

**Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554**

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

VERIZON REPLY COMMENTS

The Commission has always relied on industry stakeholders to accomplish the complex task of developing etiquette protocols that achieve coexistence among diverse unlicensed technologies. The result is that unlicensed bands have thrived as private stakeholders work in good faith to ensure fair and responsible use of this important common resource. Verizon and its technology partners embrace that cooperative tradition. Verizon’s planned deployment of LTE-U will involve low-power small cells that comply with the Commission’s rules for unlicensed spectrum and fully implement the strong etiquette protocols that the LTE-U Forum developed to avoid harming any other unlicensed technologies.

LTE-U is not the “regular” LTE deployed in licensed spectrum but rather is a version of LTE designed from the beginning by the LTE-U Forum to operate fairly in unlicensed spectrum. This new technology offers consumers the ability to use unlicensed spectrum for bandwidth-intensive uses such as downloading videos or apps, while enjoying all of the benefits of LTE, including high download speeds and the ability to move seamlessly across different cells.

Some commenters express concerns about unlicensed LTE, including LTE-U. Most of them express an interest in engaging constructively with proponents of unlicensed LTE, and ask the Commission to continue to monitor developments. A few parties, however, appear to want to

impose on LTE-U (and on other unlicensed versions of LTE) higher etiquette requirements than have been implemented for Wi-Fi or for other unlicensed technologies. But LTE-U shares with Wi-Fi at least as well as Wi-Fi operators share among themselves, and there is no basis to expect LTE-U to meet an even higher standard.

I. THE COMMISSION SHOULD NOT PRE-JUDGE THE USE CASES AND TECHNOLOGIES THAT MAY EMERGE IN UNLICENSED BANDS.

A. The Commission Should Continue To Adhere to its Successful Policies of Flexible Use and Technological Neutrality.

It would be a mistake to assume that existing unlicensed technologies represent the pinnacle of unlicensed innovation. New, transformative unlicensed technologies will emerge as the market drives operators to develop new paradigms for meeting consumers exploding demand for bandwidth. As long as new entrants comply with the Commission’s rules and implement techniques to avoid harming other unlicensed users, the Commission should support continued innovation by continuing its longstanding policies of flexible use of technological neutrality. Prescribing particular etiquette protocols for new technologies would artificially raise barriers to entry, which “could potentially stifle innovation or preclude the use of certain types of devices” in unlicensed spectrum.¹

Numerous economic studies describe the consumer benefits of wireless operators’ use of unlicensed spectrum for data offload. For example, one study observes that British Telecom has leveraged its base of wireline customers to create network of Wi-Fi hotspots that are open to all of its mobile customers.² While some operators may choose to focus exclusively on Wi-Fi as

¹ See *Modification of Parts 2 and 15 of the Commission’s Rules for Unlicensed Devices and Equipment Approval*, ET Docket No. 03-201, Order & Second Memorandum Opinion and Order, FCC 14-80, 29 FCC Rcd. 6366, 6370 ¶¶ 11 (2014).

² See Paul Milgrom, Jonathan Levin, & Assaf Eilat, *The Case for Unlicensed Spectrum*, ¶¶ 46-47 (2011), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1948257 (last visited June 26, 2015).

their customers' offload option, many consumers may want other options, including ones that address the fact that existing Wi-Fi solutions are "islands of coverage" that tie consumers to particular hotspots.³ With LTE-U, Verizon intends to offer its customers the ability to move seamlessly between LTE-U cells and other cells in Verizon's licensed network without losing connectivity.⁴ Consumers will benefit from this, as well as future innovation, made possible by the Commission's policies of flexible use and technological neutrality for unlicensed spectrum.

B. Concerns About Operations That Use Both Licensed and Unlicensed Technologies Are Misplaced.

Some parties incorrectly suggest that technologies such as LTE-U that use licensed frequencies as "control" channels raise public policy concerns. Those arguments appear to be rooted in backwards-looking assumptions about "licensed" and "unlicensed" operations. But the industry is moving away from these artificial distinctions towards more flexible models under which consumers can enjoy the benefits of unlicensed spectrum without relinquishing the benefits of licensed service.

Google asks the Commission to ensure that LTE-U and LAA "will not systematically exclude unlicensed-only technologies."⁵ But far from using unlicensed spectrum inefficiently or irresponsibly, the etiquette protocol for LTE-U uses a *licensed* channel as the *primary* carrier and an unlicensed one for supplemental downlink. That preserves unlicensed spectrum better than any "standalone" unlicensed operator could because the unlicensed spectrum is always secondary carrier to the licensed primary carrier, which means that the unlicensed channel is

³ See Chris Ziegler, *Wi-Fi hotspots are a threat to my sanity; A well-intentioned effort to move you off LTE can sometimes leave you with no data at all*, The Verge (Mar. 13, 2015), available at <http://www.theverge.com/2015/3/13/8208107/wi-fi-hotspots-are-a-threat-to-my-sanity> (last visited June 26, 2015).

⁴ See Richard Bennett, *Why LTE Unlicensed Outperforms Wi-Fi*, High Tech Forum, May 12, 2015, available at <http://hightechforum.org/why-lte-unlicensed-outperforms-wi-fi/> (last visited June 26, 2015).

⁵ Google Inc. Comments at 10.

cleared when traffic can be carried on licensed spectrum⁶ Moreover, when it does use unlicensed spectrum, Verizon's network will use it in a highly spectrally efficient manner and will employ robust etiquette protocols. That will minimize the amount of unlicensed spectrum needed to meet any given level of consumer demand, which in turn will benefit all consumers by reducing overall congestion in unlicensed bands.⁷

The Dynamic Spectrum Alliance expresses concern that ownership of licensed spectrum might become a “de facto prerequisite for deploying unlicensed technologies,”⁸ and NCTA makes the remarkable assertion that holders of licensed spectrum conspired to block the development of a “standalone” version of unlicensed LTE that does not rely on any licensed control channel.⁹ That is wrong. If existing Wi-Fi users want to transition to a standalone version of LTE in unlicensed spectrum, there is nothing impeding them from developing a technology designed for that use case. Indeed, Qualcomm is developing a standalone version of unlicensed LTE,¹⁰ and many of NCTA's members have the economic and technical capability to drive the development of new standalone technologies, if doing so fits with their business plans.

II. ALL STAKEHOLDERS NEED TO WORK TOGETHER IN GOOD FAITH TO ENSURE THAT EXISTING AND FUTURE TECHNOLOGIES COEXIST.

A. Verizon and its Technology Partners Designed LTE-U from the Beginning To Avoid Harming Other Unlicensed Operations.

Verizon is a major Wi-Fi provider with a strong incentive to ensure nothing harms that important technology. Verizon has thus made sure the LTE-U Forum designed LTE-U from the beginning with etiquette protocols that protect real-world Wi-Fi deployments. Those protocols

⁶ Stone Declaration at ¶ 7.

⁷ Verizon Comments at 6-7.

⁸ Dynamic Spectrum Alliance Comments at 1.

⁹ NCTA Comments at 33-35.

¹⁰ Qualcomm Comments at 6.

include “listening” before “talking,” taking turns with other unlicensed users when it is not possible to select an unused channel, and completely turning off (i.e., not using any unlicensed spectrum) the unlicensed carrier when it not needed to supplement the primary (licensed) one.¹¹

Tests show that that suite of sharing features results in sharing that is at least as effective as the sharing that takes place between Wi-Fi users.¹² The combination of those robust etiquette features and LTE-U’s high spectral efficiency will benefit consumers by minimizing overall congestion in the unlicensed ecosystem.¹³ And Verizon’s deployment of LTE-U will consist of targeted, low-power small cells, even further reducing any risk that LTE-U might displace other unlicensed users.¹⁴

B. The Commission Should Reject Suggestions that LTE-U Should Meet Higher Etiquette Standards than Those Routinely Used for Wi-Fi and Other Unlicensed Technologies.

A few parties criticize LTE-U for allegedly failing to meet higher etiquette standards than those used for Wi-Fi and other unlicensed technologies. Verizon is eager to continue to work cooperatively with all unlicensed stakeholders. But it is illogical and unfair to insist that LTE-U meet standards that exceed the standards Wi-Fi and other unlicensed technologies have historically met. While it is crucial that new entrants to the unlicensed ecosystem avoid harming existing ones, existing users do not have superior spectrum usage rights.

1. The Coexistence Testing of LTE-U Conforms to Industry Standards and the Results are Compelling.

The LTE-U Forum did extensive testing of LTE-U/Wi-Fi coexistence. The results show that not only does LTE-U not harm Wi-Fi, but that LTE-U may in fact be more “polite” to Wi-Fi

¹¹ Verizon Comments at 3-4.

¹² *Id.* at 4-5.

¹³ *Id.* at 6-7.

¹⁴ *Id.* at 5.

devices than Wi-Fi devices are to one another.¹⁵ No party disputes that, directionally, the results are impressive. For example, it is remarkable that replacing Wi-Fi devices with LTE-U in one laboratory test actually reduced overall congestion, resulting in improved performance for all devices (including Wi-Fi).¹⁶

Rather than dispute that the testing results are compelling, NCTA argues that the tests do not represent “realistic” scenarios because they do not model sufficiently-dense environments or because they modeled LTE-U’s effect on “outdated” Wi-Fi technology.¹⁷ There is no merit to that. The tests used the most popular and highly-recommended Wi-Fi devices on the market today, and tested the same coexistence scenarios that Wi-Fi vendors themselves have historically used to evaluate Wi-Fi’s own sharing protocols.¹⁸

2. It Is Unreasonable To Expect LTE-U To Precisely Mimic a Particular Version of Wi-Fi or To Meet Higher Sharing Standards than Wi-Fi.

Every new unlicensed technology uses (or should use) protocols that protect other unlicensed users. In doing so, each technology must develop and implement protocols that make sense for that technology. So although LTE-U employs many of the same etiquette techniques that Wi-Fi employs, it does not—and could not—precisely mimic any particular version of Wi-Fi. Yet Google appears to contend that LTE-U should mimic a specific Wi-Fi technique and should do so in a way that meets higher etiquette standards than Wi-Fi operators meet either in practice or in their own coexistence tests.¹⁹

¹⁵ *Id.* at 4-5.

¹⁶ *Id.*

¹⁷ NCTA Comments at 14-16.

¹⁸ Stone Declaration, ¶ 6. Nor is there merit to the assertion that LTE-U can be expected to degrade Wi-Fi’s latency. *See* NCTA Comments at 15. The LTE-U Forum has validated coexistence of LTE-U and Wi-Fi with time-sensitive traffic (multiple VoIP calls) running over the Wi-Fi devices. Stone Declaration, ¶ 8.

¹⁹ Stone Declaration, ¶ 7.

First, Google contends that LTE-U’s duty cycle—the mechanism enabling an LTE-U device to share with another unlicensed device while both operate on the same channel—is not calibrated to result in optimal time-sharing between LTE-U and Wi-Fi. According to Google, this results in LTE-U packets sometimes interrupting Wi-Fi transmission mid-frame and thus causing a slow-down in the Wi-Fi device’s transmission rate.²⁰ Occasional collisions to Wi-Fi packets are inevitable, and indeed the same phenomenon occurs when different versions of Wi-Fi operate on a co-channel basis.²¹ But under realistic conditions, this happens rarely,²² a fact validated by Verizon’s test results showing that LTE-U does not significantly affect Wi-Fi’s performance.²³

Second, Google argues that LTE-U lacks a coexistence mechanism for “moderate” levels of interference, which it defines as levels below -62dBm.²⁴ That is a red herring. LTE-U’s coexistence mechanisms can support operation below -62 dBm, so LTE-U could theoretically be configured to address this purportedly “moderate” interference scenario. Google does not, however, present any reason to expect that LTE-U meet a different standard than the -62 dBm level set forth in the Wi-Fi standard.

C. It Is Not Reasonable for NCTA to Criticize LTE-U Based on Analyses of Etiquette Protocols That Are *Different* than Those Developed for LTE-U.

Rather than evaluate the actual technology that Verizon intends to deploy—the LTE-U developed in the LTE-U Forum—NCTA expresses concerns about *other* possible versions unlicensed LTE. NCTA laments that the adaptive duty cycle protocol—the burst of transmissions it uses in order to share a particular channel with another unlicensed user—of one

²⁰ Google Comments at 5-6.

²¹ Stone Declaration, ¶ 7.

²² Stone Declaration, ¶¶ 6-7.

²³ Verizon Comments at 4-5.

²⁴ Google Comments at 8, Att. A at 2.

version of unlicensed LTE is not calibrated to share effectively with Wi-Fi. NCTA cites a study finding that that etiquette protocol did not work well because its long transmission cycle—500 milliseconds—coexisted poorly with Wi-Fi. That is the same conclusion that the LTE-U Forum reached when developing a duty cycle for LTE-U. Verizon will limit the LTE-U duty cycle to a shorter duration and incorporate “punctures” or brief pauses during its transmission ON cycle. Testing confirms that these measures address any concerns about LTE-U’s impact to Wi-Fi, including to latency-sensitive applications.²⁵ In other words, the LTE-U Forum identified the problem that NCTA highlights and successfully cared for it.

Also, NCTA suggests that LTE-U’s sharing mechanisms are “optional” and that operators might not use them in practice.²⁶ Those concerns are unfounded. Verizon is committed to using unlicensed spectrum responsibly, and will deploy only LTE-U equipment that includes all of the etiquette protocols.²⁷ The Commission can, of course, monitor the unlicensed ecosystem to confirm that NCTA’s hypothetical concerns do not occur in real life.

²⁵ Stone Declaration, ¶ 8.

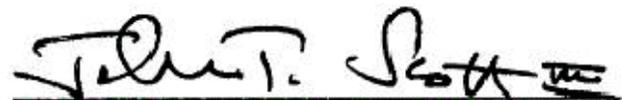
²⁶ NCTA Comments at 23-26.

²⁷ Stone Declaration, ¶ 3

The great majority of commenters acknowledge that new entrants to the unlicensed ecosystem have the same rights to unlicensed spectrum as existing users. While some express concerns about unlicensed LTE, most parties encourage to the Commission to generally continue a monitoring role and to let the industry stakeholders work through coexistence issues. Verizon and the LTE-U Forum have undertaken extensive informal and formal outreach to the unlicensed community, especially the Wi-Fi community, and are continuing that process.²⁸

Respectfully submitted,

Of Counsel:
Kathleen Grillo

A handwritten signature in black ink that reads "John T. Scott III". The signature is written in a cursive style and is positioned above a horizontal line.

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²⁸ Verizon Comments, Stone Declaration, ¶ 11.

DECLARATION OF WILLIAM H. STONE

1. I have reviewed the comments to the FCC's public notice inquiring about the use of LTE on unlicensed spectrum. Because a number of commenters expressed concerns about the effectiveness of LTE-U's etiquette protocols, I submit this declaration to provide further detail and clarification about Verizon's implementation and planned deployment of LTE-U.

2. *Concern: LTE-U's coexistence algorithms are proprietary.* It is common for standards-bodies to define technical specifications that rely on vendor-specific or proprietary implementation. Although 3GPP sets standards for LTE, implementation is always proprietary and each LTE vendor implements those standards differently. For example, each vendor employs a unique and proprietary scheduling algorithm for resource management and channel control. Wi-Fi follows a similar approach. Many Wi-Fi vendors employ proprietary algorithms and technology in implementing certain features. For example, "rate control" refers to the algorithm used by Wi-Fi devices to determine the transmission rate of each transmitted frame. This algorithm is, as Google notes, "proprietary"¹ and "is a very vendor-specific aspect of Wi-Fi."² Concerns about LTE-U's proprietary coexistence algorithms were discussed with unlicensed stakeholders at an all-day workshop hosted by the LTE-U Forum on May 28, 2015. As a result of that workshop and feedback from the Wi-Fi community, the LTE-U Forum published a set of coexistence specifications.³

3. *Concern: LTE-U's coexistence mechanisms are "optional" and not mandated.* By design, Part 15 rules have minimal technical requirements that allows unlicensed spectrum to be

¹ Google Comments, Attachment A, Nihar Jindal & Donald Breslin, *LTE and Wi-Fi in Unlicensed Spectrum: A Coexistence Study* at 10 (2015) ("Jindal & Breslin Study").

² Jindal & Breslin Study at 9.

³ See LTE-U SDL Coexistence Specifications V1.2 (2015-06) (posted June 25, 2015) (http://www.lteuforum.org/uploads/3/5/6/8/3568127/lte-u_forum_lte-u_sdl_coexistence_specifications_v1.2.pdf)

a platform for “permission-less innovation.” This approach has been remarkably successful, allowing a diverse set of unlicensed technologies and uses to develop and evolve over time. Despite these minimal rules, most unlicensed technologies adopt one or more coexistence mechanisms to improve performance and allow for other users to access the medium. LTE-U is no different. Verizon and its partner companies established the LTE-U Forum to develop technical specifications that ensure LTE-U shares fairly with other unlicensed technologies. Every Verizon device and base station will undergo a rigorous performance and conformance review to ensure compliance with the LTE-U Forum’s specifications. Non-compliant equipment will not be allowed on Verizon’s network.

4. *Concern: LTE-U’s coexistence mechanisms are controlled by the operator and could be changed or disabled.* Operators need some flexibility to adjust parameters in optimizing networks. This flexibility is common for both licensed and unlicensed technologies. Managed Wi-Fi networks are often optimized for a particular deployment scenario or use-case. The Commission can and should monitor the evolution of the unlicensed ecosystem to ensure that technologies and uses remain consistent with Part 15.

5. *Concern: Operators have no incentive to share unlicensed spectrum fairly with Wi-Fi.* Verizon has Wi-Fi in every smartphone, tablet, mobile hotspot, and FiOS router. Wi-Fi is and will continue to be an important part of the way our customers connect to the Internet. Because we have a strong interest in ensuring that nothing compromises our consumers’ use of Wi-Fi, Verizon and its partner companies developed detailed and robust etiquette protocols for LTE-U.

6. *Concern: The LTE-U Forum’s coexistence scenarios are unrealistic.* Some commenters questioned whether the LTE-U’s coexistence mechanisms would work in real-world

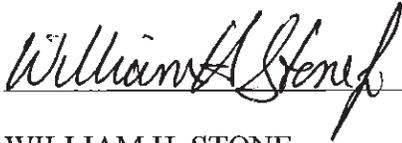
or moderately dense Wi-Fi deployment scenarios. These concerns are misplaced. First, all LTE-U Forum simulations and testing are based on the current 802.11ac standard using a wide variety of top-selling 5 GHz Wi-Fi equipment. Second, all LTE-U coexistence simulation and test results either meet or exceed Wi-Fi's coexistence simulation and test results.

7. *Concern: LTE-U uses different coexistence mechanisms than Wi-Fi.* Many commenters would prefer that LTE-U mimic Wi-Fi's coexistence mechanisms. This is both unnecessary and counterproductive. There is no "standard" or "correct" etiquette protocol. Different technologies and uses employ different coexistence techniques. While both technologies are based on carrier sensing to achieve coexistence, LTE-U and Wi-Fi are fundamentally different in the way they access and manage the medium. Wi-Fi uses Carrier Sense Multiple Access (CSMA) to randomly access a channel, giving multiple transmitters, in theory, an equal probability to any given channel. Since uncoordinated access points are unmanaged, collisions are inevitable, and Wi-Fi uses initial deferral or exponential back-off to mitigate its impact. LTE-U, by contrast, uses Carrier Sense Adaptive Transmission (CSAT) to deterministically access a channel. CSAT divides spectrum by the time domain so that its use is proportional to the long-term medium utilization statistics of its neighbor nodes. In addition, because LTE-U is *always* a secondary carrier to a licensed primary carrier, LTE-U fully clears the unlicensed channel(s) if traffic can be handled on licensed spectrum. All LTE-U coexistence simulations and test results either meet or exceed Wi-Fi over Wi-Fi coexistence simulations and test.

8. *Concern: LTE-U will degrade latency-sensitive applications running over Wi-Fi.* The LTE-U Forum did extensive testing of LTE-U's impact on latency-sensitive applications. Because tests show that longer duty cycles such as 500 ms can have a negative impact, Verizon

will limit the LTE-U duty cycle to a shorter duration and incorporate “punctures” or brief pauses during its transmission ON cycle. Testing confirms that these measures address any concerns about LTE-U’s impact to latency-sensitive applications.

I hereby declare under penalty of perjury that the foregoing declaration is true and correct to the best of my knowledge and belief. Dated this 26th day of June, 2015.

A handwritten signature in cursive script, reading "William H. Stone", written over a horizontal line.

WILLIAM H. STONE