**IEEE P802.15**

**Wireless Personal Area Networks**

|  |  |
| --- | --- |
| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) |
| Title | Coexistence Document for IEEE 802.15.4ab (proposed outline+NBA chapter) |
| Date Submitted | May 2024  |
| Source | Benjamin Rolfe (Blind Creek Associates), Alex Krebs (Apple) | Voice: Fax: DeprecatedE-mail: [ben.rolfe @ ieee.org, a\_krebs @ apple.com] |
| Re: | Analyze the coexistence of 802.15.4z and other 802 wireless systems  |
| Abstract | IEEE 802.15.4 Coexistence Document |
| Purpose | Document coexistence analysis |
| Notice | This document has been prepared to assist the IEEE P802.15. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein. |
| Release | The contributor acknowledges and accepts that this contribution becomes the property of IEEE and may be made publicly available by P802.15. |

**Contents**

1 Introduction 4

1.1 Acronyms 4

1.2 Terminology 4

2 Overview 5

2.1 Overview of 802.15.4z UWB 5

2.1.1 Frequency bands of interest 5

2.1.2 Relevant 802 Standards 5

2.1.3 Summary of Amendment 6

2.1.4 MAC Enhancements and Coexistence Impact 6

2.2 Overview of Coexistence Mechanisms in 802.15.4 6

2.3 Coexistence Analysis Methodology 6

3 Dissimilar Systems Sharing the Same Frequency Bands 6

3.1 802.11 Coexistence 7

3.1.1 802.11 WLAN impact on 802.15.4 UWB 7

3.1.2 802.15.4 UWB impact on 802.11 WLAN 7

3.2 802.15.4 Coexisting Systems 7

3.3 Other 802 Wireless systems considered 7

4 802.15.4 UWB systems 8

4.1 HRP 8

4.2 LRP 8

5 802.15.6 UWB systems 9

6 Conclusions 9

7 Bibliography 9

**Table of Figures**

No table of figures entries found.

**Table of Tables**

[Table 1: Other 802 Wireless Standards in the Subject Bands 5](#_Toc144226241)

# Introduction

This document provides a summary of coexistence analysis which has been performed evaluate the performance of systems using the 802.15.4 UWB (HRP and LRP) PHYs as amended by P802.15.4ab with respect to other 802 wireless standards which may operate in the same band.

The PAR for P802.15.4ab may be found in [1] .

802 standards to consider:

* 802.11 (ax, be)
* 802.15.6a
* Legacy 802.15.4 UWB (HRP, LRP)
* 4ab NB and UWB
* ??

## Acronyms

NB Narrow-band
NBA Narrow-band Assist
MMS Multi-millisecond
PSDU PHY service data unit
cPSDU Compact PSDU
UWB Ultra-wide band
eDAA Enhanced detect-and-avoid
LBT Listen before talk
CCA Channel clear assessment

## Terminology

The following terms, when used in this document, have the following meaning:

“base standard” means 802.15.4-2020 as and all approved amendments at the time this document has been prepared including 802.15.4z-2020.

“802.15.4” means the base standard.

“This amendment” means amendment P802.15.4ab [1]: Standard for Low-Rate Wireless Network Amendment: Enhanced Ultra Wide-Band (UWB) Physical Layers (PHYs) and Associated Medium Access and Control (MAC) sublayer Enhancements

# Overview

Things to cover in the overview

* Background on UWB
* History of UWB in 15.4 (briefly: 4a, f, z)
* Methodology used
* Reference to other relevant documents (coex studies and demonstrations)
* Coexisting systems considered
* Coexistence scenarios

Other stuff we know about:

* 802.15.4 PHYs operating in the overlapping bands (new NB channels in 6 GHz)
* 802.16 operating in the 3.4 to 3.8 GHz band (maybe no longer relevant)
* 802.11 OFDM operating in 5GHz and 6GHz bands (11ax, 11be)

## Overview of 802.15.4ab UWB

### Frequency bands of interest

The defined channel plans for UWB cover the frequency range from 3.1 GHz to 10.6 GHz. The actual spectrum used varies by region.

The 802.15.4 Narrow band channel plan defined in this amendment overlaps with the UWB channel plan the frequency range from 5.725 to 5.850 GHz and 5.925 to 6.425 GHz.

The 802.11 OFDM channel plan overlaps the UWB channel plan in the frequency range 5 GHz to 7 GHz.

[can provide details of the channel plans]

### Relevant 802 Standards

Table 1 lists the other 802 standard that may operate in overlapping bands. This information was derived from Annex E of [4] and [5]. [NEEDS TO BE UPDATAED]

Table 1: Other 802 Wireless Standards in the Subject Bands

|  |  |  |  |
| --- | --- | --- | --- |
| **Standard** | **Frequency Band (MHz)** | **PHY description** | **Notes** |
| 802.15.4 | 3244–4742  | HRP UWB low band | Clause 16 |
| 802.15.4 | 5944–10 234 | HRP UWB high band | Clause 16 |
| 802.15.4 | 6289.6–9185.6 | LRP UWB | Clause 19 |
| 802.11-2016 | 4000  | 10, 20, 40 MHz channel spacing | Not specifically analyzed in this document: WLAN operation is restricted by regional regulations and not expected to be operating in same place as UWB systems.[[1]](#footnote-1) |
| 802.11-2016 | 4002.5 | 5 |
| 802.11-2016 | 4850 | 20 |
| 802.11-2016 | 4890  | 10,20, 80, 160 MHz channel spacing |
| 802.11-2016 | 4937.5  | 5 MHz channel spacing |
| 802.11-2016 | 5000  | 10, 20, 40, MHz channel spacing |
| 802.11-2016 | 5002.5  | 5 |
| 802.11ax | 5935 - 7115 | 10,20, 80, 160 |  |
| 802.16-2012 | 3400 - 3800  |  |  |

Note that the majority of WLAN applications use channel spacing 20 to 80 MHz. The analysis referenced in this document mostly consider channel spacing from 5 to 160 MHz.

### Summary of Amendment

* Overview of the amendment

### MAC Enhancements and Coexistence Impact

## Overview of Coexistence Mechanisms in 802.15.4

* CSMA, SSBD, Aloha, 2.5 MHz channels, NB channel switching, NB channel allow list (c.f. eDAA), LBT, coordination packets
* Other features to enhance coexistence including new features

## Coexistence Analysis Methodology

Mostly by references.

# Dissimilar Systems Sharing the Same Frequency Bands

This clause presents coexistence considerations with other 802 systems which are specified to operate in some of the same frequency bands. For the purpose of this clause, dissimilar is defined as other than IR-UWB operating according to the 802.15.4 UWB standard.

## 802.11 Coexistence

### 802.11 WLAN impact on 802.15.4 UWB

### 802.15.4 UWB impact on 802.11 WLAN

#### 802.15.4 LE UWB PHY impact on 802.11 WLAN

This amendment (4ab) introduces a new Low-Energy UWB PHY (LE UWB PHY) with PHY layer parameters defined for non-coherent data communications. The LE UWB PHY applies several coexistence strategies. This section describes the LE UWB PHY strategies for mitigation of impact on 801.11 WLAN and on other communications occupying the same bands.

The use of Energy Detection (ED) afforded by the non-coherent receiver of the LE UWB PHY allows for enhanced detection of non-UWB transmissions for enhanced mitigation of interference to other systems. Listen-before-talk is easily implemented. In fact, the LE UWB PHY is intended to be combined with the Spectrum Sensing Based Deferral (SSBD) mechanism as described in Clause 6. SSBD based CCA LBT provides the ability for the LE UWB PHY to detect concurrent networks transmission and to delay its own transmission or switch center frequency to avoid interfering. A practical demonstration of the effectiveness of SSBD is described in the “SSBD enabled UWB radio coexistence with Wi-Fi 6e demo” document [34].

In addition to SSBD, the LE UWB PHY utilizes shorter preamble sequences and has shorter airtime relative to previous PHYs, thus providing additional robustness and mitigation of interference.

The combination of the above-mentioned coexistence strategies used by the LE UWB PHY will mitigate interference to both similar and dissimilar systems.

#### 802.15.4 HRP UWB PHY impact on 802.11 WLAN

To do…

### 802.15.4 NB impact on 802.11 WLAN

802.15.4 ranging services that operate under regulatory and public safety requirement constraints use typical airtime duty cycles between 1.5 and 5% [29, 30]. 95% or greater of the available airtime is typically available to other radio technologies operating in the same frequency bands.

To further improve on coexistence between the 802.15.4 NB OQPSK and 802.11 WLAN, shorter packet durations are attainable through newly introduced higher rate 500k/1M modulations and the introduction of the newly introduced compact PSDU format. For ranging distance measurements, NB airtime is reduced in comparison to the 802.15.4 NB OQPSK 250kbps by up to 38% [26], therefore reducing the chances of packet collisions with 802.11 WLAN operating in the same frequency band. Additionally, the spectral efficiency has been improved by reducing the NB channel bandwidth to 2.5 MHz in 5.725 to 5.850 GHz and 5.925 to 6.425 GHz, thereby doubling the channels per MHz in comparison to the NB channel allocation in 2.400 to 2.480 GHz where 5 MHz bandwidth per NB channel are used.

An improved channel switching mechanism with improved statistical properties is newly defined that distributes packet transmissions sequentially over the increased number of up to 250 NB channels. The likelihood of sequential NB packet collisions with 802.11 WLAN primary channels is therefore reduced by up to 6.25 fold over NB operation in the 2.4 GHz band [27]. Periodic NB packet transmissions on fixed channels such as background advertising and control traffic are allocated in 4ab in newly allocated spectrum outside of the channel map used by 802.11 WLAN such that no interference is cast [28].

To allow improved spectrum sensing and interference avoidance techniques such as eDAA [31], 4ab newly introduces explicit control over the channel map selection. Specifically, when the presence of other radio is attested by in-band or out-of-band methods, 4ab NB devices may exclude possibly conflicting channels in the shared spectrum from access, therefore enabling efficient spectrum sharing with 802.11 WLAN and other radio technologies [32].

In addition to spectrum sensing techniques for channel map selection, the NBA-MMS ranging protocol specifically suppresses unnecessary packet transmissions following unrecoverable collision events or channel busy assessments using LBT/CCA [27]. In contrast to CSMA controlled channel access, 4ab ranging eliminates the airtime overhead created by ACK/NACK control transmissions by disallowing retries of packet transmissions outside of the statically allocated packet slots. Instead all packet transmissions are cancelled following a non-recoverable packet error, thereby guaranteeing a fixed upper bound on duty cycle that is set by the 4ab MAC ranging configuration.

The strict adherence to statically scheduled traffic provides the ability for other radio technologies to easily sense channel occupancy patterns and to avoid interference entirely by adapting an orthogonal schedule. Additionally, 4ab actively promotes coordination between radios by introducing periodic broadcast packet transmissions that can be used to reveal channel occupancy patterns and interference avoidance information to other radios without spectrum sensing abilities [33].

## 802.15.4 Coexisting Systems

As shown in Table 1, the 802.15.4 UWB channel plans avoid the bands used by non-UWB PHYs defined by 802.15.4. Coexistence with legacy UWB systems is described in 4 .

## Other 802 Wireless systems considered

#  802.15.4 UWB systems

This clause describes the coexistence situation for this amendment and existing 802.15.4 UWB systems.

## HRP

## LRP

# 802.15.6 UWB systems

# Conclusions

# Bibliography

1. Project Authorization Request, Standard for Low-Rate Wireless Network Amendment: Enhanced Ultra Wide-Band (UWB) Physical Layers (PHYs) and Associated Medium Access and Control (MAC) sublayer Enhancements <https://development.standards.ieee.org/myproject-web/app#viewpar/12569/9081>
2. IEEE Std 802.15.4-2020
3. IEEE Std 802.15.4z-2020
4. P802.15.4ab Draft
5. IEEE Std. 802.11-2020 IEEE Standard for Information Technology – Telecommunications and Information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
6. IEEE Std 802.11ax
7. 802.15.4z CAD: <https://mentor.ieee.org/802.15/dcn/18/15-18-0523-06-004z-coexistence-document-15-4z.docx>
8. 802.11be CAD: <https://mentor.ieee.org/802.11/dcn/21/11-21-0706-08-00be-tgbe-coexistence-assessment-document.docx>
9. Doc. SE45(18)112R5 Monte Carlo studies for the UWB section of the report. [https://www.cept.org/DocumentRevisions/se-45---was/rlans-in-the-frequency-band-5925-%E2%80%93-6425-mhz/13375/SE45(18)112R3\_Updated%20UWB%20Studies](https://www.cept.org/DocumentRevisions/se-45---was/rlans-in-the-frequency-band-5925-%E2%80%93-6425-mhz/13375/SE45%2818%29112R3_Updated%20UWB%20Studies)
10. IEEE P802.15-19-0143-00-004z D. Neirynck RLAN and UWB systems Coexistence Study
11. S. J. Shellhammer, Estimating Packet Error Rate Caused by Interference – A Coexistence Assurance Methodology, IEEE 802.19-05/0029r0, September 14, 2005.
12. Frequency Sharing for Radio Local Area Networks in the 6 GHz Band, RKF Engineering Solutions, January 2018 [https://s3.amazonaws.com/rkfengineering-web/6USC+Report+Release+-+24Jan2018.pdf](https://s3.amazonaws.com/rkfengineering-web/6USC%2BReport%2BRelease%2B-%2B24Jan2018.pdf)
13. Some possibly interesting references:
14. <https://mentor.ieee.org/802.15/dcn/22/15-22-0631-04-006a-definition-of-coexistence-levels-and-how-to-support-higher-levels.pptx>
15. <https://mentor.ieee.org/802.15/dcn/23/15-23-0101-04-006a-qualitative-approach-to-coexistence-and-qos-mechanisms.docx>
16. <https://mentor.ieee.org/802.15/dcn/23/15-23-0338-01-04ab-nb-coexistence.pptx>
17. <https://mentor.ieee.org/802.15/dcn/23/15-23-0108-01-006a-proposal-on-mac-features-for-coexisting-dependable-bans.ppt>
18. <https://mentor.ieee.org/802.15/dcn/23/15-23-0137-01-006a-inference-avoidance-in-coexisting-uwb-networks.ppt>
19. <https://mentor.ieee.org/802.15/dcn/23/15-23-0137-01-006a-inference-avoidance-in-coexisting-uwb-networks.ppt>
20. <https://mentor.ieee.org/802.15/dcn/22/15-22-0652-00-006a-soft-spectrum-adaptation-ssa-based-on-pulse-shaping-for-interference-mitigation-between-uwb-radio-and-other-coexisting-radio.pptx>
21. <https://mentor.ieee.org/802.15/dcn/22/15-22-0642-00-04ab-ssbd-enabled-uwb-radio-coexistence-with-wi-fi-6e-demo.pptx>
22. <https://mentor.ieee.org/802.15/dcn/22/15-22-0642-02-04ab-ssbd-enabled-uwb-radio-coexistence-with-wi-fi-6e-demo.pptx>
23. <https://mentor.ieee.org/802.15/dcn/22/15-22-0456-00-04ab-uwb-channel-usage-coordination-for-better-uwb-coexistence.pptx>
24. <https://mentor.ieee.org/802.15/dcn/22/15-22-0358-00-04ab-coexistence-with-wi-fi-by-using-narrowband-mirroring-channel.pptx>
25. <https://mentor.ieee.org/802.15/dcn/22/15-22-0261-00-04ab-coexistence-discussion-on-nb-assisted-uwb.pptx>
26. NBA-MMS-UWB Compressed PSDU, 15-22-0604-00-04ab.
27. Narrowband Channel Access and Interference Mitigation for NBA-MMS-UWB, 15-22-0340-01-04ab.
28. NBA-MMS-UWB Native Discovery Concept, 15-23-033-02-4ab.
29. Analysis of the Scalability of UWB Indoor Localization Solutions for High User Densities, Ridolfi et al., Sensors (Basel), June 2018, doi: [10.3390/s18061875](https://doi.org/10.3390/s18061875)
30. Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 3: Requirements for UWB devices for ground based vehicular applications, ETSI EN 302 065-3 v2.1.0, 2016.
31. EN 303 687 NB Proposals for DAA Optimisation, BRAN(21)109h004r2, ETSI.
32. Bluetooth Wi-Fi Coexistence: Channel Access Simulation Study, Ratnesh Kumbhkar (Intel), https://mentor.ieee.org/802.11/dcn/23/11-23-1503-00-coex-bluetooth-wi-fi-coexistence-channel-access-simulation-study.pptx
33. Updates on UWB Channel Usage Coordination, Mingyu Lee et al. (Samsung), 15-23-006700-04ab.
34. SSBD enabled UWB radio coexistence with Wi-Fi 6e demo, Frederic Nabki et al. (SPARK Microsystems), 15-23-0642-02-04ab.
1. Per the advice of the 802.11 WG Coexistence SC in response to inquiry by the task group. [↑](#footnote-ref-1)