Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 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 NOKIA

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REPLY COMMENTS OF NOKIA

Nokia respectfully submits this Reply to comments filed in response to the Commission's Notice of Proposed Rulemaking ("*NPRM*")[1] seeking comment on specific spectrum bands above 24 GHz to promote the next generation of wireless.

[1] *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, GN Docket Nos. 14-177 et al., Notice of Proposed Rulemaking (rel. Oct. 23, 2015) ("*NPRM*").

In these Reply Comments, Nokia reviews the current record in this proceeding, demonstrating wide consensus on a number of topics that will unlock the promise of the bands considered in the NPRM. Next, these Reply Comments discuss the coexistence study submitted by ViaSat, and demonstrate that it uses flawed assumptions that lead to serious questions about the conclusions they draw. Contrary to the assertions of ViaSat, the Commission should adopt its proposal for Fixed Satellite Service (FSS) operators to acquire terrestrial rights if they wish to obtain enhanced interference protection for their secondary FSS services.

Nokia then reiterates its advocacy for higher power levels than those proposed in the NPRM and demonstrates the benefits of those higher power levels to both outdoor and in-building 5G communications. These Reply Comments conclude with a discussion of 5G and security, and include as an attachment an IEEE Conference Paper, "Towards 5G Security," which discusses potential security requirements and mechanisms for 5G mobile networks.

I. THE RECORD REFLECTS CONSENSUS ON A NUMBER OF IMPORTANT ISSUES

Nokia is pleased to find wide agreement in the record on a number of important points that will promote the success of the next generation of wireless. To provide some key examples of agreement, there is strong support for the Commission moving forward expeditiously to authorize mobile operations in the four bands identified in this proceeding: (1) the 27.5-28.35 GHz band (28 GHz band); (2) the 37.0-38.6 GHz band (37GHz band); (3) the 38.6-40 GHz band (39 GHz band); and (4) the 64-71 GHz band.[2]

The record further demonstrates broad agreement with Nokia that the Commission must not stop with those four bands. A number of Commenters stressed the need to continue to

[2] *See, e.g.,* Comments of AT&T at 3-4; Comments of Ericsson at 4-5, 19; Comments of Mobile Future at 3; Comments of T-Mobile USA, Inc. at 4; Comments of Verizon at 5-6, 13.

explore additional bands.[3] As discussed in Nokia's Comments, the range 24.25-29.5GHz, which covers the 28GHz band is extremely important and worth extensive studies. Low-band and mid-band spectrum also are critical. The 3.7-4.2 GHz and 3.1-3.55 GHz could be particularly valuable, as these bands would open up over 1 GHz of valuable spectrum when combined with 3.5GHz (3.55-3.7 GHz). Nokia also urges the Commission to consider the 1300-1390 MHz band.

The record shows a clear consensus for the Commission adopting rules for licensed use of the 28 GHz, 37 GHz, and 39 GHz. Nokia further recommended that the Commission include licensed and unlicensed uses in the 64-71 GHz band, allocating unlicensed from 64-66 GHz and licensed use from 66-71 GHz. The record demonstrates substantial support for this proposal.[4]

There is similarly strong support for creating a single band of spectrum from 37-40 GHz subject to uniform service rules. A number of parties demonstrated why the "hybrid" scheme proposed in the NPRM for the lower portion of that band would be technically and administratively problematic.[5] In addition to these considerable hurdles, there is a lack of interest in the record from property owners to deploy in-building networks in the 37 GHz band, further weighing against the novel hybrid licensing scheme.

There are a number of other aspects of the licensing framework where there is consensus in the record. Commenters widely agree that the geographic licensing area should be larger than county-level.[6] Nokia believes that the Commission should use Basic Trading Areas for the 28

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[3] *See, e.g.*, Comments of 4G Americas at 15-17; Comments of Ericsson, at 24-26; Comments of CTIA at 7; Comments of T-Mobile USA, Inc. at 4-9.

[4] *See, e.g.*, Comments of AT&T at 17; Comments of CTIA at 17-19; Comments of Ericsson at 19-20; Comments of Mobile Future at 16-17; Comments of T-Mobile USA, Inc. at; 14-15.

[5] *See, e.g.*, Comments of AT&T at 16; Comments of CTIA at 15-17; Comments of the Consumer Technology Association f/k/a The Consumer Electronics Association ("CTA") at 3; Comments of Ericsson at 7-8; Comments of T-Mobile USA, Inc. at 12-13; Comments of Verizon, 6-10.

[6] *See, e.g.*, Comments of 4G Americas at 4-9; Comments of AT&T at 17-19; Comments of CTA at 11-12; Comments of Ericsson at 9-10; Comments of Verizon at 10-12.

GHz and Economic Areas for the remaining bands considered in this proceeding (37 GHz, 39 GHz, and 66-71 GHz, if licensed).

Both the license terms and the performance requirements should be tailored to provide more certainty to encourage investments in 5G technologies in the mmW bands.[7] For similar reasons Nokia asserts that the Commission should not impose a "use it or share it" obligation on these bands.[8] In its initial Comments, Nokia further described the importance of secondary markets to facilitating deployment of the mmWave bands. This is yet another example of industry consensus in the record.[9]

II. THE COEXISTENCE STUDY OF FSS WITH 5G SYSTEMS FILED BY VIASAT INCLUDES INCORRECT ASSUMPTIONS

In its Comments, ViaSat submitted a study that purports to model coexistence between FSS and 5G systems. Nokia respectfully submits, however, that this study includes flawed assumptions that lead to incorrect conclusions.

Specifically, ViaSat presented a study that discusses the interference from ViaSat's earth stations into 5G networks in the 27.5-28.35 GHz band based on the Commission's proposed boundary field strength limit of 47 dBμV/m for such 5G networks.[10] In particular, the Commission proposed that:

> The predicted or measured median field strength at any location on the geographical border of a licensee's service area shall not exceed 47 dBμV/m unless the adjacent affected service area licensee(s) agree(s) to a different field strength. This value applies to both the initially offered service areas and to partitioned service areas.[11]

[7] *See, e.g.,* Comments of 4G Americas at 9-10; Comments of AT&T at 19-20; Comments of Cisco Systems, Inc. at12-14; Comments of CTIA at 23-26; Comments of T-Mobile USA, Inc. at 18-19.
[8] *See, e.g.,* Comments of AT&T 20-22; Comments of CTIA at 26-27; Comments of Verizon at 20-21.
[9] *See, e.g.,* Comments of CTA at 14-15; Comments of Verizon at 13.
[10] Comments of ViaSat at 13.
[11] *NPRM*, Appendix A, Proposed Rules, § 30.204 (Field Strength Limits).

As ViaSat recognizes in its Comments, however, the Commission's assumptions are unclear regarding the reference bandwidth for the proposed Field Strength Limits (e.g. per 1 MHz, or for entire bandwidth of the 5G receiver, which is located on the geographical border of a licensee's service area).[12] This information is very important as it impacts the compatibility study of earth stations with 5G systems.

With the reference bandwidth unspecified, ViaSat's then assumes that the reference bandwidth should be 5.5MHz by default:

> While a reference bandwidth was not specifically provided in the NPRM, the text does reference Part 27 rules, which references a channel bandwidth of 5.5 MHz. In this analysis the 47 dBμV/m value has been scaled accordingly to 39.6 dBμV/m to reflect the field strength in any one MHz bandwidth.[13]

Nokia does not dispute that the Part 27 rules reference Field Strength Limits measured over a channel bandwidth of 5.5 MHz. Nokia disagrees, however, that this should automatically be the assumption used in the coexistence study of FSS with 5G systems.

If we assume that the reference bandwidth is the 5G receiver bandwidth, which is between 2% and 5% of carrier frequency, the Field Strength Limits would be 47 dBμV/m per 560 MHz, which increases ViaSat's calculated compatibility distance of 161m to 1632m, i.e., by a factor of 10. While 1632m could still be a reasonable compatibility distance that could perhaps be reduced further, it is not one that justifies ViaSat's argument that it is not necessary to require 28 GHz Band earth station operators to acquire terrestrial spectrum rights through geographic licenses to protect their facilities from the impact of new terrestrial mobile services.

It is therefore important for the Commission to clarify what reference bandwidth is to be used for the field strength at any location on the geographical border of a licensee's service area

[12] Comments of ViaSat at Exhibit 1.
[13] *Id.*

when calculating compatibility distances due to interference from an FSS earth station into a 5G system.

Aside from a need for the Commission to clarify the reference bandwidth, Nokia believes that a more appropriate methodology for the calculation of compatibility distance value would be a link budget calculation between FSS transmitters and 5G receivers. Using a link budget approach, the acceptable value of interferences towards a 5G receiver can be defined in terms of max I/N, where I states for interferences caused by FSS transmitter and N states for 5G receiver noise floor. Furthermore, system level simulations of 5G systems similar to those provided by Nokia[14] in our initial Comments would provide an even more accurate view of the interference from the secondary FSS systems into the 5G systems.

Nokia therefore, respectfully disagrees with ViaSat's comments that 28 GHz Band earth station operators need not acquire terrestrial spectrum rights to protect their facilities from the impact of new terrestrial mobile services. Instead, Nokia continues to recommend that the Commission implement market-based rules and coordination techniques to facilitate coexistence of satellite use of the 28 GHz, 37 GHz, and 39 GHz bands with 5G systems without unduly limiting and harming terrestrial use of those bands. Nokia also continues to support the Commission's proposal for FSS licensees to remove any concerns accompanying secondary status for FSS in the 28 GHz band, by permitting FSS licensees to acquire terrestrial rights with primary status. The FSS operator could do so by acquiring its own terrestrial license at auction or through secondary market arrangements with another entity that obtains a terrestrial license.

Nokia is presently studying the coexistence of FSS with 5G systems, assuming a more accurate modelling of these 5G and FSS systems. For example, 5G systems are envisioned to utilize Grid-of-Beams (GoB) transmission methods at both APs and UEs, where a preferred

[14] *See* Comments of Nokia at Appendix A.

beam direction for reception and transmission is derived based on explicit channel measurements at the intended receiver. With GoB, most, if not all, transmit power will be concentrated in a set of narrow beams directed at the intended receiver, usually deployed no higher than at street-level, and thus it is unlikely to cause any significant interference at the FSS space station. Similarly, 5G Base Station (BS) antenna downtilt could decrease separation distance between FSS Earth-to-Space transmitters and 5G BS receivers. Furthermore, if the earth stations transmitting to the satellites are more likely to be located in rural areas, then those 5G systems intended for dense urban areas are expected to have limited coexistence issues with the FSS systems. Realistic parameters of FSS systems such as channel bandwidth, interference protection, transmit power, antenna gain, etc. should also be used in the study. We intend to share the results with the Commission as they become available.

III. THE HIGHER TRANSMIT POWER FOR BASE STATIONS PROPOSED BY NOKIA IN ITS COMMENTS CAN BENEFIT BOTH OUTDOOR AND INDOOR USER EQUIPMENT SERVED BY OUTDOOR BASE STATIONS

In its Comments, Nokia provided system level simulation results to show the impact on UE throughput performance that results from increasing the transmit power from the Commission's proposed 62 dBm/100 MHz EIRP to 85 dBm EIRP for Base Stations (BSs) and the system bandwidth (200 MHz, 400 MHz and 800 MHz were considered).[15] Whether UEs were indoors or outdoors, significant increases in system performance can be achieved with higher system bandwidths, as expected. For indoor UEs, the deployment under consideration was heavily path loss limited due to the high penetration losses at 39 GHz. As a result, increasing the transmit power levels can significantly improve system performance.

[15] Comments of Nokia at Appendix A.

However, for outdoor UEs, the deployment under consideration was heavily interference limited, as shown by the fact that increasing the transmit power led to no significant improvement in system performance. Since submitting its Comments, Nokia reran the simulations for outdoor UEs assuming an inter-site distance (ISD) value much higher than the ISD considered initially in our Comments. The new deployment layout and detailed results can be found in the Appendix of this document. The new results show that when the UEs are outdoors with higher ISD values, the system under study also became heavily path loss limited and the severely path loss limited system of outdoor UEs can also significantly benefit from increasing the transmit power level of BS from the Commission's proposed 62dBm/100MHz EIRP to 85dBm EIRP.

IV. POTENTIAL SECURITY REQUIREMENTS AND MECHANISMS FOR 5G MOBILE NETWORKS

In the NPRM, the Commission raises questions on Confidentiality, Integrity and Availability[16] aspects in mmW systems. The Commission is correct to note that:

> There are high expectations that these networks will provide capabilities for a tremendous variety of new devices and applications, including traditional cellular services, M2M and Internet of Things (IoT) applications, and mission critical and public safety services, among many others . . . [and as such requires] us to better understand the security of future mmW band networks in order to promote public safety through communications networks.[17]

This is why Nokia is conducting research on security aspects for 5G mobile networks and has published a paper which covers these security aspects in more details (See attached paper, "Towards 5G Security").[18] We urge that the Commission consider this paper as it studies "how

[16] *NPRM* ¶¶ 260-265.
[17] *NPRM* ¶ 260.
[18] Towards 5G Security (Paper presented at the 14th IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom-15), Helsinki, Finland, 20-22 August, 2015).

to ensure that effective security features are built into key design principles for communications devices and networks that will use these bands."[19] In general, the security measures envisaged for 5G are expected to be related more to the use cases enabled by the use of mmW bands and not coupled with the radio characteristics of any particular frequency band.

Regarding Confidentiality, there is a need to investigate further how user identity confidentiality could be better protected from so-called "International Mobile Subscriber Identity (IMSI) catchers." The Commission asked what existing or planned methods of authentication in mobile or fixed networks provide sufficient confidentiality under the conditions planned for mmW band networks. Authentication includes identification of the mobiles, but the IDs must not be transmitted in over the radio interface in order to keep the location of a mobile confidential. There are means for this in 4G LTE, but they only protect against simple eavesdropping, not against active attacks using an IMSI catcher. Otherwise, the authentication procedures are secure (from 3G onwards) so that a mobile transmitting encrypted sensitive information can be sure that it is the true network (not an attacker) that receives (and can decrypt) the information. We envisage a need for more authentication methods to be used within a given 5G authentication framework to cater for the needs of different use cases.

Regarding Integrity, there is a need to distinguish between integrity of messages and integrity of data stored on devices. Message integrity can be ensured in essentially the same way as today, but with user plane integrity added as an optional security feature. Device integrity requires different measures related to hardware and software of the device. The reliance on the integrity of devices in exposed locations could be reduced by terminating message integrity in more security locations. These message integrity methods are independent of the physical layer of the radio interface and of the distance between access points or the distance between mobile

[19] *Id.*

and access point. Concerning the protection of the integrity of mobile devices, there is the issue that better protection, in particular by more robust software, may make the devices more expensive. In the past, there have been various instances of vulnerable devices. Developing security standards may not be the most difficult issue here. The challenge may be how to enforce them and to keep (often inexpensive) non-compliant devices off the network.

Regarding Availability, we note that "Denial-of-Service" attacks affect availability and need to be taken into account in the design of security protocols. Availability, however, also depends on aspects that cannot be addressed by traditional security measures, but rather are dependent on the physical radio layer design, such as mitigation of jamming attacks. Radio interfaces are inherently hard to protect against jamming. In this sense, it seems not possible "to support communication all the time."[20] The use of redundancy, for example, via the option to use different radio technologies and/or different access points may provide some help, but only in the sense that it increases the effort for the attacker to block the communication.

The Commission also seeks comment on the extent to which existing and previous wireless protocols do not inherently derive useful security services from the underlying transport layer and how such vulnerabilities could be prevented from propagation into mmW band networks. Nokia believes that we can build on the protocols in 4G security. But we envisage adding security features, as already mentioned above, to provide more flexibility and additional security services, depending on the need of the use case. Different trade-offs between security and service availability may apply to different use cases, and these different trade-offs could be realised in separate network slices. Cryptographic keys are derived on the application layer and applied in protocol layers well above the physical layer. Further research is needed to determine whether physical layer characteristics may be reasonably used to provide additional security, as

[20] *NPRM* ¶ 264.

an enhancement of the cryptographic protection that we believe to be indispensable for all sensitive 5G radio communication.

In sum, we note that different services may have different security requirements, and different approaches (e.g., whether they rely on security offered by the network or application layer security instead). We therefore believe the 5G security architecture must be flexible to support these different requirements in an optimal manner.

V. CONCLUSION

Nokia is pleased to submit these Reply Comments in this proceeding, which is critical to moving forward with the next generation of wireless. Nokia urges the Commission to act quickly to adopt rules consistent with Nokia's Comments and these Reply Comments.

Respectfully submitted,

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APPENDIX: SYSTEM LEVEL SIMULATIONS

Introduction and Overview

This Appendix presents a continuation of the system level simulation study described in Nokia's NPRM comments of January 2016 [1]. The purpose here is to consider the effect of a larger inter-site distance on the system performance with outdoor UE antennas with the transmit power levels considered in [1]. The simulation study in [1] considered the impact of system bandwidth and transmit power on the overall user throughput performance in a residential 5G wireless system operating at 39GHz. An example neighborhood deployment was considered with lamp-post-mounted access points with an average inter-site distance of approximately 150m. For that deployment it was shown that for outdoor mounted UE antennas, there was virtually no performance benefit in having the higher transmit power level that was considered in the study, which indicates that the performance of that particular deployment was primarily path loss (or noise) limited rather than interference limited. In this paper, we consider an example deployment having an average inter-site distance of approximately 600m. We show that even with outdoor mounted UE antennas, this particular deployment is path loss limited and that the system performance can be significantly improved with the higher transmit powers considered in [1].

Deployment Scenario and System Assumptions

Figure 1 shows the deployment scenario considered for the simulation study in [1]. The deployment consisted of a neighborhood of houses and roads arranged in a 2 block by 8 block layout. Each neighborhood block consists of 20 houses arranged with 10 houses on each side of a road. Each neighborhood block had a single access point positioned at a height of 6m (below roof-top). For the study in this paper, a similar neighborhood was assumed, but with a much lower density of access points as shown in Figure 2. Rather than one access point per block, the deployment in Figure 2 has one access point per each 16 blocks (2 block by 8 block layout). The resulting average inter-site-distance (ISD) was approximately 600m.

Unless otherwise stated, the propagation modeling, system parameters and all other assumptions were the same as in [1]. Key parameters of note for the study in this paper:

The system bandwidth was 200MHz

All UEs are outdoors (all UEs have zero penetration loss)

As with [1], for Access Points, two values for the max EIRP were considered: 62dBm per 100MHz or 85dBm.

As with [1], for UEs, two transmit power levels were considered: 43dBm and 53dBm.

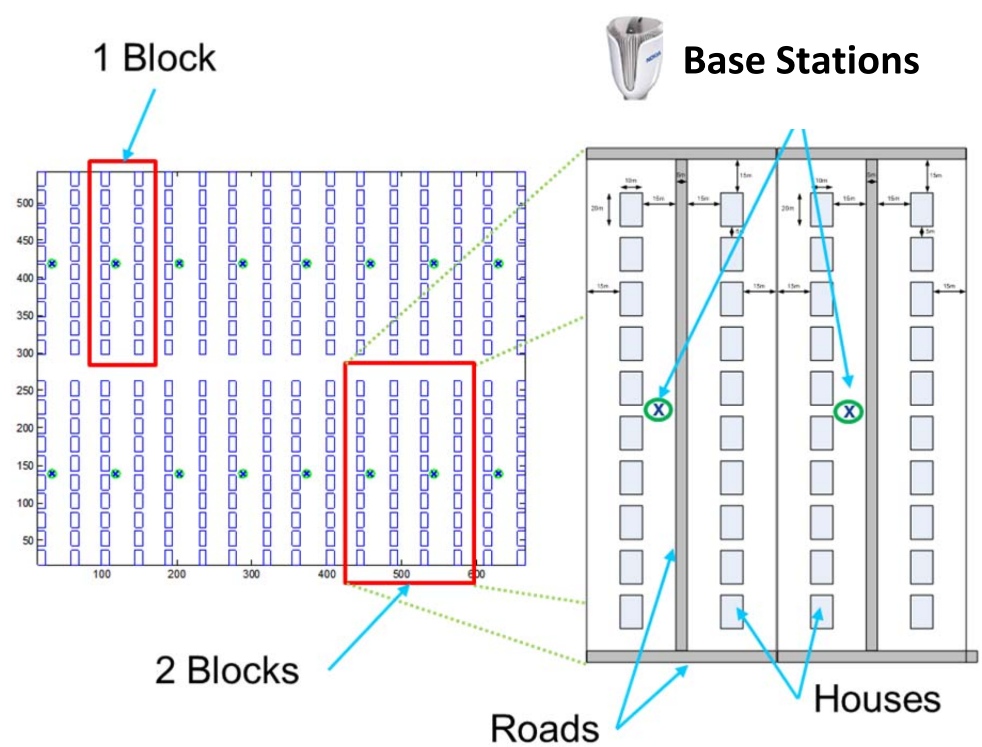


Figure 1 – Deployment scenario for 5G wireless-to-the-home simulation – average ISD approximately 150m

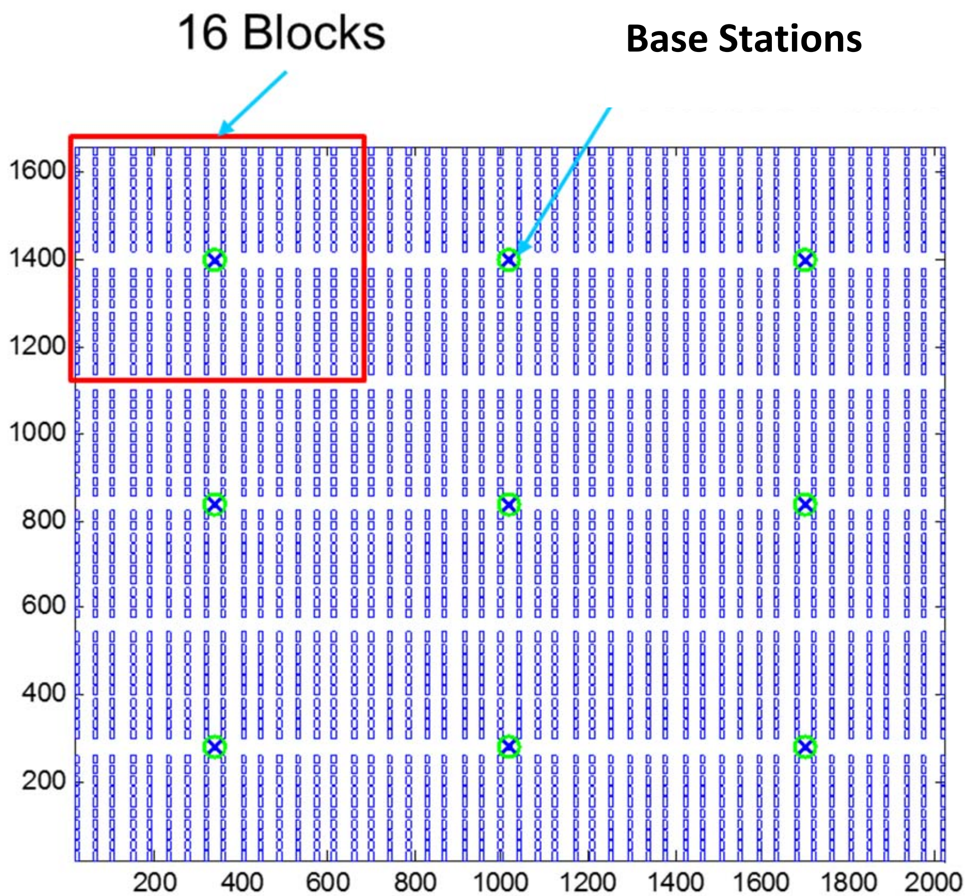


Figure 2 – Deployment scenario for 5G wireless-to-the-home simulation – average ISD approximately 600

Performance Evaluation at 39 GHz with 200 MHz Bandwidth and larger ISD

Figure 3 shows the mean and 5th percentile (cell edge) UE throughput performance for the case with all UEs located outdoors with the deployment in Figure 1 with a 150m average ISD. The top plot is for the downlink, and the bottom plot is for the uplink. These results are from [1] and are included for comparison with the results being presented in this paper. Figure 4 shows the mean and 5th percentile (cell edge) UE throughput performance for the case with all UEs located outdoors in the deployment shown in Figure 2 with a 600m average ISD. The top plot is for the downlink, and the bottom plot is for the uplink. Figure 4 shows the case for a

200MHz system bandwidth only, two max EIRP values (65dBm and 85dBm), and three cases for the active UE density: The first case is where each BS site is on average serving 10 simultaneous active UEs per site, which is the case where each site is serving the same number of active UEs as in the deployment in [1]. The second case is where the BS site is on average serving 81 active UEs. The third case is where the BS site is on average serving 162 active UEs, which represents the same density of active UEs per unit area as considered in [1]. The second case is presented simply because its active user density is roughly midway between the first and third cases. The obvious implication of a higher ISD when the active user density is unchanged is that each BS must serve a significantly higher number of active UEs, which means the system capacity is divided amongst a greater number of UEs, which will (as expected) severely degrade the achievable per-UE throughput performance.

Several observations and conclusions can be made regarding the system at 39GHz with the higher ISD value:

For outdoor UEs and a significantly increased ISD value, increasing the transmit power and the bandwidth can significantly improve the throughput performance. With outdoor UEs in the deployment being studied and the two transmit powers considered, the system is clearly path loss limited (as opposed to interference limited) since increasing the transmit power resulted in significant performance improvements.

Increasing the ISD will significantly degrade the achievable per-UE throughput performance simply due to the requirement to serve UEs with higher distances to the BS and therefore higher path losses. If the density of active users stays the same as the ISD is increased, then the per-user performance is degraded not only by the increased path losses that must be supported, but also by the need to divide the system capacity amongst a greater pool of users.

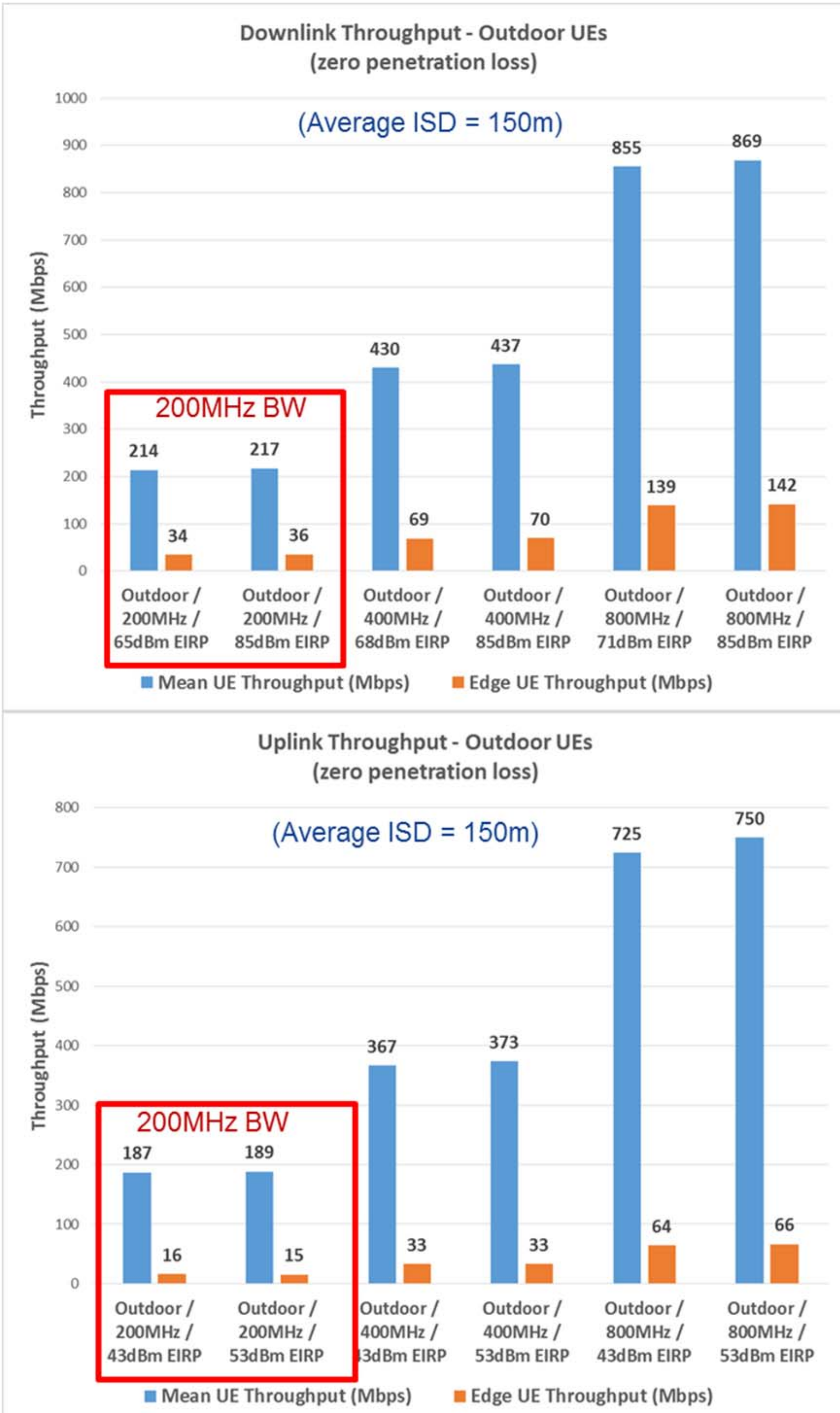
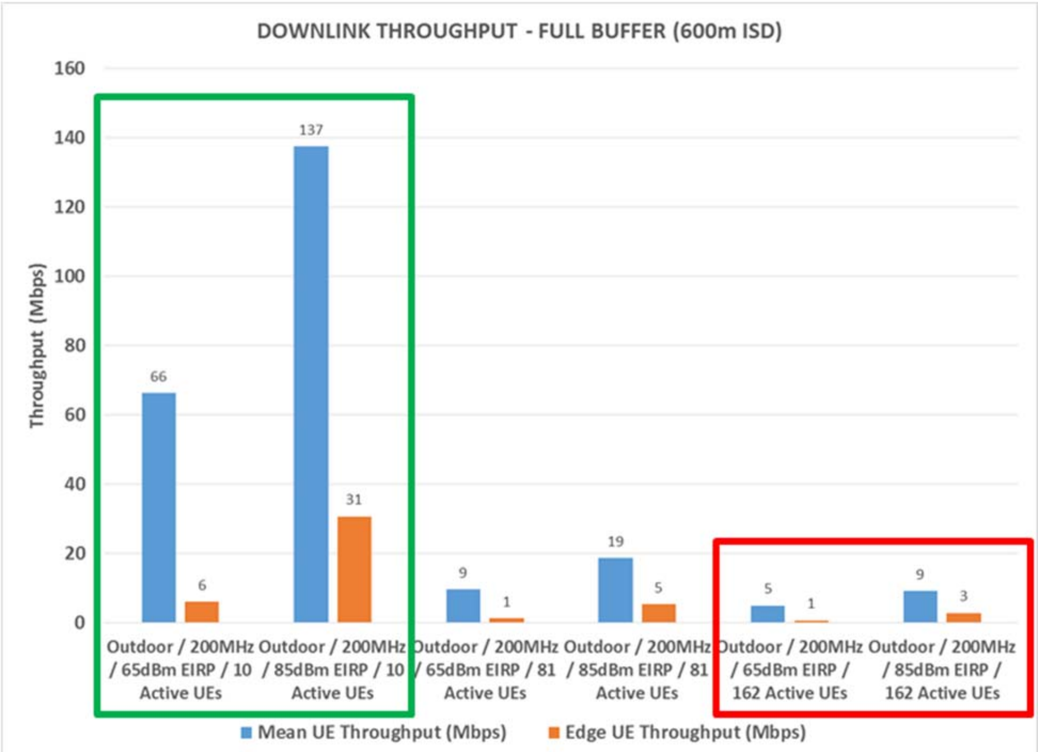


Figure 3 – Mean and 5th percentile UE throughput performance with the layout from [1] with a 150m average ISD and 100% Outdoor UEs. Downlink (top) and uplink (bottom). The red rectangles highlights the 200 MHz case that is comparable to the results in this paper. Source: [1]



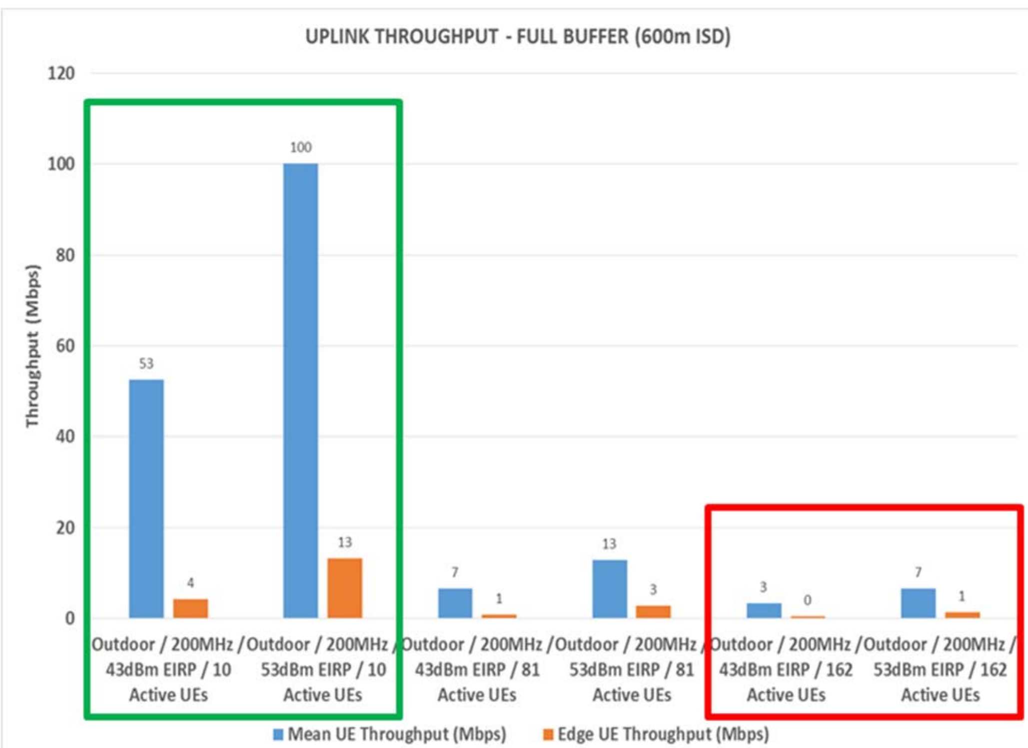


Figure 4 – Mean and 5th percentile UE throughput performance with a 600m average ISD and 100% Outdoor UEs, 200MHz system bandwidth. Downlink (top) and uplink (bottom). Green rectangle indicates results for 10 simultaneously active UEs per BS site. Red rectangle indicates results for 10 simultaneously active UEs per neighborhood block as in [1].

Throughput and SINR Statistics

This section examines the statistics of two key metrics that are helpful for understanding the performance characteristics of the 5G wireless-to-the-home system. The first metric is the CDF of the received Signal-to-Noise-Ratio (SINR) at the output of the receive antenna processing at the UE, shown in Figure 5. The second metric is the CDF of the per-UE throughput, shown in Figure 6.

The following observations can be made from the results in Figure 5 and Figure 6:

Increasing the transmit power can provide significant improvements in the SINR and throughput statistics with higher ISDs and outdoor UEs. This observation is consistent with the throughput results shown earlier and confirms the path-loss limited nature of the deployment under consideration.

For the outdoor UE scenario and a 600m ISD, the higher EIRP level provides a significant increase in system performance both in terms of received SINR and UE throughput statistics. This result confirms the path loss limited nature of the deployment under consideration even when the UEs are outdoors.

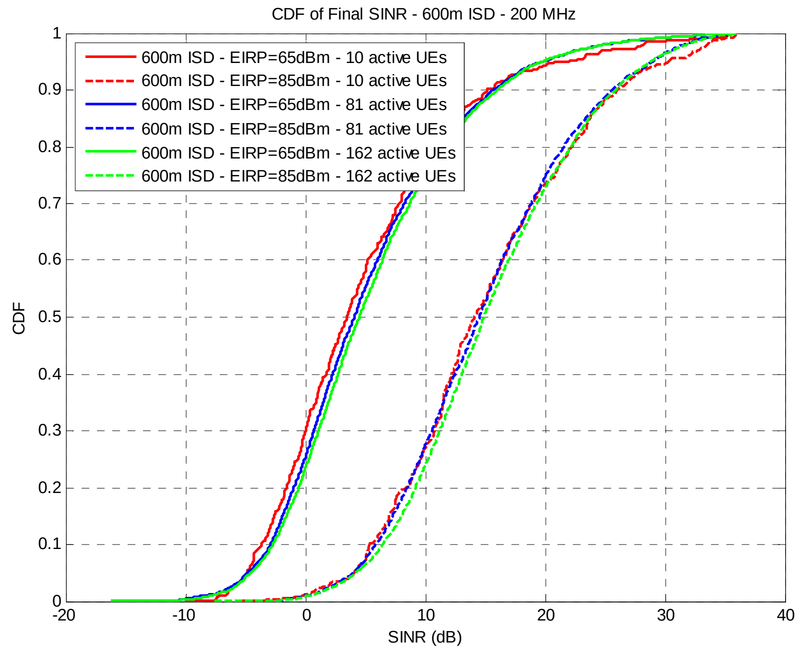


Figure 5 – CDF of post-receiver processing (final) SINR at the UE (downlink) for 200MHz with the number of simultaneously active UEs equal to 10, 81, and 162 per site and Max EIRP values of 65dBm and 85dBm.

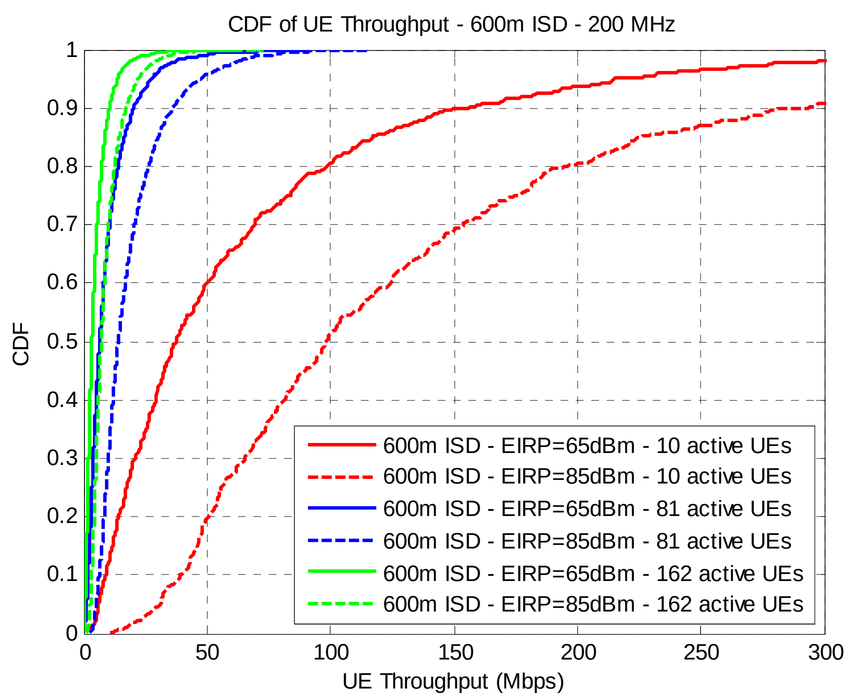


Figure 6 – CDF of Downlink UE throughput: 200MHz with the number of simultaneously active UEs equal to 10, 81, and 162 per site and Max EIRP values of 65dBm and 85dBm

Summary of Results

This paper examined the impact on system performance of increasing the transmit power with outdoor UEs and an ISD value much higher than the ISD considered in [1]. The results in this paper show that when the UEs are outdoors with higher ISD values, the system under study became heavily path loss limited, whereas the comparable system with a 150m ISD studied in [1] was clearly interference limited. As shown in this paper, a severely path loss limited system can significantly benefit from increasing the transmit power levels.

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