High Quality Network Connection and the Development of Internet of Things Drive the Demand of Wi-Fi-6

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***Abstract*—As the most popular technology, Wi-Fi is built based on Wi-Fi standards in many consumer areas. Up to now, Wi-Fi has experienced more than 20 years of development. The launch of the first generation protocol IEEE802.11 has a low popularity because it is not competitive in transmission speed and distance. With the proposal of the third generation 802.1g protocol, IEEE adds the backward compatibility feature to the new protocol. For 802.11 protocol, new technologies will be adopted in each iteration, so as to improve the network performance. Until the latest generation protocol, IEEE802.11ax launched in September 2019 has been called Wi-Fi 6.**

Wi-Fi-6 has greatly improved its performance. It introduces uplink MU-MIMO, OFDM orthogonal frequency division multiple access, 1024-qam high-order modulation and other technologies to solve the problems of spectrum resource utilization and multi-user access. Even if Wi-Fi-6 continues every new WLAN standard for a long time and only makes the conventional upgrade of single stream throughput, the main motivation behind Wi-Fi-6 is to improve the experience quality of MU-MIMO users and achieve this goal by minimizing the overall delay. Therefore, higher spectrum and the effective and efficient sharing of the spectrum have become the key to achieve the minimum capacity.

This paper also puts forward some views on the cooperation between 5G and Wi-Fi-6. For Wi-Fi networks, it has a faster update cycle than mobile networks. In addition, when users' usage habits are formed, the possibility of Wi-Fi network being replaced is low. Although 5G and Wi-Fi-6 differ in performance, they have their own advantages. They are suitable for different scenarios. 5G will have better performance in outdoor open places, such as car networking, while indoor Wi-Fi network can meet the more economical demand for high-speed Internet access, such as VR, smart home, etc.

In the third chapter of this paper, it focuses on the demand of Wi-Fi-6 driven by the development of high-quality network connection and Internet of things.

First of all, when Wi-Fi-6 was designed, high-density and high-capacity network service support has been considered, which is also the reason for supporting Wi-Fi-6 to be used in outdoor large-scale public places, indoor high-density wireless office and electronic office. However, because 5g has more advantages in the application of outdoor environment, indoor is the key application scenario of Wi-Fi-6. It is also because people's demand for information consumption, entertainment and smart device links has promoted the development of Wi-Fi-6.

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Secondly, the demand for high-quality network connection is prominent. With the promotion of national policies, it will help to speed up the construction of HD video content. As the main carrier of indoor transmission, Wi-Fi will be popularized more effectively when the terminal penetration continues to improve.

Thirdly, the demand for the Internet of things is gradually increasing. Unlike users such as laptops, IOT devices need deterministic wireless services. Therefore, enterprise Wi-Fi-6 has increasingly become the preferred platform for the indoor Internet of things. Compared with Wi-Fi-5 and 4G, Wi-Fi-6 has faster speed and can transmit data like lightning. Moreover, Wi-Fi-6 has improved in security and scalability respectively. The previous Wi-Fi router supports 250 devices to connect at the same time, but this is insignificant in front of Wi-Fi-6 that can support up to 1024 devices at the same time. Therefore, Wi-Fi-6 is ideal and economical for families and small businesses.

Finally, Wi-Fi-6 realizes the intelligent industrial scene. Although 5g and Wi-Fi-6 can now increase the rate to about 10gpbs due to technological improvements. However, because 5g network construction has just started, Wi-Fi-6 currently has greater advantages in the industrial field. Most factories have generally adopted wired network connection to realize Wi-Fi communication.

In the fourth chapter, this paper also summarizes the rapid expansion of Wi-Fi-6 market.

Today, the WLAN market is in a steady upward trend, and the Wi-Fi-6 application scenario is getting better. It is expected that the Wi-Fi-6 market will reach 24 billion yuan in 2023, which means that the chips supporting Wi-Fi-6 standards account for nearly 90% of the total. In terms of market segments, the market scale of router / gateway Wi-Fi-6 chip in China is about 300 million yuan in 2019 and is expected to exceed 4.5 billion yuan in 2023.

In the past two years, the development speed of Wi-Fi-6 is obvious to all. From new mobile phones of major brands to routers, products supporting Wi-Fi-6 technology continue to emerge.

Keyword-WLAN; Wi-Fi-6; 5G; Future Network

I. WI-FI STANDARD CONTINUES TO EVOLVE

A. Wi-Fi is a technology to realize WLAN.

Wireless local area networks (WLAN) uses radio frequency technology and electromagnetic wave to replace network cable, so as to make up for the defect of wired network coverage and achieve the purpose of network extension.

Wi-Fi (wireless fidelity) is a communication technology that conforms to IEEE 802.11 series wireless network specifications and has mutual compatibility. By definition, Wi-Fi is a technology to realize WLAN. Although there are many technologies and standards to realize WLAN, Wi-Fi is the most mainstream technology at present because the common WLAN in the consumer field is built based on Wi-Fi standards.

B. Development history of Wi-Fi

Wi-Fi has been developed for more than 20 years. 802.11 protocol began in the 1990s. In the early 1990s, the Institute of electrical and Electronics Engineers (IEEE) established a relevant working group to study and formulate the standard keeping protocol of WLAN [1]. Over time, different versions of 802.11 protocol are iterated to meet the network requirements.

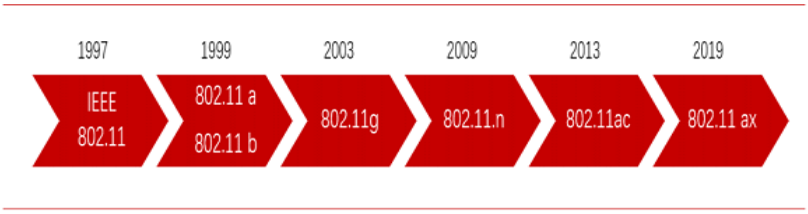

Figure 1. Important development history of 802.11 protocol

The first generation protocol IEEE 802.11-1997 was launched in June 1997, but its popularity is low because it is not competitive in transmission speed and distance. Later, IEEE 802.11 a / b protocol was introduced, in which 802.11 a protocol set the frequency band at 5GHz, and its maximum speed in the IOT layer was greatly improved to 54Mbps, but its development was limited due to slow chip development and other reasons; 802.11b protocol is based on 2.4GHz. Although its transmission speed is lower than 802.11a, it has better coverage and penetration. Because 802.11 a / b protocol was incompatible and B protocol was better in practicability, it occupied the market at that time.

802.11 g protocol is the third generation standard formulated by IEEE in July 2003. It integrates two versions of the previous generation protocol and can realize transmission at 2.4GHz and 5GHz. In addition, since this generation of protocols, IEEE has added the feature of backward compatibility to the formulation of new protocols to facilitate practical use. Due to the rise of streaming media and other services and the increasing demand for bandwidth by families and enterprises, the previous generation protocols have been unable to meet the use requirements. Therefore, a new generation protocol 802.11 N was launched in 2009. Based on 2.4GHz, it uses technologies such as multiple input multiple output (MIMO), beamforming and 40MHz binding, which makes the transmission distance longer and the rate up to 600mbps.

Over time, a growing number of protocols use 2.4GHz frequency band for transmission, and the available bandwidth is severely compressed. Therefore, the fifth generation protocol 801.22 AC focuses on 5GHz band optimization. In this generation protocol, the working bandwidth and frequency modulation efficiency of a single channel are improved while maintaining good backward compatibility. In addition, it supports multi-user multiple input multiple output (MU-MIMO). MU-MIMO routing signals can be split in multiple dimensions; Compared with the previous generation MIMO technology, it can realize parallel processing. The introduction of related technologies not only improves the real-time transmission rate, but also optimizes the network resources.

At present, 802.11 ax protocol is the latest version, which will be launched in September 2019. Compared with 802.11 AC. In addition to further optimizing the 5GHz frequency band, the protocol also pays attention to the 2.4GHz frequency band. For 802.11 protocol, new technologies are introduced in each iteration to improve the network performance.

TABLE I. IEEE802.11 PROTOCOL OF EACH GENERATION

Protocol Code	Frequency (Ghz)	Signal	Release Time	Performance Evolution
802.11	2.4	FHSS/DSSS	1997	It is one of the first generation wireless LAN standards
802.11a	5	OFDM	1999	Teee802.11a provides higher speed in the whole coverage range, and the specified frequency point is 5GHz. At present, the frequency band is not used much, and there is less interference and signal contention. 802.11a also adopts CSMA / Ca protocol. However, in the physical layer, 802.11a adopts orthogonal frequency division multiplexing
802.11b	2.4	HR-DSSS	1999	It can be used not only as a supplement to the wired network, but also as an independent network, so that network users can get rid of the constraints of network cables and realize real mobile applications. One of the key technologies of IEEE 802.11b is the use of compensation code keying CCK modulation technology, which can realize dynamic rate conversion.
8002.11g	2.4	OFDM	2003	The mission is to give consideration to 802.11a and 802.11b and pave the road and bridge for the transition from 802.11b to 802.11a. The modulation modes specified in 802.11g include OFDM used in 802.11a and CCK used in 802.11b. By specifying two modulation modes, it not only achieves the data transmission speed of IEEE802.11a 54mbit / s with 2.4GHz frequency band, but also ensures the compatibility with IEEE 802.11b products.
802.11n	2.4/5	OFDM	2009	The theoretical rate can be up to 600mbps. 802.11n can work in two frequency bands of 2.4GHz and 5GHz.
802.11ac	5	OFDM	2013	802.11ac is the successor of 802.11n. It adopts and extends the air interface concept derived from 802.11n, including wider RF bandwidth (up to 160MHz), more MIMO spatial streams (up to 8), multi-user MIMO and higher-order modulation (up to 256qam)
802.11ax	2.4/5	OFDMA	2019	Orthogonal frequency division multiple access, multiuser multiple input multiple output, high-order modulation, target wake-up time

Wi-Fi alliance promotes the development of relevant standards. The predecessor of Wi-Fi alliance is the wireless Ethernet Compatibility Alliance (WECA) [2]. In 1999, in order to promote the formulation of IEEE 802.11b specification, the wireless Ethernet Compatibility Alliance was formed. In addition, the alliance also provides verification services for products that meet relevant standards to solve the compatibility problems between different devices, so as to promote the development of IEEE 802.11 protocol. In 2002, WECA was renamed Wi-Fi alliance. At present, Wi-Fi alliance has named some standards the scale is simplified, in which the latest generation protocol IEEE 802.11 ax is called Wi-Fi 6 [3]; IEEE 802.11 AC is called Wi-Fi-5.

C. Innovation and optimization of Wi-Fi-6

The performance of Wi-Fi-6 has been greatly improved. With the increasing number of application scenarios such as video conferencing and mobile teaching, the number of terminal devices using the network is also rising. The increasing number of terminal devices will affect the network efficiency. At present, Wi-Fi6 [4] introduces uplink MU-MIMO, OFDMA orthogonal frequency division multiple access, 1024-qam high-order modulation and other technologies, which will solve the problems of

network capacity and transmission efficiency from the aspects of spectrum resource utilization and multi-user access. The goal is to increase the average throughput of users by at least four times and the number of concurrent users by more than three times compared with today's Wi-Fi-5 in a dense user environment.

TABLE II. COMPARISON OF VARIOUS SPECIFICATIONS OF WI-FI 4-WI-FI 6

	Wi-Fi 4	Wi-Fi 5		Wi-Fi 6
Agreement	802.11n	205.11ac		802.11ax
		Wave 1	Wave 2	
Operating frequency band	2.4/5GHz	5GHz		2.4/5GHz
Maximum bandwidth	40MHz	80MHz	160MHz	160MHz
Maximum modulation	64QAM	256QAM		1024QAM
Single stream bandwidth	150Mbps	433Mbps	867Mbps	1201Mbps
Maximum spatial flow	4X4	8X8		8X8
MU-MIMO	N/A	N/A	down	Up/down

1) Orthogonal frequency division multiple access (OFDMA)

Transition from OFDM to OFDMA. Before Wi-Fi6, data transmission was carried out using OFDM mode. In this mode, a single user will occupy all subcarriers and send a complete packet in a time segment. Although this transmission mode can meet the needs of a single user, a single user does not need to use all subcarriers when the data packet is small. Therefore, this transmission mode will cause a waste of network resources to a certain extent, and will increase the waiting time of other users in the case of multiple users. In order to improve user network experience, OFDMA is introduced into Wi-fi-6 protocol. OFDMA realizes multi-user multiplexing channel resources by allocating subcarriers to different users and adding multiple access in OFDM system. In addition, in Wi-Fi6 protocol, the minimum subchannel "resource unit" (RU) contains at least 26 subcarriers. Since user data is carried on the ru through subcarriers, multiple users can be transmitted at the same time in each time slice [5].

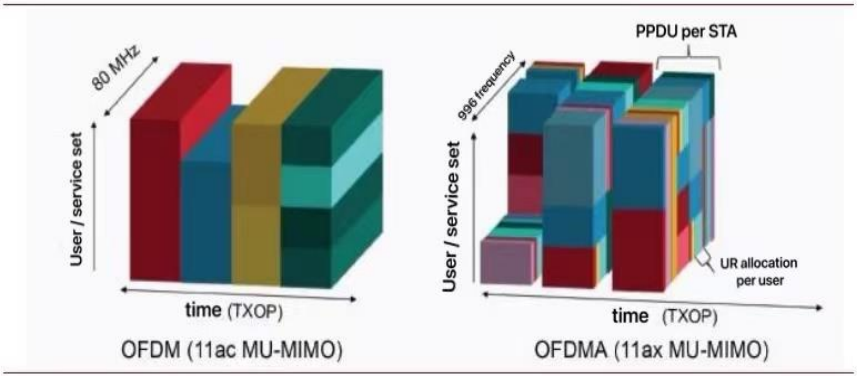

Figure 2. Comparison between OFDM and OFDMA

OFDMA transmission mode can better adapt to small packet usage scenarios. Due to the poor channel state of some nodes in the actual transmission process, if it cannot be adjusted effectively, there is the possibility of data loss. However, this phenomenon can be effectively alleviated in wi-fi6. Since Ru is the smallest sub channel in OFDMA transmission mode and wi-fi6 can allocate transmission power according to channel quality, it can realize transmission using optimal Ru resources. For users, the bandwidth requirements are different in use; In the ofmda mode, a single customer can use one or more groups of Rus to meet the bandwidth requirements. In the multi-user scenario, because multiple users can share the channel in OFDMA transmission, the delay will be effectively improved compared with OFDM. OFDMA transmission mode can meet the different needs of users. It has higher transmission efficiency and better effect in small data packets.

2) Multiuser Multiple Input Multiple Output (MU-MIMO)

MIMO technology improves data throughput. MIMO technology includes spatial diversity and spatial multiplexing. Spatial multiplexing can transmit multiple data of a single user or multiple users at the same time without changing the channel bandwidth. MIMO technology can be divided into single user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO). In the transmission process of SU-MIMO, the AP can only communicate with one user, which can increase the throughput of a single user. Compared with SU-MIMO, MU-MIMO can transmit with multiple terminals at the same time. Since MU-MIMO technology can realize concurrent transmission between AP and multiple terminals, the data throughput at the same time is improved. In the 802.11ac WAVE2 standard, the MIMO technology introduced only supports data downlink and can only transmit data to four users at most at the same time. The uplink data of users is still transmitted one by one and cannot be concurrent. However, in Wi-Fi6, this technology is more fully utilized.

Wi-Fi-6 uses full MU-MIMO technology. At the data downlink end, some versions of 802.11ac protocol support DL 4x4 MU-MIMO; In Wi-Fi-6, DL MU-MIMO is further improved and supports 8x8 transmission mode. At the data uplink, in the previous protocol, only UL SU-MIMO is supported, while Wi-Fi6 introduces UL MU-MIMO for the first time to transmit data on multiple spatial streams using the same channel resources in the case of multiple users. Therefore, after introducing DL MU-MIMO into Wi-Fi-6, DL / UL MU-MIMO technology has been supported in the protocol. With the support of MU-MIMO technology, the performance of Wi-Fi6 will be improved in the multi-user data transmission environment [6].

Summary:Under the Wi-Fi-6 standard, OFDMA and MU-MIMO develop together. From a technical point of view, OFDMA supports multiple users to improve concurrency efficiency by subdividing channels (subchannels), and MU-MIMO supports multiple users to improve throughput by using different spatial streams. In Wi-Fi-6 protocol, these two technologies can be used at the same time. Based on the cooperative development of different technologies, the transmission speed can be improved while the delay is effectively reduced. In the case of multiple users, the user network experience has been effectively improved.

TABLE III. COMPARISON OF OFDMA AND MU-MIMO TECHNOLOGIES

OFDMA	MU-MOMO
Improve efficiency	Increase capacity
Reduce delay	Higher single user rate
Best for low bandwidth applications	Best for high bandwidth applications
Most suitable for small packet message transmission	Most suitable for large packet message transmission

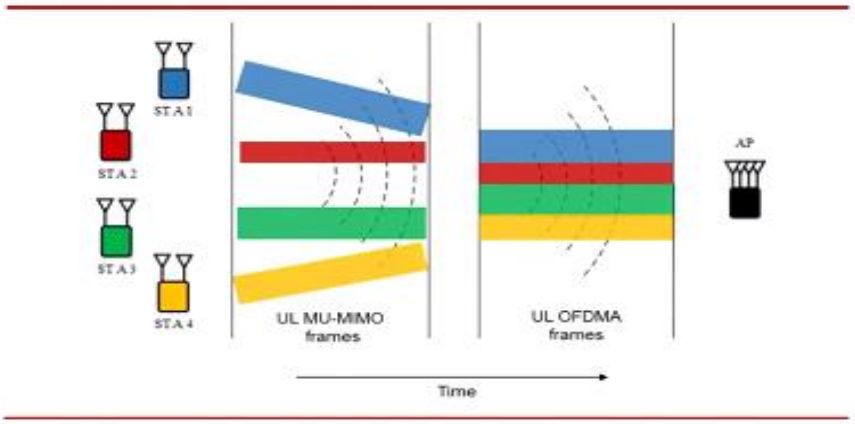

Figure 3. Multi user mode uplink scheduling sequence

3) Target wakeup time

TWT technology can make the terminal have longer endurance. With the development of science and technology, more and more electronic devices join the wireless network. On the consumer side, in addition to mobile phones, notebooks and other electronic devices, there are a large number of smart home devices in the home wireless network. Most of these devices use battery power supply. If they are active and not working for a long time, there will be the problem of power waste. Wi-Fi-6 introduces TWT technology, which allows the device to negotiate the wake-up time and enter the sleep state without data transmission. This technology can effectively reduce battery consumption and achieve longer standby time.

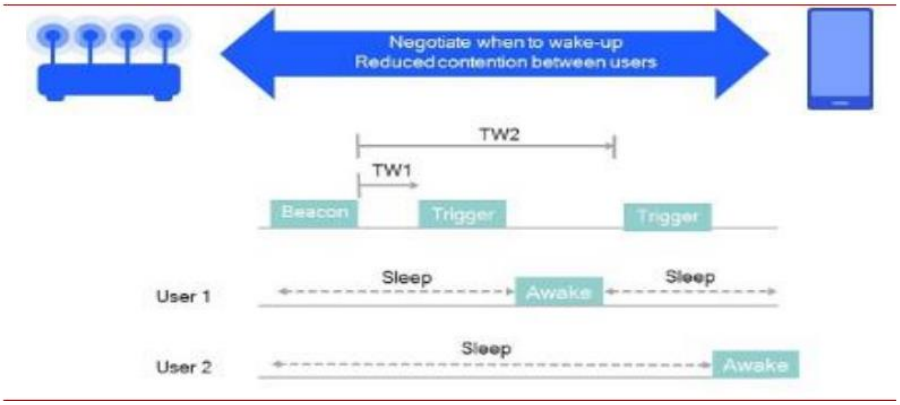

Figure 4. TWS Technology Exhibition

Summary: In addition to the technologies mentioned above, higher adjustment technology and BSS coloring coloring mechanism are also introduced into Wi-Fi-6 in terms of performance improvement. With the support of relevant technologies, the communication between the terminal and the AP is smoother through specific technologies, which not only improves the network carrying capacity, but also reduces the delay. On the consumer side, the penetration rate of smart home devices is increasing, which puts forward higher requirements for network carrying capacity. With the advancement of the Internet of things, the number of networking devices will continue to rise, whether consumer or industrial, and Wi Fi network will become one of the network access options for wireless devices.

II. 5G AND WIFI 6 DEVELOP TOGETHER

A. Competition between Wi-Fi and mobile network

Wi-Fi network has more advantages in use cost. From the spectrum used by Wi-Fi-6 and 5g, the use of Wi-Fi network is unauthorized spectrum, and the relevant spectrum can be used for data transmission when ensuring that the use right of others is guaranteed. However, for mobile communication spectrum, most countries in the world authorize the use in the form of auction, so 5g spectrum is the same as other mobile communication spectrum, and operators obtain the use right through auction. In addition, Wi-Fi network is an extension of wired network, which is more based on fixed network. For consumers, these differences are mainly reflected in the use cost [7]. When consumers use the mobile network, they pay according to their usage. Although Chinese consumers do not need to bear the cost of spectrum licensing, consumers in other regions need to share the relevant costs. Because Wi-Fi networks are more based on fixed networks and can access several terminals, when the fixed network cost is relatively fixed, the cost of a single terminal will decrease with the increase of access quantity. Therefore, considering the use cost of both, Wi-Fi network will have more advantages.

China's Wi-Fi penetration has reached a high level, and the improvement of fixed network performance is conducive to the user experience. According to quest mobile data, the penetration rate of Wi-Fi in mobile phones of mobile Internet users in China continues to rise and has been close to 90%. For users, there may be some dependence on Wi-Fi networks, so as to form usage habits. In terms of network construction, according to the 2019 communication industry statistical bulletin issued by the Ministry of industry and information technology, by the end of December, the total number of fixed Internet broadband access users of the three basic telecom enterprises had reached 449 million, with a net increase of 41.9 million in the whole year. In addition, the number of Internet broadband access ports in China reached 916 million, a net increase of 48.26 million over the end of last year. Among them, the number of FTTH / 0 ports increased by 64.79 million over the end of the previous year, reaching 836 million, accounting for 91.3% of the Internet access ports from 88.9% at the end of the previous year; By the end of June 2020, the total number of fixed Internet broadband access users of the three basic telecom enterprises had reached 465 million, a year-on-year increase of 7%, a net increase of 15.73 million over the end of the previous year. Among them, there are 434 million FTTH / O users, accounting for 93.2% of the total fixed Internet broadband access users. According to the published data, China's fixed network has a high popularity, and under the promotion of national policies such as "copper retreat and optical advance", the optical fiber penetration has reached a high position. Fiber into the home will improve

the network carrying capacity. For the Wi-Fi network based on the fixed network, with the support of the equipment, the Wi-Fi network performance will also be improved, making the user experience better.

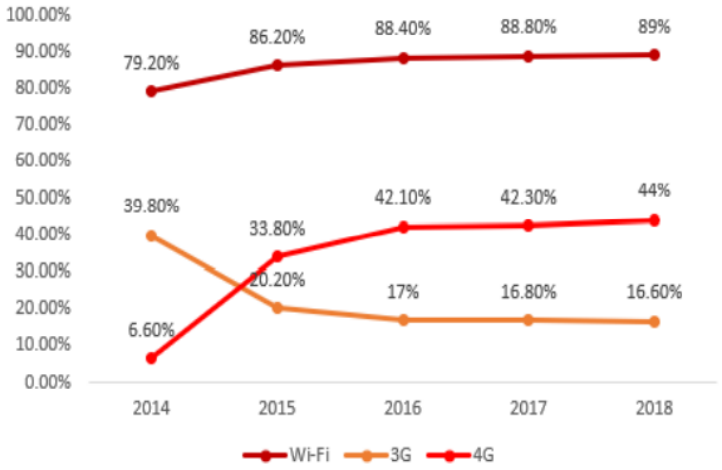

Figure 5. Penetration of mobile Internet users in different network environments;

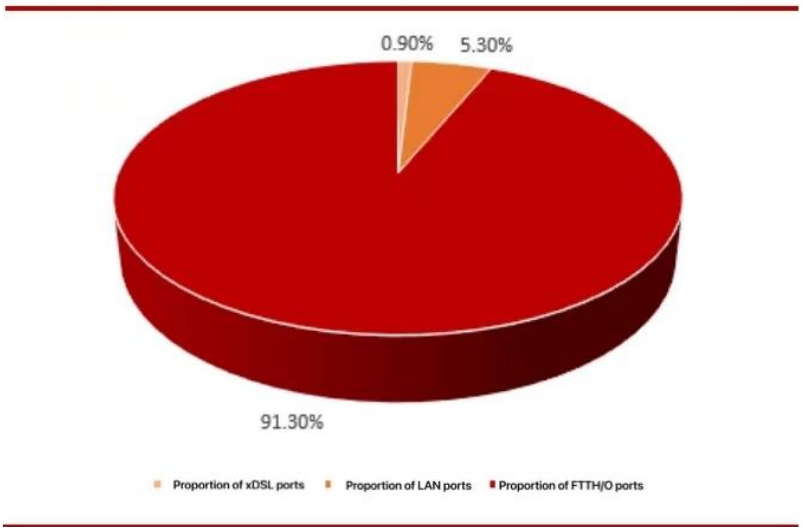

Figure 6. Proportion of Internet broadband access ports in China 2019

Summary: The statement that mobile network will replace Wi-Fi will cause heated discussion in the promotion of new mobile communication technologies of each generation. At present, 5g commercial has been realized in leading countries, and the performance of 5g communication technology has been greatly improved. However, for Wi-Fi networks, relevant technical standards are also constantly updated, and more technologies are introduced to improve network performance and provide users with a better use experience. In addition, from the perspective of the iteration cycle of relevant technologies, the update cycle of mobile communication technology is about 10 years, while the Wi-Fi standard is iterated every 5 years. When the Wi-Fi usage rate is relatively low and the superposition user usage habit has been

formed, the possibility of Wi-Fi network being replaced is low.

B. Coordinated development of Wi-Fi-6 and 5G

There is a gap between Wi-Fi-6 and 5g in performance, but each has its own advantages. 5g and wi-fi6 are the next generation mobile wireless technology and the next generation Wi-Fi technology respectively. Although the two network architectures are different, they have a great improvement in performance compared with the previous generation. Among them, 5g communication bandwidth has been greatly improved compared with 4G communication, and the theoretical downlink speed is up to 10 GB / s. In addition, the delay of 5g communication can reach the millisecond level, and the connection density can reach 1 million networked devices per square kilometer. Both the delay and connection density are 10 times higher than that of 4G communication. Therefore, the three downstream application scenarios of 5g can be realized: eMBB (enhanced mobile broadband), uRLLC (highly reliable and low delay connection) and mMTC (massive IOT). In contrast, Wi-Fi-6, according to the 2019 intelligent hardware quality report (phase II) released by China Mobile [7], it selects different standard routers of the same brand for testing. The test results show that Wi-Fi-6 routers have significantly improved performance in terms of transmission rate and delay. Moreover, with the increase of the number of users, it becomes more and more obvious. In 5g band, compared with Wi-Fi-5, the rate and delay of single user are increased by 29% and reduced by more than 5ms respectively; In the case of multiple users, the rate is increased by more than 47%. Overall, the fastest downlink speed of wi-fi6 is 9.6gb/s, and the average network delay is reduced to 20ms. Because Wi-Fi networks and 5g networks use different architectures, there are differences in performance, but they also have different advantages.

5G and Wi-Fi-6 are applicable to different scenarios, and the two will develop together. Although both 5g and Wi-Fi-6 can achieve high-density wireless access and high-capacity wireless services [8], the emphasis between them will be different. 5g communication uses sub 6 GHz high-frequency part or even millimeter wave for transmission. Although using higher frequency transmission can improve the transmission capacity, it also makes the electromagnetic wave length shorter, the signal coverage smaller than 4G communication, and the signal penetration ability decreases. Therefore, 5g will have better performance in open places outdoors. In addition, because 5g mobile network has continuous coverage capability, it can provide service support for mobile terminals, which is an advantage that any short-range communication technology does not have. Therefore, 5g has unique advantages in outdoor scenes, such as Internet of vehicles. In the indoor part, although the 5g signal micro site or pico site can effectively improve the indoor 5g signal coverage, consumers also have a more economical demand for high-speed Internet access in relatively fixed environments, such as homes and offices, and Wi-Fi network can meet the corresponding requirements. With the increasing number of indoor intelligent devices, the demand for high-density connections continues to increase. In addition, HD video, VR and voice calls are very sensitive to bandwidth and delay. Therefore, the advantages of Wi-Fi-6 are highlighted in these scenarios. In addition, if all networking devices used indoors are added with SIM module, it will have a certain impact on product design, product price and convenience of consumers. Therefore, 5g and Wi-Fi-6 have comparative advantages in different scenarios, and they will develop together [9].

Figure 7. 5G and Wi-Fi-6 usage scenarios

Summary: 5G communication and Wi-Fi-6 have greatly improved performance compared with their previous generation standards. Both can achieve high-density wireless access and high-capacity wireless services. However, due to different construction frameworks, they can adapt to different use scenarios. Among them, 5g communication outdoor space has advantages and can provide communication support for high-speed mobile terminals, while Wi-Fi-6 can provide more economical network services for the Internet of things indoors. Therefore, both can provide corresponding network support for Internet of things services, but the emphasis is different, and the two will develop together.

III. HIGH QUALITY NETWORK CONNECTION AND DEVELOPMENT OF INTERNET OF THINGS DRIVE WI-FI-6 DEMAND

The demand for network use is an important thrust driving the development of Wi-Fi-6. At the beginning of Wi-Fi-6 design, high density and high capacity network service support, including outdoor large public places, high-density venues, indoor high-density wireless office, electronic classrooms and other scenarios. Because 5g network has more advantages in outdoor environment, indoor is an important application scenario of Wi-Fi-6. In indoor space, the demand for information consumption and entertainment, smart device connection and office has become an important driving force driving the development of Wi-Fi-6.

A. prominent demand for high-quality network connection

4K / 8K UHD video has increased bandwidth requirements. Ultra high definition video technology is a new round of major technological innovation in the video industry after digitization and high definition, which is of great significance to consumers and the cultural industry. For the development of related industries, China's Ministry of industry and information technology and other departments have issued the action plan for the development of UHD video industry (2019-2022), which proposes to continuously promote the construction of 4K UHD TV content and enrich the effective supply of program content.

Create a number of typical applications of ultra-high definition video in the fields of radio and television, culture, education and entertainment, security monitoring, medical and health care, intelligent transportation, industrial manufacturing and so on. For consumers, content is the main object of their consumption. Under the promotion of national policies, it will help to speed up the construction of high-definition video content. While the UHD video content is gradually enriched, video transmission has become the focus of attention. In terms of the required bandwidth, the traditional HD service can meet the use requirements by only 20MBps bandwidth. The full 4K requires a bandwidth of more than 100Mbps, while 8K video requires a higher bandwidth. Therefore, ultra-high definition video will put forward higher requirements for transmission bandwidth.

Transmission quality will affect VR user experience. VR is a virtual environment constructed by computer. On the one hand, it can meet the needs of entertainment consumption in 2C scene; On the other hand, the 2B terminal can also inject power into the development of the industry. At present, VR technology is gradually implemented, and some related products have been launched into the market. However, in actual use, due to network transmission and other problems, users will feel uncomfortable and affect the user experience. In addition, with the maturity of cloud computing and edge computing, local VR will also change to cloud VR, and the network requirements will be higher. According to the data released by HUAWEI, VR technology has high requirements for bandwidth and delay. Therefore, with the gradual popularization of VR technology, the demand for network is also gradually increasing.

Summary: from the perspective of relevant business scenarios, UHD video, VR and other applications mostly occur in indoor scenarios. As the main carrier of indoor transmission, Wi-Fi will increase the network load when the demand for relevant services increases. Therefore, the terminal demand will promote the innovation of Wi-Fi standard to deal with the network. As a new generation standard, Wi-Fi-6 can meet the application needs of ultra-high definition video and VR. With the continuous improvement of terminal penetration, it will be conducive to the popularization of relevant standards.

B. The Demand for Internet of things is gradually increasing

Wi-Fi network is an important part of smart device connection. The Internet of things (IOT) is an important trend. Unlike user devices such as laptops, IOT devices need deterministic wireless services, such as polling every 5 milliseconds, otherwise they will shut down or low-power services. Traditionally, these needs have been met through proprietary, niche or operator specific technologies, but with excellent economies of scale and simple it management, enterprise Wi-Fi has increasingly become the preferred indoor Internet of things platform. In order to meet these IOT operational needs, Wi-Fi-6 and its IOT features (such as low power consumption and certainty) are expected to accelerate this adoption. According to Cisco data, Wi-Fi is already the third largest connection mode of the Internet of things. It is expected that by 2021, the number of Internet of things devices connected through Wi-Fi is expected to reach 12 billion.

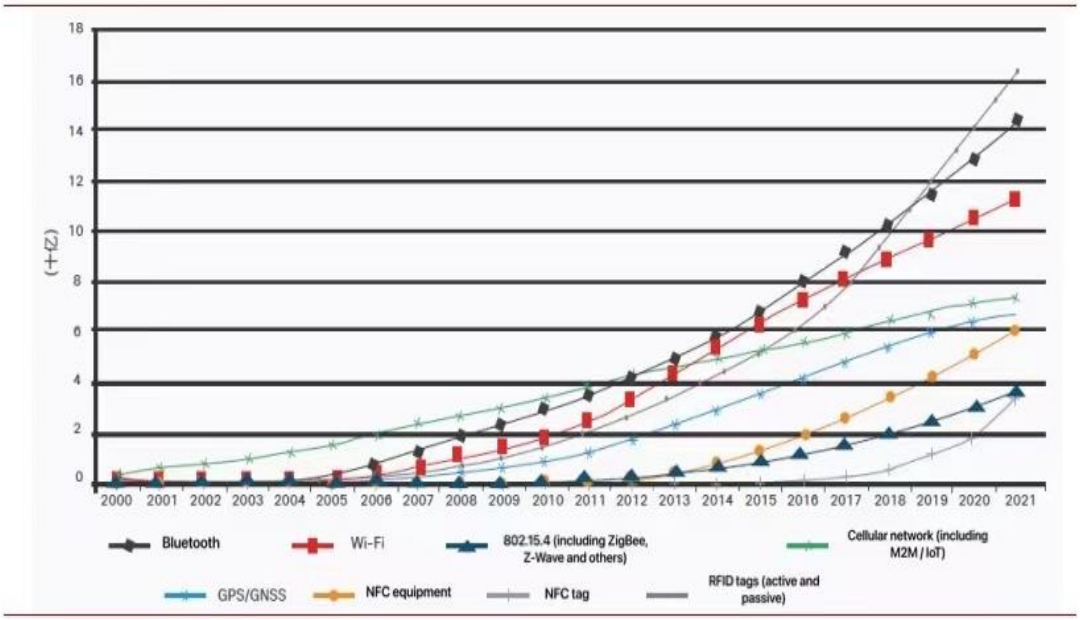

Figure 8. Internet of things trends

1) Wi-Fi-6 enables intelligent industrial production scenarios

In terms of transmission rate, Wi-Fi-6 is upgraded by introducing MU-MIMO technology, and the maximum rate of Wi-Fi-6 can reach 9.6Gbps; 5g communication technology because of the use of mass MIMO technology, the maximum support rate reaches 10Gbps. In terms of transmission capacity, Wi-Fi-6 supports OFDMA technology to enable multiple devices and applications to transmit and receive data at the same time. 5g adopts NOMA technology, which can enable more users to connect without reducing the transmission rate. Although Wi-Fi-6 has similar performance to 5g, Wi-Fi-6 currently has greater advantages in the industrial field [10]. Firstly, the construction of 5g network has just started. It takes a long time from the construction coverage of macro base station to the realization of indoor stable connection of small base stations; However, at present, most factories have generally adopted wired network connection, and it is more convenient to realize Wi-Fi communication connection through wired network. Secondly, the tariff of 5g industrial private network has not been implemented. At present, there are only 5g consumer charges. At present, the initial prices of 5g packages determined by the three communication operators in the first batch are 128 yuan, 129 yuan and 129 yuan respectively, including 30GB / month 5g traffic; However, there are many data to be transmitted in industrial scenarios, and 30GB traffic may not be enough. Wi-Fi-6 connects to a wired network through a wireless router. Wired network charges are fixed charges, while routers can be understood as one-time charges. With the increase of service time, the cost gradually decreases. Therefore, wi-fi6 has cost advantages in industrial scenario applications.

Mettis Aerospace has a huge production base in West Midlands, UK, covering 27 acres, with 515 employees and 3000 manufacturing equipment. In 2019, the company conducted a test on Wi-Fi 6 in the factory. In the test, Wi-Fi-6 uses a channel with a bandwidth of 80 MHz to achieve a download rate of 700 Mbps and a delay of less than 6 milliseconds. The applications implemented

on site include 4K video upload, large file transmission, message transmission, voice and video communication, Internet of things sensors, etc. from the test results, Wi-Fi-6 realizes wireless communication with high reliability, high quality, high bandwidth and low delay. Mettis Aerospace plans to deploy Wi-Fi6 throughout the plant as part of a comprehensive IT infrastructure upgrade in the next five years.

Figure 9. The use of wifi6 was tested in the factory

2) Wi-Fi-6 becomes a smart home network link

Smart home takes residence as the carrier, integrates automatic control technology, computer technology and Internet of things technology, organically combines the functions of home appliance control, environmental monitoring, information management and audio-visual entertainment, and provides a more portable, comfortable, safe and energy-saving family living environment through the centralized management of home equipment. With the development of science and technology, smart home has gradually entered the family life of ordinary residents, and will become a part of family life in the future. According to strategy analytics, the global smart home market reached US $84 billion in 2017, an increase of 16% over US $72 billion in 2016. In 2018, the total consumer spending on global smart home devices, systems and services will be close to US $96 billion, and the CAGR will reach 10% to US $155 billion in the forecast period (2018-2023). North America will account for 41% or $40 billion of total expenditure, followed by the Asia Pacific region of $26 billion and Western Europe of $17 billion.

In China, according to the statistical data of the report on market prospect and investment strategy planning of China's smart home equipment industry, the scale of China's smart home market in 2015 was 40.34 billion yuan, a year-on-year increase of 41.0%. The report shows that the scale of China's smart home market is expected to reach 142.2 billion yuan in 2019, showing a trend of increasing by 100 billion yuan year by year. If the average annual compound growth rate is about 38.13% in the next five years (2019-2023), we predict that the scale of China's smart home market will reach more than 200 billion yuan in 2020 and exceed 500 billion yuan in 2023.

There are three mainstream protocols for smart home: Bluetooth, Wi-Fi and ZigBee. Bluetooth technology is an open global standard for wireless data and voice communication. It is a special

short-range wireless technology connection based on low-cost short-range wireless connection to establish a communication environment for fixed and mobile devices. ZigBee is a low-speed and short-distance wireless network protocol. The bottom layer is the media access layer and physical layer based on IEEE 802.15.4 standard. The main features are low speed, low power consumption, low cost, support for a large number of online nodes, support for a variety of online topologies, low complexity, fast, reliable and safe. Although the three protocols are short-range connection protocols, there are differences in performance. From the transmission distance, Wi-Fi > ZigBee > Bluetooth.In terms of power consumption, Wi-Fi > Bluetooth > ZigBee, and Bluetooth and ZigBee devices can be powered by batteries.In terms of transmission rate, Wi-Fi > ZigBee > Bluetooth.

TABLE IV. COMPARISON OF THREE INTERNET OF THINGS PROTOCOLS

	Bluetooth	**Wi-Fi**	**ZigBee**
Network organization	Dot communication network	Star Communication Network	Mesh communication network
Maximum transmission rate	2 Mpbs	300 Mpbs	250Mpbs
Transmission range	10-100m	100-300m	50-300m
Power consumption	low power consumption	High power consumption	secondary

According to the data of the National Bureau of statistics, the per capita residential construction area in China's cities in 2016 was 36.60 square meters. According to the calculation of a family of four, the living area of a family is about 144 square meters. If the family wants to arrange the smart home system, the transmission distance of Bluetooth is not enough to support, and Wi Fi and ZigBee will be better choices. Compared with Wi Fi, ZigBee has advantages in transmission range and power consumption when the maximum transmission rate is slightly inferior. However, in terms of products, at present, ZigBee technology mainly adopts 2.4GHz of ISM frequency band in China, which has weak diffraction ability and wall penetration ability, is vulnerable to obstacles, and is vulnerable to interference from Wi Fi and Bluetooth in the same frequency band. In addition, the development of main products is difficult, the development cycle is long, the product cost is high and the penetration rate is low. Therefore, at present, Wi Fi is the mainstream use protocol of smart home.

IV. WI-FI6 MARKET IS EXPANDING RAPIDLY, AND THE INDUSTRY IS DISTRIBUTED FROM TOP TO BOTTOM

A. Rapid expansion of Wi-Fi-6 market scale

According to the data of Cisco white paper, the number of M2M connections will reach 14.7 billion and CAGR will reach 19% in 2023. In addition, the number of M2M connections will be half of all connections. In M2M applications, home connection will become a common phenomenon. By 2023, home connections will account for 48% or nearly half of the total M2M connections. For a long time, one of the main solutions to meet the growing bandwidth demand is to use Wi-Fi network to enable operators to expand capacity to meet the needs of their users. By 2023, there will be nearly 628 million public Wi-Fi hotspots in the world, up from 169 million

hotspots in 2018, an increase of four times. Regionally, the compound annual growth rate in central and Eastern Europe reached 38%, the compound annual growth rate in Asia Pacific and Latin America reached 37%, the compound annual growth rate in the Middle East and Africa reached 30%, and the compound annual growth rates in North America and Western Europe were 25% and 20% respectively. According to IDC data, the overall scale of WLAN market reached US $230 million in the third quarter of 2019, which is in a steady upward trend [11].

Although the Wi-Fi Alliance announced the Wi-Fi-6 standard in October 2018, the relevant certification plan was officially launched on September 16, 2019. After the release of relevant standards, although some manufacturers have launched relevant routing products, there are some disadvantages, such as less terminal product support and higher product pricing. After the certification work is started, manufacturers will be more active in the introduction of relevant technologies, so as to promote relevant product development. The promotion of Wi-Fi-6 certification is conducive to the expansion of Wi-Fi-6 market scale. IDC predicts that in 2020, the scale of Wi-Fi-6 market in China will be close to US $200 million, and by 2023, the scale of China's Wi-Fi-6 market will reach US $1 billion, with an annual compound growth rate of 71%.

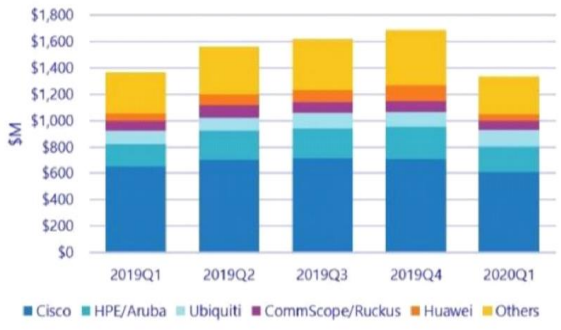

Figure 10. 2019Q1-2020Q1 enterprise router market share

B. Wi-Fi receiving terminal: Mobile flagship covers the whole line, followed by tablet

1) The flagship products of mobile phones widely support Wi-Fi-6

Major mobile phone manufacturers have released Wi-Fi-6 standard mobile phones, and their penetration in mobile phones will gradually increase. Before the Wi-Fi alliance started Wi-Fi-6 standard certification, only a few mobile phone manufacturers launched corresponding terminals. Take Samsung as an example. In February 2019, the new generation of flagship Galaxy S10 series mobile phones was officially released. Since no manufacturer has released relevant products before, Galaxy S10 series mobile phones will become the first batch of mobile phones in the world to support Wi Fi 6. Since then, Samsung has also introduced relevant technologies into the note 10 series. However, not all mobile phones support Wi-Fi-6, and only note 10 + models provide relevant support. Although Samsung launched Wi-Fi-6 standard mobile phones in early 2019, they were not introduced in all subsequent mobile phones. Most mobile phone manufacturers have not launched relevant products. However, this situation has improved. From the mobile phones released by various manufacturers, except Samsung and apple, most domestic mobile phone manufacturers will launch Wi-Fi-6 products in 2020. At present, all mainstream brands are beginning to pay attention to the Wi-Fi-6 standard. Although most mobile phones supporting Wi-Fi-6 standard are brand flagship models with relatively high price, with the development of Wi-Fi-6 certification and increasing attention, more mobile phones will support Wi-Fi-6 standard and their penetration rate will gradually increase.

2) Tablet devices follow closely

Compared with mobile phones, tablet computers have the same functions as mobile

phones except for the lack of mobile phone functions. Tablet computers have larger battery capacity, wider screen vision and higher definition display. If the tablet computer is equipped with touch pen, external keyboard and other accessories, it can undertake light office tasks. Tablet has been recognized by consumers because of its large screen, portability, office and other characteristics. Tablet computers have become one of the electronic devices that consumers carry when they travel. Affected by the epidemic in 2020, home office and distance education have become measures taken by many countries and regions in the world at the time of serious epidemic. In order to adapt to telecommuting and distance teaching, the sales of tablet computers have increased greatly. According to Canalys data, the sales volume in the second quarter of 2020 reached 37.5 million, a year-on-year increase of 26.1%. Among them, Apple's sales increased by 19.8% year-on-year, accounting for 38.0% of the total sales; Samsung's sales increased by 39.2% year-on-year, accounting for 18.7% of the total sales. HUAWEI's sales increased by 44.5% year-on-year, accounting for 12.7% of the total sales.

TABLE V. Q2 TABLET PC SHIPMENTS IN 2020

Vender(company)	Q2 2020 Shipments	Q2 2020 Marker Share	Q2 2019 Shipments	Q2 2019 Marker Share	Annual Growth
Apple	14,249,000	38.0%	11,894,000	40.0%	19.8%
Samsung	7,024,000	18.7%	5,048,000	17.0%	39.2%
Huawei	4,770,000	12.7%	3,300,000	11.1%	44.5%
Amazon	3,164,000	8.4%	2,308,000	7.8%	37.1%
Lenovo	2,810,000	7.5%	1,838,000	6.2%	52.9%
Others	5,525,000	14.7%	5,379,000	18.1%	2.7%
Total	37,542,000	100.0%	29,767,000	100.0%	26.1%

Although the tablet has released LTE version or cellular version, cellular data can be used through SIM card. However, from the use environment, tablet computers are mainly used indoors. In the indoor environment, cellular communication may be easily interfered or intercepted, and the use experience needs to be improved. In addition, considering that the scenarios when using tablet computers are generally video or games and other applications that consume a lot of traffic, if cellular data is used, it may cause a large tariff burden. Therefore, tablets generally connect to the network through Wi-Fi. As a new generation of wireless WLAN technology, Wi-Fi-6 has the advantages of low delay, high capacity and high rate. It has become a new element for tablet manufacturers to release new products. Taking the top three tablet computer manufacturers as an example, HUAWEI, SAMSUNG and APPLE have launched their own tablets supporting Wi-Fi-6 in 2020.

C. Routing equipment: domestic brands catch up and split the development trend of key fields

1) Overseas giants have obvious advantages, and domestic brands catch up

The terminal is responsible for receiving the network signal, and the router is responsible for transmitting the network signal. Router is a hardware device connecting two or more networks. It acts as a gateway between networks. It is a special intelligent network device that reads the address in each data packet and then determines how to transmit it. It can understand different

protocols, such as Ethernet protocol used in a LAN and TCP / IP protocol used in the Internet. In this way, the router can analyze the destination address of data packets transmitted from various types of networks, convert the address of non TCP / IP network into TCP / IP address, or vice versa. Then, according to the selected routing algorithm, each packet is transmitted to the specified location according to the best route. So routers can connect non TCP / IP networks to the Internet.

According to the functional classification, routers can be divided into backbone routers, enterprise routers and access routers. Backbone routers realize the interconnection of enterprise networks. The requirements for it are speed and reliability, while the cost is secondary. In 2018, the annual revenue of HUAWEI routers in the operator market increased by 8.6%, ranking first in the list with 30% market share. This is also the first time that HUAWEI's IP core router has surpassed the annual market share of the overall operator's IP router field after ranking first in the global operator market share in 2017. In 2019, HUAWEI's router products ranked first in the market share of global operators for three consecutive years. Enterprise or campus level routers connect many terminal systems. Its main goal is to realize as many endpoint interconnections as possible at the lowest cost, and further require to support different quality of service. According to IDC data, Cisco's WLAN revenue fell 6.7% year-on-year to $611 million in Q1 2020. Cisco remains the market share leader, with a market share of 45.7% in the quarter, up from 44.6% in 2019. HPE Aruba's revenue increased by 14.2% year-on-year, and its market share increased from 13.8% in 2019 to 14.4% in the first quarter of 2020. Ubiquiti's WLAN revenue increased by 24.8% year-on-year, with a market share of 9.5%, higher than 7.0% in 2019. CommScope (formerly arris / ruckus) revenue fell 4.7% year-on-year and its market share was 5.2%. HUAWEI's revenue fell 15.0% year-on-year and its market share was 3.8%. According to IDC data, Ruijie ranks second in China's enterprise WLAN market with a market share of 23.95%. Among them, Ruijie ranks first with 40.66% in the Wi-Fi-6 category market.

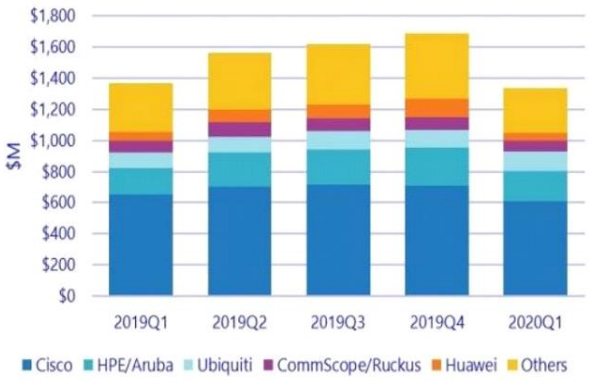

Figure 11. 2019Q1-2020Q1 enterprise router market share

Access routers connect small business customers in homes or ISPs. Access level routers are divided into single frequency routers and dual frequency routers. The single frequency router is a traditional router, and the Wi-Fi signal is only 2.4GHz. 2.4GHz is a low-frequency signal, which has the advantages of strong penetration and longer propagation distance. For large houses, it can have better coverage capacity; However, the disadvantage is that most devices are applicable to the 2.4GHz frequency band, and the interference is large where there are many users. In addition to a 2.4GHz Wi-Fi signal, the dual band router also has a 5GHz Wi-Fi signal. Advantages of 5GHz Wi-Fi: wide signal bandwidth, clean wireless environment, less interference, stable network speed, and can support higher wireless rate; The disadvantage is that the attenuation is large when propagating in air or obstacles, and the coverage distance is generally smaller than 2.4GHz.

In terms of brand attention, in 2019, tp link, which has long been at the forefront of the wireless router market, fell in market attention, ranking second with 14.9%. In the past two years, HUAWEI has continued to receive market attention, reaching 16.8% in 2019, ranking first in brand attention.

2) Split key components of Wi-Fi equipment and grasp the development trend

According to the research report forecast of global Wi-Fi chip market scale in 2022 released by market and markets, the global Wi-Fi chip market scale reached US $15.89 billion in 2016 and is expected to increase to US $19.72 billion in 2022. At present, Wi-Fi devices are still dominated by Wi-Fi-5 products, and Wi-Fi-6 products are expected to enter a rapid penetration period in 2020. According to Dell'Oro's prediction, the shipments of chips supporting Wi-Fi-6 will account for 10% of the total shipments in 2019, and will reach about 90% by 2023, becoming a real mainstream product. At present, the mainstream Wi-Fi-6 router CPU suppliers in the market include Hisilicon, MediaTek, Broadcom, Qualcomm, Intel, etc. Most of them adopt Cortex-A53 of arm company, and some also adopt MIPS architecture. In terms of technology, Qualcomm's Wi-Fi 6 chip adopts 14nm process technology, which is relatively advanced. Most manufacturers use 28nm process chips. In terms of main frequency, the minimum specification is dual core processor, Qualcomm Technology is relatively advanced, and the whole system realizes four core processor.

TABLE VI. SOME WIFI 6 CHIP SUPPLIERS AND THEIR PRODUCTS

Manufacturer	Model	Framework	Process Nm	Dominant Frequency	Representative Model
HiSilicon	Hi5651L	Cortex-A53	28	Binuclear 1.2GHz	HuaweiAX3
	Hi5651T	Cortex-A53	28	Tetranuclear 1.4GHz	HuaweiAX3 Pro
MTK	MT7621DAT	MIPS32 1004Kc	28	Binuclear 880MHz	TL-XDR1860
	MT7622B	Cortex-A53	28	Binuclear 1.35GHz	TL-XDR3230
Broadcom	BCM6750	Cortex-A7	28	Trinuclear 1.5GHz	ASUS AX3000
	BCM6755	Cortex-A7	28	Tetranuclear 1.5GHz	ASUS AX56U
	BCM4906	Cortex-A53	28	Binuclear 1.8GHz	ASUS AX92U
	BCM4908	Cortex-A53	28	Tetranuclear 1.8GHz	ASUS AX88U
Qual comm	IPQ6000	Cortex-A53	28	Tetranuclear 1.2GHz	XIAOMI AX1800
	IPQ8071A	Cortex-A53	14	Tetranuclear 1GHz	XIAOMI AX3600
	IPQ8072A	Cortex-A53	14	Tetranuclear 2GHz	ASUS AX89X
	IPQ8074(A)	Cortex-A53	14		
Intel	GRX350	MIPS32 34Kc	40	Binuclear 800MHz	NETGEAR RAX40

An independent wireless chip processes a single signal. It can be divided into two chips responsible for 2.4G signal and 5G signal, or it can be concentrated into one chip. Some models of processors can also process single frequency signals (i.e. 2.4G or 5G) or dual frequency signals at the same time. According to our data statistics, at present, most of them use a single chip to be responsible for a single signal, so there will be two or more wireless chips in the Wi-Fi device. Taking Xiaomi AX3600 router as an example, the IPQ8071A processor is adopted, the chip of 2.4G signal is QCN5024, and the chip of 5G signal is QCN5054.

FEM has become the mainstream of wireless power amplifier. There are three main ways of wireless power amplifier: PA and LNA are encapsulated to form two chips respectively, PA + LNA is integrated, and FEM is adopted. Based on the integration of PA and LNA, FEM adds additional functions such as power detection. According to our statistics, nearly 70% of the power amplifiers in Wi-Fi-6 routers adopt FEM mode.

Some players of MU-MIMO began to break through gradually. Traditional router MU-MIMO is mainly in 2, 3 and 4 modes, and even some products do not have MU-MIMO. In the initial stage of Wi-Fi-6, MU-MIMO of Wi-Fi devices mainly exists in 2 and 4 modes. At present, some players of the router have developed products supporting 4*2 MU-MIMO. For example, ASUS AX11000 router is equipped with 4*2 MU-MIMO. Not only ASUS, but also router brands such as NetWare RAX200, Orbi RBK852 and Velop MX5300 are equipped with 4*2 MU-MIMO.

V. EXPECTATION

The high network speed under the Wi-Fi-6 standard will have a significant impact on our life. Although 5g has many similarities with its application scenarios, Wi-Fi-6 still has its unique role. Such as enterprise WLAN, industrial scenarios such as smart factory and unmanned storage; High density scenes, such as airports, hotels, large venues, etc; New intelligent terminals, such as wearable devices, smart home, Ultra HD applications, VR / AR, etc.; Service scenarios, such as telemedicine, require high speed, large capacity and low delay.

In the future digital construction, Wi-Fi still has long-term vitality. Under the trend of the integration of cloud management, innovation, operation and maintenance and IOT, it is constantly realizing technology evolution and product updating. The value Wi-Fi-6 brings to enterprises is mainly reflected in extensive connection, extreme experience, improving efficiency, optimizing process, innovating business, etc.

In short, compared with the cost of 5g, Wi-Fi-6 can also be regarded as a good complement of 5g, which not only saves cost, but also helps enterprises achieve a high performance level. In the new infrastructure era, the challenge of connection begins with the business needs of the actual scene, such as the demand for extreme speed brought by the intelligent era, the demand for ultra-low delay in emerging fields such as automatic driving, the demand for massive connection, the demand for business integration, and so on.

Eventually, more Wi-Fi- 6 products will spring up.

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