Standardization Trends in IEEE 802.11be/bn

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Abstract

We introduce the latest trends in the Institute of Electrical and Electronics Engineers (IEEE) 802.11be (11be), which will be the main standard of the next generation of wireless local area networks (LANs), and the IEEE 802.11bn (11bn), the following primary standard of 11be. The IEEE 802.11 standard is the most used unlicensed wireless LAN system globally, recognized as Wi-Fi. Wi-Fi is implemented in laptop computers and smartphones, Internet of Things devices, and home appliances. Its usage models also extend from consumer markets to business solutions such as industrial automation and intelligent agriculture in the 11bn era.

Keywords: IEEE 802.11bn, IEEE 802.11be, Wi-Fi 7

1. Standardization of IEEE 802.11 WG

The Institute of Electrical and Electronics Engineers (IEEE) 802.11 Working Group (WG) [1] is a group that discusses and decides the technical specifications of the IEEE 802.11 wireless local area network (LAN) systems, recognized as Wi-Fi*. The WG is a subsidiary of the IEEE Standards Association (SA) that covers standardization activities of IEEE. The IEEE 802.11 WG consists of several subgroups, such as Task Groups (TGs), which create technical specifications, and Study Groups (SGs), which clarify the scope and target of TGs. Other subgroup types are Interest Topic Groups (TIGs), which discuss the possibility of standardization for specific topics, Standing Committees (SCs), which discuss general topics of wireless LAN systems, and Ad-hoc groups (AHGs) that address global issues. The technical specification defined by TGs is to be released as the IEEE 802.11xx. Usually, "xx" is a combination of alphabet. Hereafter, we assume that 11xx indicates the technical specification of the IEEE 802.11xx. **Table 1** lists each subgroup of the IEEE 802.11 WG and its topic as of December 2023.

2. Certification of wireless LAN devices by Wi-Fi Alliance

Wi-Fi Alliance [2] is an industrial organization that certifies the interoperability of devices and promotes marketing for wireless LAN systems and devices. Wi-Fi Alliance gives certification of a wireless LAN device on the basis of the IEEE 802.11 standard as Wi-Fi X, which passed the inspection of the test plan on the basis of the corresponding IEEE 802.11 standard. Here, X denotes the corresponding Wi-Fi generation number. For example, a wireless LAN device with Wi-Fi 6/6E certification means that the device has passed the Wi-Fi test plan of the 11ax. A test plan for Wi-Fi 7 is currently being discussed on the basis of the 11be draft standard.

3. IEEE 802.11be: Extremely High Throughput

TGbe is discussing and defining the 11be standard as the main technical specification next to 11ax. The project name of creating 11be is Extremely High Throughput (EHT), and the aims are enabling at least one mode of operation capable of supporting a maximum throughput of at least 30 Gbit/s at the media

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

Table 1. Subgroups of the IEEE 802.11 WG.

Subgroup	Project topic	Completion date
TGbb	Light Communications	June 2023
TGbe	Extremely High Throughput	December 2024
TGbf	Wireless LAN Sensing	March 2025
TGbh	Randomized and Changing MAC Addresses	September 2024
TGbi	Enhanced Data Privacy	March 2026
TGbk	320 MHz Positioning	November 2024
TGme	802.11 Accumulated Maintenance Changes	September 2024
TGbn	Ultra High Reliability	May 2028
AMP SG	Ambient Power	-
AIML TIG	Artificial Intelligence / Machine Learning	-
ARC SC	Architecture	-
COEX SC	Coexistence	-
JTC1 SC	Support Liaison with Joint Technical Committee1 / SC6	-
WNG SC	Wireless LAN Next Generation	-
ITU AHG	International Telecommunication Union Liaison	-

access control (MAC) layer level and defining at least one mode of operation capable of improved worst-case latency and jitter. As well as 11ax, 11be will use the frequency band of 6 GHz in addition to those of 2.4 and 5 GHz. In Japan, a part of the 6 GHz band (5925–6425 MHz) was made available from September 2, 2022.

TGbe was established in May 2019 and will end their standardization activities in December 2024. Draft standard 5.0 was released in December 2023, and almost all specifications of various features are settled. Detailed functions are under review per comments from IEEE 802.11 WG members. The editorial review called Mandatory Draft Review (MDR), which is required to issue the formal IEEE standard, has begun. A ratification vote called Sponsor Ballot (SB) at the IEEE SA level will begin in January 2024. Thus, the status of the standardization process of 11be is in the final phase to be published.

3.1 Main technical features of IEEE 802.11be

New features for improving frequency-utilization efficiency, wider frequency bandwidth, and latency reduction will be defined in the 11be. Multi-link operation is a new feature that was never defined in the old standard before 11ax. Combining these features enables a 2.4 times improvement of the maximum data rate at the physical (PHY) layer from 9.6 Gbit/s (11ax) to 23 Gbit/s (11be). Applying the multi-link operation that enables simultaneous transmissions will enhance throughput at the MAC layer, and 11be aims to achieve a maximum throughput of at least 30 Gbit/s by using this feature. **Table 2** lists the effect of throughput enhancement of 11be compared with 11ax.

(1) Features of frequency-utilization efficiency and wider frequency bandwidth

The 11be standard defines 4096 quadrature amplitude modulation (QAM) as a modulation scheme of each subcarrier of the orthogonal frequency division multiplexing (OFDM) symbol, which achieves a 1.2 times higher modulation rate than 11ax (1024 QAM). In 11ax, a resource unit (RU) that indicates grouped subcarriers in a channel bandwidth of orthogonal frequency division multiple access (OFDMA), is assigned to each station (STA). Multiple RU (MRU) defined in 11be, however, enables the assignment of multiple RUs to an STA. This feature establishes several patterns of RU combinations, allowing for more flexible resource allocation.

(2) Multi-link operation

The 11be standard specified a new feature defined as multi-link operation that was never defined in the old standard before 11ax. In multi-link operation, a wireless device defined as a multi-link device (MLD) can support more than one affiliated STA or access point (AP) and operate using one or more affiliated STAs or APs. This feature enables an AP/STA to bundle multiple transmission paths (links), thus achieves a higher transmission rate in accordance with the number of links. **Figure 1** shows a conceptual image of multi-link operation.

Table 2. Effect of throughput enhancement of 11be.

	Functions	IEEE 802.11ax	IEEE 802.11be	Enhancement from 11ax
PHY layer	Maximum modulation level	1024 QAM (10 bit/subcarrier)	4096 QAM (12 bit/subcarrier)	1.2 times
	Maximum channel bandwidth	160 MHz	320 MHz	2 times
	Maximum number of spatial stream	8	8	Same
	Maximum data rate	9.6 Gbit/s	23 Gbit/s (without multi-link operation)	2.4 times
MAC layer	Multi-link operation	None	Maximum 15 links	In accordance with the number of links

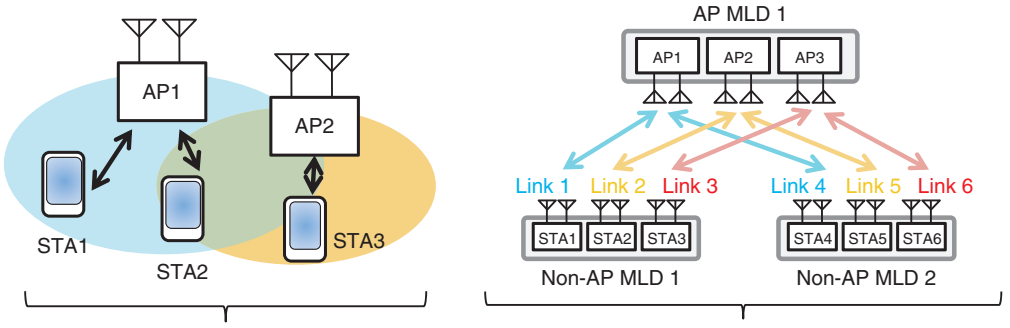

Fig. 1. Concept of multi-link operation.

(3) Feature of latency reduction

In 11be, the latency-reduction feature defined as restricted target wake time (TWT) will be supported. This feature ensures a specific period within the scheduled service period (SP) for latency-sensitive traffic. Therefore, contention between latency-sensitive traffic and non-latency sensitive traffic is reduced, and latency-sensitive traffic generated periodically can be transmitted more reliably.

(4) Other new features

A new peer-to-peer (P2P) feature without setting up any connections between STAs will be defined. In this new P2P feature, called triggered transmission opportunity (TXOP) sharing mode 2, an AP obtains time for P2P transmission representatively, and the designated STA can transmit data frames to the other STA directly. Emergency preparedness communications service (EPCS) will also be defined in 11be. This feature can prioritize the transmission of specific STAs authorized by networks in advance.

3.2 Standardization activities of NTT for 11be

The predecessors of TGbe were EHT TIG and EHT SG, which were launched in 2018 (TGbe was formed in 2019). The focus was initially only on improving maximum throughput, and reducing latency was not included in the scope of 11be. In the subgroup called Real Time Application (RTA) TIG, NTT and several companies discussed and considered latency and jitter reduction for industrial automation, cloud gaming, and so on around the same time as EHT TIG and SG. NTT collaborated with the RTA TIG's leading contributors to create a report document [3] that summarizes RTA TIG's activities. We input this document

into EHT SG and emphasized the importance of latency-reduction features when EHT SG created the Project Authorization Request (PAR), which defines the scope and necessity of the standard, and Criteria for Standards Development (CSD), which describes the significance of the standard and market requirements. This document is referenced not only in 11be but also in the PAR and CSD of 11bn. After the establishment of TGbe, NTT continued to solicit that 11be should have some form of latency reduction and notification of latency related information features. Therefore, 11bn will have a latency-reduction feature, such as restricted TWT, and new signaling information, such as quality-of-service characteristic elements.

4. IEEE 802.11bn: Ultra High Reliability

In parallel with the standardization discussions for 11be, discussions were underway to formulate the next primary standard after 11be. In January 2022, the establishment of a new primary SG following 11be was proposed at the Wireless Next Generation (WNG) SC, which discusses the need for standardization regarding specific functions and topics. After several months of discussion, the Ultra High Reliability (UHR) SG was established and launched in September 2022. The main topic of UHR SG was to create the PAR and CSD for the next generation of wireless LANs following 11be. On the basis of the agreement of creating the PAR and CSD, TGbn was established in November 2023. The standardization of 11bn is scheduled to be completed in May 2028. Though the main scope of the existing primary standards, 11bn or before, is the enhancement of maximum throughput or improving channel efficiency, 11bn focuses on improving the reliability of wireless LANs. Specifically, in the same frequency band as 11be (2.4/5/6-GHz band), latency characteristics, packet loss, and throughput characteristics in received power according to distance will be improved by 25% compared with 11be in 11bn. Improved AP power saving and P2P will also be considered. As of December 2023, UHR SG mainly discusses functional proposals from various companies to achieve the scope described in the PAR and CSD.

4.1 Features under consideration for 11bn

In UHR SG and TGbn, many companies have proposed various features for 11bn as follows. Note that these features have not been decided for technical specifications but are under discussion.

(1) Multi-AP coordination

Multi-link operation defined in 11be enables coordination using multiple wireless interfaces equipped with a single MLD. In contrast, multi-AP coordination improves frequency efficiency and reliability through cooperation between multiple independent APs. This feature had been discussed in early TGbe; however, TGbe decided not to include this feature in 11be specifications due to the timeline compliance and implementation complexity. Therefore, discussions of multi-AP coordination have been taken over by TGbn. Several types of coordination forms are under consideration. Coordinated spatial reuse (Co-SR) controls transmission power to decrease interference to STAs. Coordinated beamforming (Co-BF) enables simultaneous transmission to each target STA of each AP without generating interference by coordinated beamforming and nulling. In joint transmission (JT), multiple APs transmit identical signals simultaneously with synchronization, and a receiver STA can combine multiple identical signals. **Figure 2** shows conceptual images of multi-AP coordination.

(2) Distributed RU

As described in the previous section, the MRU feature was defined in 11be. TGbn is discussing its enhancement to distributed-tone RUs (dRUs). This feature does not assign RUs by several patterns of combinations but freely, which offers more flexibility. For example, the same data block can be assigned to multiple RUs for redundancy, and the reliability of data transmission improves.

(3) Latency reduction

Restricted TWT defined in 11be can protect a specific period for latency-sensitive traffic generated periodically. In addition to the enhancement of restricted TWT, support for non-periodic (sporadic) latency-sensitive traffic is under consideration in 11bn. Preemption can interrupt latency-sensitive traffic into ongoing transmission by the frequency and/or time domain and transmit with priority. A function that ensures transmission of latency-sensitive traffic by using triggered TXOP sharing and enhancement of a buffer status report, which notifies an AP or an STA of the requirement of latency bound in real time, are also considered.

(4) Other features under consideration

Power-saving functions applying multi-link operation and/or multi-AP coordination, extension of area coverage of a wireless LAN network using relay architecture, and enhancement of security functions are under discussion in 11bn.

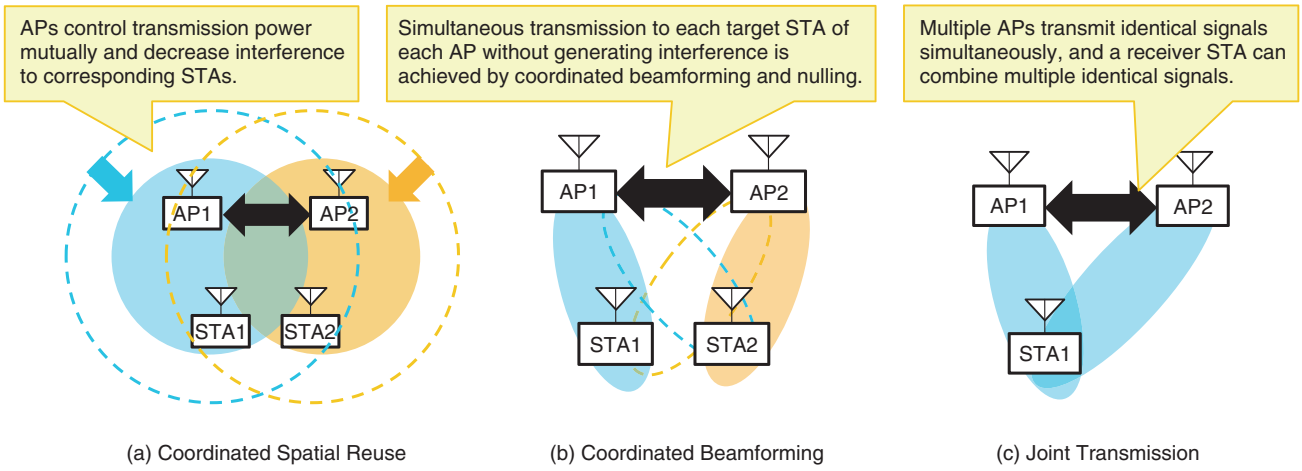

Fig. 2. Conceptual images of multi-AP coordination.

4.2 Discussion on utilizing millimeter wave

Whether to include the millimeter-wave frequency band (60 GHz) as the target frequency in addition to existing frequency bands such as 2.4/5/6 GHz was an important topic in UHR SG, which discusses the scope of 11bn. Although 11ad/ay are standards for wireless LAN systems that use millimeter waves, this discussion topic in UHR SG assumes using millimeter waves as additional links for multi-link operation features, which is unrelated to 11ad/11ay. As a result of the discussion, UHR SG decided that the millimeter-wave band should be discussed in a separate subgroup from TGbn, and the Integrated Millimeter Wave (IMMV) SG was launched in November 2023.

4.3 Standardization activities of NTT for 11bn

NTT has continued to promote the need to improve latency characteristics and reliability in wireless LAN since RTA TIG launched in 2018 and proposes to expand the Wi-Fi market not only for the consumer but also for business use cases requiring certain communication qualities such as low latency. This contribution changed the scope of mainstream wireless LAN standards from improving maximum throughput, such as 11be or before, to improving reliability in 11bn. NTT also proposed the PAR [4] and CSD [5] of 11bn with other companies and contributed to including important business use cases such as industrial automation, robotics, logistics, and smart agriculture in these prospective documents for establishing TGbn [6]. At the same time as the TGbn foundation, Yusuke Asai, a distinguished researcher of NTT, was elected 11bn leadership officer (Secretary).

5. Conclusions

This article explained the standardization trends in and NTT's activities for the next generation of extremely high throughput wireless LAN IEEE 802.11be and the next leading standard after 11be, the ultra-high reliability wireless LAN IEEE 802.11bn.

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