World WLAN Application Alliance

WAA-TS 017-2025

Technical Specifications for WLAN Device Networking Performance and Experience in Home Scenarios

(Based on IEEE 802.11be-2024)

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Forword

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Contents

1 Overview

1.1 Scope

This document specifies technical requirements for networking performance such as bandwidth, latency, roaming, and connection and service experience of WLAN devices that support the 802.11be protocol in a home scenario.

1.2 Applicability

This document is applicable to the design, development, production, and testing of wired and wireless networking devices that support the IEEE 802.11be technology, and tests conducted by the WAA alliance on the networking performance and the experience of home scenario WLAN devices.

1.3 Word Usage

In this document, the word "shall" is used to indicate a mandatory requirement. The word "should" is used to indicate a recommendation. The word "may" is used to indicate that something is permitted. The word "can" is used to indicate that something is possible.

2 Normative References

The following documents constitute essential terms of this document by normative reference. For a dated reference document, only the version corresponding to that date applies to the document. For a reference document not dated, the latest version (including all change requests) is applicable to the document.

[1] IEEE Std. 802.11-2024 (IEEE Standard for Information Technology Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks Specific Requirements Part 11: Wireless Local Area Network Medium Access Control (MAC) and Physical Layer (PHY) Specifications) IEEE Standard for Information Technology Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

[2] IEEE Std. 802.11be-2024 (IEEE Standard for Information Technology-Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks-Specific Requirements Part 11: Wireless Local Area Network Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 2: Extremely High Throughput) IEEE Standard for Information Technology-Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks-Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 2: Enhancements for Extremely High Throughput.

[3] IEEE Std. 802.11i-2004 (IEEE Standard for Information Technology-Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks-Specific Requirements Part 11: Wireless Local Area Network Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6 Medium Access Control (MAC) Security Enhancements.

[4] IEEE Std. 802.11k-2008 (IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC)and Physical Layer (PHY) Specifications Amendment 1: Radio Resource Measurement of Wireless LANs).

[5] IEEE Std. 802.11v-2011 (IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 8: IEEE 802.11 Wireless Network Management).

[6] Wi-Fi Alliance WPA3™ Specification Version 3.5. https://www.wi-fi.org/system/files/WPA3%20 Specification%20v3.5.pdf

3 Terms and Definitions

3.1 Scenario

The scenario generally refers to a system and system running. The system includes an endpoint, a network, a radio propagation environment, a server, a user, and the like. The system running includes interaction conditions of subsystems and components in specific use, including various factors that affect network performance and service performance, for example, a mobile phone being 3 m away from a wireless router, and a user joining a video conference.

3.2 Home scenario

In this document, the "home scenario" generally refers to a service scenario including network elements (internet access device, internet service, endpoint, and the like) involved in activities such as learning, entertainment, and social production performed by a user by using a network at home.

3.3 Scenario model

The scenario model is a set of requirements for devices and environmental elements for a user, such as endpoint, network, and radio propagation environment, that is proposed to simulate an operating environment of a user, to configure a test platform and to construct a comprehensive system for performance tests. Different scenario models may be used for different network basic performance requirements and service performance requirements, to reflect different actual operating environments of a tested device.

3.4 Basic performance requirements

Basic requirements for evaluating network performance, for example, indicators such as bandwidth, access endpoint connection capability, coverage, and latency, when a network user uses the network. Most of the indicators are requirements on devices, and some of the indicators are networking requirements, such as roaming capability. The network basic performance requirements can support evaluation of service performance requirements.

3.5 Service performance requirements

Performance requirements on a network used by multiple services are evaluated from a perspective of applications using the network. A type of the service that uses the network, a quantity of services, and a proportion of each service type are specified. Similar to a typical networking model, simulation is close to an actual operating environment of a user, and a network capability for supporting application experience is evaluated. The performance requirements include user experience with an interactive system (including but not limited to video freezing, voice delay, operation delay, and the like).

3.6 Test platform

The test platform is a comprehensive system that includes elements such as endpoint, network, and radio propagation environment, aiming to simulate a network environment of a user, where an environment parameter, a network parameter, and an endpoint parameter may be modified to complete performance tests for a device, a network, and a service.

3.7 Latency

The latency is an end-to-end latency that needs to be guaranteed for different service networks.

3.8 Packet loss ratio

The packet loss ratio is a proportion of a quantity of packets that fail to be sent in a total quantity of packets.

3.9 Service concurrency

The service concurrency means that users who actually access a network use the network or a service simultaneously within a same period.

3.10 2.4 GHz

The 2.4 GHz generally refers to a 2.4 GHz band spectrum used by a device in a wireless local area network as permitted by a country. Specified available spectrums vary between countries, and devices need to comply with corresponding national technical requirements on radio frequency and technical requirements on interference avoidance (for example, the frequency range of the 2.4 GHz band for a wireless local area network as permitted by the People's Republic of China is 2400 MHz to 2483.5 MHz).

3.11 5 GHz

The 5 GHz generally refers to a 5 GHz band spectrum used by a device in a wireless local area network as permitted by a country. Specified available spectrums vary between countries, and devices need to comply with corresponding national technical requirements on radio frequency and technical requirements on interference avoidance (for example, the frequency range of the 2.4 GHz band for a wireless local area network as permitted by the People's Republic of China is 5150 MHz to 5350 MHz and 5725 MHz to 5850 MHz).

3.12 Dual bands

The dual bands mean that a networking device is capable of simultaneously transmitting or receiving signals on two different frequency bands. Frequency bands permitted for use vary between countries. Devices need to comply with corresponding national technical requirements on radio frequency and technical requirements on interference avoidance (for example, the frequency range of the dual bands permitted for use in the People's Republic of China is 2400 MHz to 2483.5 MHz, 5150 MHz to 5350 MHz, and 5725 MHz to 5850 MHz).

3.13 Triple bands

The triple bands mean that a networking device is capable of simultaneously transmitting or receiving signals on three different frequency bands. Frequency bands permitted for use vary between countries. Devices need to comply with corresponding national technical requirements on radio frequency and technical requirements on interference avoidance (for example, the frequency range of the triple bands permitted for use in the People's Republic of China is 2400 MHz to 2483.5 MHz, 5150 MHz to 5350 MHz, and 5725 MHz to 5850 MHz).

3.14 Channel bandwidth

Different channel bandwidths, such as 20 MHz, 40 MHz, 80 MHz, and 160 MHz, should follow national requirements on spectrum division.

3.15 Interference

The interference is impact on reception of a wireless communication system caused by unwanted energy generated by one or more of emission, radiation, induction, or a combination thereof. The interference is manifested as performance degradation, misunderstanding, or information loss, which can be avoided if such unwanted energy does not exist.

4 Acronyms and Abbreviations

The following acronyms and abbreviations are applicable to this document.

AC: Access Controller

AP: Access Point

CSMA/CA: Carrier Sense Multiple Access With Collision Avoidance

FTTR: Fiber to The Room

IP: Internet Protocol

IPTV: Internet Protocol Television

KPI: Key Performance Indicator

KQI: Key Quality Indicator

LAN: Local Area Network

MAC: Medium Access Control

MTU: Maximum Transmission Unit

MIMO: Multiple Input Multiple Output

MLO: Multi Link Operation

MRU: Multi Resource Unit

NSS: Number of Spatial Stream

OPEN-SYS: Open System

OWD: One-Way Delay

PHY: Physical Layer

RTT: Round-Trip Time

SAE: Simultaneous Authentication of Equals

SSID: Service Set Identifier

STA: Station

TCP: Transmission Control Protocol

TID: Traffic Identifier

UDP: User Datagram Protocol

WEP: Wired Equivalent Privacy

WLAN: Wireless Local Area Network

WPA3: WLAN Protected Access3

VR: Virtual Reality

5 Network Structure and Device Component in a Home Scenario

5.1 Home Scenario Networking Structure

The network includes segments of home network, access network, metropolitan area network, backbone network, and carrier interconnection, as shown in Figure 1. Each segment is defined as follows:

1. Home network segment: a segment from a user endpoint to a network-side interface of a user-side device in the access network and a network-side interface of a user-side sub-device in the access network.

2. Access network segment: a segment from the network-side interface of the user-side device in the access network to a network-side interface of a local device in the access network.

3. Metropolitan area network segment: a segment from the network-side interface of the local device in the access network to an egress of the metropolitan area network.

4. Backbone network + server segment: a segment from the egress of the metropolitan area network to a server.

This document focuses on technical requirements for WLAN performance and experience indicators of the home network segment.

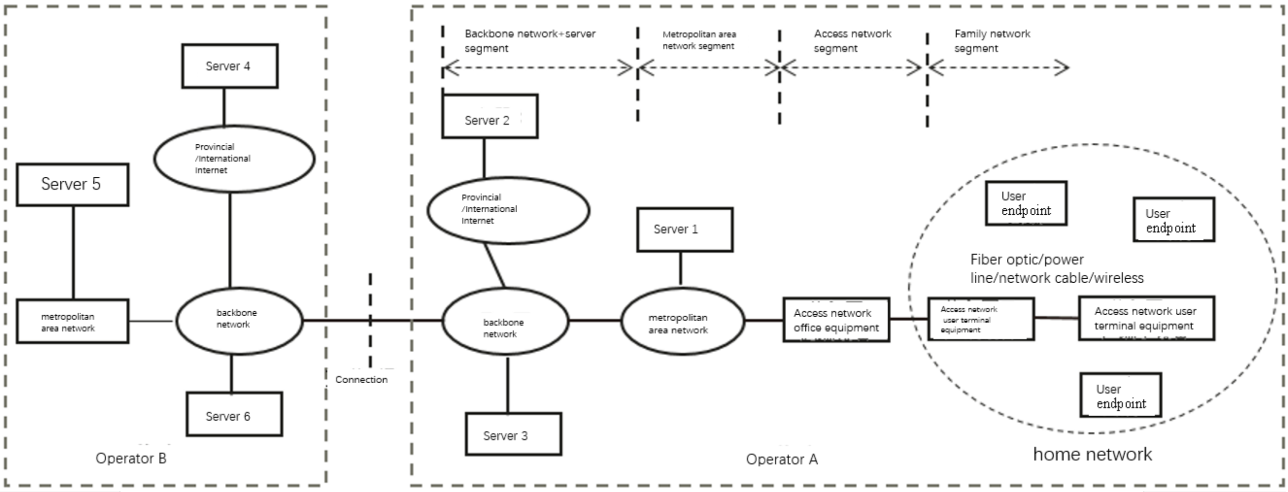

Figure 1 Diagram of a network structure

5.2 Device Definition

In the home scenario, product forms mainly include devices such as home gateway, wireless router, wireless router networking suite, and FTTR networking suite.

Based on a quantity of network devices in a home, tested objects in the home scenario are classified into single-gateway or single-router products and home networking including multiple devices.

Single device: home gateway or wireless router.

Home device networking: networking devices such as FTTR, home AC+AP, and wireless networking router. This document specifies only WLAN devices that support an IEEE 802.11be technology in a home environment of a networking environment.

6 Overview of WLAN Device Networking Performance Requirements in a Home Scenario

6.1 Overview of WLAN Device Networking Basic Performance in a Home Scenario

For a multi-device networking scenario in the home scenario, as shown in Figure 2, bandwidth, latency, connection, roaming, green security, and intelligent O&M are six major network performance indicators that guarantee home WLAN service experience.

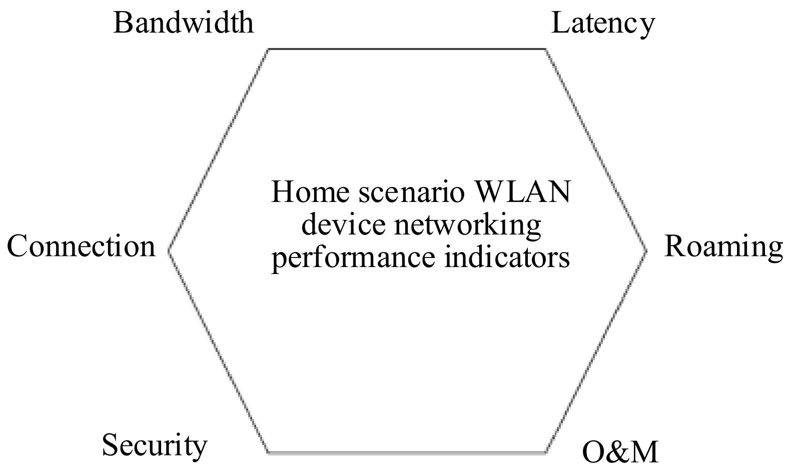

Figure 2 Home scenario WLAN device networking performance indicators

6.2 Overview of KPIs and KQIs of a Service Carried in Home Scenario WLAN Device Networking

Home scenario services include voice, web browsing, upload/download, IPTV, mobile game, cloud game, internet video, remote education/online education, cloud VR, and the like. For the foregoing services, network-related KQI indicators that affect service experience and perception of a user are shown in Figure 3.

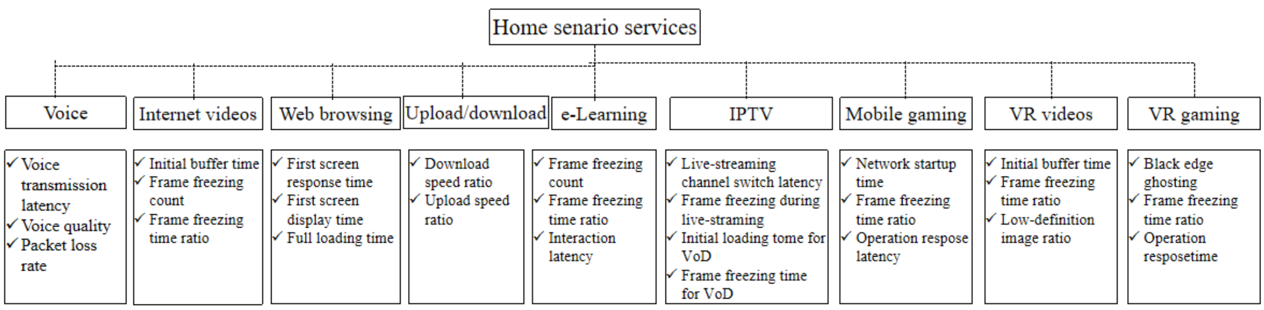

Figure 3 Home scenario service KQI indicators

The home scenario service KQI indicators refer to perceivable indicators that affect user experience, for example, operation duration and freeze rate. From a perspective of network KPI, network elements that affect KQI indicators of a service mainly include the following indicators:

1. minimum bandwidth required by the service;
2. maximum latency and latency jitter that the service needs to satisfy; and
3. maximum packet loss ratio that the service needs to satisfy.

A service experience scenario defined in this specification is mainly used for evaluating, by constructing a comprehensive family scenario, indicators such as bandwidth, latency, latency jitter, and packet loss ratio of each service application in a typical scenario.

7 Basic Performance Requirements for WLAN Device Networking in a Home Scenario

7.1 Bandwidth

7.1.1 Bandwidth Parameter and Scenario Model

7.1.1.1 Bandwidth Parameter

The bandwidth parameter refers to an indicator of maximum performance that can be obtained when a single user uses a WLAN. In a home scenario, the bandwidth indicator directly affects experience of services, such as speed test, data download, 4K video, and cloud game, that have a high requirement on the bandwidth.

In a multi-device networking scenario, bandwidth indicators of a WLAN interface are mainly a maximum throughput of a WLAN interface for a networking master device and a networking slave device (focus on the AP for AC+AP networking) and a concurrent throughput of multiple APs in the networking scenario.

7.1.1.2 Home Networking Bandwidth Scenario Model 1: Bandwidth for a Single User Accessing a Master/Slave Device at a Short Distance without Interference

In an ideal condition (without interference), the user accesses the networking master device and the networking slave device (focus on the AP for AC+AP networking) at a short distance, to obtain a maximum throughput of the networking master device and the networking slave device (focus on the AP for AC+AP networking) on a single frequency band. In a scenario of multi-hotspot networking, different networking media affect bandwidth performance obtained by the user. In this specification, connection media in the home networking scenario are classified into two types: a wired networking medium and a wireless networking medium. The wired medium includes a network cable and an optical fiber, and the wireless medium is mainly a WLAN air interface. Figure 4 defines an extreme performance scenario of the wired networking medium. Figure 5 defines an extreme performance scenario of the wireless networking medium.

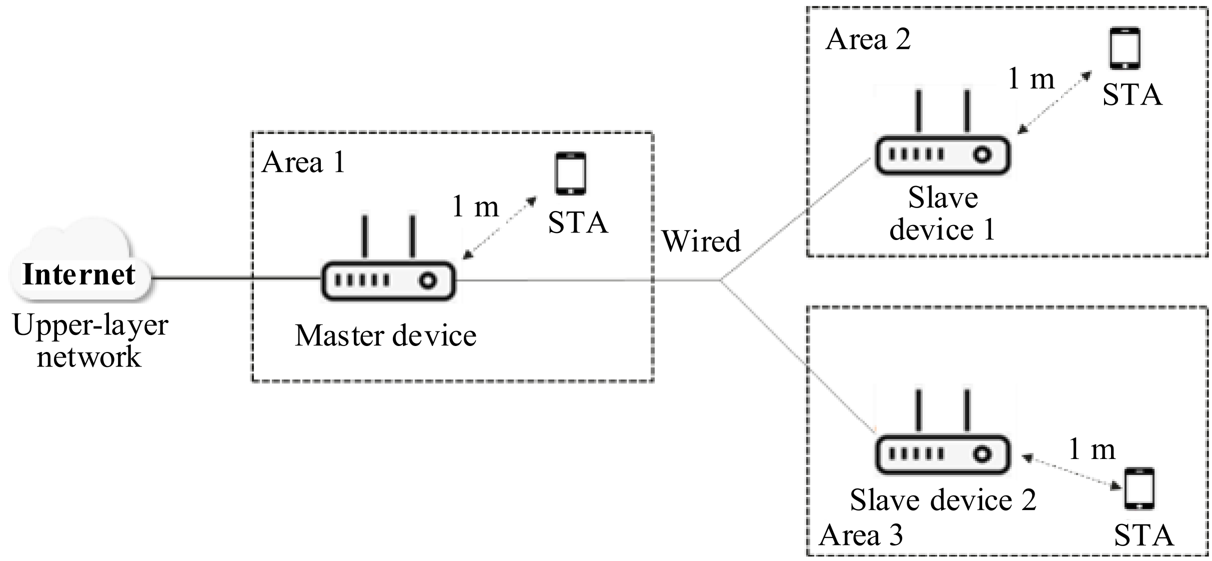

Figure 4 Diagram of a scenario of a throughput of a wired networking master/slave device for a single user

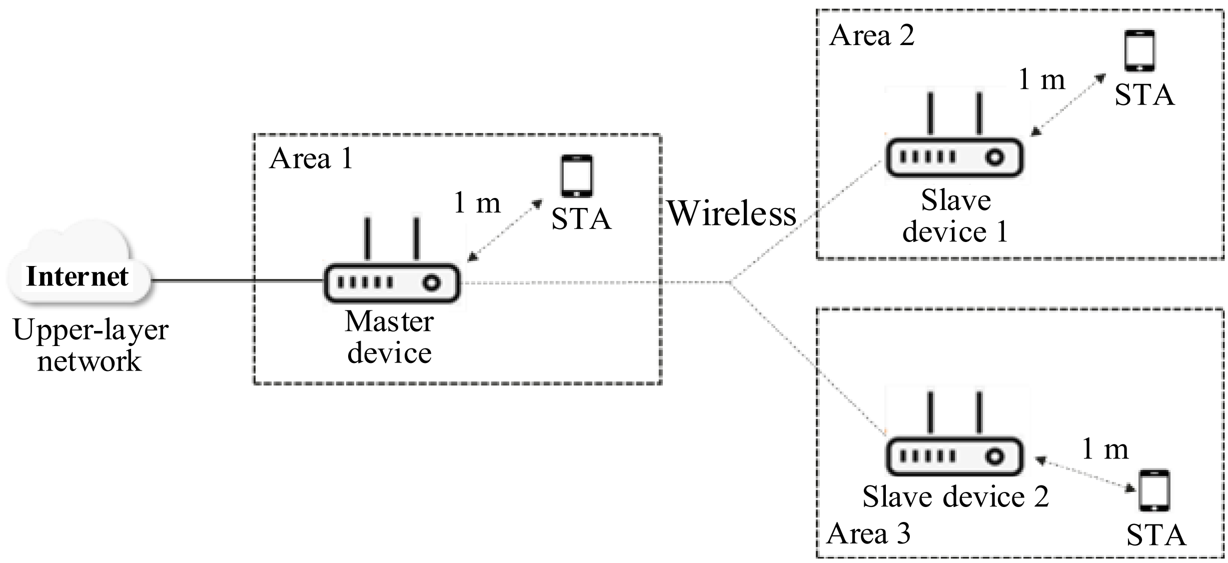

Figure 5 Diagram of a scenario of a throughput of a wireless networking master/slave device for a single user

In this scenario, a TCP service bearing capability of the networking master device and the networking slave device (focus on the AP for AC+AP networking) in an ideal air interface condition is mainly measured. To test the extreme TCP bearing capability, the following constraints are imposed on the air interface condition:

1. There are no other interference sources except for the networking device in the environment, where the other interference sources include a WLAN interference source (for example, another

gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, and a microwave oven device).

2. There are no obstacles between a used STA (for example, a mobile phone, a laptop, or a wireless network adapter) and the home networking device, where a distance between the STA and the home networking device is 1 m.
3. One user has accessed.
4. Signal strength that can be mutually detected between the networking master device (or a master router) and the networking slave device (or a slave router or an AP) should satisfy attenuation matrix models specified in Table 2, Table 3, Figure 4, and Figure 5 of T/WAA-018-2025 "Test Methods for Home Scenario WLAN Device Networking Performance and Experience (Based on IEEE 802.11be)".
5. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.
6. The packet length of a TCP service flow defined in the scenario depends on an MTU value of a network path between a server and a client, with a default MTU being 1500 bytes.

7.1.1.3 Home Networking Bandwidth Scenario Model 2: Concurrent Bandwidth of the Entire Network When Multiple APs are Connected to a Single User at a Short Distance Simultaneously

In an ideal condition (without interference), when multiple users simultaneously access a networking master device and a networking slave device (focus on the AP for AC+AP networking) at a short distance, a multi-AP concurrent throughput is obtained. As shown in Figure 6 and Figure 7, a concurrent bandwidth scenario when multiple users access a networking master device and a networking slave device (focus on the AP for AC+AP networking) simultaneously is defined.

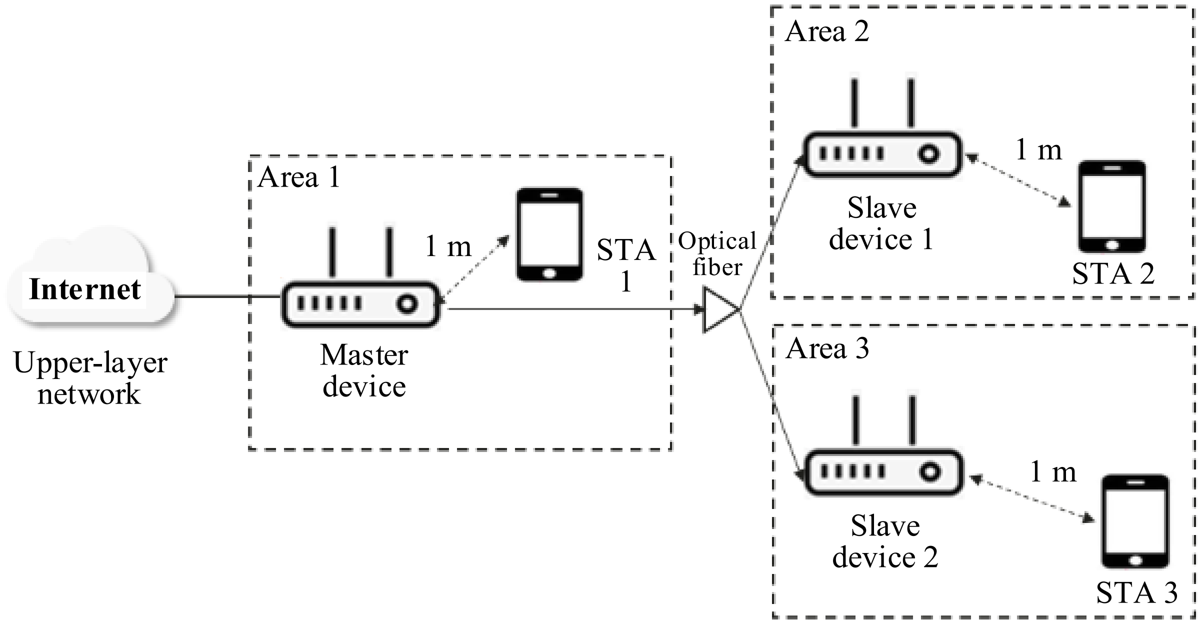

Figure 6 Diagram of a device networking concurrent bandwidth scenario (wired media networking)

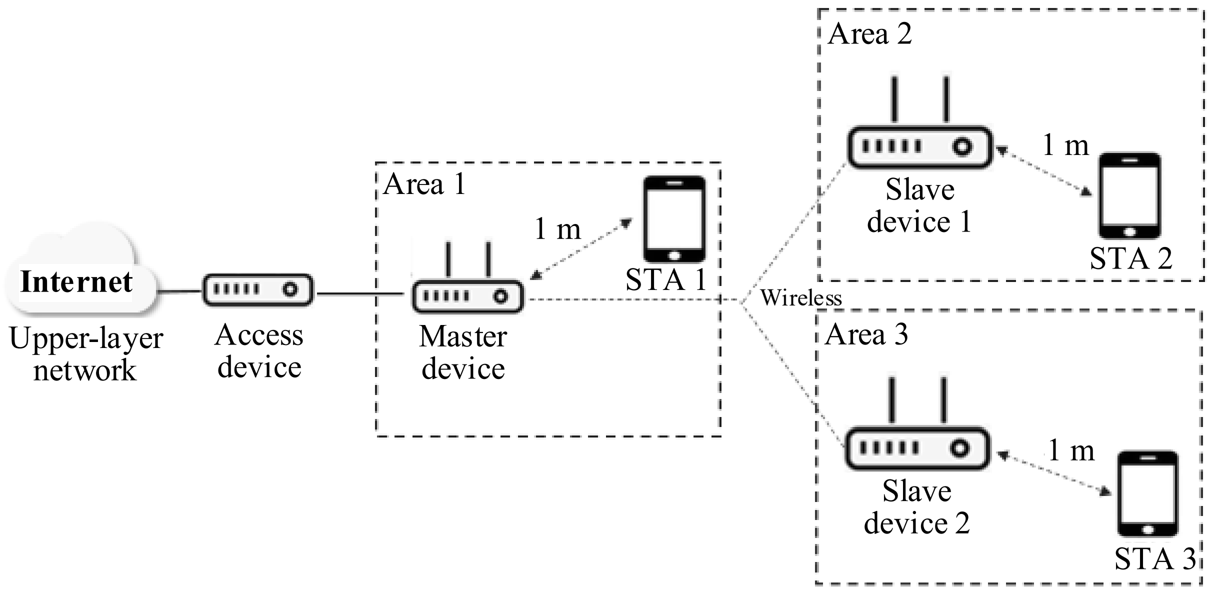

Figure 7 Diagram of a multi-device networking concurrent bandwidth scenario (wireless media networking)

In this scenario, multiple users all access the networking master device and the networking slave device at a short distance in a concurrency manner. A TCP service bearing capability during multi-AP concurrency in the home networking scenario is measured. To test the TCP bearing capability in a multi-AP concurrency scenario, the following constraints are imposed on the air interface condition:

1. There are no other interference sources except for the networking device in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, and a microwave oven device).
2. There are no obstacles between a used STA (for example, a mobile phone, a laptop, or a wireless network adapter) and the home networking device, where the distance between the STA and the home networking device is 1 m.
3. A quantity of access users is the same as that of APs in the networking.
4. Signal strength that can be mutually detected between the networking master device (or a master router) and the networking slave device (or a slave router or an AP) should satisfy the attenuation matrix models specified in Table 2, Table 3, Figure 4, and Figure 5 of T/WAA-018-2025 "Test Methods for Home Scenario WLAN Device Networking Performance and Experience (Based on IEEE 802.11be)".
5. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.
6. The packet length of a TCP service flow defined in the scenario depends on an MTU value of a network path between a server and a client, with a default MTU being 1500 bytes.

7.1.1.4 Home networking bandwidth scenario model 3: concurrent bandwidth of the entire network in a scenario in which STAs are distributed at a long/short distance

In an ideal condition (without interference), when multiple users distributed at different distances access a networking master device and a networking slave device, a maximum multi-AP concurrent throughput is obtained. As shown in Figure 8 and Figure 9, a concurrent bandwidth scenario when users at different distances access a networking master device and a networking slave device simultaneously is defined.

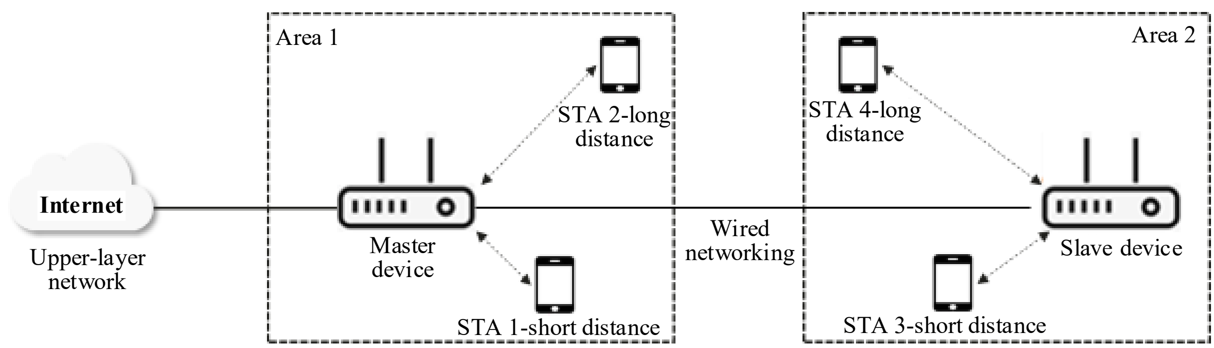

Figure 8 Multi-device networking concurrency with multiple users distributed at a long/short distance (wired networking)

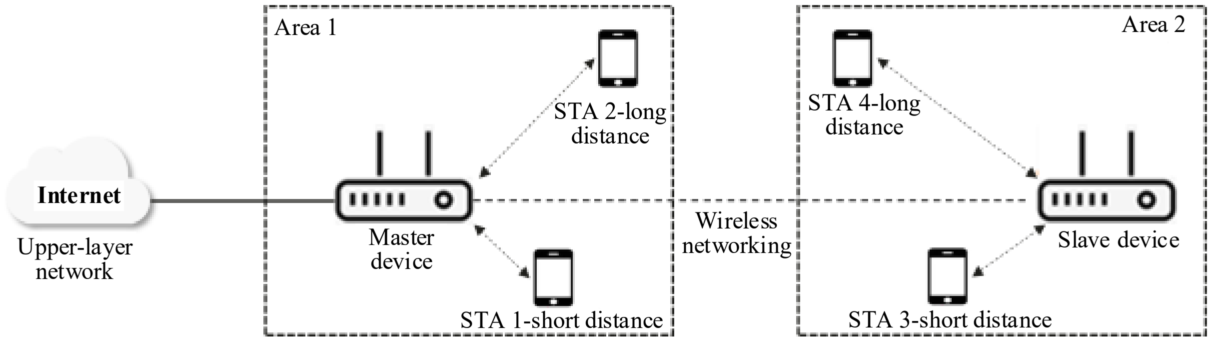

Figure 9 Multi-device networking concurrency with multiple users distributed at a long/short distance

In this home networking scenario, a user at a short distance and a user at a long distance access the networking master device and the networking slave device. In this scenario, a user with a weaker signal is likely to have fewer opportunities for good scheduling in air interface resource scheduling in the entire network. Consequently, service experience cannot be guaranteed. By measuring entire-network concurrency performance for entire-network long-distance and short-distance users and a bandwidth for the user with the weaker signal, an entire-network bandwidth capability in this scenario can be evaluated.

The following constraints are imposed on the air interface condition:

1. There are no other interference sources except for the networking device in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, and a microwave oven device).
2. There are no obstacles between a used STA (for example, a mobile phone, a laptop, or a wireless network adapter) and the home networking device.
3. The user at a short distance is 1 m away, and the user at a long distance is 10 m away.
4. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.
5. The packet length of a TCP service flow defined in the scenario depends on an MTU value of a network path between a server and a client, with a default MTU being 1500 bytes.

7.1.1.5 Home Networking Bandwidth Scenario Model 4: Concurrency Networking Bandwidth in a Scenario in Which External Interference Exists

In the interference scenario, when multiple users access a networking master device and a networking slave device (focus on the AP for AC+AP networking) at a short distance, a maximum multi-AP concurrent throughput is obtained. As shown in Figure 10 and Figure 11, a scenario of a concurrent bandwidth when multiple users simultaneously access the networking master device and the networking slave device (focus on the AP for AC+AP networking) is defined.

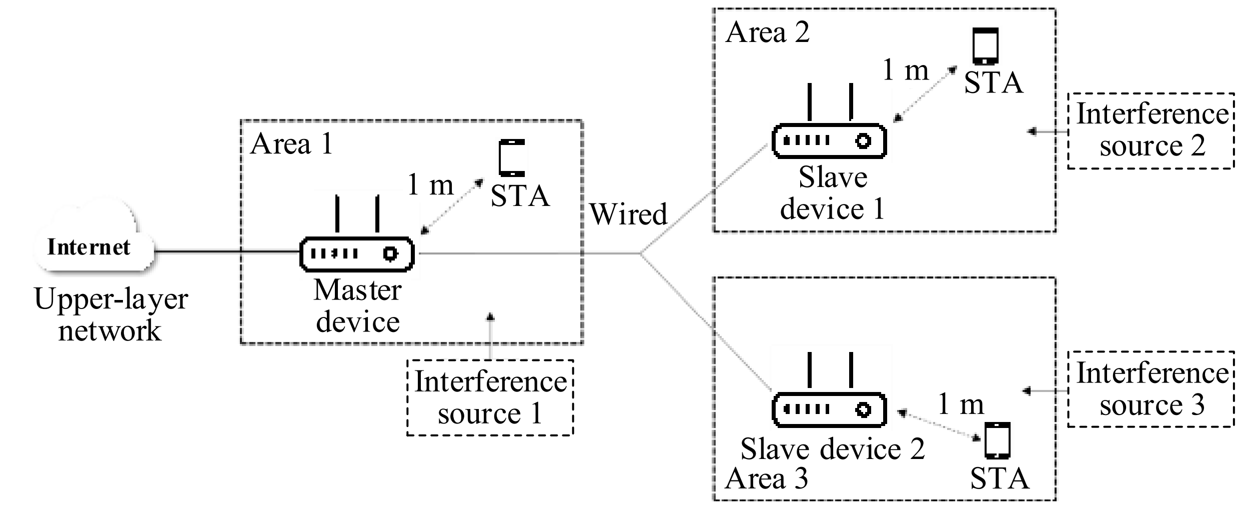

Figure 10 Multi-device networking and multi-user concurrency with interference (wired networking)

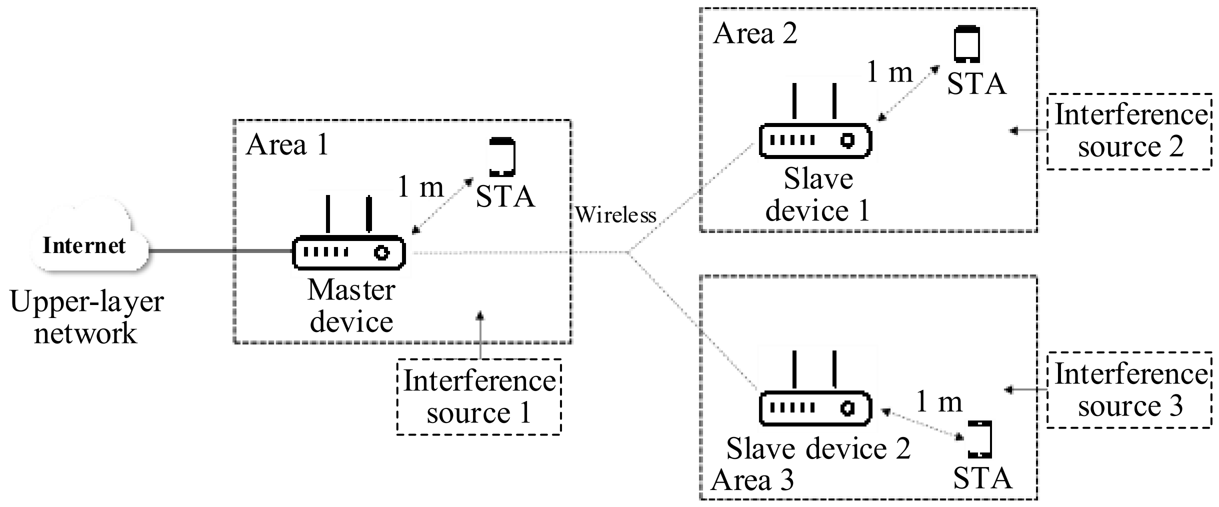

Figure 11 Multi-device networking and multi-user concurrency with interference (wireless networking)

In this home networking scenario, a TCP service bearing capability of the networking master device and the networking slave device (focus on the AP for AC+AP networking) when external interference exists is mainly measured. To test the anti-interference capability of the entire network, the following constraints are imposed on the air interface condition:

1. An external interference model is as follows:

a) When networking devices are connected to STAs by using a 5 GHz frequency band, each networking device has a co-channel interference source on the 5 GHz frequency band. Interference traffic of each interference source is 20 Mbps over downlink and 2 Mbps over uplink for co-channel interference. The service flow is of a TCP-type, signal strength on the 5 GHz frequency band between the interference source and the test endpoint ranges from –65 dBm to –70 dBm, and signal strength on the 5 GHz frequency band between the interference source and the interference STA is –30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

b) When the networking device supports dual bands and has the MLO function enabled, each networking device has a co-channel interference source on the 2.4 GHz frequency band and a co-channel interference source on the 5 GHz frequency band. An interference model is as follows:

   i. 5 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, the signal strength on the 5 GHz frequency band between the interference source and the test endpoint ranges from –65 dBm to –70 dBm, and the signal strength on the 5 GHz frequency band between the interference source and the interference STA is –30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

   ii. 2.4 GHz frequency band: Co-channel interference of 5 Mbps over downlink and 1 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 2.4 GHz frequency band between the interference source and the test endpoint ranges from –58 dBm to –63 dBm, and signal strength on the 2.4 GHz frequency band between the interference source and the interference STA is –30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

c) When the networking device supports triple bands and has the MLO function enabled, each networking endpoint has a co-channel interference source on a 5.1 GHz frequency band and a co-channel interference source on a 5.8 GHz frequency band. An external interference model is as follows:

   i. 5.1 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 5.1 GHz frequency band between the interference source and the test endpoint ranges from –65 dBm to –70 dBm, and signal strength on the 5.1 GHz frequency band between the interference source and the interference STA is –30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

   ii. 5.8 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 5.8 GHz frequency band between the interference source and the test endpoint ranges from −65 dBm to −70 dBm, and signal strength on the 5.8 GHz frequency band between the interference source and the interference STA is −30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

2. There are no obstacles between a used STA (for example, a mobile phone, a laptop, or a wireless network adapter) and the home networking device.
3. The user at a short distance is 1 m away.
4. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.

7.1.2 Bandwidth Requirements

In an ideal condition (without interference), when a user accesses a networking master/slave device at a short distance, performance requirements for obtaining a maximum throughput on a single frequency band are listed in Table 1.

Table 1 Bandwidth requirements when a single user accesses a master/slave device without interference

Networking Type	Networking Mode Between the Master Device and the Slave Device	Master/Slave Device	Endpoint WLAN Configuration	Protocol Mode	Bandwidth	Downlink Bandwidth Requirement (Mbps)
Wired networking	Optical fiber networking or 2.5 GE or higher network cable networking	Master device	5 GHz (Nss=2)	802.11be	160 MHz	1800
		Slave device	5 GHz (Nss=2)	802.11be	160 MHz	1800
		Master device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	2000

Networking Type	Networking Mode Between the Master Device and the Slave Device	Master/Slave Device	Endpoint WLAN Configuration	Protocol Mode	Bandwidth	Downlink Bandwidth Requirement (Mbps)
		Slave device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	2000
		Master device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	2650
		Slave device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	2650
	Gigabit network cable networking	Master device	5 GHz (Nss=2)	802.11be	160 MHz	1800
		Slave device	5 GHz (Nss=2)	802.11be	160 MHz	900
		Master device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	2000
		Slave device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	900
		Master device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	2650

Networking Type	Networking Mode Between the Master Device and the Slave Device	Master/Slave Device	Endpoint WLAN Configuration	Protocol Mode	Bandwidth	Downlink Bandwidth Requirement (Mbps)
		Slave device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	900
Wireless networking	Wi-Fi networking	Master device	5 GHz (Nss=2)	802.11be	160 MHz	1800
		Slave device	5 GHz (Nss=2)	802.11be	160 MHz	400
		Master device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	2000
		Slave device	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	MLO (20 MHz+160 MHz)	500
		Master device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	2700
		Slave device	5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	MLO (160 MHz+80 MHz)	600

Note 1: In a wired backhaul scenario, indicators of the slave device alone are concerned in AC+AP networking.

In an ideal condition (without interference), when multiple users access the networking master/slave device at a short distance separately, performance requirements on a maximum concurrent throughput of the entire network are listed in Table 2.

Table 2 Performance requirements on a concurrent throughput when a single STA is connected to each of multiple APs

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Type	Networking Mode Between the Master Device and the Slave Device	Endpoint WLAN Configuration	Protocol Mode	Whether AP Channels Are the Same	Bandwidth	Total Throughput Requirement (Mbps)
3	1	Wired networking	Optical fiber networking or 2.5 GE or higher network cable networking	5 GHz (Nss=2)	802.11be	Same	160 MHz	2400
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	2700
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	3600
3	1	Wired networking	Gigabit network cable networking	5 GHz (Nss=2)	802.11be	Same	160 MHz	1950
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	2200
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	2900

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Type	Networking Mode Between the Master Device and the Slave Device	Endpoint WLAN Configuration	Protocol Mode	Whether AP Channels Are the Same	Bandwidth	Total Throughput Requirement (Mbps)
3	1	Wireless networking	Wi-Fi networking	5 GHz (Nss=2)	802.11 be	Same	160 MHz	800
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11 be	Same	MLO 20 MHz+160 MHz	1000
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11 be	Same	MLO 160 MHz+80 MHz	1300

In an ideal condition (without interference), when multiple users access the networking master device and the networking slave device at a long distance and a short distance separately, performance requirements on a maximum total concurrent throughput of the entire network and a minimum throughput of a single STA are listed in Table 3.

Table 3 Performance requirements on throughputs for multiple users at long and short distances

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Type Between the Master Device and the Slave Device	STA Signal Strength Distribution (dBm)	Endpoint WLAN Configuration	Protocol Mode	Whether AP Channels Are the Same	Bandwidth	Total Throughput Requirement (Mbps)	Minimum Throughput Requirement (Mbps)
2	2	Wired networking	Close: [–30±2]	5 GHz (Nss=2)	802.11be	Same	160 MHz	1400	80

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Type Between the Master Device and the Slave Device	STA Signal Strength Distribution (dBm)	Endpoint WLAN Configuration	Protocol Mode	Whether AP Channels Are the Same	Bandwidth	Total Throughput Requirement (Mbps)	Minimum Throughput Requirement (Mbps)
			Far: [–55±2]	2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	1600	80
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	2000	140
2	2	Wireless networking	Close: [–30±2] Far: [–55±2]	5 GHz (Nss=2)	802.11be	Same	160 MHz	700	20
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	800	30
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	1000	40

In an interference scenario, when multiple users access a networking master device and a networking slave device at a short distance separately, performance requirements on a maximum concurrent throughput of the entire network are listed in Table 4.

Table 4 Performance requirement on a concurrent throughput when a single STA is connected to each of multiple APs with interference

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Type	Networking Mode Between the Master Device and the Slave Device	Endpoint WLAN Configuration	Protocol Mode	Whether AP Channels Are the Same	Bandwidth (MHz)	Total Throughput Requirement (Mbps)
3	1	Wired networking	Optical fiber networking or 2.5 GE or higher network cable networking	5 GHz (Nss=2)	802.11be	Same	160 MHz	2000
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	2300
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	3000
3	1	Wired networking	Gigabit network cable networking	5 GHz (Nss=2)	802.11be	Same	160 MHz	1600
				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	1850
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	2400
3	1	Wireless networking	Wi-Fi networking	5 GHz (Nss=2)	802.11be	Same	160 MHz	500

				2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	Same	MLO 20 MHz+160 MHz	600
				5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	Same	MLO 160 MHz+80 MHz	800

7.2 Latency

7.2.1 Latency Parameter and Scenario Model

7.2.1.1 Latency Parameter

The latency parameter refers to time required for data to travel from one end of a network (or a link) to the other end, and mainly includes a sending latency, a propagation latency, a queuing latency, and a processing latency.

Traditional latency indicators mainly include two types of latency indicators: RTT latency and OWD delay. Different latency indicators are applied to different scenarios. For TCP service interaction, the RTT latency is generally used for evaluating the latency; and for a UDP service scenario, the OWD delay is generally used.

Different from a single-device service latency scenario, in a home networking scenario, concurrency of multiple APs causes intra-networking interference, which greatly affects experience of a latency-sensitive service.

To accurately evaluate a latency of a WLAN interface of a home networking device, this document uniformly specifies starting and ending points of latency measurement as follows:

1. Two-way delay: The two-way delay is round-trip time from a service server connected to a UNI interface of a home networking master device to a WLAN endpoint (where the endpoint can access the master device or a slave device).

2. Downlink one-way delay: The downlink one-way delay starts from the service server connected to the UNI interface of the home networking master device, and ends at the WLAN endpoint (where the endpoint can access the master device or the slave device).

3. Uplink one-way delay: The uplink one-way delay starts from the WLAN endpoint (where the endpoint can access the master device or the slave device), and ends at the service server connected to the UNI interface of the home networking master device.

Based on different service types, data packet sizes, and air interface concurrency conditions, the latency indicators are defined for the following scenarios.

7.2.1.2 Home Networking Latency Scenario Model 1: Multi-user UDP Service Concurrency Latency in the Entire Network

In the networking scenario, Figure 12 shows a scenario of a multi-AP single-user UDP service concurrency latency. One WLAN user endpoint accesses each of the master device and the slave device, a sight distance between each user endpoint and the AP device connected to the user endpoint is 10 m, and UDP-type services are simultaneously running.

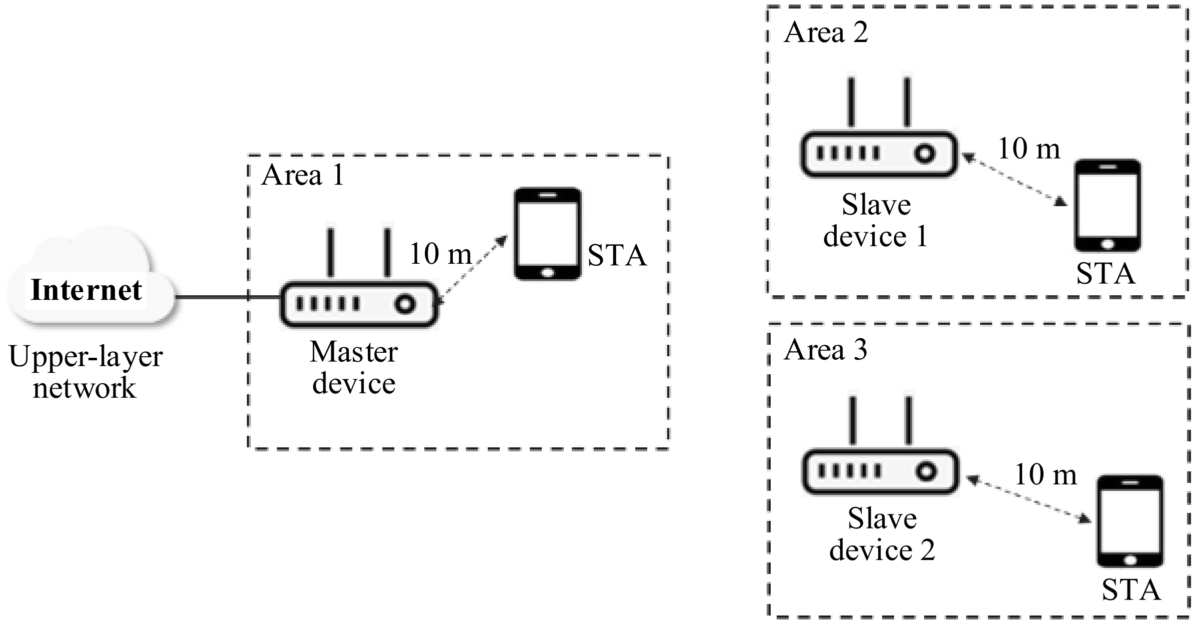

Figure 12 Diagram of a multi-user UDP service concurrency latency in the entire network

In this scenario, multiple users access the home networking master device and the home networking slave device at a long distance separately, to measure the concurrency latency generated when the UDP services are running. The following settings need to be satisfied in this scenario:

1. There are no other interference sources in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, and a microwave oven device).
2. Typical networking with three hotspots is used, where in this networking scenario, interference between the hotspots significantly affects the latency indicators.
3. A UDP service flow is used for measurement of service traffic of the latency indicators. Traffic of each user is 150 Mbps. An AC_VI priority queue is used. A payload length of the UDP service flow is defined as 1472 bytes in this scenario.
4. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and

the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.

7.2.1.3 Home Networking Latency Scenario Model 2: Multi-user TCP Service Concurrency Latency in the Entire Network

In the networking scenario, Figure 13 shows a scenario of a multi-AP multi-user TCP service concurrency latency. Two WLAN user endpoints access each of the master device and the slave device. Sight distances between an AP and WLAN user endpoints connected to the AP are 1 m and 10 m respectively, and TCP-type services are simultaneously running.

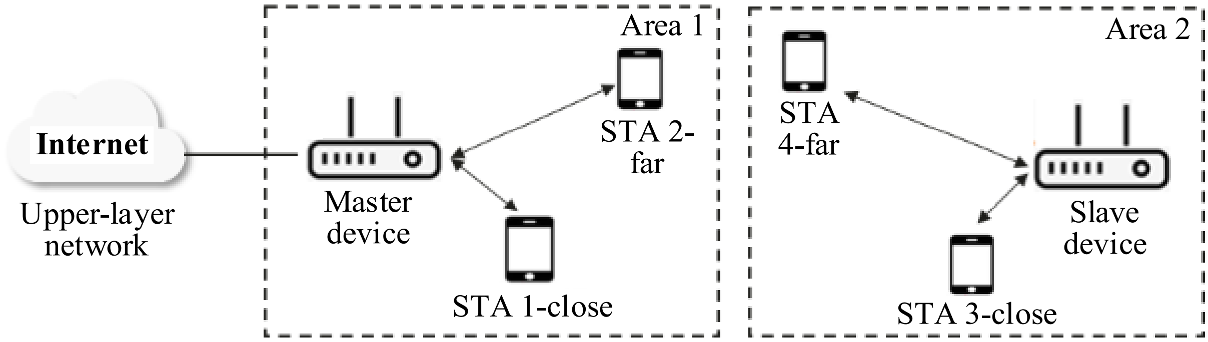

Figure 13 Multi-AP multi-user TCP service concurrency latency

In this scenario, multiple users simultaneously access a home networking master device and a home networking slave device at a short distance and a long distance separately, to measure the concurrency latency generated when the TCP services are running. The following settings need to be satisfied in this scenario:

1. There are no other interference sources in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, and a microwave oven device).
2. Typical networking with two hotspots is used, where in this networking scenario, interference between the hotspots significantly affects the latency indicators.
3. A TCP service flow is used for measurement of service traffic of the latency indicators. Traffic of each user is 150 Mbps. An AC_VI priority queue is used. A packet byte length is 1500 bytes.
4. -In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.

7.2.1.4 Home Networking Latency Scenario Model 3: Multi-user UDP Service Concurrency Latency in the Entire Network with Interference

Figure 14 shows a scenario of a multi-AP single-user UDP service concurrency latency with interference. One WLAN user endpoint accesses each of a master device and a slave device.

A sight distance between each user endpoint and the AP device connected to the user endpoint is 10 m, and UDP-type services are simultaneously running.

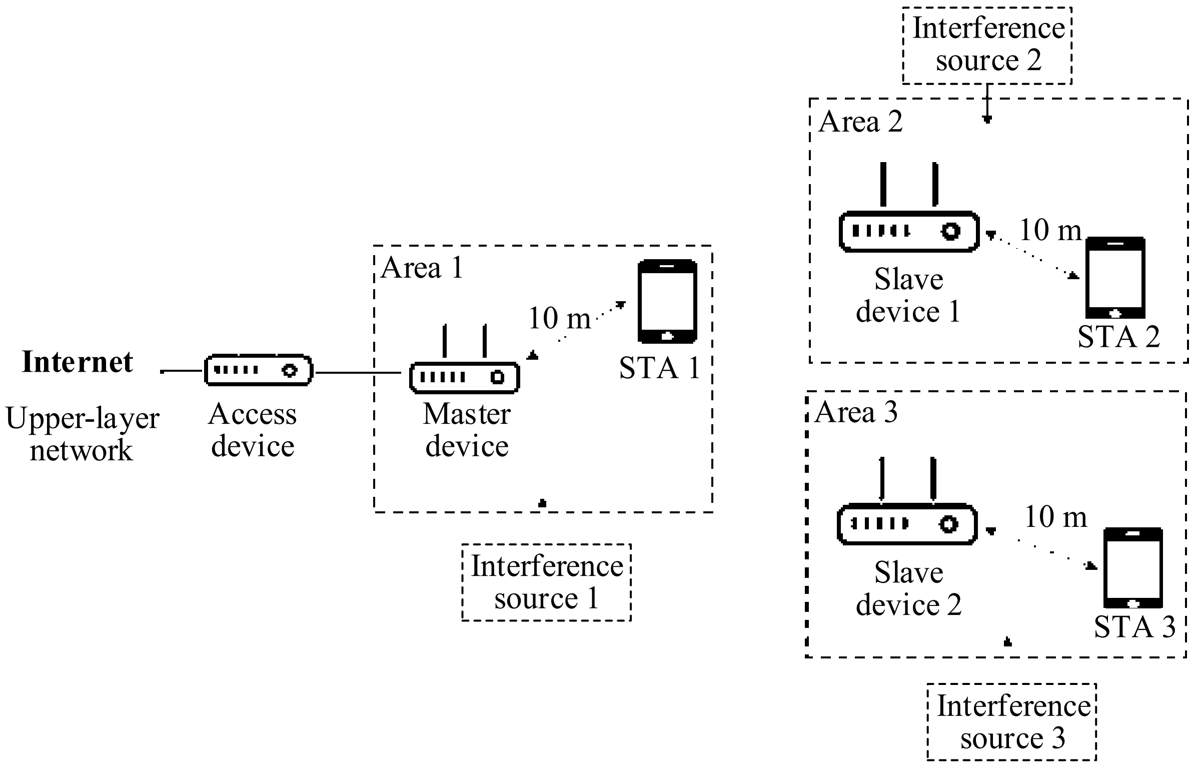

Figure 14 Diagram of a multi-AP single-user UDP service concurrency latency with interference

In this scenario, multiple users simultaneously access the home networking master device and the home networking slave device at a long distance separately, to measure the concurrency latency generated when the UDP services are running. The following settings need to be satisfied in this scenario:

1. An external interference model is as follows:

   a) When the networking device is connected to a STA by using a 5 GHz frequency band, each networking device has a co-channel interference source on the 5 GHz frequency band. Interference traffic of each interference source is 20 Mbps over downlink and 2 Mbps over uplink for co-channel interference. The service flow is of a TCP-type, signal strength on the 5 GHz frequency band between the interference source and the test endpoint ranges from –65 dBm to –70 dBm, and signal strength on the 5 GHz frequency band between the interference source and the interference STA is –30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

   b) When the networking device supports dual bands and has an MLO function enabled, each networking device has a co-channel interference source on a 2.4 GHz frequency band and a co-channel interference source on the 5 GHz frequency band. An interference model is as follows:

i. 5 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, the signal strength on the 5 GHz frequency band between the interference source and the test endpoint ranges from −65 dBm to −70 dBm, and the signal strength on the 5 GHz frequency band between the interference source and the interference STA is −30 dBm±2 dBm. The interference source and the networking device to be tested have the same channel and channel bandwidth.

ii. 2.4 GHz frequency band: Co-channel interference of 5 Mbps over downlink and 1 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 2.4 GHz frequency band between the interference source and the test endpoint ranges from −58 dBm to −63 dBm, and signal strength on the 2.4 GHz frequency band between the interference source and the interference STA is −30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

c) When the networking device supports triple bands and has an MLO function enabled, each networking endpoint has a co-channel interference source on a 5.1 GHz frequency band and a co-channel interference source on a 5.8 GHz frequency band. An external interference model is as follows:

i. 5.1 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 5.1 GHz frequency band between the interference source and the test endpoint ranges from −65 dBm to −70 dBm, and signal strength on the 5.1 GHz frequency band between the interference source and the interference STA is −30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

ii. 5.8 GHz frequency band: Co-channel interference of 20 Mbps over downlink and 2 Mbps over uplink. The service flow is of a TCP-type, signal strength on the 5.8 GHz frequency band between the interference source and the test endpoint ranges from −65 dBm to −70 dBm, and signal strength on the 5.8 GHz frequency band between the interference source and the interference STA is −30 dBm±2 dBm. The interference source and the networking device to be tested have a same channel and channel bandwidth.

2. Typical networking with three hotspots is used, where in this networking scenario, interference between the hotspots significantly affects the latency indicators.

3. A UDP service flow is used for measurement of service traffic of the latency indicators. Traffic of each user is 150 Mbps. An AC_VI priority queue is used. A packet length of the UDP service flow is defined as 1472 bytes in this scenario.

4. In the networking, WLAN protocol modes of the multiple APs are the same, and the protocol mode of the STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking..

7.2.2 Latency Requirement

In a networking scenario, a multi-AP single-user UDP service concurrency OWD delay should satisfy requirements in Table 5.

Table 5 UDP concurrency latency in a networking scenario in which multiple users access multiple devices

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Mode Between the Master Device and the Slave Device	STA Signal Strength Distribution (dBm)	Traffic Model of Each User	Byte Length (Byte)	Endpoint WLAN Configuration	Protocol Mode	Average Latency of Each User	TP99 Latency of Each User	Packet Loss Ratio
3	1	Wired networking	[-55±2]	150 Mbps	1472	5 GHz (Nss=2)	802.11be	15 ms	75 ms	0.1%
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	10 ms	50 ms	0.1%
						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	10 ms	50 ms	0.1%
3	1	Wireless networking	[-55±2]	150 Mbps	1472	5 GHz (Nss=2)	802.11be	30 ms	150 ms	0.1%
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	20 ms	100 ms	0.1%

						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	20 ms	100 ms	0.1%

In the networking scenario, a multi-AP multi-user TCP service concurrency RTT latency should satisfy requirements in Table 6.

Table 6 TCP concurrency latency in a scenario in which multiple users access networking devices

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Mode	STA Signal Strength Distribution (dBm)	Traffic Model of Each User	Byte Length (Byte)	Endpoint WLAN Configuration	Protocol Mode	Average Latency of Each User	TP99 Latency of Each User
2	2	Wired networking	[-30±2] [-55±2]	150 Mbps	1500	5 GHz (Nss=2)	802.11be	30 ms	150 ms
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	25 ms	125 ms
						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	25 ms	125 ms
2	2	Wireless networking	[-30±2] [-55±2]	150 Mbps	1500	5 GHz (Nss=2)	802.11be	50 ms	250 ms
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	40 ms	200 ms
						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	40 ms	200 ms

In an interference scenario, a multi-AP single-user UDP service concurrency OWD delay in the interference scenario should satisfy requirements in Table 7.

Table 7 UDP concurrency latency in a networking interference scenario in which multiple users access multiple devices

Quantity of APs in the Networking	Quantity of STAs Connected to a Single AP	Networking Mode	STA Signal Strength Distribution (dBm)	Traffic Model of Each User	Byte Length (Byte)	Endpoint WLAN Configuration	Protocol Mode	Average Latency of Each User	TP99 Latency of Each User	Packet Loss Ratio
3	1	Wired networking	[-55±2]	150 Mbps	1472	5 GHz (Nss=2)	802.11be	20 ms	100 ms	0.1%
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	15 ms	75 ms	0.1%
						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	15 ms	75 ms	0.1%
3	1	Wireless networking	[-55±2]	150 Mbps	1472	5 GHz (Nss=2)	802.11be	35 ms	175 ms	0.1%
						2.4 GHz (Nss=2) 5 GHz (Nss=2)	802.11be	25 ms	125 ms	0.1%
						5.1 GHz (Nss=2) 5.8 GHz (Nss=2)	802.11be	25 ms	125 ms	0.1%

7.3 Roaming

7.3.1 Roaming Parameter and Scenario Model

7.3.1.1 Roaming Parameter

In a home networking scenario, a user needs to move between different areas within a home for work and entertainment while a network service maintains uninterrupted. For a roaming scenario, a WLAN roaming indicator is mainly used for measuring a change trend of a switching latency during roaming and a change trend of throughput performance during roaming.

7.3.1.2 Home Networking Roaming Scenario Model 1: Roaming Switching Latency between Multiple APs

When a user roams between two wireless APs, service interruption time is caused by roaming switching. Figure 15 and Figure 16 show scenario models.

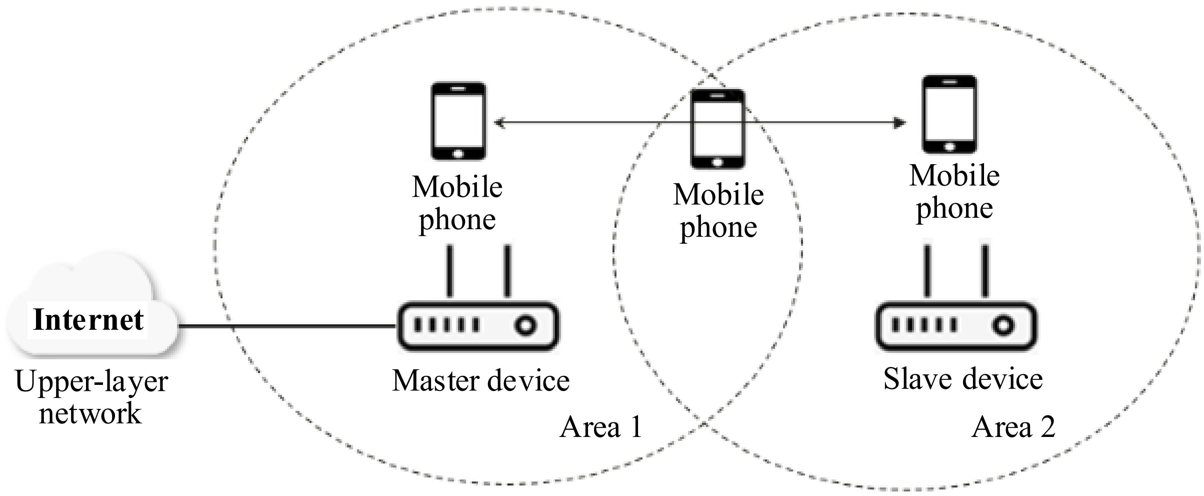

Figure 15 Diagram of a scenario of roaming between a master device and a slave device in home networking

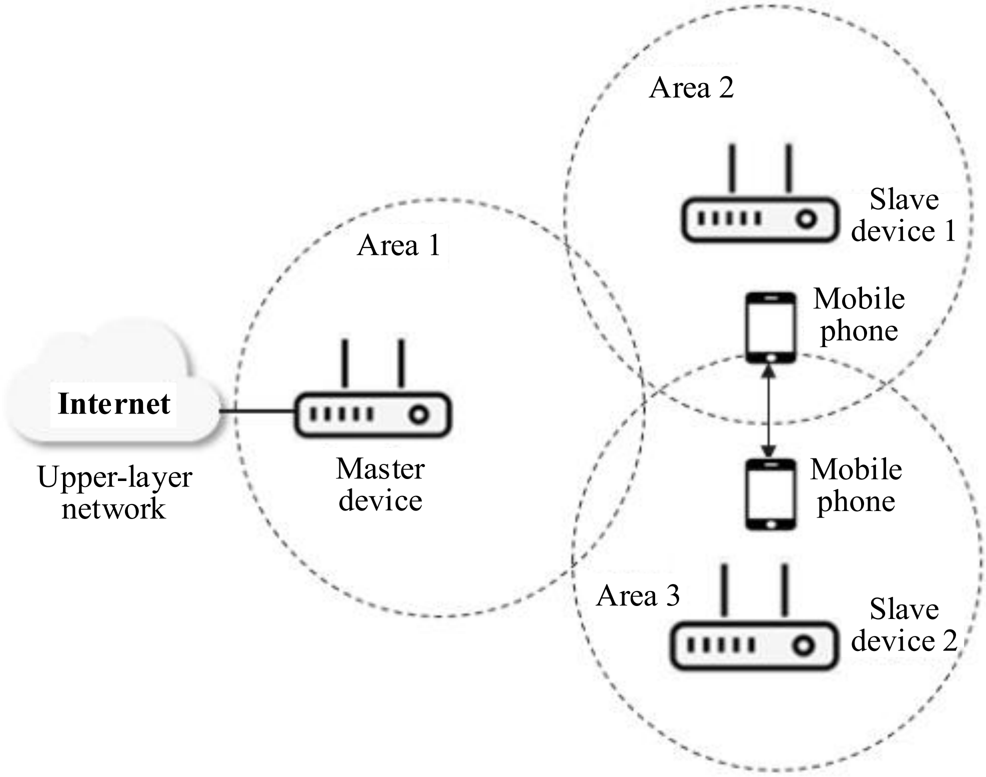

Figure 16 Diagram of a scenario of roaming between slave devices in home networking

When an endpoint moves between two wireless APs, the endpoint is switched from one BSS network to the other BSS network. A switching process involves procedures such as roaming detection, roaming decision, and roaming switching. A switching speed is a key indicator for measuring service experience quality of roaming behavior. Faster roaming switching indicates shorter service interruption time and better user experience. In a manner of constructing specific service traffic, measuring a packet loss during the roaming can be used for evaluating the roaming switching speed. In this scenario, the following constraints need to be satisfied.

1. There are no other interference sources in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, or a microwave oven device).
2. The two APs in the home networking have a proper overlapping area, that is, a mobile phone can receive signals from the two APs in a specific area.
3. The roaming endpoint moves between the two APs at a rate of 0.5 m/s.
4. Roaming endpoints include both an endpoint that supports the 802.11kv protocol and an endpoint that does not support the 802.11kv protocol (for details about IEEE 802.11k and IEEE 802.11v, see normative reference document [4] and [5]).

5. Service traffic carried by the roaming endpoint during the roaming is about 1000 pps, a payload length of a service flow packet is 1472 bytes, and a larger value in a packet loss quantity/1000 pps and a maximum latency value of a packet-by-packet latency is used as service recovery time.

7.3.1.3 Home Networking Roaming Scenario Model 2: Throughput Performance during Roaming Between Multiple APs

A minimum throughput and an average throughput are obtained by a single user when the single user roams between two wireless APs. Figure 15 and Figure 16 show diagrams of scenario models.

In addition to the roaming switching latency indicator, average performance and minimum performance during the roaming are also key indicators for evaluating roaming experience. Based on the minimum throughput and the average throughput during the endpoint roaming that are measured with rate-limited UDP traffic, reasonableness of time and duration of the endpoint roaming are evaluated.

In this scenario, the following constraints need to be satisfied.

1. There are no other interference sources in the environment, where the other interference sources include a WLAN interference source (for example, another gateway or router device) and a non-WLAN interference source (for example, Bluetooth, a cordless phone, or a microwave oven device).
2. The two APs in the home networking have a proper overlapping area, that is, a mobile phone can receive signals from the two APs in a specific area.
3. The roaming endpoint moves between the two APs at a rate of 0.5 m/s.
4. Roaming endpoints include both an endpoint that supports the 802.11kv protocol and an endpoint that does not support the IEEE 802.11kv protocol.
5. UDP service traffic carried by the roaming endpoint during the roaming is about 200 Mbps, and a payload length of a service flow packet is 1472 bytes.
6. A signal strength threshold for roaming switching of a test endpoint is set to −75 dBm.
7. In the networking, WLAN protocol modes of all APs are the same, and a protocol mode of a STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.

7.3.2 Roaming Requirement

In a home scenario, roaming indicators should satisfy requirements in Table 8 and Table 9.

Table 8 Requirements on roaming switching latency indicators

Networking Type	Roaming Path	Whether an Endpoint Supports the IEEE 802.11kv Protocol	Service Recovery Time
Wired networking	Master-Slave	Supported	300 ms
	Slave-Slave	Supported	300 ms
	Master-Slave	Not supported (optional)	500 ms
	Slave-Slave	Not supported (optional)	500 ms
Wireless networking	Master-Slave	Supported	400 ms
	Slave-Slave	Supported	400 ms
	Master-Slave	Not supported (optional)	500 ms
	Slave-Slave	Not supported (optional)	500 ms

Table 9 Requirements on roaming switching UDP throughput performance indicators

Networking Type	Roaming Path	Whether an Endpoint Supports the IEEE 802.11kv Protocol	Roaming Path Throughput Performance	
			Average Throughput Performance	Minimum Throughput Performance
Wired networking	Master-Slave	Supported	160 Mbps	60 Mbps
	Slave-Slave	Supported	160 Mbps	60 Mbps
	Master-Slave	Not supported (optional)	150 Mbps	40 Mbps
	Slave-Save	Not supported (optional)	150 Mbps	40 Mbps
Wireless networking	Master-Slave	Supported	120 Mbps	30 Mbps
	Slave-Slave	Supported	120 Mbps	30 Mbps

Networking Type	Roaming Path	Whether an Endpoint Supports the IEEE 802.11kv Protocol	Roaming Path Throughput Performance	
			Average Throughput Performance	Minimum Throughput Performance
	Master-Slave	Not supported (optional)	100 Mbps	20 Mbps
	Slave-Slave	Not supported (optional)	100 Mbps	20 Mbps

7.4 Connection

7.4.1 Connection Parameter and Scenario Model

7.4.1.1 Connection Parameter

Service concurrency is a characteristic of a home network. A connection reflects a degree of integration between a network and a physical world, and an indicator of the connection is a quantity of connected users and a quantity of concurrent users.

1. Quantity of connected users: The quantity of connected users is a maximum quantity of users who can perform access.
2. Quantity of concurrent users: The quantity of concurrent users is a quantity of users who have services at a same moment.

A theoretical model of a home WLAN duty cycle is shown in Formula (1):

$$\text{Duty Cycle (duty cycle)} = \frac{\sum_{1}^{n} T_{nrate}}{N_{SS} * (N_{CBPS} * R) * (1/T_S + T_{GI})} \tag{1}$$

In the formula:

NS: quantity of spatial streams;

NCBPS: number of coded bits per OFDM symbol;

R: bit rate;

TGI: GI length;

TS: symbol (IFFT) length; and

Tnrate: actual rate of an endpoint.

More concurrent users indicate higher air interface usage, more severe contention conflict, and poorer service experience.

In a home networking scenario, an access capability of the entire network is evaluated based on an overall throughput and a minimum single-user throughput when multiple users access APs in the networking.

7.4.1.2 Home Networking Connection Scenario Model 1: Multi-AP Multi-user Concurrent Throughput and Fairness

In an ideal condition (without interference), a concurrent throughput of the entire network and a minimum user throughput are measured when multiple users concurrently access a networking master device and a networking slave device. According to Formula (1), when actual service traffic of an endpoint increases, utilization of an air interface increases accordingly, contention conflict intensifies, and service experience deteriorates. Herein, a maximum throughput of the multi-user concurrency is used for measuring a service scheduling capability of the entire home network when concurrency of services of multiple users occurs.

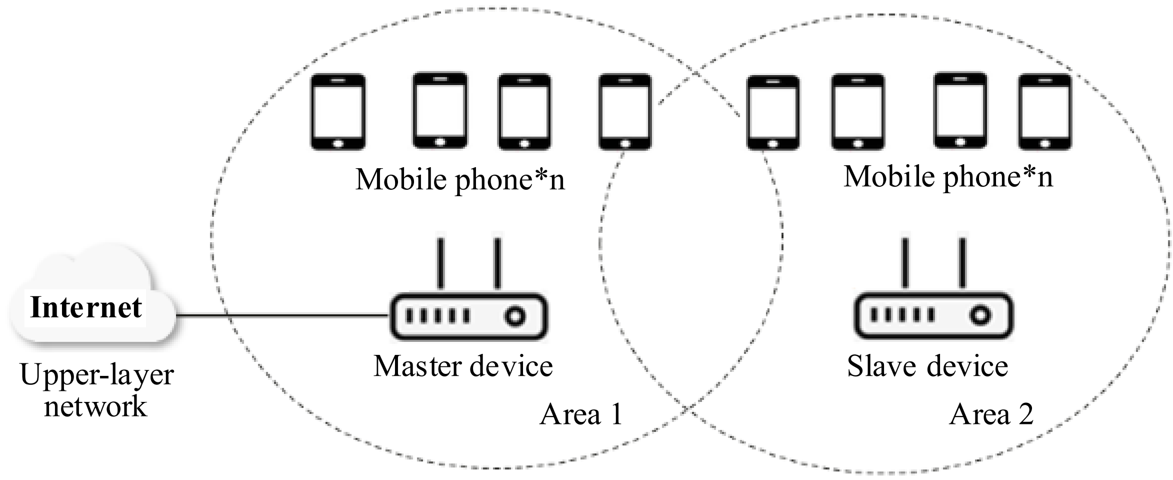

Figure 17 Multi-user concurrent throughput

As shown in Figure 17, there are two scenarios based on a quantity of users accessing a master/slave device.

Scenario 1: 16 users access the entire network. Eight users (where six users are at a short distance, and two users are at a long distance) access the master device, and eight users (where six users are at a short distance, and two users are at a long distance) access the slave device.

Scenario 2: 32 users access the entire network. 16 users (where 12 users are at a short distance, and 4 users are at a long distance) access the master device, and 16 users (where 12 users are at a short distance, and 4 users are at a long distance) access the slave device.

Based on a maximum quantity of users that a test system can support when a specific performance requirement is satisfied and that is measured via a TCP stream without rate limitation, entire network concurrent performance of a home networking device and fairness of multi-user concurrent scheduling are evaluated.

Key constraints and conditions in a multi-connection scenario are defined as follows:

1. Each STA has an independent WLAN PHY+MAC, and a STA MIMO capability is 2x2.
2. A packet length of a TCP service flow depends on an MTU value of a network path between a server and a client, with a default MTU being 1500 bytes.
3. In the networking, WLAN protocol modes of all APs are the same, and a protocol mode of a STA is the same as the WLAN protocol mode of the AP. WLANs of both the multiple APs and the STA operate in the supported highest wireless protocol. When an MLO scenario is tested, an MLO mode is enabled for both the APs and the STA in the networking.

7.4.2 Connection Requirement

Requirements on a multi-user concurrent throughput scenario:

Table 10 Requirements on connection performance indicators

Networking Type	WLAN Configuration of To-be-tested Networking	Bandwidth (MHz)	Protocol Mode	16 Concurrent Users (8+8)		32 Concurrent Users (16+16)	
				Total Throughput (Mbps)	Minimum Throughput (Mbps)	Total Throughput (Mbps)	Minimum Throughput (Mbps)
Wired networking	5 GHz (Nss=2)	160	802.11be	1300	15	1100	5
	MLO (2+2)	20+160	802.11be	1500	15	1200	5
	MLO (2+2)	160+80	802.11be	2200	15	1600	5
Wireless networking	5 GHz (Nss=2)	160	802.11be	700	4	350	2
	MLO (2+2)	20+160	802.11be	800	4	400	2
	MLO (2+2)	160+80	802.11be	1050	4	540	2

7.5 Intelligent O&M

7.5.1 Intelligent O&M Parameter and Scenario Model

A goal of the intelligent O&M is to agilely enable a new service and achieve ultimate customer experience through data and knowledge drive, maximize resource and energy utilization, and implement network automation, self-optimization, and self-healing. On this basis, network self-evolution is implemented to achieve autonomy.

1. Automation: A service is automatically deployed based on a user intent, and a final goal is to achieve fully automatic service deployment.
2. Self-healing: fault prediction and prevention, and event-based self-recovery are performed, and a final goal is to achieve fully automatic O&M.
3. Self-optimization: Adaptive adjustment and optimization are performed based on user experience, and a final goal is to achieve fully automatic optimization.
4. Autonomy: Self-evolution of a network function is achieved on the basis of the automation, the self-healing, and the self-optimization.

In a home scenario, this specification focuses on a self-healing capability of a WLAN and defines the following two fault self-healing capabilities.

Scenario 1: is a scenario in which a slave device is powered off in home networking. In the home networking, a connected STA endpoint needs to be able to quickly recover a service in a scenario in which a key node is faulty or powered off. Service recovery time can define a network self-healing capability of the home networking to some extent.

Scenario 2: is a scenario in which the slave device is disconnected in home networking. In the home networking (wired networking scenario), a connected STA endpoint needs to be able to quickly recover a service in a scenario in which a key node is disconnected from a master node. Service recovery time can define a network self-healing capability of the home networking to some extent.

7.5.2 Intelligent O&M Indicator Requirements

In Scenario 1 (the scenario in which the slave device is powered off in the home networking), the STA service recovery time is less than 30s.

In Scenario 2 (the scenario in which the slave device is disconnected in the home networking), the STA service recovery time is less than 30s.

7.6 Security

7.6.1 Security Parameter and Scenario Model

Endpoint devices in a WLAN face attack threats from the Internet or a local area network. As more smart devices, such as smart screens, smart speakers, and printers, involving user sensitive information and privacy, are connected to the network, security mechanisms related to a home networking device used as a central device in a home are classified as follows:

1. Access security

Security on a wireless side mainly includes user access and authentication security and user data transmission security. The user access and authentication security mainly relies on multiple workstation access modes and multiple user identity authentication and authorization modes to provide security assurance. In the user data security, various encryption modes are mainly used for ensuring secure transmission of user data.

Currently, user access identity authentication and data encryption modes that are supported in a home WLAN are as follows:

a) OPEN-SYS authentication is supported;

b) WEP authentication/encryption is supported;

c) A WPA2 authentication/encryption mode (TKIP/CMMP encryption) is supported; and

d) A WPA3-SAE authentication mode is supported (for details about WPA2 and WPA3, see normative reference document [3] and [6]).

A latest access authentication specification WPA3-SAE replaces a PSK authentication mode of WPA2-Personal. This can effectively defend against offline dictionary attacks and increase difficulty of brute force cracking. SAE provides forward secrecy. Even if an attacker knows a password on a network, the attacker cannot decrypt obtained traffic. This greatly improves security of a WPA3-Personal network.

In addition to authentication and encryption security measures at an access level, at an application layer, the WLAN also has control capabilities over access behavior through upper-layer software, and the control capabilities mainly include:

a) based on MAC configured with a blocklist, directly rejecting a STA to go online;

b) configuring a trustlist and performing authentication based on a MAC address;

c) performing authentication through manners such as 802.1x and portal; and

d) accessing after manual confirmation.

2. System security

The system security of the WLAN mainly manifests in protection against various attacks. In the system security, multiple protection means need to be used to achieve defense against the attacks. Common protection means include user blocklist and trustlist filtering, DoS detection, rogue AP detection, anti-MAC/IP spoofing, disabling ESSID broadcast, AP MAC/SN filtering, use of an advanced encryption algorithm, and the like.

Based on the foregoing atomic security capabilities, the WLAN security in a home scenario is classified into the following three scenarios:

Scenario 1: Anti-brute force cracking

A mode for accessing a home WLAN is generally a PSK access mode, and this mode is easy to be cracked by brute force cracking. The brute force cracking is also referred to as an exhaustion method, and is a cryptanalysis method, to be specific, used for calculating passwords one by one until an actual password is found. For example, if a password is known to be four digits and consists of all numbers, there are 10,000 possible combinations. Therefore, the correct password can be found after a maximum of 10,000 attempts. In theory, except for passwords with complete confidentiality, this method can be used for cracking any password. The only problem is how to shorten trial-and-error time. Some people use computers to increase efficiency, and others use dictionaries to narrow down a range of password combinations. A home gateway or a router should support PSK anti-brute force cracking. Frequent attempts on PSK authentication are detected, to interrupt an attempt process, so that attempt frequency and attack efficiency are greatly reduced, and the passwords are prevented from being cracked.

Scenario 2: Anti-unauthorized access of a neighboring user

Currently, WLAN user passwords are often shared by third-party software, and unauthorized access is a common phenomenon, resulting in a slow network speed of users. The users need to frequently check online users and blocklist unknown users. The home gateway or the router should support in forbidding unknown devices to access a home network. By accurately identifying attack behavior for cracking and stealing WLAN passwords, the home gateway or the router can automatically prevent malicious attack devices from accessing the home WLAN.

Scenario 3: Anti-protocol packet attack

Malicious users send a large quantity of protocol packets to attack a system. As a result, the system cannot process a service request of a common user, that is, rejects a service for the common user. To protect the system, a quantity of user protocol packets received by the system is limited within a specified range. A packet that exceeds the specified range is discarded as an invalid packet, a user that initiates a DoS attack is added to the blocklist, and reception of a protocol packet from the user is rejected.

Scenario 4: Anti-man-in-the-middle attack

An unauthorized user uses a network tool to intercept a communication packet between a wireless client and a home gateway or a router, and inserts the unauthorized user into normal communication between the wireless client and an AP. Once the insertion succeeds, the unauthorized user sends a decatenation packet to force the client to be disconnected, then copies a MAC address of the authorized AP and forges a consistent SSID to lure the wireless client. In addition, an attacker's computer establishes a normal connection with the AP. In this way, all data of the wireless client is sent to the authorized AP through an attacker's access point. Therefore, the home gateway or the router needs to have an anti-man-in-the-middle attack capability.

7.6.2 Security Indicator Requirement

An anti-brute force cracking function, a function of anti-unauthorized access of a neighboring user, an anti-protocol packet attack capability, and an anti-man-in-the-middle attack capability need to be supported.

8 Service Experience Scenario Definition and Experience Requirements on Home Scenario WLAN Device Networking

8.1 Comprehensive Home Scenario Classification

From actual layout of devices involved in networking in a home scenario, typical networking that is actually used currently is performed mainly via two hotspots or three hotspots. In this scenario, a covered household area is more than 120 square meters, and multiple protocols coexist.

8.2 Typical Home Networking Scenario 1 in a Live Network

8.2.1 Definition of the Typical Home Networking Scenario 1 in the Live Network

The definition of the typical home networking scenario 1 in the live network is that in a household scenario in which a household area is about 120 square meters, two WLAN hotspots are used for achieving full coverage of a house. In this scenario, a scenario with a highest service concurrency and service experience requirement is selected as an evaluation scenario, as shown in Figure 18.

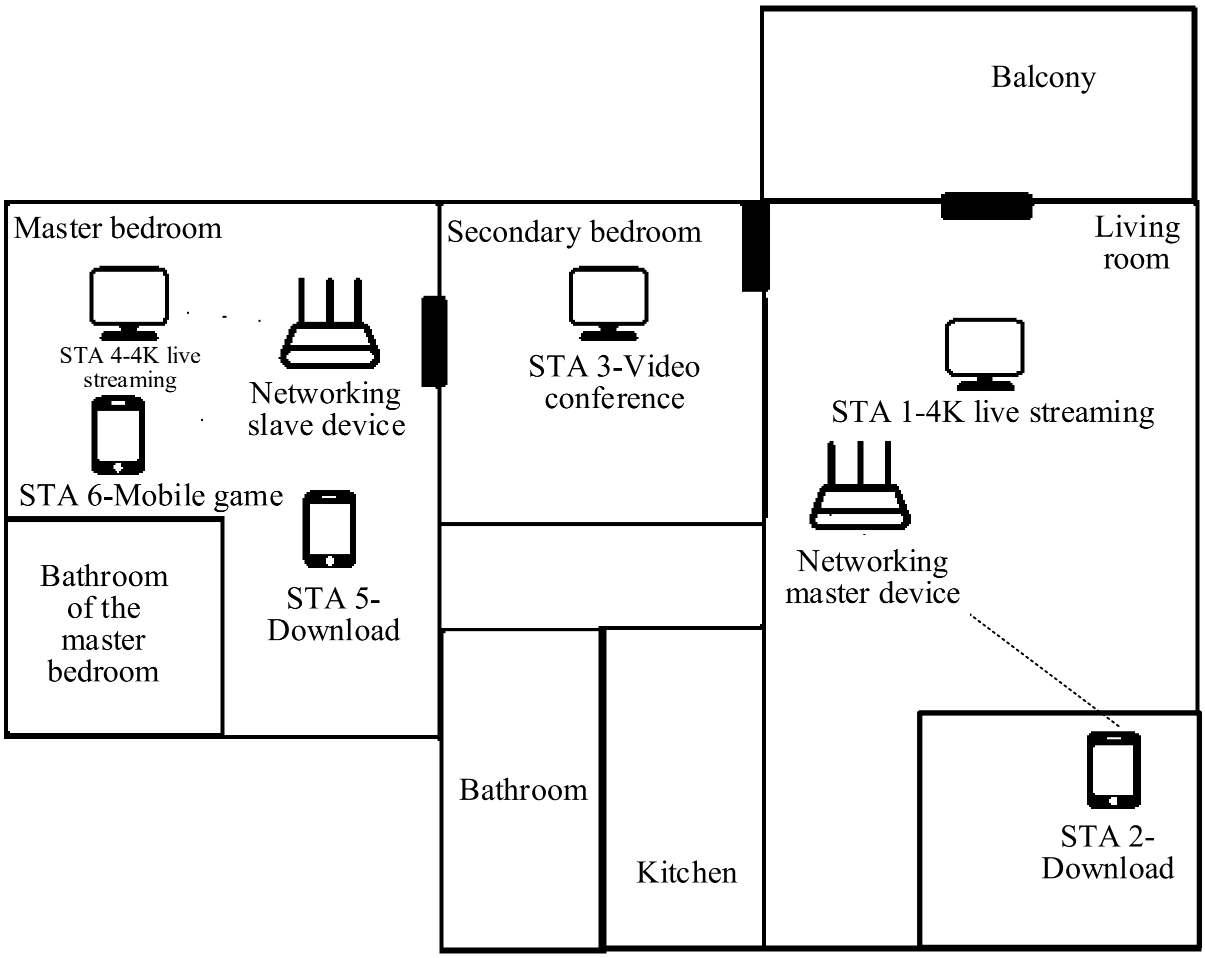

Figure 18 Diagram of a scenario of a home with two hotspots

As shown in Figure 18, in home networking, a master device is mounted in a living room, and a slave device is mounted in a master bedroom. A received signal strength indicator (RSSI) in 95% of an area is not less than –65 dBm by using the two hotspots. Common services in the home scenario are as follows:

1. Social production service: video and voice conference, web browsing, email, online education, and the like.
2. Entertainment service: video, game, instant messaging, download, and the like.

   Based on types of the services carried by the device and a concurrency rate, in this document, a service bearing capability of the networking device in a home network in this scenario is evaluated mainly based on a service that requires a high bandwidth and a low latency. Main scenarios are described as follows:

Service of the master device:

1. Short-distance 4K video streaming service (entertainment service): A sight distance between a 4K set-top box and the master device is 1 m, and the 4K set-top box accesses an MLO frequency band of the master device, to run a 4K live streaming service.
2. Long-distance download service without rate limitation (non-real-time service): A mobile phone or a laptop of a user is separated from the master device by a regular brick wall, and a distance between the mobile phone or the laptop of the user and the master device is about 5 m. The mobile phone or the laptop of the user accesses an MLO frequency band of the master device, to run the download service without rate limitation.
3. Long-distance online video conference service (social production service): The mobile phone or the laptop of the user is separated from the master device by a regular brick wall, and a distance between the mobile phone or the laptop of the user and the master device is about 5 m. The mobile phone or the laptop of the user accesses an MLO frequency band of the master device, to run the online video conference service.

Service of the slave device:

1. Short-distance 4K video streaming service (entertainment service): A sight distance between a 4K set-top box and the master device is 1 m, and the 4K set-top box accesses an MLO frequency band of the slave device, to run a 4K live streaming service.
2. Short-distance download service without rate limitation (non-real-time service): A sight distance between a mobile phone or a laptop of a user and the slave device is 3 m. The mobile phone or the laptop of the user accesses an MLO frequency band of the slave device, to run the download service without rate limitation.
3. Short-distance mobile game service (real-time entertainment service): A sight distance between the mobile phone of the user and the slave device is 3 m, and the mobile phone of the user accesses an MLO frequency band of the slave device, to run the online mobile game service.

8.2.2 Indicator Requirement for the Typical Home Networking Scenario 1 in the Live Network

Under a 1+1 home networking service model, requirements on experience of key performance indicators (KPIs) for concurrent services are as shown in the table below:

Table 11 Requirements 1 on KPI indicators of comprehensive service experience in a typical home networking scenario

Scenario Model	Service	Parameter	Wired Networking Indicator Requirement	Wireless Networking Indicator Requirement
Master device	4K video streaming	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Download service	Average download throughput	≥100 Mbps	≥50 Mbps
	Online video conference	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
Slave device	4K video streaming	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Download service	Average download throughput	≥100 Mbps	≥50 Mbps
	Mobile game service	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms

8.3 Typical Home Networking Scenario 2 in a Live Network

8.3.1 Definition of the typical home networking scenario 2 in the live network

The definition of the typical home networking scenario 2 in the live network is that in a household scenario in which a household area is about 150 square meters, three WLAN hotspots are used for achieving full coverage of a house. In this scenario, a scenario with a highest service concurrency and service experience requirement is selected as an evaluation scenario, as shown in Figure 19.

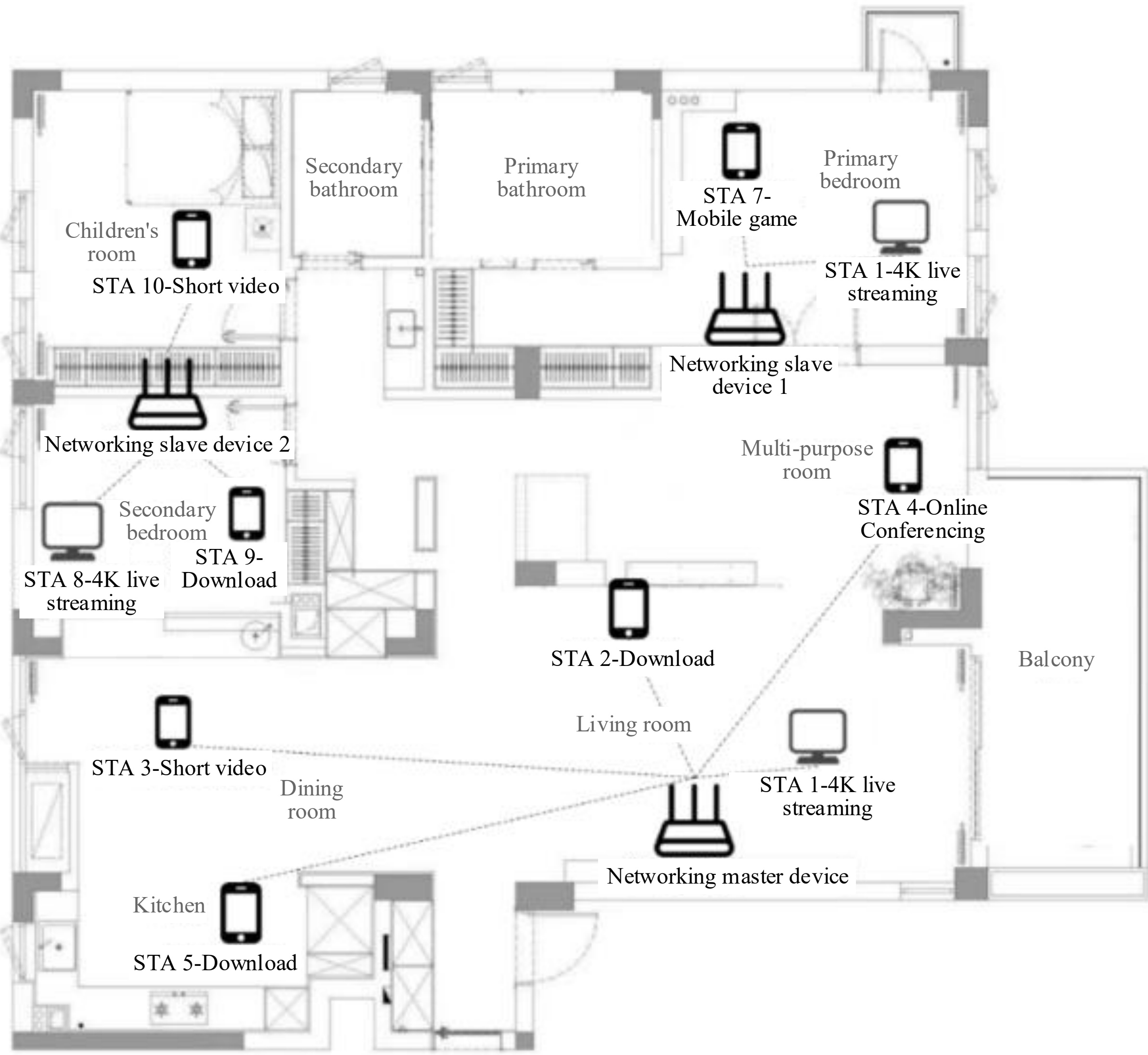

Figure 19 Diagram of WLAN service concurrency of a family of five

In home networking, a master device is mounted in a living room, one slave device is mounted in a master bedroom, and the other slave device is mounted in a secondary bedroom. A received signal strength indicator (RSSI) in 95% of an area is not less than −65 dBm by using the three hotspots. Common services in the home scenario are as follows:

1. Social production service: video and voice conference, web browsing, email, online education, and the like.
2. Entertainment service: video, game, instant messaging, download, and the like.
3. Based on types of the services carried by the device and a concurrency rate, in this document, a service bearing capability of multi-device networking in a home network in this scenario is evaluated mainly based on a service that requires a high bandwidth and a low latency. Main scenarios are described as follows:

Service of the master device:

1. Short-distance 4K video streaming service (entertainment service): A sight distance between a 4K set-top box and the master device is 1 m, and the 4K set-top box accesses an MLO frequency band of the master device, to run a 4K live streaming service.
2. Short-distance data download service without rate limitation in a mobile phone (internal home storage sharing service): A sight distance between a mobile phone of a user and the master device is 3 m, and the mobile phone of the user accesses an MLO frequency band of the master device, to run the download service without rate limitation.
3. Medium and long-distance short video service: A sight distance between a mobile phone of a user and the master device is 8 m, and the mobile phone of the user accesses an MLO frequency band of the master device, to run the short video service.
4. Long-distance online video conference service (social production service): A mobile phone or a laptop of a user is separated from the master device by a regular brick wall, and a distance between the mobile phone or the laptop of the user and the master device is about 5 m. The mobile phone or the laptop of the user accesses an MLO frequency band of the master device, to run the online video conference service.
5. Long-distance download service without rate limitation (internal home storage sharing service): A mobile phone or a laptop of a user is separated from the master device by a regular brick wall, and a distance between the mobile phone or the laptop of the user and the master device is about 5 m. The mobile phone or the laptop of the user accesses an MLO frequency band of the master device, to run the download service without rate limitation.

Service of a slave device 1:

1. Short-distance 4K video streaming service (entertainment service): A sight distance between a 4K set-top box and the slave device 1 is 1 m, and the 4K set-top box accesses an MLO frequency band of the slave device 1, to run the 4K live streaming service.
2. Short-distance mobile game service (Real-time entertainment service): A sight distance between a mobile phone of a user at a short distance and the slave device 1 is 3 m, and the mobile phone of the user accesses an MLO frequency band of the slave device 1, to run the online mobile game service.

Service of a slave device 2:

1. Short-distance 4K video streaming service (entertainment service): A sight distance between a 4K set-top box and the slave device 2 is 1 m, and the 4K set-top box accesses an MLO frequency band of the slave device 2, to run the 4K live streaming service.
2. Short-distance data download service without rate limitation in a mobile phone (home memory storage sharing service): A sight distance between a mobile phone of a user and the slave device 2 is 3 m, and the mobile phone of the user accesses an MLO frequency band of the slave device 2, to run the download service without rate limitation.
3. Short-distance short video service: A sight distance between a mobile phone of a user and the slave device 2 is 3 m, and the mobile phone of the user accesses an MLO frequency band of the slave device 2, to run the short video service.

8.3.2 Indicator Requirement for the Typical Home Networking Scenario 2 in the Live Network

Under a 1+2 home networking service model, requirements on experience of key performance indicators (KPIs) for concurrent services are as shown in Table 12:

Table 12 Requirements 2 on KPI indicators of comprehensive service experience in a typical home networking scenario

Scenario Model	Service	Parameter	Wired Networking Indicator Requirement	Wireless Networking Indicator Requirement
Master device	4K video streaming	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Download service (short distance)	Average download throughput	≥100 Mbps	≥50 Mbps
	Online video conference	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Short video service	Average round-trip time	≤60 ms	≤60 ms
		TP99 round-trip time	≤100 ms	≤100 ms
	Download service (long distance)	Average download throughput	≥30 Mbps	≥15 Mbps
Slave device 1	4K video streaming	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Mobile game service	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
Slave device 2	4K video streaming	Packet loss ratio	≤0.1%	≤0.2%
		Average one-way delay	≤50 ms	≤50 ms
		TP99 one-way delay	≤100 ms	≤100 ms
	Download service	Average download throughput	≥100 Mbps	≥50 Mbps
	Short video service	Average round-trip time	≤60 ms	≤60 ms
		TP99 round-trip time	≤100 ms	≤100 ms

8.4 Typical Home Networking Scenario 3 in a Live Network

8.4.1 Definition of the Typical Home Networking Scenario 3 in the Live Network

A typical multi-protocol hybrid access home scenario is defined as a scenario with multi-AP networking and multi-user access in a medium-sized 120 m^2 household. Two WLAN hotspots are used for achieving full coverage of the house. In this scenario, a scenario with a largest quantity of concurrent user services is selected as a test evaluation scenario. Refer to Figure 20.

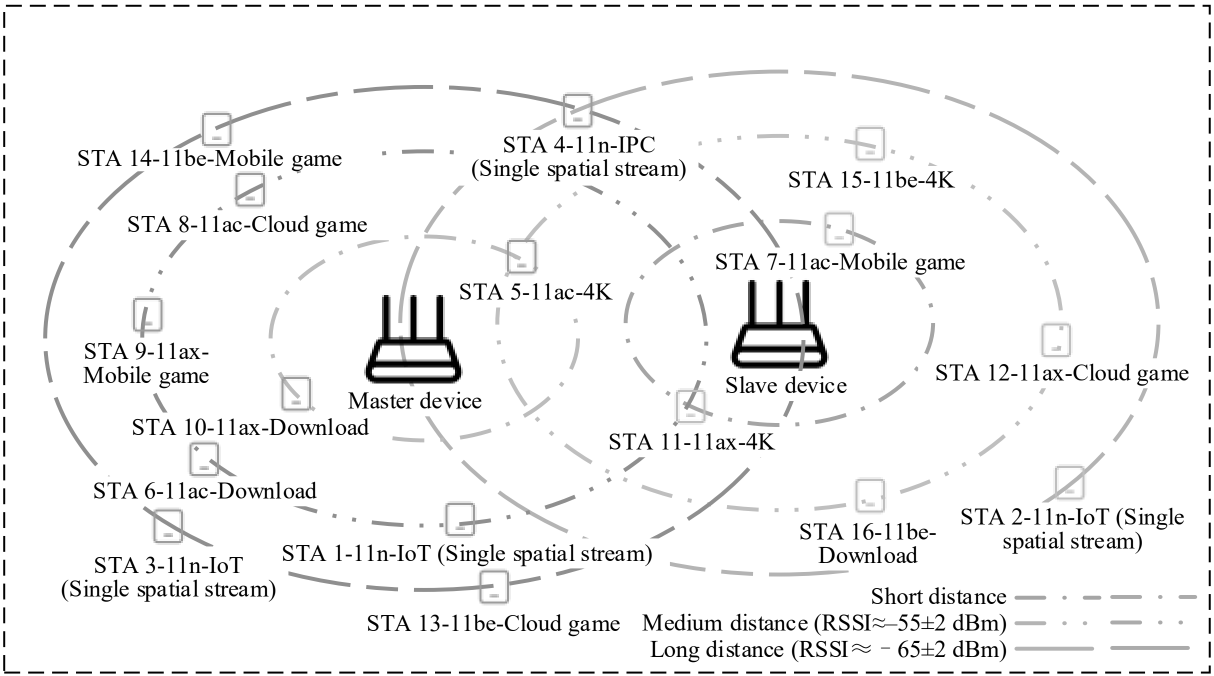

Figure 20 Experience in a multi-protocol-type hybrid access service concurrency scenario

1. External interference model:

In the environment, each AP includes two interference sources. For details about an interference source requirement, refer to the T/WAA 018-2025 Test Method for Home Scenario WLAN Device Networking Performance and Experience (Based on 802.11be).

2. STA model:

16 concurrent users are used, and five types of services such as IoT, mobile game, 4K video, cloud game, and download are included. Four STAs all use the IEEE 802.11n protocol, each use a single spatial stream, simulate three IoT devices and one camera device, and all operate at a 20 MHz channel bandwidth. Four STAs all use IEEE 802.11ac endpoints, respectively simulate one mobile game service, one 4K video service, one cloud game service, and one download service, and all operate at an 80 MHz channel bandwidth. Four STAs all use IEEE 802.11ax endpoints, respectively simulate one mobile game service (supporting a 160 MHz channel bandwidth), one 4K video service (supporting up to the 80 MHz channel bandwidth), one cloud game service (supporting the 160 MHz channel bandwidth), and one download service (supporting the 80 MHz channel bandwidth). Four STAs all use IEEE 802.11be endpoints, respectively simulate one mobile game service, one 4K video service, one cloud game service, and one download service, all operate at the 160 MHz channel bandwidth, and enable MLO functions.

3. Connection scheme:

Networking devices are visible to each other, and signal strength on a 5 GHz frequency band between the networking devices is −60 dBm±2 dBm. A STA 1/4/5/11 is visible to both a master device and a slave device, and other STAs are visible only to the master device or the slave device.

4. Service model:

    a) 4K ultra-high definition video on demand: Three STAs are deployed, a UDP service flow is used, a payload is 1472 bytes, and an AC_VI priority is set. A STA 5 is deployed at a short distance to a networking master device (where signal strength between the STA 5 and the networking master device is −30 dBm±2 dBm), the STA 5 and a networking slave device are visible to each other (where signal strength between the STA 5 and the networking slave device is −55 dBm±2 dBm), and the STA 5 operates in an 11ac mode. A STA 11 is deployed at a short distance to the networking slave device (where signal strength between the STA 11 and the networking slave device is −30 dBm±2 dBm), the STA 11 and the networking master device are visible to each other (where signal strength between the STA 11 and the networking master device is −55 dBm±2 dBm), and the STA 11 operates in an 11ax mode. A STA 15 is deployed at a medium distance to the networking slave device (where signal strength between the STA 15 and the networking slave device is −55 dBm±2 dBm), the STA 15 and the networking master device are invisible to each other, and the STA 15 operates in an 11be mode. Specific deployment positions are shown in Figure 20.

    b) Download service: Three STAs are deployed, a UDP service flow is used, a payload is 1472 bytes, and an AC_BE priority is set. A STA 6 is deployed at a medium distance to the networking master device (where signal strength on a 5 GHz frequency band between the STA 6 and the networking master device is about −55 dBm±2 dBm), the STA 6 and the networking slave device are invisible to each other, the STA 6 operates in the 11ac mode, and download traffic is 30 Mbps. A STA 10 is deployed at a short distance to the networking master device (where signal strength between the STA 10 and the networking master device is −30 dBm±2 dBm), the STA 10 and the networking slave device are invisible to each other, the STA 10 operates in the 11ax mode, and download traffic is 50 Mbps. A STA 16 is deployed at a medium distance to the networking slave device (where signal strength on the 5 GHz frequency band between the STA 16 and the networking slave device is about −55 dBm±2 dBm), the STA 16 and the networking master device are invisible to each other, the STA 16 operates in the 11be mode, and when wired networking is used between the master device and the slave device, download traffic is 50 Mbps; or when wireless networking is used between the master device and the slave device, download traffic is 25 Mbps. Specific deployment positions are shown in Figure 20.

    c) Cloud game service: Three STAs are deployed, a UDP service flow is used, and an AC_VI priority queue is used. A STA 8 is deployed at a medium distance to the networking master device (where signal strength on the 5 GHz frequency band between the STA 8 and the networking master device is about −55 dBm±2 dBm), the STA 8 and the networking slave device are invisible to each other, and the STA 8 operates in the 11ac mode. A STA 12 is deployed at a medium distance to the networking slave device (where signal strength on the 5 GHz frequency band between the STA 12 and the networking slave device is about −55 dBm±2 dBm), the STA 12 and the networking master device are invisible to each other, and the STA 12 operates in the 11ax mode. A STA 13 is deployed at a long distance to the networking master device (where signal strength on the 5 GHz frequency band between the STA 13 and the networking master device is about –65 dBm±2 dBm), the STA 13 and the networking slave device are invisible to each other, and the STA 13 operates in the 11be mode. An analog mixed packet mode is used.

d) Mobile game service: Three STAs are deployed, a UDP service flow is used, and an AC_VO priority queue is used. A STA 7 is deployed at a short distance to the networking slave device (where signal strength between the STA 7 and the networking slave device is −30 dBm±2 dBm), the STA 7 and the networking master device are invisible to each other, and the STA 7 operates in the 11ac mode. A STA 9 is deployed at a medium distance to the networking master device (where signal strength on the 5 GHz frequency band between the STA 9 and the networking master device is about –55 dBm±2 dBm), the STA 9 and the networking slave device are invisible to each other, and the STA 9 operates in the 11ax mode. A STA 14 is deployed at a long distance to the networking master device (where signal strength on the 5 GHz frequency band between the STA 14 and the networking master device is about –65 dBm±2 dBm), the STA 14 and the networking slave device are invisible to each other, and the STA 14 operates in the 11be mode. An analog mixed packet mode is used.

e) IoT device (non-IPC): Three STAs are deployed, a UDP service flow is used, a payload is 512 bytes, all UDP service flows are single spatial streams, and the three STAs operate at 2.4 GHz. Traffic of five packets is sent per second, and traffic is 20.44 Kbps. A STA 1 is deployed at a medium distance to the networking master device (where signal strength on a 2.4 GHz frequency band between the STA 1 and the networking master device is about –55 dBm±2 dBm), the STA 1 and the networking slave device are invisible to each other, and the STA 1 operates in an 11n mode. A STA 2 is deployed at a long distance to the networking slave device (where signal strength on the 2.4 GHz frequency band between the STA 2 and the networking slave device is about −65 dBm±2 dBm), the STA 2 and the networking master device are invisible to each other, and the STA 2 operates in the 11n mode. A STA 3 is deployed at a long distance to the networking master device (where signal strength on the 2.4 GHz frequency band between the STA 3 and the networking master device is about –65 dBm±2 dBm), the STA 3 and the networking slave device are invisible to each other, and the STA 3 operates in the 11n mode.

f) IoT device (IPC): One STA is deployed, a UDP service flow is used, a payload is 1472 bytes, the STA operates in the 2.4 GHz frequency band, and service traffic is 2 Mbps. A STA 4 is deployed at a long distance to the networking master device (where signal strength on the 2.4 GHz frequency band between the STA 4 and the networking master device is about –65 dBm±2 dBm), and the STA 4 and the networking slave device are visible to each other (where signal strength on the 2.4 GHz frequency band between the STA 4 and the networking slave device is about –65 dBm±2 dBm).

8.4.2 Indicator Requirement for the Typical Home Networking Scenario 3 in the Live Network

Requirements on experience of KPIs for multi-protocol concurrent services are as follows:

Table 13 Experience in a multi-protocol-type hybrid access service concurrency scenario

Protocol	**Service Scenario**	**Maximum Average Latency**	**TP99 Latency**	**Maximum Packet Loss Ratio**
IEEE 802.11be	4K video	8 ms	40 ms	0.1%
	Download	15 ms	50 ms	0.1%
	Cloud game/VR	8 ms	40 ms	0.1%
	Mobile game	8 ms	40 ms	0.1%
IEEE 802.11ax	4K video	10 ms	50 ms	0.1%
	Download	15 ms	60 ms	0.1%
	Cloud game/VR	10 ms	50 ms	0.1%
	Mobile game	10 ms	50 ms	0.1%
IEEE 802.11ac	4K video	20 ms	80 ms	0.1%
	Download	30 ms	100 ms	0.1%
	Cloud game/VR	20 ms	80 ms	0.1%
	Mobile game	20 ms	80 ms	0.1%
IEEE 802.11n	IoT (non-IPC)	30 ms	100 ms	0.1%
	IoT (IPC)	30 ms	100 ms	0.1%

Appendix A (Normative): Test and Certification Scope Requirement

For a scope of test and certification performed based on this requirement, refer to Table A.1.

Table A.1 Test and certification scope

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
7.1 Bandwidth	Bandwidth requirements when a single user accesses a master/slave device without interference	Master device-5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		Slave device-5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		Master device-MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		Slave device-MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		Master device-MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
		Slave device-MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
	Performance requirements on a concurrent throughput when a single STA is	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
	connected to each of multiple APs	MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
	Performance requirements on throughputs for multiple users at long and short distances	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
	Performance requirement on a concurrent throughput when a single STA is connected to each of multiple APs with interference	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
7.2 Latency	UDP concurrency latency in a networking scenario in	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
	which multiple users access multiple devices	MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
	TCP concurrency latency in a scenario in which multiple users access networking devices	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
	UDP concurrency latency in a networking interference scenario in which multiple users access multiple devices	5 GHz frequency band-160 MHz channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth	Not required	Mandatory
7.3 Roaming	Requirements on roaming switching latency indicators	Master-slave roaming-supporting the IEEE 802.11K/V protocol	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		Slave-slave roaming-supporting the IEEE 802.11K/V protocol	Mandatory	Mandatory
		Master-slave roaming-not supporting the IEEE 802.11K/V protocol	Optional	Optional
		Slave-slave roaming-not supporting the IEEE 802.11K/V protocol	Optional	Optional
	Requirements on roaming switching UDP throughput performance indicators	Master-slave roaming-supporting the IEEE 802.11K/V protocol-average throughput performance	Mandatory	Mandatory
		Master-slave roaming-supporting the IEEE 802.11K/V protocol-minimum throughput performance	Mandatory	Mandatory
		Slave-slave roaming-supporting the IEEE 802.11K/V protocol-average throughput performance	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		Slave-slave roaming-supporting the IEEE 802.11K/V protocol-minimum throughput performance	Mandatory	Mandatory
		Master-slave roaming-not supporting the IEEE 802.11K/V protocol-average throughput performance	Optional	Optional
		Master-slave roaming-not supporting the IEEE 802.11K/V protocol-minimum throughput performance	Optional	Optional
		Slave-slave roaming-not supporting the IEEE 802.11K/V protocol-average throughput performance	Optional	Optional
		Slave-slave roaming-not supporting the IEEE 802.11K/V protocol-minimum throughput performance	Optional	Optional

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
7.4 Connection	Requirements on connection performance indicators	5 GHz frequency band-160 MHz channel bandwidth-16 (8+8) concurrent users-total throughput	Mandatory	Mandatory
		5 GHz frequency band-160 MHz channel bandwidth-16 (8+8) concurrent users-minimum throughput	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth-16 (8+8) concurrent users-total throughput	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth-16 (8+8) concurrent users-minimum throughput	Mandatory	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth-16 (8+8) concurrent users-total throughput	Not required	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth-16 (8+8) concurrent users-minimum throughput	Not required	Mandatory
		5 GHz frequency band-160 MHz channel bandwidth-32 (16+16) concurrent users-total throughput	Mandatory	Mandatory
		5 GHz frequency band-160 MHz channel bandwidth-32 (16+16) concurrent users-minimum throughput	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth-32 (16+16) concurrent users-total throughput	Mandatory	Mandatory
		MLO frequency band-(20 MHz+160 MHz) channel bandwidth-32 (16+16) concurrent users-minimum throughput	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth-32 (16+16) concurrent users-total throughput	Not required	Mandatory
		MLO frequency band-(160 MHz+80 MHz) channel bandwidth-32 (16+16) concurrent users-minimum throughput	Not required	Mandatory
7.5 Intelligent O&M	Service recovery in an abnormal scenario	Scenario in which a slave device is powered off in home networking	Mandatory	Mandatory
		Scenario in which the slave device is disconnected in the home networking	Optional[1]	Optional[1]
7.6 Security	Service security requirement	Anti-brute force cracking	Mandatory	Mandatory
		Anti-unauthorized access of a neighboring user	Mandatory	Mandatory
		Anti-protocol packet attack	Mandatory	Mandatory
		Anti-man-in-the-middle attack	Mandatory	Mandatory

[1]For a wired networking device, a use case of the scenario in which the slave device is disconnected in the home networking is a mandatory requirement

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
8.2 Medium-sized household experience	Typical home networking scenario 1 in a live network	Master device-4K video streaming-packet loss ratio	Mandatory	Mandatory
		Master device-4K video streaming-average one-way delay	Mandatory	Mandatory
		Master device-4K video streaming-TP99 one-way delay	Mandatory	Mandatory
		Master device-download service-average throughput	Mandatory	Mandatory
		Master device-online video conference-packet loss ratio	Mandatory	Mandatory
		Master device-online video conference-average one-way delay	Mandatory	Mandatory
		Master device-online video conference-TP99 one-way delay	Mandatory	Mandatory
		Slave device-4K video streaming-packet loss ratio	Mandatory	Mandatory
		Slave device-4K video streaming-average one-way delay	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		Slave device-4K video streaming-TP99 one-way delay	Mandatory	Mandatory
		Slave device-download service-average throughput	Mandatory	Mandatory
		Slave device-mobile game service-packet loss ratio	Mandatory	Mandatory
		Slave device-mobile game service-average one-way delay	Mandatory	Mandatory
		Slave device-mobile game service-TP99 one-way delay	Mandatory	Mandatory
8.3 Large household experience	Typical home networking scenario 2 in a live network	Master device-4K video streaming-packet loss ratio	Mandatory	Mandatory
		Master device-4K video streaming-average one-way delay	Mandatory	Mandatory
		Master device-4K video streaming-TP99 one-way delay	Mandatory	Mandatory
		Master device-download service (short distance)-average throughput	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		Master device-online video conference-packet loss ratio	Mandatory	Mandatory
		Master device-online video conference-average one-way delay	Mandatory	Mandatory
		Master device-online video conference-TP99 one-way delay	Mandatory	Mandatory
		Master device-short video service-average round-trip time	Mandatory	Mandatory
		Master device-short video service-TP99 round-trip time	Mandatory	Mandatory
		Master device-download service (long distance)-average throughput	Mandatory	Mandatory
		Slave device 1-4K video streaming-packet loss ratio	Mandatory	Mandatory
		Slave device 1-4K video streaming-average one-way delay	Mandatory	Mandatory
		Slave device 1-4K video streaming-TP99 one-way delay	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		Slave device 1-mobile game service-packet loss ratio	Mandatory	Mandatory
		Slave device 1-mobile game service-average one-way delay	Mandatory	Mandatory
		Slave device 1-mobile game service-TP99 one-way delay	Mandatory	Mandatory
		Slave device 2-4K video streaming-packet loss ratio	Mandatory	Mandatory
		Slave device 2-4K video streaming-average one-way delay	Mandatory	Mandatory
		Slave device 2-4K video streaming-TP99 one-way delay	Mandatory	Mandatory
		Slave device 2-download service-average throughput	Mandatory	Mandatory
		Slave device 2-short video service-average round-trip time	Mandatory	Mandatory
		Slave device 2-short video service-TP99 round-trip time	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
8.4 Multi-protocol scenario	Typical home networking scenario 3 in a live network	IEEE 802.11be-4K video-average latency	Mandatory	Mandatory
		IEEE 802.11be-4K video-TP99 latency	Mandatory	Mandatory
		IEEE 802.11be-4K video-packet loss ratio	Mandatory	Mandatory
		IEEE802.11be-download-average latency	Mandatory	Mandatory
		IEEE 802.11be-download-TP99 latency	Mandatory	Mandatory
		IEEE 802.11be-download-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11be-cloud game-average latency	Mandatory	Mandatory
		IEEE 802.11be-cloud game-TP99 latency	Mandatory	Mandatory
		IEEE 802.11be-cloud game-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11be-mobile game-average latency	Mandatory	Mandatory
		IEEE 802.11be-mobile game-TP99 latency	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		IEEE 802.11be-mobile game-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11ax-4K video-average latency	Mandatory	Mandatory
		IEEE 802.11ax-4K video-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ax-4K video-packet loss ratio	Mandatory	Mandatory
		IEEE802.11ax-download-average latency	Mandatory	Mandatory
		IEEE 802.11ax-download-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ax-download-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11ax-cloud game-average latency	Mandatory	Mandatory
		IEEE 802.11ax-cloud game-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ax-cloud game-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11ax-mobile game-average latency	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		IEEE 802.11ax-mobile game-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ax-mobile game-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11ac-4K video-average latency	Mandatory	Mandatory
		IEEE 802.11ac-4K video-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ac-4K video-packet loss ratio	Mandatory	Mandatory
		IEEE802.11ac-download-average latency	Mandatory	Mandatory
		IEEE 802.11ac-download-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ac-download-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11ac-cloud game-average latency	Mandatory	Mandatory
		IEEE 802.11ac-cloud game-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ac-cloud game-packet loss ratio	Mandatory	Mandatory

Level-1 Indicator	Level-2 Indicator	Endpoint Configuration	Dual-band Networking Device	Triple-band Networking Device
		IEEE 802.11ac-mobile game-average latency	Mandatory	Mandatory
		IEEE 802.11ac-mobile game-TP99 latency	Mandatory	Mandatory
		IEEE 802.11ac-mobile game-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11n-IoT (non-IPC)-average latency	Mandatory	Mandatory
		IEEE 802.11n-IoT (non-IPC)-TP99 latency	Mandatory	Mandatory
		IEEE 802.11n-IoT (non-IPC)-packet loss ratio	Mandatory	Mandatory
		IEEE 802.11n-IoT (IPC)-average latency	Mandatory	Mandatory
		IEEE 802.11n-IoT (IPC)-TP99 latency	Mandatory	Mandatory
		IEEE 802.11n-IoT (IPC)-packet loss ratio	Mandatory	Mandatory

Appendix B (Informative): Reference Values of Signal Attenuation Caused by Common Obstacles

Table B.1 lists the reference values of the common obstacles.

Table B.1 Reference values of signal attenuation caused by common obstacles

Typical Obstacle	Thickness (mm)	2.4 GHz Signal Attenuation (dB)	5 GHz Signal Attenuation (dB)
Common brick wall	120	10	20
Thick brick wall	240	15	25
Concrete	240	25	30
Asbestos	8	3	4
Foam materials	8	3	4
Hollow wood	20	2	3
Common wood door	40	3	4
Solid wood door	40	10	15
Common glass	8	4	7
Thick glass	12	8	10
Armored glass	30	25	35
Load-bearing column	500	25	30
Roller shutter door	10	15	20
Steel plate	80	30	35
Elevator	80	30	35

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