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

In the Matter of	)	
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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

VERIZON COMMENTS

The communications industry must innovate and invest to meet consumers' exploding demand for wireless bandwidth. Part of that investment must be in new technologies that minimize the amount of spectrum needed to provide high-speed wireless data services. Verizon and its technology partners are developing and deploying a next-generation technology, LTE Unlicensed ("LTE-U"), which will efficiently use unlicensed spectrum for data-intensive needs, such as downloading mobile apps and streaming video. LTE-U is not the same as "standard" LTE but rather is a modified version of LTE designed specifically to work on unlicensed spectrum without harming existing unlicensed operations.

Verizon plans to deploy LTE-U in areas where consumer demand for bandwidth strains licensed spectrum capacity. In these areas, Verizon will deploy LTE-U on low-power small cells. Customers served by LTE-U will enjoy all the advantages of "standard" LTE, including fast download speeds and seamless coverage when moving between cells. And because LTE-U is a highly spectrum-efficient way to provide data service, its use will minimize overall congestion in the unlicensed ecosystem. Efficient overall use of unlicensed spectrum benefits all consumers, including ones using other unlicensed technologies such as Wi-Fi, by minimizing all providers' spectrum constraints.

Unlicensed spectrum has been such a tremendous success because operators have voluntarily developed sharing mechanisms that respect one another's legitimate uses of spectrum. Because Verizon will deploy LTE-U in the 5 GHz band, where Wi-Fi and other important unlicensed technologies are present, Verizon and its partners designed LTE-U from the beginning to avoid harming other unlicensed operations. Verizon also has a particular interest in ensuring that new uses of unlicensed spectrum do not degrade existing unlicensed operations: Verizon has put Wi-Fi into hundreds of millions of its smartphones, tablets, mobile hotspots, and FiOS routers. It has a strong interest in ensuring that nothing compromises consumers' use of Wi-Fi. In fact, published tests indicate LTE-U avoids interfering with Wi-Fi operations better than Wi-Fi operators avoid interference among themselves.

Verizon's equipment will comply with all Commission rules for operations in the 5 GHz band, including technical specifications that limit the size of LTE-U cells in the same way they limit the sizes of Wi-Fi hotspots. Verizon is also looking at other bands, including 3.5 GHz, for future deployments of versions of unlicensed LTE that will have different features. Regardless of the version of unlicensed LTE deployed, it is important that all stakeholders protect the overall unlicensed ecosystem by using spectrum responsibly. Verizon is committed to doing so.

I. LTE-U WILL NOT HARM OTHER UNLICENSED OPERATIONS.

A. LTE-U's Etiquette Protocols Ensure that It Fairly Shares Spectrum with Other Unlicensed Technologies.

LTE-U is not the same as "standard" LTE. It is a modified version of LTE designed specifically to operate in unlicensed spectrum.[1] Verizon and its vendors created the LTE-U Forum in 2014 for the purpose of developing robust etiquette protocols—steps LTE-U takes to

[1] *See* attached Declaration of William Stone, Verizon's Executive Director for Infrastructure Planning ("Stone Decl."), ¶ 4.

share spectrum fairly with other unlicensed users.[2] To accomplish that goal, the Forum took advantage of certain features in "standard" LTE technology, which have always been present but not commonly used, to create multiple sharing mechanisms that meet or exceed the etiquette used by existing unlicensed technologies.[3] Through its certification process, Verizon will ensure that all LTE-U equipment it deploys will meet the Forum's etiquette standards.[4]

1. LTE-U "Listens" Before "Talking."

LTE-U has a spectrum sensing capability. It scans the spectrum in real time to identify open frequencies—channels not occupied by other unlicensed users. If one is open, LTE-U will transmit only on that channel, thus avoiding the need to transmit on any channel being used by anyone else.[5] If there are no open channels, LTE-U will select the least interfering channel, and will also continue to scan for open frequencies and select these channels as they become available.[6]

2. LTE-U Takes Turns with Other Unlicensed Users.

LTE-U has a feature called an "adaptive duty cycle" that allows it to take turns with other users. If another user is operating on a particular unlicensed frequency, LTE-U can still operate on the same spectrum without degrading the other user's performance. LTE-U does this with a technique known as Carrier-Sensing Adaptive Transmission ("CSAT"). CSAT senses the traffic on a particular channel, such as data being carried on a Wi-Fi access point, and measures how

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[2] *Id.*, ¶ 9.
[3] The LTE-U Forum released a detailed report describing the technical specifications and coexistence mechanism for implementing LTE-U. *See* "LTE-U Technical Report, Coexistence Study for LTE-U SDL," LTE-U Forum (Feb. 2015), *available at* http://www.lteuforum.org/uploads/3/5/6/8/3568127/lte-u_forum_lte-u_technical_report_v1.0.pdf.
[4] *See* Stone Decl., ¶ 12.
[5] *Id.*, ¶ 6.
[6] *Id.*

frequently it is occurring. Depending on the amount of traffic and the pattern of that traffic, CSAT schedules bursts of traffic during those time intervals when other traffic is not present.[7]

The LTE-U Forum also developed an etiquette protocol called a "puncture" to ensure that LTE-U transmissions do not disrupt others' latency-sensitive signals, in particular Voice over Internet Protocol (VoIP) transmissions.[8] Even during LTE-U's duty cycle, i.e., when the LTE-U equipment is actively transmitting, there are multiple pauses (punctures) in its transmission permitting others' VoIP transmissions to occur on the same frequency without deterioration.

3. LTE-U Has an On/Off Switch.

Because LTE-U supplements an operator's licensed network on a secondary basis, it is used only when and where the licensed spectrum becomes congested. If there is not enough data traffic to warrant using unlicensed spectrum as a supplement, LTE-U transmits nothing on unlicensed spectrum, opening it up for others to use. In other words, LTE-U is *completely* turned off when not in use. By contrast, any technology operating exclusively on unlicensed spectrum will occupy an unlicensed channel even if only serving a low-bandwidth use such as carrying a voice call.

4. Tests and Simulations Confirm that LTE-U Shares Spectrum with Wi-Fi at Least as Well as Wi-Fi Operators Share with Each Other.

The LTE-U Forum has performed multiple simulations and tests, in both indoor and outdoor environments, to determine if the etiquette protocols built into LTE-U accomplish the Forum's goal of ensuring that LTE-U shares fairly with other unlicensed technologies. All of the results confirm that the goal was met.[9] For example, the LTE-U Forum's engineers created a coexistence test chamber with eight Wi-Fi hotspots. One by one, they turned off each Wi-Fi

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[7] *Id.*, ¶ 7.
[8] *Id.*
[9] *Id.*, ¶10.

hotspot and replaced it with an LTE-U cell operating at the same power level. Each time they replaced a Wi-Fi hotspot with an LTE-U cell, the performance of all the devices in the room—both the ones using Wi-Fi and those using LTE-U—improved.[10] In other words, not only does LTE-U not degrade Wi-Fi, but it actually improves the aggregate speeds that all users can experience by reducing the total amount of congestion.

B. LTE-U Will Be Deployed Only on a Targeted Basis Using Small Cells.

The equipment Verizon deploys for LTE-U operations in unlicensed spectrum will comply with all the Commission's Part 15 technical rules, including the rules for power limits and out of band emissions. Those rules facilitate coexistence by ensuring that operators' cell sizes are relatively small. Verizon will thus deploy LTE-U on a small cell basis, to supplement its existing licensed network in specific areas, a fact that further mitigates any concern that it might displace or disrupt other unlicensed operations.

II. LTE-U WILL BENEFIT CONSUMERS.

A. LTE-U Offers All the Benefits of LTE, Including High Data Speeds and Seamless User Mobility.

Verizon will continue to include Wi-Fi in its handsets, so its customers will continue to have the option of using Wi-Fi for their data needs, such as when downloading videos or apps. Consumers should find the LTE-U experience attractive, however, because it provides the same benefits of "traditional" LTE when using unlicensed spectrum for data-intensive applications.[11]

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[10] *Id.*
[11] *Id.*, ¶ 5.

The Commission has described LTE is a "transformative" technology,[12] and it has sparked tens of billions of dollars of investment and economic growth.[13]

LTE has transformed the communications landscape because it enables high throughput (the rate of successful data delivery across the network), so consumers can use their wireless devices for traditionally-wired applications such as real-time video and streaming media. LTE also provides low latency (time delay), so consumers can establish fast, real-time connections for video telephony, video conferencing, and other innovative services. It also has strong security mechanisms to protect consumers and the network from hacking and other harm.

LTE-U provides all of those benefits while providing seamless mobility. Because LTE-U is part of a unified LTE network, customers receiving service via LTE-U will not lose their connection if they move beyond the parameters of the small cell that is providing the service.[14]

B. All Wireless Consumers—Including Wi-Fi Users—Will Benefit from the Deployment of LTE-U Because It Will Minimize Congestion in Unlicensed Spectrum.

Because LTE-U minimizes the amount of spectrum needed to meet a given level of consumer demand for bandwidth, it will free up more spectrum for all consumers by reducing overall congestion in the unlicensed bands.[15] That means that consumers, regardless of the unlicensed technology they use—whether Wi-Fi, LTE-U, or something else—will benefit from better device performance as LTE-U is deployed because their operators will have reduced

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[12] Opinion, *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 11-121, Eighth Broadband Progress Report, 27 FCC Rcd 10342, ¶ 6 (Aug. 21, 2012).

[13] *See, e.g.*, Mobile Future website, *available at* http://mobilefuture.org/issues/economic-opportunity/ (describing how the app market went from nonexistence in 2007 to a projected $46 billion industry in 2016).

[14] *See* Stone Decl., ¶ 5

[15] *Id.*, ¶ 10.

spectrum constraints. By contrast, if consumers are served only by less spectrally-efficient technologies, for any given level of total consumer demand there would be more congestion in unlicensed frequencies and thus more downward pressure on wireless broadband speeds.

C. U.S. Consumers Will Benefit from U.S. Operators' Ability To Rapidly Deploy LTE-U.

Verizon intends to deploy LTE-U in the 5 GHz band, specifically in its UNII-1 and UNII-3 portions,[16] in 2016. A similar version of unlicensed LTE technology, Licensed Assisted Access ("LAA"), is currently in the standards-setting process. There is no reason for operators in the United States to delay providing customers the benefits of LTE-U until after that process concludes because the features being developed for LAA are not relevant to LTE-U's deployment in this country.

One difference between the two versions is that LAA will enable a licensed carrier to use unlicensed spectrum to supplement uplink operations as well as downlink, whereas LTE-U supplements only downlink.[17] Verizon's planned deployment does not need LAA's uplink capability because it will use unlicensed spectrum only for supplemental downlink, i.e., to ensure that customers experience fast download speeds. The second difference is that the LAA standard will include a special protocol to protect incumbent radar systems in Europe and Japan that operate in the 5 GHz band, a feature that U.S. carriers need not wait for given that there are no radar systems in the United States using the portions of the 5 GHz spectrum that LTE-U uses.[18]

U.S. consumers and the U.S. economy will benefit from rapid deployment of LTE-U, just as they benefitted at the beginning of this decade when Verizon and other U.S. operators rapidly

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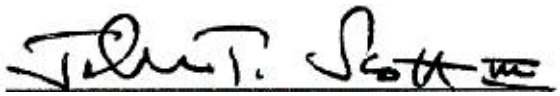
[16] *Id.*, ¶ 4.
[17] *Id.,* ¶ 14. To the extent operators deploy a version of LTE in the 3.5 GHz band, it is likely they will use LAA. The Commission has determined that devices operating in that band must be capable to two-way communication, a requirement LAA meets. *Id.*, ¶ 14.
[18] *Id.,* ¶ 13.

deployed LTE years ahead of most of the rest of the world. In the rest of the world, communications providers and regulators are still working hard to catch up to the United States' commanding lead in LTE availability.[19] The United States is poised for a similar head start with LTE-U because the Commission's policy of technological neutrality facilitates innovation, and because deployments in other regions need to wait for the LAA standardization process to conclude.

Respectfully submitted,

Of Counsel:
Kathleen Grillo



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[19] The United States stands alone with four facilities-based LTE providers. It has 5% of the world's population but 47% of its LTE subscribers. *See* CTIA "Wireless Quick Facts," *available at* http://www.ctia.org/your-wireless-life/how-wireless-works/wireless-quick-facts.

DECLARATION OF WILLIAM H. STONE

1. I am Executive Director of Radio Access Network Planning for Verizon, and in that capacity I am responsible for advanced technology planning for Verizon, including new technology assessments, development of network evolution plans, participation in industry standard groups, and spectrum planning. I have been directly involved in the planning and deployment of Verizon's current broadband services—Ev-DO Rev A and LTE—and the network infrastructure to support those services. In particular, I have been responsible for assessing the company's ongoing spectrum capacity needs and identifying additional spectrum that can meet those needs both in the short term and over the longer term.

2. During my 26-year career in the wireless industry, I have served in a variety of network leadership positions where my responsibilities included network planning, engineering, and system performance. I have appeared on numerous wireless industry panels and programs concerning network evolution and spectrum. I have also testified at two FCC workshops: the National Broadband Plan Workshop on Spectrum in September 2009, and the Workshop on Technical Issues Related to 700 MHz Interoperability in April 2011.

3. I submit this declaration to explain how Verizon will use a version of LTE designed for unlicensed spectrum, called LTE-U, to give our consumers a more robust and seamless mobile broadband experience with better coverage and faster download speeds. I begin by describing LTE-U and its etiquette protocols, which ensure that LTE-U shares spectrum fairly and responsibly with other unlicensed users. Next, I summarize the work of the LTE-U Forum and Verizon's recent workshop with unlicensed stakeholders. Finally, I consider how LTE-U technology and use-cases could evolve over time.

4. LTE-U Defined. While LTE was designed for and is currently deployed in licensed spectrum, LTE-U is specifically created to operate in *unlicensed* spectrum. LTE-U is based on the existing 3GPP Release 10/11/12 specifications. It will comply with all applicable requirements from FCC Part 15 rules for the 5 GHz band's UNII-1 (5150-5250 MHz) and U-NII-3 (5725-5850 MHz) frequencies, including maximum transmit power, in-band and out-of-band emission requirements, power spectral density, and—for the UNII-3 band—the minimum bandwidth requirement.

5. Verizon will deploy LTE-U in small cells to augment its 4G LTE network, providing consumers with higher data download speeds, lower latency, better coverage, and smoother transitions between licensed and unlicensed spectrum. LTE-U will allow Verizon to use unlicensed spectrum opportunistically for supplemental downlink capacity using carrier aggregation. Verizon's licensed spectrum will be the "primary carrier," serving as an anchor for the unlicensed spectrum, which will be the "secondary carrier." Time-sensitive traffic, such as signaling and control information, or time-sensitive data, like VoLTE, will be carried on the primary carrier using Verizon's licensed spectrum. Traffic that is not time-sensitive will be carried on both the primary carrier and the secondary carrier using unlicensed spectrum. With a single, unified LTE core network, LTE-U will enable Verizon to support both licensed and unlicensed spectrum as efficiently as possible. Verizon will begin deploying LTE-U in its indoor enterprise systems in 2016.

6. Unlike licensed spectrum, unlicensed spectrum is a shared resource. LTE-U adopts three coexistence mechanisms or etiquette protocols to ensure fair sharing with other unlicensed technologies. *First*, LTE-U has a spectrum-sensing capability. It senses the RF environment to identify open frequencies—channels not occupied by other unlicensed users. If one is open,

LTE-U will transmit only on that channel, thus avoiding the need to transmit on any channel being used by anyone else. If there are no open channels, LTE-U will select the least interfering channel. LTE-U will also continue to scan for open frequencies and select these channels as they become available.

7. *Second*, LTE-U has a feature called an "adaptive duty cycle" that allows it to take turns with other users. If another user is operating on a particular unlicensed frequency, LTE-U can still operate on the same spectrum without degrading the other user's performance. LTE-U does this with a technique known as Carrier-Sensing Adaptive Transmission ("CSAT"). CSAT senses the traffic on a particular channel, such as data being carried on a Wi-Fi access point, and measures how frequently it is occurring. Depending on the amount of traffic and the pattern of that traffic, CSAT will divide the channel by time domain according to the channel utilization. To protect latency-sensitive traffic like VoIP from degradation, LTE-U incorporates "punctures" or brief pauses during its transmission ON cycle.

8. *Third*, because LTE-U uses unlicensed spectrum opportunistically as a secondary carrier, LTE-U is in OFF-state when there is no traffic on the secondary carrier or when there is no data in the buffer for users. In other words, if there is not enough data traffic to warrant using unlicensed spectrum, LTE-U transmits nothing on unlicensed spectrum, opening it up for others to use.

9. LTE-U Forum. In April 2014, Verizon formed the LTE-U Forum with our technology partners Alcatel-Lucent, Ericsson, LG Electronics, Qualcomm Technologies, and Samsung. The LTE-U Forum had a single objective: to develop and publish a set of specifications for LTE-U products based on 3GPP Release 10/11/12 that would ensure fair sharing and coexistence with other unlicensed technologies, such as Wi-Fi.

10. The LTE-U Forum and its individual member companies conducted an extensive review of LTE-U/Wi-Fi coexistence through computer simulations, lab testing, and over-the-air testing. The Forum defined seven simulation scenarios for indoor and outdoor coverage, examining the fairness of medium occupancy and the maximum duration for LTE-U transmissions. All simulations show that when LTE is simply deployed in unlicensed spectrum without the above coexistence mechanism, LTE causes significant performance degradation on coexisting Wi-Fi access points. But when these coexistence mechanisms are implemented, LTE-U behaves as a comparable neighbor to Wi-Fi compared to Wi-Fi as a neighbor, while LTE-U significantly outperforms Wi-Fi. In fact, one Qualcomm test evaluated the impact of substituting LTE-U for Wi-Fi in a dense deployment environment. The test began with nine Wi-Fi access points operating in a small RF-screened test chamber. As the Wi-Fi access points were replaced with LTE-U, the remaining Wi-Fi access points saw an *increase* in data throughput. This performance improvement comes from a combination of higher LTE link efficiency due to advanced techniques such as "hybrid automatic repeat request" ("H-ARQ) and higher Media Access Control ("MAC") layer efficiency (due to universal frequency reuse of LTE). The LTE-U Forum published these test results and its recommended coexistence mechanisms on March 2, 2015.[1]

11. Since then, Verizon and LTE-U Forum members have done extensive formal and informal outreach to unlicensed stakeholders, including the Wi-Fi community, to educate them about LTE-U and its etiquette protocols. On May 28, 2015, the LTE-U Forum hosted an all-day

[1] See Verizon Press Release on 3/2/2015at http://www.prnewswire.com/news-releases/lteu-forum-explores-technical-possibilities-of-lte-in-unlicensed-spectrum-300043401.html; See the LTE-U Technical Report, LTE-U Supplemental Downlink Coexistence Specifications, and eNode B and UE Minimum Performance Specifications at http://www.lteuforum.org/.

workshop with 29 different companies and organizations from the wireless industry.[2] The workshop was a technical "deep dive" into the LTE-U Forum's specifications and coexistence mechanisms. As a result of this workshop and feedback from the Wi-Fi community, the LTE-U Forum agreed to provide additional information by publishing (i) a reference coexistence algorithm, and (ii) additional test cases to the coexistence specification.

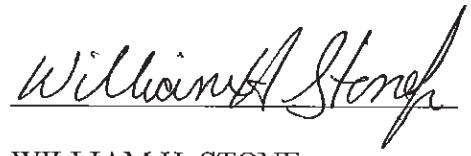
12. As part of its rigorous performance and conformance certification process, Verizon will ensure that all base stations and devices comply with the LTE-U Forum's specifications.

13. LTE-U and Its Evolution. The use of LTE in unlicensed spectrum continues to evolve. Work is underway in 3GPP to develop a second version that could be used in other countries and in other unlicensed bands. License Assisted Access ("LAA"), which is being developed as part of 3GPP Release 13, modifies the LTE waveform to incorporate a specific Listen-Before-Talk ("LBT") protocol required in Europe and Japan. Like LTE-U, LAA will use spectrum sensing to find a vacant channel, adopt time-sharing techniques to coexist with Wi-Fi, and it will vacate the spectrum when it is not needed. With its modified waveform, LAA is expected to be compatible with all 5 GHz bands, including the U-NII-2A and U-NII-2C bands.

14. Verizon also anticipates that LAA could be used in the 3.5 GHz band. Because LAA is expected to incorporate both downlink and uplink transmissions, it will comply with the Commission's recent 3.5 GHz service rules, which require bi-directional capability. LAA and Release 13 are expected to complete the standard's process in 2016, with equipment commercially available in 2017.

[2] List of participants: LTE-U Forum members (ALU, Ericsson, LGE, Qualcomm Technologies, Samsung, Verizon); mobile operators (AT&T and T-Mobile USA); infrastructure vendors (Nokia and SpiderCloud); device and chipset vendors (Altair, Google, HTC, Intel, Marvell, MediaTek, Microsoft, Motorola, Sequans, and SONY); test equipment vendors (Anritsu and Rhode & Schwarz); Wi-Fi vendors and technology enablers (Aruba, Broadcom, Cisco, and Ruckus); and other organizations (CableLabs, IEEE 802.19, and the Wi-Fi Alliance (WFA)).

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 11th day of June, 2015.



WILLIAM H. STONE