|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Received: Subject: Proposed modification to M.1450-5  | **Document 5A/xx** |
| **X May-June 2022** |
| **English only** |
| Institute of Electrical and Electronics Engineers |
| Proposed modification to M.1450-5 |

**Source Information**

IEEE 802 LAN/MAN Standards Committee (LMSC) respectfully submits this submission to ITU-R Working Party 5A (WP 5A). IEEE 802 is a committee of the IEEE Standards Association and Technical Activities, two of the Major Organizational Units of the Institute of Electrical and Electronics Engineers (IEEE). IEEE has about 420,000 members in about 190 countries and supports the needs and interests of engineers and scientists broadly. In submitting this document, IEEE 802 acknowledges and respects that other components of IEEE Organizational Units may have perspectives that differ from, or compete with, those of IEEE 802. Therefore, this submission should not be construed as representing the views of IEEE as a whole[[1]](#footnote-1).

**Introduction**

This document proposes updates to the [[491] Annex 15](https://www.itu.int/dms_pub/itu-r/md/19/wp5a/c/R19-WP5A-C-0491%21N15%21MSW-E.docx) - Working document towards a preliminary draft revision of Recommendation ITU-R M.1450-5 - Characteristics of broadband radio local area networks. The proposed changes are indicated via the ‘track changes’ and highlighted in yellow. Section 6 Table 3 is expected to be updated from the results of WRC-19.

We applaud the efforts of the participants in WP 5A for undertaking this work and giving IEEE 802 the opportunity to contribute.

**Discussion**

Since the last revision of ITU-R M.1450-5 (2014), there have been a number of updates to IEEE 802 standards that we would like to share with WP 5A for consideration.

**Proposal**

Incorporate the proposed updates below in the next revision of ITU-R M.1450.

**Contact:** LYNCH Michael **E-mail:** freqmgr@ieee.org

**Incl.: Annex 1**

|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Source: Document 5A/TEMP/170(Rev.1) | **Annex 15 toDocument 5A/491-E** |
| **2 December 2021** |
| **English only** |
| Annex 15 to Working Party 5A Chairman’s Report |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT REVISION OF Recommendation ITu-R M.1450-5 |
| Characteristics of broadband radio local area networks |

(Questions ITU-R 212/5 and ITU-R 238/5)

(2000-2002-2003-2008-2010-2014)

[Editor’s Note: Terms of mandatory nature, such as ‘shall’, cannot be used in ITU-R Recommendations, which are voluntary; the working document needs to be amended accordingly.]

[Editor’s note: Due to time constraints, this document was not agreed, and it is still under consideration and needs to be revised. Participants are invited to submit input contributions to progress this work at the next meeting of WP5A and therefore it is considered as a working document for ease of reference at this stage and only for information.]

Summary of the revision

*[Editor’s Note: To be updated when the preliminary draft revision is agreed.]*

This revision includes additional characteristics of broadband radio local area networks (RLANs).

This revision includes additional interference mitigation techniques under frequency sharing environments.

Scope

This Recommendation provides the characteristics of broadband radio local area networks (RLANs) including technical parameters, and information on RLAN standards and operational characteristics. Basic characteristics of broadband RLANs and general guidance for their system design are also addressed.

The ITU Radiocommunication Assembly,

considering

*a)* that broadband radio local area networks (RLANs) are widely used for fixed, semi‑fixed (transportable) and portable computer equipment for a variety of broadband applications;

*b)* that broadband RLANs are used for fixed, nomadic and mobile wireless access applications;

*c)* that broadband RLAN standards currently being developed are compatible with current wired LAN standards;

*d)* that it is desirable to establish guidelines for broadband RLANs in various frequency bands;

*e)* that broadband RLANs should be implemented with careful consideration to compatibility with other radio applications,

recognizing

that the use of the frequency bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470‑5 725 MHz by RLAN’s is covered in Resolution **229 (Rev.WRC-19)**,

noting

*a)* that Report ITU-R F.2086 provides technical and operational characteristics and applications of broadband wireless access systems (WAS) in the fixed service;

*b)* that other information on broadband WAS, including RLANs, is contained in Recommendations ITU-R F.1763, ITU-R M.1652, ITU-R M.1739 and ITU-R M.1801,

[Editor’s Note: it has been considered whether the references to ITU-R Recommendations and Reports above should be moved to the ‘recognizing’ part and the ‘noting’ instead should point to Table 3 with the information on frequency bands in use by Administrations – proposals are invited].

recommends

[1 that the broadband RLAN standards in Table 2 should be used by administrations wishing to implement broadband RLANs (see also Notes 1, 2 and 3). The frequency bands shown in Table 2 are only there for reference and shows the bands that the broadband RLAN standards are capable of operating within. ~~Administrations who wish to implement the RLAN shall utilize the frequency bands identified for RLAN in the ITU Radio Regulations according to Resolution~~ **~~229 (Rev.WRC-19)~~**~~. Implementing broadband RLAN standards in any frequency bands not considered in Radio Regulations or studied by ITU-R are not allowed and should be treated under Article~~ **~~4.4~~** ~~of the RR;~~

1*bis*  that Table 3 should be used to see the details on the bands that have been made available for RLAN use by Administrations;]

*~~Option 1:~~*

~~[1 that the broadband RLAN standards in Table 2 should be used by administrations wishing to implement broadband RLANs (see also Notes 1, 2 and 3). The frequency bands shown in Table 2 indicate where the broadband RLAN systems conforming with the standards in this Recommendation have been operating;~~

~~1~~*~~bis~~*  ~~that Table 3 should be used to see the details on the bands that have been made available for RLAN use by Administrations;]~~

*~~Option 2:~~*

~~[1 For guidance on the characteristic of broadband RLAN systems standards, Table 2 can be referred to. Administrations who wish to implement the RLAN shall utilize the frequency bands identified for RLAN in the ITU Radio Regulations according to Resolution~~ **~~229 (Rev.WRC-19)~~**~~. Implementing broadband RLAN standards in any frequency bands not considered in Radio Regulations or studied by ITU-R are not allowed and should be treated under Article~~ **~~4.4~~** ~~of the RR.~~

~~Implementing broadband RLAN standards in any frequency bands not considered in Radio Regulations or studied by ITU-R should be on a non-exclusive, non-interference and non-protected basis.]~~

[Editor’s Note: Japan’s comment: “Administrations have the right to implement RLANs in the frequency bands allocated to mobile services in the RR. We are concerned that the proposed texts would impose a strict limitation on the right.”]

~~…~~

~~NOTE 4 – Table 3 should be used to see the details on the bands that have been made available for RLAN use by Administrations.~~

~~NOTE 5~~ *~~[Editor’s note: develop note to address the concern on possible extensions/additions of the frequency bands in Table 2]~~*

2 that Annex 2 should be used for general information on RLANs, including their basic characteristics;

3 that the following Notes should be regarded as part of this Recommendation.

NOTE 1 – Acronyms and terminology used in this Recommendation are given in Table 1.

NOTE 2 – Annex 1 provides detailed information on how to obtain complete standards described in Table 2.

NOTE 3 – This Recommendation does not exclude the implementation of other RLAN systems.

~~NOTE 4 – Administrations wishing to implement RLANS should ensure that those systems do not cause interference or claim protection from certain other primary services as defined in the Radio Regulations.~~

TABLE 1

Acronyms and terms used in this Recommendation

Access method Scheme used to provide multiple access to a channel

AP Access point

ARIB Association of Radio Industries and Businesses

ATM Asynchronous transfer mode

Bit rate The rate of transfer of a bit of information from one network device to another

BPSK Binary phase-shift keying

BRAN Broadband Radio Access Networks (A technical committee of ETSI)

Channelization Bandwidth of each channel and number of channels that can be contained in the RF bandwidth allocation

Channel Indexing The frequency difference between adjacent channel centre frequencies

DFT Discrete Fourier Transform

DFT-S OFDM DFT-spread OFDM

CSMA/CA Carrier sensing multiple access with collision avoidance

DAA Detect and avoid

DFS Dynamic frequency selection

DSSS Direct sequence spread spectrum

e.i.r.p. Equivalent isotropically radiated power

ENG Electronic News Gathering

ETSI European Telecommunications Standards Institute

Frequency band Nominal operating spectrum of operation

FHSS Frequency hopping spread spectrum

HIPERLAN2 High performance radio LAN 2

HiSWANa High speed wireless access network – type a

HSWA High speed wireless access

IEEE Institute of Electrical and Electronics Engineers

IETF Internet Engineering Task Force

LAN Local area network

LBT Listen before talk

MU Medium utilisation

MMAC Multimedia mobile access communication

Modulation The method used to put information onto an RF carrier

MIMO Multiple input multiple output

OFDM Orthogonal frequency division multiplexing

OFDMA Orthogonal frequency division multiple access

PSD Power spectral density

PSTN Public switched telephone network

QAM Quadrature amplitude modulation

QoS Quality of Service

QPSK Quaternary phase-shift keying

RF Radio frequency

RLAN Radio local area network

RU Resource unit

SSMA Spread spectrum multiple access

Tx power Transmitter power – RF power in Watts produced by the transmitter

TCP Transmission control protocol

TDD Time division duplex

TDMA Time-division multiple access

TPC Transmit power control

WATM Wireless asynchronous transfer mode

Vocabulary

[Source: [Annex 17](https://www.itu.int/dms_pub/itu-r/md/15/wp5a/c/R15-WP5A-C-0844%21N17%21MSW-E.docx) to [Doc. 5A/844](https://www.itu.int/md/R15-WP5A-C-0844/en)]

Dynamic frequency selection (DFS)

An interference mitigation technique under frequency sharing environment, which is based on avoiding a channel on which a predefined signal is detected.

Transmit power control (TPC)

A technique to control the transmit power to improve the RF link quality, to avoid interference into other devices and/or extend the battery life.

TABLE 2-1

Characteristics including technical parameters associated with broadband RLAN standards: IEEE and ATIS

| Characteristics | IEEE Std 802.11-2020(Clause 16, commonly knownas 802.11b) | IEEE Std 802.11-2020(Clause 17, commonly knownas 802.11a(1)) | IEEE Std 802.11-2020(Clause 18, commonly known as 802.11g(1)) | IEEE Std 802.11-2020(Clause 17, Annex D and Annex E, commonly known as 802.11j) | IEEE Std 802.11-2020(Clause 19, commonly known as 802.11n) | IEEE Std 802.11-2020- (Clause 20, commonly known as 802.11ad) | IEEE Std 802.11-2020(Clause 21, commonly knownas 802.11ac) | IEEE Std 802.11-2020 (Clause 23, commonly knownas 802.11ah) | IEEE Std 802.11ax-2021 | IEEE Std 802.11ay-2021  | ATIS RLAN(\*) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Access method** | **CSMA/CA, SSMA** | **CSMA/CA** | **Scheduled, CSMA/CA** | **CSMA/CA** | **CSMA/CA**  | **CSMA/CA,****Trigger-based access and OFDMA** | **Scheduled, CSMA/CA** | **Scheduled, CSMA, TDMA/TDD** |
| Modulation | CCK (8 complex chip spreading) | 64-QAM-OFDM 16-QAM-OFDMQPSK-OFDMBPSK-OFDM52 subcarriers(see Fig. 1) | DSSS/CCKOFDMPBCCDSSS-OFDM | 64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDM52 subcarriers(see Fig. 1) | 64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDM56 subcarriers in 20 MHz114 subcarriers in 40 MHzMIMO, 1-4 spatial streams  | Single Carrier: DPSK, π/2-BPSK, π/2-QPSK, π/2-16QAMOFDM: 64-QAM, 16-QAM, QPSK, SQPSK352 subcarriers | 256-QAM-OFDM64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDM56 subcarriers in 20 MHz114 subcarriers in 40 MHz242 subcarriers in 80 MHz484 subcarriers in 160 MHz and 80+80 MHzMIMO, 1-8 spatial streams  |  256-QAM-OFDM64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDM26 subcarriers in 1 MHz56 subcarriers in 2 MHz114 subcarriers in 4 MHz242 subcarriers in 8 MHz484 subcarriers in 16 MHz MIMO, 1-4 spatial streams | 1024-QAM256-QAM-OFDM64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDMNon-OFDMA:242 subcarriers/frequency segment in 20 MHz484 subcarriers/frequency segment in 40 MHz996 subcarriers/frequency segment in 80 and 80+80 MHz1992 subcarriers/frequency segment in 160 MHz OFDMA RU Size:26, 52, 106, 242, 484, 996, 1992 subcarriers/RUMIMO, 1-8 spatial streams  | Single Carrier: DPSK, π/2-BPSK, π/2-QPSK, π/2-8-PSK, π/2-16QAM, π/2-64-QAM, π/2-64-NUCOFDM: DCM BPSK,DCM QPSK,16-QAM,64-QAM355 subcarrriers in 2.16 GHz773 subcarrriers in 4.32 GHz1193 subcarrriers in 6.48 GHz1611 subcarrriers in 8.64 GHz | OFDM:256-QAM, 64-QAM, 16-QAM, QPSKMIMO 1-4 spatial streamsDFT-S-OFDM:256-QAM, 64-QAM, 16-QAM, QPSK, π/2-BPSK |

TABLE 2-1 (*continued*)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | IEEE Std 802.11-2020(Clause 16, commonly knownas 802.11b) | IEEE Std 802.11-2020(Clause 17, commonly knownas 802.11a(1)) | IEEE Std 802.11-2020(Clause 18, commonly known as 802.11g(1)) | IEEE Std 802.11-2020(Clause 17, Annex D and Annex E, commonly known as 802.11j) | IEEE Std 802.11-2020(Clause 19, commonly known as 802.11n) | IEEE Std 802.11-2020 (Clause 20, commonly known as 802.11ad) | IEEE Std 802.11-2020(Clause 21, commonly knownas 802.11ac)  | IEEE Std 802.11-2020 (Clause 23, commonly knownas 802.11ah) | IEEE Std 802.11ax-2021 | IEEE Std 802.11ay-2021  | ATIS RLAN(\*) |
| Data rate  | 1, 2, 5.5 and 11 Mbit/s | 6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s | 1, 2, 5.5, 6, 9, 11, 12, 18, 22, 24, 33, 36, 48 and 54 Mbit/s | 3, 4.5, 6, 9, 12, 18, 24 and 27 Mbit/s for 10 MHz channel spacing6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s for 20 MHz channel spacing | From 6.5 to 288.9 Mbit/s for 20 MHz channel spacingFrom 6 to 600 Mbit/s for 40 MHz channel spacing  | From 693.00 to 6756.75 Mbit/s | From 6.5 to 693.3 Mbit/s for 20 MHz channel spacingFrom 13.5 to 1 600 Mbit/s for 40 MHz channel spacing From 29.3 to 3 466.7 Mbit/s for 80 MHz channel spacingFrom 58.5 to 6 933.3 Mbit/s for 160 MHz and 80+80 MHz channel spacing | From 0.300 to 17.7778 Mbit/s for 1 MHz channel spacingFrom 0.650 to 34.6667 Mbit/s for 2 MHz channel spacingFrom 1.350 to 80.000 Mbit/s for 4 MHz channel spacing From 2.925 to 173.3333 Mbit/s for 8 MHz channel spacingFrom 5.850 to 346.6667 Mbit/s for 16 MHz channel spacing  | From 0.4 to 117.6 Mbit/s for 26-tone RUFrom 0.8 to 235.3 Mbit/s for 52-tone RUFrom 1.6 to 500.0 Mbit/s for 106-tone RUFrom 3.6 to 1 147.1 Mbit/s for 242-tone RU and 20 MHz non-OFDMA channel spacingFrom 7.3 to 2 294.1 Mbit/s for 484-tone RU and non-OFDMA 40 MHz channel spacing From 15.3 to 4 803.9 Mbit/s for 996-tone RU and npon-OFDMA 80 MHz channel spacingFrom 30.6 to 9 607.8 Mbit/s for 2×996-tone RU and 160 MHz and 80+80 MHz channel spacing | From 630.00 to 8 316.00 Mbit/s for 2.16 GHzFrom 1 376.25 to 18 166.50 Mbit/s for 3.32 GHzFrom 2 126.25 to 28 066.50 Mbit/s for 6.48 GHzFrom 2 872.50 to 37 917.00 Mbit/s for 8.64 GHz | Up to 453 Mbit/s for 20 MHz channelUp to 907 Mbit/s for 40 MHz channelUp to 1 386 Mbit/s for 60 MHz channelUp to 1 857 Mbit/s for 80 MHz channel |

TABLE 2-1 (*continued*)

| Characteristics | IEEE Std 802.11-2020(Clause 16, commonly knownas 802.11b) | IEEE Std 802.11-2020(Clause 17, commonly knownas 802.11a(1)) | IEEE Std 802.11-2020(Clause 18, commonly known as 802.11g(1)) | IEEE Std 802.11-2020(Clause 17, Annex D and Annex E, commonly known as 802.11j) | IEEE Std 802.11-2020(Clause 19, commonly known as 802.11n) | IEEE Std 802.11-2020- (Clause 20, commonly knownas 802.11ad) | IEEE Std 802.11-2020(Clause 21, commonly knownas 802.11ac) | IEEE Std 802.11-2020(Clause 23, commonly knownas 802.11ah) | IEEE Std 802.11ax-2021  | IEEE Std 802.11ay-2021  | ATIS RLAN(\*) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency band | 2 400-2 483.5 MHz | 5 150-5 250 MHz(4)5 250-5 350 MHz(3)5 470-5 725 MHz(3)5 725-5 825 MHz | 2 400-2 483.5 MHz | 4 940-4 990 MHz(2)5 030-5 091 MHz(2)5 150-5 250 MHz(4)5 250-5 350 MHz(3) 5 470-5 725 MHz(3)5 725-5 825 MHz | 2 400-2 483.5 MHz5 150-5 250 MHz(4)5 250-5 350 MHz(3) 5 470-5 725 MHz(3)5 725-5 825 MHz | 57-71 GHz | 5 150-5 250 MHz(4)5 250-5 350 MHz(3) 5 470-5 725 MHz(3)5 725-5 825 MHz | 755-787 MHz779-787 MHz863-868.6 MHz902-928 MHz916.5-927.5 MHz917.5-923.5 MHz  |  2 400-2 483.5 MHz5 150-5 250 MHz5 250-5 350 MHz (3) 5 825-5 850 MHz5 850-5 895 MHz5 925-7 125 MHz~~]~~~~()~~ | 57-71 GHz  | 5 150-5 925 MHz ~~(\*\*)~~ |
| Channel indexing | 5 MHz | 5 MHz in 2.4 GHz20 MHz in 5 GHz | 2 160 MHz | 20 MHz | 1 MHz | 20 MHz  | 2 160 MHz | 20 MHz |
| Spectrum mask | 802.11b mask(Fig. 4) | OFDM mask (Fig. 1) | OFDM mask(Figs. 2A, 2B for 20 MHz and Figs. 3A, 3B for 40 MHz) | 802.11ad mask (Fig. 5) | OFDM mask(Fig. 2b for 20 MHz, Fig. 3b for 40 MHz, Fig. 3c for 80 MHz, Fig. 3d for 160 MHz, and Fig. 3e for 80+80 MHz) |  802.11ah mask (Fig. 6a for 1 MHz, Fig. 6b for 2 MHz, Figure 6c for 4 MHz, Fig. 6d for 8 MHz and Fig. 6e for 16 MHz) | Spectrum Mask (Fig. 7a for 20 MHz, Fig. 7b for 40 MHz, Fig. 7c for 80 MHz, Fig. 7d for 160 MHz and Fig. 7e for 80+80 MHz) | 802.11ay mask (Fig .8a for 2.16 GHz, Fig. 8b for 4.32 GHz, Fig. 8c for 6.48 GHz, Fig. 8d for 8.64 GHz and Fig. 8e for 2.16+2.16 GHz)Fig. 8f for 4.32+4.32 GHz) | Fig. 9A for 20 MHz, Fig. 9B for 40 MHz, Fig. 9C for 60 MHz, Fig. 9D for 80 MHz |
| **Transmitter** |  |
| Interference mitigation | LBT | LBT/DFS/TPC | LBT | LBT/DFS/TPC | Entergy Detect,Frequency, Time and Spatial sharing | LBT/DFS/TPC | Entergy Detect CCA, Frequency, Time and Spatial sharing | LBT/DFS/TPC | Entergy Detect, Frequency, Time and Spatial sharing | LBT/DFS/TPC |
| **Receiver** |  |  |  |  |  |  |  |  |  |  |
| Sensitivity | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard | Listed in Standard |
| Notes to Table 2-1(1) Parameters for the physical layer are common between IEEE 802.11a and ARIB HiSWANa.Resolution **229 (Rev.WRC-19)** recognizes that outdoor WAS/RLANs operating in the 5 150-5 250 MHz can be controlled and/or limited. . (\*) See ATIS.3GPP.37.213V1640 and related ATIS Standards. |

TABLE 2-2

Characteristics including technical parameters associated with broadband RLAN standards: ETSI and ARIB

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Characteristics | ETSIEN 300 328(0) | ETSI EN 301 893(0) | ARIBHiSWANa,(1) | ETSI EN 302 567(0) | ETSI [EN 303 687](0)(\*\*) |
| **Access method** |  | **TDMA/TDD** |  | **TBD** |
| Modulation | No restriction on the type of modulation | 64-QAM-OFDM16-QAM-OFDMQPSK-OFDMBPSK-OFDM52 subcarriers(see Fig. 1) |  | TBD |
| Data rate  |  | 6, 9, 12, 18, 27, 36 and 54 Mbit/s |  | TBD |
| Frequency band | 2 400-2 483.5 MHz | 5 150-5 350(5)and 5 470-5 725 MHz(3)(\*) | 4 900 to 5 000 MHz(2)5 150 to5 250 MHz (4)(\*) | 57-66 GHz | [5 925-6 425] |
| Channel indexing |  | 20 MHz | 20 MHz channel spacing 4 channels in 100 MHz |  | TBD |
| Spectrum mask |  | Fig. 1x | OFDM mask(Fig. 1) |  | TBD |
| Transmitter |  |  |  |  |  |
| Interference mitigation | DAA/LBT, DAA/non-LBT, MU | LBT/DFS/TPC | LBT |  | TBD |
| Receiver |  |  |  |  |  |
| Sensitivity |  |  |  |  |  |
| *Notes to Table 2-2*(0) These Harmonized Standards (HS) are not technology standards, but rather are used to demonstrate that products, services, or processes comply with relevant EU legislation. *[Editor’s Note: Source Doc. 5A/379 (ETSI TC BRAN); to be further updated]*(1) Parameters for the physical layer are common between IEEE 802.11a and ARIB HiSWANa.(2) See 802.11j-2004 and JAPAN MIC ordinance for Regulating Radio Equipment, Articles 49-20 and 49-21.(3) DFS rules apply in the 5 250-5 350 and 5 470-5 725 MHz bands in many administrations and administrations must be consulted.(4) Resolution **229 (Rev.WRC-19)** recognizes that the number of outdoor WAS/RLANs operating in the 5 150-5 250 MHz can be controlled and/or limited. . *[EDITOR’s NOTE: TO BE UPDATED PER WRC-19]* (\*) Pursuant to Resolution **[229 (Rev.WRC-19)](https://www.itu.int/oth/R0A0600009D/en)** and subject to not causing harmful interference to existing services(\*\*) *[Editor’s Note; this standard is still in draft form; this information is to be updated by ETSI at future meetings]* |  |

Figure 1a

OFDM transmit spectrum mask for 802.11a, 11g, 11j,
and HiSWANa systems



NOTE 1 – The outer heavy line is the spectrum mask for 802.11a, 11g, 11j, HiSWANa and the inner thin line is the envelope spectrum of OFDM signals with 52 subcarriers.

NOTE 2 – The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

NOTE 3 – In the case of the 10 MHz channel spacing in 802.11j, the frequency scale shall be half.

Figure 1b

Transmit spectrum mask for EN 301 893



NOTE – dBc is the spectral density relative to the maximum spectral power density of the transmitted signal.

FIGURE 2a

Transmit spectral mask for 20 MHz 802.11n transmission in 2.4 GHz band



NOTE – Maximum of −45 dBr and −53 dBm/MHz at 30 MHz frequency offset and above.

FIGURE 2b

Transmit spectral mask for a 20 MHz 802.11n transmission in 5 GHz band and
transmit spectral mask for 802.11ac



NOTE – For 802.11n, the maximum of –40 dBr and –53 dBm/MHz at 30 MHz frequency offset and above. For 802.11ac, the transmit spectrum shall not exceed the maximum of the transmit spectral mask and –53 dBm/MHz at any frequency offset.

FIGURE 3a

Transmit spectral mask for a 40 MHz 802.11n channel in 2.4 GHz band



NOTE – Maximum of −45 dBr and −56 dBm/MHz at 60 MHz frequency offset and above.

FIGURE 3b

Transmit spectral mask for a 40 MHz 802.11n channel in 5 GHz band and
transmit spectral mask for 802.11ac



NOTE – For 802.11n, maximum of –40 dBr and –56 dBm/MHz at 60 MHz frequency offset and above. For 802.11ac, the transmit spectrum shall not exceed the maximum of the transmit spectral mask and −56 dBm/MHz at any frequency offset.

FIGURE 3c

Transmit spectral mask for an 80 MHz 802.11ac channel



NOTE – The transmit spectrum shall not exceed the maximum of the transmit spectral mask and −59 dBm/MHz at any frequency offset.

FIGURE 3d

Transmit spectral mask for a 160 MHz 802.11ac channel



NOTE – The transmit spectrum shall not exceed the maximum of the transmit spectral mask and −59 dBm/MHz at any frequency offset.

FIGURE 3e

Transmit spectral mask for a 80+80 MHz 802.11ac channel



NOTE – The transmit spectrum shall not exceed the maximum of the transmit spectral mask and −59 dBm/MHz at any frequency offset.

Figure 4

Transmit spectrum mask for 802.11b



Figure 5

Transmit spectrum mask for 802.11ad



FIGURE 6a

Transmit spectrum mask for 1 MHz 802.11ah channel



FIGURE 6b

Transmit spectrum mask for 2 MHz 802.11ah channel



FIGURE 6c

Transmit spectrum mask for 4 MHz 802.11ah channel



FIGURE 6d

Transmit spectrum mask for 8 MHz 802.11ah channel



FIGURE 6e

Transmit spectrum mask for 16 MHz 802.11ah channel



FIGURE 7a

Transmit spectrum mask for 20 MHz 802.11ax channel



FIGURE 7b

Transmit spectrum mask for 40 MHz 802.11ax channel



FIGURE 7c

Transmit spectrum mask for 80 MHz 802.11ax channel



FIGURE 7d

Transmit spectrum mask for 160 MHz 802.11ax channel



FIGURE 7e

Transmit spectrum mask for 80+80 MHz 802.11ax channel



FIGURE 8a

Transmit spectrum mask for 2.16 GHz P802.11ay channel



FIGURE 8b

Transmit spectrum mask for 4.32 GHz P802.11ay channel



FIGURE 8c

Transmit spectrum mask for 6.48 GHz P802.11ay channel



FIGURE 8d

Transmit spectrum mask for 8.64 GHz P802.11ay channel



FIGURE 8e

Transmit spectrum mask for 2.16+2.16 GHz P802.11ay channel



FIGURE 8f

Transmit spectrum mask for 4.32+4.32 GHz P802.11ay channel



Figure 9a

Transmit spectrum mask for 20 MHz ATIS RLAN



NOTE – The spectrum emission mask is defined relative to the maximum power density in a 1 MHz measurement bandwidth within the channel bandwidth. The relative power of any transmitter emission shall not exceed the levels indicated by the mask or -30 dBm/MHz whichever is the greatest.

Figure 9b

Transmit spectrum mask for 40 MHz ATIS RLAN



NOTE – The spectrum emission mask is defined relative to the maximum power density in a 1 MHz measurement bandwidth within the channel bandwidth. The relative power of any transmitter emission shall not exceed the levels indicated by the mask or -30 dBm/MHz whichever is the greatest.

Figure 9c

Transmit spectrum mask for 60 MHz ATIS RLAN



NOTE – The spectrum emission mask is defined relative to the maximum power density in a 1 MHz measurement bandwidth within the channel bandwidth. The relative power of any transmitter emission shall not exceed the levels indicated by the mask or -30 dBm/MHz whichever is the greatest.

Figure 9d

Transmit spectrum mask for 80 MHz ATIS RLAN



NOTE – The spectrum emission mask is defined relative to the maximum power density in a 1 MHz measurement bandwidth within the channel bandwidth. The relative power of any transmitter emission shall not exceed the levels indicated by the mask or -30 dBm/MHz whichever is the greatest.

Annex 1

Obtaining additional information on RLAN standards

The ETSI EN 300 328, EN 301 893 and EN 302 567 standards can be downloaded from <http://pda.etsi.org/pda/queryform.asp>. In addition to these standards, the Hiperlan type 2 standards can still be downloaded from the above link.

The IEEE 802.11 standards can be downloaded from: http://standards.ieee.org.

IEEE 802.11 has developed a set of standards for RLANs, IEEE Std 802.11 – 2016, which has been harmonized with IEC/ISO[[2]](#footnote-2). The medium access control (MAC) and physical characteristics for wireless local area networks (LANs) are specified in ISO/IEC/IEEE 8802-11:2018, which is part of a series of standards for local and metropolitan area networks. The medium access control unit in ISO/IEC/IEEE 8802-11:2018 is designed to support physical layer units as they may be adopted dependent on the availability of spectrum. Approved amendments to the IEEE Std 802.11-2016 base standard include IEEE Std 802.11ah-2016. IEEE Std 802.11 operates in the frequency bands up to 71GHz.

The ATIS RLAN standards can be downloaded from: <http://www.atis.org/3gpp-documents/Rel16>

Annex 2

Basic characteristics of broadband RLANs
and general guidance for deployment

[Editor’s note: Invite administrations to provide information on deployment guidance.]

# 1 Introduction

Broadband RLAN standards have been designed to allow compatibility with wired LANs such as IEEE 802.3 and ATM at comparable data rates. Some broadband RLANs have been developed to be compatible with current wired LANs and are intended to function as a wireless extension of wired LANs using TCP/IP and ATM protocols. License-exempt use of spectrum allocations globally further promoted development of broadband RLANs allowing many applications such as cellular offload, voice/video over RLAN, audio/video streaming, mobile hotspot, real-time gaming, AR/VR to be supported in various segments including enterprise and residential connectivity, health, education, retail, leisure/hospitality, smart cities, transportation, IoT and Industrial IoT.

Portability is a feature provided by broadband RLANs but not wired LANs. Laptop computers and palmtop are portable and have the ability, when connected to a wired LAN, to provide interactive services. However, when they are connected to wired LANs they are no longer portable. Broadband RLANs allow portable computing devices such as notebooks, tablets, smartphones and wearable devices to remain portable and operate at maximum potential.

# Advanced applications such as cellular offload, voice/video over RLAN, audio/video streaming, mobile hotspot, real-time gaming, AR/VR require improvement in performance characteristics of RLAN such as throughput and latency. 2 Mobility

[Editor’s note: Description of portable RLAN should be updated as it’s more and more popular used today.]

Broadband RLANs may be either pseudo fixed as in the case of a desktop computer that may be transported from place to place or portable as in the case of battery operated notebooks, tablets, smartphones and wearable devices with integrated wireless LAN connectivity. Relative velocity between these devices and an RLAN wireless access point remains low. RLAN devices are generally not designed to be used at automotive or higher speeds.

*~~[~~*~~The latest WAS/RLAN technology is capable to support not only the fixed stations, but also portable, and even moving stations. It is very common to see the use of portable WAS/RLAN devices especially at the tourist hotspots.~~*~~]~~*

# 3 Operational environment and considerations of interface

Broadband RLANs are predominantly deployed inside buildings, in offices, factories, warehouses, etc. For RLAN devices deployed inside buildings, emissions are attenuated by the structure. In order to better support the outdoor operations, WAS/RLAN has developed various features including longer Orthogonal Frequency Division Multiple (OFDM) symbol, preamble includes repeated Legacy Signal field (L-SIG), extended range preamble includes repeated High Efficiency Signal A field (HE-SIG-A), dual carrier modulation improves robustness in Data field. ~~[However, the use of WAS/RLAN in the outdoor environment shall be carefully decided. For example, Resolution~~ **~~229 (Rev.WRC-19)~~** ~~defines the use conditions for 5 GHz WAS/RLAN. Implementing broadband RLAN standards in any frequency bands not studied by ITU-R are not allowed and shall not cause harmful interference to, and shall not claim protection from harmful interference caused by a station operating in accordance with the provisions of the Regulation.]~~

RLANs utilize low power levels because of the short distances inside buildings. Power spectral density requirements are based on the basic service area of a single RLAN, often defined by a circle with a radius from 10 to 50 m. When larger networks are required, RLANS may be logically concatenated via bridge or router function to form larger networks without increasing their composite power spectral density.

One of the most useful RLAN features is the connection of mobile computer users to a wireless LAN network. In other words, a mobile user can be connected to his own LAN subnetwork anywhere within the RLAN service area. The service area may expand to other locations under different LAN subnetworks, enhancing the mobile user’s convenience.

There are several remote access network techniques to enable the RLAN service area to extend to other RLANs under different subnetworks. The Internet Engineering Task Force (IETF) has developed a number of the protocol standards on this subject.

To achieve the coverage areas specified above, it is assumed that RLANs require a peak power spectral density of e.g. approximately 10 mW/MHz in the 5 GHz operating frequency range (see Table 3). For data transmission, some standards use higher power spectral density for initialization and control the transmit power according to evaluation of the RF link quality. This technique is referred to as transmit power control (TPC). The required power spectral density is proportional to the square of the operating frequency. The large scale, average power spectral density will be substantially lower than the peak value. RLAN devices share the frequency spectrum on a time basis. Activity Factor will vary depending on the usage, in terms of application and period of the day.

Broadband RLAN devices are normally deployed in high-density configurations and may use an etiquette such as listen before talk and dynamic channel selection (referred to here as dynamic frequency selection, DFS) or TPC to facilitate spectrum sharing between devices.

# 4 System architecture including fixed applications

Broadband RLANs are often point-to-multipoint architecture. Point-to-multipoint applications commonly use omnidirectional, down-looking antennas. The multipoint architecture employs several system configurations:

– point-to-multipoint centralized system (multiple devices connecting to a central device or access point via a radio interface);

– point-to-multipoint non-centralized system (multiple devices communicating in a small area on an ad hoc basis);

– RLAN technology is sometimes used to implement fixed applications, which provide point‑to-multipoint (P-MP) or point-to-point (P-P) links, e.g. between buildings in a campus environment. P-MP systems usually adopt cellular deployment using frequency reuse schemes similar to mobile applications. Technical examples of such schemes are given in Report ITU-R F.2086 (see § 6.6). Point-to-point systems commonly use directional antennas that allow greater distance between devices with a narrow lobe angle. This allows band sharing via channel and spatial reuse with a minimum of interference with other applications;

–RLAN technology is sometimes used for multipoint-to-multipoint (fixed and/or mobile mesh network topology, in which multiple nodes relay a message to its destination). Omnidirectional and/or directional antennas are used for links between the nodes of the mesh network. These links may use one or multiple RF channels. The mesh topology enhances the overall reliability of the network by enabling multiple redundant communications paths throughout the network. If one link fails for any reason (including the introduction of strong RF interference), the network automatically routes messages through alternate paths.

# 5 Interference mitigation techniques under frequency sharing environments

[Editor’s note: Invite administrations to provide information on mitigation techniques to ensure coexistence under frequency sharing environments.]

RLANs are generally intended to operate in unlicensed or license-exempt spectrum and must allow adjacent uncoordinated networks to coexist whilst providing high service quality to users. In the 5 GHz bands, sharing with primary services must also be possible. Whilst multiple access techniques might allow a single frequency channel to be used by several nodes, support of many users with high service quality requires that enough channels are available to ensure access to the radio resource is not limited through queuing, etc. One technique that achieves a flexible sharing of the radio resource is DFS.

In DFS all radio resources are available at all RLAN nodes. A node (usually a controller node or access point (AP)) can temporarily allocate a channel and the selection of a suitable channel is performed based on interference detected or certain quality criteria, e.g. received signal strength, *C*/*I*. To obtain relevant quality criteria both the mobile terminals and the access point make measurements at regular intervals and report this to the entity making the selection.

In the 5 250-5 350 MHz and 5 470-5 725 MHz bands, DFS must be implemented to ensure compatible operation with systems in the co-primary services, i.e. the radiolocation service.

DFS can also be implemented to ensure that all available frequency channels are utilized with equal probability. This maximizes the availability of a channel to node when it is ready to transmit, and it also ensures that the RF energy is spread uniformly over all channels when integrated over a large number of users. The latter effect facilitates sharing with other services that may be sensitive to the aggregated interference in any particular channel, such as satellite-borne receivers.

TPC is intended to reduce unnecessary device power consumption, but also aids in spectrum reuse by reducing the interference range of RLAN nodes.

Some administrations have authorized broadband RLANs across 5 925-7 125 MHz to respond to increased demand for low-cost wireless Internet connectivity. The decisions allowed RLANs to share this spectrum with incumbent services under rules that are carefully crafted to protect the licensed services and to enable both RLANs and incumbent licensed operations to thrive throughout the band. To protect licensed incumbents in the 6 GHz band, some administrations may require some of the following RLAN mitigation techniques: operating on a no protection, no harmful interference basis, requiring RLANs to implement contention-based protocol, limiting RLAN e.i.r.p., adopting exclusion zones around specific sites, restricting operation to indoor locations only, prohibiting access points on oil platforms and aboard ships, and allowing higher power RLAN access points to operate subject to an antenna pointing restriction and an Automatic Frequency Coordination (AFC) system.

Many administrations have authorized broadband RLANs in the band 5 925-7 125 MHz (or portions thereof) to respond to increased demand for wireless connectivity. The authorizations are intended to allow RLANs to share this spectrum with incumbent services under rules that are crafted to protect the licensed services and to enable both unlicensed and incumbent licensed operations to continue to thrive throughout the band.

To protect the Fixed Satellite Service, one administration allowed fixed outdoor access points to operate at e.i.r.p. levels up to 36 dBm subject to an antenna pointing restriction and an Automatic Frequency Coordination (AFC) system, with limited RLAN e.i.r.p. in 6 875-7 125 MHz. To protect the radio astronomy service in 6 650-6 675.2 MHz, one administration adopted exclusion zones for certain RLAN access points in that band around specific radio astronomy sites. To protect electronic news gathering (ENG) in the mobile service, one administration limited RLAN e.i.r.p. in 6 425-6 525 and restricted operation to indoor locations only. One administration also prohibited low power indoor and standard power access points on oil platforms and aboard ships to protect EESS.

Some enterprise-grade RLAN access points may have the capability of blocking off certain sub-bands to prevent interference to incumbent licensed operations, including nearby ENG receivers. The incorporation of this capability should be considered on a national basis to preserve access to a portion of 5 925-7 125 MHz at indoor and outdoor sports venues and other locations where ENG systems may operate.

# 6 General technical characteristics

[Editor’s note: Some texts around Table 3 (based on WRC-12) should be updated based on the results of WRC-19.]

Table 3 summarizes technical characteristics applicable to operation of RLANs in certain frequency bands and in certain geographic areas. Operation in the 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz frequency bands are in accordance with Resolution **229 (Rev.WRC‑19)**.

TABLE 3

General technical requirements applicable in certain administrations and/or regions

*[Editor’s Note: It has been proposed to add to the table the new column “Other use conditions”, to replace the footnotes below the table]*

| General band designation | Administration or region | Specific frequency band(MHz) | Transmitter output power(mW)(except as noted) | Antenna gain(dBi) | Other use conditions |
| --- | --- | --- | --- | --- | --- |
| 2.4 GHz band | USA | 2 400-2 483.5 | 1 000 | 0-6 dBi(1) (Omni) |  |
| Canada | 2 400-2 483.5 | 4 W e.i.r.p.(2) | N/A |  |
| CEPT | 2 400-2 483.5 | 100 mW (e.i.r.p.)(3) | N/A |  |
| China | 2 400-2 483.5  | 20 dBm (e.i.r.p. for integrated antenna gain < 10 dBi) 10 dBm/MHz (e.i.r.p. for Integrated antenna gain < 10 dBi)27 dBm (e.i.r.p. for antenna gain >= 10 dBi)17 dBm/MHz (e.i.r.p. for Integrated antenna gain >= 10 dBi) |  | Interference Avoidance mechanism is mandatoryAdditional out of band emission limit applies in order to protect the service in the adjacent band and in specific bands. |
| Japan(4) | 2 471-2 4972 400-2 483.5 | 10 mW/MHz10 mW/MHz | 0-6 dBi (Omni)0-6 dBi (Omni) |  |
| 5 GHz band(5), (6) | USA | 5 150-5 250(7)5 250-5 3505 470-5 7255 725-5 8505 850-5 895 | 502.5 mW/MHz25012.5 mW/MHz25012.5 mW/MHz1 00050.1 mW/MHz | 0-6 dBi(1) (Omni)0-6 dBi(1) (Omni)0-6 dBi(1) (Omni)0-6 dBi(8) (Omni) |  |
| Canada | 5 150-5 250(7)5 250-5 3505 470-5 7255 725-5 850 | 200 mW e.i.r.p.10 dBm/MHz e.i.r.p.25012.5 mW/MHz (11 dBm/MHz) 1 000 mW e.i.r.p.(9)25012.5 mW/MHz (11 dBm/MHz)1 000 mW e.i.r.p.(9)1 00050.1 mW/MHz(9) |  |  |
| CEPT(16) | 5 150-5 250(7)5 250-5 350(10)5 470-5 7255 945-6 425  | 200 mW (e.i.r.p.)10 mW/MHz (e.i.r.p.)200 mW (e.i.r.p.)10 mW/MHz (e.i.r.p.)1 000 mW (e.i.r.p.)50 mW/MHz (e.i.r.p.)200 mW (e.i.r.p.)(17) 25mW (e.i.r.p.)(18)  | N/A | Operation in the 5 250-5 350 MHz band is limited to indoor use |
|  | China | 5 150-5 350 | 23 dBm (e.i.r.p.)10 dBm/MHz (e.i.r.p.) |  | Indoor use only (use within vehicle is prohibited). 5 250-5 350 MHz, TPC and DFS are mandatory.Interference Avoidance mechanism is mandatoryAdditional out of band emission limit applies in order to protect the service in the adjacent band and in specific bands |
| 5 725-5 850 | 33 dBm (e.i.r.p.)19 dBm/MHz (e.i.r.p) |  | Interference Avoidance mechanism is mandatoryAdditional out of band emission limit applies in order to protect the service in the adjacent band and in specific bands |
|  | Japan(4) | 4 900-5 000(11)5 150-5 250(7)5 250-5 350(10)5 470-5 730 | 250 mW50 mW/MHz1 W (e.i.r.p.)200 mW (e.i.r.p.)1 W (e.i.r.p.) | 13 N/AN/AN/A | 4 900-5 000 MHz is for fixed wireless access, registered.Operation in the 5 250-5 350 MHz band is limited to indoor use |
| 6 GHz band\* | CEPT | 5 945-6 425 MHz | Low Power Indoor(LPI)(13) 23 dBm (e.i.r.p.)10 dBm /MHz (e.i.r.p.)Very Low Power (VLP) (14)14 dBm (e.i.r.p.)1 dBm/MHz (e.i.r.p) (15) | N/A | LPI equipment use is limited to indoor only use.No fixed outdoor use is allowed by VLP equipment.Narrowband VLP devices that operate in channels bandwidths below 20 MHz can operate at a higher e.i.r.p. density up to 10 dBm/MHz if they implement a frequency hopping mechanism based on at least 15 hop channels |
| USA  | 5 925-7 125 MHz (20)5 925-6 425 MHz6 525-6 875 MHz | Low Power Indoor (LPI): 30 dBm (max. e.i.r.p.); 5 dBm/MHz andClient Connected to Low Power Access Point (AP): 24 dBm (max e.i.r.p.); -1 dBm/MHzStandard Power (SP) AP (AFC Controlled): 36 dBm (max. e.i.r.p.); 23 dBm/MHz and Client Connected to SP AP: 30 dBm (max e.i.r.p); 17 dBm/MHzSP AP (AFC Controlled): 36 dBm (max. e.i.r.p.); 23 dBm/MHz and Client Connected to SP AP: 30 dBm (max. e.i.r.p.); 17 dBm/MHz | N/A |  |
| 57-71 GHz | Europe(19) | 57-71 GHz (C1)57-71 GHz (C2) | 40 dBm (e.i.r.p.)(12)13 dBm/MHz (e.i.r.p)40 dBm (e.i.r.p.) 13 dBm/MHz (e.i.r.p) | N/AMax conducted power 27dBm |  |

*[Editor’s Note: Some of the Notes to Table 3 below have been moved to the new column “Other use conditions”]*

|  |
| --- |
| *Notes to Table 3*(1) In the United States of America, for RLANs operating in the 5 GHz band, for antenna gains greater than 6 dBi, some reduction in output power required. See sections 15.407 and 15.247 of the FCC’s rules for details.(2) Canada permits point-to-point systems in this band with e.i.r.p. > 4 W provided that the higher e.i.r.p. is achieved by employing higher gain antenna, but not higher transmitter output power.(3) This requirement refers to ETSI EN 300 328.(4) See Japan MIC ordinance for Regulating Radio Equipment, Articles 49-20, 49-20-2 and 49-21 for details.(5) Resolution **229 (Rev.WRC-19)** establishes the conditions under which WAS, including RLANs, may use the 5 150‑5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz.(6) DFS rules apply in the 5 250-5 350 MHz and 5 470-5 725 MHz bands in regions and administrations and must be consulted.(7) In Japan, registration is required for RLAN access points with maximum e.i.r.p. greater than 200 mW. *[EDITOR’s NOTE: TO BE UPDATED PER WRC-19] [Editor’s note: Texts for USA, Canada and Europe may be added]* In the U.S., providers deploying more than 1,000 outdoor access points in the 5 150-5 250 MHz band must notify the FCC and ensure that the maximum e.i.r.p. at any elevation angle above 30 degrees as measured from the horizon shall not exceed 125 mW.(8) In the United States of America, for antenna gains greater than 6 dBi, some reduction in output power required, except for systems solely used for point-to-point. See sections 15.407 and 15.247 of the FCC’s rules for details.(9) See RSS-210, Annex 9 for the detailed rules on devices with maximum e.i.r.p. greater than 200 mW: <http://strategis.ic.gc.ca/epic/site/smt-gst.nsf/en/sf01320e.html>.(12) This refers to the highest power level of the transmitter power control range during the transmission burst if transmitter power control is implemented. Fixed outdoor installations are not allowed.(16) See ECC Decision (04)08 https://docdb.cept.org/download/3450 and ECC Decision (20)01 https://docdb.cept.org/download/1448. (17) Limited to indoor usage. (18) No fixed outdoor usage. (19) See ERC Recommendation 70-03 Annex 3 (Table 3) entries c1 and c2 <https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf>. (20) The above technical requirements are as of October 2021 and are under review.(\*)(\*) Some administrations have further RLAN use cases under review. |

1. This document solely represents the views of the IEEE 802 LAN/MAN Standards Committee and does not necessarily represent a position of either the IEEE, the IEEE Standards Association or IEEE Technical Activities. [↑](#footnote-ref-1)
2. [ISO/IEC 8802-11:2005](http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=39777&ICS1=35&ICS2=110&ICS3=), 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. [↑](#footnote-ref-2)