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	)	

COMMENTS OF ALCATEL-LUCENT

Alcatel-Lucent submits these responses to the questions provided by the Office of Engineering and Technology and Wireless Telecommunications Bureau in the above-captioned proceeding.

I. INTRODUCTION AND SUMMARY

Alcatel-Lucent is the leading IP networking, ultra-broadband access and cloud technology specialist. Alcatel-Lucent is dedicated to making global communications more innovative, sustainable and accessible for people, businesses and governments worldwide.

Underpinning the company's leadership in driving transformation from voice telephony to high-speed digital delivery of data, video and cloud services is Bell Labs, one of the world's foremost technology research institutes, responsible for countless breakthroughs that have shaped the networking and communications industry. These innovations have resulted in 8 Nobel Prizes, a Turing Award, an Emmy, a Grammy and an Oscar. Alcatel-Lucent has been recognized by Thomson Reuters as a Top 100 Global Innovator, as well as being named by MIT Technology Review as among the Top 50 "World's Most Innovative Companies." Alcatel-Lucent has also been recognized for innovation in sustainability, being named Industry Group Leader in the Technology Hardware & Equipment sector in the Dow Jones Sustainability Indices

review, for making global communications more sustainable, affordable and accessible, all in pursuit of our mission to realize the potential of a connected world.

Below, Alcatel-Lucent provides an overview of the importance of both Wi-Fi and LTE unlicensed technologies and Alcatel-Lucent's place in the development of those technologies. These Comments then address each of the specific questions posed in this proceeding.

II. WI-FI AND LTE UNLICENSED TECHNOLOGIES ARE A CRITICAL COMPONENT TO MEETING WIRELESS DEMAND

The use of unlicensed and shared spectrum is a critical partner to licensed, exclusive use spectrum for meeting the ever-increasing demands of wireless mobile growth. Unlicensed spectrum already is widely leveraged in existing mobile broadband deployments using Wi-Fi technology and, in the future, using LTE in unlicensed spectrum. As part of its Wireless Unified Networks (WUN) strategy, Alcatel-Lucent is leading the introduction of solutions for integrating current LTE networks with Wi-Fi and unlicensed LTE networks to deliver higher Quality of Experience (QoE) to the mobile network users. WUN consists of two component technologies, namely Wi-Fi Boost and Cellular Boost.

Alcatel-Lucent's Wi-Fi Boost technology combines the downlink of Wi-Fi with the uplink of cellular. This capability requires an OS software update to existing user devices that are capable of both cellular and Wi-Fi transmissions, and software updates in the network to blend the Wi-Fi and cellular access networks. Alcatel-Lucent is weaving together collaboration with operators and UE partners to build the end-to-end ecosystem for Wi-Fi Boost deployment. Alcatel-Lucent plans to trial the Wi-Fi Boost capabilities in the third quarter of 2015 with commercial availability targeted by the first quarter of 2016.

Alcatel-Lucent is introducing additional performance enhancements (Wi-Fi Boost Plus), by aggregating the cellular downlink with the Wi-Fi downlink, and achieving further Wi-Fi coverage extension by offloading Wi-Fi ACKs onto the cellular uplink. Wi-Fi Boost and Boost Plus complement and provide an evolution path to the 3GPP LTE Wi-Fi Aggregation (LWA) standards currently under development. Alcatel-Lucent is actively contributing to enhancements to current LWA scope and technical content to ensure it serves the most pertinent deployment scenarios.

Cellular Boost leverages LTE deployment in unlicensed spectrum (5 GHz band) to enhance the performance of the cellular network. The lower transmit power requirements of the unlicensed spectrum makes LTE deployment in the unlicensed spectrum primarily a small cell deployment technology.

With respect to LTE deployment in unlicensed spectrum, there are two solutions that are being pursued: (1) LTE-U as the outcome of the LTE-U Forum; and (2) Licensed Assisted Access (LAA) which is being investigated in 3GPP. (Details of the two solutions are provided below in the response to Q1.) Alcatel-Lucent is one of the key participants and contributors to both activities. The LTE-U Forum (http://www.lteuforum.org/) includes as key participating members Verizon, Alcatel-Lucent, Ericsson, LG Electronics, Qualcomm Technologies, and Samsung.

The Boost architecture fits within a broader framework of unification across multiple air interfaces: LTE, licensed and unlicensed, WLAN and future 5G access. 5G access is also expected to support both licensed and unlicensed operation using similar principles to those defined for LTE addressing both existing 3GPP bands and new spectrum above 20 GHz, and hence potentially addressing the unlicensed bands near 60 GHz.

Therefore, Alcatel-Lucent is developing carrier-grade unlicensed solutions involving both Wi-Fi and LTE technologies, and it is also in Alcatel-Lucent's interest to ensure that any solution for LTE in unlicensed spectrum achieves fair coexistence with Wi-Fi.

III. ANSWERS TO SPECIFIC QUESTIONS POSED IN THIS PROCEEDING

Q1: <u>What different variations of LTE in unlicensed spectrum (e.g., LTE-U, LAA) are under active development or on a roadmap for future development? How do they relate to one another in terms of technology, potential use, and timing of availability?</u>

There are two solutions that are being pursued for LTE deployment in unlicensed spectrum. The current focus is on solutions that combine unlicensed secondary carriers with a primary carrier that is anchored in licensed spectrum using carrier aggregation to achieve higher throughput and enhanced user QoE. Each of these two solutions employs appropriate coexistence mechanisms to harmoniously coexist with the incumbent Wi-Fi in the unlicensed spectrum. Due to the lower transmit power requirements of the unlicensed spectrum, LTE deployment in the unlicensed spectrum is primarily a small cell deployment technology.

1) LTE-U is a solution developed based on 3GPP LTE Rel-10/11/12, with implementation-based approach at the eNB to properly address the coexistence issue. This solution applies to regions such as the U.S. and Korea that do not mandate Listen-Before-Talk (LBT) regulations. To harmoniously co-exist with the incumbent Wi-Fi, LTE-U employs channel selection and LTE-U ON/OFF duty cycle mechanisms to share the unlicensed channel in TDM manner with Wi-Fi and other operators' LTE-U deployments. The LTE-U technical specifications were defined and published in March 2015 by the LTE-U Forum. Field trials for LTE-U-capable small cells are targeted for the 3rd Quarter 2015, with potential commercial deployment in the 2nd Quarter 2016. The only mode of operation defined for LTE-U is the Supplemental Downlink (SDL) mode where up to two contiguous 20 MHz secondary unlicensed carriers may carry user Best Effort (BE) data in downlink only with assistance from an anchor primary licensed carrier. The following documents published by the LTE-U Forum [Available Online: http://www.lteuforum.org/documents.html], represent the updates to the RF and testing requirements in LTE as specified in 3GPP for operation of LTE-U in the unlicensed 5 GHz band:

- eNB Minimum Requirements for LTE-U SDL V1.0 (2015-02) (Modifications to 3GPP TS 36.104);
- UE Minimum Requirements for LTE-U SDL V1.0 (2015-02) (Modifications to 3GPP TS 36.101);
- Base Station (BS) conformance testing for LTE-U SDL (Modifications to 3GPP TS36.141) – Currently under LTE-U forum review to be published soon; and

- UE conformance testing for LTE-U SDL (Modifications to 3GPP TS36.521) – Currently under LTE-U forum review to be published soon.

2) LAA is currently being investigated as a standardized solution in 3GPP LTE R13, and the first version is expected to be standardized in R13. The study item on LAA, which has devoted the major effort to the coexistence performance evaluation, has been completed in all the RAN working groups and is expected to be closed in RAN#68 plenary meeting in June 2015. An R13 work item on LAA is expected to be approved in RAN#68 to start the actual standardization work. LAA is expected to employ LBT as the co-existence mechanism to share an unlicensed channel with the incumbent Wi-Fi and any other networks including LAA. This is partly to comply with the LBT regulations in certain regions such as Europe and Japan. Compliance with the LBT regulations will result in changes to the LTE waveform at the Physical (PHY) and Media Access Control (MAC) layers. Development efforts for an LAA-capable small cell may start once the LAA technical specifications are finalized (expected March 2016). LAA in Rel-13 is expected to support at least SDL mode of operation with DL transmission only, and also possibly to support unlicensed secondary carriers that will carry both downlink and uplink, with assistance from the anchor primary licensed carrier. The channel bandwidth (e.g. 20 MHz or less) and the number of unlicensed secondary carriers supported by LAA is not yet defined in the ongoing study item discussions. Although future consideration of stand-alone LTE in unlicensed bands may be considered in 3GPP in the future, the current work in 3GPP focuses on LTE in unlicensed bands used in conjunction with licensed spectrum.

Q2: <u>What is the current state of development of the LTE-U and LAA standards and what is the anticipated schedule for completion of the LTE-U and LAA standards?</u>

For LTE-U operation in the unlicensed 5 GHz band, the technical specifications were defined and published by the LTE-U Forum in March 2015. [Available Online: http://www.lteuforum.org/documents.html]. LTE-U employs channel selection and LTE-U ON/OFF duty cycle mechanisms to share the unlicensed channel in TDM manner with Wi-Fi and other operators' LTE-U deployments. The LTE-U Forum is currently actively seeking feedback and input from the Wi-Fi industry and standards body via presentations and workshops to achieve consensus about this co-existence mechanism.

As noted above in response to Question 1, LAA standardization activities are currently ongoing in 3GPP R13. The study item on LAA has been completed in all the RAN working groups and is expected to be closed in RAN#68 plenary meeting in June 2015. Please refer to the 3GPP website (http://www.3gpp.org/dynareport/36889.htm) for the up-to-date Technical Report 36.889 for the LAA study item. An R13 work item on LAA is expected to be approved in RAN#68 to start the actual standardization work, and LTE R13 specifications are expected to be published by March 2016. LAA will employ LBT mechanism for co-existence with Wi-Fi in the unlicensed spectrum. LAA compliance with the LBT regulations will result in LTE waveform changes at the PHY, and MAC layers.

Q3: **<u>What is the status of coordination between 3GPP and the IEEE 802.11 on LTE-U and LAA, and what is the process for coming to agreement on appropriate sharing characteristics to ensure coexistence with the IEEE 802.11 family of standards?</u>**

The LTE-U Forum has engaged the Wi-Fi Alliance (WFA), and IEEE 802.11 Standards Group to seek their feedback about the published technical specification for LTE-U.

- On March 9, 2015, LTE-U Forum (Verizon and Qualcomm jointly) presented an overview of LTE-U technology to the WFA, and addressed key questions on co-existence.
- On May 28, 2015, LTE-U Forum hosted a workshop that included IEEE/WFA industry bodies, key Wi-Fi and cellular infrastructure and device vendors, to present the LTE-U Forum co-existence specifications, simulation results, and give live demos to seek feedback and consensus.

The key LTE-U Forum participants also develop and/or deploy Wi-Fi products and services, and, therefore, achieving a harmonious LTE and Wi-Fi co-existence in the unlicensed spectrum is their top priority.

Since the start of the 3GPP LAA study item in R13, the 3GPP activities involve a large number of members from the Wi-Fi industry. There has also been constant information exchange between 3GPP and IEEE/WFA, which aims to ensure the fair coexistence between LAA and Wi-Fi. Some of the highlights include:

- In December 2014, IEEE 802 LMSC (Local and Metropolitan Area Network Standards Committee) gave a presentation at the 3GPP RAN#66 plenary meeting on the coexistence lessons learned when dealing with unlicensed spectrum.
- In January and February 2015 respectively, IEEE 802 LMSC and WFA Board of Directors invited the chair of 3GPP RAN to give a presentation on the status of the ongoing LAA work.
- In February 2015, IEEE 802 LMSC sent a liaison statement to 3GPP regarding coexistence of LAA and IEEE 802. 3GPP responded by updating the simulations assumptions based on IEEE's recommendations, and further sent a response liaison statement to IEEE.
- In March 2015, IEEE sent a liaison statement to 3GPP on clarification of LBT Categories and LAA/802.11 coexistence. 3GPP responded by adding some additional simulation assumptions and providing point-by-point reply to IEEE's comments with two response liaison statements.
- In May 2015, 3GPP LAA Study Item Rapporteur gave a presentation on the LAA study item status at an IEEE 802 session.
- In May 2015, IEEE sent a follow-up liaison statement regarding LAA. 3GPP sent a response liaison statement providing point-by-point reply to IEEE's comments.

- IEEE and 3GPP are also considering the possibility of having a joint workshop in July 2015 that includes 3GPP and other industry stakeholders.

These industry discussions are expected to continue until progress is made to reach a successful conclusion.

Q4: <u>What are the anticipated technical characteristics (e.g. bandwidth(s), listen-before-talk, transmission durations, etc.) of LTE-U and LAA?</u>

The LTE-U specification, as per the LTE-U Forum, defines the use of up to two contiguous 20 MHz unlicensed carriers that could be used in carrier aggregation mode with a primary carrier that is anchored in licensed spectrum for its SDL mode of operation.

For LAA, the channel bandwidth (e.g., 20 MHz or less) of the unlicensed carriers is not yet defined. Similarly, the total number of unlicensed carriers used in the LAA operations is also not yet specified. However, because LAA is being developed under a carrier aggregation framework, it is expected that the core specifications will support a total number of aggregated carriers (unlicensed and licensed) of up to 32 after the R13 work item on carrier aggregation enhancement beyond 5 carriers is completed. LAA will additionally abide by the LBT regulations, and support a maximum channel occupancy period mandated in different regions (e.g. ~10 miliseconds in Europe, and 4 miliseconds in Japan).

Q5: <u>What tests or analyses have been performed to understand the impact of LTE-U and LAA on the existing commercial wireless and unlicensed ecosystems?</u>

The LTE-U Forum has conducted and published extensive simulation studies for LTE coexistence with Wi-Fi in the unlicensed spectrum. As part of the LTE-U technical and coexistence specifications, the LTE-U Forum has published the following documents [Available Online: http://www.lteuforum.org/documents.html].

- LTE-U Technical Report V1.0;
- LTE-U SDL Co-existence specifications V1.0 and V1.1;
- UE Minimum Requirements for LTE-U SDL V1.0 (2015-02) (Modifications to 3GPP TS 36.101);
- eNB Minimum Requirements for LTE-U SDL V1.0 (2015-02) (Modifications to 3GPP TS 36.104);
- g eNB Conformance Test Specifications for LTE-U SDL V1.0 (2015-06) (Modifications to 3GPP TS36.141); and
- UE Conformance Test Specifications for LTE-U SDL V1.0 (2015-06) (Modifications to 3GPP TS36.521-1).

On May 28, 2015, the LTE-U Forum hosted a workshop that included IEEE/WFA industry bodies, key Wi-Fi and cellular infrastructure and device vendors to present the LTE-U Forum specifications, and seek feedback from the Wi-Fi community. The workshop included live demos, and testing of over-the-air outdoor environment scenario

using a significant number of different brands of commercial Wi-Fi access points and client devices with Wi-Fi carrying VoIP calls, video, and a mixture of data and other traffic. These tests all verified that LTE-U does not have any adverse impact on Wi-Fi, and demonstrated that LTE-U is a good neighbor to Wi-Fi, even in a dense environment.

For an LAA feasibility study in the unlicensed spectrum, extensive simulations have been performed to evaluate the coexistence performance between LAA and Wi-Fi. The simulations covered a large number of cases, including indoor and outdoor scenarios, different LBT mechanisms, best effort data and VoIP traffic, DL-only and DL+UL deployment, etc. During the study item phase, 26 sources (including Wi-Fi companies) have provided coexistence performance evaluation results for LAA and Wi-Fi for at least one scenario. The evaluation results showed that when an appropriate channel access scheme (i.e. LBT scheme) is used, LAA achieves fair coexistence with Wi-Fi (i.e., LAA does not impact Wi-Fi more than another Wi-Fi network). In fact, it is recommended by the study item conclusion that an LBT scheme with random back-off and variable contention window size (similar to what is used by Wi-Fi) should be adopted, at least for downlink data transmission in LAA, to ensure fair coexistence. Please refer to the Technical Report 36.889 (http://www.3gpp.org/dynareport/36889.htm) for detailed information including evaluation results and observations.

Q6: <u>Precisely how will LAA integrate licensed and unlicensed carriers, particularly with regard to controlling access to spectrum?</u>

LAA will employ carrier aggregation to integrate secondary unlicensed carriers with a primary carrier that is anchored in licensed spectrum. The licensed carriers will carry all critical signaling, and mobility data. In the DL-only mode of LAA operation, the unlicensed secondary carriers will carry the downlink data transmission only. Whereas in the UL+DL LAA mode of operation the secondary unlicensed carries will carry both uplink and downlink data transmission. It is generally expected that LAA cells will be used to offload the best effort data from the licensed cells in a busy situation, and the operators can choose not to use LAA cells when the licensed cells are not busy.

Q7: <u>To what extent is a standalone form of LTE-U being developed, that is, a form that can operate without a licensed primary channel?</u>

To date, the LTE-U Forum has not sought to develop a stand-alone solution for LTE-U. Rather, the LTE-U Forum's work has focused on an SDL mode of operation where a secondary unlicensed carrier in downlink-only is accompanied by a primary carrier that is anchored in licensed spectrum using carrier aggregation.

3GPP R13 LAA has similarly focused on non-standalone operation, meaning that LAA cells are always aggregated with a primary carrier anchored in licensed spectrum. The standalone mode of LTE in unlicensed spectrum (without requiring assistance from a licensed carrier) is not currently being considered in R13. However, this does not preclude the possibility that it will be considered in 3GPP in the future.

Q8: <u>Are existing devices capable of software upgrades to implement LTE-U and LAA?</u>

Existing devices or user equipment will not be able to support LTE-U/LAA deployment. New RF band support (unlicensed 5 GHz, or the 3.5 GHz shared spectrum) will be needed on the next generation devices as well as LTE-U/LAA-capable small cells to enable the deployment of LTE in the unlicensed spectrum.

Appropriate coexistence mechanisms such as the channel selection and LTE-U ON/OFF duty cycle mechanisms for LTE-U and LBT for LAA will be needed for coexistence with Wi-Fi in the unlicensed spectrum. The implementation of these coexistence mechanisms and new RF band support will have subsequent design impact on the small cells and the user equipment for LTE-U/LAA support.

Q9: <u>What frequency bands are envisioned for deployment of LTE-U and LAA?</u>

For the LTE-U deployment, the initial unlicensed frequency bands specified by the LTE-U Forum are the 5 GHz U-NII-1 and U-NII-3 bands.

For 3GPP R13 LAA, the work item is yet to be started. However, it is expected that the core specifications will not be limited to any particular frequency band. After the core specifications are completed, the RF requirements for each frequency band can be added as needed. It is possible that the band specification for LAA could include all of the 5 GHz U-NII bands including U-NII-2 band that has dynamic frequency selection requirements.

LAA-capable small cells, and UEs supporting both uplink and downlink, may also be deployed in the shared spectrum such as the 3.5 GHz band, including a three-tier spectrum architecture:

- Tier 1: Incumbent operations (primary);
- Tier 2: Priority Access Licensees (PALs), secondary to the incumbent, with interference protection from other PALs and from Tier 3;
- Tier 3: Generalized Authorized Access (GAA) with no protection

The 3.5GHz band will be suitable for: (1) small cell deployment with LTE-L (Licensed) in the Priority Access tier; and (2) LAA (supporting both uplink and downlink unlicensed secondary carriers with assistance from the primary carrier anchored in licensed spectrum with assistance from the primary carrier anchored in licensed spectrum) and Wi-Fi in the GAA tier. With 3.5 GHz RF band support, the LAA capable small cells and end-user devices supporting both uplink and downlink will thus be able to take advantage of the shared licensed spectrum as well.

Q10: <u>What plans do carriers and manufacturers have for pre-standard deployment of LTE-U and LAA equipment including possible upgrades to 3GPP-based LTE-U or LAA and how would the above questions (particularly with respect to coexistence issues) be addressed relative to pre-standard versions of LTE-U and LAA?</u>

Alcatel-Lucent is actively participating in the ongoing 3GPP R13 standardization activities for LTE deployment in the unlicensed spectrum known as LAA. The LAA study item for R13 is expected to be closed in June 2015, and an R13 work item is expected to be approved in June 2015. R13 specifications are expected to be published by March 2016.

LAA involves non-trivial modifications to LTE in order to support LBT and discontinuous transmissions. LAA-capable small cell development efforts are expected to begin once the ongoing standardization activities reach stable state over the next year.

As discussed above, Alcatel-Lucent also is currently working on a non-LBT based solution known as LTE-U, developed by the LTE-U Forum. LTE-U is based on the existing 3GPP Release 10/11/12 LTE specifications, and requires no changes to the existing LTE air interface waveform for its operation. However, LTE-U requires additional software at each small cell to implement channel selection and LTE-U ON/OFF duty cycle mechanisms for co-existence with Wi-Fi as per the technical specifications defined and published by the LTE-U Forum earlier this year [Available Online: http://www.lteuforum.org/documents.html]. Alcatel-Lucent is targeting third quarter 2015 to support a field trial of a LTE-U capable small cell with a potential commercial availability in second quarter of 2016.

IV. CONCLUSION

Alcatel-Lucent requests that the Commission consider these Comments as it moves forward with consideration of these important issues.

Respectfully submitted,

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