Operations May Necessitate New RF Exposure Requirements And Assessment Techniques

It may be necessary to provide new RF exposure requirements and assessment techniques for mobile operations in the bands above 24 GHz.[29] For fixed and mobile applications using millimeter wave frequency bands, the current power density limits remain applicable because the exposure is in the "far field." For portable handset applications, however, this may not hold true, so new limits based on tissue temperature should be defined.

Additionally, as noted above, mobile operations in the millimeter wave bands will differ from mobile operations in bands below 6 GHz. Millimeter wave handsets are likely to have multiple element antennas with adaptive beamforming where radiation patterns change with time depending on the multipath environment and transmission paths are optimized by aiming radiation away from the user's body. In addition, because millimeter wave handsets will be

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[28] *See NOI* at ¶ 45.

[29] Certain RF exposure metrics used for mobile operations in bands below 6 GHz do not apply to the millimeter wave bands. *See* 47 C.F.R. § 1.1310(a) (Specific absorption rate (SAR) evaluation involves assessing "the environmental impact of human exposure to radiofrequency (RF) radiation … within the frequency range of 100 kHz to 6 GHz (inclusive)"). While portable handsets operating in bands above 24 GHz are not currently subject to the SAR limits, there is a power density limit. *See* 47 C.F.R. § 1.1310(e).

designed for gigabit data transmission, handset transmissions are not likely to be continuous. Thus, it will be important to implement time averaging and appropriately account for the effect of multiple element antennas when determining portable handset compliance with RF exposure rules in the bands above 24 GHz.

Qualcomm looks forward to working with the Commission to develop appropriate limits and assessment techniques for future millimeter wave mobile devices.

H. Global Harmonization Of These Bands Should Be Favored

The Commission should favor global harmonization in the millimeter wave bands used for mobile operations where possible because it lowers equipment costs, particularly antenna and RF transceiver complexity, and also offers end users a more predictable QoE when traveling outside the U.S.[30] At the same time, the desire for global harmonization should not stop the FCC from taking action to define a new mobile service in the identified millimeter wave bands despite the fact that other countries have no plans to do so; setting rules to support mobile operations in the millimeter bands will help to spur innovation, which is clearly in the public interest.

I. The Commission Should Focus On Authorizing Licensed Mobile Services in the LMDS, 39 GHz and 37/42 GHz Bands

The FCC should promptly issue NPRMs focused on opening these LMDS, 39 GHz and 37/42 bands for mobile use and issue geographic area licenses for large blocks of spectrum that permit mobile operations in these bands on an exclusive basis.[31] Licensing these bands on an exclusive basis will allow the licensee to provide a reliable QoS and high QoE for users and

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[30] *See id.* at ¶ 48. The air-interface definition at baseband, network architectures and procedures can be made mostly band agnostic. 4G LTE has provided a precedent for defining scalable bandwidths, and 5G interfaces can implement a similar approach. As explained in Section III.C of these comments, the FCC also should aim to provide large blocks of contiguous spectrum because it lessens device complexity, size, and cost.

[31] *See NOI* at ¶¶ 92-96.

enable quick remediation in the unlikely event that licensed mobile use causes interference to other users of the band. Exclusive use licensing thus "assign[s] 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."[32]

Qualcomm believes that it is possible to deploy mobile services in these bands without causing harmful interference to current users of these bands. For example, mobile operations also can protect radio astronomy observations in the 42.5 to 43.5 GHz band so long as the locations are registered and co-existence parameters are known.[33]

For services such as LMDS and 39 GHz, which have not been as successful as the Commission had hoped and where many licenses were cancelled due to the licensees' failure to meet the construction requirements, Qualcomm submits that the FCC should auction that spectrum for mobile use. In addition to auctioning large blocks of spectrum within these bands on a geographic basis, the FCC should set a ten year license term with reasonable construction requirements to ensure that these bands are put to use in a timely manner.

J. <u>The FCC Also Should Expand The Current 60 GHz Unlicensed Band</u>

The Commission should promptly issue an NPRM proposing to expand the current 60 GHz unlicensed band (*i.e.*, the 57 to 64 GHz band) to include the 64 to 71 GHz band identified in the *NOI*.[34] This band is useful for ultra-high-speed unlicensed uses, such as

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32 *Id*. at ¶ 89.

33 *See id*. at ¶ 69.

34 *See id*. at ¶¶ 70-74.

streaming Ultra HD audiovisual content across a large room, as Qualcomm has recently demonstrated.[35]

IV. 5G Services And Applications Will Be Supported By New Kind Of Network

Qualcomm believes that 5G services and applications will need to be supported by a new kind of network that has multiple communications access paths supported by a broad collection of spectrum bands that include bands heretofore not used for mobile broadband connectivity such as the bands identified in the *NOI*. 5G operations will need the scalability and adaptability across an extreme variation of use cases and will not just provide higher peak data rates. It will, however, be important to support high data rates consistently and uniformly, including at the cell edges. New 5G services will need to connect everything from simple sensors to complex robots and therefore require significant improvements over 4G LTE connectivity.

We believe that the fundamental building block for 5G services will be a new air interface that is scalable across all services and use cases, and supports all spectrum bands and types of spectrum access rights, both licensed and unlicensed spectrum, with both exclusive use spectrum and shared spectrum. All available spectrum bands will be used to ubiquitously provide new services; from the lower sub-5 GHz bands that provide excellent coverage to bands above 5 GHz to provide more capacity to much higher millimeter wave bands that can support targeted capacity needs in concentrated areas with high demand.

While tomorrow's 5G-based network will take advantage of new spectrum bands and use a new air interface, it also will take advantage of 4G, 3G, LTE-Direct, LTE-Unlicensed, and Wi-

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[35] *See* Kanu Chadha Qualcomm onQ blog, "Qualcomm Connectivity Workshop Showcases The Future Of Wireless" (Nov. 12, 2014) (Noting 60 GHz Wi-Fi demo where a tablet device wirelessly streamed 4K video to a large display at rates greater than 4 Gbps) *available at* https://www.qualcomm.com/news/onq/2014/11/12/qualcomm-connectivity-workshop-showcases-future-wireless (*last accessed* Jan. 15, 2015)

Fi investments through a new network architecture that supports simultaneous multi-band, multi-mode connectivity in devices that handle a greater number of bands than is possible today. Qualcomm expects 5G services to take advantage of new spectrum opportunities that will become available beyond 2020 and include 2G/3G/4G re-farming and millimeter wave spectrum.

5G services also will provide broader enhancements such as scalability and reliability in addition to improving dimensions like data rates, capacity, and latency, as well as business dimensions like dynamic subscriptions, deployment, and network sharing models that could include more streamlined third party access. By way of example, it may be possible to offer dynamic subscriptions to users based on their lifestyle that covers all connectivity needs in their homes, vehicles, for phones, tablets, wearables and other devices.

Qualcomm also understands that completely different service models may be needed to support the massive number of connected things and mission critical services. New service models will open up new business opportunities for 5G network operators to host new services and provide a platform for new markets and subscription models that include sponsored connectivity. At the same time, a unified 5G platform will scale for a wide range of services — from traditional wide area deployments to support for enterprises, hotspots at stadiums, residential deployments — and support a broad collection of innovative applications and device-types.

CONCLUSION

Qualcomm strongly supports the Commission's efforts to free up additional spectrum resources for mobile broadband use at 24 GHz and above, for these bands will be an important piece of the 5G spectrum solution. It is equally important that the FCC, NTIA, other federal agencies that rely upon spectrum, and Congress redouble their efforts to free up additional sub-5 GHz spectrum for commercial mobile broadband use because those spectrum resources will be essential to continue fueling intense mobile broadband competition and supporting the successful rollout of 5G services in 2020 and beyond.

Respectfully submitted,

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