Essentiality Report on Wi-Fi 6 Patents

1. Introduction

1.1 What is Wi-Fi 6 (802.11ax)

Today, Wi-Fi is available at home, office, school, restaurants and stores as a matter of course, and Wi-Fi is a well-known technology for everyone.

Wi-Fi standards are set by IEEE (Institute of Electrical and Electronics Engineers), and alphabets after "IEEE 802.11" indicate the generation of the Wi-Fi standards. The official name of the Wi-Fi 6 standard is "IEEE802.11ax". On the other hand, "Wi-Fi" is the brand name used by the Wi-Fi Alliance, an industry group that aims to promote Wi-Fi.

IEEE802.11ax is the latest Wi-Fi standard in practice, and Wi-Fi 6 technology offers benefits such as "higher data rates", "increased capacity", "performance in environments with many connected devices", and "improved power efficiency". In addition, the main functions include OFDMA (orthogonal frequency division multiple access), MU-MIMO (downlink multi-user multiple input, multiple output), Beamforming, 160 MHz (160 MHz channel bandwidth), Target Wake Time, BSS coloring, 8 spatial streams, and 1024-QAM (1024 quadrature amplitude modulation mode).[1]

Thus, Wi-Fi 6 technology can be applied to a wide range of use cases, for example, in a high-density environment with a lot of people in a stadium or an educational site, or with a lot of devices in a manufacturing facility.

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[1] Wi-Fi Alliance, Wi-Fi CERTIFIED 6™: A new era for Wi-Fi®, https://www.wi-fi.org/download.php?file=/sites/default/files/private/Wi-Fi_CERTIFIED_6_Highlights_201910_0.pdf (accessed 2020-08-14)

1.2 Wi-Fi 6 standardization activities in IEEE and Key players

To further improve the efficiency of Wi-Fi, shortly after the release of IEEE 802.11ac (Wi-Fi 5) in March 2013, IEEE 802.11 set up a study group (SG) named as HEW (High-Efficiency Wireless). In March 2014, the IEEE 802 executive committee approved the PAR (Project Authorization Request) of HEW SG and the 802.11 Task Group ax (TGax) was formed to develop the technical specification. IEEE 802.11ax released Draft 1.0 in November 2016, Draft 2.0 in October 2017, Draft 3.0 in June 2018, Draft 4.0 in January 2019, Draft 5.0 in September 2019, and Draft 6.0 in November 2019, and as of now, IEEE 802.11ax is scheduled to be finally accepted as a standard in November 2020.[2]

To understand the key players in the Wi-Fi 6 standardization activities, we analyzed the number of contributions in TGax and HEW SG by using the IEEE official website as shown in Fig. 1. If there are multiple versions in a single contribution, the multiple versions were counted together as one contribution.[3] Fig.1 shows the cumulative number of contributions published each year from 2013 to 2020, i.e., the top 20 contributors up to March 2020. The red bars show a cumulative number of the contributions submitted by November 2016, when the Draft 1.0 was released, and the blue bars show a cumulative number of the contributions submitted after November 2016. The Draft 1.0 defines most of the basic features, and some chipset company started to design new chips around the release of the Draft 1.0[4,5,6]. Huawei was in the leading position before the Draft 1.0 was released. Qualcomm, in the first place in the total ranking, has increased the number of contributions especially after the Draft 1.0 was released.

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[2] IEEE, OFFICIAL IEEE 802.11 WORKING GROUP PROJECT TIMELINES - 2020-02-04, http://www.ieee802.org/11/Reports/802.11_Timelines.htm, (accessed 2020-06-11)

[3] For example, there are six versions of "OFDMA Numerology and Structure" which is contribution of TGax as shown in the following six URLs (IEEE802.11-15/0330r0 to r5), and these versions are collectively counted as one.
 IEEE802.11-15/0330r0 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-00-00ax-ofdma-numerology-and-structure.pptx
 IEEE802.11-15/0330r1 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-01-00ax-ofdma-numerology-and-structure.pptx
 IEEE802.11-15/0330r2 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-02-00ax-ofdma-numerology-and-structure.pptx
 IEEE802.11-15/0330r3 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-03-00ax-ofdma-numerology-and-structure.pptx
 IEEE802.11-15/0330r4 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-04-00ax-ofdma-numerology-and-structure.pptx
 IEEE802.11-15/0330r5 https://mentor.ieee.org/802.11/dcn/15/11-15-0330-05-00ax-ofdma-numerology-and-structure.pptx

[4] Quantenna announced 802.11ax Draft 1.0-compliant Wi-Fi chipset in October 2016, https://www.anandtech.com/show/10772/quantenna-announces-draft-80211ax-wifi-chipset (accessed 2020-06-11)

[5] Qualcomm Announced 802.11ax Draft 1.0-compliant Wi-Fi chipset in February 2017, https://www.qualcomm.com/news/releases/2017/02/13/qualcomm-announces-first-end-end-80211ax-wi-fi-portfolio (accessed 2020-06-11)

[6] NXP Announced 802.11ax Draft 1.0-compliant Wi-Fi chipset in February 2017, https://www.nxp.com/docs/en/fact-sheet/LA1575FAMILYFS.pdf (accessed 2020-06-11)
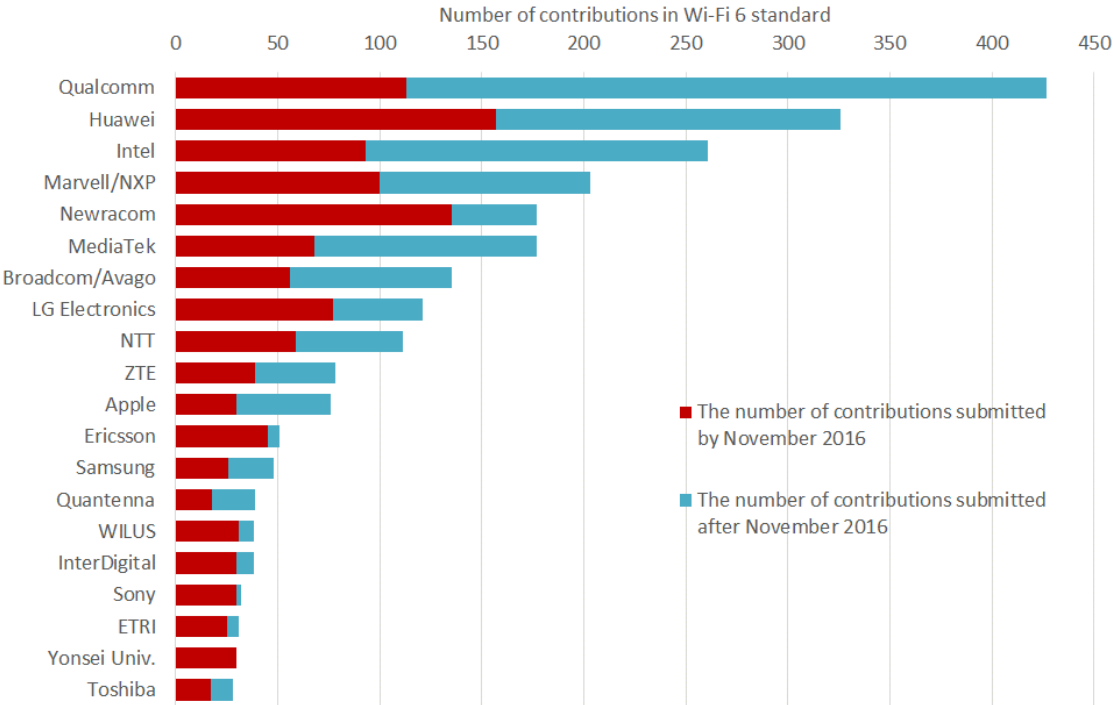
Fig. 1 Number of contributions in Wi-Fi 6 standard: Top 20 contributors

1.3 Purpose of analyzing essentiality of Wi-Fi 6 related patent families and Challenge

We aim to clarify the current status of Wi-Fi 6 SEP (standard-essential patent) families by manually making technical essentiality search to Wi-Fi 6 related patent families.

The terms of "Wi-Fi 6 related patent family" and "Wi-Fi 6 SEP family" used in this report have the following meanings:

Wi-Fi 6 related patent family means an active granted patent family (i) which has at least one granted patent in US, EP, JP, CN and KR as of April 6, 2020, wherein the active granted patent family has a specification including keywords relating to "802.11ax" (e.g., TGax, HEW, 802.11ax), and (ii) which lists at least one participant who attended in TGax from the top 20 contributors in Fig. 1, as an inventor of the active granted patent family.

Wi-Fi 6 SEP family means a patent family having the granted patent of which independent claim(s) substantially read onto features of the target standard as a result of our manual essentiality review of the granted patent in the Wi-Fi 6 related patent family.

This report does not consider the validity of each Wi-Fi 6 SEP.

Our challenge was to identify the Wi-Fi6 related patent families under the situation that almost all of patent holders relating to Wi-Fi 6 technology submitted a blanket declaration without listing any patent according to the IEEE IPR policy[7] (see Item 2.1). For reference, we can easily identify declared patents in 3GPP since patent holders have to specify all patents to be declared according to the ETSI (European Telecommunications Standards Institute) IPR policy[8].

We hope that this report highlights the current situation of the Wi-Fi 6 SEP race, and helps many stakeholders relating to Wi-Fi 6 technology to make more practical discussion and better determination.

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[7] IEEE, Section 6 of the IEEE SA Standards Board Bylaws, https://standards.ieee.org/about/policies/bylaws/sect6-7.html#6 (accessed 2020-08-13)
[8] ETSI, Intellectual Property Rights (IPRs), https://www.etsi.org/intellectual-property-rights (accessed 2020-08-13)

2. Patent Analysis Methodology

2.1 Method of retrieving Wi-Fi 6 related patent families

IEEE permits blanket declarations that do not disclose specific patent numbers in SEP declarations. While blanket declarations provide broader FRAND assurances to patentees, they bring difficulty to see the landscape of SEP ownership by not identifying specific patents.

To retrieve Wi-Fi 6 related patent families, we focused on the top 20 contributors in Fig. 1 (i.e., Qualcomm, Huawei, Intel, Marvell/NXP, Newracom, MediaTek, Broadcom/Avago, LG Electronics, NTT, ZTE, Apple, Ericsson, Samsung, WILUS, InterDigital, Quantenna, ETRI, Sony, Toshiba, and Yonsei University) and took the keywords search strategies to retrieve patents relating to 802.11ax, and also to retrieve patents by using participant names attending the TGax as an complementary. We retrieved the Wi-Fi 6 related patent families which has at least one granted patent in US, EP, JP, CN and KR. We executed the search by using Questel Orbit database on April 6th, 2020.

2.2 Method of essentiality review for Wi-Fi 6 related patent families

In this report, each Wi-Fi 6 related patent family (3874 patent families) extracted by the aforementioned search strategy was determined its essentiality for Wi-Fi 6 standard by comparing with the target standard documents (draft version of Wi-Fi 6 "IEEE P802.11ax™/D6.0" and "IEEE P802.11REVmd/D3.0"). In more detail, the following steps were used to extracting Wi-Fi 6 SEP families.

➢ Step 1 : Relevancy check
  ➢ Our analysts conducted a manual review of Wi-Fi 6 related patent families (3874 patent families) to identify the relevant patent data. The relevancy check of each patent was conducted to ascertain its relevancy to various aspects of the target standard.
  ➢ The relevancy review was performed based on analysis of one representative granted patent per patent family. Further, the review was primarily based on analysis of Title, Abstract, and Claim(s) of each representative granted patent. On a need basis, our analysts also referred to specification of the representative granted patent.
  ➢ For each patent family, the representative granted patent for this step was selected as the latest active granted patent in US, EP, JP, CN and KR as of April 6, 2020.
  ➢ Representative granted patents published in languages other than English was analyzed using machine translated text obtained from Espacenet[9].

➢ Step 2 : Substantive analysis (essentiality analysis and categorization)
  ➢ The relevant patent data from the Step 1 was considered in this phase. The substantive analysis included essentiality analysis and categorization as follows.
  ➢ Essentiality analysis:
    ➢ For determining the essentiality of each relevant patent family from the Step 1, our analysts compared the independent claim(s) of the representative granted patent with one or more technical features present in the target standard. Based on the extent of overlap between the independent claim and the identified features, we determined a Wi-Fi 6 related patent family as essential when the representative granted patent's independent claim(s) substantially read onto features of the target standard.
    ➢ The representative granted patent for this step was selected as the latest active granted patent in US, EP, JP, CN and KR as of April 6, 2020.
    ➢ Representative granted patents published in languages other than English was analyzed

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9 Espacenet, https://worldwide.espacenet.com/

using machine translated text obtained from Espacenet.

➢ Categorization:

   ➢ Each relevant patent family from the Step 1 was manually reviewed and categorized into one or more relevant technical categories listed below.

      ✧ First dimension
- PHY (Physical Layer)
- MAC (Medium Access Control Layer)

      ✧ Second dimension
- OFDMA
- MU-MIMO
- Beamforming
- 160MHz
- Target wake time
- BSS coloring
- 8 spatial streams
- 1024-QAM

   ➢ The categorization was performed based on manual review of one representative granted patent per patent family. Further, the categorization was primarily based on analysis of Title, Abstract, and Claim(s) of each representative granted patent. On a need basis, our analysts also referred to specification of the representative granted patent.

   ➢ For each patent family, the representative granted patent for this step was selected as the latest active granted patent in US, EP, JP, CN and KR as of April 6, 2020.

   ➢ Representative granted patents published in languages other than English was analyzed using machine translated text obtained from Espacenet.

3.Landscape of Wi-Fi 6 SEP families

3.1 Wi-Fi 6 SEP holders ranking

Fig. 2 shows a ranking of the top 8 companies in terms of the number of the Wi-Fi 6 SEP families. Qualcomm and Huawei holding more than 110 Wi-Fi 6 SEP families are in the leading position and followed by Intel, LG Electronics, Newracom, and Marvell. This is mainly because Qualcomm and Huawei have submitted maximum number of contributions in TGax and HEW SG for Wi-Fi 6 (see Fig. 1). The number of the Wi-Fi 6 SEP families of Marvell includes the patent families transferred from Marvell to NXP Semiconductors.[10]

Number of Wi-Fi 6 SEP families (active granted patent famililies)

Company	Count
QUALCOMM	115
HUAWEI	113
INTEL	95
LG ELECTRONICS	88
NEWRACOM	63
MARVELL/NXP	43
BROADCOM/AVAGO	14
MEDIATEK	14
Others	73
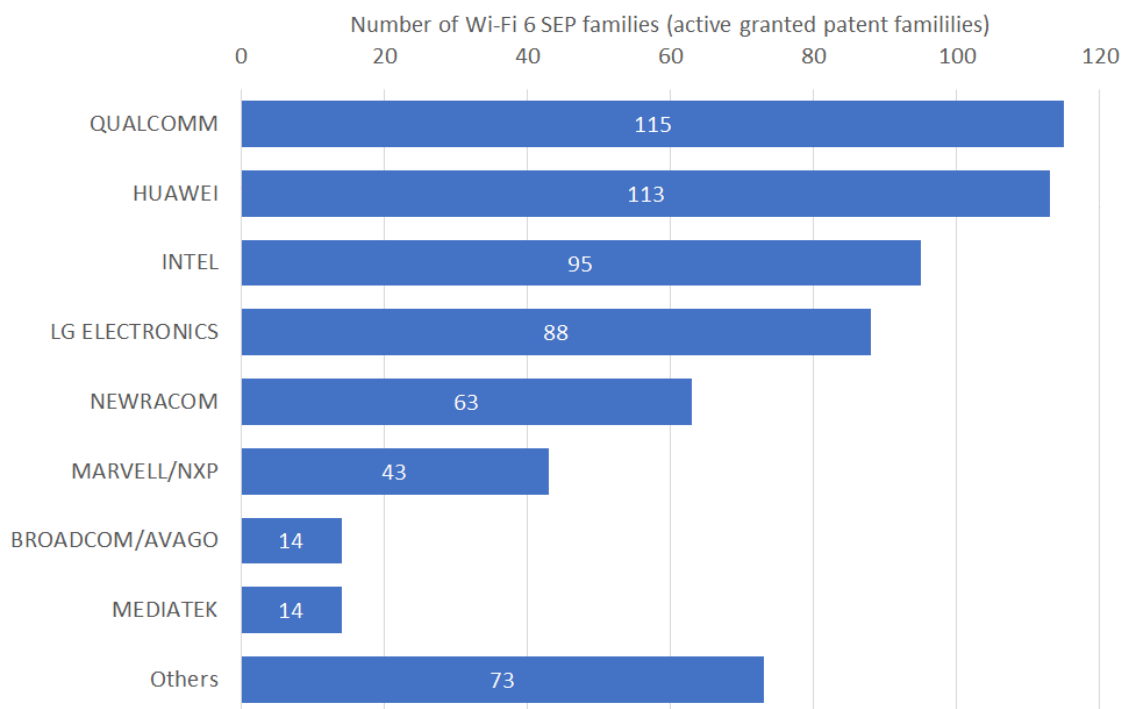
Fig. 2 Wi-Fi 6 SEP holders ranking

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[10] NXP Semiconductors acquired Marvell's Wi-Fi and Bluetooth connectivity assets in 2019.
https://investors.nxp.com/news-releases/news-release-details/nxp-and-marvell-announce-final-regulatory-approval-and-expected/
(accessed 2020-08-21)

3.2 Trend of cumulative number of Wi-Fi 6 SEP families

Fig. 3 shows a trend of a cumulative number of the Wi-Fi 6 SEP families owned by each company in terms of priority year. Because this analysis is based on granted patent families as of April 6, 2020 and does not count patent families having only pending applications under examination, we can see that there are few increase in the number of the Wi-Fi 6 SEP families in the last three years of 2016 to 2018. HEW SG started its activity to consider the improvement of spectrum efficiency to enhance the system throughput/area in high density scenarios of APs and/or STAs in May 2013,[11] TGax discussions started in May 2014,[12] and the first Draft (Draft 1.0) was released in November 2016. Hence, there seems to be an increased number of the Wi-Fi 6 SEP families around the year 2014, 2015, and 2016, as they laid the basic building blocks for the Draft 1.0. Qualcomm and Huawei are top-ranked in terms of the number of the Wi-Fi SEP families filed in and after 2014.
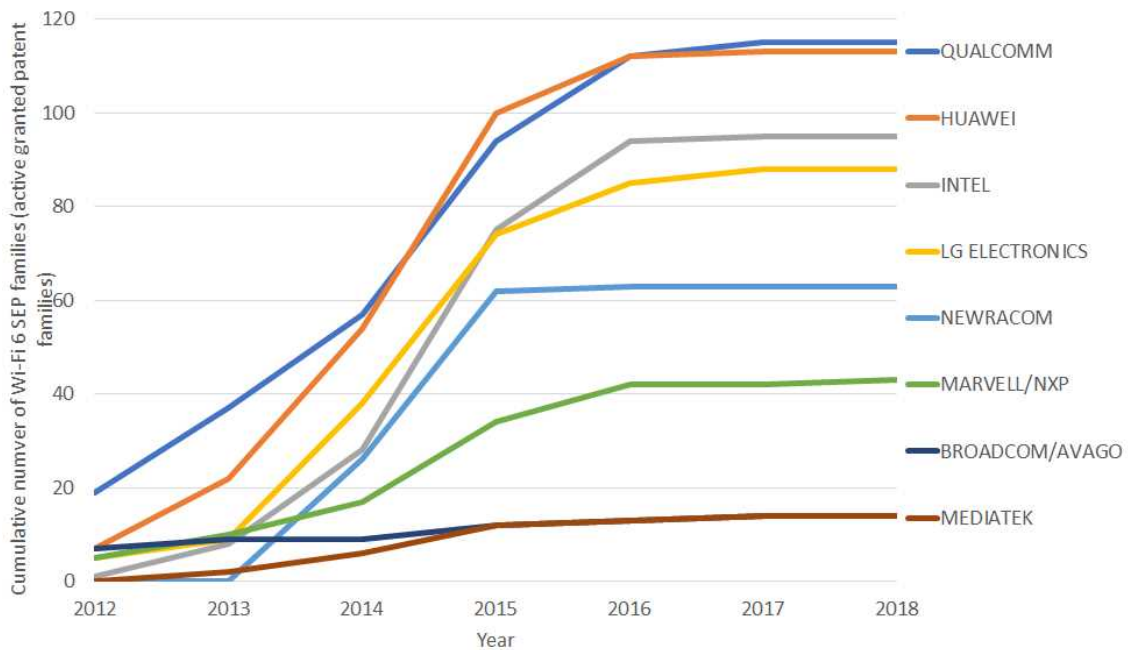

Fig. 3 Cumulative number of Wi-Fi 6 SEP families counted by priority year

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[11] IEEE P802.11 - TASK GROUP AX - GROUP INFORMATION UPDATE, May 2013 - Waikoloa, HI, http://www.ieee802.org/11/Reports/tgax_update.htm#may2013 (accessed 2020-08-24)

[12] IEEE P802.11 - TASK GROUP AX - GROUP INFORMATION UPDATE, May 2014 - Waikoloa, HI, http://www.ieee802.org/11/Reports/tgax_update.htm#may2014 (accessed 2020-08-24)

3.3 Correlation between the number of contributions and the number of Wi-Fi 6 SEP families

Fig. 4 shows that there is a positive correlation between the number of contributions in Wi-Fi 6 and the number of the Wi-Fi 6 SEP families for the top 8 companies, while we can see a diviation depending on companies.
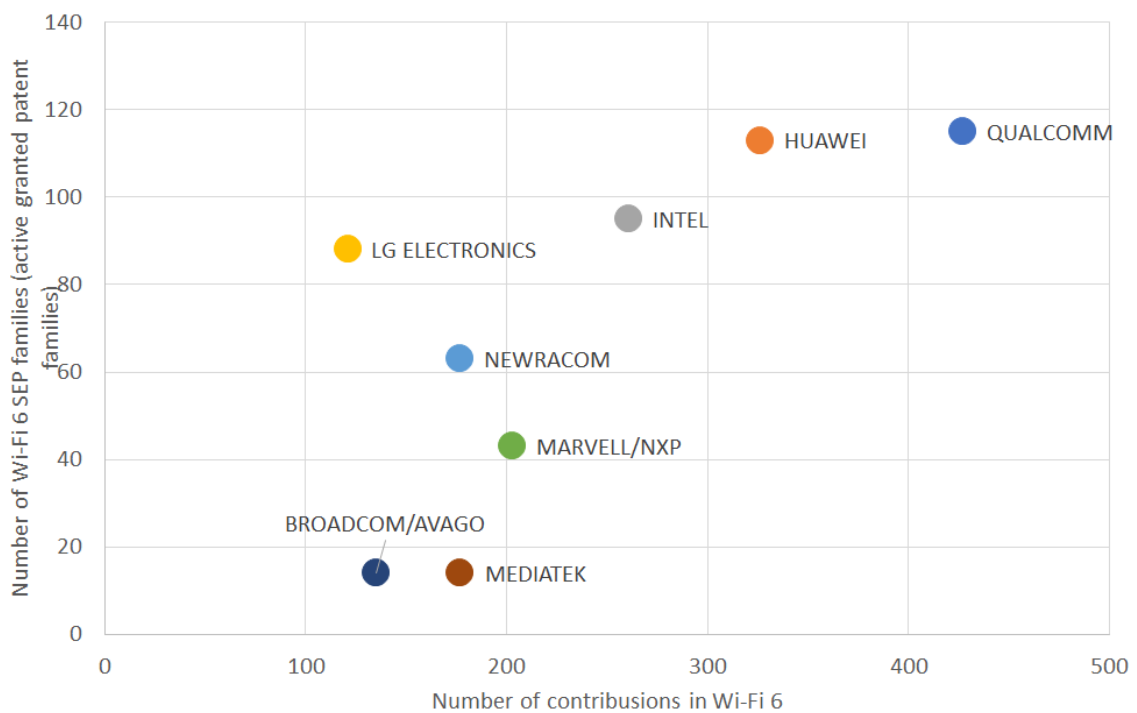

Fig. 4 Correlation between the number of contributions and the number of Wi-Fi 6 SEP families

3.4 Categorization of Wi-Fi 6 SEP families

3.4.1 PHY/MAC

Figs. 5 and 6 show the number of the Wi-Fi 6 SEP families relating to PHY and MAC (i.e., the first dimension) respectively. Huawei is in the leading position in PHY, followed by Intel, LG, and Qualcomm. Qualcomm is in the leading position in MAC, followed by Huawei and Intel.
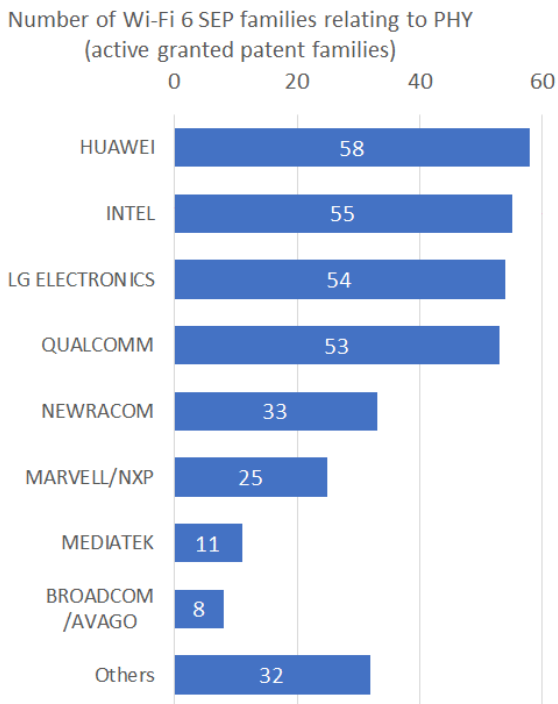

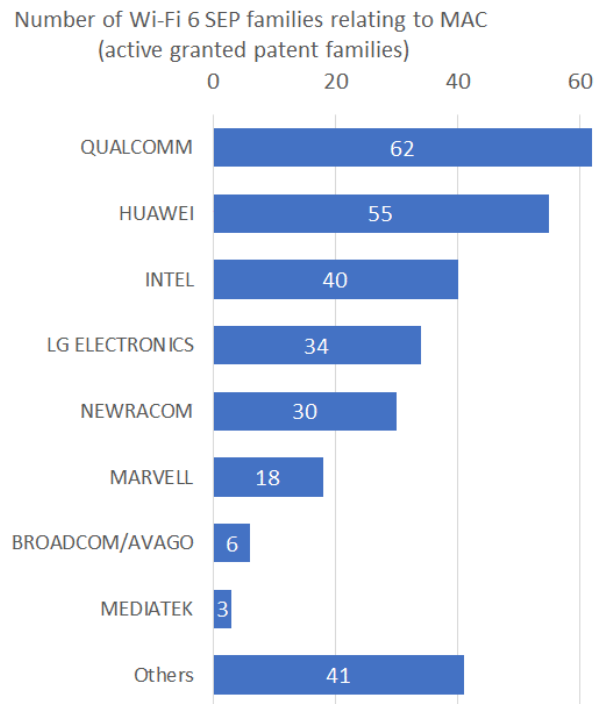Fig. 5 Number of Wi-Fi 6 SEP families relating to PHY

Fig. 6 Number of Wi-Fi 6 SEP families relating to MAC

3.4.2 OFDMA

Fig. 7 shows the number of the Wi-Fi 6 SEP families relating to OFDMA, MU-MIMO, Beamforming, 160MHz, Target wake time, BSS coloring, 8 spatial streams, 1024-QAM. As shown in Fig. 7, OFDMA has the highest number of the Wi-Fi 6 SEP families in the second dimension and contributes more than half of the total Wi-Fi 6 SEP families. Wi-Fi 6 standard specifies an enhancement to MU-MIMO in a previous-generation standard, based on a new access mechanism of OFDMA, so MU-MIMO SEP families have a big overlap with OFDMA SEP families. Therefore, in this section, the analysis focuses on the Wi-Fi 6 SEP families relating to OFDMA.
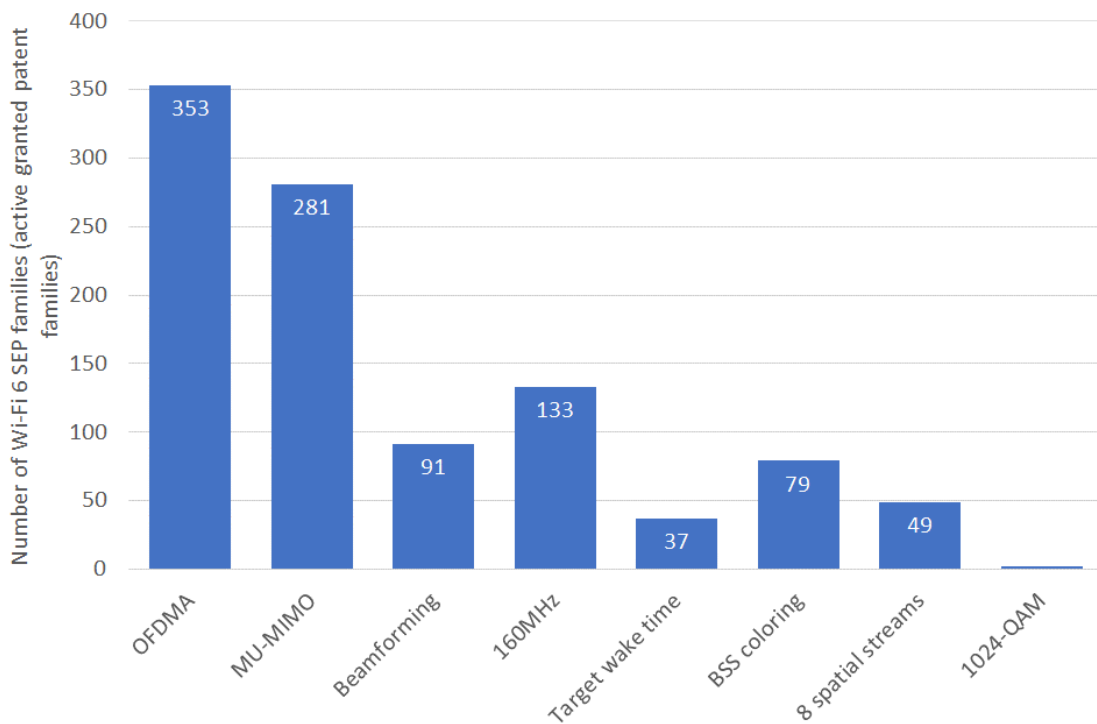

Fig. 7 Number of Wi-Fi 6 SEP families in the second dimension

OFDMA (Orthogonal frequency division multiple access)[13] more effectively shares channels to increase network efficiency and lower latency for both uplink and downlink traffic in high demand environments.

Wi-Fi 6 delivers significantly higher capacity in high-demand environments and enables client devices

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[13] Wi-Fi Alliance, Wi-Fi CERTIFIED 6™ : A new era for Wi-Fi®, https://www.wi-fi.org/download.php?file=/sites/default/files/private/Wi-Fi_CERTIFIED_6_Highlights_201910_0.pdf (accessed 2020-08-24)

to effectively leverage the capacity through various means, particularly spectrum division and bandwidth allocation, to mitigate the effects of contention. Communication with multiple devices for both UL and DL traffic can therefore be scheduled simultaneously.

OFDMA is a multiple access mode in 802.11ax and was first introduced into a Wi-Fi system. Before 802.11ax, the OFDM mode is used for data transmission, and users are distinguished by time segment. During each time segment, one user occupies all subcarriers and sends a complete data packet, as shown in the following figure:
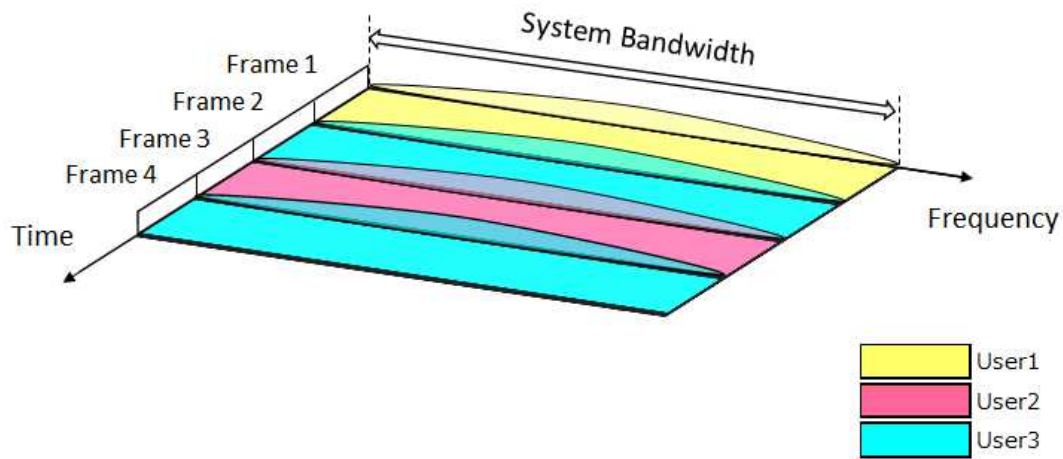

Fig. 8 OFDM working mode

OFDMA is a technology different from OFDM. It allows multiple users to reuse channel resources by allocating subcarriers to different users and adding multiple access in the OFDM system. 802.11ax supports the uplink and downlink MU mode; therefore, this mode can also be called MU-OFDMA.
In addition, the 802.11ax standard defines the smallest subchannel as a resource unit (RU). Each RU includes at least 26 subcarriers, and users are distinguished by time-frequency RUs. The resources of the entire channel are divided into small fixed time-frequency RUs. In this mode, user data is carried on each RU. Therefore, on the total time-frequency resources, multiple users may simultaneously send data on each time segment, as shown in the following figure.
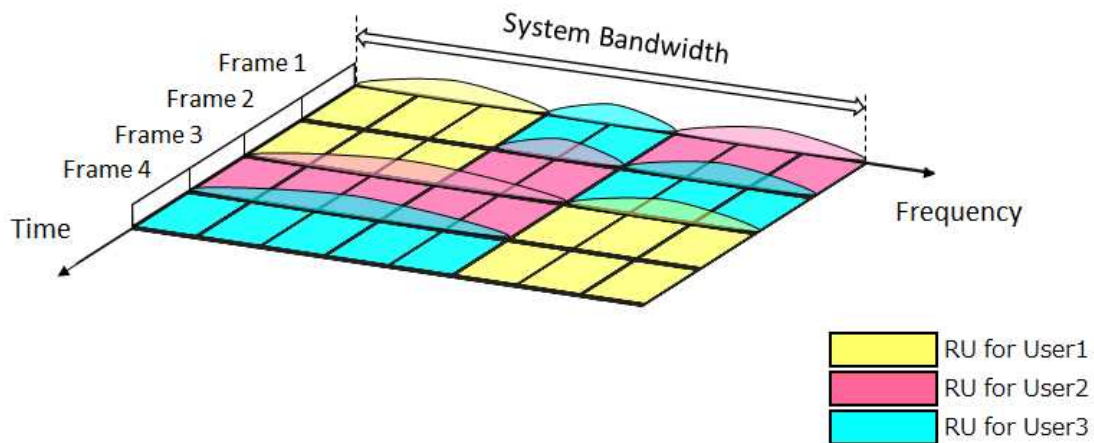
Fig. 9 OFDMA working mode

Compared with the huge and complex system of cellular communication, Wi-Fi system is well known for its simple and convenient system in the industry. Since OFDMA is a relatively complex access technology, a big challenge to be faced when the new access mechanism OFDMA is introduced in both uplink and downlink transmission of Wi-Fi 6 is how to resolve protocol design problems such as resource allocation and signaling indication in Wi-Fi system without adding to much complexity. Therefore, a large quantity of patents are related to OFDMA in Wi-Fi 6. Some article says that the most disruptive innovation in Wi-Fi 6 consists in the adoption of OFDMA for both of the uplink and downlink directions.[14]

Fig 10 shows a ranking of the top 9 companies in terms of the number of the Wi-Fi 6 SEP families relating to OFDMA. Among the top companies, Huawei holds the maximum number of the Wi-Fi 6 SEP families relating to OFDMA, followed by Qualcomm and Intel.

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[14] Evgeny Khorov, Anton Kiryanov, Andrey Lyakhov, and Giuseppe Bianchi, "A Tutorial on IEEE 802.11ax High Efficiency WLANs", IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 21, NO. 1, FIRST QUARTER 2019
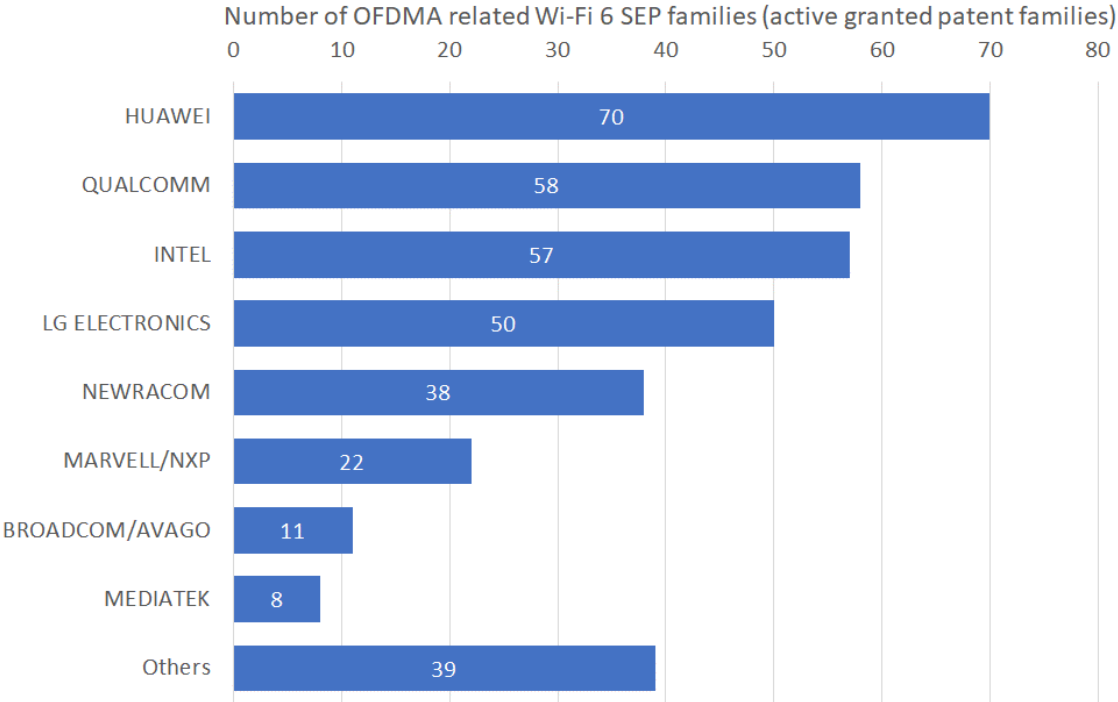
Number of OFDMA related Wi-Fi 6 SEP families (active granted patent families)

Fig. 10 OFDMA related Wi-Fi 6 SEP holders ranking

4.Conclusion

The Wi-Fi 6 is expected to enhance the communication environment in a wide range of use cases. The spread of the Wi-Fi 6 will bring big changes in various industries.

What we have learned from this analysis is as follows;

1. There is a positive correlation between the number of contributions in the Wi-Fi 6 and the number of the Wi-Fi 6 SEP families.

2. Qualcomm and Huawei lead SEP race for Wi-Fi-6 technology followed by Intel, LG Electronics, Newracom, and Marvell.

3. Huawei is in the leading position in the number of the Wi-Fi 6 SEP families relating to PHY, followed by Intel, LG, and Qualcomm. Qualcomm is in the leading position in the number of the Wi-Fi 6 SEP families relating to MAC, followed by Huawei and Intel.

4. OFDMA is a focused area in the Wi-Fi 6 SEPs, and Huawei is in the leading position of the number of the Wi-Fi 6 SEP families in OFDMA, followed by Qualcomm and Intel.

We hope that this report helps many stakeholders relating to Wi-Fi 6 technology to make more practical discussion and better determination.

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