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VIA ELECTRONIC FILING

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

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

Dear Ms. Dortch:

Broadcom Corporation ("Broadcom") thanks the Federal Communications Commission ("FCC" or "Commission") for opening this docket to provide for public discussion regarding the use of LTE in unlicensed bands.[1]

Broadcom is a global leader in wired and wireless communications semiconductors. We ship over 7 million chips on a daily basis. We have a meaningful presence in nearly all categories of products that require communications chips, and have one of the broadest portfolios in the industry. We estimate that 99.98% of all Internet traffic goes through at least one Broadcom chip. Because of our diversity in the market, we have a unique understanding of the overall communications ecosystem and the various technologies used to transmit data. We are innovating to ensure a smooth flow of data from the data center, to the Internet service provider, to the home gateway or router, to the client device that that you use to watch movies or surf the web. Broadcom is an active member of all the relevant standards bodies addressing Wi-Fi and LTE (i.e., IEEE, Wi-Fi Alliance, 3GPP) and is actively contributing to discussions on the evolution of the related standards and how technologies operating using both Wi-Fi and unlicensed versions of LTE can coexist without creating harmful interference with technologies already operating in the unlicensed bands.

As the Commission noted, some have expressed concerns related to the coexistence between unlicensed LTE and other technologies already operating in the spectrum bands designated for unlicensed use, such as Wi-Fi. Based on our simulations, which are discussed in further detail below, Broadcom believes that LAA can coexist with Wi-Fi given proper planning and the incorporation of robust coexistence mechanisms, but stakeholders must be incentivized to develop and implement those mechanisms.[2] Broadcom has considerable concerns about LTE-U's coexistence with Wi-Fi and believes that it is unlikely to be a good neighbor because the coexistence algorithms are proprietary, because of variations in equipment, and ultimately because coexistence is controlled at time of operation, among other reasons discussed further below.

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[1] For the purposes of these comments related to unlicensed LTE, when Broadcom refers to LTE-U, we are referring to the technology being contemplated by the LTE-U Forum and when we refer to License Assisted Access or LAA, we are referring to the technology being contemplated by the 3GPP standards body.

[2] This belief is based on our understanding of the technology and reasonable assumptions, but there is no substitute for actual testing, and such tests may reveal results that are not contemplated by the parameters in our simulations.

Current State of LTE-U and LAA Standards

"*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?*"

Broadcom does not believe that LTE-U as envisioned by the LTE-U Forum meets the normal criteria of a standard. Participation in this group is restricted; detailed specifications are not provided; and sharing algorithms are proprietary. We understand that that LTE-U may be deployed in early 2016. Broadcom believes that LAA is likely to be standardized in 2016. We understand that the priority focus for 3GPP consideration is supplemental downlink, and that supplemental uplink will be considered in the future.

Coordination between 3GPP and IEEE

"*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?*"

Broadcom is unaware of any formal collaboration or coordinating mechanism between IEEE 802.11 and the LTE-U Forum on LTE-U coexistence, with Wi-Fi. LAA is being standardized by the 3GPP. The process is reliant upon 3GPP and its member organizations. There is no formal role for IEEE 802.11 in the 3GPP process. Broadcom understands that communications have been established between the two groups, and IEEE has liaised with 3GPP, but strong collaboration and close coordination between 3GPP and IEEE is necessary to ensure a standards process that appropriately ensures LAA coexistence with the over 10 billion Wi-Fi devices that have been shipped as of this date.

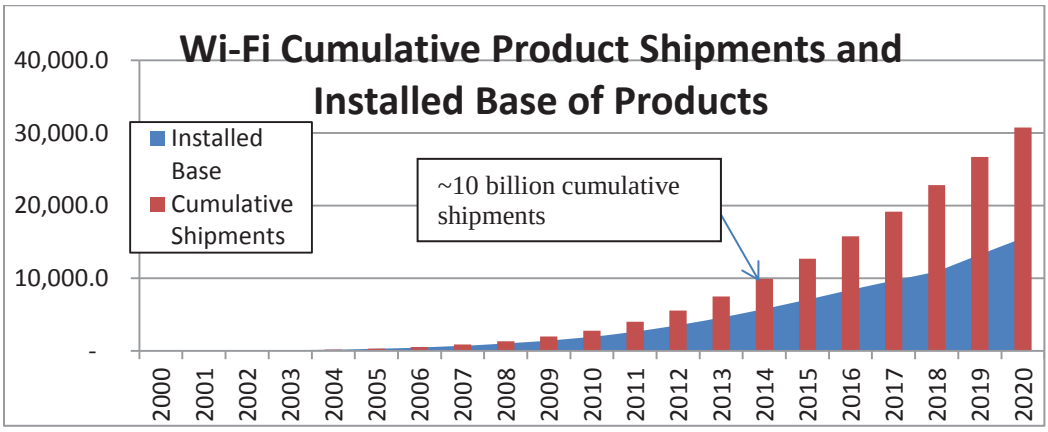

Figure 1. Cumulative Wi-Fi-enabled Product Shipments and Installed Base of Wi-Fi-enabled Products: World Market, Forecast: 2000 to 2020. (Source: ABI Research)

Closer collaboration between 3GPP, IEEE, and Wi-Fi Alliance would ensure that critical technical characteristics are carefully considered in the 3GPP Study Items on LAA. In particular, the standards-setting process should evaluate coexistence with Wi-Fi as it is currently deployed in the market: it should recognize that Wi-Fi devices can operate using 20 to 160 MHz channels, incorporate multiple-input multiple-output (MIMO) technology, and using explicit transmit beamforming (TxBF). Any study of LTE-U or LAA coexistence with Wi-Fi looking not contemplating wider channel solutions, MIMO, or TxBF would not be representative of a typical real world network in 5GHz. Furthermore, closer collaboration between

3GPP, IEEE, and Wi-Fi Alliance would ideally lead to interoperability testing and certification that ensures that deployed devices coexist fairly.

Anticipated LTE-U and LAA Technical Characteristics

"*What are the anticipated technical characteristics (e.g. bandwidth(s), listen-before-talk, transmission durations, etc.) of LTE-U and LAA?*"

LTE was designed for use on licensed spectrum, and use/interference is designed to be managed by a single operator. Broadcom understands that individual operators deploying LTE-U may implement coexistence mechanism parameters differently, according to their business priorities and technical capabilities. This means that there will be significant variation in the amount of time LTE-U occupies the unlicensed spectrum from market to market. Since LTE was never designed for unlicensed use or sharing with other technologies, it has not had to develop the attributes necessary for fair coexistence. Broadcom understands that LTE-U contemplates coexistence mechanisms, but such mechanisms are not mandated. We understand that original equipment manufacturers (OEMs) will have significant discretion in how they choose to implement such coexistence mechanisms and some equipment may be friendlier to unlicensed devices than others. However, we understand that a common thread for LTE-U is that coexistence mechanisms appear to rely more on assessing the unlicensed spectrum, and forcing other technologies, such as Wi-Fi, to use their politeness protocols (e.g., listen-before-talk (LBT)) to transmit during LTE-U idle periods. In this way, LTE-U appears to control or manage the medium. Broadcom looks forward to learning more about LTE-U as a result of this docket.

With respect to LAA, Broadcom understands that 3GPP contemplates deployment in 20 MHz channels as an initial matter, but that wider channels (e.g., 40 MHz, 80 MHz, 80 + 80 MHz, 160 MHz) are contemplated for 3GPP standardization at a future date. As described in the previous section, impact of LAA or LAA on wider bandwidth Wi-Fi (e.g., 40-160 MHz channels) is not understood, nor is it being studied in 3GPP currently. Creation of wider LTE-U or LAA channels would ensure greater overlap in channels used by LTE-U or LAA and wider Wi-Fi channels, which would create an even greater impetus for thorough study prior to deployment.

Broadcom conducted studies to determine the most important coexistence challenges that unlicensed LTE should address prior to deployment. Based on our simulations, Broadcom suggests standardization of at least a three-pronged approach to healthy and fair coexistence among broadband unlicensed technologies, but others may be required as well. First, such technologies should have an initial wait or defer time (we suggest ~43 microseconds) to allow for unaffiliated data transmissions to complete prior to arbitration and transmission. Second, the technologies should incorporate a coexistence mechanism that backs-off rapidly when significant interference with other users is detected (exponential back-off). Third, the technologies should incorporate LBT prior to each data transmission. LBT should be capable of detecting lower levels of energy, preamble, or carrier sense (e.g., energy detection at -82 dBm to -92 dBm) than the existing LBT requirements in some countries (i.e., -62dBm).

LTE-U and LAA Tests

"What tests or analyses have been performed to understand the impact of LTE-U and LAA on the existing commercial wireless and unlicensed ecosystems?"

Broadcom has conducted several simulations to determine appropriate coexistence principles that LTE-U and/or LAA should incorporate to ensure fair coexistence with existing Wi-Fi devices. Our simulations study the effects that unlicensed LTE would likely have on Wi-Fi throughput, latency, and VoIP dropped calls under various coexistence scenarios.

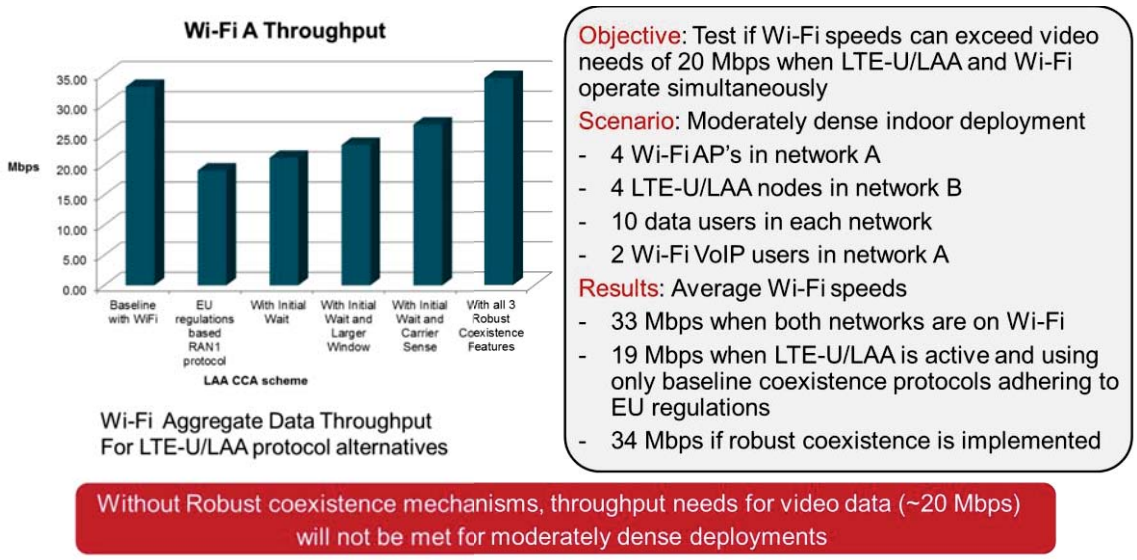

Figure 2. Broadcom simulation demonstrating the impact that unlicensed LTE would have on Wi-Fi throughput speeds under various coexistence assumptions.

As demonstrated Figure 2, Broadcom believes that unlicensed LTE is likely to coexist well with Wi-Fi if it has the ability to detect weak Wi-Fi signals (-82 dBm), it incorporates an initial defer time of at least 43 microseconds prior to arbitration, and it incorporates exponential back-off to be more adaptive to congestion in moderately dense operating environments. But, our simulations show that inadequate coexistence mechanisms severely degrade Wi-Fi.

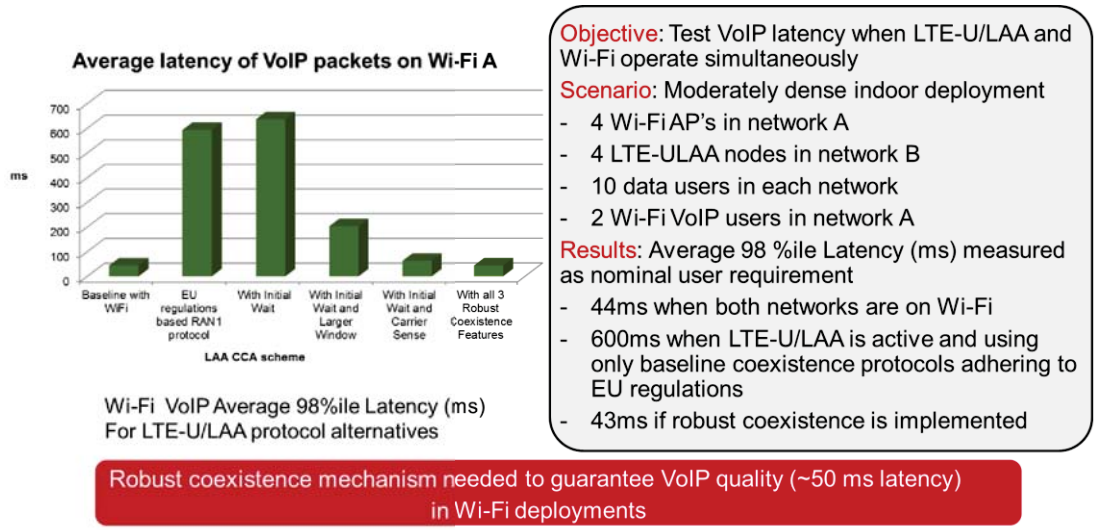

Figure 3. Broadcom simulation demonstrating the impact that unlicensed LTE would have on latency of VoIP packets over Wi-Fi under various coexistence assumptions.

As demonstrated Figure 3, Broadcom believes that unlicensed LTE would not have a detrimental impact to real-time services over Wi-Fi if it incorporates the three coexistence mechanisms explored in our

simulation. However, unless all three are incorporated, Broadcom believes that real time services could be severely impacted.

To further investigate the potential impact on real time services, Broadcom and Intel both explored VoIP outage as a result of LAA with listen-before-talk (LBT) at -62 dBm and -82 dBm (see Figure 4 below).[3] A VoIP outage exists when less than 98% of packets have greater than 50 milliseconds of delay. Broadcom and Intel simulations were also based on an initial defer time (34 microseconds for Intel and 43 microseconds for Broadcom) and exponential backoff.

VoIP Outage	Low loading		Medium Loading		High Loading	
	WiFi/WiFi	WiFi/LAA	WiFi/WiFi	WiFi/LAA	WiFi/WiFi	WiFi/LAA
Intel -62 dBm LAA LBT	14%	33%	35%	52%	52%	76%
Intel -82 dBm LAA LBT	14%	0%	35%	9%	52%	30%
Broadcom -62 dBm LAA LBT	0%	0%	10%	40%	30%	50%
Broadcom -82 dBm LAA LBT	0%	0%	10%	0%	30%	0%

Figure 4. LAA Impact on VoIP over Wi-Fi simulated by Broadcom and Intel for 3GPP RAN1 (R1-151823 and R1-152936).

The results of the simulations demonstrate consistent degradation of VoIP unless LAA coexistence mechanisms are robust, especially in moderately dense and highly dense deployments.

Based on our simulations, the results appear clear: Adding the appropriate robust coexistence mechanisms makes all the difference in determining whether LTE-U or LAA can operate as a good neighbor to unlicensed technologies, such as Wi-Fi.

We look forward to reviewing other comments in relation to this docket and to working with the Commission should it have any questions with respect to this filing.

Sincerely,

/s/ Christopher Szymanski
Christopher Szymanski
Director, Global Regulatory Affairs
Broadcom Corporation

[3] See R1-151823 and R1-152936 3GPP RAN1 documents.