White Paper

Anritsu Advancing beyond

Key Technologies for IEEE 802.11be (Wi-Fi 7)

Table of Contents

1. IEEE 802.11be (Wi-Fi 7) Overview

The IEEE (Institute of Electrical and Electronics Engineers) will release a new amendment standard IEEE 802.11be - Extremely High Throughput (EHT). The new 802.11be amendment aims to achieve much faster and larger-capacity data transmission compared to the previous 802.11ax. Although 802.11be is still an upcoming standard, the Wi-Fi Alliance® clarified Wi-Fi 7 will be the next major generational Wi-Fi technology evolution based on the developing the 802.11be standard.

802.11ax is the first WLAN standard that operates in the 6 GHz frequency band. In addition to using the 6 GHz band with abundant spectrum resources and less interference from other wireless systems, 802.11ax uses OFDMA (Orthogonal Frequency Division Multiple Access) technology. This technology enables 802.11ax to achieve higher effective throughput instead of increasing its theoretical maximum transmission rate. 802.11be will also support the 6 GHz frequency band. The goal of the standard is to provide more efficient data transmission with a larger capacity at a higher speed by expanding existing technologies as well as adopting new technologies not used by previous WLAN standards.

By providing data throughput exceeding 30 Gbps with low latency over wireless communications, 802.11be is expected to be a fundamental technology for the latest applications and services, including video streaming with higher definition than 4K, augmented reality (AR), and virtual reality (VR).

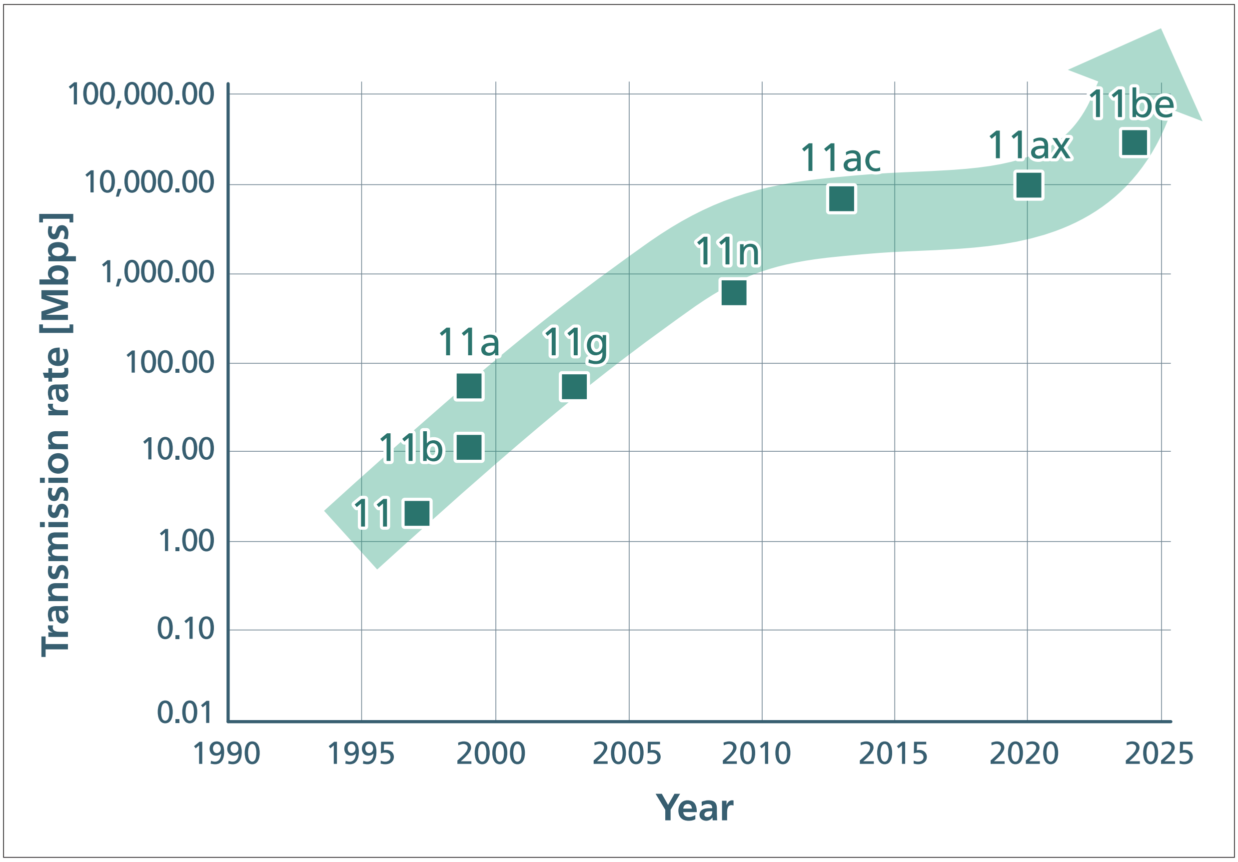
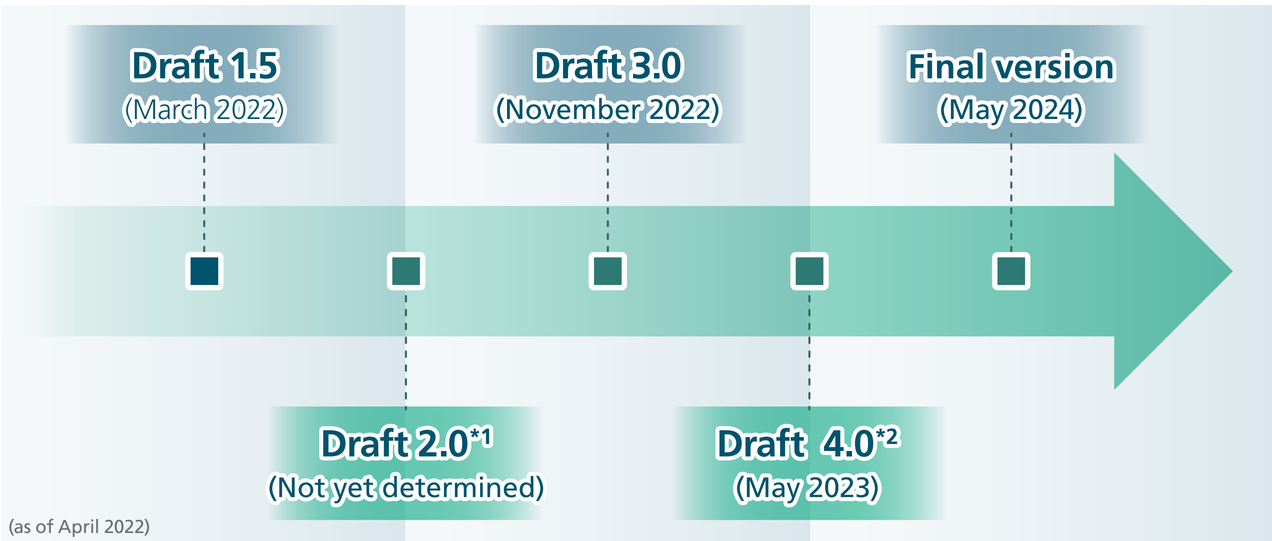


Figure 1: Progress of Transmission Rates for each 802.11 Standard

2. Standardization Timeline

Development of the 802.11be amendment is ongoing, with a goal of a final version expected by May 2024 as shown in Figure 2.

WLAN equipment compliant with an 802.11 standard is often commercialized based on the draft version of the standard. This is also expected to be true for 802.11be. In the 802.11be amendment, the main items are divided into two groups, Release 1 and Release 2. Therefore, Draft 2.0, in which the technical specifications of Release 1 are approximately finalized, will be a milestone, and Draft 2.0-compliant products are expected to appear on the market in 2022/23.



*1: Release 1 is expected to be based on Draft 2.0; however, as of April 2022, it is not known when Draft 2.0 will be released.

*2: Release 2 is expected to be based on Draft 4.0.

Figure 2: 802.11be Process and Timeline

3. Key Technologies to be Adopted in IEEE 802.11be

The 802.11 standard covers the Physical layer (PHY) and Data Link layer of the OSI reference model. In the 802.11 definition, the Data Link layer is divided into the two sublayers: Logic Link Control and Medium Access Control (MAC). There are changes from 802.11ax in both the PHY layer and MAC sublayer.

In the PHY layer, the standard is trying to contribute to the increased transmission rate by extending the technologies adopted by 802.11ax. In the MAC sublayer, on the other hand, introducing several new technologies is under discussion.

Table 1: Scope of 802.11 Standard

Layer	OSI Reference Model	802.11 Standard
7	Application	Out of scope
6	Presentation	Out of scope
5	Session	Out of scope
4	Transport	Out of scope
3	Network	Out of scope
2	Data Link	Out of scope (Logic Link Control)
		Medium Access Control (MAC)
1	Physical	Physical (PHY)

Table 2: Major Differences Between 802.11ax and 802.11be

Layer	Main Candidate Features	802.11ax (Wi-Fi 6/6E)	802.11be (Wi-Fi 7)
MAC	Multi-band and multichannel aggregation and operation (Multi-link)	Not supported	New feature (On the table)
	Enhanced link adaptation and retransmission protocol	Not supported	New feature (On the table)
	Multi-Access Point (AP) coordination	Not supported	New feature (On the table)
PHY	Resource Unit	Single RU	Multiple RU
	Channel width (max.)	160 MHz	320 MHz
	Subcarrier modulation (max.)	1024QAM	4096QAM
	Spatial stream (max.)	8 streams	16 streams

* These candidate features are described in the Spec Framework Document.

4. Details of Each Technology

PHY Layer

• Multiple Resource Unit (RU)

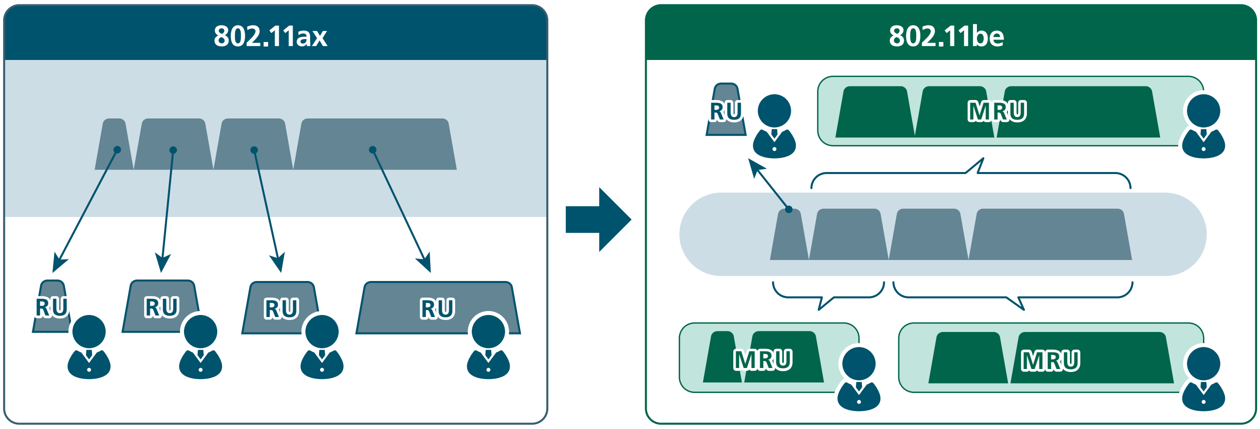


Figure 3: IEEE 802.11ax and 802.11be Channel Allocation

The Resource Unit (RU) is a unit of channel allocation that appeared with OFDMA introduced into 802.11ax. In 802.11ax, a user can be assigned only to one RU. In 802.11be, this will be extended to allow allocation of multiple RUs to one user. This is expected to enable more flexible use of frequencies, prevent interference, and increase throughput.

• Maximum Channel Width

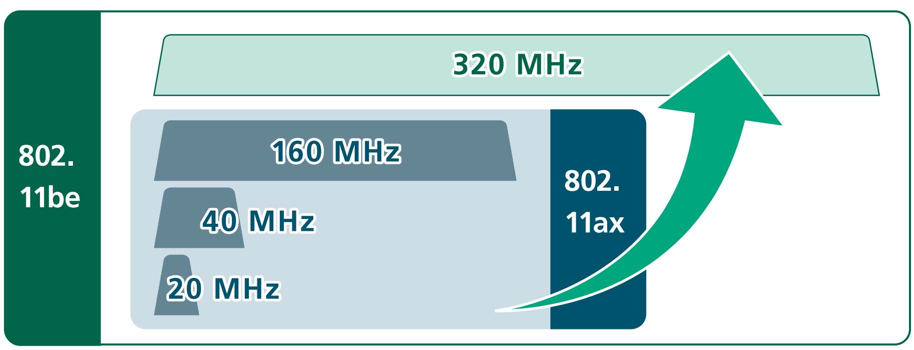


Figure 4: IEEE 802.11ax and 802.11be Channel Widths

Table 3: Maximum Channel Width in 802.11

802.11 Standard	11b	11a	11g	11n	11ac	11ax	11be
Maximum Channel Width [MHz]	20	20	20	40	160	160	320

100% Increase in Data Rate

The maximum channel width of 802.11ax is 160 MHz, which is the same as 802.11ac. The specification has been the same for a long time in the WLAN standard. In addition, because the 802.11ac standard supports the 5 GHz band and the band is also used by weather radars, only a limited range of frequencies is freely available for WLAN applications. For this reason, the 160 MHz channel width has hardly been used in actual operation. Now that 802.11ax supports the 6 GHz band, a channel width of 160 MHz has finally become available. 802.11be will support a bandwidth of up to 320 MHz, which is twice as wide as the conventional bandwidth and doubles the data rate compared to 802.11ax. The 6 GHz band supports up to three 320 MHz channels.

4. Details of Each Technology

• **Subcarrier Modulation (Max.)**

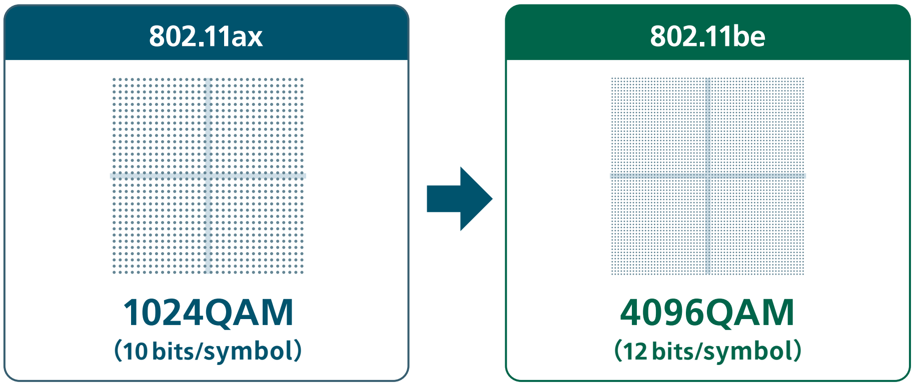


Figure 5: 802.11ax and 802.11be Max. Symbols

20% Increase in Data Rate Compared to 802.11ax

Table 4: 802.11 Modulation Schemes

802.11 Standard	11b	11a	11g	11n	11ac	11ax	11be
Subcarrier Modulation Scheme	DBPSK DQPSK	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM 256QAM	BPSK QPSK 16QAM 64QAM 256QAM 1024QAM	BPSK QPSK 16QAM 64QAM 256QAM 1024QAM 4096QAM

Table 5: Bits per Symbol by Modulation Scheme

Modulation Scheme	BPSK	QPSK	16QAM	64QAM	256QAM	1024QAM	4096QAM
Number of Bits per Symbol	1	2	4	6	8	10	12

The WLAN standard has supported multilevel modulation technologies since 802.11b. Over the generations, more advanced multilevel modulation technologies have been introduced and 802.11be will support 4096QAM as new technology. This will increase the data rate per symbol by 20% compared to 802.11ax.

Spatial Stream (Max.)

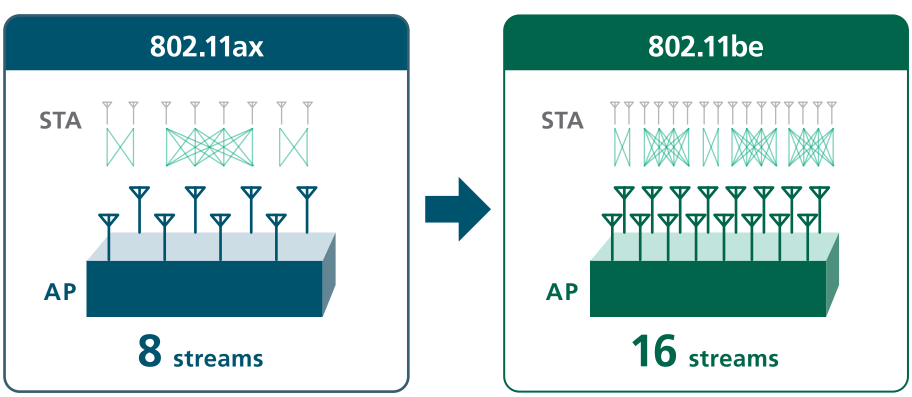


Figure 6: Comparison of 802.11ax and 11be Max. Spatial Streams

100% Increase in Data Rate Compared to 11ax

Table 6: Maximum Number of Spatial Streams in 802.11

802.11 Standard	11b	11a	11g	11n	11ac	11ax	11be
# of spatial streams	na	na	na	4	4	8	16

802.11ax supports the maximum of 8 streams for spatial multiplexing used since 802.11n. 802.11be will support up to 16 streams, doubling the data rate compared to 802.11ax.

MAC Layer

Technologies under consideration for introduction in the MAC include many that did not exist in the pre-802.11ax WLAN standards.

• Multi-band/Multichannel Aggregation and Operation (Multi Link)

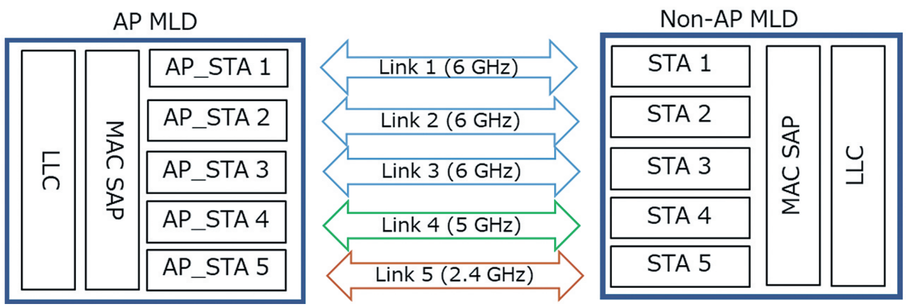


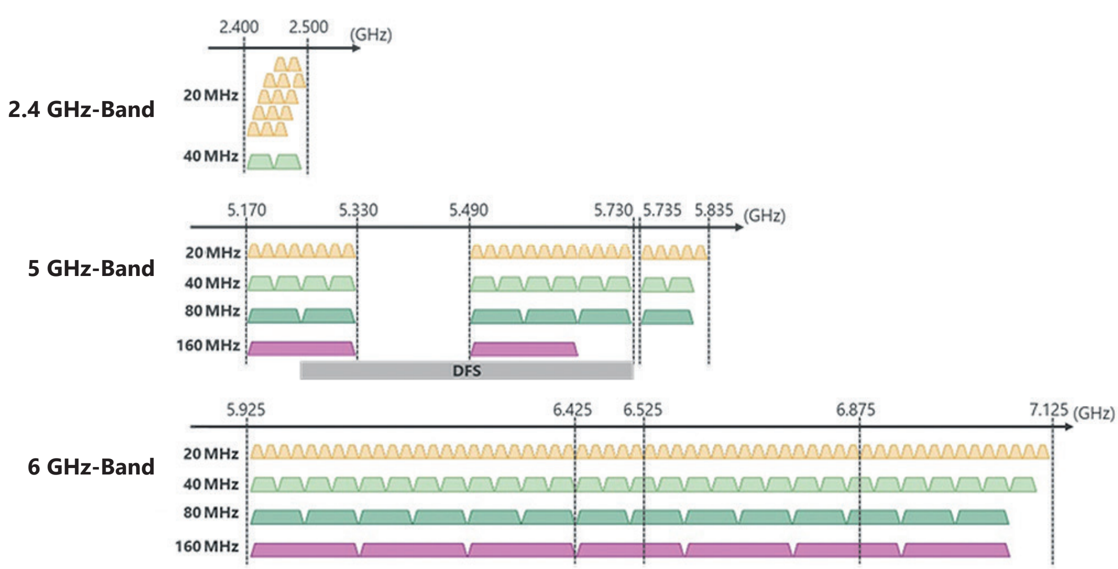
Figure 7: Overview

802.11be defines a multi-link device (MLD) as a new logical entity. An MLD has a single MAC service access point (MAC SAP) and multiple affiliated stations (STAs). It enables WLAN devices to communicate simultaneously in parallel with each other over multiple links. Discussions are under way on the specification in which multiple links can be established in one frequency band or in different bands. It is expected to have better reliability and throughput. Using the multi-link feature in the 6 GHz band, where a wider range of frequencies is available, may achieve a transmission rate of over 100 Gbps.

Table 7: Estimated Data Rate Per Number of Multi-links

# of links	Configuration (Modulation: 4096 QAM, SS: 16 streams)		Max. Data Rate
	Band [GHz]	Channel width Configuration	
2	6	320 MHz × 2 links	92 Gbps
3	6	320 MHz × 3 links	138 Gbps
4	5/6	80 MHz × 1 link + 320 MHz × 3 links	149 Gbps
11	2.4/5/6	40 MHz × 2 links + 80 MHz × 2 links +160 MHz × 7 links	194 Gbps

Frequency Bands Available to 802.11be



The channel configuration for 320 MHz is being considered in the amendment process.

Figure 8: Frequency Bands and Channel Widths Available to IEEE 802.11be

4. Details of Each Technology

• Enhanced Link Adaptation and Retransmission Protocols

Adoption of new advanced error correction technologies such as Hybrid Automatic Repeat Request (HARQ) is under consideration instead of the conventional error correction technologies (Binary Convolutional Coding (BCC), Low Density Parity Check (LDPC)) and automatic retransmission control. Retransmitting only the minimum data required for error correction, instead of retransmitting the entire lost packet when a packet error occurs, is expected to improve frequency utilization and throughput.

• Multi-Access Point (AP) Coordination

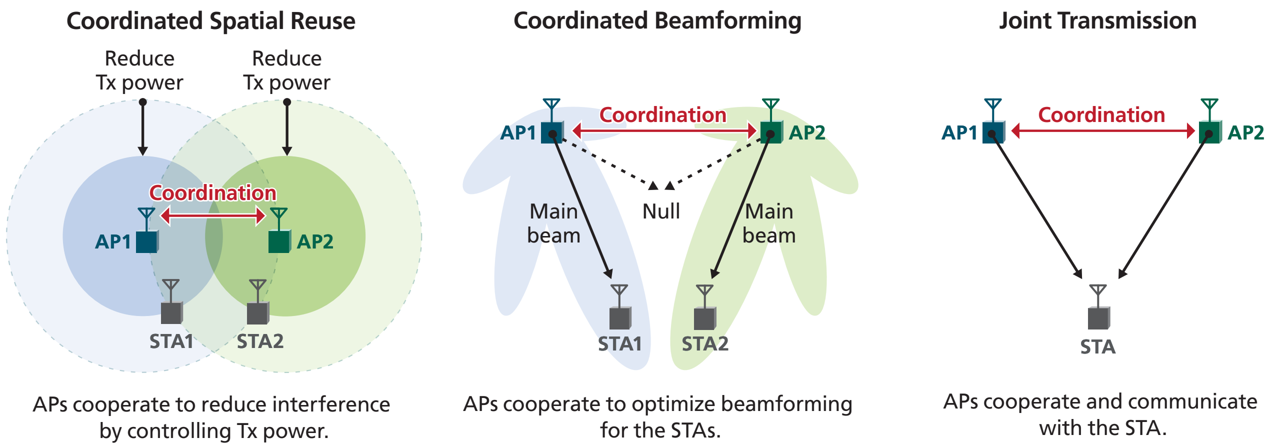


Figure 9: Overview of Multi-Access Point Coordination

IEEE is also considering multi-access point coordination technology for 802.11be, which has not been included in 802.11. Using this technology, adjacent APs on the network cooperate and coordinate to optimize communication with client devices. Previously, multiple APs in close proximity could cause radio-wave interference, so each AP commonly used a different frequency (band channel). 802.11be aims to improve both reliability and communication speed by suppressing radio-wave interference by controlling the transmission power between APs, by beamforming control, and by allowing multiple APs to coordinate and communicate with clients.

5. Status of the 6 GHz Band

The use of unlicensed 6 GHz band has dramatically increased the possibilities of WLAN technology. The 6 GHz band, that is based on the ITU guidelines, is used in many countries for fixed and satellite communication, as well as for broadcasting services. These existing licensed systems are given priority for using 6 GHz band frequencies, and license-free use is permitted only to the extent that it does not interfere with these operations, while coexistence guidelines are still being established.

There are two methods by which countries allocate the 6 GHz band: by freeing-up the full 1200 MHz of spectrum immediately, such as the USA, and by freeing-up the lower 500 MHz (5925 MHz to 6425 MHz) bandwidth first, where frequency coexistence is relatively easy. Discussions on opening higher frequencies are also active in countries that have opened the lower 500 MHz band in advance, and it is expected that WLANs will be able to use the 1200 MHz in many countries in the future. As mentioned above, one feature of 802.11be is the 320 MHz channel width, which is essential to securing vast frequency resources to use this technology.

Devices that support 6 GHz band WLAN are already on the market in the USA. Among the several categories of device types, Low Power Indoor APs and stations are beginning to be used indoors. Just as the 5 GHz frequency band is partly shared with weather radar and other applications, the 6 GHz frequency band is shared with existing fixed and satellite communications services. However, no strict restrictions are imposed for indoor use, and the 6 GHz band is very useful for improving home and office communication environments. The 2.4/5 GHz band conventionally used by WLAN is very crowded due to the spread of *Bluetooth*® and WLAN devices, making the 6 GHz band very useful because it avoids crowding and supports easy communications.

Outdoor use is expected to start with adoption of Automated Frequency Coordination (AFC) enabling coexistence with existing licensed 6 GHz band communication systems.

Also, a "Very Low Power," device type is being considered as a 6 GHz band feature that does not exist in the 2.4/5 GHz band. It is a type of device that attempts to prevent interference with licensed systems by limiting the transmission power to a low level rather than using AFC, and is mainly intended for operation of AR/VR devices. Although not yet approved in the USA, it is still under consideration and might be introduced alongside AFC.

Table 8: International Frequency Allocation in 6 GHz Band

Frequency [MHz]		5925 - 6700	6700 - 7075	7075 - 7145
Primary Allocations	FIXED	✓	✓	✓
	FIXED-SATELLITE	✓	✓	na
	MOBILE	✓	✓	✓

Table 9: US's 6 GHz Band Allocation Policy

Band		U-NII 5	U-NII 6	U-NII 7	U-NII 8
Frequency [MHz]		5925 - 6425	6425 - 6525	6525 - 6875	6875 - 7125
Bandwidth [MHz]		500	100	350	250
Maximum EIRP [dBm]	Standard-Power Access Point (AFC Controlled)	36	na	36	na
	Low-Power Access Point (indoor only)	30	30	30	30

Table 10: EU's 6 GHz Band Allocation Policy

Frequency [MHz]		5945 - 6425
Bandwidth [MHz]		480
Maximum EIRP [dBm]	Low Power Indoor WAS/RLAN Devices	23
	Very Low Power WAS/RLAN Devices	14

Overview of Automated Frequency Coordination (AFC) System

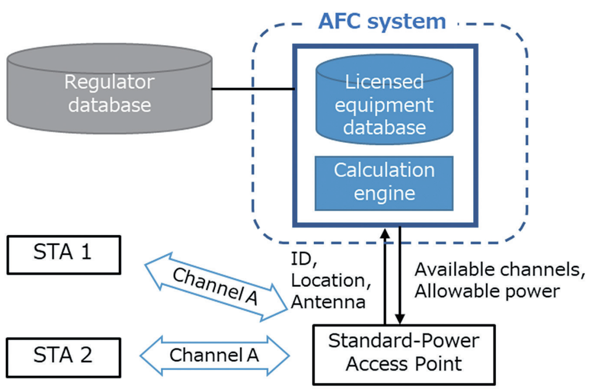
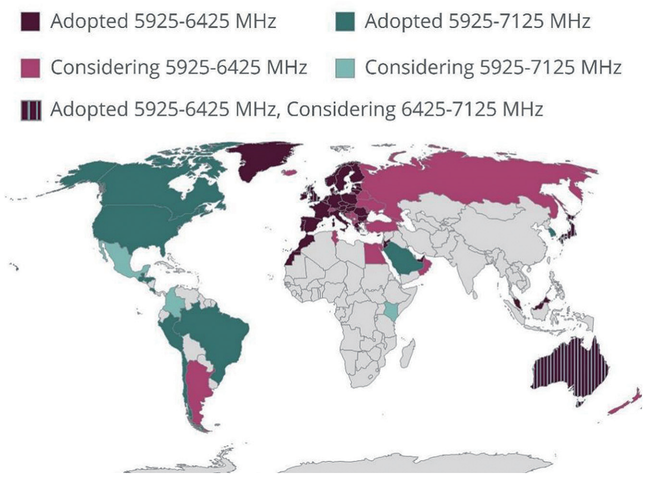


Figure 10: Overview

Before emitting radio waves, the access point notifies the AFC system of its latitude, longitude, altitude, antenna performance information, and more, and inquires whether radio waves in the 6 GHz band can be used at that location. The AFC system determines whether emissions would interfere with licensed systems operating in the vicinity, and if there is an available frequency (channel), it notifies the access point of that information. Access points can only emit radio waves in the 6 GHz band if the AFC system permits them to do so.

5. Status of the 6 GHz Band

Figure 11 shows the global allocation status of the 6 GHz band at May 2022.



Source: Wi-Fi Alliance® https://www.wi-fi.org/countries-enabling-wi-fi-6e

Figure 11: Global Allocation Status of the 6 GHz Band by Region

■ Japan's 6 GHz Band allocation Policy

In Japan, an investigation report on coexistence with current systems and a draft system was presented in April 2022, and it is expected that the release will start from the lower 500 MHz band where there is a high possibility of coexistence. Regarding the higher 700 MHz band, the risk of interference with broadcasting, public, and general business systems has not been eliminated, and continued investigation is planned. Since there are cases where the validity of the simulation model has been questioned, it is expected that the conditions for coexistence will be derived by repeatedly reviewing the simulation model and verifying actual devices in the field.

Table 11: Results of Consideration for Sharing with Existing System (Created from Data on Information and Communication Council of MIC Report)

Frequency [MHz]		5925 - 6425	6425 - 6570	6570 - 6870	6870 - 7075	7075 - 7125
Bandwidth [MHz]		500	145	300	205	50
Existing Systems	Fixed Stations for Telecommunications Business	Possible (LPI/VLP)	Possible (LPI/VLP)	Possible (LPI/VLP)	Possible (LPI/VLP)	Possible (LPI/VLP)
	Fixed Satellites for Telecommunications Business	Possible (LPI/VLP)	—	—	—	—
	Broadcasting Business (Fixed/Mobile)	—	Consideration ongoing	Consideration ongoing	Consideration ongoing	Consideration ongoing
	Public/General Business (Fixed)	—	—	Consideration ongoing	—	—
	Radio Astronomy	—	—	Not possible (6650 - 6675)	—	—

Table 12: Draft 6 GHz band WLAN System Technical Requirements

Frequency [MHz]		5925 - 6425
Bandwidth [MHz]		500
Maximum EIRP [dBm]	Low Power Indoor	23
	Very Low Power	14

Issues Still to Examine

Support for IEEE 802.11be

Promotion of frequency sharing with existing wireless systems

- 5925 – 6425 MHz band
  - Standard power mode frequency sharing premised on introduction of AFC systems
  - Review of sharing conditions, etc.
  - Frequency sharing with narrowband transmission systems with bandwidths of 20 MHz or less using frequency hopping
- 6425 – 7125 MHz band
  - Frequency sharing with broadcasting/public/general business systems
  - Frequency allocation based on WRC-23 and trends in other countries

Advancing beyond

Specifications are subject to change without notice.

• **United States**
Anritsu Americas Sales Company
450 Century Parkway, Suite 190, Allen, TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• **Canada**
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• **Brazil**
Anritsu Eletronica Ltda.
Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• **Mexico**
Anritsu Company, S.A. de C.V.
Blvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• **United Kingdom**
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• **France**
Anritsu S.A.
12 avenue du Québec, Immeuble Goyave,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50

• **Germany**
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1,
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• **Italy**
Anritsu S.r.l.
Spaces Eur Arte, Viale dell'Arte 25, 00144 Roma, Italy
Phone: +39-6-509-9711

• **Sweden**
Anritsu AB
Kistagången 20 B, 2 tr, 164 40 Kista, Sweden
Phone: +46-8-534-707-00

• **Finland**
Anritsu AB
Technopolis Aviapolis, Teknobulevardi 3-5 (D208.5.),
FI-01530 Vantaa, Finland
Phone: +358-20-741-8100

• **Denmark**
Anritsu A/S
c/o Regus Winghouse, Ørestads Boulevard 73, 4th floor,
2300 Copenhagen S, Denmark
Phone: +45-7211-2200

• **Russia**
Anritsu EMEA Ltd.
Representation Office in Russia
Tverskaya str. 16/2, bld. 1, 7th floor., Moscow, 125009, Russia
Phone: +7-495-363-1694
Fax: +7-495-935-8962

• **Spain**
Anritsu EMEA Ltd.
Representation Office in Spain
Paseo de la Castellana, 141. Planta 5, Edificio Cuzco IV
28046, Madrid, Spain
Phone: +34-91-572-6761

• **Austria**
Anritsu EMEA GmbH
Am Belvedere 10, A-1100 Vienna, Austria
Phone: +43-(0)1-717-28-710

• **United Arab Emirates**
Anritsu EMEA Ltd.
Anritsu A/S
Office No. 164, Building 17, Dubai Internet City
P. O. Box – 501901, Dubai, United Arab Emirates
Phone: +971-4-3758479

• **India**
Anritsu India Private Limited
6th Floor, Indiqube ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru – 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• **Singapore**
Anritsu Pte. Ltd.
11 Chang Charn Road, #04-01, Shriro House, Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• **Vietnam**
Anritsu Company Limited
16th Floor, Peakview Tower, 36 Hoang Cau Street, O Cho Dua Ward,
Dong Da District, Hanoi, Vietnam
Phone: +84-24-3201-2730

• **P.R. China (Shanghai)**
Anritsu (China) Co., Ltd.
Room 2701-2705, Tower A, New Caohejing International
Business Center No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• **P.R. China (Hong Kong)**
Anritsu Company Ltd.
Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• **Japan**
Anritsu Corporation
8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• **Korea**
Anritsu Corporation, Ltd.
5FL, 235 Pangyoyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 13494 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

• **Australia**
Anritsu Pty. Ltd.
Unit 20, 21-35 Ricketts Road, Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• **Taiwan**
Anritsu Company Inc.
7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

2106

Printed in Japan 05/AUG/2022 ddcm/CDT Catalog No. Wi-Fi7-E-R-1-(1.00)