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Wi-Fi 7

Technology White Paper

Omada Launches a Complete Lineup of
Wi-Fi 7 Access Points
to Meet Diverse Business Needs

Learn More About Our Wi-Fi 7 APs >>

Contact us at b2bsales.usa@tp-link.com

Contents

1 Overview of Wi-Fi Standards

Since its inception in 1990, the IEEE 802.11 project has changed people's way of connecting over the past 32 years. Wi-Fi, defined by a series of IEEE 802.11 standards, is the most popular wireless technology for data transmission. With faster modulation and encoding schemes (MCS), wider channels, and multiple input multiple output (MIMO) technology, the performance of Wi-Fi has also been greatly improved, increasing from 2 Mbps of IEEE 802.11 in 1997 to 9.6 Gbps of 802.11ax (Wi-Fi 6) now.

The formulation of the first-gen Wi-Fi standards took 7 years. However, such a low rate (2 Mbps) was far from enough for Ethernet (100 Mbps), thus IEEE revised a series of standards at a higher speed, such as 802.11a/b/g. Due to the adoption of new MCS (which supports the 2.4 GHz and 5 GHz bands), the rate was increased to 54 Mbps. 802.11a, with OFDM technology, formed the basic framework for subsequent Wi-Fi standards.

With a higher encoding rate, double bandwidth of 40 MHz and the breakthrough in MIMO technology, Wi-Fi 4 (802.11n) increased the rate to 600 Mbps.

Wi-Fi 5 realized a decuple in Wi-Fi rate to 7 Gpbs. Some reasons for this breakthrough: QAM was developed from 64-QAM to 256-QAM, with a 30% increase in symbol rate. Bandwidth was increased fourfold to 160 MHz. The spatial stream was doubled to a maximum of 8, and DL MU-MIMO technology was adopted.

Wi-Fi 6 increased the nominal rate by 37% through adopting OFDMA and supporting UL/DL MU-MIMO and 1024-QAM simultaneously.

	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 6E
Launch date	2007	2013	2019	2021
IEEE standard	802.11n	802.11ac	802.11ax	
Max data rate	1.2 Gbps	3.5 Gbps	9.6 Gbps	
Bands	2.4 GHz, 5 GHz	5 GHz	2.4 GHz, 5 GHz	6 GHz
Channel size	20, 40 MHz	20, 40, 80 80+80, 160 MHz	20, 40, 80 80+80, 160 MHz	
Modulation	64-QAM	256-QAM	1024-QAM	
MIMO	4x4 MIMO	4x4 MIMO, DL MU-MIMO	8×8 UL/DL MU-MIMO	

Figure 1-1 Wi-Fi Standard Comparison

2 Wi-Fi 7 Technology Introduction

2.1 What is Wi-Fi 7 (IEEE 802.11be)?

Wi-Fi 7 is the upcoming Wi-Fi standard, also known as IEEE 802.11be Extremely High Throughput (EHT). It works across all three bands (2.4 GHz, 5 GHz, and 6 GHz) to fully utilize spectrum resources. While Wi-Fi 6 was built in response to the growing number of devices in the world, Wi-Fi 7's goal is to deliver astounding speeds for every device with greater efficiency. If you're struggling with constant buffering, lag, or congestion, a Wi-Fi 7 router may be your best solution.

PHY	Number of data subcarriers	Coding rate	Bits/symbol	Time per OFDM symbol (0.8μs GI)	1SS	4SS	8SS	16SS
802.11ax	1960 (160 MHz)	×5/6	× log2(1024)	÷ 13.6 μs	1.2 Gbps	4.8 Gbps	9.6 Gbps	NA
802.11be	3920 (320 MHz)	×5/6	× log2(4096)	÷ 13.6 μs	2.88 Gbps	11.52 Gbps	23.04 Gbps	46.08 Gbps

Figure 2-1 Wi-Fi 7 Rate Calculation

Wi-Fi 7 introduces 320 MHz ultra-wide bandwidth, 4096-QAM, Multi-RU, and Multi-Link Operation to provide speeds 4.8× faster than Wi-Fi 6 and 13× faster than Wi-Fi 5. With these breakthroughs, Wi-Fi 7 can unlock more scenarios than ever before.

2.2 Driving Factors of Wi-Fi 7

The emergence of Wi-Fi 7 is inseparable from the demand for higher throughput and lower latency by new technologies such as 4K/8K video, AR, VR, etc. To meet such demand, the 802.11 working group launched the 11be project.

2.2.1 Internal Driving Factor—IEEE

Although Wi-Fi 6 realized a 37% nominal rate increase, it was not as concrete as the 10-fold rate increase of Wi-Fi 5. The difference stemmed from the original intention of the Wi-Fi 6 project, which aimed to improve efficiency rather than data rates. Meaning, Wi-Fi 6 could offer better experiences in high-density environments, but its "negligible growth" in speed was unable to attract new customers. That's why TGbe switched its focus back to throughput and user experience while establishing Wi-Fi 7 standards. In May 2018, Extremely High Throughput Topic Interest Group (EHT TIG) was established immediately after Wi-Fi 6 was finalized, which was the predecessor of the later 802.11be Working Group (TGbe).

In short, Wi-Fi 7 is designed for high throughput and low latency. The objectives of Wi-Fi 7 are geared towards attracting new customers with a much higher nominal rate, which promises great success in the market.

2.2.2 External Driving Factor—Market

Wi-Fi accounts for over half of all user traffic connections; the rest is supported by cellular networks. Almost every 10 years, there are new innovations in wireless connectivity. These two technical standards have a "win-win" relationship: each generation of cellular networking (2G/3G/4G) has offloaded more and more traffic to Wi-Fi networks since Wi-Fi is faster and more cost-effective. As such, businesses continue to choose to adopt Wi-Fi. 5G technology not only supports operators to provide better voice and video services but also boosts the demand for high throughput and real-time applications — such as 8K video, which needs a compression ratio of 20 Gbps. AR/VR experiences with zero vertigo require latency of less than 10 ms. The vigorous development of IoT also introduces a challenge for enterprises. Namely, how to securely and easily connect hundreds or thousands of electronic devices to an enterprise IT network that meets operational and engineering needs. This sets higher technical requirements for wireless services, such as low-power consumption (no unnecessary signals sent) and certainty (e.g., polling every 5 milliseconds sequentially, otherwise shutting down). C-end customers are also faced with these challenges.

2.3 Technical Innovations

The 11be project aimed to realize goals related to higher nominal data rates, higher spectral efficiency, better interference mitigation, and RTA support.

To achieve these goals, the 802.11 working group discussed approximately 500 proposals from different fields that can be mapped to the following seven directions of Wi-Fi 7: EHT PHY, EDCA with 802 TSN Features, Enhanced OFDMA, Multi-Link Operation, Channel Sounding Optimization, Advanced PHY Techniques, and Multi-AP Cooperation. After further evaluation and verification, these technical directions were grouped into physical layer (PHY) innovation and medium access control (MAC) innovation.

2.3.1 320 MHz Ultra-Wide Bandwidth

Wi-Fi 6 expanded the Wi-Fi band from 80 MHz to 160 MHz, effectively doubling the number of channels. Wi-Fi 7 takes it a step further by doubling the bandwidth of Wi-Fi 6, extending everything to 320 MHz.

Wi-Fi 7 adds new bandwidth modes including contiguous 240 MHz, noncontiguous 160+80 MHz, contiguous 320 MHz, and noncontiguous 160+160 MHz. This means more flexibility with channel allocations for less congestion.

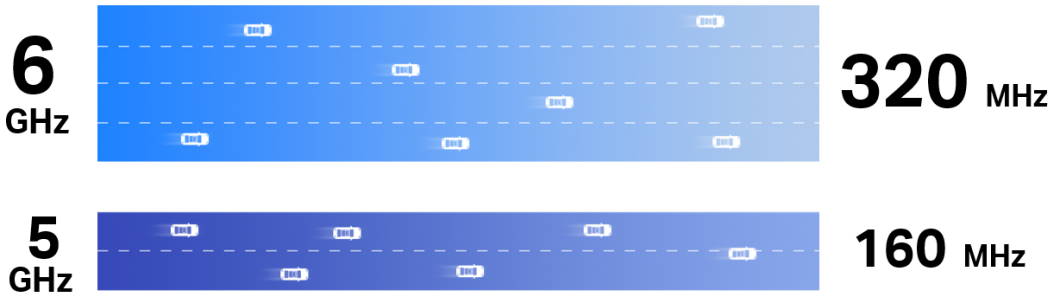


Figure 2-2 Higher Bandwidth & Flexibility

2.3.2 4K-QAM

Extensively used in 802.11 Wi-Fi standards, QAM (Quadrature Amplitude Modulation) translates digital packets into an analog signal that can wirelessly transfer data. By varying the phase and amplitude of radio waves, the technology improves spectral efficiency by incorporating more data into each transmission.

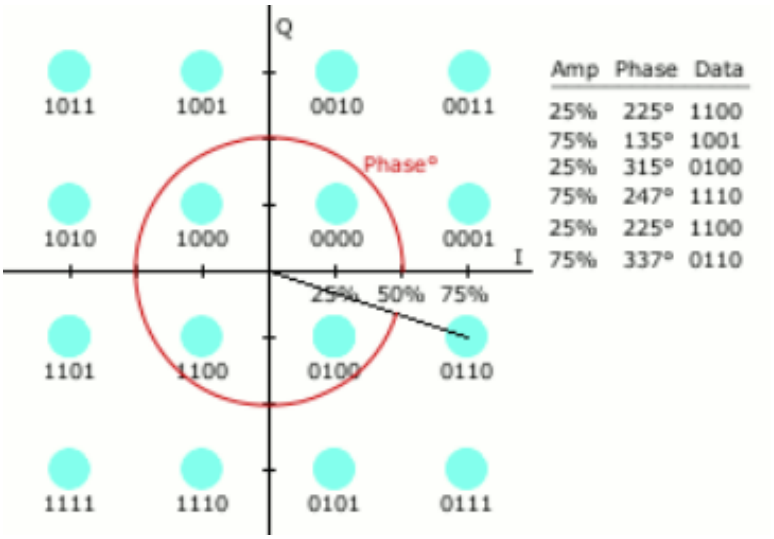


Figure 2-3 QAM Technology

QAM sets a suitable constellation size to achieve arbitrarily high spectral efficiencies. It usually arranges constellation points in a square grid with equal vertical and horizontal spacing. In digital telecommunications, data is usually binary, so the number of points on the grid is typically a power of 2 (like 2, 4, 8, 16...), corresponding to the number of bits per symbol.

The simplest and most commonly used QAM constellations consist of points arranged in a square, such as 16-QAM, 64-QAM, and 256-QAM. By moving to a higher-order constellation, it's possible to transmit more bits per symbol.

Bits per Symbol	Number of Symbols	QAM Modulation
4	$2^4 = 16$	16-QAM
6	$2^6 = 64$	64-QAM
8	$2^8 = 256$	256-QAM
...		

Figure 2-4 Data Calculation

To further enhance peak rates, Wi-Fi 7 adopts a higher-order modulation scheme: 4096-QAM. This enables each symbol to carry 12 bits rather than 10

bits, which means 20% higher theoretical transmission rates than Wi-Fi 6's 1024-QAM.

A higher transmission rate allows users to obtain higher transmission efficiency. Now you can watch flawless 4K/8K videos, play massive online games without lag, or live stream from your home computer. With 4096-QAM, streaming just got that much better.

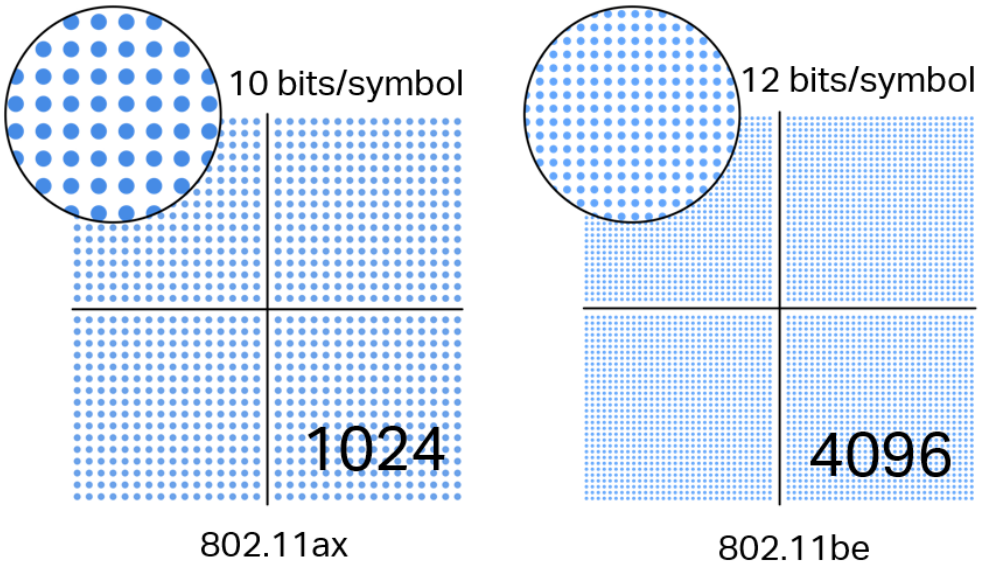


Figure 2-5 4K-QAM

2.3.3 16×16 MU-MIMO

MIMO, or Multiple-Input Multiple-Output, refers to the use of multiple transmitting and receiving antennas so that signals are sent and received continuously between a transmitter and receivers to improve overall communication quality. This technology makes full use of space resourcing to double the system channel capacity without increasing the spectrum resources and antenna transmission power. It's considered the core technology of next-generation mobile communication.

MU-MIMO (Multi-User Multiple-Input Multiple-Output) provides services for multiple devices simultaneously by using a reasonable allocation of antennas and sending out waveform phase superposition through the antenna. To meet the growing traffic demands generated by the increasing number of Wi-Fi devices, APs have continued to increase the number of antennas and improve spatial multiplexing capabilities.

Wi-Fi 7 increases the number of spatial streams from 8 to 16. The theoretical physical transmission rate is thus doubled compared with Wi-Fi 6. With Wi-Fi 7's 16 streams, every device has enough bandwidth to run smoothly.

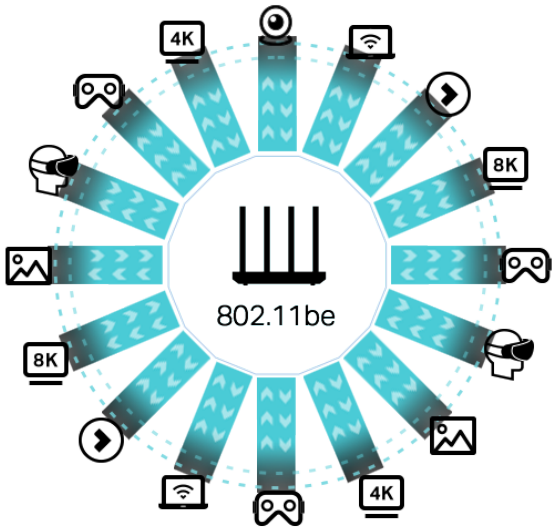


Figure 2-6 16×16 MU-MIMO

2.3.4 Preamble Puncturing

Previously, busy channels meant bands could not be fully used. Assuming that an AP is transmitting data on a second 80 MHz band, if channel 56 is busy, then that band cannot be fully used. Data would only be sent through the primary channel.

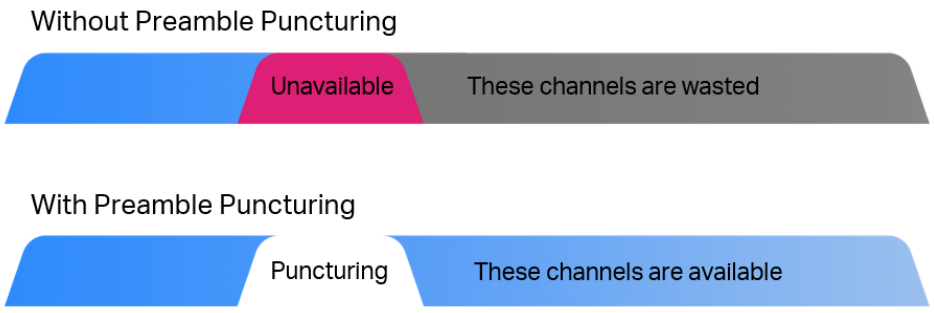


Figure 2-7 Preamble Puncturing

With Preamble Puncturing technology, the interference would be blocked, and the three other 20 MHz channels can be used to improve channel utilization.

2.3.5 Multi-RU

With Wi-Fi 6, each user can only send or receive frames on an assigned resource unit (RU), which significantly limits the flexibility of the spectrum resource scheduling. To solve this problem and further enhance spectral

efficiency, Wi-Fi 7 allows multiple RUs to be assigned to a single user and allows combining RUs* for increased transmission efficiency.

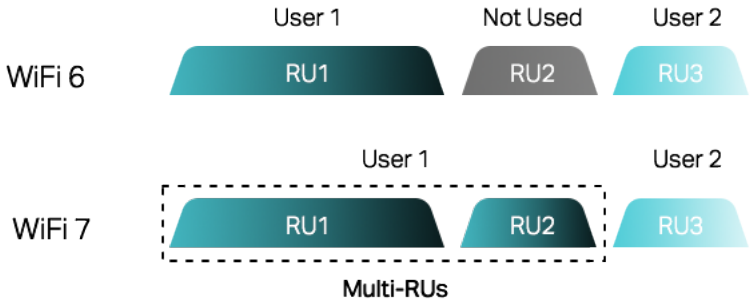


Figure 2-8 Multi-RU

*To achieve the trade-off between combination complexity and spectral efficiency, small-size RUs (less than 242 tones) can only be combined with small-size RUs, whereas large-size RUs (more than or equal to 242 tones) can only be combined with large-size RUs. Mixing small-size RUs and large-size RUs is not allowed.

2.3.6 Multi-Link Operation

In previous Wi-Fi generations, including Wi-Fi 6 and Wi-Fi 5, a device can only connect to one Wi-Fi band — either the 2.4 GHz band or 5 GHz band. The latest Wi-Fi 6E products now also connect to 6 GHz.

However, only one Wi-Fi band is available for a client. Let's take a typical Wi-Fi 6 AX3000 router, with maximum Wi-Fi speeds of 2402 Mbps on the 5 GHz band and 574 Mbps on the 2.4 GHz band, as an example. If you connect your phone to the Wi-Fi, you'll find that only the 2402 Mbps on 5 GHz or 574 Mbps on 2.4 GHz are accessible for every connection. This means that one band goes unused, or you might limit your speeds by choosing the slower band.

Multi-Link Operation (MLO) solves this dilemma. It enables devices to simultaneously send and receive data across different frequency bands and channels.

With MLO, Wi-Fi 7 supports establishing multiple links between the Station (STA, such as your phone) and Wi-Fi access point (AP, such as your router). Connecting to the 2.4 GHz, 5 GHz, and 6 GHz bands simultaneously increases throughput, reduces latency, and improves reliability. It is ideal for emerging applications like VR/AR, online gaming, remote offices, and cloud computing.

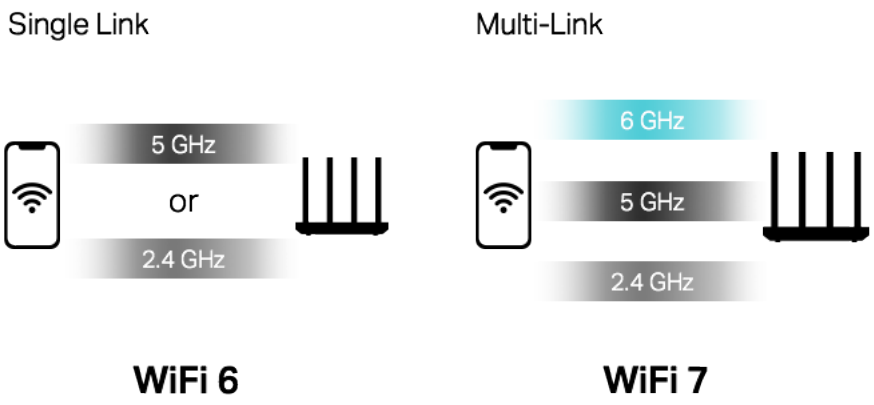


Figure 2-9 Multi-Link Operation

*How Does MLO Work?

MLO is an improvement on the MAC layer. It uses MLD (Multi-Link Devices) multi-link aggregation to achieve higher throughput, lower latency, and higher reliability. MLO uses MLD multi-link seamless dynamic switching to achieve load balancing and low latency.

a. Operating Mode

Wi-Fi 7 MLO mainly includes two modes: STR Mode and NSTR Mode.

(1) STR Mode (Simultaneous Transmit and Receive Operation)

STR Mode refers to simultaneous transceiver mode or asynchronous mode. That is, two or more links work completely independently, and they don't interfere with each other.

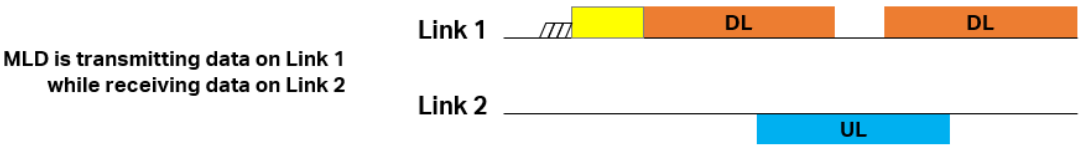


Figure 2-10 STR Mode

(2) NSTR Mode (Non-simultaneous Transmit and Receive Operation)

NSTR Mode refers to non-simultaneous transceiver mode or asynchronous mode. That is, simultaneous receiving and sending operations are not allowed. At a single time, all links can only receive or all links can send data.

Figure 2-11 NSTR Mode

(3) Others

Apart from STR/NSTR modes, there are other MLO modes. Due to the different application scenarios of Wi-Fi 7 MLO, such as Mesh and EasyMesh, there are multiple links composed of multiple physical IC radios at both ends of the AP-STA connection. There are also multiple links composed of conventional mobile devices with a single IC.

b. Technical Features

The main technical features of MLO can be divided into two aspects — packet-level features and flow-level features. The packet-level aggregation improves latency and peak performance while flow-level routing optimization improves latency and overall throughput.

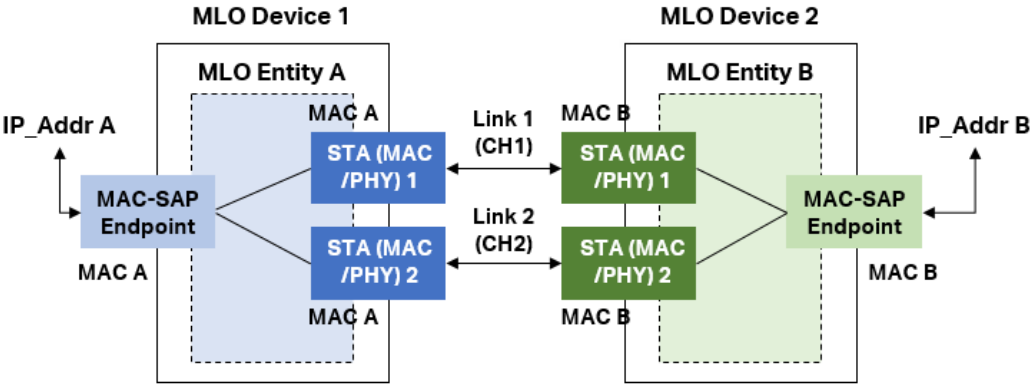


Figure 2-12 Packet-Level Aggregation

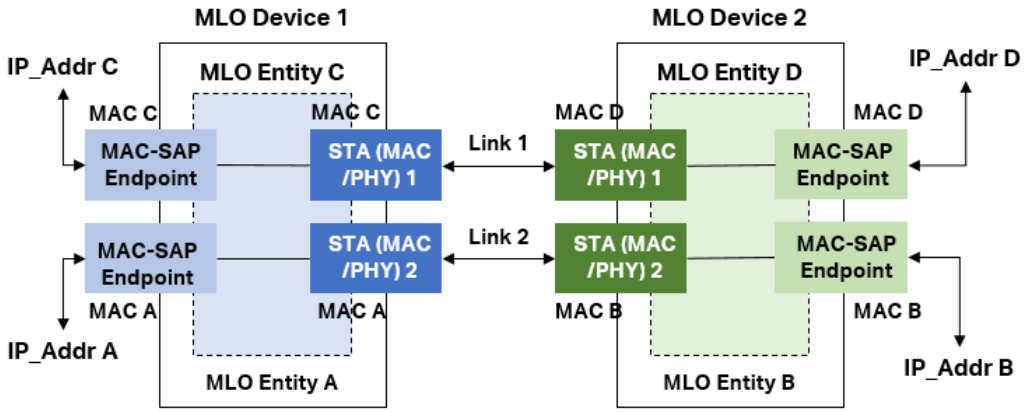


Figure 2-13 Flow-Level Aggregation

The main features are:

Packet Level Aggregation

- Packets of the same TID (Traffic Identifier) can be sent on one or more radios
- Helps with low-latency and peak throughput improvement

Cross-Wake-Up Signaling for Power-Saving

- AP indicates a buffering unit on a link that the STA is monitoring
- STA can indicate wake-up of a link using another link
- STA can monitor a link in idle mode to receive BSS/TIM information of other links

Fast Link-Transition

- The active link(s) can be switched dynamically to adapt to load/co-ex conditions
- Beneficial for 11be single-radio STAs

Multi-Primary Channel Access

- Needed for latency improvements

Shared Single Session Across Links

- Single BA (Block Acknowledgement) session per TID, shared sequence number space
- Single authentication and key derivation for unicast packets
- Separate group keys for broadcast/groupcast packets

2.4 Benefits and Applications of Wi-Fi 7

As has been introduced, Wi-Fi 7 dramatically hits the peak data rates of 46 Gbps. With such a high network speed, you can enjoy 4K/8K video/AR/VR as you wish. It will change people's way of communication and deepen people's connection. Moreover, Wi-Fi 7 will change the business mode that we are accustomed to, bringing more than we can imagine.

2.4.1 Benefits

With the upcoming 7th generation of Wi-Fi, the ultimate online experience will be unleashed: it can accelerate throughput up to 46 Gbps. Worst Case Latency is 100× better compared to Wi-Fi 6 with 15× better AR/VR performance. With 320 MHz and MLO (Multi-Link Operation), Wi-Fi 7 provides up to 5× greater capacity than Wi-Fi 6.

At home, you'll want a stable and simple network, but 5G requires many more radio access points and suffers from poor connectivity indoors. 5G will also cost more, so the better choice would be to build a unique Wi-Fi network. By hooking up a Wi-Fi 7 router or a whole home Wi-Fi 7 system, you can experience less lag and more bandwidth for super-smooth video and gameplay.

For the business sector, the economics behind both technologies is worth considering. Even after years of development, 5G is still at an early stage, meaning expensive deployment. In fact, the signal of 5G in office buildings or parks will suffer from walls and other interference, so Wi-Fi 7 will continue to provide superior performance indoors.

2.4.2 Application Scenarios

With Wi-Fi 7, you can surf all kinds of sites, stream flawless 4K/8K videos, and transmit any data package you need, all without having to wait for a long time. If you are a gaming enthusiast, Wi-Fi 7 will bring you an extremely real experience like never before. With both speed and delay enhancement, coupled with enhanced AR/VR, experience the wonderful integration of the virtual and real world. Telecommuting, massive video conferencing, and data cloud services will also flourish with Wi-Fi 7. Powerful internet signals will roll out everywhere you go, making everything connected.

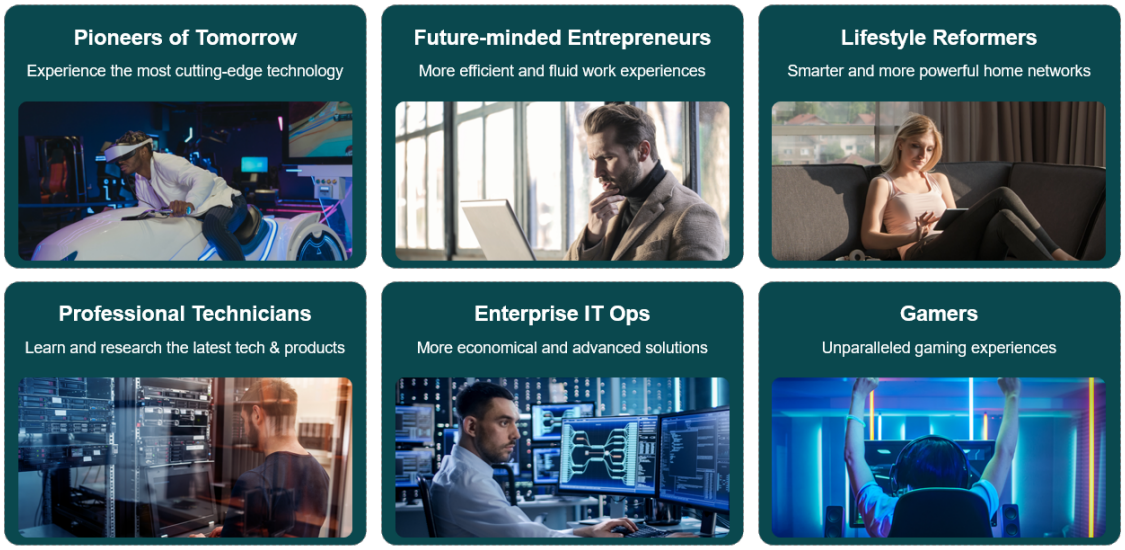


Figure 2-14 Wi-Fi 7 Applications

3 Industry Analysis

3.1 Industry Overview

Worldwide, Qualcomm and Broadcom are still leading the launch of Wi-Fi 7 products. Slightly different from the past, MTK from Taiwan is also likely to release Wi-Fi 7 products in synchronization with Broadcom.

Qualcomm, Broadcom, and MTK are all focusing on tri-band (4+4+4) products now, making full use of the high-frequency broadband band of 6 GHz. Their first mass production is expected to start in Q4 of 2022. After that, quad-band and dual-band products will follow suit.

TP-Link has close cooperation with the three companies above, and we have made corresponding decisions in each product line.

In terms of certification, the 6 GHz protocol band and certification standard of Wi-Fi 7 are the same as that of Wi-Fi 6E, and the new 6 GHz channels in the US and EU provide two to three times the available spectrum than before, which is expected to be adopted by 70+ countries.

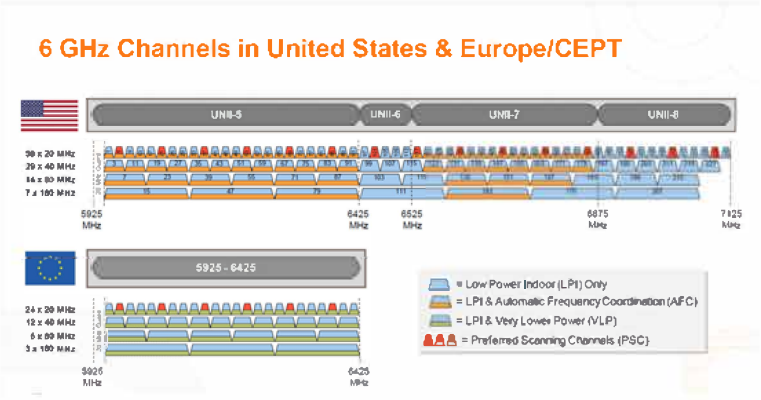


Figure 3-1 6 GHz Openness

In addition, according to supply chain news and Wi-Fi 6 debut experience, Asus and Netgear are expected to launch Wi-Fi 7 products at year-end or CES 2023.

3.2 Market Trend

The success of Wi-Fi 6 sets an example for Wi-Fi 7: Wi-Fi 6 has achieved great success and has been widely accepted since its release. In the third year after the release of the technology, annual global shipments have reached

55 million units, with a year-on-year growth rate of 181%. At the same stage after Wi-Fi 5 release, the shipment of Wi-Fi 5 devices was only 17 million units. In the post-pandemic era, people's need for high-speed network is surging, which will bring higher market acceptance for Wi-Fi 7.

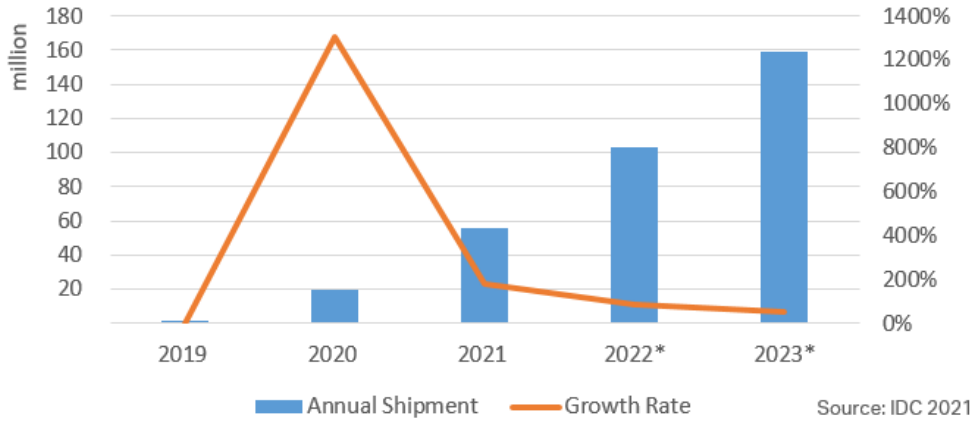


Figure 3-2 Annual Shipment Change of Wi-Fi 6 Products

The 2B market will see faster growth than the 2C market: Compared with the 2C market, the 2B market will have higher acceptance of new technologies. The popularity of new technologies in the 2B market is rising. Wi-Fi 6 took more than 20% of the 2B market share in just 1 year, while Wi-Fi 5 took 2 years. Wi-Fi 7 is expected to boom in the 2B market in 2024.

New technology is a key influencing factor in people's purchasing: When buying a network product, 27% of customers will take Wi-Fi technology into consideration—this ranks 3rd among many factors. In other words, the emergence of Wi-Fi 7 will surely be a factor influencing customers' purchasing decisions.

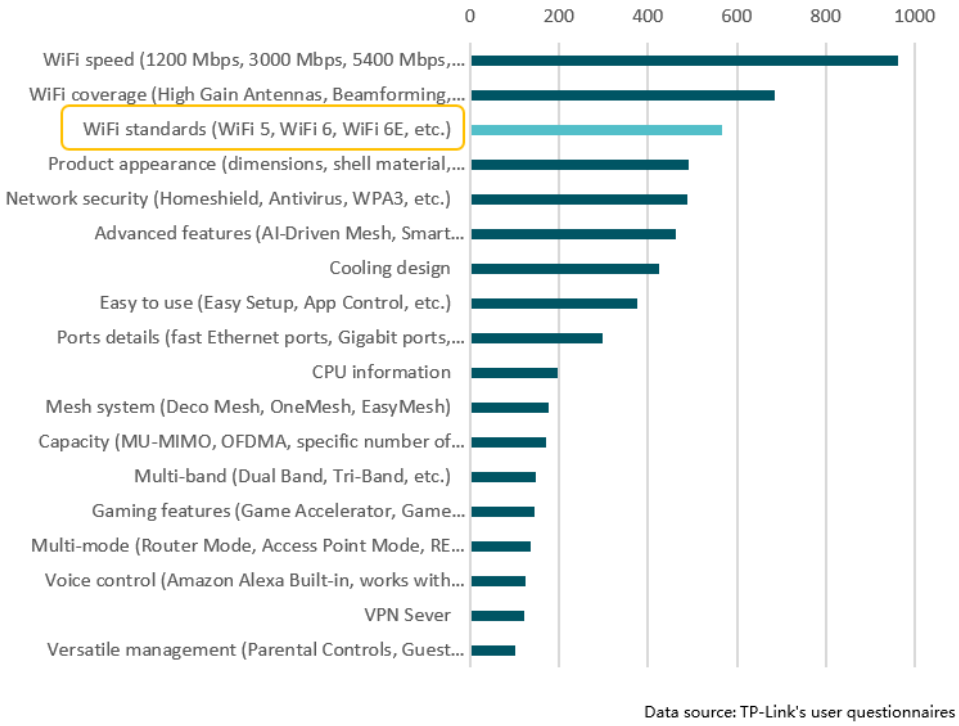


Figure 3-2 Factors Influencing People's Purchasing

4 Omada & Wi-Fi 7

Upgrade to High-Performance Wi-Fi 7 – Faster, Smoother, and Within Reach

As business demands evolve, so do the requirements for reliable, high-performance Wi-Fi. Today's internet speeds often exceed the capacity of earlier Wi-Fi standards, making it crucial to upgrade for peak performance. Omada by TP-Link, now with Wi-Fi 7 (IEEE 802.11be), introduces Extremely High Throughput (EHT), delivering multi-gigabit speeds, increased connection reliability, and ultra-low latency, even in high-density environments. Designed for demanding spaces like offices, hotels, and educational institutions, Omada's Wi-Fi 7 empowers businesses to handle modern, high-bandwidth applications - from seamless video conferencing to cloud-based tools and IoT devices. This new standard also brings advanced features like Multi-Link Operation (MLO), using multiple bands to enhance both speed and stability.

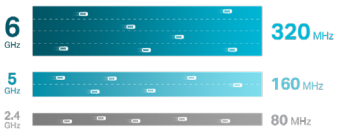
For small and medium businesses, upgrading to Omada by TP-Link with Wi-Fi 7 ensures competitive advantage in a connected world, delivering the uninterrupted, high-quality connectivity that employees, customers, and guests expect.

6 Gbps Band

Wider, Cleaner, More Efficient

Up to 320 MHz on 6 GHz

Double the Width, Double the Speed

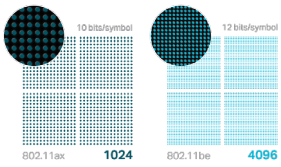


Multi-Link Operation

Higher Speed, Lower Latency, More Reliable

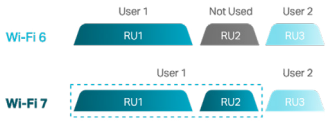
4K-QAM

Packs 120% Data for Higher Speeds



Multi-RU

Makes Full Use of Every Resource



Preamble Puncturing

No Waste, No Congestion

5 Conclusion

In recent years, some new applications requiring ultra-high throughput and ultra-low latency have prompted the IEEE 802.11 standard to evolve further to accommodate these new services' features, which has driven the R&D of Wi-Fi 7.

TP-Link continues to live up to its role as the leading WLAN product provider worldwide. As a member in the first echelon of Wi-Fi 7 R&D, TP-Link has launched the world's first complete Wi-Fi 7 solution, covering home & enterprise Wi-Fi 7 products. Maintain your curiosity and wait for TP-Link to bring you the next amazing generation of connectivity.

Omada Brings Wi-Fi 7 Within Reach

EAP783 MSRP $499.99
A Formidable Top-Tier Wi-Fi 7 Access Point

EAP773 MSRP $189.99 **& EAP772** MSRP $169.99
A Perfect Balance of Speed and Value in Wi-Fi 7

EAP723 MSRP $139.99
A Solid Entry-Level Wi-Fi 7 Access Point

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