IEEE P802.11
Wireless LANs

|  |
| --- |
| TGax Coexistence Assurance Document |
| Date: 2019-06-24 |
| Author(s): |
| Name | Affiliation | Address | Phone | Email |
| Eldad Perahia | HPE |  |  | eldad.perahia@hpe.com |
|  |  |  |  |  |

Abstract

This serves as the coexistence assurance document for TGax in meeting the requirement of the CSD.

R3: Updated to address PAR change to frequency range

R4: Updated to address comments from 802.19 on CA document

R5: Same content as R4; Changed document date and header date to reflect date of WG11approval

R6: Updated to address comments from 802.19 on CA document from D4.0 letter ballot

# Introduction

This document addresses coexistence of IEEE 802.11ax [1] per the PAR [2] and CSD [3]. The relevant sections of the P802.11ax PAR and CSD are outlined below:

* PAR scope:
	+ This amendment defines operations in frequency bands between 1 GHz and 7.125 GHz. The new amendment shall enable backward compatibility and coexistence with legacy IEEE 802.11 devices operating in the same band.
* CSD:
	+ Response to 1.1.2: “Will the WG create a CA document as part of the WG balloting process as described in Clause 13? YES”

# Frequency Bands of Operation defined in IEEE 802.11ax

Though the PAR specifies the frequency range between 1 GHz and 7.125 GHz, 802.11ax is an amendment to the IEEE 802.11 standard, defining enhancements to 802.11n in the 2.4 GHz frequency band, 802.11ac in 5 GHz frequency bands and an extension into the 6 GHz band.

In the 802.11ax amendment, channelization for the 2.4 and 5 GHz frequency bands remain unchanged.

The new channelization for the 6 GHz band is shown below:

Channel center frequency = Channel starting frequency + 5 × *nch* (MHz)

Channel starting frequency is 5.940 GHz

*nch*: center frequency index

* 20 MHz channel spacing *nch*: 1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 105, 109, 113, 117, 121, 125, 129, 133, 137, 141, 145, 149, 153, 157, 161, 165, 169, 173, 177, 181, 185, 189, 193, 197, 201, 205, 209, 213, 217, 221, 225, 229, 233
* 40 MHz channel spacing *nch*: 3, 11, 19, 27, 35, 43, 51, 59, 67, 75, 83, 91, 99, 107, 115, 123, 131, 139, 147, 155, 163, 171, 179, 187, 195, 203, 211, 219, 227
* 80 MHz channel spacing *nch*: 7, 23, 39, 55, 71, 87, 103, 119, 135, 151, 167, 183, 199, 215
* 160 MHz channel spacing *nch*: 15, 47, 79, 111, 143, 175, 207

# Active IEEE 802 wireless standards operating in the same frequency bands of operation as IEEE 802.11ax

802.15 standards and amendents specifically in the 2.4, 5, and 6 GHz band are listed below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Identifier** | **Standards/Amendment** | **Clause**  | **PHY Name** | **Frequency Band (GHz)** |
| 3-1 | 802.15.3-2016 | 10 | PHY for 2.4 GHz | 2.4 – 2.485 GHz |
| 3-2 | 802.15.4-2015 | 12 | O-QPSK PHY | 2450, 868, 915, 780, 2380 MHz |
| 3-3 | 802.15.4-2015 | 15 | CSS PHY | 2450 MHz |
| 3-4 | 802.15.4-2015 | 16 | HRP UWB PHY | 249.6 – 749.6 MHz, 3.1 – 4.8 GHz and 6.0 – 10.6 GHz |
| 3-5 | 802.15.4-2015 | 18 | MSK PHY | 433.05 – 434.79 MHz and 2400 – 2483 MHz  |
| 3-6 | 802.15.4-2015 | 19 | LRP UWB PHY | 6.2826 – 9.1856 GHz  |
| 3-7 | 802.15.4-2015 | 20 | SUN FSK PHY | 169, 450, 470, 863, 901, 915, 928, 1427, 2450 MHz |
| 3-8 | 802.15.4-2015 | 21 | SUN OFDM PHY | 470–510 , 779–787, 863–870, 902–928, 917–923.5, 920–928, 2400–2483.5 MHz |
| 3-9 | 802.15.4-2015 | 22 | SUN O-QPSK PHY | 470, 780, 868, 915, 917, 920, and 2450 MHz |
| 3-10 | 802.15.4q-2016 | 31 | TASK PHY | 433.050-434.790, 470-510, 779-787, 863-876, 902–928, 2400-2483.5 MHz |
| 3-11 | 802.15.4q-2016 | 32 | RS-GFSK PHY | 915 and 2450 MHz |
| 3-12 | 802.15.4t-2017 | 18 | MSK PHY | 433.05 – 434.79 MHz and 2400 – 2483 MHz |
| 3-13 | 802.15.4z |  |  | 6-10 GHz |

# Selected non-802 market relevant standards operating in the same frequency bands as IEEE 802.11ax

|  |  |  |
| --- | --- | --- |
| **Identifier** | **Standards/Amendment** | **Frequency Band (GHz)** |
| 4-1 | 3GPP LAA | 5GHz/6GHz |
| 4-2 | 3GPP NR-U | 5HGz/6GHz |

# Mechanisms supporting Coexistence with non-802.11 systems

The mechanism defined in IEEE 802.11 standards for 802.11 devices to coexist with non-802.11 devices is clear channel assessment (CCA). 802.11ax continues to use CCA rules in the 2.4, 5, and 6 GHz bands.

According to 802.11ax 27.3.19.6.3 & 27.3.19.6.4 [1], a PHY must set its CCA indication to busy as follows

* “for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (-82 + 20 = -62 dBm) in the primary 20 MHz channel …”
* “Any signal within the secondary 20 MHz channel at or above a threshold of -62 dBm...”
* “Any signal within the secondary 40 MHz channel at or above a threshold of -59 dBm...”
* “Any signal within the secondary 80 MHz channel at or above -56 dBm.”

The first two bullets above are the same as 802.11n.

The conditions for secondary 40 MHz channel and secondary 80 MHz channel are the same as 11ac for 80 MHz and 160 MHz channels, respectively. Since the power spectral density is the same for each case, the CCA performance will be comparable for the various bandwidths.

# Coexistence analysis: non 802.11 systems

Section 3 standards 3-1 through 3-3, 3-5, 3-7 and 3-12 overlap with IEEE 802.11 and 802.11ax operation in the 2.4 GHz band only. CCA is the mechanism used by existing IEEE 802.11 standards for coexistence in the 2.4 GHz band and will also be used by 802.11ax. No significant changes to coexistence are anticipated with 802.11ax operation in the 2.4 GHz band.

Section 3 standards 3-4 and 3-6 and the 3-13 amendment under development overlap with planned IEEE 802.11ax operation in the 6 GHz band. IEEE 802.11ax is expected to operate in the band under new regulations, which are currently being defined. The 3-4 and 3-6 and the 3-13 ultra-wideband (low power spectral density) systems operate beneath the noise floor of systems operating in the 6 GHz band, and are generally required by regulation to accept all interferers. The Electronic Communications Committee (www.cept.org/ecc) has produced a report on sharing and compatibility between proposed radio local area networks and current systems in the band including UWB, see [16].

CCA is used to provide coexistence in the 5 GHz band with the specifications identified in section 4 of this document. Significant industry work has been and is underway to analyze 802.11/LAA coexistence in simulations, regulations, and deployments which are just underway in the 5 GHz band, see [5-15]. This will continue for 6 GHz band operation.

# Mechanisms supporting Coexistence with legacy 802.11 systems

802.11ax continues to use a common preamble, the non-HT short training field, non-HT long training field, and non-HT signal field as the initial fields in all new 802.11ax PPDUs for coexistence with legacy 802.11 systems as was implemented in mixed-format 802.11n and 802.11ac PPDUs. Therefore PHY-level coexistence with legacy devices will be similar as was in 802.11n and 802.11ac.

# New 802.11ax features which may affect coexistence

The following features introduced in 802.11ax may affect 802.11ax coverage area and transmitted energy in the environment:

* Uplink multi-user operation
* Spatial reuse
* Extended range operation
* New OFDM waveform design
* Preamble Puncturing
* Operation in 6 GHz band

Each of these features and their potential impact on coexistence is described below.

## Uplink Multi-User Operation

While 802.11n added multi antenna transmission with MIMO and 802.11ac added downlink multi-user MIMO, the total EIRP transmitted by a device was limited by both regulatory restrictions and device costs resulting in energy on the air similar to 802.11g/a devices.

With 802.11ax uplink multi-user operation, multiple client devices will transmit simultaneously to the AP during an uplink transmission. With uplink OFDMA and 80 MHz, up to 37 client devices could be transmitting simultaneously. Furthermore, with uplink OFDMA, an individual client device could transmit on a resource unit as narrow as ~2 MHz, resulting in substantially higher power spectral density depending on the regulatory limits. With uplink MU-MIMO, up to 8 client devices could be transmitting simultaneously. The aggregate energy on the air during an uplink multi-user transmission will be the sum of all the client devices, and could be much higher than in 802.11n/ac.

## Spatial Reuse

802.11ax introduces the concept of spatial reuse (SR) to increase capacity in a dense environment by increasing frequency reuse between BSS’s. Two SR operations have been specified and are described below.

The first type of SR allows a device to increase its “OBSS\_PD threshold” in conjunction with decreasing it’s transmit power. In 802.11n/ac, the signal detect level of a valid 802.11 signal is -82 dBm in 20 MHz. This first SR rule allows for an OBSS signal detect level up to -62 dBm of valid OBSS 802.11ax signals, depending on the corresponding decrease in transmit power of the device.

The second SR rule employs a more dynamic approach by which a device examines new SR information in the 802.11ax preamble on a packet by packet basis. The new SR information in the preamble provides a parameter that allows a third party device to determine whether it would be possible to initiate an SR transmission during a subsequent uplink multi-user transmission.

The important aspect of SR with respect to coexistence is that with 802.11ax SR techniques, there may be more simultaneous transmissions on the air, which may increase the overall interference floor.

## Extended Range Operation

802.11ax introduces a new PPDU format with a more robust preamble to address outdoor extended range environments. The short and long training fields are boosted by 3 dB, and the signal fields are repeated twice. For the data field of the PPDU, both Dual Carrier Modulation and narrower transmission bandwidth can both be used for diversity gain and noise bandwidth reduction, respectively.

These modifications can expand 802.11ax BSS coverage area relative to 802.11n/ac, which may affect coexistence with neighboring systems. That said, in 2.4 GHz a BSS employing the 1 Mbps 802.11 waveform with long preamble would have comparable coverage area.

## New OFDM Waveform Design

In 802.11n (in 2.4 GHz) and 802.11n/ac (in 5 GHz) the 20 MHz channelization uses a 64pt FFT with edge tones at +/-28. In 802.11ax (in both 2.4 and 5 GHz) the 20 MHz channelization uses a 256pt FFT with edge tones at +/-122. More spectrum is occupied within the channel bandwidth with the new 802.11ax OFDM waveform design.

That said, due to the narrower subcarrier spacing (312.5 kHz for 802.11n/ac vs 78.125 kHz for 802.11ax), the spectral rolloff for 802.11ax will be sharper and will result is lower emissions beyond +/- 11 MHz (see figure below).



## Preamble Puncturing

In a downlink multi-user transmission, an AP may choose to not populate certain sub-channels of its 80 or 160 MHz channel bandwidth if it finds the sub-channels busy. In the HE-STF, HE-LFT and data field that are transmitted in HE format, this is performed by only assigning the free sub-channels to users. The L-STF, L-LTF, L-SIG, RL-SIG, and HE-SIG-B preamble fields are transmitted in legacy mode and utilize the technique termed Preamble Puncturing to not transmit preamble fields in the corresponding 20 MHz sub-channels.

With respect to coexistence, the spectral “holes” created by preamble puncturing are not protected by a TX spectral mask. The TX spectral mask only applies to the entire 80 or 160 MHz channel bandwidth. Therefore other systems in these sub-channels could see higher out-of-band emissions than that experienced by two neighboring systems where the out-of-band transmissions by each system are restricted by a TX spectral mask.

## Operation in the 6 GHz Band

The PAR was amended to support up to 7.125 GHz [2]. A new global operating class in Table E-4 is created with a channel starting frequency of 5.940 GHz. Section 28.3.22 defines channel numbering from 1 to 253. Channel bandwidths include 20, 40, 80, and 160 MHz [1].

Some of the differences between operation in 6 GHz versus operation in 2.4 or 5 GHz are listed below:

* A new out-of-band discovery mechanism is defined, enabling discovery of 6 GHz APs enabled by 2.4 or 5 GHz APs providing information about the 6 GHz APs
* Pre-association frames intended for a 6 GHz AP can be tunneled via a co-located lower band AP
* Scanning in the 6 GHz band
	+ Preferred scanning channels are defined, and 6-GHz-only APs are recommended to set up the BSS with the primary channel in a preferred scanning channel
	+ Additional rules are established to limit blind probing in the 6 GHz band
* No HT (11n) or VHT (1ac) transmissions are defined in the 6 GHz band

# Definitions

* Orthogonal frequency-division multiple access (OFDMA) - users are allocated different subsets of subcarriers which can change from one PPDU to the next
* Dual Carrier Modulation (DCM) – replicate the same information on different subcarriers for frequency diversity gain and narrow band interference protection

# References

[1] Draft P802.11ax D4.0

[2] 11-17-0913-02-00ax-par-modification-to-support-6-ghz-band

[3] 11-14-0169-01-0hew-ieee-802-11-hew-sg-proposed-csd

[4] IEEE Std 802.11-2016

[5] Christina Vlachou, Ioannis Pefkianakis, and Kyu-Han Kim. 2018. LTERadar: Towards LTE-Aware Wi-Fi Access Points. Proc. ACM Meas. Anal. Comput. Syst. 2, 2, Article 33 (June 2018) <https://dl.acm.org/citation.cfm?id=3224428>

[6] C. Capretti, F. Gringoli, N. Facchi, and P. Patras. LTE/Wi-Fi Co-existence Under Scrutiny: An Empirical Study. In ACM WiNTECH’16.

[7] André Cavalcante, Erika P. L. Almeida, Robson D. Vieira, Sayantan Choudhury, Esa Tuomaala, Klaus Doppler, Fabiano de S. Chaves, Rafael C. D. Paiva, and Fuad M. Abinader Jr. Performance Evaluation of LTE and Wi-Fi Coexistence in Unlicensed Bands. In IEEE VTC’13.

[8] Z. Guan and T. Melodia. U-LTE: Spectrally-Efficient and Fair Coexistence Between LTE and Wi-Fi in Unlicensed Bands. In IEEE INFOCOM’16.

[9] Yubing Jian, Chao-Fang Shih, Bhuvana Krishnaswamy, and Raghupathy Sivakumar. Coexistence of Wi-Fi and LAA-LTE: Experimental evaluation, analysis and insights. In IEEE ICCW’15.

[10] Nihar Jindal and Donald Breslin. LTE and Wi-Fi in Unlicensed Spectrum: A Coexistence Studys. In Google TR, 2015.

[11] Yingzhe Li, François Baccelli, Jeffrey G Andrews, Thomas D Novlan, and Jianzhong Charlie Zhang. Modeling and analyzing the coexistence of Wi-Fi and LTE in unlicensed spectrum. IEEE Transactions on Wireless Communications, 15(9):6310–6326, 2016.

[12] Michael Olbrich, Anatolij Zubow, Sven Zehl, and Adam Wolisz. WiPLUS: Towards LTE-U Interference Detection, Assessment and Mitigation in 802.11 Networks. In European Wireless’17.

[13] Sangki Yun and Lili Qiu. Supporting WiFi and LTE Co-existence. In IEEE INFOCOM’15.

[14] Coexistence Test Plan, Wi-Fi Alliance, <https://www.wi-fi.org/file/coexistence-test-plan>

[15] Coexistence Guidelines for LTE in Unlicensed Spectrum Studies, Wi-Fi Alliance, http://www.wi-fi.org/file/coexistence-guidelines-for-lte-in-unlicensed-spectrum-studies

[16] Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz, ECC Report 302, CEPT ECC, [https://cept.org/files/9522/Draft%20ECC%20Report%20302rev..docx](https://urldefense.proofpoint.com/v2/url?u=https-3A__cept.org_files_9522_Draft-2520ECC-2520Report-2520302rev..docx&d=DwMGaQ&c=C5b8zRQO1miGmBeVZ2LFWg&r=CJpcKjV7C3TczgWxHrsFmPscm1VuXKM-giLBsGdAZJk&m=i3Xw2ZPlZqLehRXO1WKeeMT68mo8u1Yuo4S2bxPohs8&s=UARqQgc-kmo67ikGQVCJkqodqWbENbRgzBpCjczFxAw&e=)