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Technical Specification for WLAN Performance in Campus Office Scenarios

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Contents

Foreword

This document is proposed and managed by the Standards Committee of the World Wireless LAN Application Development Alliance.

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Campus Office Scenario: WLAN Performance Technical Specification

1 Scope

This document regulates the technical requirements for wireless local area network (WLAN) performance and experience of devices in campus office scenarios. Devices in campus office scenarios include wireless routers.

This document is applicable to the design, development, production, and test of campus wireless routers.

2 Normative References

The contents of the following documents, through normative references, constitute essential provisions of this document. For reference documents with a date, only the version corresponding to the date is applicable to this document. For undated reference documents, the latest version (including all amendments) is applicable to this document.

Wireless IEEE Std. 802.11-2020 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

3 Terms and Definitions

3.1 scene

In this document, "scene" is used to refer to systems and system operations. The system includes terminals, networks, wireless transmission environments, servers, and users. The system operation includes the interaction conditions between subsystems and components, including various factors that affect the network performance and service performance, for example, the mobile phone and the wireless router within 3 meters, and participating in video conferences.

3.2 campus

In this document, "campus" refers to enterprises or organizations, including enterprises, campuses, government agencies, and business areas. The park has an internal network to make the business operations of enterprises or institutions more efficient.

3.3 basic performance

Basic network performance evaluation parameters, such as bandwidth, access terminal connection capability, coverage, and delay, are used to evaluate network performance when network users use the network. Most of the indicators are required for devices, and some of the indicators are required for networking, such as roaming capability. Basic network performance requirements support assessment of service performance requirements.

3.4 service performance

Evaluating the performance parameters of the network for multiple services based on the applications in the network. Specify the service types, number of services, and proportion of each service type on the multi-service network. Use the typical networking model to simulate the actual application environment and evaluate the support capability of the network for application

experience. Performance requirements include the human experience of interactive systems (including but not limited to video frame freezing, voice delay, and operation delay). It also includes machine-to-machine interaction requirements (e.g., processing delays required by robot control in the industrial field).

3.5 testbed

A comprehensive system that consists of terminals, networks, and wireless propagation environments. It is used to simulate the user network environment. Environment parameters, network parameters, and terminal parameters can be modified to test the performance of devices, networks, and services.

3.6 scene model

In order to simulate the user network environment, the environment elements and equipment requirements such as terminal, network, wireless propagation, are proposed to configure the testbed and build the comprehensive performance test system. Different scenario models may be used for different basic network performance requirements and service performance requirements to reflect different actual application environments of the tested devices.

3.7 latency

End-to-end (E2E) delay that needs to be guaranteed for different service networks.

3.8 packet loss rate

Proportion of the number of packets that fail to be sent to the total number of packets.

3.9 concurrency

Proportion of the number of users who are using the network to the total number of access users in the same period.

3.10 channel bandwidth

The bandwidth settings of 20 MHz, 40 MHz, 80 MHz, and 160 MHz on different frequency bands shall comply with the spectrum division requirements of the local country.

Noted 1: 2.4 GHz refers to the 2.4 GHz frequency band that can be used by WLANs in different countries. Devices must comply with the RF technical requirements and interference avoidance requirements of the countries where they are used. (For example, People's Republic of China allows the 2.4 GHz frequency band (2400 MHz to 2483.5 MHz) to be used by WLANs.).

Noted 2: 5 GHz refers to the 5 GHz frequency band that can be used by WLANs in different countries. Devices must comply with the RF technical requirements and interference avoidance technical requirements of the corresponding country. (For example, People's Republic of China allows the WLAN to use the 5 GHz frequency bands: 5150-5350 MHz and 5725-5850 MHz)

3.11 interference

The impact of useless energy generated by one or more types of emission, radiation, sensing, or a combination thereof on the reception of a radio communications system. The impact of interference is represented by performance deterioration, misunderstanding, or information loss, which can be avoided if such interference does not exist.

4 Acronyms and Abbreviations

The following acronyms and abbreviations apply to this document:

AC: Access controller

AES: Advanced Encryption Standard
AP: Access point
CSMA/CA: Carrier sense multiple access with collision avoidance
CCMP: Counter Mode with CBC-MAC Protocol
DoS: Denial of Service
EAP: Extensible Authentication Protocol
ESSID: Extended Service Set Identifier
FTP: File Transfer Protocol
GI: Guard Interval
IFFT: Inverse fast Fourier transformation
IP: Internet Protocol
KPI: Key performance indicator
KQI: Key quality indicator
MAC: Media Access Control
MU-MIMO: Multi-user Multiple-input Multiple-output
NSS: Number of Spatial Streams
OWD: One-way delay
OWE: Opportunistic Wireless Encryption
OPEN-SYS: Open System
PEAP: Protected Extensible Authentication Protocol
PSK: Pre-shared Key
RTT: Round trip time
RSSI: Received Signal Strength Indication
STA: Station
SAE: Simultaneous Authentication of Equals
SN: Sequence Number
SSID: Service Set Identifier
TCP: Transmission Control Protocol
TP99: Top 99 percentile
TKIP: Temporary Key Integrity Protocol
UDP: User Datagram Protocol
WAPI: WLAN Authentication and Privacy Infrastructure
WEP: Wired Equivalent Privacy
WLAN: Wireless local area network
WPA: Wi-Fi Protect Access

5 Overview of Campus Office Network Performance Requirements

5.1 Overview of Service KQIs in Campus Office Networks

Services in campus office scenarios include voice, Internet video, web browsing, upload/download, video conferencing, mobile gaming, and wireless projection. The actual usage

ratio of various services should refer to Appendix B. The following figure shows the network-related KQIs that affect user experience for the preceding services.

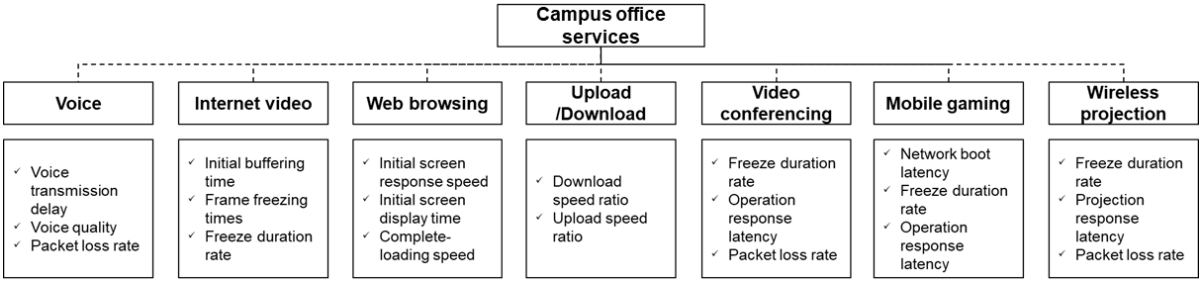

Figure 1 Service KQIs in a campus scenario

In campus office scenarios, service KQIs refer to indicators that can be perceived by users and affect user experience, such as operation duration and freeze duration rate. From the perspective of network performance, network-related factors that affect service KQIs of a service include the following:

a. Minimum bandwidth required by services
b. Maximum delay and jitter that meet service requirements
c. Maximum PLR rate that meets service requirements

5.2 Overview of Device Basic Performance Requirements on Campus Office Network

In campus office network, the network device performance is the foundation of network services. The experienced network experts can determine whether a network has the capability to carry a single service or multiple services combinations based on the performance of network devices. This document adopts bandwidth, latency, coverage, connection, roaming, and security as six common network performance indicators to ensure the WLAN service experience. These six indicators are also the basic requirements for devices, and serve as a reference for experts to evaluate the device's services carrying capability. Please refer to Figure 2 for details.

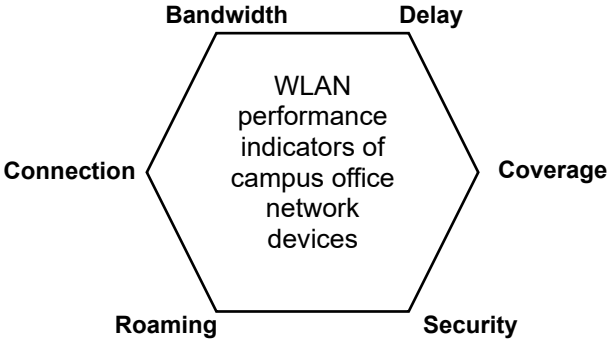

Figure 2 Basic performance indicators of campus office network

5.3 Overview of Typical Service Performance Requirements on Campus Office Networks

Network users may not know which technologies are used to provide network services and how to provide services for the network. This document specifies typical service application scenarios. By constructing a typical campus office service scenario model, the bandwidth, delay, delay jitter, and packet loss rate of a wireless router in multi-service integrated usage are evaluated.

6 Basic Performance Requirements for Campus Office Network Devices

6.1 Bandwidth Indicator

6.1.1 Indicator and Scenario Definition

6.1.1.1 The bandwidth indicator

The bandwidth indicator refers to the maximum performance that can be achieved for a single user on the WLAN. In campus office scenarios, bandwidth directly affects the experience of bandwidth-intensive services, such as speed test, data download, Internet video, and video conferencing.

In a single-device scenario, the bandwidth indicator is used to measure the maximum throughput of the WLAN interfaces. The following scenarios are involved:

6.1.1.2 Scenario 1: Interference-free single-band single-user

In ideal conditions (without interference), a STA accesses a radio (2.4 GHz or 5 GHz) of an AP at a short distance to obtain the maximum throughput on a single frequency band (The scenario model is shown in Figure 3).

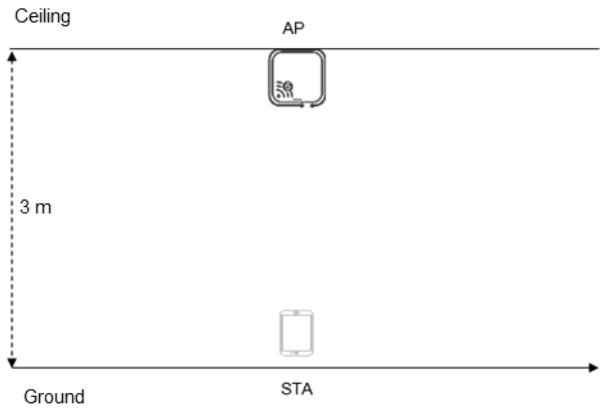

Figure 3 Maximum performance for a single STA on a single band

This scenario is used to measure the TCP service bearing capability of the AP operating in ideal air interface conditions. To test the maximum TCP bearing capability, the following air interface conditions shall be met:

- There are no interference sources on the same frequency band, including Wi-Fi interference sources (such as other gateways or routers) and non-Wi-Fi interference sources (such as Bluetooth, cordless phones, and microwave ovens).

- There are no obstacles between the STA and AP. The AP is ceiling-mounted at a height of 3 meters, and the STA is located below the AP.
- The STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The number of access STAs on the AP is 1.
- The packet length of TCP service flows is 1500 bytes.

6.1.1.3 Scenario 2: Interference-free multi-band two-user concurrency

In ideal conditions (without interference), two STAs concurrently access radios of an AP to obtain the maximum multi-band concurrent throughput.

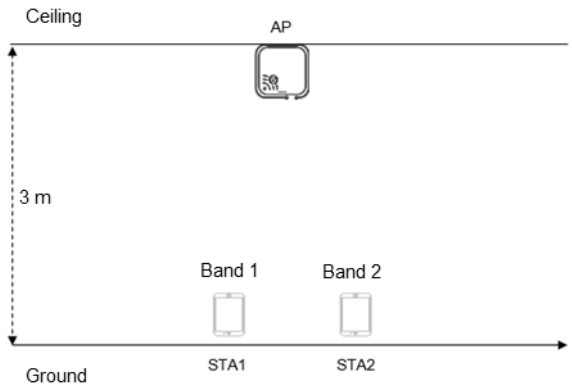

Figure 4 Performance for STAs on Multi-band

This scenario is used to measure the TCP service bearing capability upon multi-band concurrency (The scenario model is shown in Figure 4). The AP in this scenario supports concurrency on the 2.4 GHz and 5 GHz frequency bands. To test the maximum TCP bearing capability in multi-band concurrency scenarios, the following air interface conditions shall be met:

- There are no interference sources on the same frequency band, including Wi-Fi interference sources (such as other gateways or routers) and non-Wi-Fi interference sources (such as Bluetooth, cordless phones, and microwave ovens).
- There are no obstacles between the STAs and AP. The AP is ceiling-mounted at a height of 3 meters, and the STAs are located within a range of 1 m below the AP.
- Each STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The number of STAs is the same as the number of radios supported by the AP. E.g., For dual-band AP, the AP connects to one STA on each band.
- The packet length of TCP service flows is 1500 bytes.

6.1.1.4 Scenario 3: Interference-free single-band MU-MIMO

In ideal conditions (without interference), three STAs access a single radio (2.4 GHz or 5 GHz) of an AP at a short distance to obtain the maximum MU-MIMO throughput on a single frequency band.

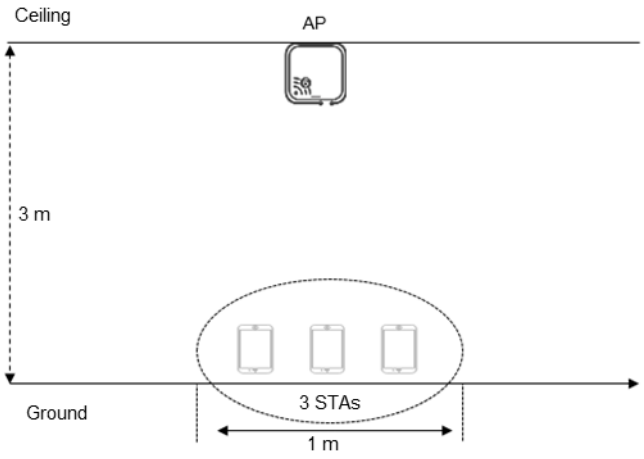

Figure 5 Maximum MU-MIMO performance in a three-STA scenario

This scenario is used to measure the TCP service bearing capability of an AP that supports the MU-MIMO concurrency capability and operates in ideal air interface conditions when three STAs connect to the AP (The scenario model is shown in Figure 5). To test the maximum TCP bearing capability, the following air interface conditions shall be met:

- There are no interference sources on the same frequency band, including Wi-Fi interference sources (such as other gateways or routers) and non-Wi-Fi interference sources (such as Bluetooth, cordless phones, and microwave ovens).
- There are no obstacles between the STAs and AP. The AP is ceiling-mounted at a height of 3 meters, and the STAs are located within a range of 1 meter below the AP.
- Each STA has two antennas (for transmit (Tx) or receive (Rx)), complies with 802.11ax, and supports MU-MIMO.
- The number of single radio access STAs is 3.
- The packet length of TCP service flows is 1500 bytes.

6.1.2 Requirements

Interference-free single-band single-user scenario (6.1.1.2), as described in Table 1.

Table 1 Maximum performance indicator for a single STA

Protocol	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	DL Throughput (Mbps)	UL Throughput (Mbps)	Mandatory or Not
802.11ax	2	2.4	20	≥180	≥180	Yes
802.11ax	2	2.4	40	≥360	≥360	No
802.11ax	2	5	40	≥360	≥360	Yes
802.11ax	2	5	80	≥720	≥720	No
802.11ax	2	5	160	≥1400	≥1400	No

Interference-free multi-band two-user concurrency scenario (6.1.1.3). Table 2 lists the maximum multi-band concurrent throughput.

Table 2 Multi-band concurrent access performance of a single device

Protocol	NSS of the STA	Frequency Band 1 (GHz)	Bandwidth 1 (MHz)	Frequency Band 2 (GHz)	Bandwidth 2 (MHz)	DL Throughput (Mbps)	UL Throughput (Mbps)	Mandatory or Not
802.11ax	2	2.4	20	5	20	≥290	≥290	Yes
802.11ax	2	2.4	20	5	40	≥430	≥430	Yes
802.11ax	2	2.4	40	5	80	≥860	≥860	No
802.11ax	2	2.4	40	5	160	≥1400	≥1400	No

Interference-free single-band MU-MIMO scenario (6.1.1.4). Table 3 lists the maximum concurrent throughput for three STAs.

Table 3 Maximum MU-MIMO performance in a three-STA scenario

Protocol	NSS of the AP	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	DL Throughput (Mbps)	Mandatory or Not
802.11ax	4	2	5	40	≥360	Yes
802.11ax	4	2	5	80	≥750	No
802.11ax	8	2	5	40	≥430	Yes
802.11ax	8	2	5	80	≥900	No

6.2 Connection Indicator

6.2.1 Indicator and Scenario Definition

6.2.1.1 Connection Indicator

Service concurrency is a characteristic of a campus office network. Connections reflect the degree of integration between the network and the physical world. The connection indicator refers to the number of connected users (concurrent access users) and the number of concurrent users (users with concurrent services).

The theoretical WLAN duty cycle model is calculated using the formula (1):

$$\text{Duty Cycle} = \frac{\sum_1^n T_{\text{nrate}}}{N_{ss} * (N_{\text{CBPS}} * R) * (1/(T_S + T_{GI}))} \quad (1)$$

- N_{SS}: indicates the number of spatial streams.
- N_{CBPS}: indicates the total number of coded bits in each OFDM symbol.
- R: indicates the coding rate.
- T_{GI}: indicates the GI length.
- T_S: indicates the symbol (IFFT) length.
- T_{nrate}: indicates the actual rate of a STA.

A larger number of concurrent users indicate a higher air interface usage, resulting in more severe contention conflicts and degrading service experience. In campus office scenarios, the

measurement scenarios of the connection indicator are defined based on the number of concurrent users.

6.2.1.2 Scenario 1: Single-band multi-user concurrent throughput

In ideal conditions (without interference), 10, 20, and 30 STAs concurrently access a radio (5 GHz) of an AP to obtain the total concurrent throughput and the minimum throughput of the single radio.

In campus office scenarios, different STAs carry services of different traffic volumes. Based on formula (1), when the actual service traffic of STAs increases, the air interface usage increases, contention conflicts intensify, and service experience deteriorates. The maximum concurrent throughput of multiple STAs is used to measure the service scheduling capability of the AP when multiple STAs concurrently run services (The scenario model is shown in Figure 6).

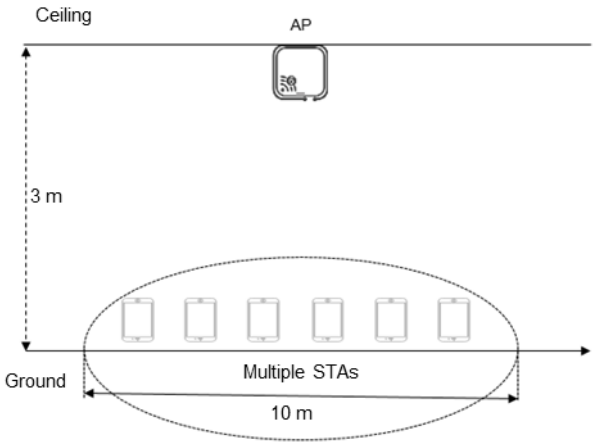

Figure 6 Single-band multi-user concurrent performance scenario

In this scenario, *N* STAs concurrently connect to one AP. The maximum number of STAs supported by the system can be obtained by measuring TCP flows without rate limiting when certain performance requirements are met. The concurrent performance of the AP and fairness of concurrent scheduling of multiple STAs can be evaluated. The key constraints and conditions in this scenario are defined as follows:

- The air interface conditions between each STA and the AP are basically the same. The AP is ceiling-mounted at a height of 3 meters, and the STAs are located within a diameter range of 10 meters below the AP.
- Each STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The packet length of TCP service flows is 1500 bytes.

6.2.2 Requirements

In campus office scenarios, the connection performance requirements are described in the following table based on the number of concurrent users.

Table 4 Single-band multi-user concurrent throughput

Protocol	NSS of the AP	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	10 Concurrent STAs Total/Minimum Throughput	20 Concurrent STAs Total/Minimum Throughput	30 Concurrent STAs Total/Minimum Throughput	Mandatory or Not
802.11ax	2	2	5	40	≥250/13	≥230/6	≥200/3	Yes
802.11ax	2	2	5	80	≥500/25	≥450/11	≥400/7	No
802.11ax	2	2	5	160	≥1000/50	≥900/23	≥800/14	No
802.11ax	4	2	5	40	≥280/14	≥250/6	≥180/3	Yes
802.11ax	4	2	5	80	≥550/28	≥500/13	≥450/8	No
802.11ax	4	2	5	160	≥1100/55	≥1000/25	≥900/16	No
802.11ax	8	2	5	40	≥300/15	≥280/7	≥250/4	Yes
802.11ax	8	2	5	80	≥600/30	≥550/15	≥500/8	No
802.11ax	8	2	5	160	≥1200/60	≥1100/30	≥1000/16	No

6.3 Coverage Indicator

6.3.1 Indicator and Scenario Definition

6.3.1.1 Coverage Indicator

In campus office scenarios, WLAN signals attenuate with the distance or wall blocking, which decreases the throughput obtained by users. User experience would be different due to different distances between STA and AP.

6.3.1.2 Scenario 1: Single user without blocking

In ideal conditions (without interference), a single STA accesses an AP within the line of sight (LOS) distance of 10 meters or 20 meters without obstacles to obtain the maximum downlink throughput (The scenario model is shown in Figure 7).

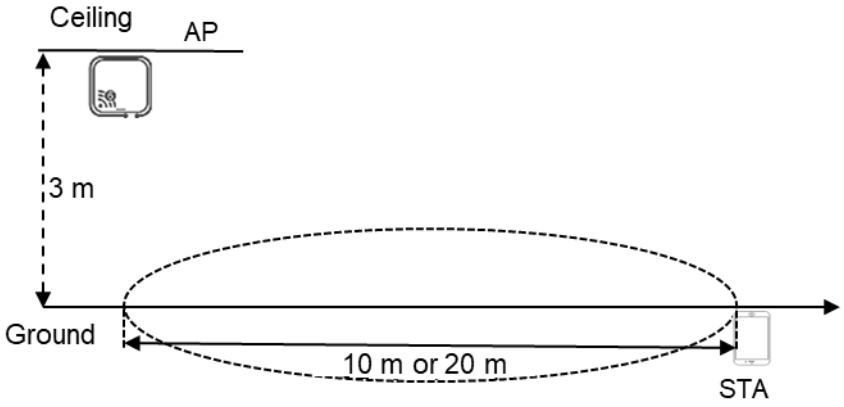

Figure 7 10 meters or 20 meters LOS performance scenario

In this scenario, to evaluate the service performance of an AP within the long-distance LOS, the scenario has the following constraints:

- There are no interference sources on the same frequency band, including Wi-Fi interference sources (such as other gateways or routers) and non-Wi-Fi interference sources (such as Bluetooth, cordless phones, and microwave ovens).
- There are no obstacles between the STA and AP. The AP is ceiling-mounted at a height of 3 meters, and the STA is located within the LOS of 10 meters or 20 meters away from the AP.
- The STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The packet length of TCP service flows is 1500 bytes.

6.3.1.3 Scenario 2: Single user with wall blocking

In ideal conditions (without interference), a single STA accesses an AP at a distance of 10 meters with a wall between them to obtain the maximum downlink throughput.

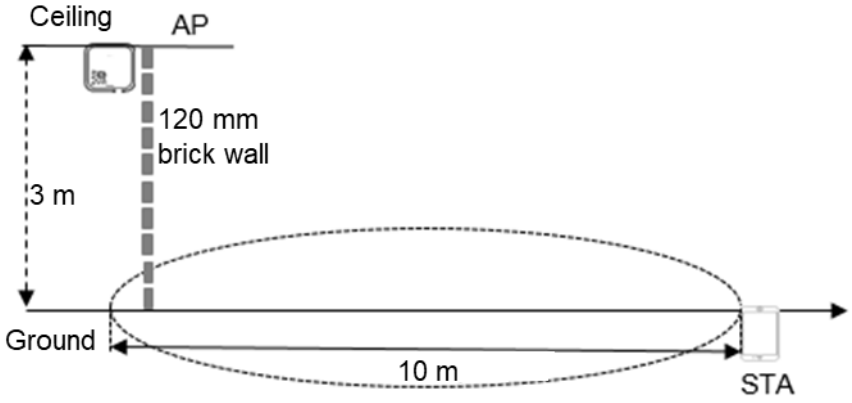

Figure 8 10 meters LOS penetrating one wall performance scenario

In a scenario where signals pass through one wall to evaluate the signal wall-penetrating capability of an AP (The scenario model is shown in Figure 8), the scenario has the following constraints:

- There are no interference sources on the same frequency band, including Wi-Fi interference sources (such as other gateways or routers) and non-Wi-Fi interference sources (such as Bluetooth, cordless phones, and microwave ovens).

- There are no obstacles between the STA and AP. The AP is ceiling-mounted at a height of 3 meters, and the STA is located at a position of 10 meters away from the AP. A brick wall of 120 millimeters thickness exists between the STA and AP, generating about 10 dB signal attenuation @ 2.4 GHz and 20 dB signal attenuation @ 5 GHz.
- The STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The packet length of TCP service flows is 1500 bytes.

6.3.2 Requirements

In campus office scenarios, the coverage performance requirements are described in the following table based on the coverage distance and direction.

Table 5 Coverage performance indicators

Protocol	NSS of the AP	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Downlink Throughput @ 10 m LOS Coverage	Downlink Throughput @ 20 m LOS Coverage	Downlink Throughput @ 10 m Distance + Penetrating One Wall	Mandatory or Not
802.11ax	2	2	2.4	20	≥90	≥80	≥30	Yes
802.11ax	2	2	2.4	40	≥180	≥150	≥50	No
802.11ax	2	2	5	40	≥180	≥150	≥50	Yes
802.11ax	2	2	5	80	≥350	≥300	≥100	No
802.11ax	2	2	5	160	≥700	≥600	≥200	No
802.11ax	4	2	2.4	20	≥120	≥100	≥40	Yes
802.11ax	4	2	2.4	40	≥230	≥200	≥80	No
802.11ax	4	2	5	40	≥230	≥200	≥80	Yes
802.11ax	4	2	5	80	≥450	≥400	≥150	No
802.11ax	4	2	5	160	≥900	≥800	≥300	No
802.11ax	8	2	5	20	≥130	≥120	≥50	Yes
802.11ax	8	2	5	40	≥250	≥230	≥100	Yes
802.11ax	8	2	5	80	≥500	≥450	≥200	No
802.11ax	8	2	5	160	≥1000	≥900	≥400	No

6.4 Roaming Indicator

6.4.1 Indicator and Scenario Definition

6.4.1.1 Roaming Indicator

In campus office scenarios, STAs need to move between different areas of the campus network without interrupting network services. In roaming scenarios, WLAN roaming indicators are used to

measure the minimum throughput and average throughput of WLAN interfaces during roaming. The scenarios are defined as follows:

6.4.1.2 Scenario 1: Single-user dual-AP roaming

In ideal conditions (without interference), a single user roams between two APs to obtain the minimum throughput and average throughput (The scenario model is shown in Figure 9).

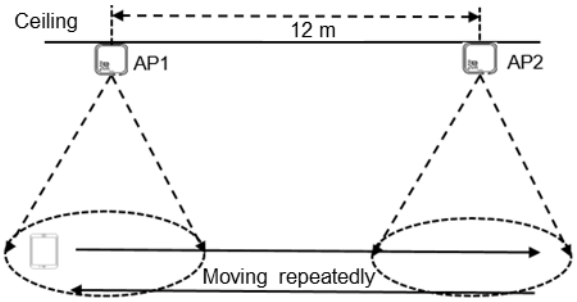

Figure 9 Roaming performance scenario

When a STA moves repeatedly between two APs, the minimum throughput and average throughput during STA roaming are measured based on TCP traffic without rate limiting. In this way, the time when the AP steers STA roaming and the STA roaming duration are evaluated. The key constraints and conditions in this scenario are defined as follows:

- There is no other interference source on the same frequency band, including Wi-Fi fidelity interference source (such as other gateway or router) and non-Wi-Fi fidelity interference source (such as Bluetooth, cordless phone, and microwave oven).
- There are no obstacles between the STA and the AP. The AP is installed on the ceiling and is 3 meters high. The transmit power of the AP is set to 15dBm. The STA repeated moves between the two APs at a speed of 0.5m/s.
- The STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The packet length of TCP service flows is 1500 bytes.

6.4.2 Requirements

In campus office scenarios, roaming performance shall meet the requirements described in the following table.

Table 6 Roaming performance indicators

Protocol	NSS of the AP	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Minimum Roaming Throughput	Average Roaming Throughput	Mandatory or Not
802.11ax	2	2	2.4	20	⩾20	⩾110	Yes
802.11ax	2	2	2.4	40	⩾35	⩾190	No
802.11ax	2	2	5	40	⩾35	⩾190	Yes
802.11ax	2	2	5	80	⩾60	⩾320	No
802.11ax	2	2	5	160	⩾100	⩾550	No
802.11ax	4	2	2.4	20	⩾25	⩾130	Yes

Protocol	NSS of the AP	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Minimum Roaming Throughput	Average Roaming Throughput	Mandatory or Not
802.11ax	4	2	2.4	40	⩾40	⩾220	No
802.11ax	4	2	5	40	⩾40	⩾220	Yes
802.11ax	4	2	5	80	⩾70	⩾360	No
802.11ax	4	2	5	160	⩾120	⩾600	No
802.11ax	8	2	5	40	⩾50	⩾230	Yes
802.11ax	8	2	5	80	⩾80	⩾400	No
802.11ax	8	2	5	160	⩾140	⩾700	No

6.5 Delay Indicator

6.5.1 Indicator and Scenario Definition

6.5.1.1 Delay indicator

The delay indicator refers to the time required for network data to be transmitted from one end to the other end. The delay indicator mainly includes the sending delay, propagation delay, queuing delay, and processing delay. Services involving real-time performance have high requirements on the WLAN delay in campus office scenarios, such as video conference, online real-time streaming media and game.

Traditional delay measurement involves two types of indicators: round trip time (RTT) and one-way delay (OWD). Different delay indicators apply for different service types. Typically, the RTT is used to evaluate the delay in TCP service interaction, and the OWD is used for evaluation in UDP services.

For common services with uplink and downlink interaction, it is recommended that the RTT is used for measurement to reflect the service experience perceived by users.

Based on different service types, data packet sizes, and air interface concurrency conditions, the delay indicators are defined as follows:

6.5.1.2 Scenario 1: Two-way delay of a single user without interference

In ideal conditions (without interference), the OWD is tested when a single STA carries the services with different traffic volumes and byte sizes (The scenario model is shown in Figure 10).

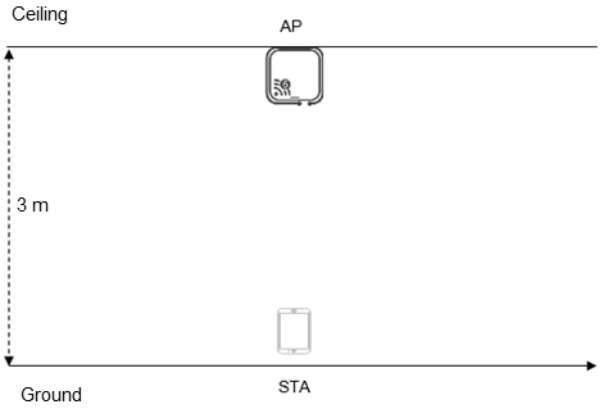

Figure 10 Single-STA delay scenario

In this scenario, to evaluate the absolute delay of the WLAN link on an AP, the following conditions shall be met:

- In campus WLAN scenarios, the delay refers to the delay from the LAN side of the AP to the STA. (During the delay test, the uplink interface of the AP shall be shielded and the downlink Ethernet interface shall be used to test the delay.)
- There is no interference source on the same frequency band, including Wi-Fi interference source (such as other gateway or router) and non-Wi-Fi interference source (such as Bluetooth, cordless phone, and microwave oven).
- There is no obstacle between the STA and AP. The AP is ceiling-mounted at a height of 3 meters, and the STA is located within a range of 1 meter below the AP.
- The STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The traffic model for delay measurement is 1500 bytes + 80% load.

6.5.1.3 Scenario 2: Non-interference multi-user concurrent two-way delay

In ideal conditions (without interference), the delay upon multi-user concurrency is tested (The scenario model is shown in Figure 11).

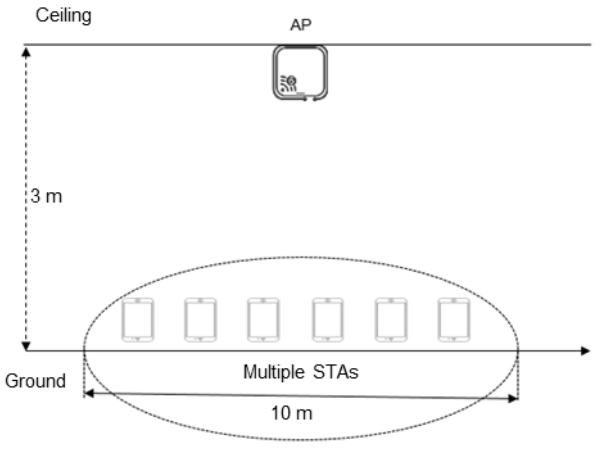

Figure 11 Multi-STA concurrent delay scenario

In this scenario, based on the CSMA/CA mechanism at the WLAN MAC layer, as the number of users increases, the delay deteriorates sharply. The following conditions shall be met:

- According to the survey on the number of STAs in the current campus office scenario, the average number of concurrent STAs is 12, and the recommended number of concurrent STAs in the multi-STA concurrent delay scenario is 15.
- In campus WLAN scenarios, the delay refers to the delay from the LAN side of the AP to the STA. (During the delay test, the uplink interface of the AP shall be shielded and the downlink Ethernet interface shall be used to test the delay.)
- There is no interference source on the same frequency band, including Wi-Fi interference source (such as other gateway or router) and non-Wi-Fi interference source (such as Bluetooth, cordless phone, and microwave oven).
- There is no obstacle between the STAs and AP. The AP is ceiling-mounted at a height of 3 meters, and the STAs are located within a range of 10 meters below the AP.
- Each STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.
- The service traffic model for delay measurement is 1500 bytes + 15 concurrent STAs + 80% loads.

6.5.1.4 Scenario 3: Two-way delay of interference multi-user concurrency

The multi-STA concurrent delay when interference exists is tested (The scenario model is shown in Figure 12).

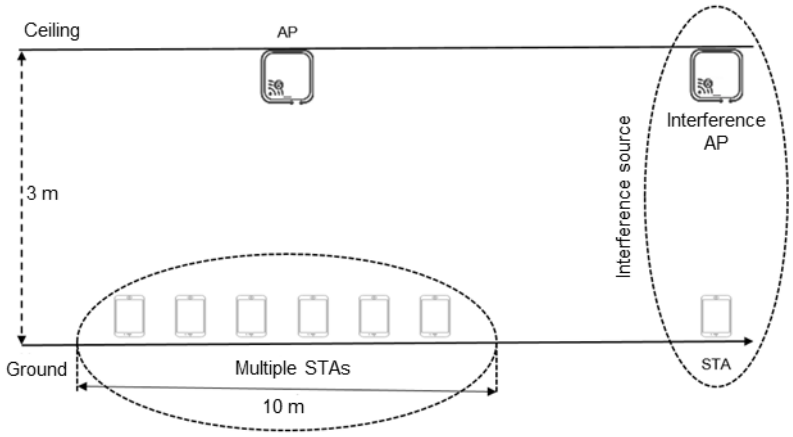

Figure 12 Multi-STA concurrent delay when interference exists

In the scenario with interference, the WLAN air interface is occupied by other interference signals, which cause packet loss and retransmission during data transmission. Retransmission increases the service delay. In this scenario, the following conditions must be met:

- According to the survey on the number of STAs in the current campus office scenario, the average number of concurrent STAs is 12, and the recommended number of concurrent STAs in the multi-STA concurrent delay scenario is 15.
- In campus WLAN scenarios, the delay refers to the delay from the LAN side of the AP to the STA. (During the delay test, the uplink interface of the AP shall be shielded and the downlink Ethernet interface shall be used to test the delay.)
- There is no interference source on the same frequency band, including Wi-Fi interference source (such as other gateway or router) and non-Wi-Fi interference source (such as Bluetooth, cordless phone, and microwave oven).
- There is no obstacle between the STAs and AP. The AP is ceiling-mounted at a height of 3 meters, and the STAs are located within a range of 10 meters below the AP.
- Each STA has two antennas (for transmit (Tx) or receive (Rx)) and complies with 802.11ax.

- The interference source is defined as follows:
  - 5 GHz: 12 Mbps @ 1500 bytes co-channel interference service flow, with the interference signal strength ranging from –65 dBm to –70 dBm
  - 2.4 GHz: 6 Mbps @ 1500 bytes co-channel interference service flow, with the interference signal strength ranging from –65 dBm to –70 dBm
- The service traffic model for delay measurement is 1500 bytes + 15 concurrent STAs + 80% loads.

6.5.2 Requirements

In an ideal environment, the delay requirements for different service traffic volumes of a single STA are described in the following table.

Table 7 Single-STA delay in non-interference scenarios

Protocol	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Byte Length (Byte)	Traffic Volume (Mbps)	Average DL Delay (ms)	Mandatory or Not
802.11ax	2	2.4	20	1500	145	≤6	Yes
802.11ax	2	2.4	40	1500	290	≤6	No
802.11ax	2	5	40	1500	290	≤6	Yes
802.11ax	2	5	80	1500	600	≤6	No
802.11ax	2	5	160	1500	1200	≤6	No

In an ideal environment, the delay requirements for different service traffic volumes of multiple STAs are described in the following table.

Table 8 Multi- STA delay in non-interference scenarios

Protocol	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Byte Length (Byte)	Traffic Volume per STA (Mbps)	Average DL Delay (ms)	TP99 Delay (ms)	Mandatory or Not
802.11ax	2	2.4	20	1500	7	≤15	≤20	Yes
802.11ax	2	5	40	1500	14	≤15	≤20	Yes
802.11ax	2	5	80	1500	30	≤15	≤20	No
802.11ax	2	5	160	1500	60	≤15	≤20	No

In an environment with interference, the delay requirements for different service traffic volumes of multiple STAs are described in the following table.

Table 9 Multi- STA delay in interference scenarios

Protocol	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Byte Length (Byte)	Traffic Volume per STA (Mbps)	Average DL Delay (ms)	TP99 Delay (ms)	Mandatory or Not
802.11ax	2	2.4	20	1500	6	≤40	≤80	Yes
802.11ax	2	5	40	1500	12	≤40	≤80	Yes

Protocol	NSS of the STA	Frequency Band (GHz)	Bandwidth (MHz)	Byte Length (Byte)	Traffic Volume per STA (Mbps)	Average DL Delay (ms)	TP99 Delay (ms)	Mandatory or Not
802.11ax	2	5	80	1500	25	⩽40	⩽80	No
802.11ax	2	5	160	1500	50	⩽40	⩽80	No

6.6 Security Indicator

6.6.1 Security Features and Network Security Protection

STAs on a WLAN are under constant attack. To defend against network attacks, the security mechanisms of network devices are classified into access security and system security. This document provides access security requirements for office network devices in the campus. The access security requirements are classified into the following types:

a. Access security

Currently, the campus office network supports the following user access authentication and data encryption modes:

1. Wired Equivalent Privacy (WEP) authentication/encryption support
2. Hybrid encryption can be configured for terminals, for example, Wi-Fi Protected Access (WPA) + 802.1X authentication/encryption.

   NOTE See reference [1] for WPA
3. WLAN Authentication and Privacy Infrastructure (WAPI) authentication/encryption

   Note: For details about WAPI, see reference [2].
4. Portal authentication (web authentication)

6.6.2 Requirements

APs shall support the security policies described in the following table.

Table 10 Security access indicator

Authentication Mode	Mandatory
WPA	Yes
WPA2	Yes
WPA3	Yes
WAPI	No
Portal	Yes

7 Campus Office Scenario Definition and Experience Requirements

7.1 Typical Campus Office Scenario 1 - Light load/Heavy load

7.1.1 Definition

Scenario 1 represents a typical use case within a campus office environment. For testing and evaluation purposes, the scenario that involves the highest number of concurrent users is selected, as shown in Figure 13.

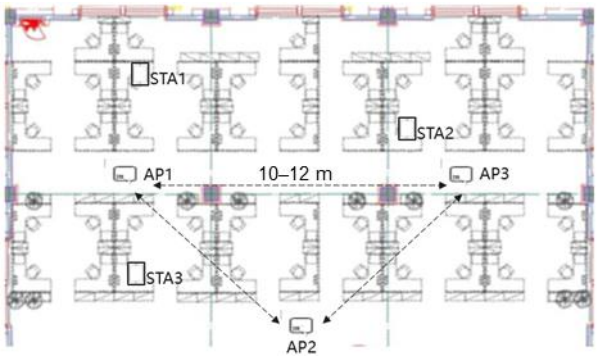

Figure 13 Campus office scenario

In this scenario, APs are ceiling-mounted at a height of 3 meters with a spacing of 10 to 12 meters. The RSSI is greater than or equal to –65 dBm across 95% of the coverage area. In the 5 GHz frequency band + 40 MHz bandwidth networking scenario, the distance between co-channel APs is 27 meters. The following are the typical service types:

- Wireless office services: video and voice conferencing, web browsing, email, etc.
- Personal non-office services: video, gaming, instant messaging, etc.

Based on the number of STAs within the coverage area of a single AP, the scenarios are classified as light-load or heavy-load scenarios:

- Light load: 40 STAs are connected to a single AP, with a concurrency rate of 30%. Typical services include simultaneous upload/download activities on 3 STAs and simultaneous video conferencing on 15 STAs.
- Heavy load: 80 STAs connected to a single AP, with a concurrency rate of 30%. Typical services include simultaneous upload/download activities on 10 STAs and simultaneous video conferencing on 30 STAs.

7.1.2 Indicator Requirements

The following table describes the KPI requirements of concurrent services in campus office scenarios.

Table 11 Campus office scenario indicators

Test Environment	Service Scenario	Indicator Item	NSS of the AP	Indicator Value
• Mode: 802.11ax • Frequency band: 5 GHz • Bandwidth: 40 MHz • NSS: 2	Light load: On a single radio, 3 STAs download files via FTP simultaneously.	Total FTP download rate (Mbps)	2	≥300
			4	≥350
			8	≥400
	Light load: On a single radio, 15 STAs participate in video conferences and 3 STAs download files via FTP simultaneously.	Average RTT (ms)	N/A	≤200
		High delay rate (proportion of RTT > 1000 ms)	N/A	≤3%
		PLR	N/A	≤3%
		Total FTP download rate (Mbps)	N/A	≥150
	Heavy load: On a single radio, 10 STAs download files via FTP simultaneously.	Total FTP download rate (Mbps)	2	≥250
			4	≥300
			8	≥350
	Heavy load: On a single radio, 30 STAs participate in video conferences and 3 STAs download files via FTP simultaneously.	Average RTT (ms)	N/A	≤200
		High latency ratio (proportion of RTT > 1000 ms)	N/A	≤3%
		PLR	N/A	≤3%
		Total FTP download rate (Mbps)	N/A	≥100
	The distance between co-channel APs is 24 meters. On a single radio of each AP, 7 STAs participate in video conferences and 3 STAs download files via FTP simultaneously.	Average RTT (ms)	N/A	≤200
		High latency ratio (proportion of RTT > 1000 ms)	N/A	≤3%
		PLR	N/A	≤3%
		Total FTP download rate (Mbps)	2	≥200
			4	≥400
			8	≥800

7.2 Typical Campus Office Scenario 2 - Mobile Office

7.2.1 Definition

Scenario 2 represents a typical use case within a campus office environment. For testing and evaluation purposes, the scenario that involves the highest number of concurrent users is selected, as shown in Figure 14.

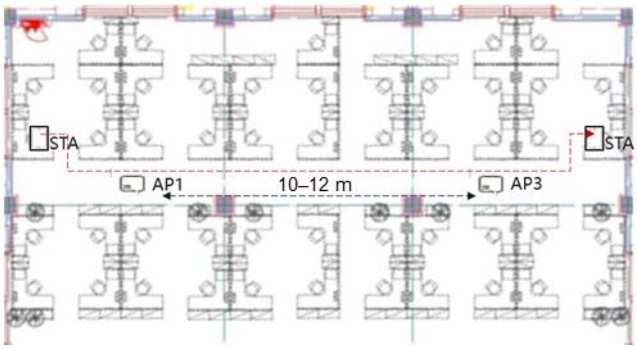

Figure 14 Mobile office scenario

In this scenario, APs are ceiling-mounted at a height of 3 meters with a spacing of 10 to 12 meters. The RSSI is greater than or equal to –65 dBm across 95% of the coverage area, with four or five users per square meters. A single AP has 40 STAs connected, with a concurrency rate of 30%. STAs move within coverage areas of different APs for mobile officing. The following are the typical service types:

- Wireless office services: video and voice conferencing, web browsing, email, etc.
- Personal non-office services: video, gaming, instant messaging, etc.

7.2.2 Indicator Requirements

The following table describes the KPI requirements of concurrent services during roaming in mobile office scenarios.

Table 12 Mobile office scenario indicators

Test Environment	Service Scenario	Indicator Item	NSS of the AP	Indicator Value
• Mode: 802.11ax • Frequency band: 5 GHz • Bandwidth: 40 MHz • NSS: 2	The distance between co-channel APs is 12 meters. On a single radio of each AP, 15 STAs participate in video conferences, and 1 STA downloads files via FTP and repeatedly moves back and forth two APs at a speed of 0.5 m/s.	Average RTT (ms)	N/A	≤200
		High latency ratio (proportion of RTT > 1000 ms)	N/A	≤3%
		PLR	N/A	≤3%
		FTP download rate (Mbps)	N/A	≥100

7.3 Typical Campus Office Scenario 3 - Video Streaming

7.3.1 Definition

Scenario 3 represents a typical use case within a campus office environment. For testing and evaluation purposes, the scenario that involves the highest number of concurrent users is selected, as shown in Figure 15.

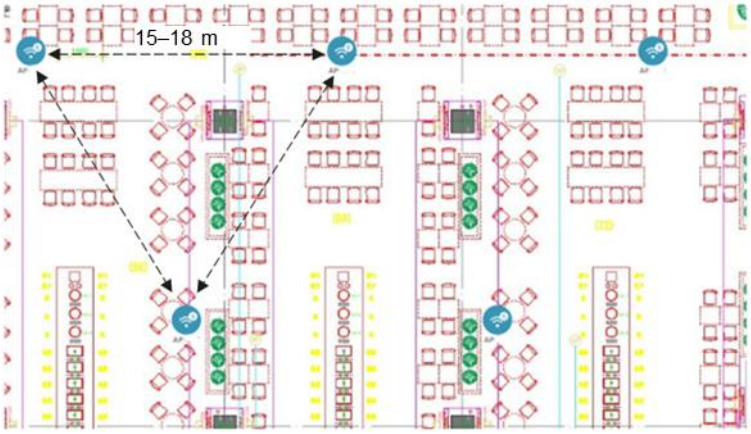

Figure 15 Canteen scenario

In this scenario, APs are ceiling-mounted with a spacing of 15 to 18 meters. The RSSI is greater than or equal to –65 dBm across 95% of the coverage area, with four or five users per square meters. A single AP has 60 STAs connected, with a concurrency rate of 50%. The typical service types include web browsing, HD video, instant messaging, etc.

7.3.2 Indicator Requirements

The following table describes the KPI requirements of concurrent services during roaming in canteen scenarios.

Table 13 Canteen scenario indicators

Test Environment	Service Scenario	Indicator Item	NSS of the AP	Indicator Value
• Mode: 802.11ax • Frequency band: 5 GHz • Bandwidth: 40 MHz • Number of spatial streams: 2	A maximum number of STAs are connected to a single radio and use video streaming services.	Average RTT (ms)	N/A	≤200
		High latency ratio (proportion of RTT > 1000 ms)	N/A	≤0.5%
		PLR	N/A	≤0.1%
		Number of connected STAs	N/A	≥30

Appendixes A

(informational)

Reference Values of Signal Attenuation Caused by Common Obstacles

Refer to Table A.1 for reference signal attenuation values of common obstacles.

Table A.1 Signal attenuation reference values for 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

Appendixes B

(informational)

Common Services and Average Bandwidth in Campus Office Scenarios

Table B.1 describes common services in campus office scenarios, service rate requirements, and service proportions.

Table B.1 Description and proportion of common services in campus office scenarios

Service Type	Single-Service Baseline Rate (Mbps)	Proportion of each business in the office						
		High-Density Office Area	Common Office Area	Conference Room	Leisure Area	Exhibition Hall	Cafe	Other Public Areas
HD video	16	10%	10%	0%	40%	0%	50%	20%
Video conferencing	4	30%	30%	0%	0%	0%	0%	0%
E-whiteboard (wireless projection)	8	10%	10%	30%	0%	10%	0%	0%
Email	16	10%	10%	30%	0%	30%	0%	10%
Web browsing	4	10%	10%	20%	20%	30%	20%	20%
Gaming	1	0%	0%	0%	10%	0%	0%	20%
Instant messaging	0.5	20%	20%	20%	20%	30%	20%	20%
VoIP	0.5	10%	10%	0%	10%	0%	10%	10%

Reference

[1]. Wi-Fi Alliance WPA3™ Specification Version 3.1

[2]. IEEE 802.11ax-2021: 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 1: Enhancements for High-Efficiency WLAN