Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the matter of	)	
Office of Engineering and Technology and Wireless Telecommunications Bureau Seek Information on Current Trends in LTE-U and LAA Technology	))))	ET Docket No. 15-105

REPLY TO COMMENTS

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Overview

The first round of filings on LTE-U and LAA illustrate that there is a language ambiguity behind which stakeholders are hiding. A majority of the filings include the term 'fair use' or an equivalent as an explicit goal of any regulation or standard concerning use of unlicensed bands. However, few of the filers even attempt to define the term, and none provide definitions specific enough to guide regulations or standards. The parties are using the term to mean very different things, and a conflict between the FCC's stated values for the unlicensed bands is the culprit. Each party assumes a definition of 'fair' that is based on the value that most suits their self-interest. A framework is necessary for standards bodies (or the FCC) to resolve these conflicts.

Once such a framework is established, and the value conflict resolved, the FCC must recognize that current constraints on the unlicensed bands are insufficient. Regulations allow structurally advantaged users (such as those that have access to towers and thus high antenna-heights) to asymmetrically interfere with other users without breaking power constraints. It will prove difficult to prevent large scale, unfriendly coexistence mechanisms without causing real harm to other users of the band (besides Wi-Fi and Bluetooth) that so far have not caused significant degradation to other users, even without friendly coexistence mechanisms. The Commission should potentially distinguish between large and small scale installations of a given technology. For the unlicensed bands, the FCC should also look into adopting approaches similar to the ones it is considering for other bands with privileged users, among other regulations concerning coexistence protocols and tower access.

1. The FCC needs a doctrine of 'Fair Use' on unlicensed bands that incorporates its values.

The comments, coexistence mechanisms, activity by standards bodies, and potential rules all hinge on the definition of 'fair.' Whether the standards bodies act or the FCC does, fairness must first be defined and agreed upon. This fact is recognized by multiple filers. In the IEEE 802 LAN-MAN Standards Committee filing, it was argued that "an agreement between 3GPP and IEEE 802 is needed on what fairness means in a range of realistic usage scenarios[1]" and that this issue is important enough that all stakeholders need to be involved. As currently constructed, the

[1] Comments of IEEE 802 LAN-MAN Standards Committee on Docket No. 15-105, submitted 6/08/2015, page 2

Part 15 rules neither provide guidance on what fairness means nor require that users (or any future technology) consult with other stakeholders.

Existing understandings/definitions of 'Fair Use' are either underdeveloped or too specific. A large number of filings in the initial period discuss 'fair share,' 'fair and reasonable manner,' 'fair coexistence,' and other similar terms. However, few even attempt to define the term, and the definitions that are offered are problematic:

a. Huawei – "LAA is being designed to enable fair coexistence with existing Wi-Fi networks; that is, to have no impact on Wi-Fi services with respect to throughput and latency any more than would an additional Wi-Fi network on the same carrier.[2]"

The same sentiment – to define a 'good neighbor' as one that affects Wi-Fi the same way it affects itself – appears in other comments as well. This definition is problematic for several reasons. First, the definition is not quantifiable or generalizable. The impact by a Wi-Fi network on itself depends on the location, network(s) size, version of 802.11, terrain, and geometry of network nodes, to name a few variables, and so it is near impossible to generally characterize the impact on throughput or latency. Second, it is not clear that a technology's coexistence with itself is a good metric. For example, as future 802.11 standards are developed, past standards may be deemed a bad neighbor. The definition also pre-supposes that there is a dominant status-quo stakeholder in the band in question and that this stake-holder deserves some special consideration. Even if the definition is sufficient for the 5 GHz or 2.4 GHz unlicensed bands, it provides no guidance for fair use on future, new unlicensed bands. If the FCC does not want to have this debate every time a new technology or band comes up, this definition is not sufficient.

b. Broadcom – "Broadcom suggests standardization of at least a three-pronged approach to healthy and fair coexistence among broadband unlicensed technologies, but others may be required as well. First, such technologies should have an initial wait or defer time (we suggest ~43 microseconds) to allow for unaffiliated data transmissions to complete prior

[2] Comments of Huawei Technologies on Docket No. 15-105, submitted 6/11/2015, page 6

to arbitration and transmission. Second, the technologies should incorporate a coexistence mechanism that backs-off rapidly when significant interference with other users is detected (exponential back-off). Third, the technologies should incorporate LBT prior to each data transmission. LBT should be capable of detecting lower levels of energy, preamble, or carrier sense (e.g., energy detection at -82 dBm to -92 dBm) than the existing LBT requirements in some countries (i.e., -62dBm).[3]"

And

Cablevision, on what the LTE-U Forum has stipulated – "the proponents of LTE-U and LAA consider sharing 'fair' so long as Wi-Fi can deliver 4 Mb/s – a fraction of what consumers are enjoying today[4]."

Both these definitions are quantifiable and verifiable. However, they have their own pitfalls. The Broadcom definition presents a *mechanism* to achieve "healthy and fair coexistence," but it does not define the term itself. As a result, this definition cannot move the debate toward a consensus: it may be *a* mechanism to achieve 'fairness,' but it is prone to the criticism that other mechanisms (such as those without LBT) are sufficient.

On the other side, avoiding the question of whether Cablevision is correct in its claim of what the LTE-U forum believes, it would be a mistake to specify any number as a minimum rate. Such a specification would require the FCC to come up with a reasonable rate every few years. It also pins the definition to Wi-Fi, while a professed reason of the unlicensed bands is to support new technologies not available today.

<u>The FCC needs to define its values on the unlicensed bands and resolve contradictions in the values. Until then, 'fair' cannot be defined</u>. The dearth of good, generalizable, quantifiable definitions of 'fair' is not a failure on the parts of the filers. Rather, this case is one where the stated values of the FCC, including the stated goals of the unlicensed bands, contradict:

a. The unlicensed bands are the 'Innovation Bands.' They are specifically meant to allow the development of the next great technology, one that is unknown today and

[3] Comments of Broadcom Corporation on Docket No. 15-105, submitted 6/11/2015, page 3.
[4] Comments by Cablevision on Docket No. 15-105, submitted 6/11/2015, page 16.

for which specific regulations cannot possibly exist. The FCC has a mandate to protect these bands while not accidentally regulating potential innovation away.

b. Today, after billions of dollars of investment, Wi-Fi has matured to become a critical component of our national infrastructure[5]. The FCC has an economic mandate to protect that investment and its benefits. More generally, the FCC has an economic interest in how spectrum is used.

These mandates lead to two questions regarding choices:

a. Should the status quo (and its past investments) on an unlicensed band be protected to the potential detriment of more innovative technologies?
b. Should future potential innovation be protected to the detriment of techniques that may increase capacity today?

These questions are not just philosophical – they lead to different policy decisions in the LTE-U/LAA debate. The question of whether to mandate LBT hinges on these questions. Suppose non-LBT protocols are found to both significantly degrade Wi-Fi performance but overall increase capacity[6]. Whether to mandate LBT hinges on the first question. Now suppose that there is a technology that could dramatically increase spectral efficiency on unlicensed bands, but it would significantly hinder future innovation and would push out other users. Whether to regulate coexistence to the detriment of the current technology hinges on the second question. The parties disagree on the facts, and so it is unclear whether these cases apply to the LTE-U/LAA discussion. However, even if the technological facts were settled, as currently constructed there is no framework through which a 'fair coexistence mechanism' can be found.

Other values also affect any definition of 'fair.'

a. Should commercial vs. public interest matter?

[5] This fact is well document. For example, refer to "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014–2019 White Paper," *Cisco*, accessed March 23, 2015, http://cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html.

[6] There will probably not ever be a consensus on these questions without large installations, as is discussed below.

b. How much does diversity of technologies and applications matter, and how much does general data capacity?
c. Does a user's access to other spectrum, or its ability to bid on licensed spectrum, matter?
d. Adding a new network node or technology, almost by definition, will affect performance of other nodes. How do we say how much is too much?

These issues must be clarified by the FCC.

'Technological Neutrality' is a method, not a goal. In his reply comments, Leigh Chinitz summarizes the 'Technological Neutrality' stance and explores the history of Part 15 regulations[7]. He argues that "the Commission has considered what the specific characteristics of the band would have to be in order to make it a successful commons, and they have done their best (and have made changes over time) to put rules into place that would support those characteristics[8]". However, the question no longer is just what 'characteristics' the band should embody, but rather what the Commission has decided is the standard for 'success.' Different values lead to different standards lead to different characteristics lead to different rules.

Being 'technology neutral' is a method to achieve a goal, not a goal unto itself. One may argue that 'technology neutral' helps support future innovation or is an important component of a regulation that can stand the test of time. It may also be true that 'technology neutral' is necessary for competitive fairness between various parties. On the other hand, it may be true that 'technology neutral' hinders the Commission's ability to protect its economic incentives. The Commission must first decide its preeminent values and then attempt to answer the 'technology neutral' question. Otherwise, just as in defining 'fair,' it cannot come up with a coherent decision.

2. Transmit Power and Power Spectral Density constraints are not enough anymore.

Regardless of what the FCC decides are its most important values for the unlicensed bands, it is clear that existing constraints are not enough. The LTE-U/LAA debate has raised issues on unlicensed use that must be addressed before large installations and investment make it

[7] Reply Comments of Leigh M. Chinitz Docket No. 15-105, submitted 6/22/2015, page 16-17
[8] Ibid.

too late to address. However, any potential regulations must keep in mind numerous other devices (besides Wi-Fi and Bluetooth) that also use the band.

Coexistence Protocols. The comments in the initial filing indicate that there is a clear disagreement about whether LTE-U/LAA coexistence protocols are sufficient, and it is unlikely that this issue will be resolved through simulations, analysis, or small prototypical systems. Leigh Chinitz summarizes these disagreements in his reply comments, concluding that "this is an intractable problem on which proponents and opponents will never agree, and simulation conditions and parameters can be discussed forever[9]." Worse, even if it is established that a technology is not a good neighbor, current regulations are insufficient to block such a device. Standards bodies may enforce their definitions of 'friendly coexistence,' but there is no guarantee of compliance or friendliness without FCC rulemaking.

Antenna Height[10]. Numerous comments discussed the importance of coexistence protocols, and disagreed on its facts. One issue that was forgotten is that signal propagation is a function of much more than transmit power. Unlike the coexistence issue, it is a settled question that antenna height matters both for short-link and large-link signal propagation. Most path loss models "use the distance, carrier frequency, and transmitter and receiver heights as input[11]." A doubling of the transmit antenna height is equivalent to somewhere between a 2x to 4x gain in transmit power in most models under most standard conditions.

This propagation characteristic undoubtedly and systemically favors the cellular companies and, by extension, LTE-U and LAA in this debate. The marginal cost to add an antenna is drastically lower for existing tower owners and leasers. Thus, under existing rules, the unlicensed bands could evolve into a heterogeneous network where the distinguishing factor between base stations is their antenna height, not their transmit power. The tower-installed antennas would serve as the 'macrocells,' while all others would be 'small cells.' Each installation would interfere with far more antennas than from which it receives interference. The

[9] Reply Comment of Leigh M. Chinitz Docket No. 15-105, submitted 6/22/2015, page 6
[10] This issue was brought to my attention by Dr. Michael Marcus.
[11] C. Phillips, D. Sicker, and D. Grunwald, "A Survey of Wireless Path Loss Prediction and Coverage Mapping Methods," *IEEE Communications Surveys Tutorials* 15, no. 1 (First 2013): 255–70, doi:10.1109/SURV.2012.022412.00172.

large existing academic literature on heterogeneous networks can be applied here. If the goal is to maximize capacity in the band (ignoring fairness issues):

"If offloaded users can also be served in 'normal' slots when the macros are on, then the optimal amount of blanking grows in proportion to the small cell density … for plausible small cell deployments, the optimal amount of blanking is approximately one half. This strikes many as counter-intuitive but it is true: the macrocells (the apparent network bottleneck) should be shut off about half the time, because they are also the biggest interferers." [12]

A coexistence protocol should not just treat the macrocell as just another interferer vying for time blocks. Its special status as an asymmetric interferer requires a more careful protocol. The discussion gets even more complicated when users cannot switch from one tier to the other, such as when one provider operates the macro cells and others operate the small cells, as fairness issues are involved.

It is important to note that this concern is not LTE-U/LAA specific. It applies to any case where one provider disproportionately has access to towers and thus higher antenna heights, even if the provider is using the same technologies as others. If a cellular company wants to dominate the unlicensed band, as many opponents claim in their filings, it may be able to do so even with Listen Before Talk (LBT) or Wi-Fi itself. All it has to do is install antennas on many of its existing towers, without the additional capacity-increasing techniques it would otherwise implement to support heterogeneous networks on its licensed bands. Note that this concern is not new. Comcast and other cable companies routinely hang Wi-Fi Access Points from their existing cable infrastructure[13].

A more careful network analysis must be done on this issue to fully understand how densely these high-height antennas can be installed before it pushes out other users. How much indoor penetration there is from tower-mounted antennas also will play a large role. It may be that the antenna height is not high enough, or the installations dense enough, to significantly degrade capacity on other nodes. It remains an open question whether the FCC should regulate such advantages, but interest by cellular companies increases the urgency.

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[12] Jeffrey Andrews et al., "An Overview of Load Balancing in HetNets: Old Myths and Open Problems," *Wireless Communications, IEEE* 21, no. 2 (2014): 18–25.

[13] Paul Kapustka, "How cable companies have quietly dominated public Wi-Fi," on Oct. 11, 2013, http://www.techhive.com/article/2053943/how-cable-companies-have-quietly-dominated-public-wi-fi.html

Any potential regulation must be carefully designed to prevent collateral harm. Installing antennas on towers improves signal propagation and thus capacity in the absence of cells that are degraded, but competitive fairness and the potential for future innovation is harmed if certain advantaged companies can take over the band.

On the other hand, the long history of pole attachment regulations makes it clear that the FCC has the authority and a historical precedent to deal with such issues. It has recognized in the past that structural economic advantages such as access to towers should not insurmountably advantage one user or technology over another.

Values trade-off from one another, and different values may be more important in different cases[14]. Numerous devices, not just Wi-Fi or Bluetooth, operate on the unlicensed bands in question, including wireless backhaul and baby monitors. Many of these devices do not have coexistence mechanisms such as LBT or exponential back-off. For these devices, the existing regulations are sufficient because the gain in the 'innovation' and 'diversity' values outweighs the economic issues regarding degradation of Wi-Fi – there simply are not enough of these devices in a given area to degrade co-located Wi-Fi significantly. The FCC must consider these devices in any rule-making: ensuring friendly coexistence from LTE-U/LAA should not come at the expense of other devices that on sum do not cause prohibitive interference. The risk of over-regulation is real. It will be difficult to design device-level regulation that would prevent a potential takeover from a large scale implementation of LTE-U/LAA without unnecessarily harming these numerous other devices.

The FCC can take a similar view as it has of protecting privileged communication. In a notice on June 15, 2015, the FCC sought comment regarding issues related to the establishment of a new Citizens Broadband Radio Service in the 3550–3700 MHz band (3.5 GHz Band)[15]. Though targeted toward protecting privileged communication on the band, this notice seeks comments on how to regulate aggregate interference in a fair and non-discriminatory manner. This discussion can prove valuable for the unlicensed bands in question for LTE-U/LAA. As indicated above, a

[14] This section was prepared with advice from Dr. Charles Jackson.
[15] Federal Register, Vol. 80, No. 114 on June 15, 2015. http://www.gpo.gov/fdsys/pkg/FR-2015-06-15/pdf/2015-14495.pdf

single ‘unfair’ device is often not problematic because it does not cause significant degradation. However, many of such devices in a small and congested area may cause unacceptable degradation. Scale is the true reason for concern with LTE-U/LAA: the potential for large deployments that may not coexist in a friendly enough manner.

There are significant enforcement challenges in attempting to regulate aggregate interference. Worse, there is no concept of a privileged user on the unlicensed bands, and so measuring interference at any given location/receiver does not make sense (any single interferer close enough to another receiver would measure as being above the aggregate interference threshold). These challenges may prove economically and technologically unsurmountable, and regulating sum interference may be impossible. However, the FCC is right to seek comments on how to avoid direct regulation of such interference in the CBRS notice. Depending on how that filing progresses, proposed solutions may be able to be modified for the case where there is no privileged user. Regardless, the FCC needs to directly tackle this issue of scale of deployments on the unlicensed bands.

Summary and Recommendations

Value judgements are nuanced, and it is not necessarily harmful for the FCC to have values that sometimes conflict. However, when they do, as in this case, the FCC must provide guidance. Standards bodies may be the best avenue for regulation, but the FCC needs to first decide what it is willing to protect.

Antenna height differences and coexistence protocols illustrate the gap in current regulations. These concerns are not new, but the potential for LTE-U and LAA adds new urgency to the problem. The advantages or protocols themselves are not problematic, as demonstrated by existing devices with similar characteristics; the scale of potential new installations, however, is troublesome. It may not be possible to regulate out such concerns without opening up a regulatory can of worms, but the FCC must at the least articulate its goals for the unlicensed bands. It should also consider seeking comment on how to factor in the dimension of installation scale on the unlicensed bands.

Respectfully Submitted,

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