GLOBAL WI-FI 6 TECHNOLOGY INNOVATION AND STANDARD ESSENTIAL PATENT ANALYSIS REPORT

(2022)

Intellectual Property and Innovation Development Center of China

Academy of Information and Communications Technology

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Introduction

With development over the past two decades, the transmission rate provided by the Wi-Fi technology has increased from 2 Mbps to current gigabytes per second. Currently, applications supported have evolved from mere web browsing to HD videos, high-speed downloading, teleconferencing, and so on. In 2013, to further improve system spectral efficiency and throughput in dense device scenarios, IEEE started the standardization of Wi-Fi 6, a next-generation Wi-Fi technology. In 2019, Wi-Fi 6 was officially put into commercial use. Mainstream vendors have launched chips, terminals, and routers that support Wi-Fi 6. Wi-Fi 6 products are gaining popularity in the market since they are launched because of their high performance, low latency, and high rate. According to research of the Wi-Fi Alliance, the market share of Wi-Fi 6 reached 50% in three years. It is estimated that the market share of Wi-Fi 6 products will exceed 80% by the end of 2025.

Along with Wi-Fi 6 standardization and commercial use, major innovators around the world actively develop Wi-Fi 6 patent portfolio to be commensurate with Wi-Fi 6 innovation achievements. To clarify the distribution of global Wi-Fi 6 standard essential patents (SEPs), the Intellectual Property and Innovation Development Center of the China Academy of Information and Communications Technology set up an evaluation panel to evaluate the essentiality of Wi-Fi 6 patents found

through search, to obtain Wi-Fi 6 SEP-related data. Based on the evaluated Wi-Fi 6 SEP-related data, the evaluation panel prepared the *Global Wi-Fi 6 Technology Innovation and Standard Essential Patent Analysis Report (2022)*. Statistics and analysis are made in the report in terms of priority year, legal status, jurisdiction layout, patentee and technology, and so on, demonstrating the global Wi-Fi 6 innovation activities and development trends.

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I. Wi-Fi 6 and Wi-Fi 6 Standardization Process

(1) Introduction to Wi-Fi 6

Nowadays, Wi-Fi technologies have become one of the main manners for hundreds of millions of devices to access the Internet. The Wi-Fi series standards are developed by the Institute of Electrical and Electronics Engineers (IEEE), and IEEE classifies Wi-Fi standards into the 802.11 series. In 1997, IEEE launched the first 802.11 standard, which supports a theoretical maximum data rate of only 2 Mbps. To meet people's needs for higher transmission rates, IEEE released 802.11b/802.11a (1999) and 802.11g (2003). The 802.11n standard released in 2009 introduces new transmission and access technologies to achieve a theoretical maximum transmission rate of 600 Mbps. It is the first 802.11 standard that supports both 2.4 GHz and 5 GHz frequency bands. The 802.11ac standard released in 2013 supports higher-order modulation technologies and higher channel bandwidth. The theoretical maximum transmission rate reaches 6.9 Gbps.

New application scenarios such as telemedicine, industrial Internet, and augmented reality/virtual reality (AR/VR) emerge in recent years, and the increasing number of IoT devices are connected to the network, posing higher requirements on the performance and network capacity of 802.11 standards. To adapt to emerging fields and dense-user scenarios, IEEE started in 2013 the development 802.11ax, a next-generation 802.11

standard.

In 2018, the Wi-Fi Alliance [1], another important international organization in the Wi-Fi field, decided to identify the 802.11 standards with a new naming scheme, to improve the identification and recognition of Wi-Fi technologies. The Wi-Fi Alliance renamed 802.11ax to Wi-Fi 6 by referring to the naming scheme of 2G to 5G cellular mobile communication, and renamed the previous two generations of 802.11 standards 802.11ac and 802.11n to Wi-Fi 5 and Wi-Fi 4. In 2019, the Wi-Fi Alliance launched Wi-Fi 6 interoperability certification and test specifications, marking the first year of Wi-Fi 6 commercial use.

Table 1 802.11/Wi-Fi standards

Standard	Standard Approval Year	Maximum Bandwidth	Theoretical Maximum Rate
802.11ax/Wi-Fi 6	2021	160 MHz	9.6 Gbps
802.11ac/Wi-Fi 5	2013	160 MHz	6.9 Gbps
802.11n/Wi-Fi 4	2009	40 MHz	600 Mbps
802.11g	2003	20 MHz	54 Mbps
802.11a	1999	20 MHz	54 Mbps
802.11b	1999	20 MHz	11 Mbps
802.11	1997	20 MHz	2 Mbps

Source: public information

Wi-Fi 6 provides a theoretical maximum rate of 9.6 Gbps. Key technologies such as orthogonal frequency division multiple access

[1] Another important international organization in the Wi-Fi field, which aims to promote the marketization and interoperability of Wi-Fi products, and is responsible for the certification and trademark authorization of Wi-Fi products.

(OFDMA) and uplink multi-user multiple-input multiple-output (MU-MIMO) are introduced to effectively improve the rate, capacity, and efficiency. Meanwhile, energy efficiency, coverage, and security are also enhanced, meeting user access requirements in dense device scenarios, such as shopping malls, factories, and offices. Wi-Fi 6 also enables deployment in new application scenarios requiring high rate, large capacity, and low power consumption.

(2) Wi-Fi 6 Industry Status Quo

The Wi-Fi 6 industry chain consists of the chip level (upstream), the device level (midstream), and the application level (downstream).

The chip level of the Wi-Fi 6 industry chain mainly includes chips and chip modules. Wi-Fi 6 chips used in wireless network devices and smartphones are mainly from enterprises such as Qualcomm, Broadcom, and MediaTek[2]. Huawei's proprietary Wi-Fi 6 chips, such as Kirin W650 and Gigahome 650, are deployed on multiple Huawei routers and terminals. The significant increase in the Wi-Fi 6 data transmission rate poses higher requirements on the computing power and power consumption of Wi-Fi 6 chips. Currently, Wi-Fi 6 chips generally use the 16 nm, 22 nm, 28 nm, or higher-specification process. According to the prediction of ABI Research[3], the global shipment of Wi-Fi 6 chips is expected to increase from 400

[2] MediaTek is short for MediaTek Inc., which is a global fabless semiconductor company.
[3] ABI Research is a technology intelligence company based in the United States, whose main research fields include mobile communication and Internet of Things (IoT).

million in 2020 to 3.3 billion in 2025. According to the report released by IDC[4], Wi-Fi 6 will take most of share on the Chinese market by 2024, and the market size in China will reach USD 1.1 billion.

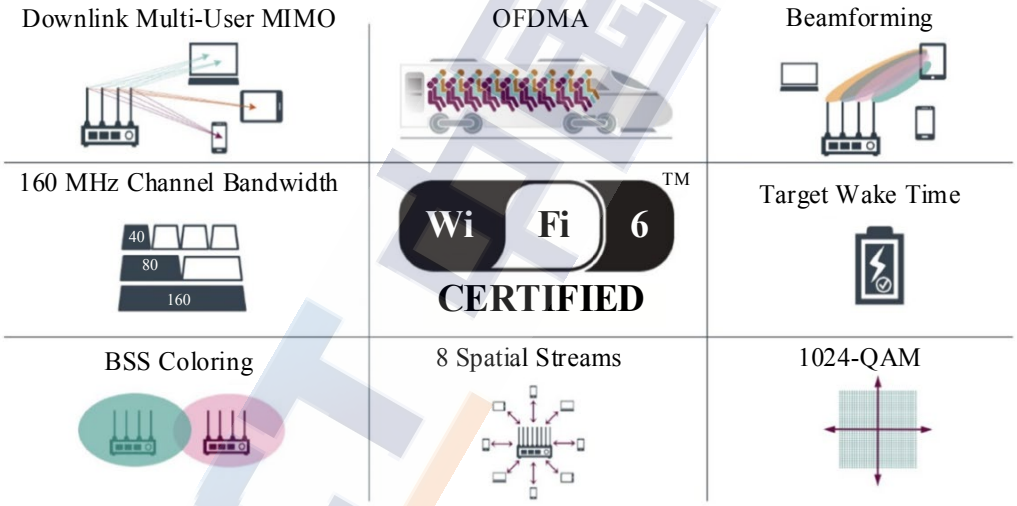
The device level of the Wi-Fi 6 industry chain includes wireless network devices and terminal devices. The wireless network devices mainly refer to wireless routers, which can be classified into home routers and enterprise routers based on application scenarios. Prices of Wi-Fi 6 home routers have gradually dropped from high prices at the beginning of commercial use to reasonable prices, and Wi-Fi 6 has replaced Wi-Fi 5 as the first choice for consumers. The enterprise routers are mainly used in factories, shopping malls, and airports. These application scenarios require Wi-Fi 6 enterprise routers to work with higher stability, security, and automation. Multiple mainstream vendors have offered Wi-Fi 6 deployment solutions for enterprise users. According to the research conducted by the market research company Dell'Oro Group[5], 90% of enterprises are expected to deploy Wi-Fi 6 by 2023. The terminal devices include IoT devices such as smartphones, notebook computers, tablet computers, and smart appliances, and other innovative consumer electronic devices. The enhanced low-power technology of Wi-Fi 6 supports terminal devices in low-power network connections, enabling IoT applications such

[4] IDC is a world-famous provider of information technology, telecommunications industry and consumer technology consultation, advisor and activity services.
[5] Dell'Oro Group is a US market research company that specializes in competition analysis of telecommunications, enterprise network infrastructure, and cyber security.

as smart home, AR/VR, and smart healthcare.

(3) Key Wi-Fi 6 Technologies

To meet requirements of emerging fields and dense user scenarios for efficiency, capacity, and power consumption, Wi-Fi 6 introduces brand-new physical layer design and media access control (MAC) layer design. According to the research report[6] of the Wi-Fi Alliance, Wi-Fi 6 has eight key technical features: OFDMA, MU-MIMO, beamforming, 160 MHz channel bandwidth, target wake time, basic service set coloring, 8-stream spatial reuse, and 1024 quadrature amplitude modulation (1024-QAM).



Source: Wi-Fi Alliance

Figure 1 Eight key technical features of Wi-Fi 6

Wi-Fi 6 uses key technologies, such as OFDMA and MU-MIMO, to improve network efficiency and capacity, the amount of concurrent transmission of devices increases by several times, and adapting to various

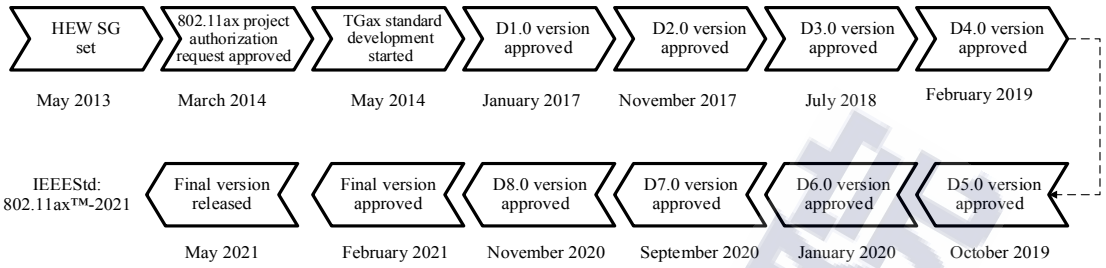
[6] See https://www.wi-fi.org/download.php?file=/sites/default/files/private/Wi-Fi_CERTIFIED_6_Highlights_201910_0.pdf.

high-density deployment scenarios. The beamforming technology concentrates beam energy in a specific spatial range, which can significantly increase the user rate in the specific spatial range and improve the overall network throughput. Wi-Fi 6 supports multiple 160 MHz contiguous channel bandwidths or 80+80 MHz discontiguous channel bandwidths, effectively addressing insufficient Wi-Fi frequency bands. The target wake time (TWT) technology coordinates a communication time between a terminal and an access point (AP). The terminal only needs to wake up at a negotiated wake time, and is in a sleep state at another time. This technology lowers power consumption of the terminal, and reduces contention between terminals. Wi-Fi 6 introduces an intra-frequency transmission identification mechanism, that is, the basic service set coloring (BSS coloring) technology. A terminal identifies co-channel interference based on a BSS coloring field added to a data packet header, effectively reducing co-channel interference and improving multi-device service capability. Wi-Fi 6 supports simultaneous transmission based on 8-stream spatial reuse, further improving space utilization. Wi-Fi 6 provides a higher-order modulation technology, that is, 1024-QAM. Each symbol of 1024-QAM can carry 10 bits of data. Compared with 256-QAM of Wi-Fi 5 where each symbol carries 8 bits of data, Wi-Fi 6 increases data throughput of a single spatial stream by 25%.

(4) Wi-Fi 6 Standardization Process

The Wi-Fi series standards are developed by the 802.11 Working Group (WG) of the Institute of Electrical and Electronics Engineers (IEEE). In May 2013, the 802.11 Working Group established the High Efficiency WLAN Study Group (HEW SG). A main research objective of HEW SG is to improve system spectral efficiency and area throughput in high density scenarios. In March 2014, HEW SG's 802.11ax project authorization request was approved by the IEEE Standards Board. In May of the same year, the Task Group ax (TGax) was established and development of the 802.11ax standard was started[7]. In January 2017, the Draft 1.0 (D1.0) version of the 802.11ax standard was approved. Since then, the D2.0 to D8.0 versions of the 802.11ax standard were approved in November 2017, July 2018, February 2019, October 2019, January 2020, September 2020, and November 2020 respectively. The final version of the 802.11ax standard was approved by the IEEE Standards Board in February 2021 and released in May 2021[8].

[7] See https://www.ieee802.org/11/Reports/tgax_update.htm.
[8] See https://www.ieee802.org/11/Reports/802.11_Timelines.htm.



Source: IEEE

Figure 2 802.11ax (Wi-Fi 6) standardization process

(5) Wi-Fi 6 Proposal Statistics

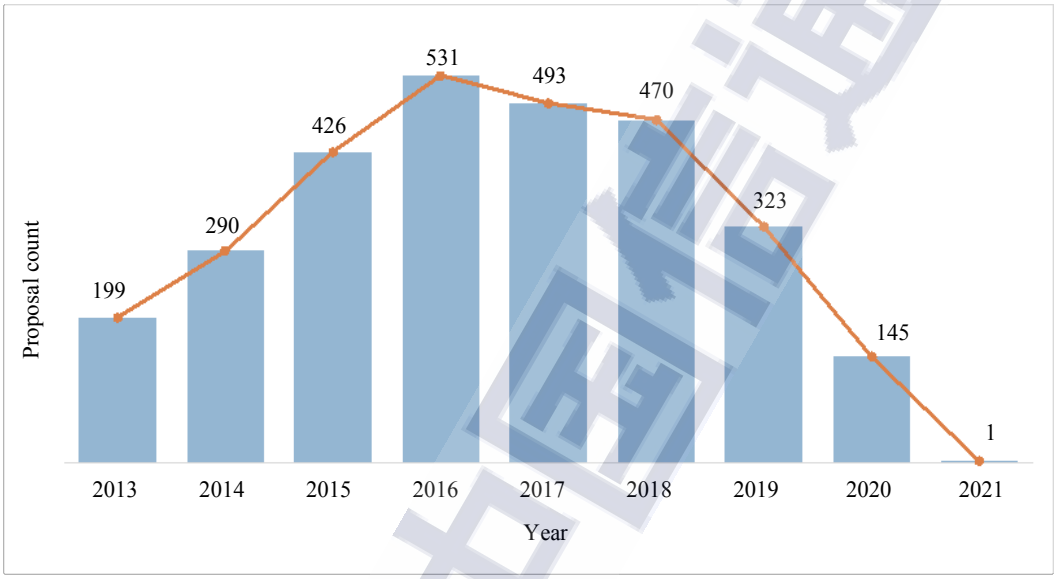
In the 802.11ax (Wi-Fi 6) standardization process, enterprises submit proposals to HEW SG and TGax of IEEE to promote 802.11ax (Wi-Fi 6) standardization. To demonstrate standardization activities of enterprises, the evaluation panel performed a statistical analysis of the 802.11ax (Wi-Fi 6) proposals.

The evaluation panel obtains data of all HEW SG and TGax proposals from the IEEE website[9], and process the proposal data with deduplication and assignee normalization to obtain 802.11ax (Wi-Fi 6) proposal data for statistics.

Enterprises submitted 2878 proposals of 802.11ax (Wi-Fi 6) to HEW SG and TGax from 2013 to 2021. The number of proposals increased year by year between 2013 and 2016 and peaked in 2016. In the same period, the enterprises actively advance development for basic features of the 802.11ax (Wi-Fi 6) standard, including multi-user technology and frame structure design. The first draft version D1.0 of the 802.11ax (Wi-Fi 6)

[9] See https://mentor.ieee.org/802.11/documents.

standard was approved in January 2017. Since 2017, with gradual improvement of the 802.11ax (Wi-Fi 6) standard, the number of proposals has decreased year by year. The final version of the 802.11ax (Wi-Fi 6) standard was approved and released at the beginning of 2021. Since then, no new 802.11ax (Wi-Fi 6) proposal is generated.

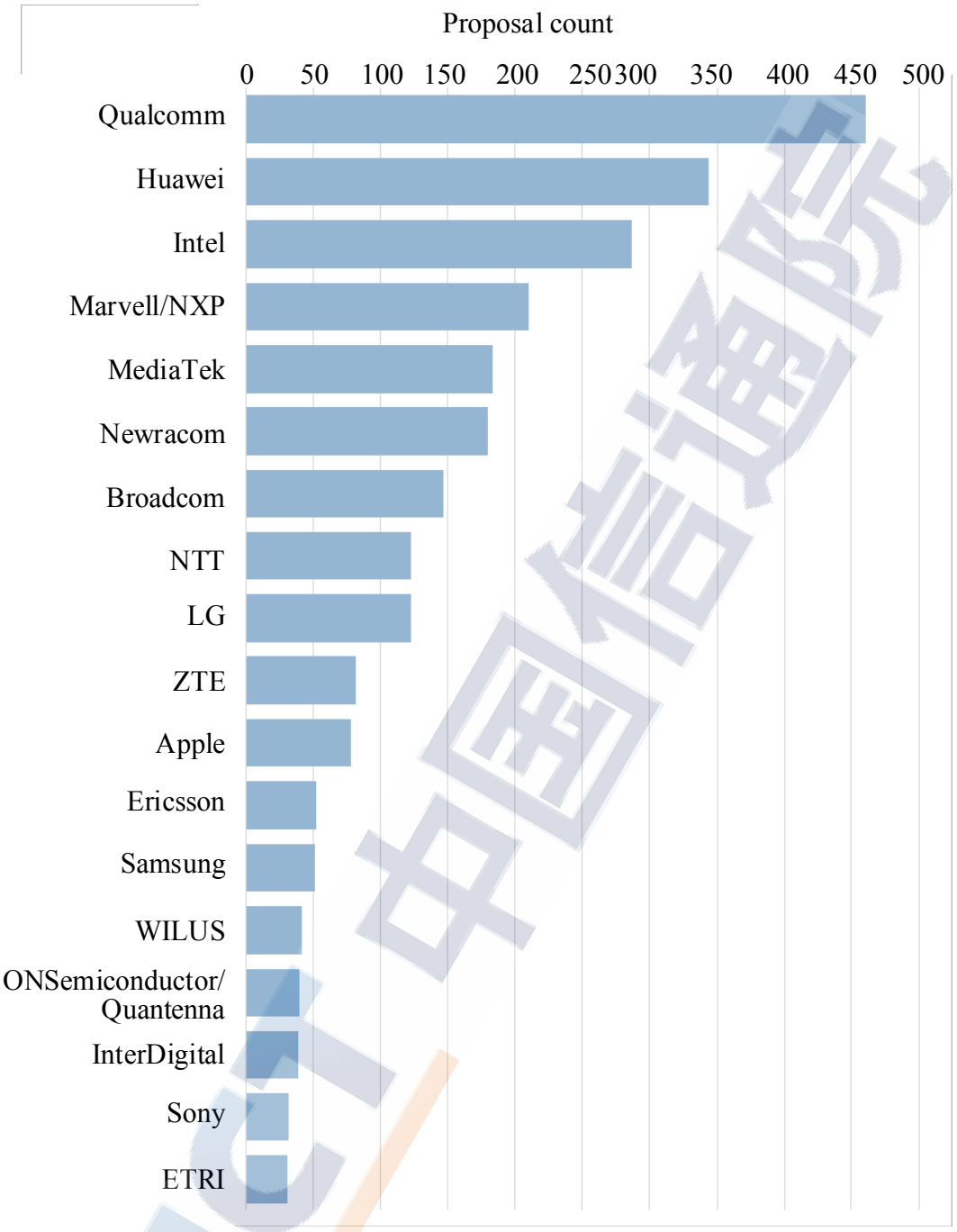


Source: China Academy of Information and Communications Technology

Figure 3 Annual trend of 802.11ax (Wi-Fi 6) proposals

Eighteen enterprises, including Huawei, ZTE, Intel, Qualcomm, Marvell/NXP [10], MediaTek, Broadcom, NTT [11], and LG, are top contributors to 802.11ax (Wi-Fi 6) proposals, who contribute about 87% of all 802.11ax (Wi-Fi 6) proposals.

[10] The Dutch semiconductor vendor NXP (NXP Semiconductors) announced its acquisition of Wi-Fi connectivity services from the US semiconductor vendor Marvell (Marvell Technology) in 2019.
[11] NTT is short for Nippon Telegraph and Telephone Corporation.

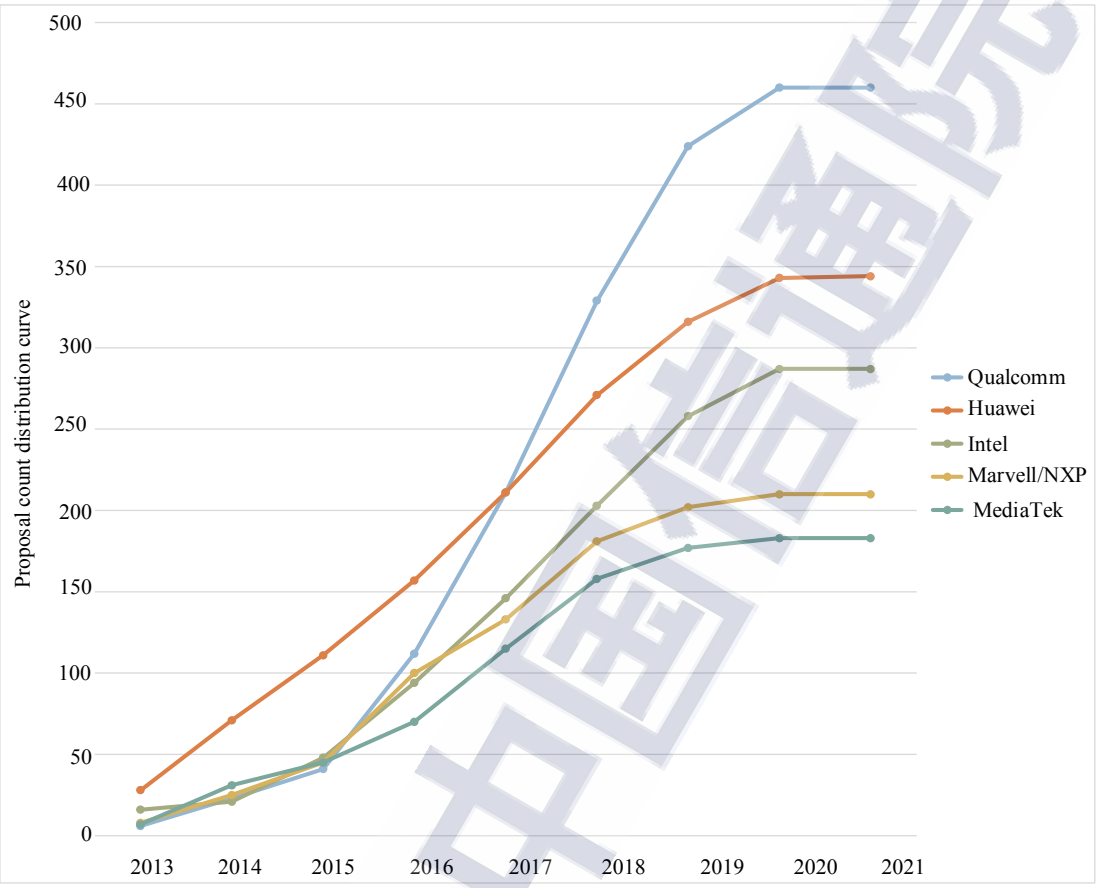


Source: China Academy of Information and Communications Technology

Figure 4 Number of 802.11ax (Wi-Fi 6) proposals

Huawei has been an active participant in the development of the 802.11ax standard since 2013. The number of proposals has increased year by year and ranked first before 2017. After the release of the first draft version D1.0 of the 802.11ax (Wi-Fi 6) standard in 2017, Qualcomm

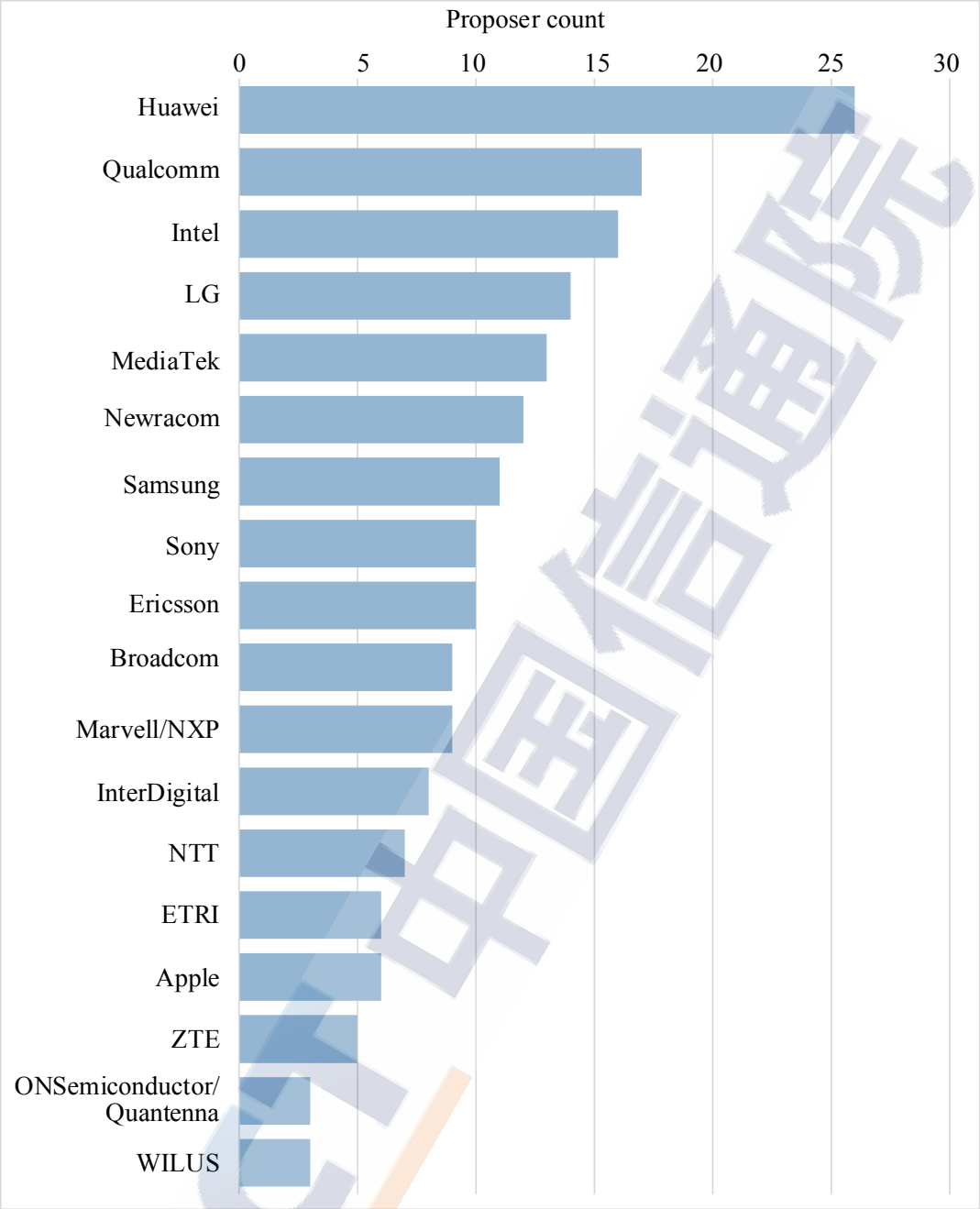
stepped up its participation in standardization, and the number of proposals submitted by Qualcomm exceeded that of Huawei since 2018.



Source: China Academy of Information and Communications Technology

Figure 5 Cumulative number of proposals: Top 5 contributors

To some extent, the number of proposers of an enterprise can reflect the investment of the enterprise in Wi-Fi 6 standards. Among the 18 enterprises that contribute most to Wi-Fi 6 (802.11ax) proposals, Huawei, Qualcomm, and Intel have the largest number of proposers.



Source: China Academy of Information and Communications Technology

Figure 6 Number of proposers: Top 18 contributors

II. Wi-Fi 6 SEP Description

(1) Definition of SEP

In general, an SEP refers to a patent that must be implemented when a standard is implemented, while a technology specified in the standard

falls within the protection scope of the patent. The SEP is sometimes referred to as a standard patent for short. The standard includes international standards, national standards, industry standards, and so on.

(2) Source of Wi-Fi 6 Standards

The full name of the 802.11 series standards developed by IEEE is the Wireless Local Area Network (WLAN) Medium Access Control (MAC) and physical layer (PHY) specifications. IEEE releases the 802.11 standards every four to five years. A later version of the 802.11 standards contains all the contents of the previous version and introduces enhanced technical features defined by IEEE. IEEE approved the 802.11-2020 standard in 2020. This standard is based on the 802.11-2016 standard and includes new features such as bridge network transmission link enhancement and pre-association discovery. The 802.11ax-2021 standard (Wi-Fi 6) is an enhancement to 802.11-2020. Based on the 802.11-2020 standard, 802.11ax-2021 defines the technical feature of "high efficiency wireless local area network (HEW) enhancement".

Therefore, this report uses the IEEE 802.11ax-2021 standard as the source of Wi-Fi 6 standards.

(3) Determining of Wi-Fi 6 Patent Families

In the field of mobile communication, 3GPP[12] is a major organization for developing mobile communication standards. As one of the

[12] 3GPP: 3rd Generation Partnership Project

organizational partners of 3GPP, the IPR policy of ETSI[13] encourages its members to declare what they deem to be SEPs. In contrast, the IPR policy of IEEE allows IEEE participants to submit a *Letter of Assurance* (LOA), and also requires the participants to make a license commitment for potential SEPs they hold. However, the LOA of IEEE does not require the participants to provide specific patent information. Up to now, there is only one declared patent for the 802.11ax (Wi-Fi 6) standard[14]. In this case, patents related to Wi-Fi 6 need to be obtained through patent search.

The evaluation panel takes the following steps to determine patent families related to Wi-Fi 6 that are to be evaluated:

Step 1: Search for Wi-Fi 6 patent data. The evaluation panel constructs a search statement with Wi-Fi 6 name keywords (such as Wi-Fi 6, 11ax, HEW, and TGax), technical branch keywords (such as OFDMA, MU-MIMO, and BSS coloring), and Wi-Fi 6 standard keywords (such as trigger frame, high efficiency long training field, and high efficiency short training field), limits the patent applicants to be the top 18 contributors in terms of proposal contribution, and conducts supplementary search for Wi-Fi 6 patents whose inventors are participant representatives of the 18 contributors. For the search statement constructed according to the foregoing search strategy, International Patent Classification (IPC) numbers are further limited, and noise keywords are removed from titles,

[13] ETSI: European Telecommunications Standards Institute
[14] See https://standards.ieee.org/about/sasb/patcom/patents/.

abstracts, and claims. The search start date (priority date) is January 1, 2011[15], and the search end date (publication date) is July 19, 2021. Finally, after the patent family is expanded in INPADOC based on the search result, Wi-Fi 6 patent search data is obtained.

Step 2: Obtain a Wi-Fi 6 patent family to be evaluated. Obtain Chinese or English published patent from patent families with granted patents from the Wi-Fi 6 patent search data, manually review the relevance between Chinese and English granted patent families and the Wi-Fi 6 standard, and delete patent families that are not related to the Wi-Fi 6 standard to obtain the Wi-Fi 6 patent family to be evaluated[16].

Step 3: Perform essentiality evaluation for each Wi-Fi 6 patent family to be evaluated. Review all Chinese and English granted patents in the family in sequence, and perform a correspondence analysis on each independent claim of the selected patent and corresponding content of the Wi-Fi 6 standard, to determine whether the protection scope of the independent claim covers the corresponding content of the standard, and finally obtain evaluation results of essential Wi-Fi 6 patent families and non-essential Wi-Fi 6 patent families.

Based on the 802.11ax (Wi-Fi 6) standard framework[17], the evaluation panel classifies Wi-Fi 6 technologies into physical layer technologies and

[15] After the patent family is expanded, the priority date of the patent family may be prior to January 1, 2011.
[16] The Wi-Fi 6 patent family to be evaluated refers to a family that contains at least one Wi-Fi 6 granted patent in Chinese or English.
[17] See IEEE Std 802.11ax™-2021 (Amendment to IEEE Std 802.11-2020).

MAC layer technologies. Further, Wi-Fi 6 technologies may be classified based on more specific technical categories, including OFDMA, MU-MIMO, beamforming, channel access, BSS coloring, network allocation vector (NAV), frame structure design, preamble design, pilot design, channel coding, modulation technology, TWT, frame aggregation technology, and other technologies. During the evaluation, the evaluation panel judge the technical category of each Wi-Fi 6 patent family to be evaluated.

III. Wi-Fi 6 Technology Innovation and SEP Analysis

(1) Wi-Fi 6 SEP Overview

The evaluation panel selected Chinese or English granted patents in 2115 Wi-Fi 6 patent families for evaluation. Among them, 606 patent families were evaluated as patent families with essentiality to Wi-Fi 6 standards, including 3564 effective patents/patent applications.

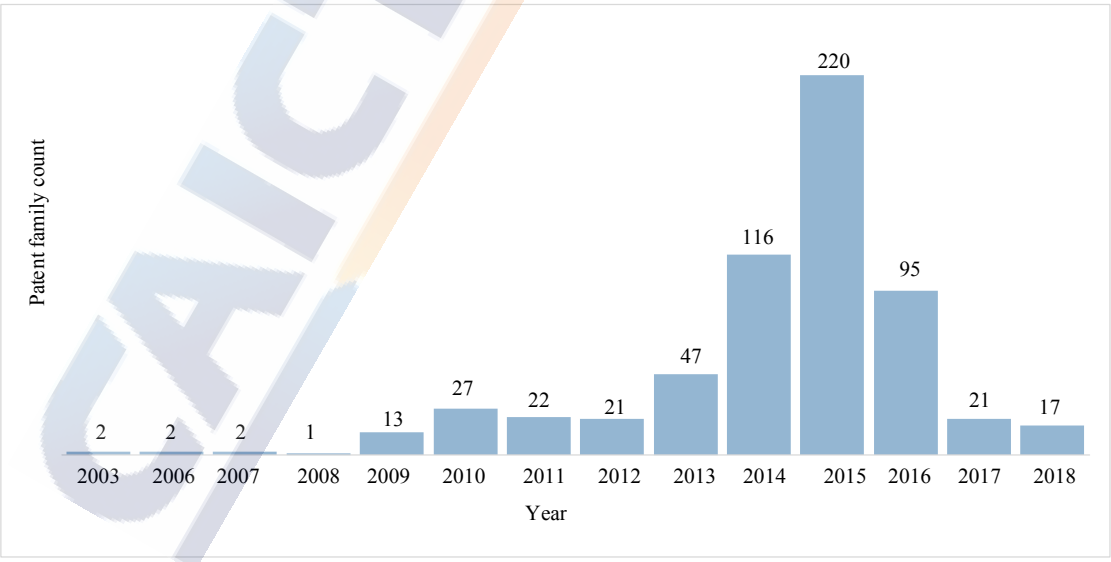
Table 2 Wi-Fi 6 patent evaluation results

Count / Statistical Item	Number of patent families	Number of effective patents/patent applications
Granted patent families that are evaluated	2115	8152
Patent families containing SEPs	606	3564

Source: China Academy of Information and Communications Technology

(2) Priority Year Analysis

According to distribution of the filing date of 606 patent families, before IEEE started the standardization of 802.11ax (Wi-Fi 6) in 2013, enterprises had started the pre-research of Wi-Fi 6 standards and filed a small number of Wi-Fi 6 SEPs. Since 2013, enterprises have been actively participating in the development of Wi-Fi 6 standards, and have been filed Wi-Fi 6 SEPs. The number of Wi-Fi 6 SEPs peaked in 2015 and dropped year by year since then.

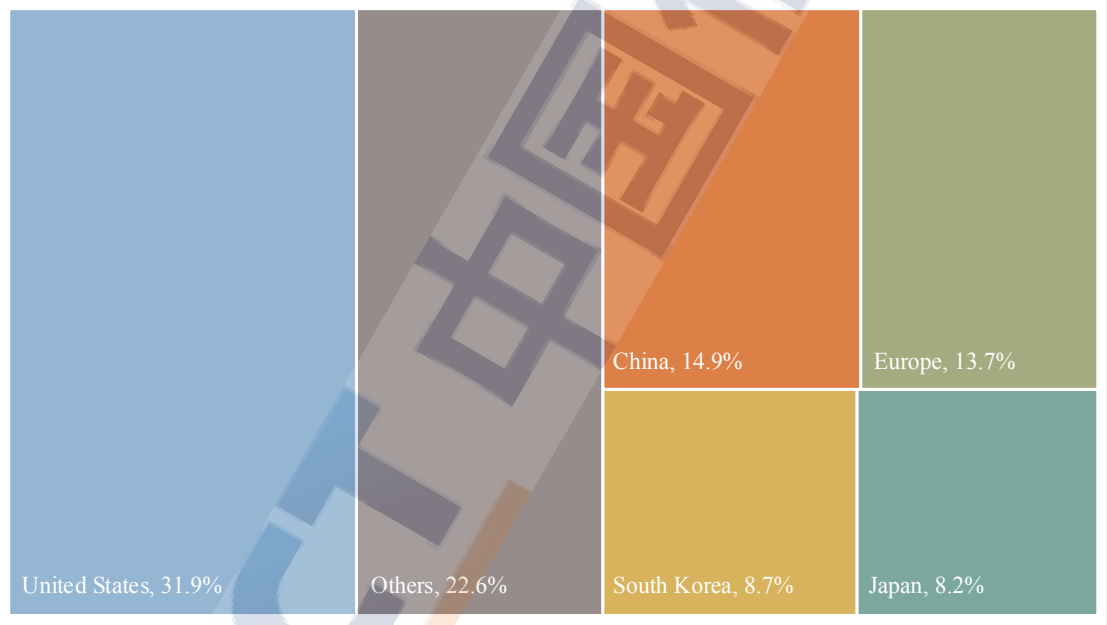


Source: China Academy of Information and Communications Technology

Figure 7 Priority year distribution of Wi-Fi 6 SEP families

(3) Jurisdiction Layout Analysis

Among the 3564 Wi-Fi 6 effective patents/patent applications of the 606 families, the US ranks first in terms of application count, accounting for 31.9%; China ranks second, accounting for 14.9%; and Europe, South Korea, and Japan account for 13.7%, 8.7%, and 8.2% respectively. The other 22.6% of the patents are contributed by other 33 countries or regions, including Brazil, Canada, and Australia who contribute more.



Source: China Academy of Information and Communications Technology

Figure 8 Wi-Fi 6 SEP families jurisdiction layout

(4) Patentee Analysis

Among the enterprises that have contributed to standard proposals, the total number of Wi-Fi 6 SEP families held by eight enterprises exceeds 90% of the total number of Wi-Fi 6 SEP families. The eight enterprises are

Qualcomm, Huawei, Intel, LG, Marvell/NXP, MediaTek, Broadcom, and ZTE. Qualcomm ranks first, accounting for 20.46%. Huawei ranks second, accounting for 20.30%.

(5) Technical Category Analysis

According to technical category distribution of the Wi-Fi 6 SEP families, frame structure design is the technical category with the largest number of patent families. The 802.11ax (Wi-Fi 6) standard has brand-new designs for multiple types of control frames such as trigger frames and block acknowledgment frames and multiple types of management frames such as beacon frames and association request/response frames, so that enterprises can deploy a large number of SEPs in the technical category of frame structure design.

Preamble design is also an important direction of standard improvement, and the number of patent families related to preamble design ranks second. The 802.11ax (Wi-Fi 6) standard introduces brand-new fields such as a high efficiency signal A (HE-SIG-A) and a high efficiency signal B (HE-SIG-B) in a physical layer preamble. Enterprises file related SEPs with focus on format design and processing process of the new fields.

OFDMA is one of the most critical technologies of Wi-Fi 6, and the number of patent families related to OFDMA ranks third. Standards prior to Wi-Fi 6 use the orthogonal frequency division multiplexing (OFDM) technology. In the OFDM technology, different users are distinguished

based on different time periods. In each time period, a user occupies all subcarriers on a channel bandwidth. Even if data transmission of the user does not need to occupy all the subcarriers, an idle subcarrier cannot be scheduled to another user, causing low efficiency of data transmission and a long time delay. Wi-Fi 6 introduces the more efficient OFDMA technology based on the OFDM technology. In the OFDMA technology, the channel bandwidth is further divided into subchannels with a predetermined number of subcarriers, and the subchannels with the predetermined number of subcarriers are allocated to different users, so that multiple users can reuse the channel bandwidth, and frequency domain resources are fully utilized. The introduction of new frame structure design and preamble design is mostly to match the introduction and enhancement of multi-user technologies such as OFDMA and MU-MIMO.

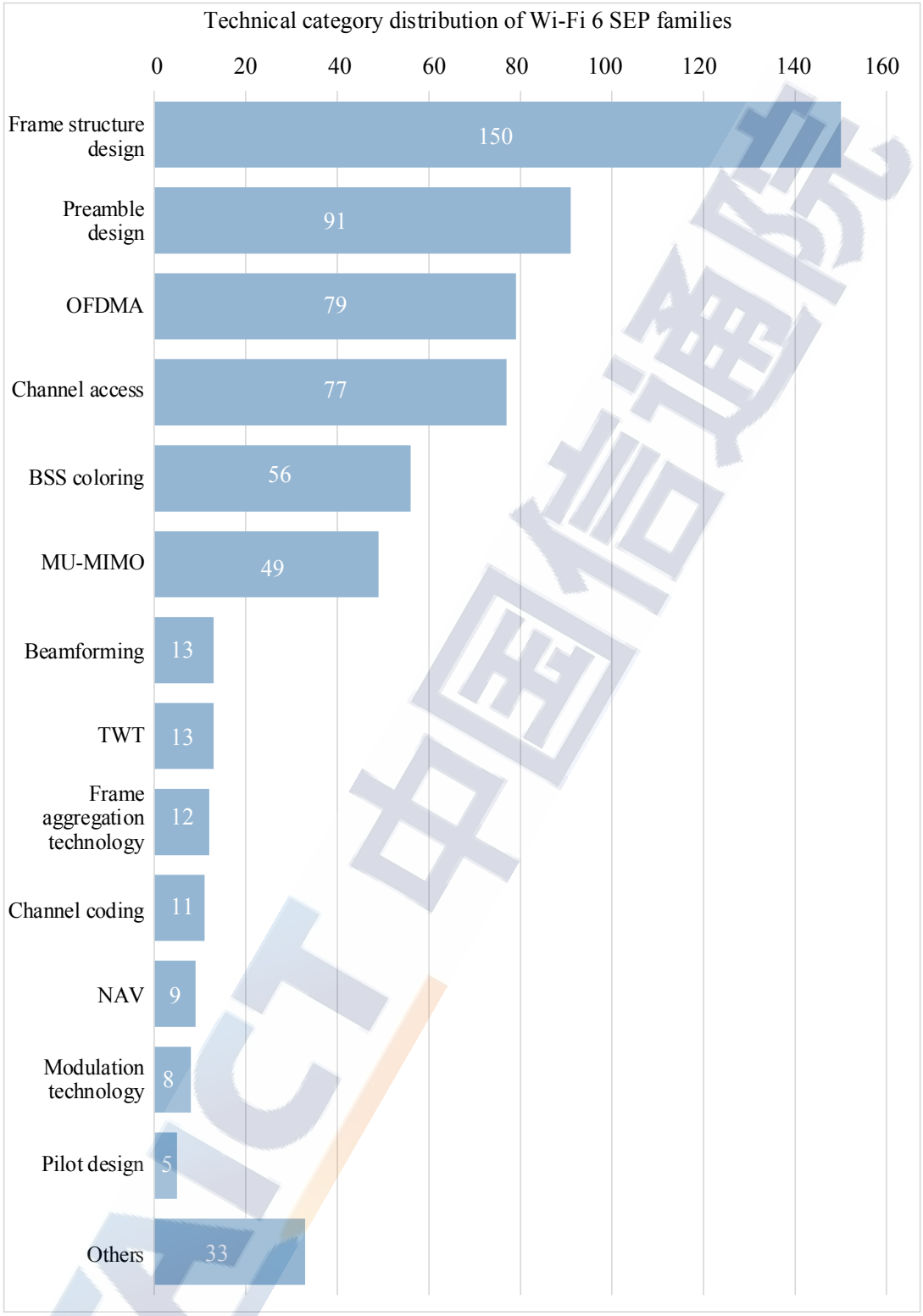
Channel access is an improvement of the user access channel mechanism made in Wi-Fi 6. The improved mechanism schedules data transmission of a specific user by using a trigger frame, so that distributed scheduling prior to Wi-Fi 6 is changed to centralized scheduling in Wi-Fi 6. For the improved channel access mechanism of Wi-Fi 6, enterprises have filed a large number of patents in the mechanism design.

BSS coloring is a new intra-frequency transmission identification mechanism introduced in Wi-Fi 6, and many enterprises file patents in this technical category. In the BSS coloring mechanism, a BSS color field is

added to a physical layer packet header to color data from different basic service sets (BSS). A receive end can identify co-channel transmission interference signals as early as possible by using the BSS Color field.

MU-MIMO is another key multi-user technology of Wi-Fi 6, and there are a large number of patent families in this technical category. The MU-MIMO technology uses same channel resources to simultaneously transmit data to multiple users on multiple spatial streams, bringing multiplexing gains and effectively improving system capacity and user rates. The MU-MIMO technology has been applied to Wi-Fi 5 standards. However, Wi-Fi 5 supports only downlink 4x4 MU-MIMO and does not support uplink MU-MIMO. In addition to downlink MU-MIMO of Wi-Fi 5, Wi-Fi 6 also introduces uplink MU-MIMO and further increases the number in MU-MIMO, so that 8x8 MU-MIMO is supported in both uplink and downlink transmission. That is, a maximum of eight spatial streams can be used to receive data from eight users or transmit data to eight users at the same time.

However, in other technical categories such as beamforming, TWT, frame aggregation technology, channel coding, NAV, modulation technology, and pilot technology, there are less SEPs.



Source: China Academy of Information and Communications Technology

Figure 9 Technical category distribution of Wi-Fi 6 SEP families

In terms of physical layer technologies, Huawei ranked first with

20.59% of physical layer Wi-Fi 6 SEP families, and Qualcomm ranked second with the figure being 17.65%. Specifically, Huawei files many patents in physical layer technologies such as frame structure design, preamble design, and OFDMA. Other follower companies holding physical layer patents include Intel, LG, Marvell/NXP, and MediaTek.

In terms of MAC layer technologies, Qualcomm ranked first with 22.75% of MAC layer Wi-Fi 6 SEP families, and Huawei ranked second with the figure being 20.06%. Other follower companies holding MAC layer patents include Intel, LG, Marvell/NXP, and ZTE.

IV. Conclusion

We analyze global Wi-Fi 6 patent data in this report with standard proposal data supplementing as a reference. We search for Wi-Fi 6-related patents of the top 18 proposal contributors and evaluate the essentiality to the standards. We also analyze the evaluation results in terms of the priority year, legal status, jurisdiction layout, patentee, and technical category to demonstrate the technical innovation activities in the Wi-Fi 6 standard in the information communications industry.

The evaluation results show that among the 2115 Wi-Fi 6 patent families searched and evaluated (published before July 2021), 606 were evaluated as Wi-Fi 6 SEP families. Top holders in terms of patent family count include Qualcomm, Huawei, Intel, LG, Marvell/NXP, MediaTek,

Broadcom, and ZTE. The total number of Wi-Fi 6 SEP families of the eight enterprises exceeds 90% of the total number of Wi-Fi 6 SEP families that are evaluated. From the technical perspective, frame structure design, preamble design, and OFDMA are technical categories with most patents.

It should be noted that this report is intended to analyze the technical innovation activities of the information communications industry in terms of Wi-Fi 6 standards. Although the number of SEPs held by an innovator is strongly related to its standardization activities, other innovators may also hold important Wi-Fi 6 SEPs. In addition, evaluation results vary with time and search strategy. CAICT will follow up and analyze innovation activities in this field and release related research results.

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