IP Network eBook Series

# Wi-Fi 7

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HUAWEI

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# Preface

## Author Introduction

**Xia Zhou**: Serves as a documentation engineer for Huawei's wireless local area network (WLAN) products. Since joining Huawei in 2010, Ms. Zhou has been dedicated to documentation development for Huawei data center switches, WLAN products, and campus network solutions. She has made significant contributions to developing the book *Enterprise Wireless Local Area Network Architectures and Technologies*.

## About This Book

This book describes the latest Wi-Fi 7 standard, its performance improvements over previous standards, and key new technologies introduced in Wi-Fi 7. In this book, you will also find the typical applications of Wi-Fi 7 and Huawei's next-generation Wi-Fi 7 AP product.

# Intended Audience

This book is intended for information and communications technology (ICT) practitioners, such as network engineers with a basic knowledge of Wi-Fi technology and operations experience. It is also worth reading for anyone with Wi-Fi service requirements or with a general interest in the next-generation Wi-Fi standard.

# Symbol Conventions

Note Supplements important information in the main text. **Note** is used to address information not related to personal injury, equipment damage, and environment deterioration.

Caution Indicates a low-risk hazard that, if not avoided, could result in minor or moderate injury.

# Table of Contents

# Chapter 1

# What Is Wi-Fi 7?

**Abstract**

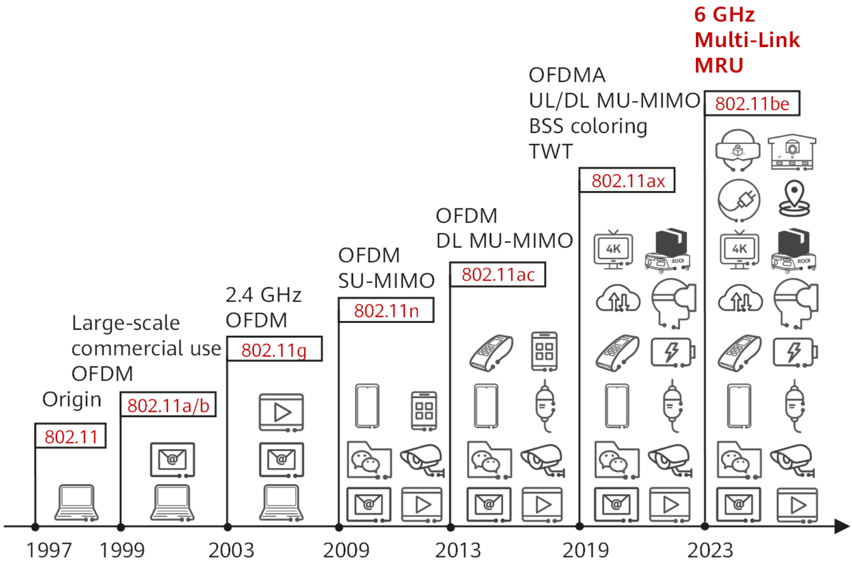
This chapter describes the evolution of Wi-Fi standards, the differences between the standards, and the advantages of Wi-Fi 7.

## 1.1 Birth of Wi-Fi 7

With the booming development of emerging applications such as mobile Internet, fully-wireless office, and augmented reality (AR)/virtual reality (VR) immersive home entertainment, individual's requirements for wireless access bandwidth gradually increase from 1000 Mbit/s to 10 Gbit/s. As such, the Institute of Electrical and Electronics Engineers (IEEE) launches the latest wireless local area network (WLAN) standard — 802.11be, also known as Extremely High Throughput (EHT), which will be officially designated Wi-Fi 7.

IEEE has defined numerous standards in the communications industry, such as IEEE 802.3 (Ethernet) and IEEE 802.11 (WLAN). As early as 1990, IEEE set up a dedicated 802.11 Working Group to study and formulate WLAN standards. Fast-forward to 1997, and the world's first 802.11 standard (802.11-1997) for WLAN was launched. Since then, IEEE has released a new standard every four to five years, as shown in Figure 1-1.

Figure 1-1 802.11 standard evolution




- Standard origin: 802.11-1997 defeats other standards to become the first widely used WLAN standard in the industry.
- Standard enhancement: 802.11b makes the large-scale commercial use of WLAN possible by delivering speeds of 11 Mbit/s. 802.11a further increases the WLAN speeds to 54 Mbit/s by applying orthogonal frequency division multiplexing (OFDM) technology to the 5 GHz frequency band.
- Standard extension and compatibility: 802.11g extends the use of OFDM technology to the 2.4 GHz frequency band and is backward compatible with 802.11b.
- High Throughput (HT) standard based on multiple-input multiple-output (MIMO) and OFDM: 802.11n supports single-user MIMO (SU-MIMO) and OFDM, and delivers speeds of up to 600 Mbit/s.

- Very High Throughput (VHT) standard: 802.11ac supports downlink multi-user MIMO (DL MU-MIMO), provides channel bandwidth of up to 160 MHz, and delivers speeds of up to 6933.33 Mbit/s.
- High Efficiency (HE) standard: 802.11ax introduces technologies such as orthogonal frequency division multiple access (OFDMA), uplink MU-MIMO (UL MU-MIMO), basic service set (BSS) coloring, and target wake time (TWT), further improving the throughput in high-density scenarios and increasing the speeds to 9607.8 Mbit/s.
- EHT standard: Based on the 6 GHz spectrum introduced in Wi-Fi 6E, 802.11be supports various technologies such as multiple resource unit (MRU) and multi-link to further improve the throughput and deliver speeds of up to 23050 Mbit/s.

Table 1-1 compares the capabilities of different 802.11 standards.

Table 1-1 802.11 standards comparison

| Standard Version | Frequency Band (GHz) | PHY Technology | Modulation Scheme | Number of Spatial Streams | Channel Bandwidth (MHz) | Data Rate (Mbit/s) |
|---|---|---|---|---|---|---|
| 802.11 | 2.4 | IR, FHSS, and DSSS | - | - | 20 | 1 and 2 |
| 802.11b | 2.4 | DSSS/CCK | - | - | 20 | 5.5 and 11 |
| 802.11a | 5 | OFDM | 64-QAM | - | 20 | 6 to 54 |
| 802.11g | 2.4 | OFDM<br>DSSS/CCK | 64-QAM | - | 20 | 1 to 54 |
| 802.11n | 2.4 and 5 | OFDM<br>SU-MIMO | 64-QAM | 4 | 20 and 40 | 6 to 600 |

| Standard Version | Frequency Band (GHz) | PHY Technology | Modulation Scheme | Number of Spatial Streams | Channel Bandwidth (MHz) | Data Rate (Mbit/s) |
|---|---|---|---|---|---|---|
| 802.11ac | 5 | OFDM<br>DL MU-MIMO | 256-QAM | 8 | 20, 40, 80, 160, and 80+80 | 6 to 6933.33 |
| 802.11ax | 2.4 and 5 | OFDMA<br>UL/DL MU-MIMO | 1024-QAM | 8 | 20, 40, 80, 160, and 80+80 | 6 to 9607.8 |
| 802.11be (Wi-Fi 7) | 2.4, 5, and 6 | OFDMA<br>UL/DL MU-MIMO | 4096-QAM | 8 | 20, 40, 80, 160, 80+80, 160+160, and 320 | 6 to 23050 |

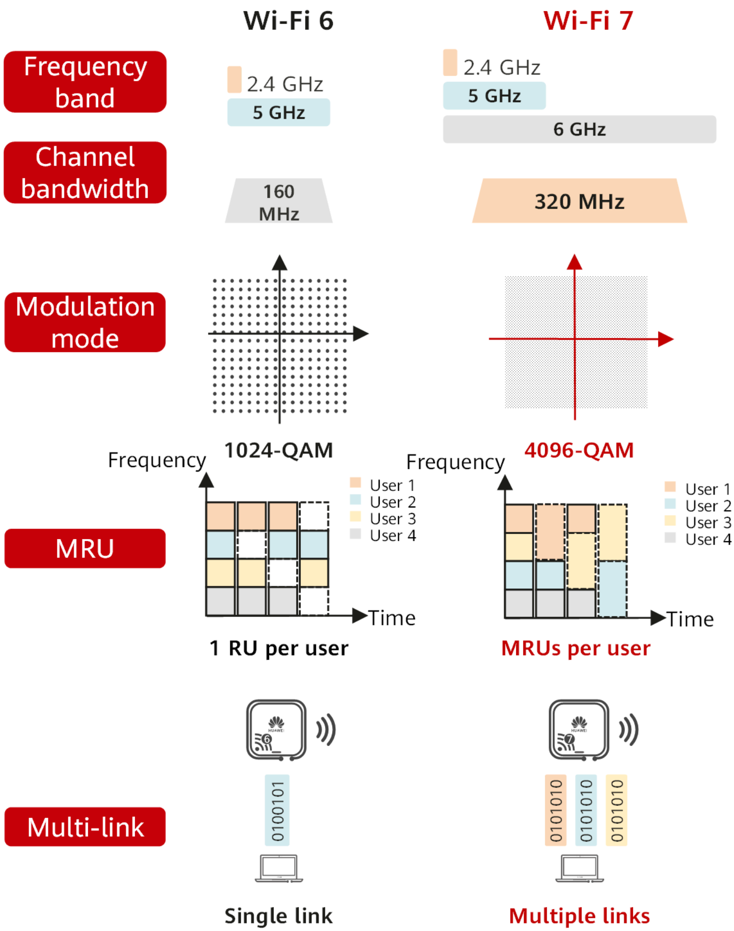
**Note**

The data rate in the table above refers to the maximum rate of a single radio.

# 1.2 Wi-Fi 7 vs. Wi-Fi 6, Faster and Beyond

In addition to the significant speed improvements over Wi-Fi 6, Wi-Fi 7 delivers much higher user performance. Figure 1-2 shows the comparison of the two Wi-Fi standards.

Figure 1-2 Wi-Fi 7 vs. Wi-Fi 6




## Spectrum resources: faster speeds and less interference

Wi-Fi 7 supports the 6 GHz frequency band, which can be used only by 6 GHz-capable devices and therefore suffers from less interference. Additionally, the latest anti-interference technologies, such as OFDMA and Coordinated Spatial Reuse (CoSR), are applied to further reduce interference.

**Maximum bandwidth: faster speeds**

The maximum channel bandwidth in Wi-Fi 7 is increased from 160 MHz (Wi-Fi 6) to 320 MHz, increasing speeds by 100%.

**Modulation scheme: faster speeds**

The order of the modulation scheme in Wi-Fi 7 is increased from 1024-QAM (Wi-Fi 6) to 4096-QAM, increasing speeds by 20%.

**MRU: lower latency**

Wi-Fi 7 supports MRU for dynamic resource scheduling, reducing service latency by 25%.

**Multi-link: higher reliability and lower latency**

Multi-link technology introduced in Wi-Fi 7 supports multiple links for terminals, implementing multi-fed and selective receiving and improving reliability.

# Chapter 2
# 4096-QAM

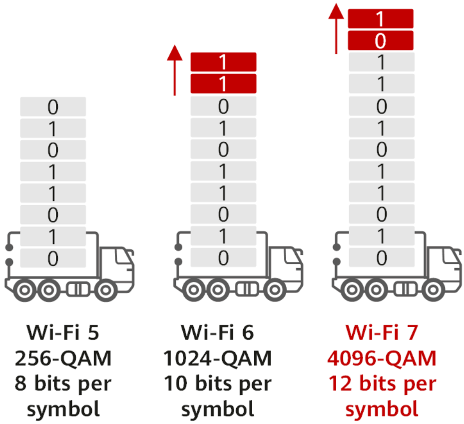
**Abstract**

This chapter describes how 4096-QAM introduced in Wi-Fi 7 improves data transmission speeds.

## 2.1 How Does 4096-QAM Increase Speeds?

Generations of Wi-Fi standards have been dedicated to improving data transmission speeds. One of the ideas is to improve the capability of carrying data per symbol. As shown in Figure 2-1, if we compare the symbol as a truck, a higher-order QAM mode allows us to carry even more information on each truck, which translates to faster data transmission.

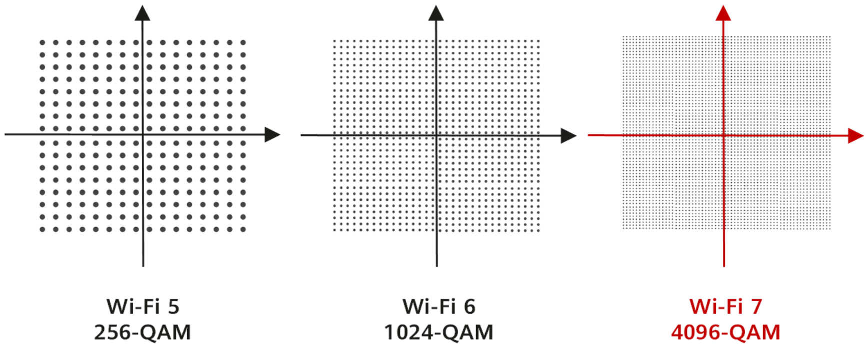
Figure 2-1 Data carried per symbol in different Wi-Fi standards




In Wi-Fi standards, a higher QAM order can improve the capability of carrying data per symbol. As shown in Figure 2-2, Wi-Fi 5 and Wi-Fi 6 use 256-QAM and 1024-QAM, respectively, with each symbol carrying 8-bit and 10-bit data. In Wi-Fi 7 that adopts the higher-order 4096-QAM, this capability is expected to increase to 12 bits.

With such improvements in each generation of Wi-Fi standards, Wi-Fi 6 increases the data throughput of a single spatial stream by 25% compared to Wi-Fi 5, and Wi-Fi 7 further increases this value by 20% compared to Wi-Fi 6.

Figure 2-2 QAM modes adopted in Wi-Fi 5, Wi-Fi 6, and Wi-Fi 7




## 2.2 Is a Higher QAM Order Indicative of Better Performance?

The QAM order is not simply a "more is better" scenario. As the carrier bandwidth used for sending a symbol and the transmission duration are both fixed, a higher order leads to a smaller difference between two symbols. This places high requirements on the environment and the components of the receiver and transmitter.

If the environment is noisy with a small signal-to-noise ratio (SNR), symbols are difficult to demodulate, making the demodulation process prone to errors. This means that a lower-order QAM mode is the only option in these "noisy" environments.

Put differently, if we speak too fast in a noisy environment, individual words may be drowned out.

# Chapter 3
# MRU

**Abstract**

This chapter describes the reason why MRUs are introduced in Wi-Fi 7 and MRU-based resource allocation.

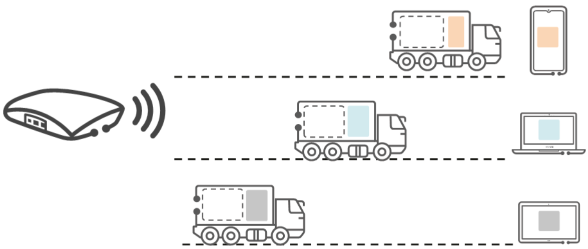
## 3.1 OFDMA and RU

Before delving into MRU, we need to understand the concepts of orthogonal frequency division multiple access (OFDMA) and resource unit (RU).

### OFDMA

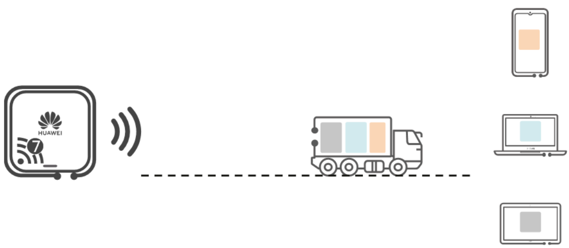
One of the key differences between Wi-Fi 6 and Wi-Fi 5 is that the former introduces the multi-user technology — OFDMA, which makes it possible to improve spectrum utilization by allowing users to share channel resources. In OFDM, an AP communicates with each user in point-to-point mode in each period. If the AP needs to communicate with three users, it takes three transmission periods. This means that each time data is sent, one user occupies the entire channel regardless of the user data amount. Let's imagine Wi-Fi communication as an express delivery service, where information represents the goods to be transported to the receiver. In OFDM, a truck delivers one package per trip, regardless of its size. As a consequence, some of the space in the truck is usually wasted, as shown in Figure 3-1.

Figure 3-1 Multi-user transmission in OFDM



To make better use of the truck's space, Wi-Fi 6 introduces OFDMA. It divides channel resources into multiple RUs. Different users are allocated these RUs, which carry their respective data. In this way, the data of multiple users can be sent on one channel simultaneously, as shown in Figure 3-2.

Figure 3-2 Multi-user transmission in OFDMA



OFDMA achieves point-to-multipoint communication between an AP and multiples users, greatly improving communication efficiency.

# RU and Tone

RUs are the minimum transmission units in OFDMA. To simplify OFDMA-based scheduling, Wi-Fi 6 defines seven types of RUs: 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, 484-tone RU, 996-tone RUs, and 2x996-tone RUs. Based on these, Wi-Fi 7 supports one more RU type thanks to the new 320 MHz channel. Table 3-1 lists the number of *XX*-tone RUs supported at different channel bandwidth values. Assuming that a 320 MHz channel is only divided into 26-tone RUs, then theoretically, it allows an AP to communicate with a maximum of 148 terminals simultaneously.

Table 3-1 Number of RUs at different channel bandwidth values

| RU Type | 20 MHz | 40 MHz | 80 MHz | 160 or 80+80 MHz | 320 or 160+160 MHz |
|---|---|---|---|---|---|
| 26-tone RU | 9 | 18 | 37 | 74 | 148 |
| 52-tone RU | 4 | 8 | 16 | 32 | 74 |
| 106-tone RU | 2 | 4 | 8 | 16 | 32 |
| 242-tone RU | 1 | 2 | 4 | 8 | 16 |
| 484-tone RU | - | 1 | 2 | 4 | 8 |
| 996-tone RU | - | - | 1 | 2 | 4 |
| 2x996-tone RU | - | - | - | 1 | 2 |
| **4x996-tone RU (New in Wi-Fi 7)** | **-** | **-** | **-** | **-** | **1** |

In terms of *XX*-tone RU, *XX* represents the number of tones included in an RU. For example, a 26-tone RU indicates that the RU includes 26 tones.

The tone concept mentioned here is also known as subcarrier. Wireless signals are transmitted on fixed frequencies, which are also called carriers, and the

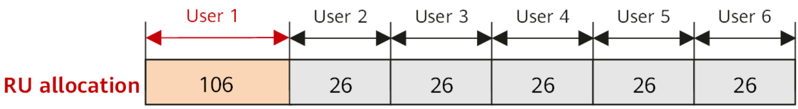
802.11 standard further divides these frequencies into subcarriers, that is, tones. For example, a 20 MHz channel in Wi-Fi 6 is divided into 256 tones, with 78.125 kHz spacing, which represents only one quarter compared to Wi-Fi 5 (312.5 kHz), as shown in Figure 3-3. Among these tones, 234 data tones are used for transmission, which is the number of valid subcarriers mentioned above. As for the 320 MHz channel bandwidth introduced in Wi-Fi 7, the total number of tones is 4096, in which there are 4x980 data tones.

Figure 3-3 RU division for a 20 MHz channel


# 3.2 MRU-based Resource Allocation

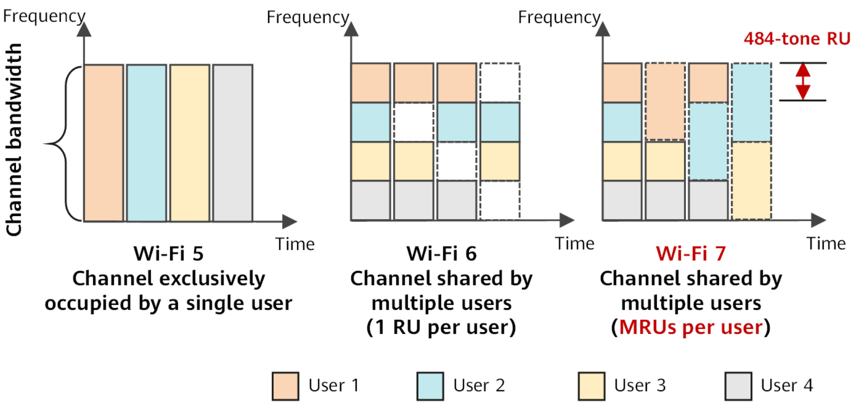
In practice, Wi-Fi 6 allocates different types of RUs to different users. For example, a 20 MHz channel is allocated to users 1 to 6, as shown in Figure 3-4. A 106-tone RU is allocated to user 1, and 26-tone RUs are allocated to the other users.

Figure 3-4 Multi-user RU allocation




However, according to RU allocation in Wi-Fi 6, each user can be allocated only one RU in a period. As a result, some RUs become idle, leading to resource waste and lack of flexibility. To break through this limitation, Wi-Fi 7 introduces MRU technology, which allows a single user to occupy multiple RUs simultaneously. An MRU consists of selected combinations of multiple RUs of different sizes. Figure 3-5 shows the detailed channel occupation in different Wi-Fi standards.

Figure 3-5 Channel occupation comparison between Wi-Fi 5, Wi-Fi 6, and Wi-Fi 7




In MRU, RU combinations are subject to some constraints in order to achieve a balance between implementation complexity and spectrum resource utilization. For example, small size RUs (< 20 MHz) can only be combined with small size RUs to form small size MRUs, and large size RUs (⩾ 20 MHz) can only be combined with large size RUs to form large size MRUs, as detailed in Table 3-2.

Table 3-2 MRU types

| RU Type | RU Combination | Bandwidth (MHz) |
|---|---|---|
| Small size MRU | 26+106-tone | 20, 40, 80, 160, or 320 |
| | 26+52-tone | 20, 40, 80, 160, or 320 |
| Large size MRU | 242+484-tone | 80, 160, or 320 |
| | 484+996-tone | 160 or 320 |
| | 2x996-tone | 160 or 320 |
| | 242+484+996-tone | 160, only for non-OFDMA transmission |
| | 484+2x996-tone | 320 |
| | 3x996-tone | 320 |
| | 484+3x996-tone | 320 |
| | 4x996-tone | 320 |

# Chapter 4
# Multi-Link

**Abstract**

This chapter describes the multi-link technology introduced in Wi-Fi 7 and the benefits from this technology.

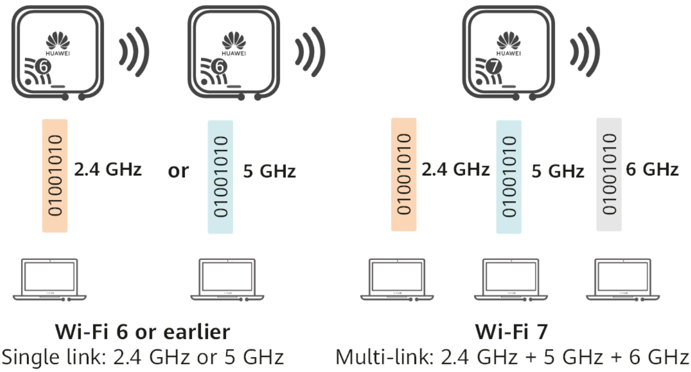
## 4.1 What Is Multi-Link?

In Wi-Fi 6 and earlier standards, an AP and a STA can establish a link only using one radio at a time even though they both support multiple radios.

To further improve throughput and reduce latency, the Wi-Fi 7 standard introduces multi-link operation (MLO) technology, which allows an AP and a STA to establish multiple links between each other simultaneously for data communication. Figure 4-1 compares link establishment between the AP and STA.

In the Wi-Fi 7 standard, an MLO-capable device is defined as a multi-link device (MLD). The MLD has a plurality of independent PHYs. Wi-Fi 7 introduces a MAC that can coordinately manage each independent PHY. This MAC capability resolves issues in multi-link aggregation, channel access, data transmission, etc.

Figure 4-1 Wi-Fi 6 vs. Wi-Fi 7

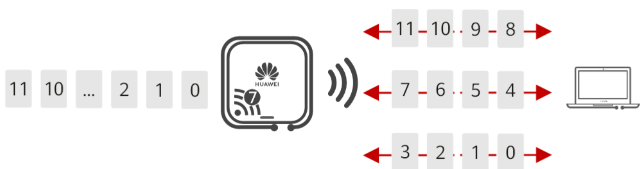



# 4.2 What Benefits Does Multi-Link Bring?

MLO enables data flows to be sent to MLDs over different radios. The following MLO modes are supported:

- Mode 1: Higher performance

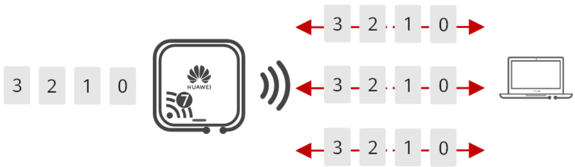
Figure 4-2 High performance




Multiple links are used for load balancing, improving the peak single-user throughput.

- Mode 2: Higher reliability

Figure 4-3 Higher reliability




Multiple links are used for multi-fed and selective receiving, improving link reliability.

Chapter 5

# Other Wi-Fi 7 Enhancements

**Abstract**

This chapter describes several other key technologies leveraged by Wi-Fi 7: physical layer protocol data unit (PPDU) format optimization, restricted target wake time (R-TWT) for power saving, 802.11ba deep power saving, and 802.11az high-precision positioning.

## 5.1 PPDU Formats in Wi-Fi 7

In Wi-Fi 6, PPDUs are reconstructed to support the OFDMA function. Wi-Fi 6 defines four new PPDU formats:

- HE SU PPDU: applies to single-user packet transmission.
- HE MU PPDU: applies to simultaneous multi-user transmission.
- HE Trigger-based PPDU (HE TB PPDU): applies to UL OFDMA and UL/DL MU-MIMO scenarios. The Trigger frame in the HE TB PPDU format a terminal receives from an AP contains resource allocation information used for simultaneous multi-user uplink transmission.

- HE extended range SU PPDU (HE ER SU PPDU): applies to outdoor long-range scenarios.

Figure 5-1 Four new PPDU formats introduced in Wi-Fi 6


Wi-Fi 7 evolves based on the Wi-Fi 6 PPDUs. Specifically, Wi-Fi 6 defines the HE SU and HE MU PPDUs as two independent PPDU types, while Wi-Fi 7 integrates the two types of PPDUs into an EHT MU PPDU. This new PPDU can be used for both SU and MU transmission. Just like the HE TB PPDU in Wi-Fi 6, Wi-Fi 7 also defines the EHT TB PPDU. Figure 5-2 shows the formats of PPDUs specific to Wi-Fi 7.

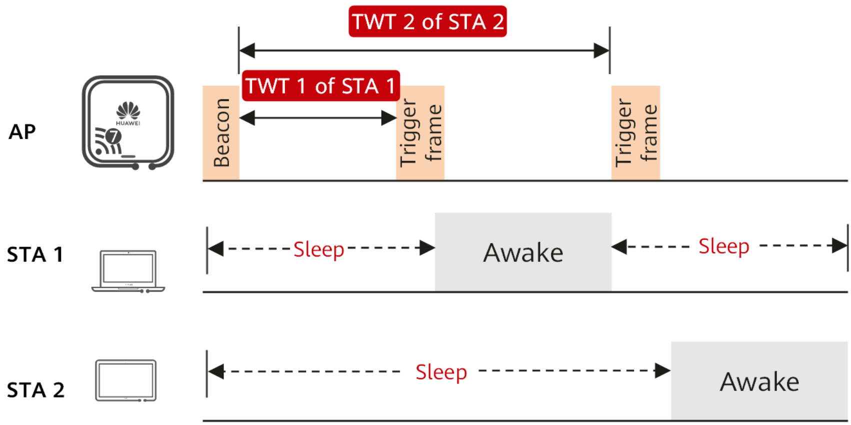
Figure 5-2 Wi-Fi 7 PPDU formats


The universal signal (U-SIG) field is introduced in Wi-Fi 7. Different from the SIG design in Wi-Fi 6 and earlier versions, the U-SIG field in Wi-Fi 7 contains PHY version information and is forward compatible with various possible PPDU formats in the future, simplifying the PPDU format identification process on the receiver.

# 5.2 R-TWT for Power Saving

To save power, Wi-Fi 6 introduces the target wake time (TWT) mechanism, which was originally designed in 802.11ah for devices with low traffic volumes (especially IoT devices). The TWT mechanism enables an AP and a STA to establish a TWT agreement and negotiate TWT service periods (SPs). This ensures that the STA is awake only within the SPs. Figure 5-3 shows the TWT mechanism.

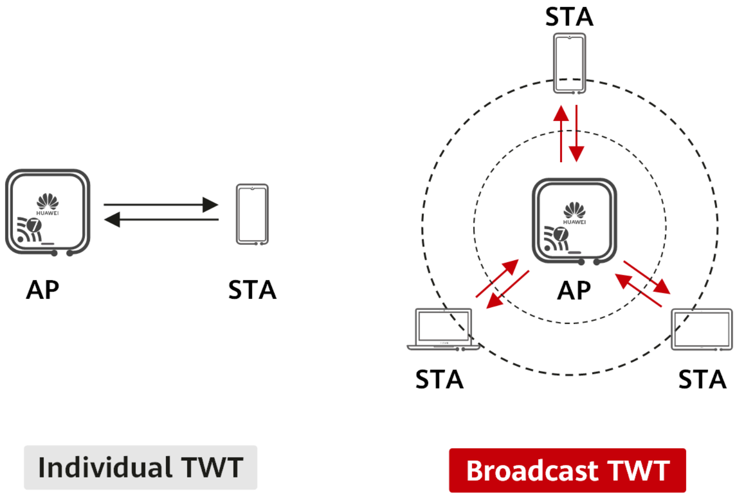
Figure 5-3 TWT mechanism




This mechanism is similar to a home delivery service. The recipient does not need to wait at home to receive the goods but can discuss with the courier to receive the goods at a fixed time.

There are two TWT modes: individual TWT and broadcast TWT, as shown in Figure 5-4.

Figure 5-4 Individual TWT and broadcast TWT




Individual TWT requires a corresponding agreement between an AP and a STA, where the STA only recognizes the TWT it obtained through negotiation with the AP.

However, it takes a long time for the AP to negotiate with each STA one by one. To simplify negotiation, Wi-Fi 6 defines broadcast TWT, which does not require an individual TWT agreement. Broadcast TWT is managed by the AP. In this mechanism, the TWT SPs are announced by the AP, and STAs send requests to the AP to join the broadcast TWT operation. After joining the broadcast TWT, the STAs can obtain the AP's broadcast TWT SPs.

According to Wi-Fi 6, individual TWT is mandatory for APs but not for STAs, and broadcast TWT is not mandatory for APs. Wi-Fi 7 defines a multi-link TWT mechanism based on MLO technology, and defines restricted TWT (R-TWT) for latency-sensitive traffic. R-TWT allows APs to use enhanced channel access and resource reservation mechanisms to provide more predictable latency, lower worst-case latency, and/or lower jitter, as well as provide higher reliability for transmission of latency-sensitive traffic. R-TWT inherits the negotiation mechanism of broadcast TWT, and carries required information in the TWT Setup frame.

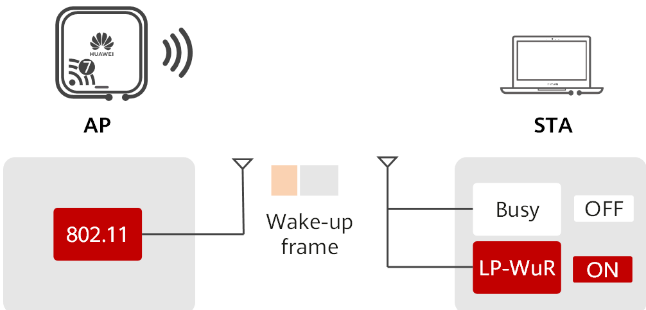
# 5.3 802.11ba for Deep Power Saving

The TWT mechanism has been introduced to Wi-Fi to save power by enabling devices to periodically sleep and wake up. In spite of this, there are still some issues, for example, devices still need to wake up periodically to check whether channels are idle. To prevent these issues, Wi-Fi 7 introduces 802.11ba for deep power saving. 802.11ba refers to Wake-up Radio (WuR), which has been widely used in the IoT field. WuR performs well in low-power, delay-tolerant, and on-demand data collection scenarios, such as smart homes, wildlife tracking, and storage monitoring.

WuR can achieve deep power saving because:

- The device sets the communications module to the deep sleep mode, and enables only one wake-up receiver with ultra-low power consumption. After receiving a wake-up frame, the wake-up receiver wakes up the communications module to receive and send data and signaling.
- The wake-up frame is modulated simply using on-off keying (OOK) and transmitted over 4 MHz channels, greatly reducing the power consumption and costs of the wake-up receiver.

Figure 5-5 WuR working diagram



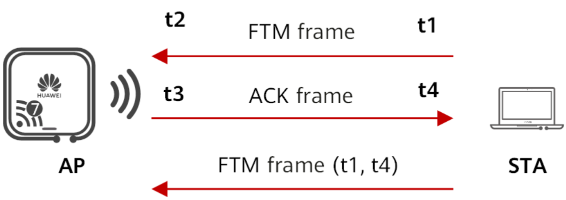
# 5.4 802.11az for High-Precision Positioning

802.11az, referred to as Next Generation Positioning (NGP), aims to replace widely used signal strength-based positioning technologies. 802.11az uses Fine Timing Measurement (FTM).

The two ends of a link function as the initiating STA (ISTA) and responding STA (RSTA), respectively. The ISTA and RSTA exchange FTM and ACK frames, so that the RTT can be calculated to measure the distance between them. Figure 5-6 shows the frame exchange process between the ISTA and RSTA. The ISTA records the FTM frame sending timestamp as $t1$ and the ACK frame receiving timestamp as $t4$. The RSTA records the FTM frame receiving timestamp as $t2$ and the ACK frame sending timestamp as $t3$. In the next FTM-ACK frame exchange process, the ISTA sends $t1$ and $t4$ to the RSTA. Based on these timestamps, the RSTA can calculate the RTT as follows: RTT = $t4 - t1$ ($t3 - t2$). Based on this formula, the frame processing delay $\Delta t$ can be calculated by deducting $t3$ from $t2$.

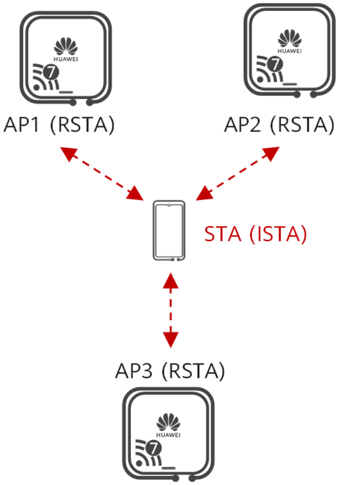
The RTT is calculated as follows: RTT = $(t2 - t1) + (t4 - t3)$. Then, the distance between the ISTA and RSTA can be estimated based on the speed of light and RTT/2.

Figure 5-6 FTM implementation



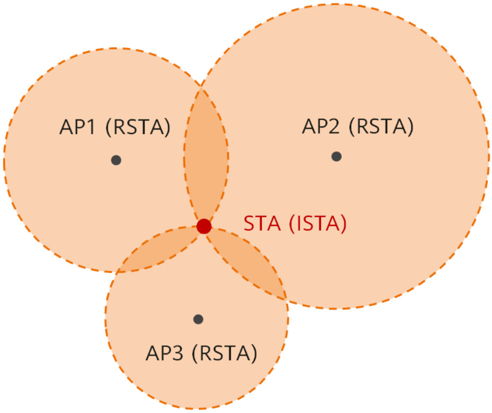

Due to the synchronization precision, the recorded timestamps $t2$ and $t4$ may deviate. The first-path delay or phase offset is typically used on the ISTA and RSTA to compensate for the deviation, thereby improving the ranging precision. Additionally, in Wi-Fi 7, the channel bandwidth has been extended to 320 MHz, which can further improve the ranging precision.

Figure 5-7 802.11az networking diagram




As shown in the preceding figure, an 802.11az network consists of one STA and multiple APs. To estimate the STA's position, FTM and the trilateration positioning method are used, with the latter requiring at least three APs. In this example, the STA is the ISTA and the three APs are RSTAs. The ISTA sets up FTM sessions with the three RSTAs that are not positioned in a straight line to obtain its relative distances from the RSTAs. Then, a circle is drawn with each distance as the radius. The ISTA is positioned at the intersection point of the three circles, as shown in Figure 5-8.

Figure 5-8 Trilateration positioning method



# Chapter 6
# Huawei's Unique Wi-Fi 7 Technologies

**Abstract**

This chapter describes the key technologies introduced in Huawei Wi-Fi 7, including Wi-Fi Shield, VIP user experience assurance, and converged scheduling.

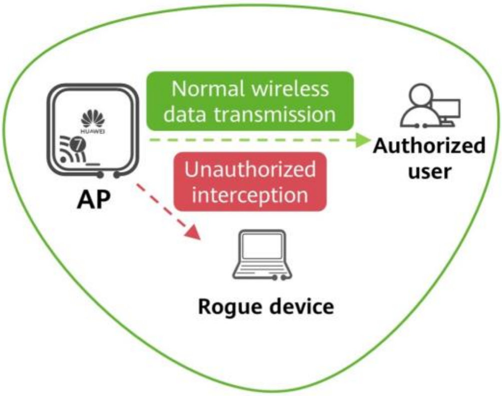
## 6.1 Wi-Fi Shield

### Background of Wi-Fi Shield

Thanks to the convenience of wireless networks, more and more people are accessing the Internet through Wi-Fi. However, Wi-Fi signals are transmitted in the air and can be received by anyone within a certain area. This brings opportunities for malicious users to intercept data of authorized users. As shown in Figure 6-1, on a complex Wi-Fi network, malicious users can deploy rogue devices near authorized users to capture and decrypt wireless data packets of authorized users.

To block unauthorized interception, Huawei develops the innovative Wi-Fi Shield technology. This technology ensures wireless security by preventing malicious users from identifying packets of authorized users.

Figure 6-1 Unauthorized interception




## Differences and Relationships Between Wi-Fi Shield and Traditional Encryption Technologies

Traditional Wi-Fi security technologies usually use encryption algorithms to encrypt wireless data packets. As such, malicious users can intercept packets but cannot understand them.

Leveraging the beamforming capability of APs, Huawei's Wi-Fi Shield technology sends extra interference signals. Malicious users can only receive a disordered superposition of the valid signals and interference signals, and cannot demodulate the signals. In other words, they cannot even intercept the signals.

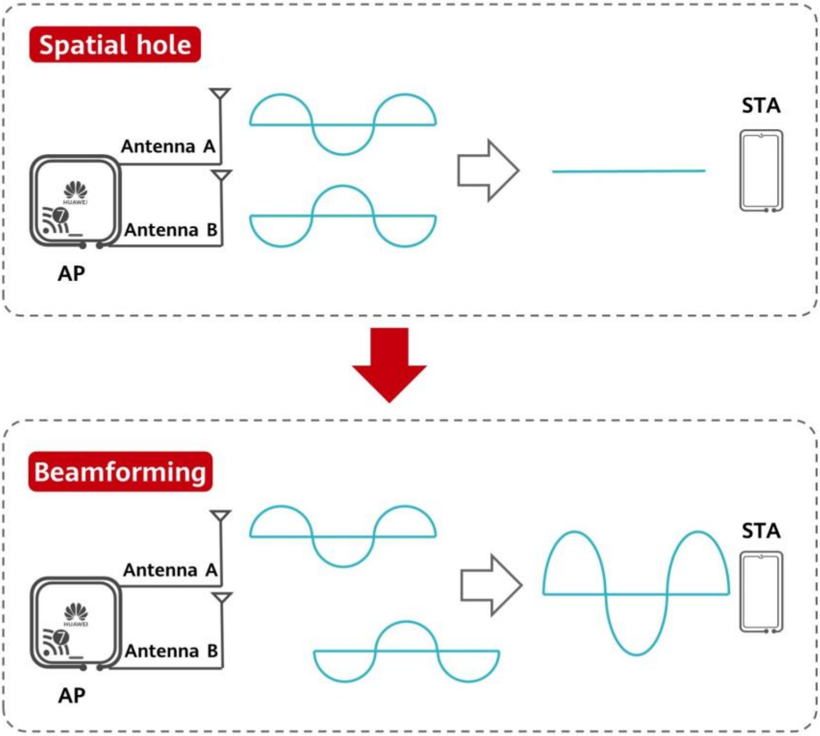
Can we use Wi-Fi Shield and traditional encryption technologies together?

The answer is yes. Wi-Fi Shield and traditional encryption technologies are independent of each other in different phases of data transmission. Traditional encryption technologies may still be cracked. Therefore, when users have high requirements on data security, a combination of data encryption and Wi-Fi Shield can be used to further enhance security.

## Working Principles of Wi-Fi Shield

The Wi-Fi Shield technology is based on the beamforming capability of APs. An AP has multiple antennas. When signals of different antennas are superimposed, they affect each other. As shown in Figure 6-2, beamforming changes the shape of beams by compensating phases of transmit antennas. As such, wireless signals can be transmitted to target STAs in a centralized and directional manner.

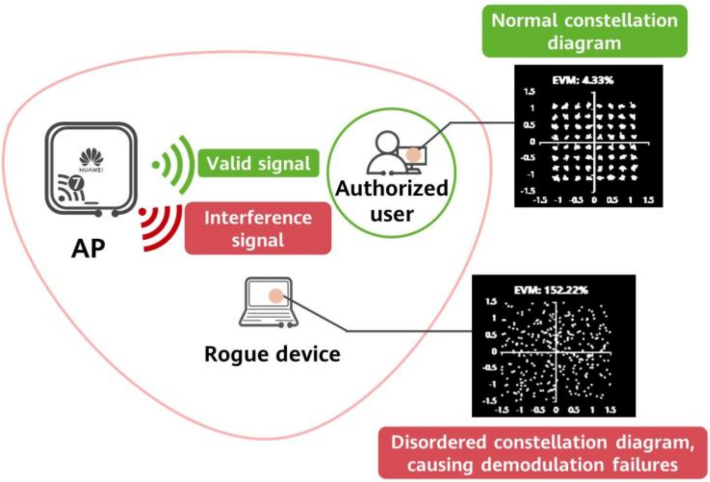
Figure 6-2 Beamforming implementation




However, in general radio signal transmission, although a sending direction may be adjusted, a receiving location is not accurate enough. In addition to the main lobe area with the most concentrated energy, some energy is usually distributed to the side lobe area. As a result, signals may also be received at other locations.

To make the signal receiving location more accurate, Wi-Fi Shield uses an additional antenna to transmit interference signals, including human interference that cannot be identified by STAs. After a STA that needs to be protected normally accesses the Wi-Fi network, the AP determines the location of the STA before sending data, and adjusts the transmission direction of the interference signal based on the location information. In this way, the interference is 0 only at the location of the target STA, and the data received by the authorized user is not affected. As shown in Figure 6-3, interference signals overlap with valid signals at other positions and cannot be identified, causing a data demodulation failure for unauthorized STAs.

Figure 6-3 Working principles of Wi-Fi Shield




To ensure that the target STA is protected while it is moving, Wi-Fi Shield dynamically updates the location information of the STA, ensuring consistent Wi-Fi security for users wherever they go. Compared with smart antennas featuring always-on signals for users, Wi-Fi Shield has different principles and purposes. Smart antennas directly adjust the direction of valid signals to enhance signal strength. In contrast, Wi-Fi Shield adjusts the direction of interference signals to accurately send data in point-to-point mode.

Even when there are multiple users on the network, Wi-Fi Shield can still ensure data security of these users. If there are multiple STAs to be protected, Wi-Fi Shield provides independent protection for each STA, customizing interference signals when data is sent to each STA.

# 6.2 VIP User Experience Assurance

## Why Do We Need VIP User Experience Assurance?

On a WLAN, a channel utilization of more than 80% suggests there is network congestion, which may cause service suspension, poor user experience, and even service loss on STAs. However, traditional wireless network scheduling policies cannot distinguish VIP users from common users, so all users contend for the same network resources. The problem is, key services such as online conferencing need to be preferentially guaranteed for VIP users such as enterprise CXOs. To achieve this, the IT department needs to focus on the network experience of such services as well as offering quick issue response and closure.

This is where VIP user experience assurance comes in. VIP user experience assurance provides differentiated service assurance based on users, so that the VIP user experience is not compromised even by wireless network congestion.

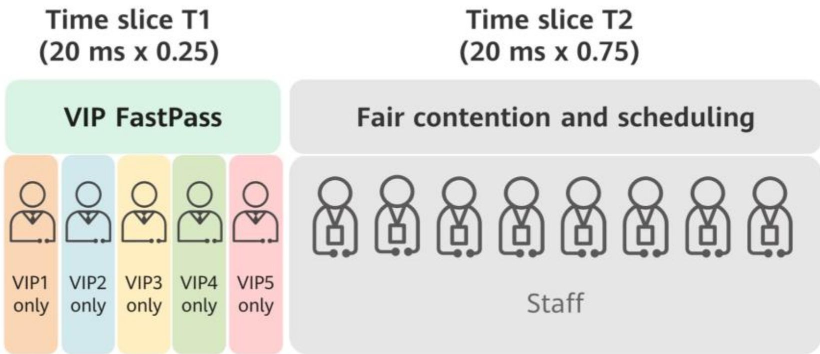
## How Does VIP User Experience Assurance Work?

Huawei uniquely provides two VIP user experience assurance technologies: VIP FastPass and VIP per-packet power control.

**VIP FastPass**

When there is wireless network congestion, traditional VIP resource reservation solutions can only ensure that data of VIP users enters high-priority queues inside APs, without being able to guarantee timely data transmission over the air interface. If there are severe signal collisions on the air interface, these solutions cannot meet the service latency requirements. To address this, VIP FastPass reserves air interface time slices for uplink and downlink traffic of VIP users when network congestion occurs. This ensures the controllable latency in sending and receiving wireless packets of VIP users.

Figure 6-4 Time slice allocation by VIP FastPass




As shown in Figure 6-4, in a single transmission period, VIP FastPass reserves 25% time slices for VIP users. Within the reserved time slices, VIP users are allocated equal amounts of bandwidth; within the remaining 75% time slices, VIP users and common users compete for bandwidth resources.

To better ensure the experience of VIP users, VIP FastPass also restricts the number of VIP users and allocable bandwidth.

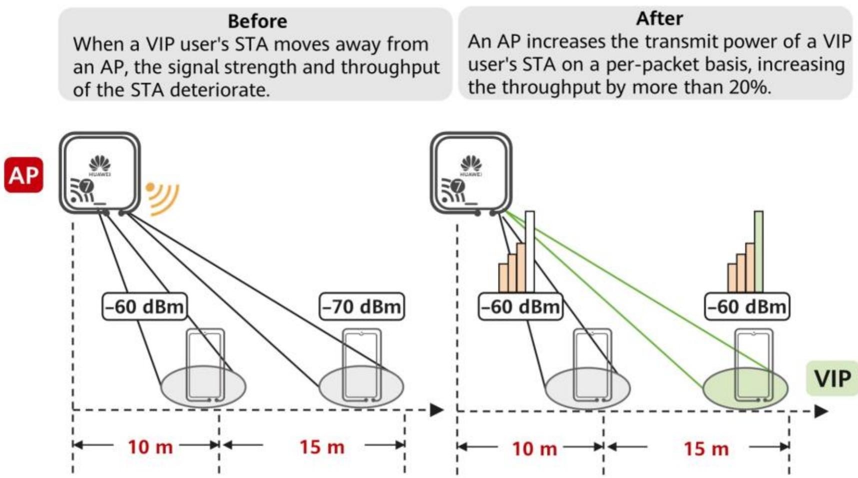
1. Restriction on the number of VIP users: By default, a maximum of five VIP users are supported. With the default settings, the average latency of VIP users does not exceed 50 ms in congestion scenarios. If the number of VIP FastPass users is manually set to 10, the average latency of VIP users is kept within 100 ms.

2. Restriction on the allocable bandwidth for VIP users: The bandwidth reserved for each VIP user equals the air interface bandwidth divided by the number of VIP users. That means the latency and packet loss of traffic beyond the reserved bandwidth cannot be guaranteed by VIP FastPass. In most cases, the traffic of VIP users' key services (such as voice and video services) does not occupy much bandwidth (usually no more than 4 Mbit/s). Additionally, APs will preferentially schedule the traffic in the high-priority video (VI) and voice (VO) queues during the reserved time slices. Therefore, the voice and video service experience can be largely guaranteed for VIP users.

**VIP Per-Packet Power Control**

As shown in Figure 6-5, when a VIP user's STA moves or is associated with an AP far away from it, the signal strength and throughput of the STA decrease as the distance between the STA and AP increases. In this case, the VIP user experience cannot be efficiently improved by VIP FastPass. Against this backdrop, VIP per-packet power control technology is introduced. This technology enables an AP to dynamically measure the downlink AP signal strength received by a VIP user's STA. Through intelligent measurement, the AP adjusts the transmit power for the STA on a per-packet basis in a weak-signal scenario (signal strength < –68 dBm). This achieves a more than 20% increase in the throughput of the VIP user's STA.

Figure 6-5 Effect of VIP per-packet power control




The measurement mechanism can be implemented in two solutions. One solution calculates the path loss based on the STA signal strength received by the AP and the estimated power of the STA. The other solution obtains the AP's signal strength measured by the STA through 802.11k messages. However, the power of STAs is uncertain. For example, the power of one STA may be 17 dBm, and that of another may be 20 dBm. Therefore, the path loss measured based on the packets sent by STAs may be inaccurate. As such, VIP per-packet power control combines the two solutions to address the measurement errors caused by the uncertain power of STAs as well as achieving more accurate power adjustment.

## Application and Benefits

Huawei's solution provides dedicated transmission "lanes" for VIP users so that they enjoy exclusive services. This ensures that VIP users enjoy uncompromised experience (with less than 50 ms latency) in the case of network congestion, and can enjoy 20% higher bandwidth than common users in weak-signal scenarios.

Figure 6-6 VIP FastPass


As shown in Figure 6-6, VIP FastPass technology reserves bandwidth resources for VIP users in advance so that VIP users can preempt bandwidth resources anytime, anywhere. In the case of network congestion, the average latency of VIP users is reduced by 75%, from 200 ms to less than 50 ms.

VIP per-packet power control technology can identify packets of VIP users and increase the transmit power of VIP users on a per-packet basis. Moreover, the technology prevents interference with neighboring APs caused by the overall AP power increase, achieving always-on signals for users. This ensures high bandwidth for VIP users even if they are located at the edge of wireless signal coverage. Compared with common users, VIP users can enjoy 20% higher bandwidth.

# 6.3 Converged Scheduling

## What Is Converged Scheduling?

In high-density scenarios such as enterprise offices and educational institutions, there are typically a large number of STAs, with high concurrency and severe interference. As such, enterprise WLANs urgently need a solution to improve multi-user concurrency efficiency in high-density scenarios. On live networks, service packets are typically bursty and discrete, and a large number of small packets are sent in single-user (SU) mode. This increases the number of signal collisions on the air interface and reduces the downlink transmission efficiency. Additionally, TCP packets are mostly used to carry high-concurrency services on the live network. Although TCP can ensure highly reliable information transmission, yet the upper-layer TCP ACK mechanism usually performs multiple uplink and downlink interactions over the air interface. As a result, uplink and downlink transmission collisions are severe in multi-user concurrency scenarios, causing packet loss. This further deteriorates the downlink wireless transmission efficiency.

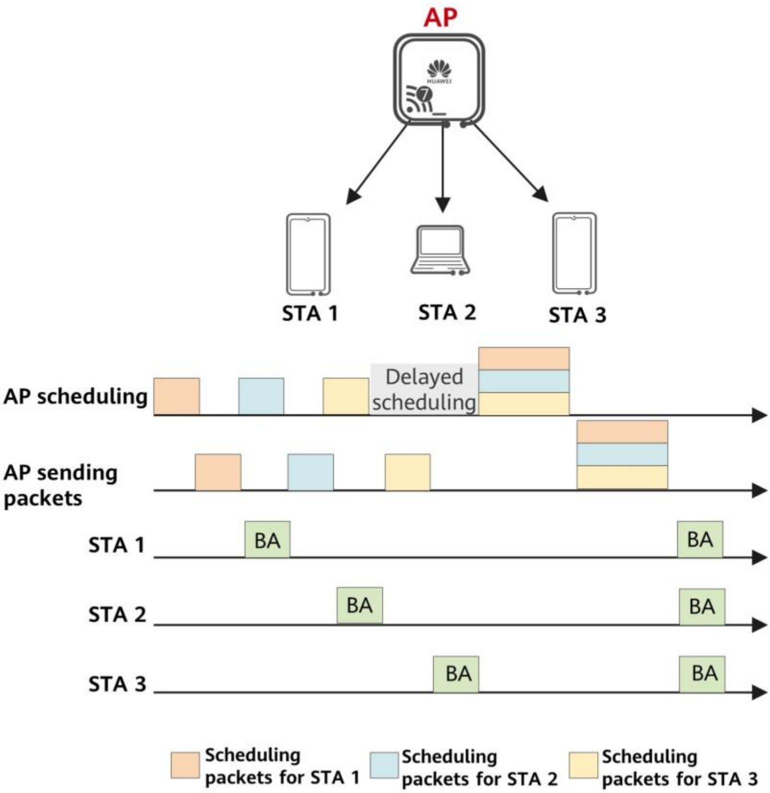
To address these issues, the converged scheduling algorithm is introduced. For multi-user concurrent services in high-density scenarios, the converged scheduling algorithm employs different methods to improve the downlink and uplink transmission efficiency: pre-scheduling based on multi-user multiple-input multiple-output (MU-MIMO) for downlink traffic; orthogonal frequency division multiple access (OFDMA) scheduling for uplink small TCP ACK packets.

## How Does Converged Scheduling Work?

1. Downlink pre-scheduling based on MU-MIMO

Compared with SU-MIMO, MU-MIMO usually provides throughput performance gains in large-packet transmission scenarios. However, a burst of service packets will prevent simultaneous scheduling of packets of multiple users. Even if the packets can be scheduled, the packet buffers of these users are insufficient, failing to achieve the air interface performance gains of MU-MIMO. For greedy services characterized by unlimited bandwidth requirements and long transmission duration, downlink pre-scheduling based on MU-MIMO reduces the packet scheduling frequency and allows more packets to stay in the scheduling buffer. This extends the single-frame transmission duration, increases the MU-MIMO packet transmission opportunities, and reduces the number of small-packet transmissions over the air interface. This ultimately improves the downlink transmission efficiency, as shown in Figure 6-7.

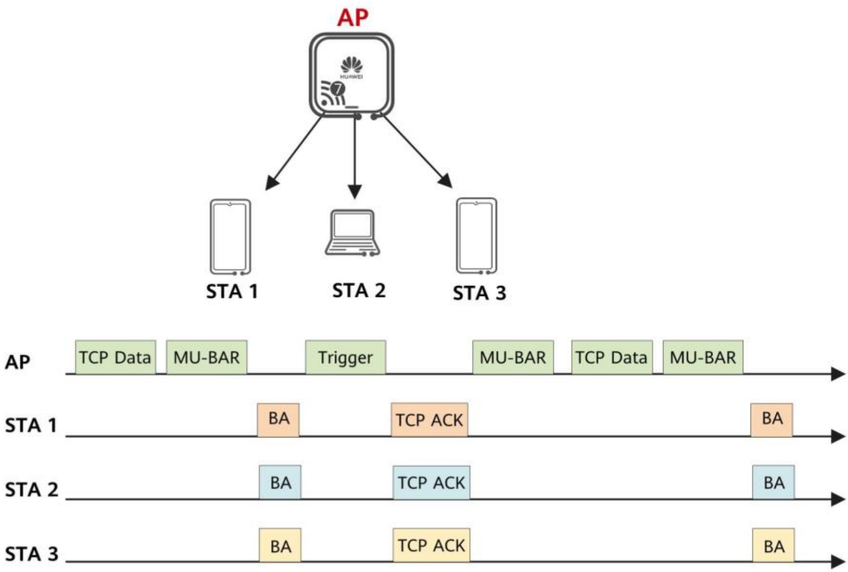
Figure 6-7 Downlink pre-scheduling based on MU-MIMO




2. Uplink OFDMA scheduling for small packets

OFDMA introduced in Wi-Fi 6 provides throughput performance gains in small-packet transmission scenarios. This technology saves air interface overheads such as the channel access and backoff time, time for sending PPDU PHY frame headers, and Block Ack (BA) time. Additionally, OFDMA helps to mitigate collisions caused by multi-user channel contention. When STAs run TCP services concurrently, an AP schedules small TCP ACK packets using OFDMA to control the unordered, free channel contention in the uplink direction. This in turn reduces uplink and downlink transmission collisions, and ensures high efficiency in sending downlink TCP packets, as shown in Figure 6-8.

Figure 6-8 Uplink OFDMA scheduling for small packets



Chapter 7

# Wi-Fi 7 Application Scenarios


**Abstract**

Wi-Fi 7 is ideal for many kinds of emerging applications, such as AR/VR, 4K and 8K video streams, cloud computing, video calling, video conferencing, and remote office. This means that in addition to the traditional application scenarios of enterprises, Wi-Fi 7 will be more beneficial to emerging application scenarios.

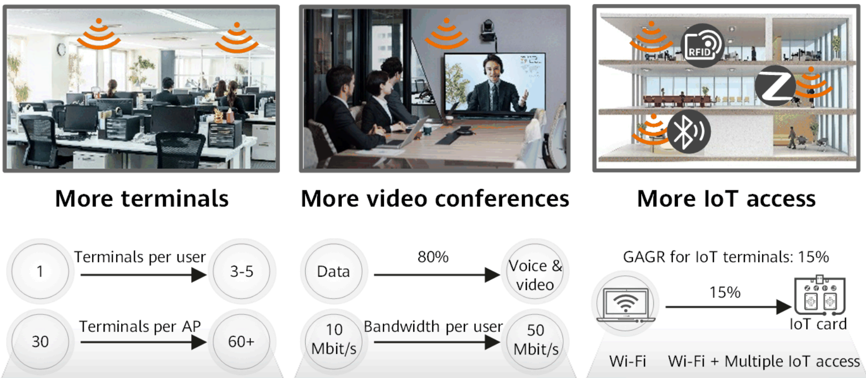

## 7.1 High-Quality 10 Gbps Office Campus Network

In enterprise office environments, wireless is becoming the dominant network access mode. Nowadays, every office area needs to have Wi-Fi coverage, with some office areas having no wired network ports whatsoever, making the office environment more open and intelligent. In the future, even high-bandwidth services, including enterprise cloud desktop office, telepresence conferences, and

4K videos, will be migrated from wired to wireless networks. Meanwhile, new technologies such as VR/AR and virtual assistant will be directly deployed on wireless networks. These new application scenarios pose higher requirements on enterprise WLAN.

One result of this trend is the sharp increase in the number of terminals. The number of access terminals of a single user has increased from one in the past to three to five at present, which means that the number of access terminals connected to a single AP will multiply. The second change is reflected on applications. For example, the number of enterprise office video conferences has increased sharply, the proportion of voice/video traffic to user traffic has increased continuously, and the user bandwidth has increased from 10 Mbit/s to 50 Mbit/s. In addition, with the rise of smart buildings, a large number of IoT terminals will access the network. This makes the convergence of Wi-Fi and IoT networks become a trend.

Figure 7-1 High-Quality 10 Gbps Office Campus Network



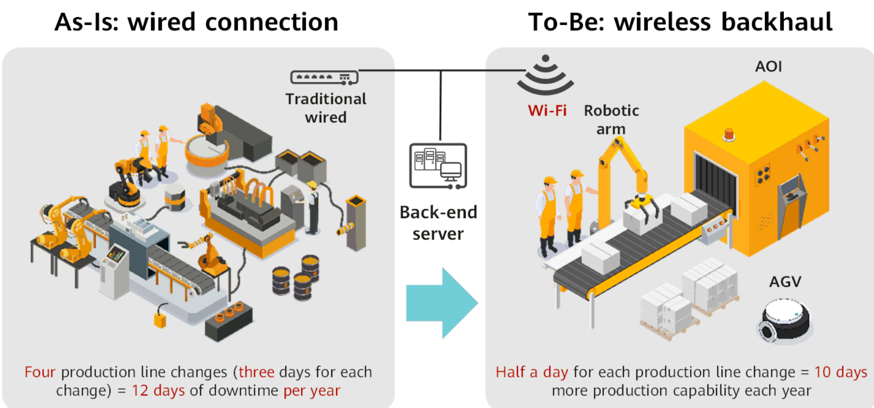

The next-generation Wi-Fi standard — Wi-Fi 7 — represents another major milestone in the development of Wi-Fi. On the one hand, Wi-Fi has obtained a new unlicensed spectrum: 6 GHz. This significantly improves the capacity of Wi-Fi networks, ushering in the era of 10 Gbps indoor wireless communication. At the same time, Wi-Fi 7 improves the multi-user concurrent performance, enabling the network to maintain excellent service capabilities in the case of high-density access and heavy service load.

With the further development of information technologies and enterprise digitalization, more efficient and intelligent collaboration and office modes (virtual humans, AR-assisted office, online AI computing, etc.) may emerge in future enterprise office scenarios. Wi-Fi 7 is fully prepared for this trend, helping to build ultra-broadband 10 Gbps office networks.

# 7.2 High-Quality 10 Gbps Production Campus Network

A key part of smart manufacturing is making production lines fully wireless to achieve flexible production. For example, a mobile phone manufacturing enterprise has 300 production lines, and changes the production lines at least once every quarter to produce mobile phones of different models. When wired networks are used, a single production line change leads to at least three days of downtime. After wireless networks are used, the downtime is reduced to less than half a day for each change. This shows that wireless reconstruction of production lines is critical.

Figure 7-2 High-Quality 10 Gbps Production Campus Network



On industrial production networks, services related to wireless communication are control and collection services as well as high-bandwidth transmission services.

**Control and collection services**

- Remote control: has certain requirements on network latency and bandwidth. For example, remote video control services require network latency to be no more than 20 ms. In addition, network bandwidth assurance must be provided based on the definition of remote control videos.
- Onsite control: includes production line PLC, production line I/O, and device motion control. The network traffic is typically sporadic. For different control objects, differentiated requirements are posed on key indicators such as network latency and packet loss rate, which are typically at the millisecond level.
- AGV control: Typically, network latency of about 50 ms is required by services such as wireless-based automated guided vehicle (AGV) navigation as well as remote diagnosis and maintenance guidance. Network interruptions lasting for over one second is not allowed.
- Sensor-based collection services: include sensor information collection as well as video detection and collection. Typical applications include environment sensing and data collection. The packet sending period is about 100 ms to 10s, and the rate is 100 kbit/s.

Wi-Fi 7 networks can provide ultra-low latency, and can therefore carry remote control, AGV control, and sensor-based collection services. Onsite control services can be carried over wireless networks based on customers' requirements.

**High-bandwidth transmission services**

- AOI: The automated optical inspection (AOI) technology is used to inspect the quality of electronic components and printed circuit boards (PCBs) in industrial production. The principle is to take photos of objects to be detected by using a high-resolution optical imaging system, and then analyze the images through image processing algorithms to detect defects and defective products. AOI requires a high-speed and stable wireless network to transmit image data, so as to ensure detection accuracy and timeliness.

- Device program download: Commercial software of automobiles and electronic devices will be upgraded at the last phase on the production line. This leads to relatively high bandwidth consumption and requires high-bandwidth wireless connections.

The Wi-Fi 7 network provides 10 Gbps wireless connection capabilities for the production network. Therefore, the preceding services can be carried over the Wi-Fi 7 network.

# Chapter 8
# Huawei Wi-Fi 7 APs

**Abstract**

This chapter describes Huawei's enterprise Wi-Fi 7 APs.

## Triple-Radio Wi-Fi 7 AP: AirEngine 8771-X1T

Huawei AirEngine 8771-X1T is a next-generation Wi-Fi 7 (802.11be) AP. It has built-in dynamic-zoom smart antennas and supports a total of 12 spatial streams on the 2.4 GHz (4x4 MIMO), 5 GHz (4x4 MIMO), and 6 GHz* (4x4 MIMO) frequency bands, delivering speeds of up to 18.67 Gbit/s. This AP offers users a fiber-like wireless experience, making it applicable to a wide range of innovative scenarios such as metaverse, extended reality (XR) remote collaboration, XR telemedicine, and XR interactive teaching.

** The support for 6 GHz frequency band varies depending on local laws and regulations of different countries and regions, and the 6 GHz radio can be shut down or switched to another frequency band.*

Figure 8-1 AirEngine 8771-X1T

Huawei AirEngine 8771-X1T has the following features and capabilities:

- Unique 12T12R capability allows the AP to deliver up to 12 spatial streams and a throughput of 18.67 Gbit/s. This makes the AP ideal for heavy-traffic services such as AR/VR and XR remote collaboration.
- Built-in dynamic-zoom smart antennas can dynamically switch between the omnidirectional and high-density modes based on specific scenarios, improving network-wide performance in high-density mode and ensuring high-density service experience for users.
- The triple-radio design (1 x 2.4 GHz radio + 1 x 5 GHz radio + 1 x 6 GHz or 5 GHz radio) increases the number of concurrent users by 50%.

## Triple-Radio Wi-Fi 7 AP: AirEngine 6776-56TP

Huawei AirEngine 6776-56TP is a next-generation indoor AP that complies with the Wi-Fi 7 (802.11be) standard. It supports eight spatial streams on the 2.4 GHz (2x2 MIMO), 5 GHz (2x2 MIMO), and 5 GHz (4x4 MIMO) radios, delivering speeds of up to 9.33 Gbit/s. It has built-in smart antennas, ensuring always-on signals for users. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. These strengths make it ideal for densely populated scenarios such as mobile office, education, venues, and conferences.

Figure 8-2 AirEngine 6776-56TP

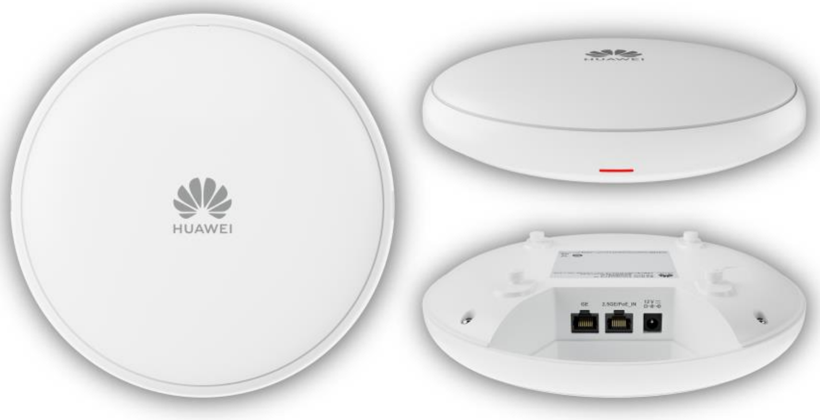
Huawei AirEngine 6776-56TP has the following features and capabilities:

- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.
- The triple-radio design (1 x 2.4 GHz radio + 2 x 5 GHz radios) increases the number of concurrent users by 50% and delivers a maximum speed of 9.33 Gbit/s.
- PoE cascading and PoE power supply for low-energy PDs requires no local power supply or power cables.

## Dual-Radio Wi-Fi 7 AP: AirEngine 5776-26

Huawei AirEngine 5776-26 is a next-generation indoor AP that complies with the Wi-Fi 7 (802.11be) standard. It supports six spatial streams on the 2.4 GHz (2x2 MIMO) and 5 GHz (4x4 MIMO) frequency bands, delivering speeds of up to 6.45 Gbit/s. It has built-in smart antennas, ensuring always-on signals for users. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. These strengths make it ideal for indoor coverage scenarios such as small and midsize enterprise office, education, and retail scenarios.

Figure 8-3 AirEngine 5776-26




Huawei AirEngine 5776-26 has the following features and capabilities:

- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.
- MLO and MRU technologies make data transmission more efficient and orderly. Additionally, 4096-QAM modulation is supported. Each device supports a total of six spatial streams and can deliver speeds of up to 6.45 Gbit/s.
- Built-in Bluetooth 5.4 and NearLink SLE 1.0 support innovative applications. In addition, this AP can flexibly expand to support applications of multiple IoT protocols (such as RFID and ZigBee) through a USB interface card after a software upgrade.

# Dual-Radio Wi-Fi 7 AP: AirEngine 5773-23H

Huawei AirEngine 5773-23H is a next-generation indoor AP that complies with the Wi-Fi 7 (802.11be) standard. It supports four spatial streams on the 2.4 GHz (2x2 MIMO) and 5 GHz (2x2 MIMO) frequency bands, delivering speeds of up to 3.57 Gbit/s. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. Additionally, it supports the hybrid cable solution and high-quality Ethernet solution, enabling flexible deployment and saving customer TCO. These strengths make this AP ideal for indoor coverage scenarios such as small and midsize enterprise office, education, and healthcare scenarios.

Figure 8-4 AirEngine 5773-23H


Huawei AirEngine 5773-23H has the following features and capabilities:

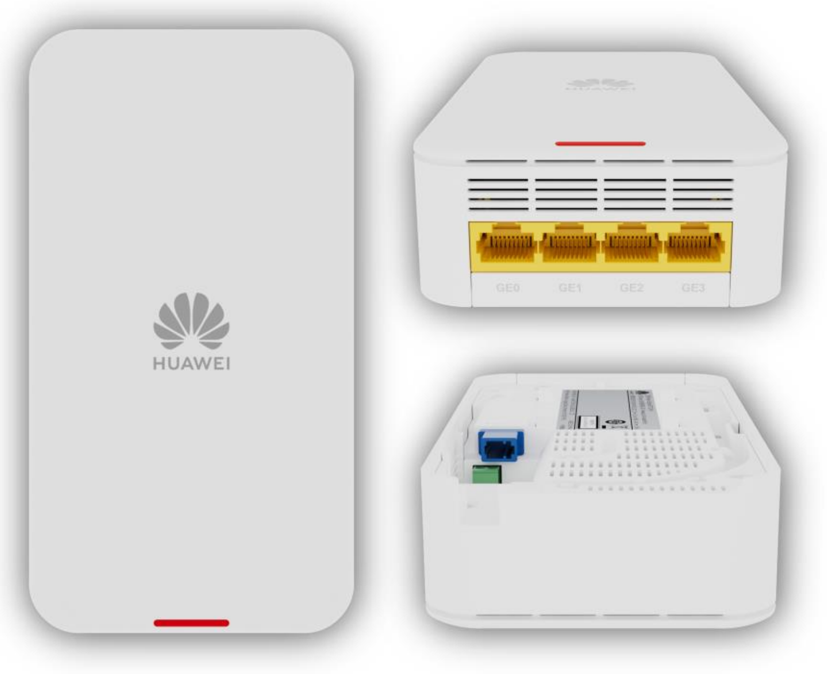
- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.
- MLO and MRU technologies make data transmission more efficient and orderly. Additionally, 4096-QAM modulation is supported. Each device supports a total of four spatial streams and can deliver speeds of up to 3.57 Gbit/s.

- The optical-electrical separation for a hybrid cable on the AP's uplink optical port allows for more flexible deployment through data transmission and 2000 m PoE power supply on one port. In addition, the AP is equipped with a built-in bottom-layer optical module that accommodates an optical fiber in plug-and-play mode, saving an external optical module.

# Dual-Radio Wi-Fi 7 AP: AirEngine 5773-23HW

Huawei AirEngine 5773-23HW is a next-generation wall plate AP that complies with the Wi-Fi 7 (802.11be) standard. It supports four spatial streams on the 2.4 GHz (2x2 MIMO) and 5 GHz (2x2 MIMO) frequency bands, delivering speeds of up to 3.57 Gbit/s. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. Additionally, it supports the hybrid cable solution and simplified network solution, enabling flexible deployment and saving customer TCO. These strengths make this AP ideal for indoor coverage scenarios such as school dormitories and hotels.

Figure 8-5 AirEngine 5773-23HW




Huawei AirEngine 5773-23HW has the following features and capabilities:

- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.
- MLO and MRU technologies make data transmission more efficient and orderly. Additionally, 4096-QAM modulation is supported. Each device supports a total of four spatial streams and can deliver speeds of up to 3.57 Gbit/s.
- The optical-electrical separation for a hybrid cable on the AP's uplink optical port allows for more flexible deployment through data transmission and 2000 m PoE power supply on one port. In addition, the AP is equipped with

a built-in bottom-layer optical module that accommodates an optical fiber in plug-and-play mode, saving an external optical module.

## Dual-Radio Wi-Fi 7 AP: AirEngine 5773-22P

Huawei AirEngine 5773-22P is a next-generation indoor AP that complies with the Wi-Fi 7 (802.11be) standard. It supports four spatial streams on the 2.4 GHz (2x2 MIMO) and 5 GHz (2x2 MIMO) frequency bands, delivering speeds of up to 3.57 Gbit/s. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. Additionally, compact in size, it can be flexibly deployed and saves customer TCO. These strengths make this AP ideal for indoor coverage scenarios such as small and midsize enterprise office, education, and healthcare scenarios.

Figure 8-6 AirEngine 5773-22P


Huawei AirEngine 5773-22P has the following features and capabilities:

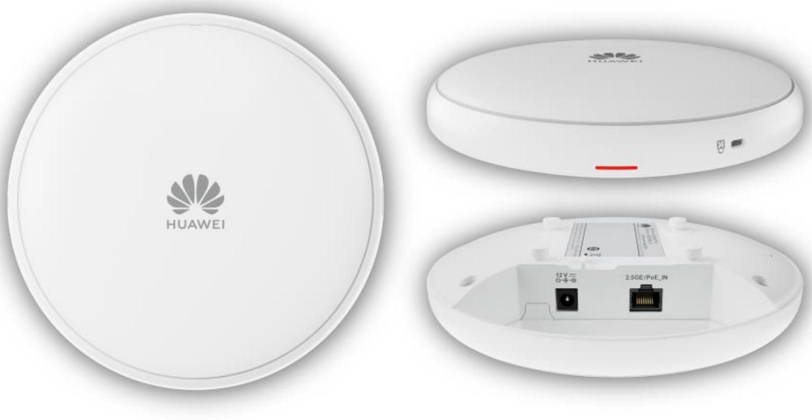
- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.

- MLO and MRU technologies make data transmission more efficient and orderly. Additionally, 4096-QAM modulation is supported. Each device supports a total of four spatial streams and can deliver speeds of up to 3.57 Gbit/s.
- PoE cascading and PoE power supply for low-energy PDs requires no local power supply or power cables.

## Dual-Radio Wi-Fi 7 AP: AirEngine 5773-21

Huawei AirEngine 5773-21 is a next-generation indoor AP that complies with the Wi-Fi 7 (802.11be) standard. It supports four spatial streams on the 2.4 GHz (2x2 MIMO) and 5 GHz (2x2 MIMO) frequency bands, delivering speeds of up to 3.57 Gbit/s. It has built-in smart antennas, ensuring always-on signals for users. With the all-new Wi-Fi 7 technology, this AP can greatly improve users' wireless network experience. Additionally, compact in size, it can be flexibly deployed and saves customer TCO. These strengths make this AP ideal for indoor coverage scenarios such as small and midsize enterprise office, hospitals, and shopping malls and supermarkets.

Figure 8-7 AirEngine 5773-21




Huawei AirEngine 5773-21 has the following features and capabilities:

- Built-in dual-band co-planar smart antennas automatically suppress interference and achieve two-fold signal strength at the same location, delivering stable wireless coverage without any coverage holes.
- MLO and MRU technologies make data transmission more efficient and orderly. Additionally, 4096-QAM modulation is supported. Each device supports a total of four spatial streams and can deliver speeds of up to 3.57 Gbit/s.
- Built-in Bluetooth 5.4 and NearLink SLE 1.0 support innovative applications. In addition, this AP can flexibly expand applications of multiple IoT protocols (such as RFID and ZigBee) through a USB interface card after a software upgrade.

# A Acronyms and Abbreviations

Table A-1 Acronyms and abbreviations

| Acronym/Abbreviation | Full Name |
|---|---|
| AGV | automated guided vehicle |
| AI | artificial intelligence |
| AOI | automated optical inspection |
| AP | access point |
| AR | augmented reality |
| BSS | basic service set |
| CCK | complementary code keying |
| CoSR | coordinated spatial reuse |
| DSSS | direct sequence spread spectrum |
| EHT | Extremely High Throughput |
| FHSS | frequency hopping spread spectrum |
| GI | guard interval |

| Acronym/Abbreviation | Full Name |
|---|---|
| HE | High Efficiency |
| HE MU PPDU | HE multi-user PPDU |
| HE SU PPDU | HE single-user PPDU |
| HE TB PPDU | HE Trigger-based PPDU |
| IEEE | Institute of Electrical and Electronics Engineers |
| IoT | Internet of Things |
| IR | infrared |
| MAC | medium access control |
| MIMO | multiple-input multiple-output |
| MLD | multi-link device |
| MLO | multi-link operation |
| MRU | multiple resource unit |
| MU-MIMO | multi-user multiple-input multiple-output |
| OFDM | orthogonal frequency division multiplexing |
| OFDMA | orthogonal frequency division multiple access |
| OOK | on-off keying |
| PHY | physical layer |
| PLC | programmable logic controller |
| PPDU | PHY protocol data unit |
| QAM | quadrature amplitude modulation |
| RTT | round trip time |
| R-TWT | restricted TWT |
| RU | resource unit |
| SNR | signal-to-noise ratio |

| Acronym/Abbreviation | Full Name |
|---|---|
| STA | station |
| SU-MIMO | single-user multiple-input multiple-output |
| TWT | target wake time |
| VR | virtual reality |
| WFA | Wi-Fi Alliance |
| Wi-Fi | Wireless Fidelity |
| WLAN | wireless local area network |
| WuR | wake-up radio |
| XR | extended reality |

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