September 9, 2015

Via ECFS

Julius P. Knapp
Chief, Office of Engineering and Technology
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Office of Engineering & Technology and Wireless Telecommunications Bureau Seek Information on Current Trends in LTE-U and LAA Technology — ET Docket No. 15-105

Dear Mr. Knapp:

The LTE-U Forum[1] and T-Mobile US, Inc. ("T-Mobile") are pleased to respond to the questions in your August 5, 2015 letter seeking additional information concerning LTE-U. As you note in your letter, the FCC record already contains a significant number of LTE-U test results, including testing of the etiquette protocols in the LTE-U specifications, that demonstrate that LTE-U will not harm Wi-Fi and is in fact a better neighbor to Wi-Fi than Wi-Fi is to itself.

We have been clear to the FCC and the public that it is critical that LTE-U and Wi-Fi coexist successfully. Our companies are all strong supporters of Wi-Fi. Millions of our consumers rely upon Wi-Fi every day.[2] We have deep, continuing business interests in Wi-Fi, and we have every incentive to ensure that these technologies operate alongside each other well. We would never have developed or pursued deployment of LTE-U if it would harm our customers' use and enjoyment of Wi-Fi. To the contrary, LTE-U was developed to provide consumers who choose to use it a great broadband experience without causing any adverse impact on those opting to use Wi-Fi. LTE-U, along with the other LTE Unlicensed technologies, will play an important role in easing the mobile broadband spectrum crunch, achieving unparalleled efficiency in unlicensed spectrum, and delivering a far better mobile broadband experience for American consumers. LTE-U demonstrates, once again, that the "permission-less innovation" enabled by the FCC's Part 15 rules is highly beneficial for the American public.

As described in more detail in the attached Technical Response, LTE-U adopts three etiquette protocols to ensure fair sharing with other technologies in the UNII-1 and UNII-3 bands.

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 a channel occupied by another user. This spectrum sensing performed by LTE-U small cells is similar to the channel sensing done today by some Wi-Fi equipment. (Testing has shown that some Wi-Fi equipment

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1 The member companies of the LTE-U Forum are Alcatel-Lucent, Ericsson, LG Electronics, Samsung Electronics, Qualcomm, and Verizon.

2 *See, e.g.,* T-Mobile Comments at 4-6; Verizon Comments and Reply Comments.

does not perform channel sensing accurately, and that there is a wide variation in the ability of Wi-Fi nodes to share spectrum fairly with other Wi-Fi nodes and equipment using other technologies.)

Second, if there are no open channels, LTE-U will select the "least crowded" channel using an "adaptive duty cycle" that allows it to take turns with other users without degrading their performance. LTE-U does this with a technique for accessing unlicensed channels known as Carrier-Sensing Adaptive Transmission ("CSAT"). CSAT dynamically determines the amount of time that an LTE-U small cell will transmit and listen so the unlicensed spectrum is used fairly.

CSAT is the analog of Carrier Sense Multiple Access (CSMA), the channel-access technique used by Wi-Fi. While CSAT and CSMA are functionally similar, their approach to sharing an unlicensed channel is fundamentally different. CSMA allows a user to randomly access a channel, giving multiple transmitters—at least in theory—an equal probability of accessing any given channel. Sometimes, however, there are collisions between Wi-Fi nodes trying to transmit. CSAT, by contrast, measures the actual traffic of neighboring nodes and ensures that each node will be able to use a given channel for an equal proportion of time. At the end of every duty cycle, CSAT rescans the unlicensed frequencies to look for an open channel and, if none is found, adapts its duty cycle to real-time changes in traffic patterns. CSAT is always enabled and cannot be disabled or modified by an operator.

Third, because LTE-U will be used for supplemental downlink, traffic always defaults first to an operator's licensed network. Unlicensed spectrum is only used when the licensed spectrum becomes congested. The unlicensed channel is in an "OFF-state" if traffic can be carried on an operator's licensed spectrum. When unlicensed spectrum is needed, all signaling and control information is carried on licensed spectrum, which becomes the "anchor" channel. The anchor channel cannot control or change CSAT. Instead, the anchor channel only carries the signaling and control information for any traffic carried on unlicensed spectrum.

All the tests of LTE-U by members of the LTE-U Forum, which are in the FCC's record, show that these etiquette protocols allow LTE-U to share unlicensed spectrum fairly with no adverse impact to Wi-Fi.

The technical work that the LTE-U Forum has done to enable successful coexistence between LTE-U and Wi-Fi is also informing and advancing the coexistence work on LAA and standalone LTE in unlicensed (e.g. MuLTEfire). This work has been shared with the Wi-Fi Alliance, the IEEE, and other industry stakeholders and is being used to improve Wi-Fi coexistence with other Wi-Fi operations. The end result of this work will be improved performance of both LTE Unlicensed and Wi-Fi and a greatly enhanced user experience on mobile broadband for American consumers.

The FCC's technology-neutral approach towards the unlicensed bands has established the U.S. as a market leader for unlicensed innovation. Maintaining this regulatory approach will further the technology leadership of the U.S. in the race to introduce more spectrally efficient unlicensed innovations into the marketplace, such as LTE-U and MuLTEfire, and benefit mobile consumers. LTE Unlicensed, in all forms, will both improve the user experience on mobile broadband for consumers and fairly share unlicensed spectrum with Wi-Fi.

We thank you for your interest in LTE-U, and we are happy to answer any further questions you may have. We will continue collaborating with stakeholders all across the

wireless industry to answer questions and address concerns over LTE-U, while we work to deploy the technology as soon as possible for the benefit of consumers.

Respectfully submitted,

Member Companies of the LTE-U Forum and T-Mobile

Att.

cc:

Chairman Tom Wheeler	Renee Gregory	Johanna Thomas
Comm. Mignon Clyburn	Jessica Almond	Ira Keltz
Comm. Michael O'Rielly	Louis Peraertz	Roger Sherman
Comm. Ajit Pai	Erin McGrath	John Leibovitz
Comm. Jessica Rosenworcel	Brendan Carr	Chris Helzer

Technical Response to Questions in J. Knapp August 5, 2015 Letter

Detailed responses to the questions posed in the August 5, 2015 Knapp letter are provided below.

> *Q1: "Though the record reflects significant testing of CSAT sharing protocol with Wi-Fi, commenters did not provide information regarding the rationale behind the selection of certain key parameters for CSAT. Specifically, we would like to know, what was the basis for selecting the maximum permissible transmission and the minimum listening periods? Some specifications seem to suggest that these parameters are implementation-dependent and may be set by operators. Please explain the decision to have CSAT transmit on a channel even if it appears to be occupied."*

Response: At the outset, it is important to clarify that both Wi-Fi and LTE-U use channels that are occupied if there is no vacant channel available. Both technologies share the spectrum with other nodes on the same channel. To be sure, the sharing protocols used by the two technologies operate differently. The CSAT sharing protocol used by LTE-U ensures that it will coexist successfully with Wi-Fi. An LTE-U node will first look for a vacant channel, and it will use a vacant channel if it finds one. If not, it will use the "least crowded" channel by taking turns using the channel based on the number and traffic load of neighboring Wi-Fi nodes (and any other LTE-U nodes) that are also sharing the channel. LTE-U uses an on/off protocol that ensures no LTE-U node ever uses the channel more than its proportionate share of the time, and that Wi-Fi nodes also are able to use the channel for their proportionate share of the time. Extensive testing of LTE-U and Wi-Fi in many different environments, some of which are quite harsh and challenging, proves that the CSAT sharing protocol works very well and has no detrimental impact on Wi-Fi.[3] When an LTE-U node uses an occupied channel, the average throughput of other Wi-Fi nodes sharing the channel is maintained and sometimes even enhanced from what it was before the LTE-U node started transmitting.

Also, CSAT does not transmit on a channel. CSAT is the etiquette protocol that an LTE-U small cell uses to determine the amount of time that it will transmit and the amount of time that it will listen on any given channel. CSAT has been designed very carefully to ensure that LTE-U shares the spectrum fairly with Wi-Fi and does not harm Wi-Fi. LTE-U will only use the UNII-1 and UNII-3 bands, and it will only operate in downlink mode. This ensures that Wi-Fi would have exclusive use of over 200 MHz in the 5 GHz band, and that LTE-U will not support any uplink.

Before we explain how CSAT calculates the transmission and listening time periods for a small cell, we would like to highlight certain important features of CSAT that help ensure good coexistence with Wi-Fi. In the first place, CSAT is always enabled. CSAT cannot be disabled

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[3] By contrast, Wi-Fi does not ensure that each node only uses a given channel for a proportionate share of the time. Wi-Fi uses a random access protocol ("CSMA") in which multiple nodes compete for the right to transmit on a channel. CSMA does not ensure that nodes share the spectrum proportionately. In fact, our testing has shown that Wi-Fi nodes often do not share channels with one another in a uniform or fair manner. Different Wi-Fi nodes get more or less access to a given channel depending on the individual implementations of different Wi-Fi equipment vendors, which can be more or less aggressive in taking or ceding the spectrum.

or modified by any operator. Moreover, even when an LTE-U small cell starts transmitting on an unlicensed channel that it determines to be vacant, the LTE-U small cell will never occupy the unlicensed channel 100% of the time because the LTE-U small cell will periodically stop transmitting to listen for neighboring Wi-Fi nodes (as well as other LTE Unlicensed nodes). This practice ensures that each LTE-U small cell detects any other users that begin transmitting on the same channel at any time. It also addresses corner cases where, for example, a hidden Wi-Fi client is trying to associate to an AP that the LTE-U small cell cannot detect.

The LTE-U test procedures and test results using CSAT that the undersigned LTE-U Forum members have provided in our filings used the same parameters that commercial deployments will use. The LTE-U Forum Coexistence Specification contains multiple test cases to ensure the fairness of LTE-U CSAT duty cycle and to ensure that LTE-U does not harm Wi-Fi.[4] In fact, after the LTE-U Forum workshop in San Diego on May 28th, the LTE-U Forum added even additional test cases to those in the original specification.

The CSAT duty cycle is determined based on measuring the Medium Utilization ("MU") of neighboring nodes to ensure that the LTE-U node occupies the medium in an equitable manner. The procedure for computing MU and on-time has been described in LTE-U Forum workshop presentation materials[5] and in the joint Qualcomm-Verizon presentation to IEEE 802.19 meeting on July 15, 2015.

MU is computed by sensing the medium during the periods when the LTE-U small cell is not transmitting. Measurements of the channel energy are converted into a channel load metric. All users that transmit on the channel contribute to the channel load metric regardless of device type or technology used. Using the channel load metric, the LTE-U CSAT duty cycle is dynamically changed after each duty cycle. For example, when the channel is heavily loaded, the CSAT procedure reduces the LTE-U transmit time in proportion to the sensing duration. When the channel is lightly loaded, the CSAT procedure may increase the transmit time in proportion to the sensing duration. Again, the dynamic adjustment of the CSAT duty cycle is performed regardless of the radio technologies used in the channel or the device type — all users of the channel are treated equally.

The LTE-U operating parameters, such as the 50 millisecond maximum continuous "on" time set out in the LTE-U Forum Test Specification, were optimized based on the Wi-Fi Alliance's interoperability specification and after extensive testing and analysis of commercially available Wi-Fi Access Points ("APs" or nodes) to ensure that LTE-U's impact to Wi-Fi throughput, delay sensitive traffic, beacons, and rate control are minimized, while enabling acceptable LTE-U performance. As noted above, CSAT is always enabled in each LTE-U small cell even if the small cell uses a channel that is not being used by any Wi-Fi APs. In other words, under the LTE-U Forum specifications, there is no operating mode in which LTE-U is always "on" (that is, operates with 100% duty cycle), and when operating on the same channel as

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4 *See* LTE-U SDL Coexistence Specifications V1.2 (2015-06) at 8-11 *available at* http://lteuforum.org/documents.html.

5 *See* LTE-U Workshop Documents (May 28, 2015) "LTE-U Coexistence Mechanism Qualcomm May_28_2015 Presentation" at 10-12 *available at* http://lteuforum.org/workshop.html.

a full-buffer Wi-Fi link, LTE-U will not transmit more than half of the time (*i.e.*, with more than a 50% duty cycle).

Moreover, the LTE-U small cell receiver sensitivity for channel sensing, which is used to compute the MU, can be as low as approximately -90 dBm/20 MHz. This friendly behavior of LTE-U towards neighboring Wi-Fi contrasts with the -62 dBm/20 MHz energy detection threshold that Wi-Fi uses to detect non-Wi-Fi neighbors in determining its medium access and level of occupancy.

The CSAT duty cycle has been designed to minimize the impact of any potential collisions between the LTE-U off/on transition and Wi-Fi transmissions.[6] In contrast, two Wi-Fi nodes operating on the same channel using the CSMA protocol can experience collisions and in many cases will not share the spectrum fairly between one another, as already noted. Indeed, the testing and analysis performed by LTE-U Forum members proves that LTE-U, using CSAT, will coexist well with Wi-Fi and, in many cases, far better than Wi-Fi nodes coexist with other Wi-Fi nodes.

Like the specifications for other technologies deployed in unlicensed spectrum, the LTE-U Forum specifications do not dictate every aspect of the various coexistence techniques required by the specifications. Instead, they set coexistence requirements and establish testing procedures to ensure that the performance requirements are met. The LTE-U Forum coexistence requirements and the tests required to ensure that the requirements are met are far more detailed than any requirement that applies today to Wi-Fi since there is no Wi-Fi coexistence specification. LTE-U vendors must comply with the LTE-U Forum specifications, which ensure that LTE-U will coexist well with Wi-Fi.

The LTE-U Forum specifications are no different in allowing for vendor differentiation than today's Wi-Fi and cellular specifications. The Wi-Fi specifications allow for vendor differentiation in setting important channel selection and channel access parameters, and the 3GPP standardization process follows a very similar approach, particularly in the upper layers.[7] For example, the Wi-Fi rate control algorithm is not specified by the IEEE and is instead left to the manufacturer to allow for differentiation. In fact, Google has noted that there is a "wide variety" of vendor implementations of the Wi-Fi rate control algorithm.[8] And, there are other CSMA parameters used for certain implementations that vary the coexistence performance of Wi-Fi.[9]

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6 *See, e.g.,* Qualcomm June 26, 2015 Reply Comments (Appendix Section 3.2 and 3.3).

7 *See, e.g.,* Qualcomm Comments at 14, 21.

8 *See* Google Comments, Att. A at 9, n.13 ("Rate control is a very vendor-specific aspect of Wi-Fi, and a wide variety of algorithms are seen. Some algorithms automatically reduce the rate of the subsequent frame whenever a frame error occurs, while others reduce rate only after multiple errors are observed within some time window.").

9 The Wi-Fi specification allows a range of CSMA parameters to be modified to provide more aggressive Wi-Fi behavior through, for example, implementing a shorter back-off time or a longer transmission duration, which disadvantages other Wi-Fi nodes trying to access the same channel. We recognize that Wi-Fi equipment vendors typically do not expose these MAC parameters as configurable to operators of managed Wi-Fi deployments. In the same way, we

The CSAT duty cycle is an outcome of the comprehensive fair coexistence algorithm described above. The LTE-U Forum coexistence test specification will ensure that all commercial LTE-U implementations share spectrum fairly with Wi-Fi and do not harm Wi-Fi, and our testing proves that LTE-U to Wi-Fi coexistence will be significantly better than the coexistence between many commercial Wi-Fi to Wi-Fi APs today.

In sum, for cellular, Wi-Fi, and LTE-U, there is a very limited set of infrastructure parameters that an operator can set or adjust. Wireless infrastructure of all types is designed this way to streamline deployment and minimize field setup complexity. LTE-U is not any different in this regard, and the LTE-U Forum Specifications are more than ample to ensure that LTE-U will coexist well with Wi-Fi.

Q2: Can the anchor channel be used to control or change any of the parameters of CSAT or does CSAT operate completely independent of the anchor channel?

Response: The anchor channel cannot be used to modify any of the CSAT parameters, , and CSAT operates completely independent of the anchor channel. As explained in the response to Question 1, the CSAT parameters are based only on the medium utilization observed on the unlicensed channel.

Just the way LTE networks that operate solely on licensed spectrum use carrier aggregation ("CA") to bond together multiple spectrum bands to build a wider virtual pipe , LTE-U uses a licensed anchor channel to send overhead signaling to the LTE user device (or UE for User Equipment) when a secondary unlicensed channel is active. CSAT uses the LTE CA protocol in the 3GPP Release 10/11/12 specification to activate and deactivate a Supplemental Downlink ("SDL") channel in the unlicensed band, as follows: (1) prior to every "on" period, a MAC activation signal is sent to the LTE-U UE on the anchor channel so that the UE will listen for the unlicensed channel transmission; (2) the LTE small cell turns on the unlicensed channel; and (3) prior to each "off" period, a MAC deactivation signal is sent to the UE so it knows the unlicensed channel will be turned off. The SDL channel on/off periods are determined by CSAT in the small cell.

For LTE-U, the small cell uses the anchor channel to signal the on/off pattern to the UE so the UE knows when to receive traffic on the unlicensed channel. The anchor channel also provides an uplink connection that carries feedback (ACK and CQI feedback of Channel Quality Information) and traffic from the UE to the LTE-U small cell, which eliminates any interference from LTE-U UEs to other neighboring unlicensed users.

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expect LTE-U infrastructure vendors will not expose CSAT parameters to operators, thereby preventing any configuration that could result in aggressive CSAT on/off duty cycles and violate the LTE-U coexistence specification.

Q3: Will the unlicensed channel be used for downlink only, and if so, how does the LTE system know what capacity is available in the unlicensed channel and therefore how to manage the traffic between the licensed and unlicensed spectrum?

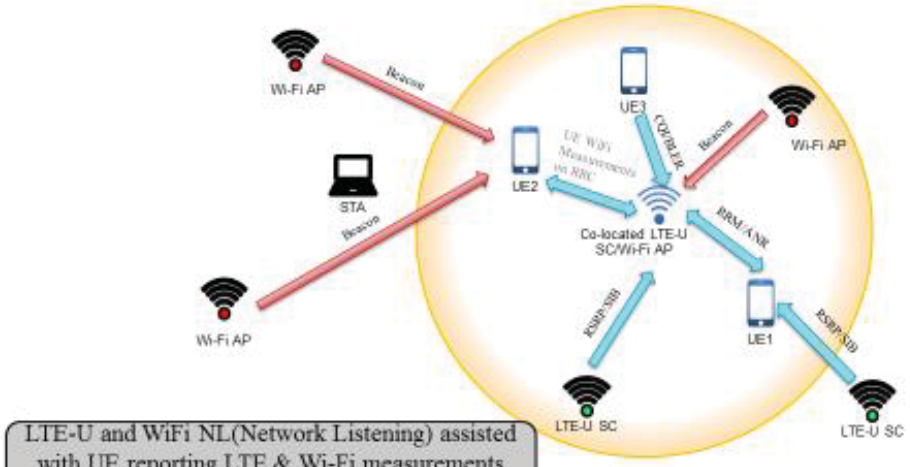
Response: Yes, in LTE-U, the unlicensed channel is used for downlink only traffic in SDL mode pursuant to the LTE-U Forum specification. The traffic management and load balancing between licensed and unlicensed band is performed by the scheduler in the LTE-U small cell. Load balancing is performed by a network scheduler typically by observing the scheduler queue, data type, and channel condition of each carrier. The channel condition of the unlicensed band carrier is determined using channel sensing to compute the channel load. Additionally, channel conditions may be assessed by a co-located LTE UE receiver and a Wi-Fi receiver in the small cell, and by LTE-U UE measurements of the unlicensed band communicated via the licensed anchor channel.

Data collected through LTE-U channel sensing could include the decoding of nearby Wi-Fi AP / station beacons / preambles (if possible), and nearby LTE-U overhead signals and channel energy measurements when these other systems are detected. The UE measurements are performed to find hidden Wi-Fi nodes that the small cell does not detect, and the UE measured information for nearby Wi-Fi and other LTE nodes are sent over the licensed anchor. The information from small cell channel sensing and UE measurements are then synthesized together as a sum of weighted metrics to estimate the loading of the unlicensed bands.

The LTE-U channel selection mechanism uses this information to determine the best unlicensed channel for LTE small cell to turn on initially, and to switch channels when the system is already on but detects a significant change in the load. This mechanism was described in detail during the LTE-U Forum workshop[10] and during the July 15, 2015 IEEE 802.19 meeting on July 15, 2015. The relevant slides used for that discussion are copied below.

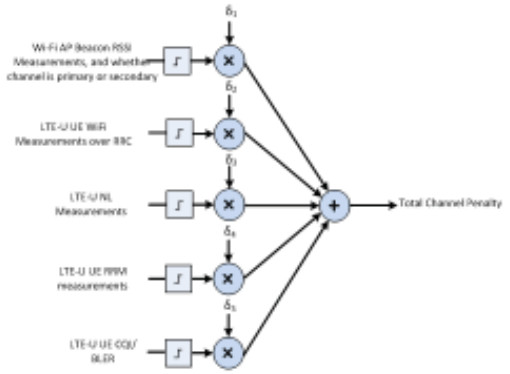
[10] *See* LTE-U Workshop Documents (May 28, 2015) "LTE-U Coexistence Mechanism Qualcomm May_28_2015 Presentation" at 6-7 *available at* http://lteuforum.org/workshop.html.

Channel Selection



LTE-U and WiFi NL(Network Listening) assisted with UE reporting LTE & Wi-Fi measurements and CQI/BLER to detect hidden nodes

Channel Penalty Function



- Different penalty weighting for different interference sources, e.g. WiFi primary channel has higher penalty compared to secondary channel
- Quantized penalty for robustness to measurement errors and to reduce bias due to outliers
  - Measures % of coverage area with some desense due to other AP interference
- Built in mechanisms to detect and mitigate frequent channel switching

For balancing the capacity load across the licensed band and the unlicensed band there is a load balancing algorithm in LTE-U that works across multiple channels in the LTE-U small

cell scheduler to manage the distribution of the load between the bands and carriers. This algorithm is similar to the techniques used by an LTE network performing carrier aggregation with licensed spectrum, and it is based on loading information on each channel, the SINR of the target UE, and QoS requirements of the traffic. The opportunistic SDL feature monitors if the unlicensed channel is needed and turns it "off" and "on" accordingly. Similar load balancing algorithms will be used by the LAA and LWA (*i.e.*, LTE-Wi-Fi Aggregation) schedulers. When the traffic load of the LTE-U small cell drops below a certain threshold, the secondary carriers in the unlicensed band are dropped and there will be no interference to neighbors in the unlicensed band. LTE-U Coexistence Specification Test Case 6.3.1 ensures such behavior from LTE-U small cells.

Q4: How does the client device respond; does it only respond with acknowledgements in the licensed band? What does the licensed system assume about the availability of the spectrum, for example that CSAT will find a channel no matter whether the spectrum is heavily occupied?

Response: The LTE-U UE will provide the small cell with ACK and CQI feedback over the licensed anchor channel for a given SDL transmission in the unlicensed band. The LTE-U UE also will send to the small cell over the licensed anchor channel unlicensed measurement reports, which are used for channel selection, as explained above. In addition, the LTE-U UE will send over the licensed anchor channel overhead signaling necessary for mobility and signaling responses. All of these overhead transmissions on the licensed anchor channel from the LTE-U UE to the LTE-U small cell will not have any impact on Wi-Fi operations because the LTE-U Forum specification does not permit any uplink transmissions on the unlicensed band.

In terms of when to turn on the SDL channel in the unlicensed band, the scheduler is able to keep track of the queue buffer size on the licensed band and only where the buffer size of the licensed band exceeds a certain threshold would the unlicensed channel be used to deliver data. And, if all unlicensed U-NII-1 and U-NII-3 channels are heavily occupied, the scheduler may decide to keep the traffic on licensed channel based on load balancing and QoS considerations. As we have explained, the scheduler first will try to find an unused unlicensed channel. If all channels are occupied, then CSAT will enable fair sharing of LTE-U in the least used channel. Moreover, if the scheduler sees that the unlicensed channel being used is beginning to experience heavy usage, to avoid congestion, the scheduler will start scheduling more data on the licensed channel. Broadly speaking, Scheduler design will optimize the throughput by statistical multiplexing to ensure that, at any given moment, data is transmitted on the channel that can provide the best quality.[11]

It is also important to note that QoS sensitive Guaranteed Bit Rate ("GBR") traffic, such as VoIP connections, are carried over the licensed channel. As stated above, these load balancing requirements and techniques would apply to LTE-U, LAA, and LWA.

Q5: [W]e seek to understand the reasons behind the strong interest in implementing the LTE-U specification in the near future that would be unique to the United States. One concern is

[11] Furthermore, this scheduler feature is not specific to LTE-U. The same scheduler design is used today by wireless operators who have deployed CA on licensed spectrum.

the claim by some commenters that the technology is being introduced in the United States because systems are not required to implement spectrum sharing etiquettes as mandated in other parts of the world. Do you anticipate that the LTE-U specification developed for 3GPP versions 10/11/12 will be introduced for the short term as a bridge to LAA, while will comply with spectrum etiquettes required elsewhere in the world? If not, why? If so, what time frame?

Response: American consumers do not want to wait for better broadband. They want it now. That's why the LTE-U Forum members developed LTE-U, and it is why we are working hard to ensure that LTE-U is deployed as soon as possible. This approach fits well with one of the core goals of the FCC's National Broadband Plan: "The United States should lead the world in mobile innovation, with the fastest and most extensive wireless networks of any nation."[12]

Having said that, LTE-U is not limited to the United States. In fact, LTE-U is under active consideration for trials and deployment by operators in other countries as well, such as South Korea, India and South Africa. LTE-U is attractive internationally, not just in the United States, because mobile operators all over the world are facing a spectrum crunch. They need to deploy wireless technologies to achieve far greater spectral efficiency and to take advantage of each and every available spectrum band to deliver a better user experience for consumers.

Indeed, operators worldwide are ramping up small cell deployments, and they want to use the latest technologies — which includes enhanced use of unlicensed spectrum — to provide more capacity and better performance to serve the six times growth in U.S. mobile data traffic that is expected over the next 5 years.[13] LTE-U and related LTE Unlicensed technologies will provide many important consumer benefits including more capacity, better throughput, full mobility, security, and seamless inter-technology handoffs.

It is not possible to know today whether LTE-U will be a short-term bridge to LAA since the LAA standard is still under development. LTE-U may ultimately evolve into LAA, but even if so, it is impossible to know now when that would occur. It is also possible that LTE-U deployments will exist in parallel with LAA deployments well into the future. Neither possibility should dictate any different regulatory approach. Whether LTE-U is a short term bridge to LAA or not, the material fact is that LTE-U complies with the FCC's Part 15 rules, and there is no basis to prevent or hinder its deployment.[14]

As for timing, there is no need to wait for the LAA standard to be finalized by 3GPP. The standards process is still at least many months away from completion, and the outcome and timing are uncertain since many of the same companies and groups opposing or trying to delay LTE-U are also opposing or trying to delay LAA. Furthermore, the sooner the LTE-U technology is introduced into the market, the quicker it can be further optimized and used to

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12 National Broadband Plan at 9.

13 *See* Thomas K. Sawanobori and Dr. Robert Roche, "MOBILE DATA DEMAND: GROWTH FORECASTS MET, Significant Growth Projections Continue to Drive the Need for More Spectrum," CTIA - The Wireless Association (June 22, 2015).

14 Nonetheless, we expect the coexistence features in future LAA equipment to leverage the many coexistence features in LTE-U, such as channel selection, network listening and medium utilization computation.

refine other technologies and evolve future technologies to further enhance the spectral efficiency of the unlicensed bands. Indeed, the introduction of the LTE technology family into the 5 GHz band is encouraging the Wi-Fi ecosystem to put more focus on Wi-Fi equipment performance and coexistence aspects and to leverage key concepts from cellular technology to accelerate the Wi-Fi technology evolution.