# ETSI GS F5G-TEST 029 V1.1.1 (2025-08)

**GROUP SPECIFICATION**

# Fifth Generation Fixed Network (F5G); Test Specification for Residential FTTR Functionality and Performance

Reference

DGS/F5G-0029

Keywords

F5G, fibre, FTTR, residential network, test

***ETSI***

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00   Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

# Contents

# Intellectual Property Rights

## Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI IPR online database.

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

## Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

**DECT™**, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™**, **LTE™** and **5G™** logo are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

# Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G).

# Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

# 1 Scope

The present document specifies test methodologies and expected results for verifying the functionality and performance of ITU-T G.fin-based on-premises network. This test specification covers optical interfaces and Wi-Fi® interfaces in residential scenarios.

# 2 References

## 2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are necessary for the application of the present document.


[1] Recommendation ITU-T G.9940: "High speed fibre-based in-premises transceivers - system architecture".

[2] Recommendation ITU-T G.9941: "High speed fibre-based in-premises transceivers - physical layer specification".

[3] Recommendation ITU-T G.9942: "High speed fibre-based in-premises transceivers - Data link layer".

[4] 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".

[5] IEEE 802.11be™: "IEEE Draft 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: Enhancements for Extremely High Throughput (EHT)".


## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

Not applicable.

# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the following terms apply:

**close-range WLAN terminal:** WLAN terminal which is 1 to 2 m to the AP and the corresponding received signal strength is equal to -30 dBm ± 2

**eye diagram analyser:** tool used to evaluate the quality of digital signals, mainly measuring eye parameters and analysing the signal quality in digital communication systems

**Far-range WLAN terminal:** WLAN terminal which is 2 to 10 m to the AP and the corresponding signal strength is equal to -55 dBm ± 2

**G.fin protocol analyser:** specialized testing tool used to monitor the data flow in the G.fin system and verify whether data exchange is carried out correctly according to the G.fin protocol specifications

**network analyser:** Ethernet performance testing tool that includes packet capture and analysis, traffic generation, bandwidth testing, performance testing, and other functions

**Optical Demultiplexing Unit (ODU):** tool used to decompose the optical signal into different wavelengths

**Optical Multiplexing Unit (OMU):** tool used to compose optical signals of different wavelengths into one signal

**Optical Power Meter (OPM):** device used to measure the power of an optical signal transmitted through a fiber-optic cable

**optical spectrum analyser:** precision instrument used to measure and analyse the optical power distribution of light signals as a function of wavelength

**Variable Optical Attenuator (VOA):** device used to dynamically adjust the power level of an optical signal

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| ACK | ACKnowledge character |
| AES | Advance Encryption Standard |
| AP | Acces Point |
| BER | Bit Error Ratio |
| CM | Continuous Mode |
| CSMA/CA | Carrier Sense Multiple Access/Collision Avoidance |
| E2E | End-to-End |
| EMS | Element Management System |
| FTTR | Fibre-To-The-Room |
| GE | Gigabit Ethernet |
| GPON | Gigabit-capable Passive Optical Network |
| HDMI | High Definition Multimedia Interface |
| IPTV | Internal Protocol TeleVision |
| LAN | Local Area Network |
| MFU | Main FTTR Unit |
| MLO | Multi-Link Operation |
| MTU | Maximum Transmit Unit |
| ODU | Optical Demultiplexing Unit |
| OLT | Optical Line Termination |

| | |
|---|---|
| OMU | Optical Multiplexing Unit |
| OPM | Optical Power Meter |
| OTA | Over The Air |
| P2MP | Point to Multipoint |
| PC | Personal Computer |
| PHY | PHYsical layer |
| PLOAM | Physical Layer Operation, Administration and Management |
| PON | Passive Optical Network |
| POTS | Plain Old Telephone Service |
| PPS | Packets Per Second |
| RMS | Remote Management System |
| RSSI | Received Signal Strength Indication |
| RTT | Round-Trip Time |
| SFU | Sub FTTR Unit |
| SLA | Service Level Agreement |
| SSID | Service Set IDentification |
| STB | Set Top Box |
| TCP | Transport Control Protocol |
| TV | TeleVision |
| UDP | User Datagram Protocol |
| VOA | Variable Optical Attenuator |
| VoIP | Voice over Internet Protocol |
| VR | Virtual Reality |
| WAN | Wide Area Network |
| WLAN | Wireless Local Area Network |
| WPA2 | Wi-Fi® Protected Access 2 |

# 4 Introduction

For residential FTTR, the test cases shall focus on the requirements from the ITU-T recommendations for optical interface and the requirements for Wi-Fi® performance. Table 1 shows the test cases about the residential FTTR which include connection function, network service function, management function, security function, optical link performance and WLAN performance.

**Table 1: Test cases for FTTR**

| Category of Test Cases | Test cases |
|---|---|
| Connection function | Maximum Ethernet packet size |
| | Downstream working wavelength |
| | Upstream working wavelength |
| | Bit rates and payload rates |
| Network service function | Network service function |
| Management function | Software upgrade in MFU |
| | Software upgrade in SFU |
| | Remote reboot MFU |
| Security function | Security functions on AES encryption |
| | Security functions on SM4 encryption (optional) |
| Optical link performance | Mean signal transfer delay |
| | Maximum number of connected SFUs |
| | Maximum differential fibre length |
| | Optical link budget |
| | Optical interface parameters of downstream direction |
| | Optical interface parameters of upstream direction |
| WLAN performance | Self-recovery capability: Powering off the SFU in FTTR |
| | Self-recovery capability: Disconnection between the MFU and SFU in FTTR |
| | Handover delay between the MFU and SFU |
| | Handover delay between SFUs in FTTR |
| | Handover Throughput |
| | Concurrent throughput: close-range and far-range WLAN terminals |
| | Concurrent throughput: close-range WLAN terminals |
| | Concurrent throughput: multiple WLAN terminals in the interference scenario |

| Category of Test Cases | Test cases |
|---|---|
| | Multiple concurrent WLAN terminals in FTTR |
| | TCP service latency for concurrent multiple WLAN terminals |
| | UDP service latency for concurrent multiple WLAN terminals |
| | TCP service latency for concurrent multiple WLAN terminals in the interference scenario |
| | UDP service latency for concurrent multiple WLAN terminals in the interference scenario |
| | Joint TCP latency and throughput |

# 5 Functional Test cases

## 5.1 Common test configuration

All testing equipment, such as network analysers and eye diagram analyser, shall be configured to match the accuracy requirement according to the expected results. The network analyser shall be connected to the MFU and the SFU(s) via the 2,5 G/GE Ethernet interface. The OLT shall be connected to the MFU with the GPON/XG(S)-PON/50G PON interface. The splitter shall be selected according to the splitting ratio and attenuation requirement [1].

## 5.2 Connection function test cases

### 5.2.1 Test case #F1.1: Maximum Ethernet packet size

#### 5.2.1.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 7.3 a G.fin network shall support Ethernet jumbo frames with lengths beyond 2 000 bytes and up to 9 000 bytes. The purpose of the test case is to evaluate the performance of FTTR system on maximum ethernet packet size.

#### 5.2.1.2 Test configuration

The test shall be configured as shown in Figure 1 and shall also meet the general configuration requirements specified in clause 5.1. Additionally, the OLT shall support Ethernet jumbo frames with lengths from 2 000 bytes up to 9 000 bytes.

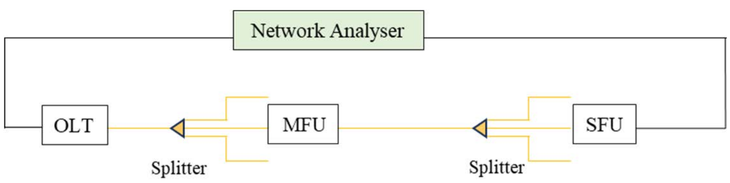


**Figure 1: The test environment of maximum Ethernet packet size**

#### 5.2.1.3 Test procedure

The test procedure shall be as following:

1) The network analyser sends 100 Ethernet frames with the frame length of 9 000 bytes to the OLT.
2) The network analyser sends 100 Ethernet frames with the frame length of 9 000 bytes to the SFU.

#### 5.2.1.4 Expected results

1) In step 1 the network analyser receives 100 Ethernet frames with a frame length of 9 000 bytes from the SFU.

2) In step 2 the network analyser receives 100 Ethernet frames with a frame length of 9 000 bytes from the OLT.

## 5.2.2 Test case #F1.2: Downstream working wavelength

### 5.2.2.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 8.5 the downstream working wavelength of the G.fin system shall be 1 490 ± 10 nm. This test case defines the methodology to verify the conformity of downstream working wavelength.

### 5.2.2.2 Test configuration

The test environment is shown in Figure 2 and shall also meet the general configuration requirements specified in clause 5.1. Additionally, the MFU continuously transmits downstream signals after power-up. The variable optical attenuator shall be used to create additional loss of the optical signal in order to make sure input power satisfy the requirement of optical spectrum analyser.

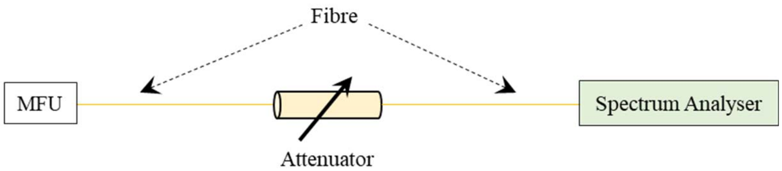


**Figure 2: The test environment of downstream working wavelength**

### 5.2.2.3 Test procedure

The test shall be conducted by the following steps:

1) After powering up the MFU, observe all its indicator lights until they reach normal status, which indicates that the MFU has successfully started.

NOTE: This makes sure that the MFU enters into normal operation.

2) Configure the optical spectrum analyser to work in the measurement wavelength range to cover the theoretic downstream wavelength of MFU. Conduct the measurement of the downstream wavelength by the spectrum analyser.

3) Record the wavelength range.

### 5.2.2.4 Expected results

If the wavelength in step 3 is within the 1 490 ± 10 nm range, the test case passes.

## 5.2.3 Test case #F1.3: Upstream working wavelength

### 5.2.3.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 8.5 the upstream working wavelength of the G.fin system shall be 1 310 ±10 nm. This test case defines the methodology to verify the conformity of the upstream working wavelength.

### 5.2.3.2 Test configuration

The test configuration is shown in Figure 3 and shall meet the general configuration requirements specified in clause 5.1. Additionally, configure the SFU to work in continuous transmission mode. If the SFU does not support continuous transmission mode, a normal connection link between MFU and SFU shall be used to let the SFU generate upstream signal.

The variable optical attenuator shall be used to create additional loss of the optical signal in order to make sure that the input power satisfies the requirement of the optical spectrum analyser.

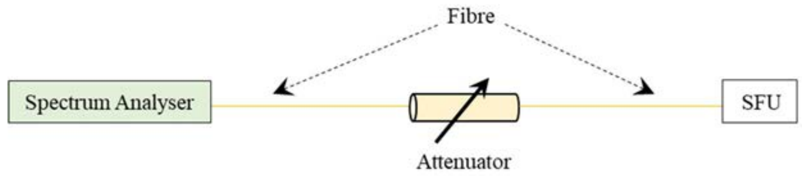


**Figure 3: The test environment of upstream working wavelength**

### 5.2.3.3 Test procedure

The test shall be conducted by the following steps:

1) Power up the SFU and wait 1 minute. Configure the SFU working in continuous transmission mode. If the continuous mode is not supported, a normal connection shall be established between a MFU and SFU.

2) Configure the optical spectrum analyser to work in the measurement wavelength range to cover the theoretic upstream wavelength of the SFU. Conduct the measurement of the upstream wavelength by the spectrum analyser.

3) Record the spectrum curve and calculate the wavelength range.

### 5.2.3.4 Expected results

If the wavelength in step 3 is within the 1 310 ± 10 nm range, the test case passes.

## 5.2.4 Test case #F1.4: Bit rates and payload rates

### 5.2.4.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 8.1 G.fin shall support the corresponding nominal line rate per each wavelength channel. This test case defines the methodology to verify the nominal line rate.

### 5.2.4.2 Test configuration

To test the MFU downstream PHY bit rates, the test shall be configured as shown in the left of Figure 4 and shall also meet the general configuration requirements specified in clause 5.1. Additionally, the Eye Diagram Analyser shall be connected to the MFU via the optical interface. The MFU continuously transmits downstream signals after power up and the Eye Diagram Analyser measures the MFU downstream optical signal to calculate the downstream PHY bit rates.

NOTE: In this test case the Eye Diagram Analyser is used to measure the PHY bit rates.

To test the SFU upstream bit rates, the test shall be configured as shown in the right of Figure 4. The Eye Diagram Analyser shall be connected to the SFU via the optical interface. The SFU is configured to work in Continuous Mode (CM) so that the SFU continuously transmits upstream signals.

After testing the PHY bit rate according to Figure 4, the environment shall be configured as per Figure 5 and shall also meet the general configuration requirements specified in clause 5.1.

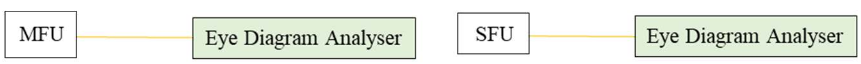


**Figure 4: The test environment of Phy bit rates**

In order to validate the maximum throughput, at least 3 GE ports or one 2,5 GE port for bidirectional traffic shall be used.

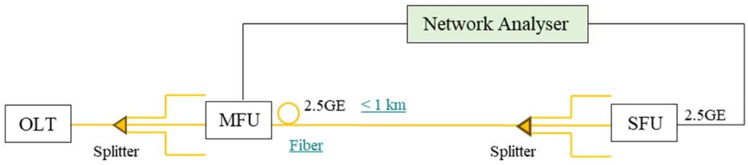


**Figure 5: The test environment of Payload rates**

#### 5.2.4.3 Test procedure

The test procedure shall be as follows:

1) Use the standard template of the Eye Diagram Analyser to measure the downstream line rate of the MFU.
2) Record the downstream line rate of the MFU.
3) Use the standard template of the Eye Diagram Analyser to measure the upstream line rate of the SFU.
4) Record the upstream line rate of the SFU.
5) Use a network analyser to simultaneously send uplink and downlink traffic to the FTTR network composed of MFU and SFU.
6) Run the throughput test for 30 seconds for each frame size:
   - 72 bytes;
   - 512 bytes; and
   - 1 518 bytes.
7) Record the throughput for upstream and downstream traffic.

#### 5.2.4.4 Expected results

1) If in step 2, the downstream line rate is within 2,5 Gbit/s ± 100 Mbps, the test case passes.
2) If in step 4, the upstream line rate is within 2,5 Gbit/s ± 100 Mbps, the test case passes.
3) If in step 7, both upstream and downstream traffic exceed 2 Gbit/s, the test case passes.

## 5.3 Network service function test cases

### 5.3.1 Test case #F2.1: Network service function

#### 5.3.1.1 Test purpose

This test case defines the methodology to verify whether the FTTR system accurately supports Internet/IPTV/VoIP services. If the device supports the aforementioned functions, such as IPTV, the corresponding tests on IPTV shall be performed; otherwise, the test record shall indicate that the system does not support this function.

#### 5.3.1.2 Test configuration

The test shall be configured as shown in Figure 6 and meet the general configuration requirements specified in clause 5.1.

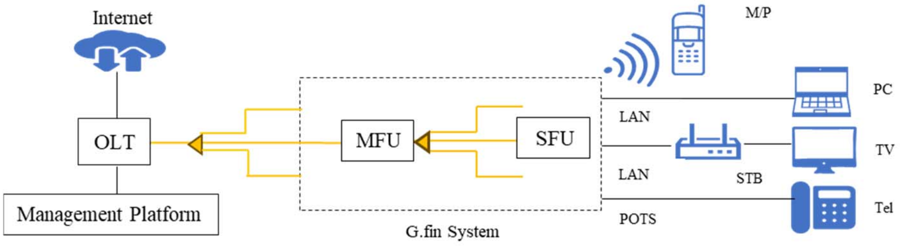


**Figure 6: The test environment of Network service function**

Additionally, the PC shall be connected to the G.fin system via the GE Ethernet interface. The Set-Top Box (STB) shall be connected to the G.fin system via the GE Ethernet interface. The Telephone shall be connected to the G.fin system via the POTS port. The TV shall be connected to the STB via the HDMI interface. The Mobile phone shall be connected to the G.fin system via WLAN.

**Pre-configuration**

MFU Configuration (Local/Remote):

1) Create an Internet WAN service.

2) Create an IPTV WAN service.

3) Create a VoIP WAN service.

SFU is configured to successfully forward the Internet/IPTV/VoIP (optional) streams.

#### 5.3.1.3 Test procedure

The test procedure shall be as follows:

1) Use a PC and a Mobile phone to access the network and check whether it can browse external websites (e.g. https://portal.etsi.org/home.aspx#/).

2) Use a Television to verify whether it can play TV programs.

3) Use a Telephone to make a call and check whether the call can be connected successfully.

#### 5.3.1.4 Expected results

1) In step 1, both, PC and Mobile phone, successfully browse external websites.

2) In step 2, the Television plays TV programs. The TV programs shall be played clearly.

3) In step 3, the Telephone call is established and maintained with clear audio.

## 5.4 Management function test cases

### 5.4.1 Test case #F3.1: Software upgrade in MFU

#### 5.4.1.1 Test purpose

This test case defines the methodology to verify whether the MFU supports software upgrade via the EMS/RMS.

#### 5.4.1.2 Test configuration

The test shall be configured as shown in Figure 7 and shall also meet the general configuration requirements specified in clause 5.1. Additionally, the MFU is successfully connected to the EMS/RMS.

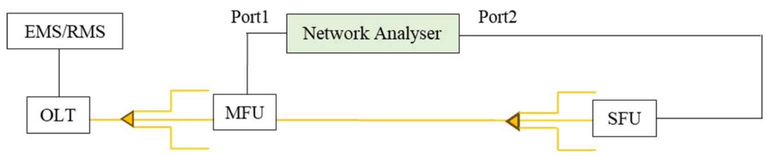


**Figure 7: The test environment of Software upgrade MFU**

#### 5.4.1.3 Test procedure

The test procedure shall be as follows:

1) Query and record the current software version number of MFU on the EMS/RMS.
2) Upgrade to a new software on the MFU by the EMS/RMS.
3) Power off and power on the MFU during the software upgrade process.
4) Use the EMS/RMS to check the software version number of the MFU.
5) Repeat step 2.
6) After completing the upgrade, use the EMS/RMS to check the software version number of the MFU.
7) Send one bidirectional traffic stream of 100 Mbps between the OLT and the SFU using network analyser.
8) Run for 1 minute and check if any packet loss occurs.

#### 5.4.1.4 Expected results

1) In step 3, the MFU is booted and connected to the EMS/RMS.
2) In step 4, the software version information of the MFU is the same as the version information recorded in step 1.
3) In step 6, the MFU software upgrade is successful, with the version number being newer than that recorded in step 1.
4) In step 8, no packet loss occurs.

NOTE: The downgrade test case is for further study.

### 5.4.2 Test case #F3.2: Software upgrade in SFU

#### 5.4.2.1 Test purpose

This test case defines the methodology to verify whether the SFU supports software upgrade via the Management Platform.

#### 5.4.2.2 Test configuration

The test shall be configured as shown in Figure 8 and meet the general configuration requirements specified in clause 5.1. Additionally, the SFU is successfully connected to the Management Platform.

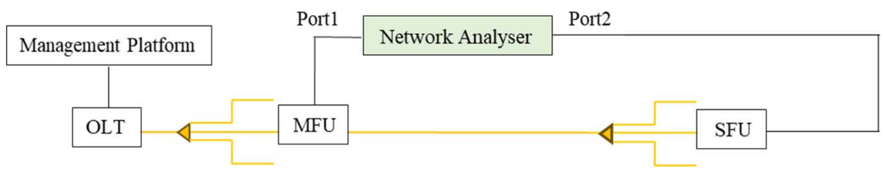


**Figure 8: The test environment of Software upgrade SFU**

#### 5.4.2.3 Test procedure

The test procedure shall be as follows:

1) Query and record the current software version number of SFU on the Management Platform.
2) Upgrade to new software on the SFU by the Management Platform.
3) Power off and power on the SFU during the software upgrade process.
4) Use the Management Platform to check the software version number of the SFU.
5) Repeat step 2.
6) After completing the upgrade, use the Management Platform to check the software version number of the SFU.
7) Send one bidirectional traffic stream of 100 Mbps between the MFU and SFU using network analyser.
8) Run for 1 minute and check if any packet loss occurs.

#### 5.4.2.4 Expected results

1) In step 3, the SFU is booted and connected to the Management Platform.
2) In step 4, the software version information of the SFU is the same as the version information recorded in step 1.
3) In step 6, the SFU software upgrade is successful, with the software version number being newer than that recorded in step 1.
4) In step 8, no packet loss occurs.

NOTE: Downgrade test case is for further study.

### 5.4.3 Test case #F3.3: Remote reboot MFU

#### 5.4.3.1 Test purpose

This test case defines the methodology to verify whether the MFU supports reboot via the Management Platform.

#### 5.4.3.2 Test configuration

The test shall be configured as shown in Figure 9 and meet the general configuration requirements specified in clause 5.1. Additionally, the MFU is successfully connected to the Management Platform.

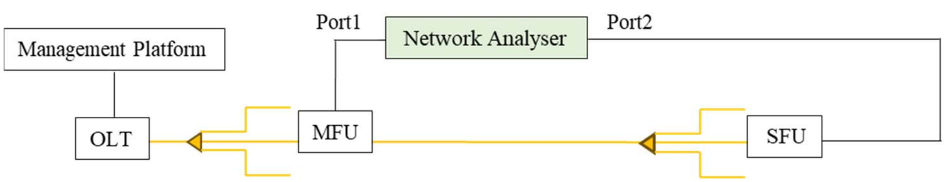


**Figure 9: The test environment of Remote reboot MFU**

#### 5.4.3.3 Test procedure

The test procedure shall be as follows:

1) Send the reboot command to the MFU via the Management Platform.
2) Wait for 60 seconds.
3) Send one bidirectional traffic stream of 100 Mbps between the MFU and SFU using network analyser.

4) Run it for 1 minute and check if any packet loss occurs.

#### 5.4.3.4 Expected results

1) In step 2, after 60 seconds, the MFU is booted and reconnected to the Management Platform. Observe all the indicator lights of MFU until they reach normal status, which indicates that the MFU has successfully started.

2) In step 4, no packet loss occurs.

## 5.5 Security function test cases

### 5.5.1 Test case #F4.1: Security functions on AES encryption

#### 5.5.1.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 9.2 and Recommendation ITU-T G.9942 [3], section 11 a G.fin network shall support AES encryption algorithms. The purpose of the test case is to verify that the FTTR system supports AES encryption.

#### 5.5.1.2 Test configuration

The test shall be configured as shown in Figure 10 and meet the general configuration requirements specified in clause 5.1. Additionally, the G.fin Protocol Analyser shall be connected to the MFU and SFU(s) via the G.fin interface.

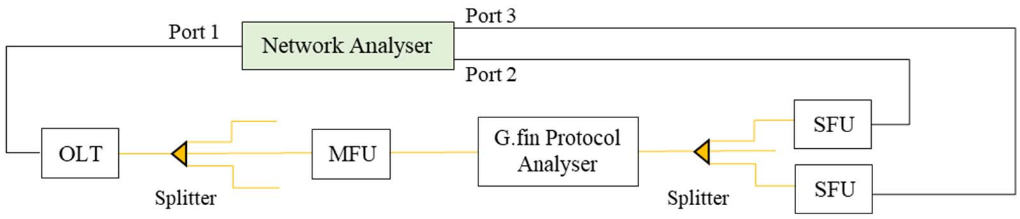


**Figure 10: The test environment of Security function**

#### 5.5.1.3 Test procedure

The test procedure shall be as the followings:

1) Configure unicast service between the OLT, MFU and SFU(s).

2) Create a 100 Mbps traffic rate stream on network analyser port 2 to port 3 respectively.

3) Create two 100 Mbps traffic rate streams on network analyser port 1.

4) Send 2 bidirectional traffic via the OLT-SFU(s) using network analyser to show the proper functioning of the OLT and SFU(s).

5) Enable AES-128 encryption function, using the G.fin protocol Analyser to capture F-PLOAM messages and check key exchange messages.

6) Confirm no packet loss during the test.

#### 5.5.1.4 Expected results

In step 5 the captured F-PLOAM messages should include at least three message types: Key_Switching_Time, Request_Key and Encryption_key message.

### 5.5.2 Test case #F4.2: Security functions on SM4 encryption (optional)

#### 5.5.2.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 9.2 and Recommendation ITU-T G.9942 [3], section 11 a G.fin network shall support SM4 encryption algorithms. The purpose of the test case is to verify that the FTTR system supports SM4 encryption.

#### 5.5.2.2 Test configuration

Refer to clause 5.5.1.2.

#### 5.5.2.3 Test procedure

The test procedure shall be as the followings:

1) Configure unicast service between OLT, MFU and SFU(s).
2) Create a 100 Mbps traffic rate stream on network analyser port 2 to port 3 respectively.
3) Create two 100 Mbps traffic rate streams on network analyser port 1.
4) Send 2 bidirectional traffic via the OLT-SFU(s) using network analyser to show the proper functioning of the OLT and SFU(s).
5) Enable SM4 encryption function, using the G.fin protocol Analyser to capture F-PLOAM messages and check key exchange messages.
6) Confirm no packet loss during the test.

#### 5.5.2.4 Expected results

Refer to clause 5.5.1.4.

# 6 Performance Test cases

## 6.1 Optical link performance test cases

### 6.1.1 Test case #P1.1: Mean signal transfer delay

#### 6.1.1.1 Test purpose

FTTR network shall support a mean signal transfer delay ≤ 1,5 ms, between the MFU and the SFU(s). The purpose of this test case is to verify that the FTTR system meets this requirement.

#### 6.1.1.2 Test configuration

The test shall be configured as shown in Figure 11 and meet the general configuration requirements specified in clause 5.1.

There are 1 MFU and 8 SFUs in the G.fin network. Meanwhile, the maximum fibre length between the MFU and SFU is 1 km.

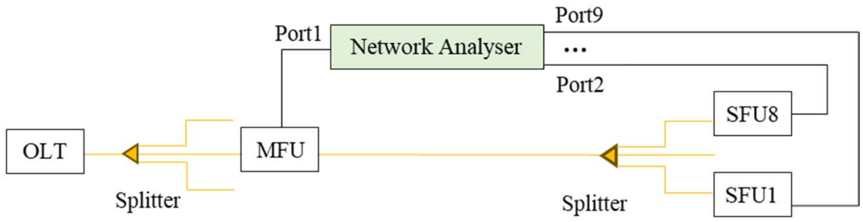


**Figure 11: The test environment of Mean signal transfer delay**

#### 6.1.1.3 Test procedure

The test procedure shall be as follows:

1) Use the network analyser to create 100 Mbps traffic stream to each SFU (SFU1-SFU8) through port 9 to port 2 respectively.

2) Create eight 100 Mbps traffic rate stream on the network analyser port 1.

3) Send 8 bidirectional traffic via the MFU-SFU(s) using the network analyser.

4) Run the latency test for 1 minute for each frame size:

   - 512 bytes;

   - 1 024 bytes; and

   - 1 518 bytes.

5) Record the mean signal transfer delay for upstream and downstream traffic.

#### 6.1.1.4 Expected results

If in step 5, both, upstream and downstream traffic delays are less than or equal to 1,5 ms, the test case passes.

### 6.1.2 Test case #P1.2: Maximum number of connected SFUs

#### 6.1.2.1 Test purpose

MFU shall support 8 SFUs for the home environment. This test case defines the methodology to verify that the FTTR system meets this requirement.

#### 6.1.2.2 Test configuration

The test shall be configured as shown in Figure 11 and meet the general configuration requirements specified in clause 5.1.

There are 1 MFU and 8 SFUs in the G.fin network. Meanwhile, the fibre length between MFU and SFU is not longer than 1 km.

#### 6.1.2.3 Test procedure

The test procedure shall be as follows:

1) Power up 8 SFUs and activate them.

2) Send 8 bidirectional traffic streams of 100 Mbps between the MFU and each SFU using the network analyser.

3) Run it for 1 minute and confirm no packet loss during the test.

#### 6.1.2.4 Expected results

1) In step 1, all 8 SFU(s) are activated successfully.

2) In step 3, no packet loss occurs.

### 6.1.3 Test case #P1.3: Maximum differential fibre length

#### 6.1.3.1 Test purpose

MFU shall support maximum differential fiber length of 100 m. This test case defines the methodology to verify the FTTR system meet this requirement.

#### 6.1.3.2 Test configuration

The test environment is shown in Figure 12 and shall meet the general configuration requirements specified in clause 5.1. There are one MFU and 8 SFUs in the G.fin network. A symmetric optical splitter (with a splitter ratio of 1:8) is used to establish the connection between the MFU and 8 SFUs. The fibre length between the MFU and the splitter shall be less than 1 m, the fibre length between the splitter and the SFU 1 to SFU 7 shall be less than 1 m while the fibre length between the splitter and the SFU 8 shall be set to 100 m [1]. The network analyser connects the MFU and SFU 2 to SFU 8 and verifies the data transmission between the MFU and all connected SFUs.

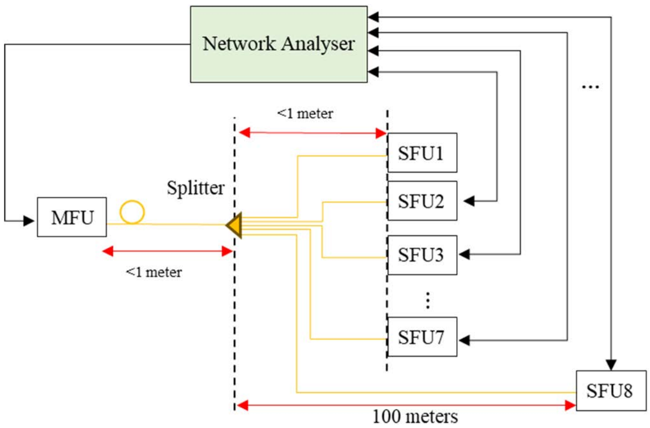


**Figure 12: The test environment of maximum differential fibre length**

#### 6.1.3.3 Test procedure

The test shall be conducted by the following steps:

1) Power-up the MFU and all SFUs, make sure that all SFUs are successfully connected to the MFU.

2) Configure the network analyser to verify the successful connection between the MFU and all SFUs except the SFU 1.

NOTE: The connection can be checked through the ping test.

3) Generate 100 Mbps symmetrical traffics of data packet between the MFU and SFU 2 to SFU 8 simultaneously for 1 minute, and count the number of packet loss of all connected ports.

4) Power down the SFU 1 and count the number of packet loss of all connected ports within 1 minute since the SFU 1 is powered down.

5) Power-up the SFU 1, and count the number of packet loss of all connected ports within 1 minute since the SFU 1 is powered up.

#### 6.1.3.4 Expected results

1) In step 1, all SFUs are successfully connected to the MFU.

2) In steps 3, 4 & 5, no packet loss occurs.

### 6.1.4 Test case #P1.4: Optical link budget

#### 6.1.4.1 Test purpose

According to Recommendation ITU-T G.9940 [1], section 8.4 a G.fin transceiver shall support the optical link budget 0 dB to 18 dB for optical link type Ra. This test case defines the methodology to verify the FTTR system meets this requirement.

#### 6.1.4.2 Test method

To test the optical link budget of 0 dB, connect the MFU and SFU directly using a short fibre with a length of less than or equal to 0,5 m. Then check whether the MFU and SFU are connected.

To test the optical link budget of 18 dB, insert a Variable Optical Attenuator (VOA) between the MFU and SFU. Adjust the VOA to achieve an optical link loss of 18 dB between the optical transmitter and receiver for both upstream and downstream. The optical link loss is calculated by subtracting the measured received power from the measured launched power. Then check whether the MFU and SFU are connected.

#### 6.1.4.3 Test configuration

**Testing 0 dB optical link budget**

To test the optical link budget of 0 dB, the test shall be configured as shown in Figure 13 and meet the general configuration requirements specified in clause 5.1. The fibre length between the MFU and SFU shall be less than or equal to 0,5 m.

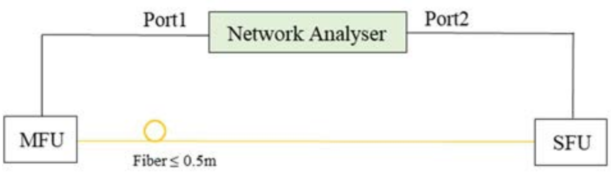


**Figure 13: The test environment of 0 dB optical link budget**

**Measuring the mean launched power of the MFU**

To measure the lean launched power of the MFU, the test setup shall be configured as shown on the left side of Figure 14. The OPM shall be connected to the MFU via the optical interface using the fibre length less than or equal to 0,5 m. Once powered on, the MFU continuously transmits downstream signals, and the OPM measures the mean launched power of the MFU. The mean launched power of the MFU should be within the range of -4 dBm to 0 dBm.

**Measuring the mean launched power of the SFU**

To measure the mean launched power of the SFU, the test shall be configured as shown on the right side of Figure 14. The OPM shall be connected to the SFU via the optical interface using the fibre length under 0,5 m. The SFU shall be configured to operate in Continuous Mode (CM), ensuring that it continuously transmits upstream signals. The mean launched power of the SFU should be within the range of -4 dBm to 0 dBm.


**Figure 14: The test environment of Mean Launched Power**

**Testing 18 dB optical link budget**

To test the optical link budget of 18 dB, the test shall be configured as shown in Figure 15. The network analyser shall be connected to the MFU and SFU via the 2,5 G/GE Ethernet interface. The VOA shall be connected to the main fibre between ODU and OMU. When measuring the downstream/upstream received optical power, the OPM shall be connected to the branch fibre/main fibre between the MFU and SFU. The fibre length between the MFU and SFU is not longer than 1 km.

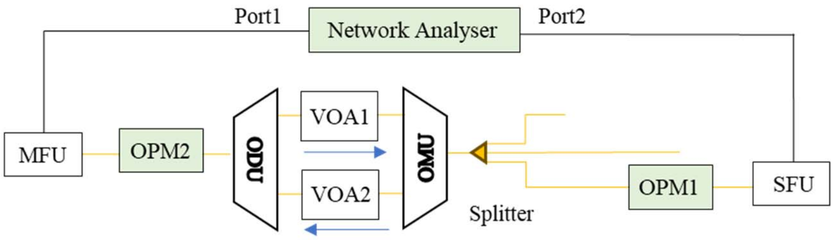


**Figure 15: The test environment of 18 dB optical link budget**

### 6.1.4.4 Test procedure

The test procedure shall be as follows:

1) Power up the MFU and SFU.
2) Verify successful activation of the SFU.
3) Send 2 bidirectional traffic streams of 100 Mbps between the MFU and SFU using the network analyser.
4) Run for 1 minute and check if any packet loss occurs.
5) Adjust the VOA1 to ensure that the value of the received optical power of the SFU from the OPM1 equals the mean launched power of the MFU minus 18 dB.
6) Verify successful activation of the SFU.
7) Send 2 bidirectional traffic streams of 100 Mbps between the MFU and SFU using the network analyser.
8) Run for 1 minute and check if any packet loss occurs.
9) Adjust the VOA2 to ensure that the value of the received optical power of the MFU from the OPM2 equals the mean launched power of the SFU minus 18 dB.
10) Verify successful activation of the SFU.
11) Send 2 bidirectional traffic streams of 100 Mbps between the MFU and SFU using the network analyser.
12) Run for 1 minute and check if any packet loss occurs.

### 6.1.4.5 Expected results

1) In step 2, the SFU is successfully activated in the 0 dB optical link budget environment.
2) In step 4, no packet loss occurs.
3) In step 6, the SFU is successfully activated in the 18 dB optical link budget environment.
4) In step 8, no packet loss occurs.
5) In step 10, the SFU is successfully activated in the 18 dB optical link budget environment.
6) In step 12, no packet loss occurs.

### 6.1.5 Test case #P1.5: Optical interface parameters of downstream direction

#### 6.1.5.1 Test purpose

According to Recommendation ITU-T G.9941 [2], section 7.4.6.2 a G.fin transceiver shall meet the requirements for the optical interface parameters in downstream direction. This test case defines the methodology to verify the optical interface parameters of downstream direction.

#### 6.1.5.2 Test configuration

1) Measuring the mean launched power of the MFU

To measure the mean launched power of the MFU, the test shall be configured as shown in Figure 16. The OPM shall be connected to the MFU via the optical interface. The fibre length between the MFU and OPM is shall be kept under 0,5 m.


**Figure 16: The test environment of Mean launched power of the MFU**

2) Measuring the extinction ratio of the MFU

To measure the extinction ratio of the MFU, the test shall be configured as shown in Figure 17. The Eye Diagram Analyser shall be connected to the MFU via the optical interface.


**Figure 17: The test environment of Extinction ratio of the MFU**

3) Measuring the side mode suppression ratio of the MFU

To measure the side mode suppression ratio of the MFU, the test shall be configured as shown in Figure 18. The optical spectrum analyser shall be connected to the MFU via the optical interface.


**Figure 18: The test environment of Side mode suppression of the MFU**

4) Measuring the minimum sensitivity at BER reference level of the SFU

To measure the minimum sensitivity of the SFU, the test shall be configured as shown in Figure 19. The network analyser shall be connected to the MFU and SFU via the 2,5 G/GE Ethernet interface. The VOA shall be connected to the main fibre between the ODU and OMU to configure the downstream optical attenuation. The OPM shall be connected to the branch fibre between the MFU and SFU. The splitter shall ensure that the MFU and SFU work well. The fibre length between the MFU and SFU is not longer than 1 km.

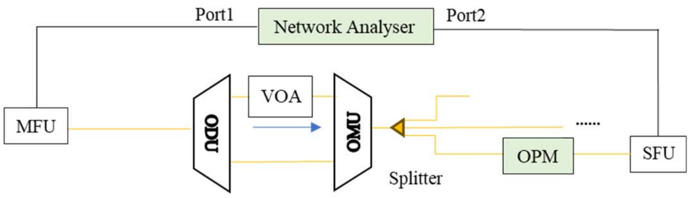


**Figure 19: The test environment of Minimum sensitivity and minimum overload**

5) Measuring the minimum overload at BER reference level of the SFU

To measure the minimum overload of the SFU, the test shall be configured as shown in Figure 19. The network analyser shall be connected to the MFU and SFU via the 2,5 G/GE Ethernet interface. The VOA shall be connected to the main fibre between the ODU and OMU to configure the downstream optical attenuation. The OPM shall be connected to the branch fibre between the MFU and SFU. The splitter shall ensure that the MFU and SFU work well. The fibre length between the MFU and SFU is not longer than 1 km.

#### 6.1.5.3 Test procedure

The test procedure shall be as follows:

1) Power up the MFU.
2) Use the OPM to measure the mean launched power of the MFU.
3) Record the value of the mean launched power of the MFU.
4) Use the Eye Diagram Analyser to measure the extinction ratio of the MFU.
5) Record the value of the extinction ratio of the MFU.
6) Use the Optical spectrum analyser to measure the side mode suppression ratio of the MFU.
7) Record the value of the side mode suppression ratio of the MFU.
8) Power up the MFU and SFU.
9) Send 2 bidirectional traffic streams of 100 Mbps between the MFU and SFU using the network analyser.
10) Adjust the VOA to gradually increase the attenuation value until the network analyser observes a BER that reaches $10^{-10}$ for the received downstream traffic stream.
11) Record the value of the received optical power of the SFU.
12) Adjust the VOA to gradually decrease the attenuation value until the network analyser observes a BER that reaches $10^{-10}$ for the received downstream traffic stream.
13) Record the value of the received optical power of the SFU.

#### 6.1.5.4 Expected results

1) In steps 3, 5, 7 the mean launched power, the minimum extinction ratio, and the minimum side mode suppression ratio of the MFU meet the requirements of Recommendation ITU-T G.9941 [2], section 7.4.6.2.
2) In steps 11, 13 the received optical power of the SFU meets the requirements of Recommendation ITU-T G.9941 [2], section 7.4.6.2.

### 6.1.6 Test case #P1.6: Optical interface parameters of upstream direction

#### 6.1.6.1 Test purpose

According to Recommendation ITU-T G.9941 [2], section 7.4.6.3 a G.fin transceiver shall meet the requirements for the optical interface parameters in upstream direction. This test case defines the methodology to verify the optical interface parameters of upstream direction.

#### 6.1.6.2 Test configuration

1) Measuring the mean launched power of the SFU

To measure the mean launched power of the SFU, the test shall be configured as shown in Figure 20. The OPM shall be connected to the SFU via the optical interface. The fibre length between the SFU and OPM is kept under 0,5 m.


**Figure 20: The test environment of Mean launched power of the SFU**

2) Measuring the extinction ratio of the SFU

To measure the extinction ratio of the SFU, the test shall be configured as shown in Figure 21. The Eye Diagram Analyser shall be connected to SFU via the optical interface.


**Figure 21: The test environment of Extinction ratio of the SFU**

3) Measuring the side mode suppression ratio of the SFU

To measure the side mode suppression ratio of the SFU, the test shall be configured as shown in Figure 22. The Optical spectrum analyser shall be connected to SFU via the optical interface.

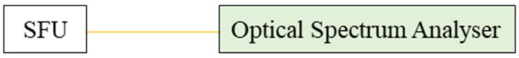


**Figure 22: Side mode suppression ratio test environment**

4) Measuring the minimum sensitivity at BER reference level of the MFU

To measure the minimum sensitivity of the MFU, the test shall be configured as shown in Figure 23. The network analyser shall be connected to the MFU and SFU via the 2,5 G/GE Ethernet interface. The VOA shall be connected to the main fibre between the ODU and OMU to configure the upstream optical attenuation. The OPM shall be connected to the main fibre between the MFU and ODU. The splitter shall ensure that the MFU and SFU work well. The fibre length between the MFU and SFU is not longer than 1 km.

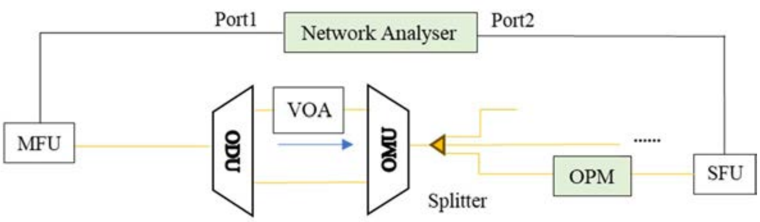


**Figure 23: The test environment of Minimum sensitivity and minimum overload**

5) Measuring the minimum overload at BER reference level of the MFU

To measure the minimum overload of the MFU, the test shall be configured as shown in Figure 23. The network analyser shall be connected to the MFU and SFU via the 2,5 G/GE Ethernet interface. The VOA shall be connected to the main fibre between the ODU and OMU to configure the upstream optical attenuation. The OPM shall be connected to the main fibre between the MFU and ODU. The splitter shall ensure that the MFU and SFU work well. The fibre length between the MFU and SFU is not longer than 1 km.

### 6.1.6.3 Test procedure

The test procedure shall be as follows:

1) Power up the SFU and configure it to operate in Continuous Mode (CM), ensuring that it is continuously transmitting upstream signals.

2) Use the OPM to measure the mean launched power of the SFU.

3) Record the value of the mean launched power of the SFU.

4) Use the Eye Diagram Analyser to measure the extinction ratio of the SFU.

5) Record the value of the extinction ratio of the SFU.

6) Use the Optical Spectrum Analyser to measure the side mode suppression ratio of the SFU.

7) Record the value of the side mode suppression ratio of the SFU.

8) Power up the MFU and SFU.

9) Send 2 bidirectional traffic streams of 100 Mbps between the MFU and SFU using the network analyser.

10) Adjust the VOA to gradually increase the attenuation value until the network analyser observes a BER that reaches $10^{-10}$ for the received upstream traffic stream.

11) Record the value of the received optical power of the MFU.

12) Adjust the VOA to gradually decrease the attenuation value until the network analyser observes a BER that reaches $10^{-10}$ for the received upstream traffic stream.

13) Record the value of the received optical power of the MFU.

#### 6.1.6.4 Expected results

1) In steps 3, 5 and 7 the mean launched power, the minimum extinction ratio, and the minimum side mode suppression ratio of the SFU meet the requirements of Recommendation ITU-T G.9941 [2], section 7.4.6.3.

2) In steps 11 and 13 the received optical power of MFU meets the requirements of Recommendation ITU-T G.9941 [2], section 7.4.6.3.

## 6.2 WLAN performance test cases

### 6.2.1 Common test configuration of WLAN performance

Unless otherwise specified, the following test configuration shall be followed:

1) The tested FTTR consists of one MFU and one or two SFU(s), which are connected through P2MP optical infrastructure.

2) When accessing FTTR WLAN, the WLAN terminal operates on the 5 GHz frequency band with default bandwidth, using WPA2/AES encryption and authentication by default.

3) The shielding box is used to isolate the MFU, SFU(s) and WLAN terminals. The initial attenuation distance is set between the MFU and SFU(s), therefore the MFU and SFU(s) are visible to each other. The RSSI detected by each other is -60 ± 2 dBm.

4) There should not be any unknown interactions or unknown interferences detected during the test. The test should be performed in a shielded environment, shielded box or a shielded room. The noise level should be below -105 dBm. The spectrum analyser should not detect any WLAN terminals on the same or neighbouring channels.

5) All tested WLAN terminals should support the Wi-Fi® bandwidth of 160 MHz.

6) To test the performance of the FTTR network, it is assumed that there are no performance bottlenecks in the access network performance.

### 6.2.2 Test case #P2.1: Self-recovery capability: Powering off the SFU in FTTR

#### 6.2.2.1 Test Purpose

To test the service recovery time when the SFU is powered off.

#### 6.2.2.2 Test Method

When the SFU is powered off in FTTR network, test the number of lost ping packets of WLAN terminal, connected to the SFU in order to measure the service recovery time.

#### 6.2.2.3 Test Configuration

The test shall be configured as shown in Figure 24.

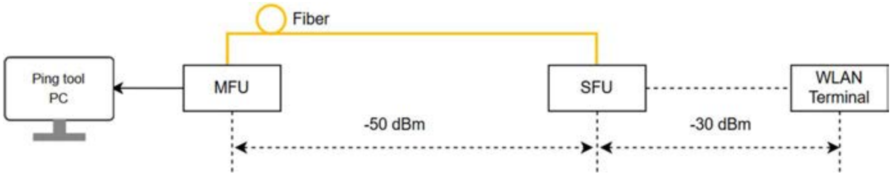


**Figure 24: The test environment of self-recovery capability**

The MFU and SFU are powered on and started normally. The WLAN channel of MFU and SFU is set to channel 36 and the bandwidth is configured to 160 MHz.

The SFU is connected to the MFU to form a FTTR network. The signal strength between the MFU and SFU is about -50 dBm.

#### 6.2.2.4 Test Procedure

1) As shown in Figure 24, connect the WLAN terminal to the 5 GHz SSID of the SFU. In the current networking topology, ensure that the WLAN terminal is connected to the 5 GHz SSID of the SFU and the WLAN terminal detects the 5 GHz SSID of the MFU.

2) Use the ping tool to continuously send ping packets at 100 ms intervals from the LAN port of the MFU to the WLAN terminal. Power off the SFU. Check the number of lost ping packets from the time when the SFU is powered off to the time when the WLAN terminal is connected to the MFU.

3) Calculate the Service Recovery Time using the following formula:

$$Service\ Recovery\ Time\ =\ Number\ of\ Packets\ Lost\ \times\ Ping\ Packet\ Sending\ interval\ of\ 100\ ms$$

4) Repeat steps 1 to 3 two times to calculate the average service recovery time when the SFU is powered off for three times.

#### 6.2.2.5 Expected Result

If in step 4 the average number of lost ping packets sent from the LAN port to the WLAN terminal is less than 10 and the average service recovery time is less than 1 second during the three power-offs, the test case passes.

### 6.2.3 Test case #P2.2: Self-recovery capability: Disconnection between the MFU and SFU in FTTR

#### 6.2.3.1 Test Purpose

To test the service recovery time after the SFU is disconnected from the MFU in FTTR network.

#### 6.2.3.2 Test Method

To test the service recovery time when the MFU or SFU is disconnected in FTTR network (such as due to fibre cut) - measure the number of lost ping packets of the WLAN terminal connected to the FTTR network.

#### 6.2.3.3 Test Configuration

The test shall be configured as shown in Figure 24:

a) The MFU and SFU are powered on and connected. The channel is set to 36 and the bandwidth is configured to 160 MHz.

b) The SFU is connected to the MFU to form a 1+1 network. The signal strength between the MFU and SFU is about -50 dBm.

#### 6.2.3.4 Test Procedure

1) Connect the WLAN terminal to the 5 GHz SSID of the SFU. In the current networking topology, ensure that the WLAN terminal is connected to the 5 GHz SSID of the SFU and that the WLAN terminal can detect the 5 GHz SSID of the MFU.

2) Use the ping tool to send ping packets continuously at 100 ms intervals from the LAN port of the MFU to the WLAN terminal. Disconnect the SFU from the MFU. Check the number of ping packets lost from the time when the SFU is disconnected to the time when the WLAN terminal is connected to the MFU.

3) Calculate the Service Recovery Time using the following formula:

$$Service\ Recovery\ Time\ =\ Number\ of\ Packets\ Lost\ \times\ Ping\ Packet\ Sending\ interval\ of\ 100\ ms$$

4) Repeat steps 1 to 3 two times to calculate the average service recovery time when the SFU is disconnected from the MFU for three times.

#### 6.2.3.5 Expected Result

If in step 4 the average number of lost ping packets sent from the LAN port to the WLAN terminal is less than 10 and the average service recovery time is less than 1 second during the three disconnections, the test case passes.

### 6.2.4 Test case #P2.3: Handover delay between the MFU and SFU

#### 6.2.4.1 Test Purpose

To test the handover delay between the MFU and SFU when a WLAN terminal connects to the FTTR network.

#### 6.2.4.2 Test Method

The handover delay refers to the service recovery time which the WLAN terminal experiences during the switch from one access point to another. The testing method for handover delay refers to the testing method for the interruption time for link protection. By transmitting packets at a constant rate during testing, the packet loss rates before and after handover are measured and used to calculate the handover delay.

#### 6.2.4.3 Test Configuration

The test shall be configured as shown in Figure 25.

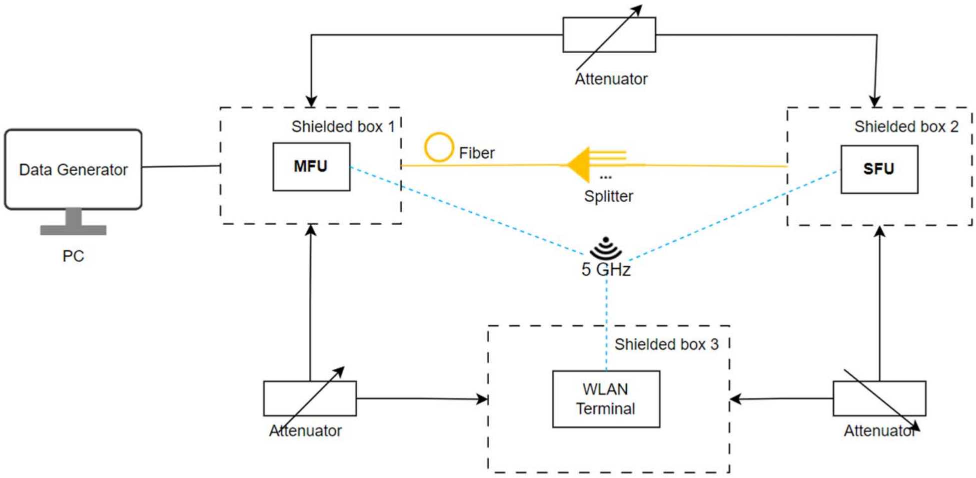


**Figure 25: The test environment of Handover delay between the MFU and SFU**

The WLAN terminal initially accesses the 5 GHz SSID of MFU. The WLAN terminal detects the RSSI of the MFU with a signal strength about -50 dBm and is initially invisible to the SFU.

### 6.2.4.4 Test Procedure

1) The WLAN terminal that is located in the shielding box 3 and accesses the 5 GHz SSID of the MFU.

2) The PC uses a data generator to send a UDP flow data of 1 000 PPS with 1 500 bytes Ethernet frame size to the WLAN terminal for 80 seconds.

3) Increase the attenuation between the shielding box 3 and the shielding box 1 at a rate of 1 dB/s from 0 dB to 80 dB while transmitting the traffic. At the same time, reduce the attenuation of shielding box 3 and shielding box 2 at a rate of 1 dB/s from 60 dB to 0 dB, so that the WLAN terminal is switched to SFU in shielding box 2.

4) Calculate the packet loss rate and the delay between each packet during the attenuation adjustment. Take the maximum value by comparing packet loss number (in 1000 PPS) and the maximum delay between each packet during the handover time. During the test, investigate the RSSI of the MFU from the WLAN terminal. Ensure that the RSSI is greater than or equal to -80 dBm and make sure that handover is completed. Otherwise, the test fails.

5) Start the data generator again and send a UDP flow of 1 000 PPS with 1 500 bytes Ethernet frame length to the WLAN terminal for 80 seconds.

6) Decrease the attenuation of shielding box 3 and shielding box 1 at a rate of 1 dB/s (from 60 dB to 0 dB). At the same time, increase the attenuation of shielding boxes 3 and 2 at a rate of 1 dB/s (from 0 dB to 80 dB) that the WLAN terminal device switches from SFU to MFU. Take the maximum value by comparing packet loss number (in 1 000 PPS) and the maximum delay between each packet during the handover time.

7) During the test, the RSSI of the SFU detected on the WLAN terminal should always be no less than -80 dBm to ensure that the handover was successfully completed. Otherwise, the test fails.

8) Repeat steps 2 to 5 for five times and record the average handover delay.

### 6.2.4.5 Expected Result

If the handover delay of the WLAN terminal between the MFU and SFU in FTTR is lower than 50 ms, in steps 4, 6 and 7, the test case passes.

### 6.2.5 Test case #P2.4: Handover delay between SFUs in FTTR

#### 6.2.5.1 Test Purpose

To test the handover delay when an WLAN terminal switches from one SFU to another.

#### 6.2.5.2 Test Method

The handover delay refers to the service recovery time when the WLAN terminal may experience during the handover process between SFUs. The testing method for handover delay refers to the testing method for handover delay between the MFU and SFU.

#### 6.2.5.3 Test Configuration

The test shall be configured as shown in Figure 26.

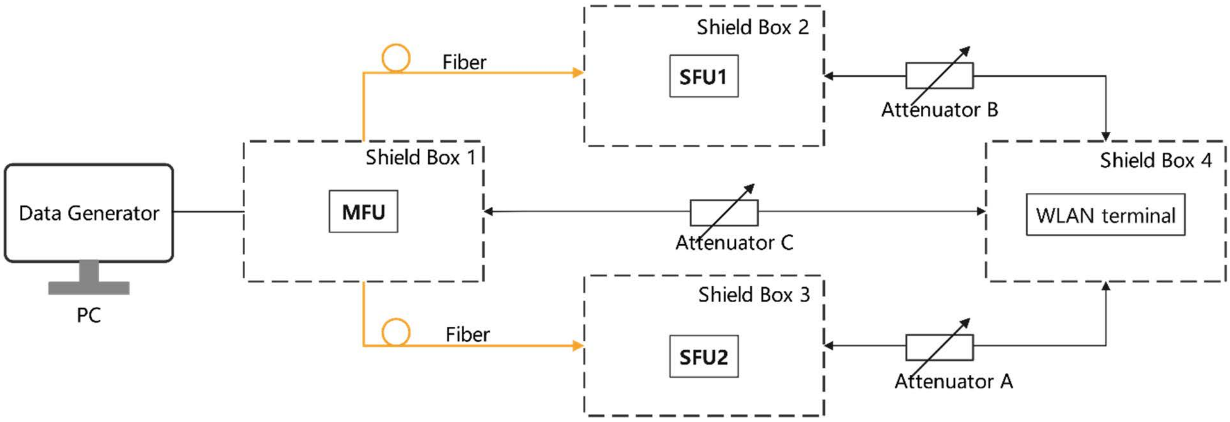


**Figure 26: The test environment of Handover delay between the SFUs**

The WLAN terminal initially accesses the 5 GHz SSID of SFU1. The RSSI from SFU1 scanned by the WLAN terminal is about -50 dBm, while the signal from SFU2 is initially invisible to the WLAN terminal.

#### 6.2.5.4 Test Procedure

1) The WLAN terminal is located in the shield box 4 and accesses the 5 GHz SSID of the SFU1.

2) The PC uses a data generator to send a UDP flow of 1 000 PPS and 1 500 bytes (Ethernet frames are 1 500 bytes) to the WLAN terminal for 80 seconds.

3) Increase the attenuation between shield box 4 and shield box 2 at a rate of 1 dB/s while transmitting traffic (0 to 80 dB). At the same time, the attenuation between shield box 4 and shield box 3 is reduced from 60 dB to 0 dB at a rate of 1 dB/s, so that the WLAN terminal is handing over to the networking of SFU2 in the shield box 3.

4) Calculate the number of packets lost/1 000 pps and the delay per packet during the attenuation adjustment process, and take the maximum one as the handover delay. During the test, the RSSI of the associated SFU detected on the WLAN terminal should always be no less than -80 dBm to ensure that the WLAN terminal has successfully switched. Otherwise, the test fails.

5) Start the data generator again and send a UDP flow of 1 000 PPS and 1 500 bytes Ethernet frame length to the WLAN terminal device from the network side for 80 seconds.

6) Decrease the attenuation between shield box 4 and shield box 2 at a rate of 1 dB/s (60 dB to 0 dB). At the same time, increase the attenuation between shield box 4 and the shield box 3 at a rate of 1 dB/s (0 to 80 dB), so that the WLAN terminal switches from SFU2 to SFU1. Similarly, calculate the number of packets lost/1 000pps and the delay per packet during the attenuation adjustment process, and take the maximum one as the handover delay. During the test, the RSSI of the associated SFU detected on the WLAN terminal should always be no less than -80 dBm to ensure that the WLAN terminal device has successfully switched. Otherwise, the test fails.

7) Repeat steps from 2 to 5 for five times and record the average handover delay.

#### 6.2.5.5 Expected Result

If the handover delay between SFUs in FTTR for the WLAN terminal is less than or equal to 50 ms, the test case passes.

### 6.2.6 Test case #P2.5: Handover Throughput

#### 6.2.6.1 Test Purpose

To test the average throughput of the WLAN terminal in FTTR network when the WLAN terminal switches between MFU and SFU.

#### 6.2.6.2 Test Method

To test the performance fluctuation in handover path by sending test traffic.

#### 6.2.6.3 Test Configuration

The test shall be configured as shown in Figure 25.

The WLAN terminal initially accesses the 5 GHz SSID of MFU. The RSSI of MFU is scanned by the WLAN terminal is about -50 dBm and the WLAN terminal signals of the SFU devices are initially invisible.

#### 6.2.6.4 Test Procedure

1) The WLAN terminal is located in the shielding box 3 and accesses the 5 GHz SSID of the MFU.

2) The PC uses a data generator to send a UDP flow of 200 Mbit/s with 1 500 byte per packet to the WLAN terminal from the LAN port of the MFU for 80 seconds.

3) Increase the attenuation of shielding box 3 and shielding box 1 at a rate of 1 dB/s from 0 dB to 80 dB. At the same time, the attenuation of shielding boxes 2 and 3 is reduced from 60 dB to 0 dB at a rate of 1 dB/s.

4) Obtain the average throughput and minimum throughput of UDP packets received by the WLAN terminal within 80 seconds during the handover.

5) Decrease the attenuation of shielding box 3 and shielding box 1 at a rate of 1 dB/s from 60 dB to 0 dB. At the same time, increase the attenuation of shielding boxes 3 and 2 at a rate of 1 dB/s from 0 dB to 80 dB.

6) Obtain the average and minimum throughput of UDP packets received by the WLAN terminal within 80 seconds during the handover.

7) Repeat steps from 2 to 6 for five times and record the average throughput of multiple handover.

#### 6.2.6.5 Expected Result

If the handover throughput in FTTR is greater than the threshold defined in Table 2 in steps 4, 6 and 7 the test case passes.

**Table 2: Expected Result for Handover Throughput**

| Handover path | Protocol | Frequency band | Channel Bandwidth (MHz) | Average throughput （Mbps) | Minimum Throughput (Mbps) |
|---|---|---|---|---|---|
| MFU -> SFU | IEEE 802.11ax [4] | 5 GHz | 160 | ≥ 170 | ≥ 70 |
| MFU -> SFU | IEEE 802.11be [5] | 5 GHz | 160 | ≥ 170 | ≥ 70 |

## 6.2.7 Test case #P2.6: Concurrent throughput: close-range and far-range WLAN terminals

### 6.2.7.1 Test Purpose

To test the concurrent throughput of FTTR when close-range and far-range WLAN terminals accesses the MFU and SFU.

### 6.2.7.2 Test Method

To test the TCP throughput, it is required to use WLAN terminals that end users are expected to use and emulate the WLAN access by actual users:

1) The distance between two WLAN terminals should be 1 meter and both devices should be on the same horizontal level.

2) WLAN terminals are connected over the air interface at a 1-meter distance from the SFU or MFU.

3) The data packet generator is located on the LAN side of the MFU or the uplink egress through a 10 G wired interface. Establish TCP test service flows with WLAN terminals. It is recommended that 10 test service flows be run between each test WLAN terminal and the data packet generator. It is recommended that the TCP window size is set to 2 Mbyte.

### 6.2.7.3 Test Configuration

The test shall be configured as shown in Figure 27:

1) The test WLAN terminal is used to access the network through MFU and SFUs.

2) The close-range WLAN terminal received signal strength is -30 dBm ± 2, and the far-range WLAN terminal received signal strength is -55 dBm ± 2.

3) The signal strength between WLAN terminal 2 and the SFU is the same as the signal strength between WLAN terminal 4 and the MFU, equal to -68 dBm ± 2 as shown in Figure 27.

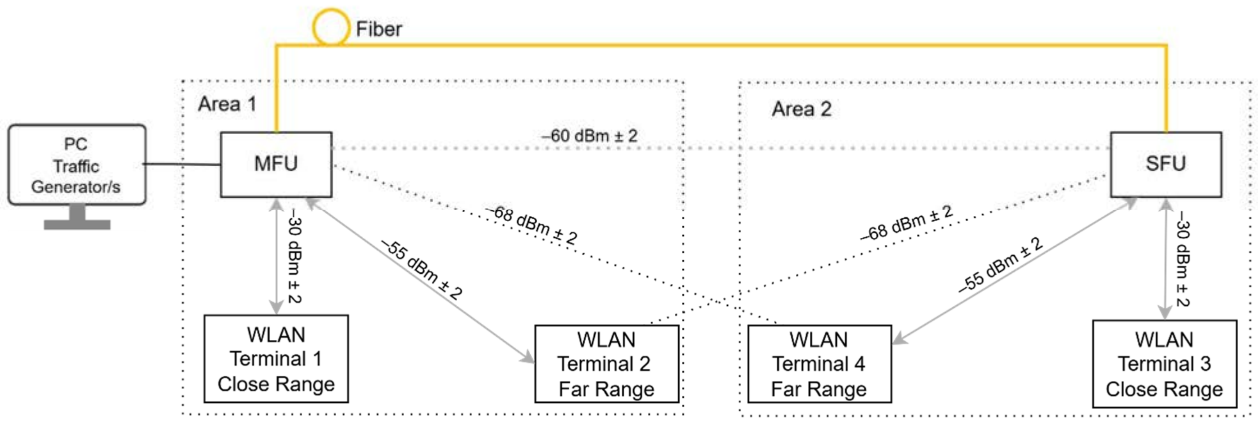


**Figure 27: The test environment of Concurrent throughput: close-range and far-range WLAN terminals**

### 6.2.7.4 Test Procedure

1) WLAN terminal 1 and WLAN terminal 2 access the FTTR network through 5 GHz WLAN interface of the MFU as close-range and far-range WLAN terminal, respectively.

2) WLAN terminal 3 and WLAN terminal 4 access the network through 5 GHz WLAN ports on the SFU as close-range and far-range WLAN terminal, respectively.

3) Connect 3 data packet generators to the LAN port of the MFU and generate downstream TCP test traffic for the access terminals of the MFU and SFU. Each data packet generator generates 10 TCP service flows for each of the 4 WLAN terminals. Therefore, each data packet generator generates 40 TCP service flows. The test is performed for 2 minutes and the downlink traffic of each WLAN terminal is recorded as Throughput 1, Throughput 2, Throughput 3 and Throughput 4.

4) Calculate the aggregated throughput using the
Throughput Aggregated = Throughput 1 + Throughput 2 + Throughput 3 + Throughput 4.

5) Calculate the minimum performance throughput using the Minimum Performance = min (Throughput 2, Throughput 4) for far-range terminals.

### 6.2.7.5 Expected Result

If in step 4 the aggregated throughput value of multiple WLAN terminals connected to the MFU and SFU is greater than the threshold defined in Table 3 the test case passes.

If in step 5 the minimum throughput of multiple WLAN terminals on FTTR network is greater than the threshold defined in Table 3 the test case passes.

**Table 3: Expected Result for Concurrent throughput - close and far-range WLAN terminals**

| Networking Topology | The number of WLAN terminals for Every MFU/SFU | WLAN configuration | Protocol | Channel Bandwidth (MHz) | Aggregated Throughput (Mbps) | Minimum Throughput (Mbps) |
|---|---|---|---|---|---|---|
| 1 MFU<br>+<br>1 SFU | 2 | 5 GHz (Nss = 2) | IEEE 802.11ax [4] | 160 | 1 200 | 80 |
| | | 5 GHz (Nss = 2) | IEEE 802.11be [5] | 160 | 1 400 | 80 |
| | | 2,4 GHz (Nss = 2)<br>5 GHz (Nss = 2) | IEEE 802.11be [5] | MLO<br>20 + 160 | 1 600 | 80 |
| | | 5,1 GHz (Nss = 2)<br>5,8 GHz (Nss = 2) | IEEE 802.11be [5] | MLO<br>80 + 160 | 2 000 | 140 |

## 6.2.8 Test case #P2.7: Concurrent throughput: close-range WLAN terminals

### 6.2.8.1 Test Purpose

To test the maximum FTTR network throughput performance using TCP when WLAN terminals access the MFU and SFUs in an FTTR network.

### 6.2.8.2 Test Method

To test the TCP throughput, it is required to use WLAN terminals that emulate the network access by actual users:

1) The distance between WLAN terminals and its associated MFU/SFU should be 1 m (equivalent to -30 dBm ± 2) and both devices should be located on the same horizontal level.

2) When using WLAN test instruments to simulate real WLAN terminals, use Over the Air (OTA) connection between the WLAN test instruments and the MFU/SFU to simulate a 1-meter line of sight for the air interface.

3) The data generator is connected on the LAN side of the MFU or on the uplink output port of the access network. When the data generator is connected to the uplink port of the access network, the data generator is connected with the uplink port 10 G fiber interface, and the data generator runs the TCP performance test service. Establish TCP test service flows with the WLAN test terminal on FTTR side. It is recommended to run 20 test service flows between each WLAN terminal and the data generator. The default MTU is 1 500 bytes, the default TCP window size is 2 MB.

### 6.2.8.3 Test Configuration

The test shall be configured as shown in Figure 28.

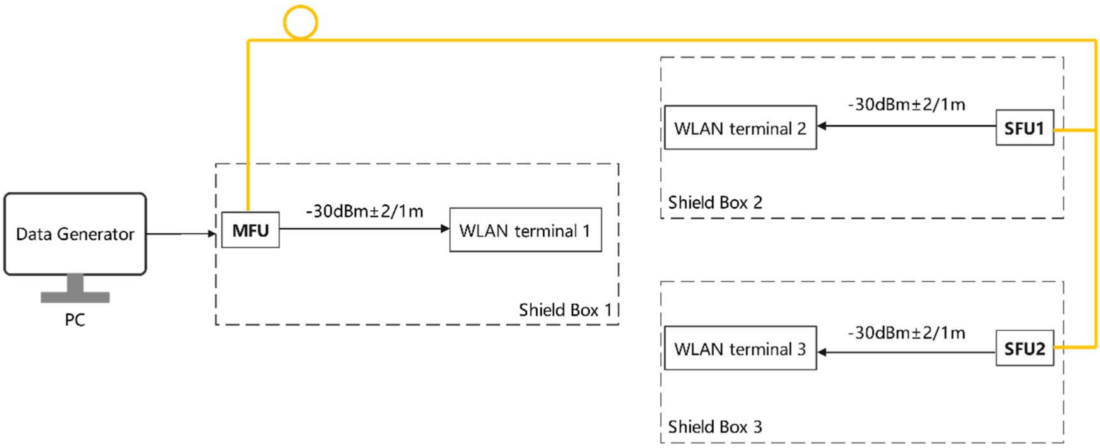


**Figure 28: The test environment of Concurrent throughput: close-range WLAN terminals**

a) The signal strength between the MFU and SFUs should meet the signal strength matrix model specified in Table 4 and Table 5, and in Figure 29 and Figure 30.

**Table 4: Radio signal strength matrix 1**

| | MFU | SFU 1 | SFU 2 |
|---|---|---|---|
| **MFU** | N/A | −60 dBm ± 2 | −60 dBm ± 2 |
| **SFU 1** | −60 dBm ± 2 | N/A | −60 dBm ± 2 |
| **SFU 2** | −60 dBm ± 2 | −60 dBm ± 2 | N/A |

Figure 29 illustrates the signal strength relationships between the MFU and two SFUs in the network signal strength matrix 1.

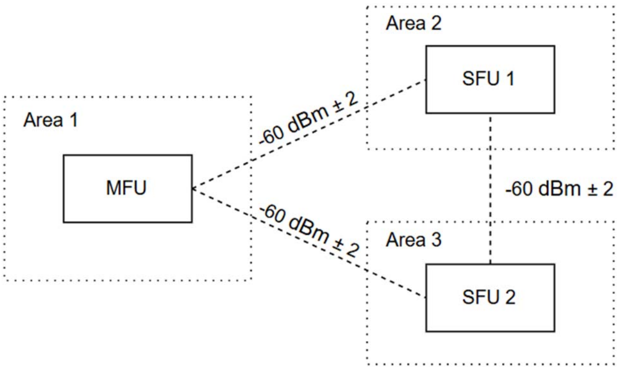


**Figure 29: Equilateral triangle wireless signal strength model**

**Table 5: Radio signal strength matrix 2**

| | MFU | SFU 1 | SFU 2 |
|---|---|---|---|
| **MFU** | N/A | −60 dBm ± 2 | −60 dBm ± 2 |
| **SFU 1** | −60 dBm ± 2 | N/A | < −90 dBm |
| **SFU 2** | −60 dBm ± 2 | < −90 dBm | N/A |

Figure 30 illustrates the signal strength relationships between the MFU and two SFUs in the radio signal strength matrix 2.

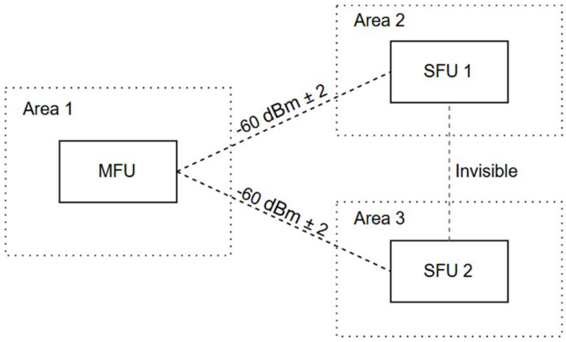


**Figure 30: Tree-shaped radio signal strength model**

### 6.2.8.4 Test Procedure

The following test should be executed 2 times using the signal strength matrix 1 for the first time and matrix 2 for the second time:

1) 3 WLAN terminals access the 5 GHz SSID of the MFU and two SFUs at the same time. The access distance is 1 m.

2) Establish 20 TCP test flows between the WLAN terminal and the data generator, and run the TCP download service continuously for 120 seconds.

3) Record the concurrent data rate of the WLAN terminals as the aggregated throughput of the FTTR network: Aggregated_Throughput.

### 6.2.8.5 Expected Result

If the throughput performance of the FTTR is greater than the threshold defined in Table 6, the test case passes.

**Table 6: Expected Result for Concurrent throughput: close-range WLAN terminals**

| Networking Topology | Number of WLAN terminals for Every MFU/SFU | WLAN Terminal configuration | Protocol | Channel Bandwidth (MHz) | Aggregated_ Throughput (Mbps) |
|---|---|---|---|---|---|
| 1 MFU<br>+<br>2 SFUs | 1 | 5 GHz (Nss = 2) | IEEE 802.11ax [4] | 160 | 2 000 |
| | | 5 GHz (Nss = 2) | IEEE 802.11be [5] | 160 | 2 400 |
| | | 2,4 GHz (Nss = 2)<br>5 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 20 + 160 | 2 700 |
| | | 5,1 GHz (Nss = 2)<br>5,8 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 80 + 160 | 3 600 |

### 6.2.9 Test case #P2.8: Concurrent throughput: multiple WLAN terminals in the interference scenario

#### 6.2.9.1 Test Purpose

To test the maximum concurrent throughput performance in FTTR network when WLAN terminals access the MFU and SFU through the WLAN in the case of external interference.

#### 6.2.9.2 Test Method

To test the TCP throughput, it is required to use a real WLAN terminal device or a WLAN test instrument that emulates the network access of real users.

1) The distance between the WLAN terminal and the connected MFU/SFU should be 1 m. Both devices should be at the same horizontal height.

2) There should not be any unknown interferences other than the specified interference sources. The test should be performed in a shielded environment, shielded box or a shielded room. The noise level should be below −105 dBm, and the spectrum analyser should not detect any WLAN terminals on the same or neighbouring channels.

3) The data generator is located at the LAN side of the MFU and is connected to the MFU through a 10 GE cable interface. Establish TCP test flows between the data generator and the WLAN terminal connected to FTTR network. It is recommended that 20 TCP test flows be run between each WLAN terminal and the data generator. It is recommended that the TCP Window Size of the data generator and the WLAN terminal be set to 2 MByte.

4) There should not be any performance bottlenecks in the data generator and the WLAN terminals.

5) The 5 GHz single-frequency interference model is defined as follows:

   - 5 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.

   - The channel and bandwidth are the same as the testing FTTR network.

6) The MLO mode (2,4 GHz + 5 GHz) interference model is defined as follows:

   - 5 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.

   - 2,4 GHz frequency band: TCP test flow 5 Mbit/s downlink and 1 Mbit/s uplink co-channel interference. The interference signal strength ranges from -60 dBm to -65 dBm.

   - The channel and the bandwidth are the same as the testing network.

7) The MLO mode (5,1 GHz + 5,8 GHz) interference model is defined as follows:

   - 5,1 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.

   - 5,8 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.

   - The channel and the bandwidth are the same as the testing FTTR network.

#### 6.2.9.3 Test Configuration

The test shall be configured as shown in Figure 31.

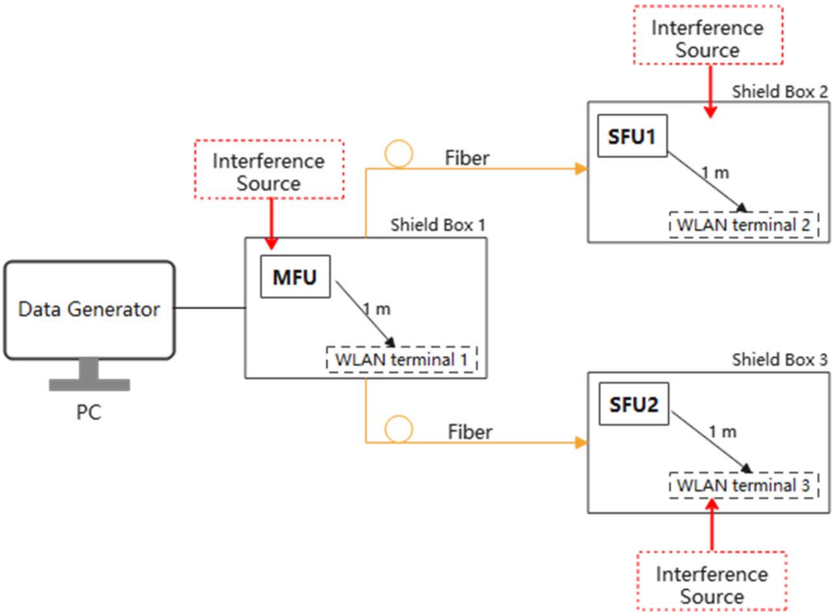


**Figure 31: The test environment of Concurrent throughput - multiple WLAN terminals in the interference scenario**

1) The signal strength between the MFU and SFU should meet the attenuation matrix model specified in Table 7.

**Table 7: Radio signal attenuation matrix**

| | MFU | SFU 1 | SFU 2 |
|---|---|---|---|
| **MFU** | N/A | -60 dBm ± 2 dBm | -60 dBm ± 2 dBm |
| **SFU 1** | -60 dBm ± 2 dBm | N/A | -60 dBm ± 2 dBm |
| **SFU 2** | -60 dBm ± 2 dBm | -60 dBm ± 2 dBm | N/A |

### 6.2.9.4 Test Procedure

1) As illustrated in Figure 31, the MFU/SFU are networked and deployed according to the radio signal attenuation matrix.

2) Enable interference source 1, 2 and 3 at the same time.

3) Connect three WLAN terminals to the 5 GHz WLAN of the MFU and two SFUs. The access distance is 1 m.

4) Establish 20 TCP test flows between each WLAN terminal and the data generator, and run the TCP parallel download service continuously for 120 seconds.

5) Record the concurrent throughput for the entire FTTR network: *Throughput_Concurrency*.

6) For the MFU/SFU that support MLO, enable the MLO mode for all the WLAN terminals and configure the concurrency for 2,4 GHz with 20 MHz and 5 GHz with 160 MHz.

7) Interference sources 1, 2, and 3 are configured based on the interference model in MLO mode.

8) Repeat steps from 2 to 5.

9) Similarly, for the MFU/SFU that support MLO, enable the MLO mode for all the WLAN terminals and configure the concurrency for 5,1 GHz with 160 MHz and 5,8 GHz with 80 MHz.

10) Repeat steps from 2 to 5.

#### 6.2.9.5 Expected Result

If the *Throughput_Concurrency* in steps 5, 8 and 10 is greater than the threshold defined in Table 8 in FTTR, the test case passes.

**Table 8: Expected Result for Concurrent throughput - multiple WLAN terminals in the interference scenario**

| Networking Topology | Number of WLAN terminals for Every MFU/SFU | TCP Traffic Mode | WLAN Terminal Configuration | Protocol | Channel Bandwidth (MHz) | Aggregated Throughput M(Mbps) |
|---|---|---|---|---|---|---|
| 1 MFU<br>+<br>2 SFUs | 1 | 150 Mbps<br>/ 1 500 Byte | 5 GHz (Nss=2) | IEEE 802.11ax [4] | 160 | ⩾ 1 800 |
| | | | 5 GHz (Nss=2) | IEEE 802.11be [5] | 160 | ⩾ 2 000 |
| | | | 2,4 GHz (Nss=2)<br>5 GHz (Nss=2) | IEEE 802.11be [5] | MLO<br>20 + 160 | ⩾ 2 300 |
| | | | 5,1 GHz (Nss=2)<br>5,8 GHz (Nss=2) | IEEE 802.11be [5] | MLO<br>80 + 160 | ⩾ 3 000 |

### 6.2.10 Test case #P2.9: Multiple concurrent WLAN terminals in FTTR

#### 6.2.10.1 Test Purpose

To test the maximum concurrent numbers of WLAN terminals that are able to carry a certain amount of services in FTTR.

#### 6.2.10.2 Test Method

When multiple WLAN terminals are connected to the FTTR, network performance deteriorates as the number of WLAN terminals increases due to the impact of air interface connection conflicts. The test case will test the maximum number of WLAN terminals under a certain Service Level Agreement (SLA) requirements.

#### 6.2.10.3 Test Configuration

The test shall be configured as shown in Figure 32:

1) A certain number of close-range and far-range WLAN terminals access MFU and SFU simultaneously.
2) The signal strength received by the close-range WLAN terminal from MFU/SFU is -30 dBm ± 2, while the signal strength received by the far WLAN terminal from MFU/SFU is -55 dBm ± 2.

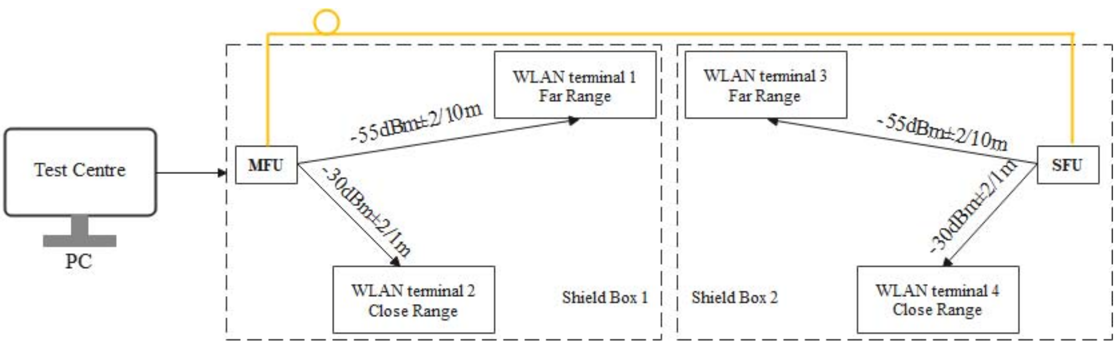


**Figure 32: The test environment of Multiple concurrent WLAN terminals in FTTR network**

#### 6.2.10.4 Test Procedure

1) Eight WLAN terminals are associated with the 5 GHz SSID of the MFU and SFU: 6 in close range and 2 in far range.

2) Use the data generator to establish 10 TCP connections with each WLAN terminal. Test the concurrent TCP throughput in the downlink for 120 seconds and record the throughput of the entire network and the minimum throughput of all the WLAN terminals and the minimum throughput of each test WLAN terminal.

3) Set the number of 5 GHz SSID WLAN terminals to 16 for the MFU and SFU: 12 in close range and 4 test WLAN terminals in far range. Repeat step 2 and then proceed to the next step.

4) Enable the MLO mode for the WLAN terminals that support the MLO function on the MFU and SFU. Configure the 2,4 GHz with 20 MHz concurrency and 5 GHz with 160 MHz concurrency. Repeat steps 1 to 3.

#### 6.2.10.5 Expected Result

If the concurrent throughput of multiple WLAN terminals at step 2 on the entire network is greater than or equal to the threshold defined in Table 9, the test case passes.

**Table 9: Expected Result for Multiple concurrent WLAN terminals in FTTR network**

| Networking Topology | WLAN Terminal Configuration | Channel Bandwidth (MHz) | Protocol | 16 WLAN terminals | | 32 WLAN terminals | |
|---|---|---|---|---|---|---|---|
| | | | | Aggregated Throughput (Mbps) | Minimum Throughput (Mbps) | Aggregated Throughput (Mbps) | Minimum Throughput (Mbps) |
| 1 MFU + 1 SFU | 5 GHz (Nss = 2) | 160 | IEEE 802.11ax [4] | 1 300 | 15 | 1 100 | 5 |
| 1 MFU + 1 SFU | 2,4 GHz (Nss = 2) | MLO 20 + 160 | IEEE 802.11be [5] | 1 500 | 15 | 1 200 | 5 |
| 1 MFU + 1 SFU | 5 GHz (Nss = 2) | MLO 160 + 80 | IEEE 802.11be [5] | 2 200 | 15 | 1 600 | 5 |

### 6.2.11 Test case #P2.10: TCP service latency for concurrent multiple WLAN terminals

#### 6.2.11.1 Test Purpose

To test the average Round-Trip Time (RTT) and 99th Percentile (TP99) latency for concurrent multiple WLAN terminals in FTTR network when carrying TCP traffic in certain interference scenarios.

#### 6.2.11.2 Test Method

End-to-End (E2E) network latency is a key factor for service experience. For latency-sensitive services (such as online mobile games and cloud VR), if the average E2E network latency exceeds tens of milliseconds, users will clearly perceive experience problems such as network lags and delayed response to operations. In residential networks, WLAN latency is the core bottleneck of E2E latency. When single WLAN terminal accesses the network at a short distance, WLAN latency is relatively low. However, when multiple WLAN terminals access concurrently and suffer from surrounding interference, the WLAN latency will deteriorate sharply. This is because the WLAN protocol is based on CSMA/CA competition.

In this test, the WLAN interference scenario is constructed through an integrated test instrument. A typical latency-sensitive service traffic model is used as the service input to test average latency and large latency ratio in a multi-user concurrent scenario.

### 6.2.11.3 Test Configuration

The test shall be configured as shown in Figure 33.

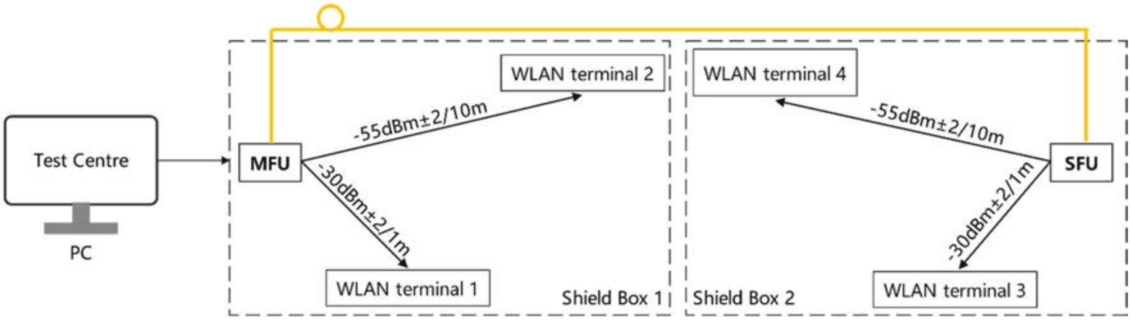


**Figure 33: The test environment of service latency for concurrent multiple WLAN terminals**

1) Four WLAN terminals access the FTTR network concurrently at different locations.

2) The WLAN parameters (mode, bandwidth, channel, authentication encryption method, etc.) of the MFU and SFU use the default configuration. The 2,4 GHz bandwidth is 20 MHz, the 5,1 GHz bandwidth is 160 MHz, and the 5,8 GHz bandwidth is 80 MHz (if supported). The 2,4 GHz and 5 GHz channels of the MFU and SFU are configured the same.

3) The WLAN terminals access the MFU/SFU using the 5 GHz channel and default bandwidth.

4) The signal strength received by the close range WLAN terminal from its associated MFU/SFU is -30 dBm ± 2, while the signal strength received by the far range WLAN terminal from its associated MFU/SFU is -55 dBm ± 2.

5) The WLAN terminal 1 and SFU are mutually invisible, and the WLAN terminal 3 and MFU are mutually invisible. The signal strength received by the WLAN terminal 2 from SFU is -68 dBm ± 2, and the signal strength received by the WLAN terminal 4 form MFU is -68 dBm ± 2.

### 6.2.11.4 Test Procedure

1) Two WLAN terminals access the network through the 5 GHz channel of the MFU. The access distances are 1 m (-30 dBm ± 2) and 10 m (-55 dBm ± 2) respectively.

2) Similarly, two WLAN terminals access the network through the 5 GHz channel of the SFU. The access distances are 1 m (-30 dBm ± 2) and 10 m (-55 dBm ± 2) respectively

3) A test centre is connected to the MFU through the LAN port and simultaneously sends a 150 Mbps downstream TCP traffic to the four WLAN terminals of the MFU and SFU. The testing centre records the packet sending time and ACK time to calculate the TCP RTT average latency and TP99 latency. The test lasts for 180 seconds recording the average RTT latency and the TP99 RTT latency of each WLAN terminal.

### 6.2.11.5 Expected Result

If the concurrent TCP latency of multiple WLAN terminals of the FTTR network is lower than or equal to the TCP latency given in the Table 10, the test case passes. The unit of the threshold is millisecond (ms).

**Table 10: Expected Result for TCP service latency for concurrent multiple WLAN terminals**

| Networking Configuration | Number of WLAN terminals for Every MFU/SFU | TCP Traffic Mode | WLAN Terminal Configuration | Protocol | Channel Bandwidth (MHz) | Average Latency (ms) | TP99 Latency (ms) |
|---|---|---|---|---|---|---|---|
| 1 MFU + 1 SFU | 2 | 150 Mbps / 1 500 Byte | 5 GHz (Nss=2) | IEEE 802.11ax [4] | 160 | 40 | 200 |
| | | | 5 GHz (Nss=2) | IEEE 802.11be [5] | 160 | 30 | 150 |
| | | | 2,4 GHz (Nss=2) 5 GHz (Nss=2) | IEEE 802.11be [5] | MLO 20 + 160 | 25 | 125 |
| | | | 5,1 GHz (Nss=2) 5,8 GHz (Nss=2) | IEEE 802.11be [5] | MLO 160 + 80 | 25 | 125 |

## 6.2.12 Test case #P2.11: UDP service latency for concurrent multiple WLAN terminals

### 6.2.12.1 Test Purpose

To test the average one-way latency and 99th Percentile (TP99) latency for concurrent multiple WLAN terminals in FTTR network when carrying UDP traffic in certain interference scenarios.

### 6.2.12.2 Test Configuration

1) The topology for the UDP latency test should be used as it is illustrated in Figure 33.

2) Four WLAN terminals access the FTTR network concurrently at different locations.

3) The WLAN parameters (mode, bandwidth, channel, authentication encryption method, etc.) of the MFU and SFU use default configuration. The 2,4 GHz bandwidth is 20 MHz, the 5,1 GHz bandwidth is 160 MHz, and the 5,8 GHz bandwidth is 80 MHz (only for tri-band terminals). The 2,4 GHz and 5 GHz channels of the MFU and SFU are configured the same.

4) The WLAN terminals access the MFU/SFU using the 5 GHz channel and default bandwidth.

5) The signal strength received by the close range WLAN terminal from its associated MFU/SFU is -30 dBm ± 2, while the signal strength received by the far range WLAN terminal from its associated MFU/SFU is -55 dBm ± 2.

6) The WLAN terminal 1 and SFU are mutually invisible, and the WLAN terminal 3 and MFU are mutually invisible. The signal strength received by the WLAN terminal 2 from the SFU is -68 dBm ± 2, and the signal strength received by the WLAN terminal 4 form the MFU is -68 dBm ± 2.

### 6.2.12.3 Test Procedure

1) Two WLAN terminals access the FTTR network through the 5 GHz channel of the MFU at the distance of about 10 m (-55 dBm ± 2) and 1 m (-30 dBm ± 2).

2) Similarly, two WLAN terminal respectively access the 5 GHz channel of two SFUs at the distance of about 10 m (-55 dBm ± 2) and 1 m (-30 dBm ± 2).

3) The test centre is connected to the MFU through the LAN port and simultaneously send 150 Mbps downstream UDP traffic to the WLAN terminals of the MFU and SFU. The test lasts for 180 seconds recording the average UDP latency and the TP99 latency of each WLAN terminal. The test centre packet generator is connected to the MFU through the LAN port and simultaneously send 150 Mbps downstream UDP traffic with a frame length of 1 500 bytes to the WLAN terminals of the MFU and SFU. The testing centre records the packet sending and receiving time to calculate the UDP latency. The test lasts for 180 seconds recording the average latency and the TP99 latency of each WLAN terminal.

4) Similarly, adjust the test centre to send the upstream UDP traffic from the WLAN terminal, with a speed of 150 Mbps, a frame length of 1 500 bytes, and the test runs during 180 seconds. Record the average upstream latency of UDP services for each WLAN terminal separately.

### 6.2.12.4 Expected Result

If the concurrent UDP latency of multiple WLAN terminals of the FTTR network is lower than or equal to the one that is given in the Table 11, the test case passes. The unit of the threshold is millisecond (ms).

**Table 11: Expected Result for UDP service latency for concurrent multiple WLAN terminals**

| Networking Topology | Number of WLAN terminals for Every MFU/SFU | UDP Traffic Mode | WLAN Terminal Configuration | Protocol | Channel Bandwidth | Average Latency (ms) | TP99 Latency (ms) | Packet Loss Rate |
|---|---|---|---|---|---|---|---|---|
| 1 MFU + 1 SFU | 2 | 150 Mbps /1 472 Byte | 5 GHz (Nss = 2) | IEEE 802.11ax [4] | 160 | 20 | 100 | 0,1 % |
| | | | 5 GHz (Nss = 2) | IEEE 802.11be [5] | 160 | 15 | 75 | 0,1 % |
| | | | 2,4 GHz (Nss = 2) 5 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 20 + 160 | 10 | 50 | 0,1 % |
| | | | 5,1 GHz (Nss = 2) 5,8 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 160 + 80 | 10 | 50 | 0,1 % |

## 6.2.13 Test case #P2.12: TCP service latency for concurrent multiple WLAN terminals in the interference scenario

### 6.2.13.1 Test Purpose

To test the average round-trip TCP latency and 99th Percentile (TP99) latency for multiple WLAN terminals access the MFU or SFU in FTTR network through the WLAN when carrying latency-sensitive services in certain interference scenarios.

### 6.2.13.2 Test Configuration

The test shall be configured as shown in Figure 34.

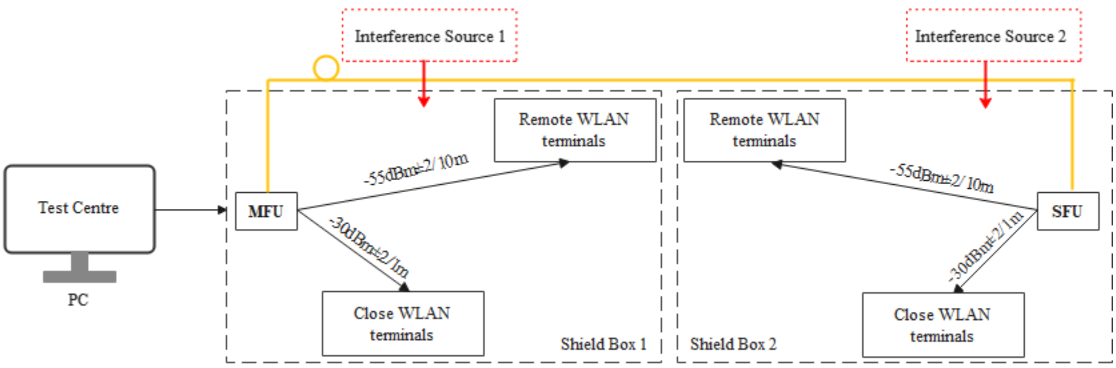


**Figure 34: The test environment of service latency for concurrent multiple WLAN terminals in the interference scenario**

Use the test WLAN terminals to access the network through different MFU/SFU or access multiple MFU/SFU concurrently.

The WLAN parameters including in minimum the mode, channel, and authentication and encryption mode of the MFU and SFUs use the default settings. The WLAN parameters (mode, bandwidth, channel, authentication encryption method, etc.) of the MFU and SFU use default configuration. The 2,4 GHz bandwidth is 20 MHz, the 5,1 GHz bandwidth is 160 MHz, and the 5,8 GHz bandwidth is 80 MHz (only for tri-band terminals). The 2,4 GHz and 5 GHz channels of the MFU and SFU are configured the same.

The test WLAN terminals use the 5 GHz or MLO mode to access MFU or SFU using the default bandwidth.

The 5 GHz single-frequency interference model is defined as follows:

- 5 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.
- The channel and bandwidth are the same as the testing FTTR network.

The MLO mode (2,4 GHz + 5 GHz) interference model is defined as follows:

- 5 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.
- 2,4 GHz frequency band: TCP test flow 5 Mbit/s downlink and 1 Mbit/s uplink co-channel interference. The interference signal strength ranges from -60 dBm to -65 dBm.
- The channel and the bandwidth are the same as the testing network.

The MLO mode (5,1 GHz + 5,8 GHz) interference model is defined as follows:

- 5,1 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.
- 5,8 GHz frequency band: TCP test flow 20 Mbit/s downstream and 2 Mbit/s upstream co-channel interference. The interference signal strength ranges from -65 dBm to -70 dBm.
- The channel and the bandwidth are the same as the testing FTTR network.

### 6.2.13.3 Test Procedure

1) Enable the interference source 1 and 2 at the same time. The interference signal strength measured by the two test terminals is -55 dBm ± 2 dBm.
2) Connect two WLAN terminals to the 5 GHz WLAN of the MFU and SFU, respectively. Figure 34 shows the position of the WLAN terminals.
3) Establish concurrent downlink TCP service flows between three WLAN terminals and the Test Centre. The payload length is 1 500 bytes. The data rate is 150 Mbit/s. The test duration is 180 seconds.
4) For the MFU and SFU that support MLO, enable the MLO mode for all WLAN terminals and configure the concurrency for 2,4 GHz with 20 MHz and the 5 GHz with 160 MHz.
5) Repeat steps from 1 to 4.
6) Similarly, for the MFU/SFU that supports MLO, enable the MLO mode for all the WLAN terminals and configure the concurrency for 5,1 GHz with 160 MHz and 5,8 GHz with 80 MHz.
7) Repeat steps from 1 to 4.

### 6.2.13.4 Expected Result

If in steps 4 and 5 the average TCP service of all WLAN terminals are less than or equal to the thresholds defined in Table 12, test case passes.

**Table 12: Expected Result for TCP service latency for concurrent multiple WLAN terminals in the interference scenario**

| Networking Topology | Number of WLAN terminals for every MFU/SFU | TCP Traffic Mode | WLAN Terminal Configuration | Protocol | Channel bandwidth (MHz) | Average Latency (ms) | TP99 Latency (ms) |
|---|---|---|---|---|---|---|---|
| 1 MFU + 2 SFUs | 2 | 150 Mbps/ 1 500 Byte | 5 GHz (Nss = 2) | IEEE 802.11ax [4] | 160 | 80 | 200 |
| | | | 5 GHz (Nss = 2) | IEEE 802.11be [5] | 160 | 80 | 200 |
| | | | 2,4 GHz (Nss = 2) 5 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 20 + 160 | 60 | 125 |
| | | | 5,1 GHz (Nss = 2) 5,8 GHz (Nss = 2) | IEEE 802.11be [5] | MLO 80 + 160 | 60 | 125 |

## 6.2.14 Test case #P2.13: UDP service latency for concurrent multiple WLAN terminals in the interference scenario

### 6.2.14.1 Test Purpose

To test the average one-way UDP latency and 99th Percentile (TP99) latency for multiple WLAN terminals access the MFU or SFUs in FTTR network through the WLAN when carrying latency-sensitive services in certain interference scenarios.

### 6.2.14.2 Test Method

Refer to clause 6.2.12.2.

### 6.2.14.3 Test Configuration

Refer to clause 6.2.13.2.

### 6.2.14.4 Test Procedure

1) Enable the interference source 1 and 2 at the same time. The interference signal strength measured by the two test terminals is -55 ± 2 dBm.
2) Connect two WLAN terminals to the 5 GHz WLAN of the MFU and two SFUs, respectively. Figure 34 shows the position of the test terminal.
3) Establish concurrent downlink UDP service flows between three WLAN terminals and the data generator. The payload length is 1 472 bytes. The data rate is 150 Mbit/s. The test duration is 180 seconds.
4) For the MFU and SFU that support MLO, enable the MLO mode for all WLAN terminals and configure the concurrency for 2,4 GHz with 20 MHz and the 5 GHz with 160 MHz.
5) Repeat steps from 1 to 4.
6) Similarly, for the MFU/SFU that supports MLO, enable the MLO mode for all the WLAN terminals and configure the concurrency for 5,1 GHz with 160 MHz and 5,8 GHz with 80 MHz.
7) Repeat steps from 1 to 4.

### 6.2.14.5 Expected Result

If in steps 4 and 5 the average UDP service latency of all WLAN terminals is less than or equal to the thresholds defined in the Table 13, the test case passes.

**Table 13: Expected Result for UDP service latency for concurrent multiple WLAN terminals in the interference scenario**

| Networking Topology | Number of WLAN terminals forevery MFU/SFU | UDP Traffic Mode | WLAN Terminal Configuration | Protocol | Channel bandwidth (MHz) | Average Latency (ms) | TP99 Latency (ms) | Packet Loss Rate |
|---|---|---|---|---|---|---|---|---|
| 1 MFU<br>+<br>2 SFUs | 2 | 150 Mbps<br>/1 472 Byte | 5 GHz<br>(Nss = 2) | IEEE 802.11ax [4] | 160 | 25 | 125 | 0,1 % |
| | | | 5 GHz<br>(Nss = 2) | IEEE 802.11be [5] | 160 | 20 | 100 | 0,1 % |
| | | | 2,4 GHz<br>(Nss = 2)<br>5 GHz<br>(Nss = 2) | IEEE 802.11be [5] | MLO<br>20 + 16 | 15 | 75 | 0,1 % |
| | | | 5,1 GHz<br>(Nss = 2)<br>5,8 GHz<br>(Nss = 2) | IEEE 802.11be [5] | MLO<br>80 + 160 | 15 | 75 | 0,1 % |

## 6.2.15 Test case #P2.14: Joint TCP latency and throughput

### 6.2.15.1 Test Purpose

To test the maximum concurrent throughput and latency performance of FTTR system when multiple WLAN terminals access the FTTR network.

### 6.2.15.2 Test Method

When WLAN terminals with latency-sensitive services and high-speed download service connected to the FTTR, the network latency and throughput performance are critical. To simulate the real network scenario, close-range WLAN terminals and far-range WLAN terminals access the FTTR concurrently, and the throughput capability of the close-range WLAN terminal and the latency performance of the far-range WLAN terminal are tested.

### 6.2.15.3 Test Configuration

The test shall be configured as shown in Figure 33:

1) One MFU and one SFU are connected through optical fibre.

2) Four WLAN terminals access the FTTR network concurrently at different locations.

3) The WLAN parameters (mode, bandwidth, channel, authentication encryption method, etc.) of MFU and SFU are default configurations. The 2,4 GHz bandwidth is 20 MHz, the 5,1 GHz bandwidth is 160 MHz, and the 5,8 GHz bandwidth is 80 MHz. The 2,4 GHz and 5 GHz channels of the MFU and SFU are configured the same.

4) The WLAN terminals access the MFU/SFU using the 5 GHz channel and default bandwidth.

5) The detectable signal strength between adjacent MFU/SFU is -60 dBm ± 2.

6) The signal strength received by the near WLAN terminal from its associated MFU/SFU is -30 dBm ± 2, while the signal strength received by the far WLAN terminal from its associated MFU/SFU is -55 dBm ± 2.

7) WLAN terminal 1 and SFU are mutually invisible, and WLAN terminal 3 and MFU are mutually invisible. The signal strength received by WLAN terminal 2 from SFU is -68 dBm ± 2, and the signal strength received by WLAN terminal 4 form MFU is -68 dBm ± 2.

#### 6.2.15.4 Test Procedure

1) Two WLAN terminals access the network through the 5 GHz channel of the MFU. The access distances are 1 m (-30 dBm ± 2) and 10 m (-55 dBm ± 2) respectively.

2) Similarly, two WLAN terminals access the network through the 5 GHz channel of the SFU. The access distances are 1 m (-30 dBm ± 2) and 10 m (-55 dBm ± 2) respectively.

3) A test centre is connected to MFU through the LAN port. Establish 10 downlink TCP test flows from the MFU/SFU to the close-range WLAN terminals for 180 seconds. Record the downlink traffic of each close-range WLAN terminal and calculate the sum of the downlink throughput of all close-range WLAN terminals.

4) Simultaneously, the test centre sends a 100 Mbit/s downlink TCP test flow to each far-range WLAN terminals for 180 seconds. Record the average TCP latency of each far-range WLAN terminal.

5) For the MFU and SFU that support MLO, enable the MLO mode for all WLAN terminals and configure the concurrency for 2,4 GHz with 20 MHz and the 5 GHz with 160 MHz.

6) Repeat steps from 1 to 4.

7) Similarly, for the MFU/SFU that supports MLO, enable the MLO mode for all the WLAN terminals and configure the concurrency for 5,1 GHz with 160 MHz and 5,8 GHz with 80 MHz.

8) Repeat steps from 1 to 4.

#### 6.2.15.5 Expected Result

When multiple WLAN terminals access the FTTR device through the WLAN, the TCP service throughput of close-range WLAN terminals and the TCP service loopback delay of far-range terminals should meet the requirements described in Table 14.

**Table 14: Expected Result for Joint TCP latency and throughput**

| Networking Topology | Number of WLAN terminals for every MFU/SFU | Terminal WLAN Configuration | Protocol | Channel Bandwidth (MHz) | Average Latency (ms) | Aggregated throughput of close-range WLAN terminal (Mbps) |
|---|---|---|---|---|---|---|
| 1 MFU + 1 SFU | 2 | 5 GHz (Nss = 2) | IEEE 802.11ax [4] | 160 | ≤ 40 | ≥ 1 600 |
| | | 5 GHz (Nss = 2) | IEEE 802.11be [5] | 160 | ≤ 40 | ≥ 1 920 |
| | | 2,4 GHz (Nss = 2)<br>5 GHz (Nss = 2) | IEEE 802.11be [5] | MLO<br>20 + 160 | ≤ 30 | ≥ 1 700 |
| | | 5,1 GHz (Nss = 2)<br>5,8 GHz (Nss = 2) | IEEE 802.11be [5] | MLO<br>80 + 160 | ≤ 30 | ≥ 2 100 |

# History

| Version | Date | Status |
|---|---|---|
| V1.1.1 | August 2025 | Publication |
| | | |
| | | |
| | | |
| | | |