Comments of

The Ultra Wide Band (UWB) Alliance

Before

The Federal Communications Commission

FURTHER NOTICE OF PROPOSED RULEMAKAING
Mid-Band Spectrum Between 3.7 and 24 GHz.

ET Docket No. 18–295
GN Docket No. 17-183

June 29, 2020
(Revised July 2, 2020)

Contents

Introduction

The Further Notice of Proposed Rulemaking (FNPRM) in the above referenced FCC Report and Order (FCC 20-51) poses several questions which deserve consideration and analysis to support further rulemaking to expand the usefulness of unlicensed spectrum in the 6 GHz band.

The UWB Alliance endorses rules changes that enable and encourage innovation which expands the usefulness and value of spectrum for all users. In the following we respond to the specific questions posed by the FCC in the FNPRM and offer constructive suggestions that will encourage efficient and effective use of the spectrum, enabling many desired applications to be addressed with existing technology solutions, while encouraging innovation to further expand the application space.

We noted in the Report and Order that the FCC used out of date information with respect to the current and projected UWB market size and economic impact. To assist the Commission, we have provided accurate information on the state of the UWB market today and have provided projections through to 2025. This information is based on numerous sources independent of and not affiliated with the UWB Alliance.

UWB Market Size and Evolution

The Ultra Wide Band Alliance (UWB Alliance) wishes to respectfully draw the Commission's attention to the data point cited in the FCC's recently published Report and Order and Further Notice of Proposed Rulemaking on Unlicensed Use of the 6 GHz Band (R&O), regarding the estimated global market value of the ultra-wideband (UWB) industry in 2022.

We would also like to submit the information below showing the evolution timelines of UWB and Wi-Fi as well as UWB and Bluetooth. These figures indicate how long these complimentary technologies took to reach sufficient maturity to be embedded within smartphone products, and therefore provide a reference point for this important milestone for UWB.

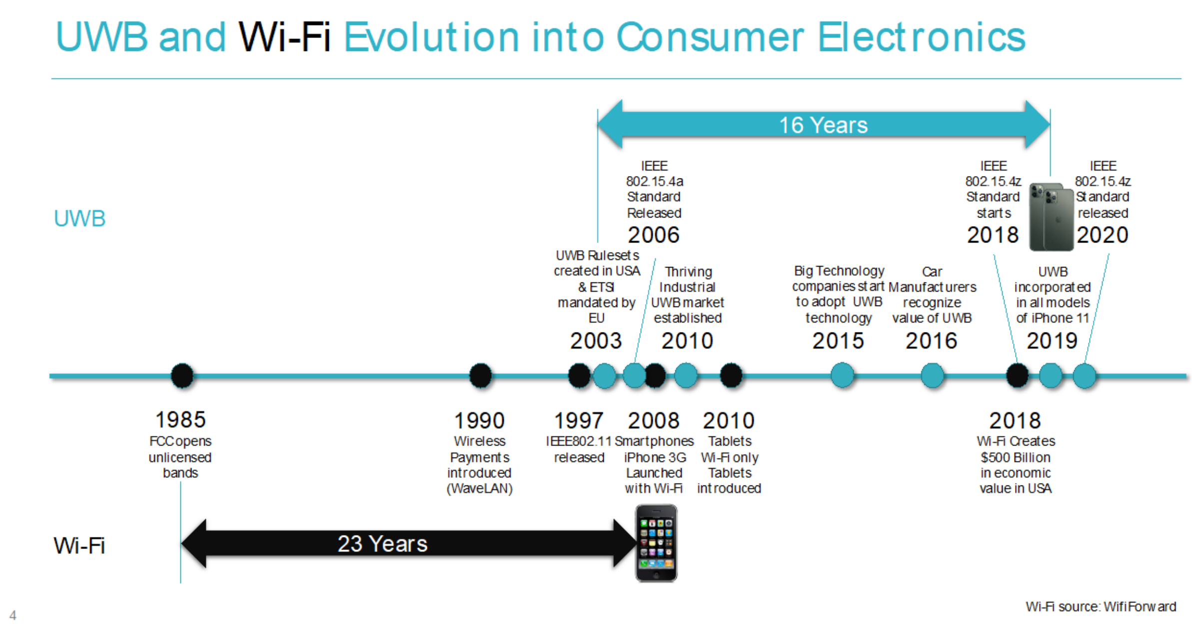

Figure 1 Evolution of UWB and Wi-Fi

One can see that UWB has taken less time (16 Years) than Wi-Fi (23 Years) to be added to mass-market mobile consumer products, including smartphone.

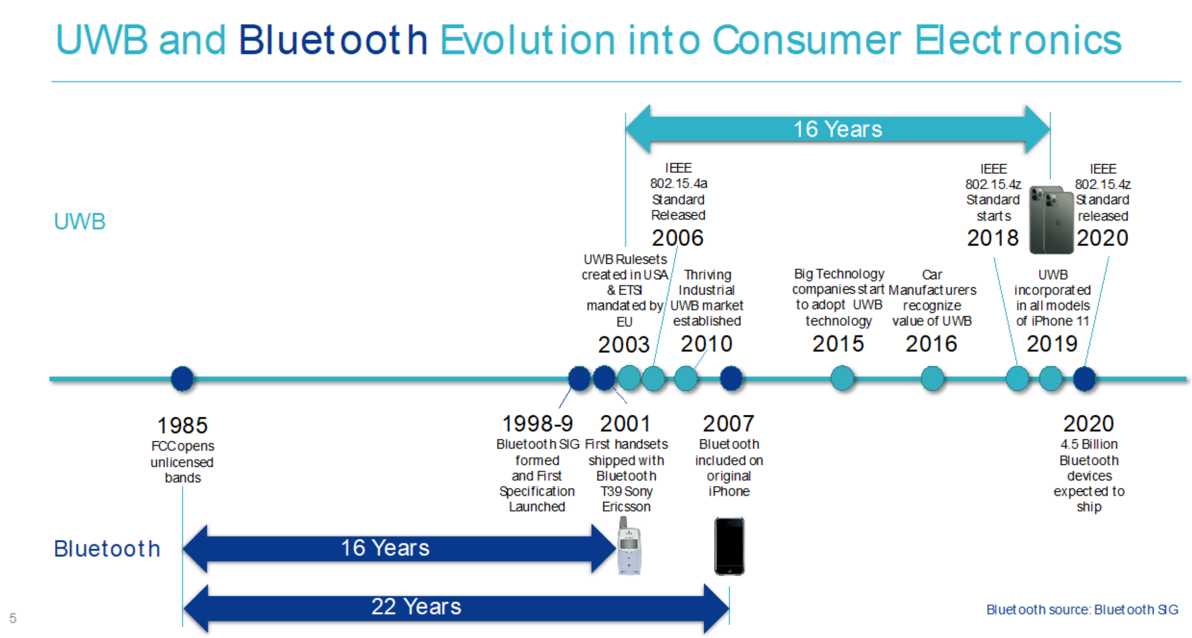

Figure 2 Evolution of UWB and Bluetooth

One can see that UWB has taken the same amount of time as Bluetooth (16 Years) to be integrated into mass-market mobile consumer products, including smartphone.

This provides valuable context for why the UWB Alliance has submitted multiple requests to the Commission to strongly consider aspects related to UWB co-existence both as part of its rulemaking and also in the formation of the Multi-Stakeholder Group in order to create a suitable framework for contention based access within the 6 GHz band. All these technologies ultimately must be able to work together inside the smartphone and associated ecosystems to leverage the combined value for the next generation of location-aware connected devices.

We would also like to draw the Commission's attention to the recently released report provided by Techno Systems Research (TSR) from May 2020 entitled, *2020 Ultra Wideband Market Analysis*.[1] This independent report supports the UWB Alliance's position that the ecosystem of products incorporating UWB will create a market that far eclipses the $85.4 million value as stated in the R&O, showing that chip sales alone (not considering the immensely larger value of economic value generated) already represents $489.5 Million in chip sale revenues this year.

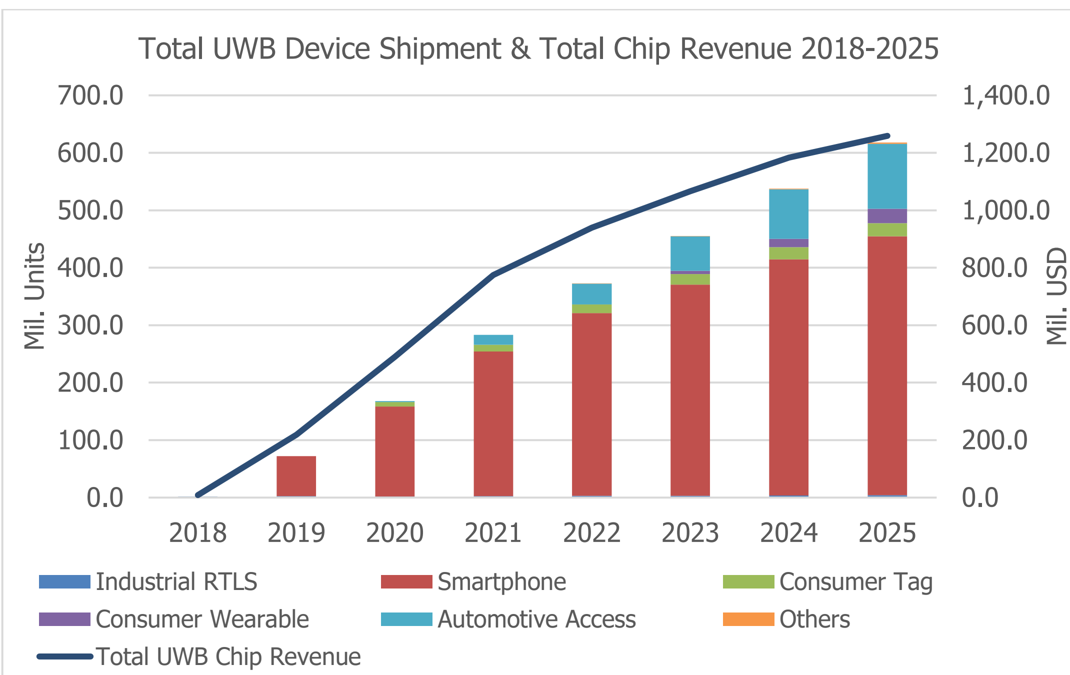

Figure 3 Device shipment and chip revenue, Source TSR Report, May 2020

[1] *2020 Ultra-Wideband Market Analysis*, Techno Systems Research (TSR), May 2020.

The TSR report indicates that UWB chip revenue alone is expected to evolve from $489.5 Million this year to $1.259 Billion by 2025.

This report is significant because it takes the following milestones into consideration:

- The widespread UWB integration into consumer devices that started with the launch of the Apple iPhone 11 family and is currently proliferating to many other smartphone vendors that are integrating UWB technology into their devices.
- The widespread adoption happening within the automotive market with the incorporation of UWB into the Digital Key Release 3.0 specification under development in the Car Connectivity Consortium. The announcement from Apple at WWDC 2020 that UWB technology will be deployed inside the 2021 BMW 5 Series, is just the first step in an industry-wide adoption of UWB within the automotive vehicular market.

The UWB Alliance is in general agreement with most of the TSR report's data-points and assumptions related to the evolution of UWB market size over the coming years. The ecosystem for UWB accessories will become a very significant portion of the overall chipset market over the next five years. For every smartphone sold there will be a minimum of 1 UWB companion device placed on the market.

The updated projections regarding the UWB are therefore reflected in the table below:

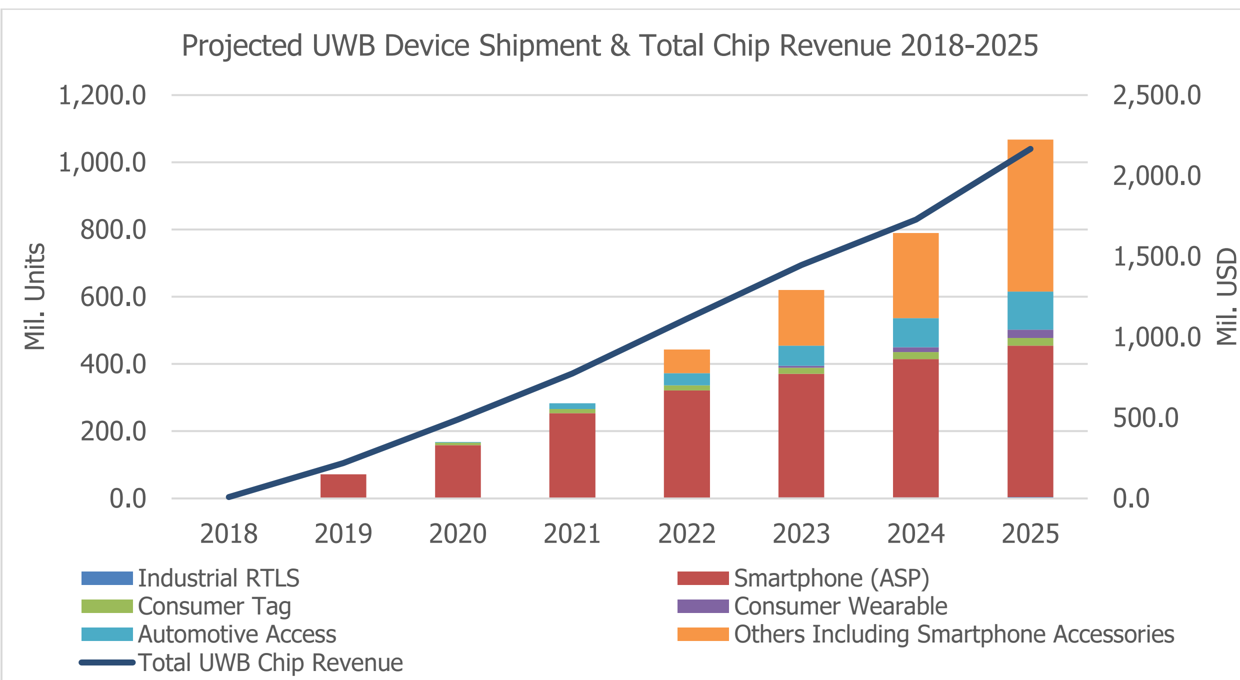

Figure 4 Device shipment and chip revenue, Source UWB Alliance, June 2020

These projections indicate that UWB technology will be integrated into numerous devices fuelling an adoption curve of over 1 billion devices annually by 2025, thus generating chipset revenues of over $2 Billion per year.

These projections are conservative when compared to the ecosystem accessory market for other radio standards such as Bluetooth and Wi-Fi following the introduction of these devices into consumer smartphone devices.[2]

The ultra-wideband industry is exploding into mainstream acceptance for multiple consumer markets including 5G IoT that are already driving huge volumes and resulting economic value. UWB's incorporation into the Apple iPhone 11 was the first of many such significant milestones for the current exponential-growth of UWB technology into high-volume consumer applications. Other smart phone manufacturers are incorporating UWB into their products as indicated by participation and contribution to standards development organizations (SDOs) such as IEEE 802.15.4z, and other industry associations.

In addition to the expansion in smartphone devices and automotive, the breadth of UWB applications include high-accuracy contact tracing for COVID-19, non-contact respiration, heart-rate, temperature and fall monitoring, VR movement and gesture sensing, providing tools for wall exploration, universal smart remote controls, sports tracking (NFL), professional audio, smart factories, stock animal health and tracking, tank level radar sensing, airport baggage handling, and bus and train control and communication. Many of these uses (e.g., high-accuracy COVID-19 contact tracing) have an intrinsic value to the public that is far beyond dollar value of the equipment used to provide it.

UWB's unique properties provide features and performance that work synergistically with other wireless technologies. No other technology can provide pinpoint accuracy and actively track locations with the minimal power requirements of UWB. It is an essential piece of the matrix of capabilities that are required to meet the IoT expectations for the next generation of 5G wireless applications.

Ultra-wideband adoption has therefore changed dramatically since 2016 and the underlying assumptions in the stated forecast used by the FCC are no longer valid. We would therefore respectfully recommend the Commission update these assumptions in the FCC record with data and projections that more closely aligned to the value that is currently being created by the

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[2] Validation by comparing total Wi-Fi vs smartphone totals sold 5 years after 2008, i.e. in 2013 – See Global Smartphone Sales to End Users 2007-2020 (S. O'Dea author, Statista, 28 Feb 2020) compared to Global Wi-Fi Enabled Equipment Shipments 2012-2017 (Statista Research Department author, Statista, 29 Oct 2013).

expanding UWB ecosystem. The revenue streams resulting from new applications that are evolving have tremendously increased the current and evolving market for UWB.

Very Low Power

The UWB Alliance endorses the concept of Very Low Power (VLP) unlicensed devices. Our members have extensive experience with very low power unlicensed devices operating under the existing rules in the United States for Wideband and Ultra-wideband systems. Reducing the potential interference footprint by reducing and containing the energy transmitted to only that which is needed greatly reduces interference for all spectrum users. Our suggestions are based upon minimizing interference to both like and unlike systems sharing the spectrum, and promote positive coexistence between users such as Wi-Fi, UWB, and incumbent licensed users.

We have considered the use cases cited for VLP by the Commission and others[3, 4, 5] as well as other likely use cases. It becomes clear from the use case requirements that control of the interference footprint of each VLP WLAN devices is critical to the success of the stated use cases as well as to the Commission's goal of maximizing value from the spectrum. We propose refinements to the VLP rules that reward intelligent control of interference footprint. Not only will this provide equitable access to the spectrum for users such as UWB and licensed incumbents, control of the interference footprint will improve performance and user density for Wi-Fi users by reducing the WLAN to WLAN interference. This is critical in the cited use cases where support for high bandwidth and high user density is essential.

We generally agree with the -8dBm/MHz Power Spectral Density (PSD) limit proposed. We appreciate that the Commission has already undertaken careful consideration when setting this limit. With predictions of billions of new unlicensed devices being deployed in the near future, the suggested PSD limit when combined with the right contention based protocol requirements and dynamic (intelligent) transmit power control provides for required performance while minimizing the risk to WLAN (e.g., Wi-Fi), other unlicensed users and licensed incumbents.

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[3] Apple Inc., Broadcom Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Microsoft Corporation, and Qualcomm Incorporated *ex parte* communication dated July 2, 2019. Comments at 4-5.

[4] Wi-Fi Alliance ex parte communication dated Jan. 17, 2020, at 1-2.

[5] Tying the maximum 14 dBm EIRP to a -8 dBm/MHz PSD EIRP assumes a 160-megahertz channel. The maximum EIRP would differ as the bandwidth changes (e.g., 11 dBm, 8 dBm and 5 dBm maximum EIRP for 20, 40 and 80-megahertz channels, respectively). Apple, Broadcom et al. July 2, 2019 ex parte, at 5,7; Apple, Broadcom et al. Dec 9, 2019 ex parte, at 8.

We agree that in some specific usage scenarios, power as high as +14 dBm may be desired. However, we also note that arbitrary use of such power level will not work well in the typical VLP AP use case. In the majority of use cases cited, the WLAN served by the VLP AP will cover a small area with a few devices (a micro-WLAN). Apple, Broadcom, et. al.[6] refer to the case of body-worn devices forming a LAN in the area on and close to the user's body.[7]

In the case of wearable computing, (e.g. the VR/AR application in a public sporting event or other large venue) there will be many adjacent micro-WLANs operating independently and simultaneously. As shown in Figure 5, +14 dBm with a typical omnidirectional antenna results in each micro-WLAN interfering with many, many neighboring micro-WLANS.

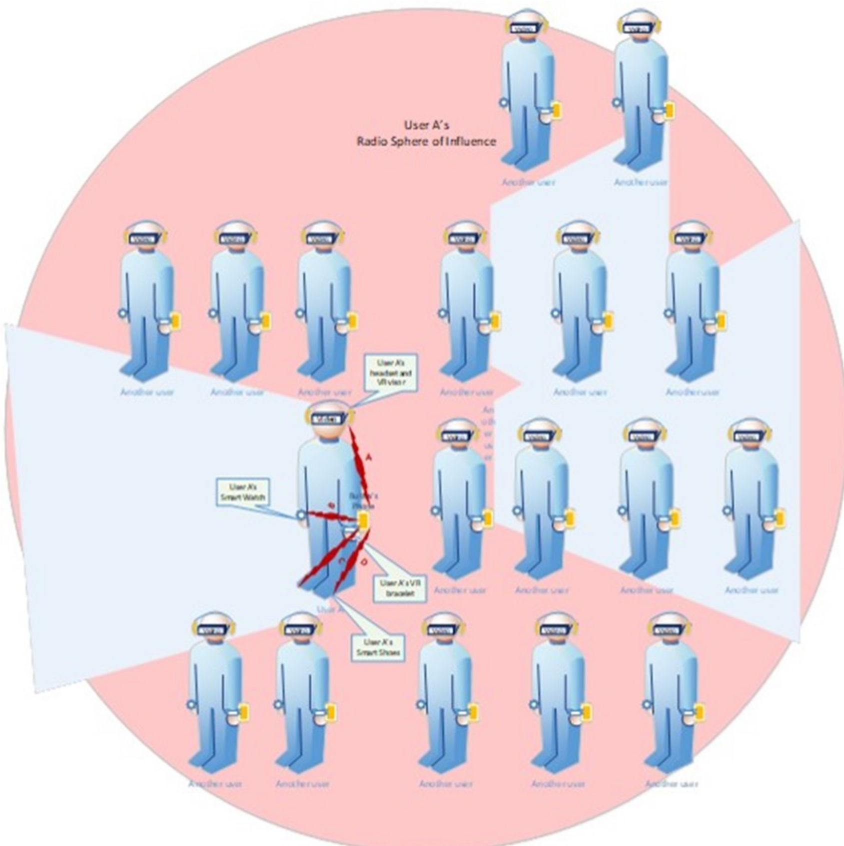

Figure 5, VR/AR example of overlapping WLANS

In this use case, however, the need for such high power is rare, limited to a single RF link and direction. For example, the AP to VR Visor link may require the highest data rates for real-time

[6] Apple Inc., Broadcom Inc., et. al, ex parte communication, dated March 18, 2020.

[7] The term Personal Area Network (PAN) is used in the cited references, however, we avoid this term as it has specific meaning in the industry that is different than how used with respect to wireless LAN (WLAN). Experience with PANs however reinforces that the need to accommodate a high density of independently operating networks is critical to success. In this document PAN is used to refer to industry standard PANs such as IEEE 802.15 and Bluetooth which typically consist of a few number of devices, often peer-to-peer, connecting over short distances at power levels typically less than the proposed here for VLP.

video. In their comments Apple, Broadcom, et. al.[8] combine the poor receiver sensitivity of the highest data rates of 802.11ax with worst case through body loss as the need for +14 dBm. In this case the link is asymmetric; the visor to AP data rate is far lower and can operate where the AP receiver sensitivity is > 30dB better. Achieving the required link margin under these conditions requires far lower transmit power. The need for higher link power is very directional – a single link between AP and a single device.

The problem with such high power is that it will disrupt neighboring micro-LANs operating in the same channels. Success for the WLAN use cases cited requires minimizing the interference footprint.

To support the widest variety of users, the rules should require antenna gain. To achieve the maximum +14 dBm EIRP, the power limit should be achieved by utilizing directional antenna gain with a much lower conducted power output. This is similar to the concept to applied by the FCC in 15.255.

We propose to allow VLP operation across all U-NII bands if one of the following power limits is used:

> (i) The average power spectral density of any emission shall not exceed -32 dBm and the peak power of any emission shall not exceed 0 dBm; or
>
> (ii) The average power spectral density of any emission shall not exceed -8 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than +12 dBi. The peak power of any emission shall not exceed +14 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 7 dBi.

In either case a contention-based protocol is needed to meet the requirements set forth in this rule.

This concept is not new to the WLAN community. The IEEE 802.11ax standard includes mechanisms to support multiple spatial streams via beam steering, and this is being expanded upon in the current Extremely High Throughput (EHT) task group. Providing an incentive to utilize the controlled energy footprint of a narrow beam by limiting peak power if not employing antenna gain and allowing a higher power via antenna gain will increase adoption of this particularly useful mechanism in the standard. This will also increase performance, enabling

[8] *See* comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Microsoft Corporation, NXP Semiconductors, Qualcomm Incorporated, and Ruckus Networks, January 21, 2020 and March 18, 2020.

many micro-LANs to coexist in a given area. Such rules would support the Commission's goals of promoting innovation. It will also expand the applicable use cases, thus increasing the market size and economic benefits.

We note that at a channel width of 160 MHz, the traditional WLAN technique of coordinated channel usage to avoid WLAN to WLAN interference does not work as there are at most 7 channels possible in the 6 GHz band. This drops to 3 with the 320 MHz channels being developed by the 802.11 working group. In the given scenarios, there are not enough channels to avoid interference by channel selection alone. As shown in Figure 6, Footprint control is essential to support the required device densities.

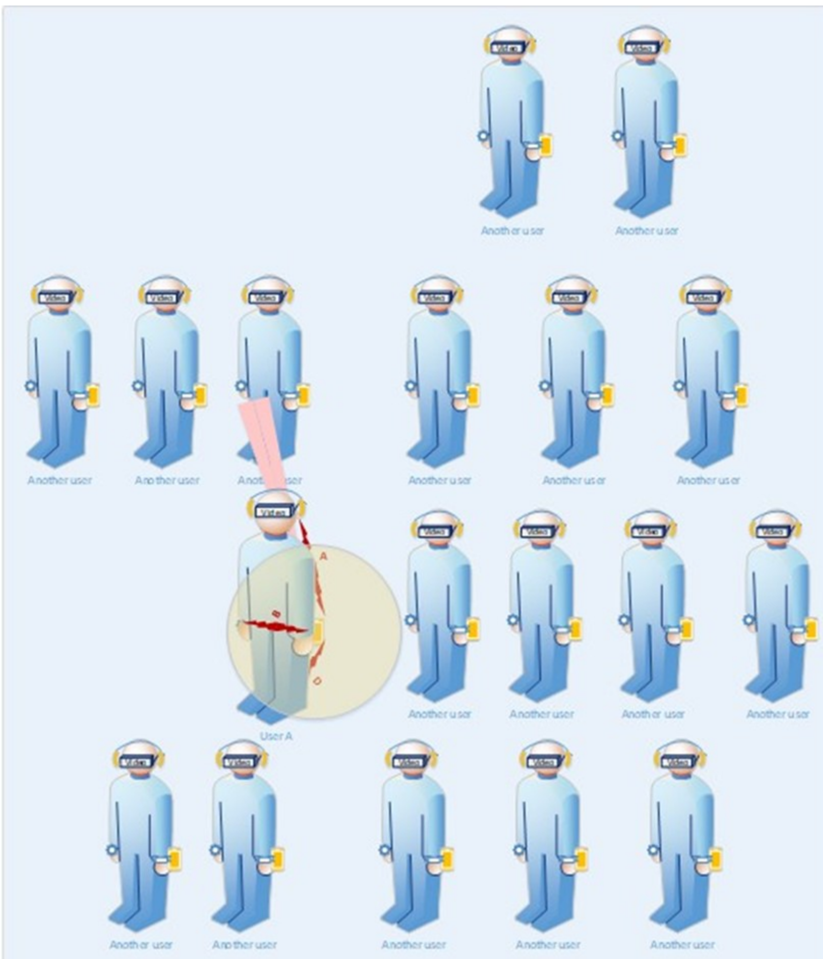

Figure 6, Impact change with directional antenna for high-speed link

It is also clear from the given scenarios that transmit power varies greatly by link and time. Models derived from empirical measurements show that loss between devices on-body locations and near body locations can be from nearly free space to over 70 dB.[9] This indicates that dynamic transmit power control can provide great benefit. We therefore also suggest that the rules provide requirements for TPC performance with incentives to develop "smart TPC" that adapts dynamically to changing conditions and reduces interference footprint. This will again dramatically improve the successful use of mobile hotspots and micro-WLANs where dense deployments are likely.

Increasing Power for Low Power Indoor Operation

We recommend the Commission preserve the current 5 dBm /MHz PSD limit for Low Power Indoor Access Points. As explained in the Report and Order[10] this is sufficient for the vast majority of indoor access point use cases and sufficient to "sustain meaningful applications especially when using wider bandwidths". We commend the Commission for striking a balance between current WLAN use cases, other incumbent users, and the need for future innovation.

The rational of increasing power limits to provide larger coverage areas via a single AP is based on outdated reasoning. A larger coverage area increases the interference footprint, thus increasing self-interference with other WLANs. In a few applications, (e.g. a large home isolated from other homes by distance), the "whole house" AP may be useful. However, in the more typical urban and suburban environment, it increases the "spectrum crisis" as neighboring overlapping WLANs are the norm.

This argument harkens back to the early days of cellular, when mobile carriers sought powerful base stations to cover large geographical areas. As adoption by consumers took off, the faults of this approach became clear. Carriers adopted methods to limit the coverage of a given base station element to increase capacity, first employing sectorization then deploying smaller and smaller sectors. The use of small cells with lower power and high efficiency antennas revolutionized the mobile industry, supporting higher user density and overall greater value from spectrum. The trend continues to smaller micro-cells to increase capacity. The modern approach by mobile carriers is to use a greater number of lower-power, lower-cost cells. This has resulted in a dramatically improved user experience. Wi-Fi performance and adoption will be improved by following the same model.

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[9] See *Channel Model for Body Area Network (BAN),* IEEE P802.15-08-0780-12-0006, November 2010, accessible at https://mentor.ieee.org/802.15/dcn/08/15-08-0780-12-0006-tg6-channel-model.pdf.

[10] Federal Communications Commission Unlicensed Use of the 6 GHz Band Report and Order and Further Notice of Proposed Rulemaking (FCC 6 GHz Report & Order/FNPRM), April 2, 2020, ET Docket No. 18-295; GN Docket No. 17-183, Paragraphs 20-51 at 110, 123, 131, 132.

The older reasoning made sense in the early days of wireless when the cost of equipment was high and dominated the cost/benefit equation. Today, access points are inexpensive. Much of the spectrum crisis cited in the Report and Order is due to a high density of devices operating in close proximity to each other. High power APs greatly expand the sphere of influence (SoI) and interference footprint and thus increase traffic congestion, thereby reducing the overall capacity of the band.

A dominant factor in the spectrum crisis is created by too much traffic in the area covered by an AP. The solution is to increase capacity, not range. It is better to be small. There are many inexpensive means to extend the “range” of a WLAN which do not have the negative impacts of increased power. Examples include using multiple low cost, low power APs; mesh networks, and in areas where there is less congestion, the use of range extenders as recognized by the Commission in formulating the U–NII rules for 6 GHz.[11]

We therefore strongly urge the Commission to keep the LPI PSD limit at 5 dBm/MHz and encourage more responsible spectrum usage.

Mobile Standard-Power APs with Automated Frequency Control (AFC)

The FCC seeks input on whether to allow standard-power access points under AFC control to be used in mobile applications under similar rules to those used for personal/portable white space devices.

We feel that allowing operation of mobile standard-power access points is contrary to the goals of the current R&O. The R&O was adopted to create the opportunity for innovators to provide new and advanced services while also ensuring that licensed incumbent operations in the band are protected from harmful interference. The rules also play a role in encouraging the growth of the IoT by connecting appliances, machines, meters, wearables, and other consumer electronics as well as industrial sensors for manufacturing. This comes with a prediction of more than 1 billion devices operating in effectively shared spectrum.

Even operating with Automated Frequency Control and contention-based Protocols, mobile standard-power APs, would become pervasive as the default wireless solution. This would discriminate against and negatively affect the operation of the LPI and VLP devices that the FCC seeks to encourage. In addition to direct interference due to uncontrollable “near far” issues

[11] FCC 6 GHz Report & Order/FNPRM, Paragraphs 20-51 at 193.

the entire aggregate RF noise floor would be raised, thus negatively affecting all wireless operation.

In addition to harming the performance of new devices that are envisioned to take advantage of innovation, catastrophic interference to incumbent services would result if a standard-power AP is operated accidentally or in error. This would be true even if the interference is momentary. The risk is not justified.

Indeed, this high risk is confirmed by considering the established operating complications and complexities witnessed by attempts to manage the existing white space database. Even after five (5) years of great effort and expense, the current white space database(s) has proven to be an overly complex and difficult project.[12] It is not uncommon for Part 74 licensed users to be unable to register for protection. The location and 20-minute update information are not always available. The connection to the ULS is not always functional or up to date. Although a well-meaning attempt to manage complicated spectrum, problems persist despite a significant amount of effort applied over many years.

These difficulties exist with a database which is only attempting to manage an extremely small data population compared to the amount of traffic which would be required to effectively manage a white space-type AFC database for mobile standard-power devices. These problems exist with a database for which reservations can be logged well in advance, and for which only a 20-minute update rate is attempted. The update rate for a mobile standard-powered AP would need to be significantly more frequent. The volume of devices tracked, combined with the need for extremely frequent (nearly real-time) update rate will create an immensely complex data condition. Even if a database and supporting infrastructure could be developed to support the performance and minimize the risk, the development time would likely be even greater than the current project of over 5 years. In addition, it would be exceedingly expensive to implement and maintain. This cost would have to be passed onto devices and consumers.

If a fast and reliable AFC database could be developed to handle the volume of data to be processed, mobile use adds an additional level of technical complexity. A correct propagation and contour model are critical for the database to properly determine safe operating conditions. These determinations vary greatly from location to location. A fixed standard-power AP has an opportunity to correctly model the possible effective contour, while transient or mobile devices do not. The computational power required to adequately determine potential interference based on likely propagation contours of a mobile device in relationship to

[12] *White Space Databases Fail to Keep Wireless Microphones Safe*, Sports Video Group News, July 24, 2019.

incumbents in the geographic environment is far too complex to ensure safe outcomes and consistent operation.

The incumbents in the 6 GHz band often include services which provide critical infrastructure and protect safety of life. Numerous concerns from cities and organizations have already been raised as to the interference and harmful risk associated with allowing Wi-Fi in the 6GHz band.[13] Therefore, allowing standard-power to operate on a mobile basis with the assumption of adequate AFC as protection would not be prudent.

In order to encourage innovative support of making broadband connectivity available to all Americans; especially those in rural and underserved areas, we feel the current R&O and proposed VLP operation will create the best conditions for maximum benefit and performance with minimized risk.

We recognize that in pursuit of improving rural and "last mile" settings, some might mistakenly believe mobile standard-power APs with AFC would assist in accomplishing this goal. These environments will also need to take advantage of the innovative new wireless devices as already set forth in the R&O and proposed VLP operation.

Contention Based Protocols

We support the Commissions goals of setting requirements that will lead to development of effective contention-based protocols (CBP). This key component is needed to provide effective sharing of the band among different unlicensed services. The combination of CBP, intelligent power control, and other measures such as low duty cycle will maximize the spectral efficiency of the coverage area. This will minimize the interference footprint, thus maximizing the usefulness of the spectrum and will create multiplied economic value in the future.

It is the duty of all spectrum users to protect other users fairly. There are multiple levers that can be exercised to provide the optimum results. The use of extremely low power and very low duty cycles are also effective means to minimize interference probability.[14] Choosing the most effective mix depends upon the bandwidth and channel utilization requirements as well as the size and scope of the interference footprint. The rules should reflect and support the many ways all unlicensed wireless technologies can work in concert to provide a diverse wireless solution ecosystem.

The UWB Alliance represents members with a vast experience in various wireless systems and protocols in addition to UWB including WLAN and other technologies that may use the 6 GHz

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[13] *See* letter from Chairman Lisa Murkowski, United States Senate Committee on Energy and Natural Resources, to FCC Commissioner Chairman Ajit Pai, June 14, 2019.

[14] *See* IEEE RLAN and UWB systems Coexistence Study, IEEE P802.15-19-0143-00-004z, March 2019.

band. Multi-system coexistence is a key part of our charter and we look forward to sharing our expertise with the multi-stakeholder group developing sharing protocols.

Some general requirements for contention-based protocols include:

- Each LPI or VLP device (AP, client or peer device) which intends to start a transmission must be able to detect ongoing transmission activities within its radius of interference (as it was defined in the interference investigations while preparing the NPRM), stated as a minimum detection probability.
- The higher the intended transmit power, the greater the potential interference radius, and so the more carefully the device needs to check for potential victim links in its reach. This could be measured in probability of detection for interference scenarios which include all potential victim radio technologies. The required sensing and deferral parameters should be based on this probability.
- Detection schemes must be based on more than just generic energy detection as previous experience and studies have shown this to be an unreliable method except under specific conditions. Detection methods should be selected to have a high probability of detecting transmissions other than WLAN systems, as suggested by the Commission. [15]
- In the case of extremely low power and duty-cycle levels (e.g. similar to Wideband and UWB) exceptions to sensing could be made due to the reduced interference area under these conditions.

The inclusion of such requirements in the U-NII rules would be immensely helpful to encourage innovation towards widespread deployment of minimum transmit power control algorithms. Valuable, ultra low power devices like UWB and even Extremely Low Power WLAN devices may be operated in the 6 GHz band under existing rules without any “listening” due to their low transmit power. Such systems (e.g. 15.250, Subpart F) are proven to not cause interference. Higher power devices like the proposed VLP U-NII devices have great potential to interfere with other unlicensed devices, including the ultra-low power systems as well as other U-NII systems, thus need to sense very carefully before transmitting according to their intended Tx power. The complexity associated with such listening processes would be a small add-on to the higher power devices (Wi-Fi) which are capable of the highest data rates and/or special applications that require higher power. Simpler, Extremely Lower Power devices would require less complexity based on their more limited interference footprint. This would motivate developers to create algorithms that assure the radios transmit with the lowest necessary power to meet the link performance as they then benefit from a simpler and faster listening/sensing process.

[15] FCC 6 GHz Report and Order, FNPRM, Paragraphs 20-51 at 221.

Implementing the described general requirements would keep the spectral environment as clean as possible in general for a given scenario/service.

Factors including intended transmit power spectral density, bandwidth, and the intended duty cycle are example metrics for interference probability. Use of high antenna gain with extremely low transmit power reduces probability of interference, as does extremely low duty cycle.

Using the product of bandwidth and power spectral density weighted with the intended duty cycle (percentage of T_{on} to T_{total}) combined with the use of transmit antenna gain provides a sound basis for assessing the probability of interference to other radio systems.

The performance of a contention-based access algorithm also depends upon the probability of detecting potential victim links. For example, high bandwidth, higher transmit power and non-directional antennas will have large interference footprint, while being more likely detected by other sensing systems. Such systems require strong sensing capability to avoid dominating the channel. Reduction of one or more of those parameters which reduces the interference footprint and/or time on the air should allow the potential transmitting device to reduce the required detection quality.

Few U-NII devices are "single radio" devices; the vast majority will host multiple radios. This is already true of high-volume devices such as mobile phones, tablets and computers. Requiring sensing of "other than Wi-Fi" devices for maximum power/duty cycle encourages use of the resources that are likely to be available in an optimized manner. Adding the capability to APs is not much additional burden with current technology.

Technical Analysis of Micro-WLAN Scenarios

Discussion of applications and scenarios

We examined the uses cases cited in the record for what the FCC proposes as VLP. We find that success of the desired use cases for WLAN require positive minimization of the interference footprint of all devices. We suggest that interference footprint control can be achieved by use of directional antennas and dynamic transmit power control, combined with duty cycle minimization. We propose requirements that will encourage and reward innovation in these technologies as well as achieve the goals stated by the Commission and WLAN advocates.

Coexistence of multiple radio systems is essential to maximizing the value of the 6 GHz band. As we have noted, there are few "single radio" devices in the modern consumer world. When considering the presented use case scenarios for VLP, it is essential to consider all the radio systems being used. The example applications cited are not "WLAN only" with all communication and sensing needs met by Wi-Fi. In order to provide the desired quality of user experience all the resources available must be used effectively. The adage that "if all you have is a hammer, then everything looks like it needs a nail" is true. Wi-Fi, UWB, Bluetooth, Near Field Communications (NFC) and other technologies all have a role to play. What we find with this analysis is that the same measures that can enhance coexistence with other services will also dramatically increase the ability of WLAN to meet the stated performance requirements. In fact, interference footprint control is essential to meeting the stated goals.

In the majority of cases cited, wireless devices can expect to encounter many co-located VLP WLANs operating simultaneously. We use the term "micro-WLAN" to describe the general characteristic of these very small WLANs that serve a very small physical area, analogous to a Personal Area Network (PAN) technologies (such as Bluetooth) and Body Area Network technologies.

Some of the cited applications require high data throughput and low latency in a small area. In the Ex Parte dated July 2, 2019, Apple Inc., Broadcom Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Microsoft Corporation, and Qualcomm Incorporated together with subsequent filings from the same or various combinations of this group, we find the following use cases:

- Mobile AR/VR
- UHD Video
- High Speed Tethering
- In-Vehicle Entertainment

According to the consortium of WLAN companies, the AP and client and/or peer to peer devices are all within 3 meters. In fact, the most common cases would have a desired network area of less than 1 meter.[16] We evaluate the requirements for both scenarios.

In the aforementioned filings, it is acknowledged that +14 dBm presents a risk of causing harmful interference in FS operations. However, using the parameters given, there is also significant risk of interference to neighboring, independently operating WLANs and PANs at the requested power of +14 dBm. Our analysis shows that in these cases, far lower power is usually sufficient, with the benefit of reducing the interference footprint dramatically. In exceptional cases, higher power may be needed to achieve the desired performance, but in these cases, it will be for a single, asymmetric link (high data rate in one direction only) between a pair of

[16] For example: the VR/AR case cites "on body" and the average human is 2 meters tall; for high speed tethering all devices are likely on the same table top; For UND video the devices are likely in the same wall unit; in-vehicle entertainment in a typical SUV with the AP centrally located.

devices. In these scenarios, focused energy through directional antenna can achieve the needed link margin with minimal expansion of the overall interference footprint.

Reducing the interference footprint will enhance the WLAN applications cited, while also reducing the "limited risk to FS operations" substantially.

In particular, the use cases for AR/VR, high speed tethering and UHD Streaming are very likely to operate where there are many independent users in a confined space. This makes coexistence of multiple WLANs critical to the use case success. For most of these applications the communicating devices are well within 1m of each other. Link budget analysis using a reference power of 0 dBm shows that with the highest data rates (and thus lowest minimum receiver sensitivity) given in IEEE Std P802.11ax, we see over 30 dB surplus in the link budget. Using 3 meters link distance, we still see an excess of almost 12 dB. In these scenarios we used the "typical" body loss values given by Apple et al of 4 dB, and used the "open" channel model which would be typical of these short distance scenarios.

Use of higher than necessary power has many harmful effects on neighboring WLANs as well as other services. As presented, it is unlikely that multiple micro-WLANs will be able to operate simultaneously at the desired performance levels, even under the condition of coordinated channel planning (which is contrary to unlicensed ad-hoc network operation). With only seven 160 MHz channels there is simply not enough channel separation. In all three of these cases, Apple et al cites low latency as a key performance requirement. Studies of 802.11 performance in the presence of interference show that packet latency is affected dramatically by interference[17]. Thus, to reach the goals stated by the WLAN users it is essential to control the impact each micro-WLAN has on its neighbors.

In other usage scenarios, Apple et. al. cite headphones, hearing aids, watches, game controllers, and other peripherals. These applications do not require the high data rates as in the above scenarios. These are applications typically employ Bluetooth and other short range, low power technologies. The primary limitation of Bluetooth in these applications is not bandwidth, but interference (typically from Wi-Fi operating in 2.4 GHz). If one were to address these uses with Wi-Fi in the 6 GHz band the lower bandwidth (e.g. 20 MHz channelization) would be sufficient, with a minimum receiver sensitivity level that is greater than 30 dB more. As the link budgets

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[17] See for example IEEE's *Impact of Network Profiles on 802.11ah and 802.15.4g Coexistence* and IEEE's *802.11ah and 802.15.4g Coexistence Simulation and Coexistence Issues* which include results for the performance impacts on 802.11 from both unlike and other 802.11 systems. The observed results are based on Medium Access Control mechanisms in 802.11 and so translate well to other bands.

show and experience with other technologies demonstrates, these links are addressed with extremely low power.

The link budgets analysis shown in the Link Budget Tables below uses a generous 6 dB link margin and assumes the worst-case receiver sensitivity allowed by IEEE Std P802.11ax. Typically, an implementation achieves much better sensitivity than the minimum required by the standard. However, we can be sure a Wi-Fi-6e compliant implementation does at least as good as the standard mandates. 3 dB link margin is adequate in most situations, but we chose to be more conservative in this analysis.

As can be seen in the link budget tables, the surplus is approximately 12 dB at 3 meters and at 1 meter the surplus is more than 30 dB. At these levels, the interference to neighboring WANs and other personal devices is substantial which will cause packet errors and increased latency. Reducing power substantially will maintain the desired link performance while greatly increasing the capacity for simultaneously operating networks.

In this scenario, increasing the transmit power (assuming omnidirectional radiation) to +14 dBm increases the sphere of influence (SoI) in which the signal is > 3dB above the receiver sensitivity of neighboring non-participating devices operating at the same data rate modes to over 15 meters. If we consider WLAN devices operating at lower data rates (e.g. 20 MHz channels) and thus higher receiver sensitivity, the SoI can be much greater. This means a +14 dBm AP may be disrupting non-participating WLANs dramatically without any benefit to its own operations! This is in addition to concern over interference to incumbents.

We note that the equivalent link margin can be achieved with 0 dBm transmit power and 14 dBi antenna gain. The difference is that the area of impact is greatly reduced, enabling adjoining WLANs to operate optimally. Applying additional gain through beam forming and improved receiver designs allows the desired link performance to be reached with greatly reduced impacts on others including neighboring WLAN’s.

Illustration of Footprint Control

Figure 5 illustrates the potential impact of a micro-WLAN on its neighbors in a VR/AR use case where the link between the VLP AP (phone) and video device (visor) requires the highest data rate (160 MHz channel at 1024 QAM). In Figure 5, relatively high power with an omni-directional antenna is used to achieve the link margin required. The User’s body may attenuate the signal substantially in one specific direction, but many other users in the area are adversely affected, receiving the signal at a level that may be higher than the intended recipient. Interference is highly likely, resulting in reduced effective throughput and increased latency. The other users are of course trying to do the same thing as User A, and if also transmitting at the same omnidirectional power will interfere with User A. As a result, none of these users has a quality experience. Note that the other devices being used for the VR/AR experience will not require such high data rates and as noted above thus need far less power to achieve acceptable link margins.

This illustrates the need to control the interference footprint not only to assure fair sharing of the band among unlicensed users and to protect incumbents, but also to achieve the performance goals of the WLAN application.

The advantages of using directional antenna gain (beam steering) is that it puts the energy where needed and not everywhere else. This allows much higher spectral reuse as well as higher potential throughput via use of multiple spectral streams[18]. Achieving the required link power via directional antenna is illustrated in Figure 6. Here the high speed video link requires additional gain in the AP to Visor direction, while other low data rate links require and use much lower power; the additional link power is achieved via antenna gain only on the link that requires the extra power. Intelligent power control is used to minimize the power used on the slower links. Combined the SoI and interference footprint is greatly reduced.

Link Budget Tables

Typical link budget for Mobile AR/VR, UHD Video, High Speed Tethering and In-Vehicle Entertainment use cases.

Link parameters	
Transmit power	0 dBm
802.11ax Transmit mode	160 MHz, 1024 QAM (1.2 Gbit/sec) OFDM
Receiver sensitivity (minimum 802.11ax)	-43 dBm
Antenna gain	0 dBi
Loss model	Open
Link distance	1m
Reliability Margin	90% (3dB Stdev)
Minimum link margin	6 dB
Loss due to body and other obstructions	4 dB

Transmit power	0.0	dBm
Gains	0.0	dB
Losses	0.1	dB

[18] See IEEE Std P802.11ax which extends support for multiple spectral streams in 802.11, the standard upon which Wi-Fi is based.

Received power	-0.1	dBm
Noise + interference power	-102.2	dBm
Median received SNR	102.1	dB
Processing gain	-30.8	dB
Median received EbNo	71.3	dB
Required EbNo	30.1	dB
Excess	41.1	dB
Margin	6.2	dB
SURPLUS	34.9	dB
Desired link reliability	90	%
Effective link reliability	99	%
Specified link distance	0.001	km
Distance for desired reliability	0.005	km

Link budget using a link distance of 3 meters.

Link parameters	
Transmit power	0 dBm
802.11ax Transmit mode	160 MHz, 1024 QAM (1.2 Gbit/sec) OFDM
Receiver sensitivity (minimum 802.11ax)	-43 dBm
Antenna gain	0 dBi
Loss model	Open
Link distance	3m
Reliability Margin	90% (3dB Stdev)
Minimum link margin	6 dB
Loss due to body and other obstructions	4 dB

Transmit power	0.0	dBm
Gains	0.0	dB
Losses	23.2	dB
Received power	-23.2	dBm
Noise + interference power	-102.2	dBm
Median received SNR	79.0	dB
Processing gain	-30.8	dB
Median received EbNo	48.2	dB
Required EbNo	30.1	dB
Excess	18.1	dB

Margin	6.2	dB
SURPLUS	11.9	dB
Desired link reliability	90	%
Effective link reliability	86	%
Specified link distance	0.003	km
Distance for desired reliability	0.005	km
Reliability mode	shadowing and fading	

Link budget with high body loss

Link parameters	
Transmit power	14 dBm
802.11ax Transmit mode	160 MHz, 1024 QAM (1.2 Gbit/sec) OFDM
Receiver sensitivity (minimum 802.11ax)	-43 dBm
Antenna gain	0 dBi
Loss model	Open
Link distance	3m
Reliability Margin	90% (3dB Stdev)
Minimum link margin	6 dB
Loss due to body and other obstructions	55 dB

Transmit power	0.0	dBm
Gains	14.0	dB
Losses	49.0	dB
Received power	-35.0	dBm
Noise + interference power	-102.2	dBm
Median received SNR	67.1	dB
Processing gain	-30.8	dB
Median received EbNo	36.3	dB
Required EbNo	30.1	dB
Excess	6.2	dB
Margin	6.2	dB
SURPLUS	0.0	dB
Desired link reliability	90	%
Effective link reliability	61	%

Specified link distance	0.001	km
Distance for desired reliability	0.001	km

Link budget showing interference footprint of +14 dBm with omni antenna at 15 meters

Link parameters	
Transmit power	0 dBm
802.11ax Transmit mode	160 MHz, 1024 QAM (1.2 Gbit/sec) OFDM
Receiver sensitivity (minimum 802.11ax)	-43 dBm
Antenna gain	14 dBi
Loss model	Open
Link distance	1m
Reliability Margin	90% (3dB Stdev)
Minimum link margin	6 dB
Loss due to body and other obstructions	4 dB

Transmit power	14.0	dBm
Gains	0.0	dB
Losses	52.9	dB
Received power	-38.9	dBm
Noise + interference power	-102.2	dBm
Median received SNR	63.2	dB
Processing gain	-30.8	dB
Median received EbNo	32.4	dB
Required EbNo	30.1	dB
Excess	2.3	dB
Margin	6.2	dB
SURPLUS	-3.9	dB
Desired link reliability	90	%
Effective link reliability	48	%
Specified link distance	0.015	km

Summary

UWB has evolved to become a mainstream consumer technology and is providing complementary functionality to other established technologies like Wi-Fi and Bluetooth. It has taken similar timescales to transition onto smartphone handsets. By 2025 for every UWB equipped smartphone sold there will be a minimum of 1 companion accessory device placed on the market. At that point it will be deployed within all high-end and many medium level smartphones. We expect the adoption curve to mirror earlier uptake of Wi-Fi and Bluetooth as the unique value of UWB becomes visible and familiar in our daily lives.

All these technologies ultimately must be able to work together inside the smartphone and associated ecosystems to leverage the combined value for the next generation of micro location-aware and highly secure connected devices.

Cellular mobile carriers expanded network capacity through spectrum reuse. They ultimately did this via provision of lower power cells. This approach needs to be reflected and encouraged through the next phase of rulemaking with unlicensed spectrum. The solution is to increase capacity, not range.

What we find with the analysis provided is that the same measures that can enhance coexistence with other services will also dramatically increase the ability of WLAN to meet the stated performance requirements. In particular, the use cases for AR/VR, high speed tethering and UHD streaming are very likely to operate where there are many independent users in a confined space. This makes coexistence of multiple WLANs critical for application to be scalable. In fact, interference footprint control is the core issue at the center of the use case’s success.

The UWB Alliance endorses the concept of Very Low Power (VLP) unlicensed devices. We also propose refinements to the VLP rules that reward intelligent control of interference footprint which is essential to support the required device densities coved in the sighted uses cases submitted by Apple Inc., Broadcom Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Microsoft Corporation, and Qualcomm Incorporated.

We suggest that interference footprint control can be achieved by use of directional antennas and dynamic transmit power control, combined with duty cycle minimization. To support the widest variety of users the rules should require a minimum antenna gain. To achieve the maximum +14 dBm EIRP, the power limit should be achieved by utilizing directional antenna gain.

We propose to allow VLP operation across all U-NII bands provided one of the following power limits is used:

(i) The average power spectral density of any emission shall not exceed -32 dBm and the peak power of any emission shall not exceed 0 dBm; or

(ii) The average power spectral density of any emission shall not exceed -8 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than +12 dBi. The peak power of any emission shall not exceed +14 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 7 dBi.

Dynamic transmit power control provides great benefits in crowded radio environments. We thus also suggest that the rules provide requirements for TPC performance with incentives to develop “smart TPC” that adapts dynamically to changing conditions and reduces interference footprint. In line with this, we also recommend the Commission preserve the current 5 dBm /MHz PSD limit for Low Power Indoor Access Points.

We believe that allowing operation of mobile standard-power access points is contrary to the goals of the current R&O. In order to encourage innovative support of making broadband connectivity available to all Americans; especially those in rural and underserved areas, we conclude that the current R&O and proposed VLP operation will create the best conditions for maximum benefit and performance with minimized risk.

We support the Commissions goals of setting requirements that will lead to development of effective contention-based protocols (CBP). This key component is needed to provide effective sharing of the band among different unlicensed services. The combination of CBP, intelligent power control, and other measures such as low duty cycle will maximize the spectral efficiency of the coverage area. This will minimize the interference footprint, thus maximizing the usefulness of the spectrum and will also create multiplied economic value in the future.

In setting these requirements for CBP, it is important to mention that the higher the intended transmit power, the greater the potential interference radius, and so the more carefully the device needs to check for potential victim links in its reach.

Detection schemes must also be based on more than just generic energy detection as previous experience and studies have shown this to be an unreliable method except under specific conditions. Detection methods should be selected to have a high probability of detecting transmissions other than WLAN systems, as suggested by the Commission.